MINISTRY OF HEALTH AND SOCIAL WELFARE
REPUBLIC OF LIBERIA

Standards for Health Infrastructure
2013

Standards for Health Infrastructure

Ministry of Health & Social Welfare

Republic of Liberia

2013

MASS Design Group
Fall Creek Engineering
Mazzetti
Nous Engineering

This work has been contracted to MASS Design Group under Subcontract No. 36514-I-11 by JSI Research and Training Institute, under the Rebuilding Basic Health Services project with funding from USAID

Table of Contents

ELECTRICITY & LIGHTING

WATER & SANITATION

PLUMBING & GAS

Acronyms

ABR	Anaerobic Baffled Reactor
ACH	Air Changes per Hour
AIDS	Acquired Immune Deficiency Syndrome
ANC	Antenatal Care
ANSI	American National Standards Institute
ART	Anti-Retroviral Therapy
ASTM	American Society for Testing and Materials
ATS	Automatic Transfer Switch
AWWA	American Water Works Association
BEmONC	Basic Emergency Obstetric and Neonatal Care
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BOQ	Bill of Quantities
BPHS	Basic Package of Health Services
CEmONC	Comprehensive Emergency Obstetric and Neonatal Care
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet per Minute
CHAI	Clinton Foundation Health Access Initiative
CHO	County Health Officer
CHSWT	County Health and Social Welfare Team
CHV	Community Health Volunteer
CM	Certified Midwife
CMU	Concrete Masonry Unit
CSEB	Cement Stabilized Earth Block
CWMA	Central Waste Management Area
DHO	District Health Officer
ECP	Erosion Control Plan
EHT	Environmental Health Technician
EmONC	Emergency Obstetric and Neonatal Care
EPHS	Essential Package of Health Services
EPI	Expanded Program on Immunization
ER	Emergency Room
ESC	Erosion and Sediment Control
FAR	Floor-Area Ratio
FF&E	Finishes, Furniture, & Equipment
GBV	Gender-Based Violence
gCHV	General Community Health Volunteer
GOL	Government of Liberia
HCT	HIV Counseling and Testing
HDPE	High Density Polyethylene
HEPA	High Efficiency Particulate Air
HIV	Human Immunodeficiency Virus
HVAC	Heating, Ventilation, and Air Conditioning
ICU	Intensive Care Unit
IPC	International Plumbing Code
IPD	In-patient Department
ISO	International Standards Organization
IU	Infrastructure Unit
LEC	Liberia Electric Corporation
LPD	Lighting Power Density
LWSC	Liberia Water & Sewer Corporation
M&E	Monitoring and Evaluation
MCH	Maternal and Child Health
MOHSW	Ministry of Health and Social Welfare
MPHP	Multi-Purpose Health Professional
MPW	Ministry of Public Works
MLME	Ministry of Lands, Mines, and Energy
NCDs	Non-Communicable Diseases
NDS	National Drug Service
NTDs	Neglected Tropical Diseases
NDU	National Diagnostic Unit
NEC	National Electric Code
NHSWPP	National Health and Social Welfare Policy & Plan
NHIP	National Health Infrastructure Policy
NGO	Non-Governmental Organization
NICU	Neonatal Intensive Care Unit
OIC	Officer in Charge
OPD	Out-Patient Department
OR	Operating Room
PA	Physician's Assistant
PACU	Post Anesthesia Care Unit
PHC	Primary Health Care
PRS	Poverty Reduction Strategy
PV	Photovoltaic
RBHS	Rebuilding Basic Health Services
RN	Registered Nurse
SDP	Service Delivery Point
SOP	Standard Operating Procedure
TB	Tuberculosis
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TTM	Trained Traditional Midwife
UVGI	Ultra-violet Germicidal Irradiation
VIP	Ventilated Improved Pit
VOC	Volatile Organic Compound
WASH	Water Quality, Sanitation, Hygiene
WHO	World Health Organization
WMA	Waste Management Area

Preface

Over the last decade, Liberia has taken great strides to rebuild its social and physical infrastructure. The 2008 Poverty Reduction Strategy (PRS) outlined the Government of Liberia's (GOL) commitment to peace building, economic revitalization, strengthened governance, and the delivery of basic health services. The GOL has established a national vision to become a middle-income country by 2030—and recognizes that health, particularly universal and holistic health, is integral to that goal.

Why infrastructure matters

A strengthened network of health facilities and service delivery points is necessary to achieve the benchmarks outlined in the Essential Package of Health Services (EPHS) and National Health and Social Welfare Policy and Plan 2011-2021 (NHSWPP).

Health facilities, however, are more than simply settings for services—they play an active role in determining the success and sustainability of health improvement measures. Appropriately designed and well-constructed health infrastructure will be vital to achieve the following outcomes:

"Infrastructure is by far one of the most important parts of health delivery."

--Dr. Moses Massaquoi, CHAI

Equitable access to health services. The NHSWPP specifies "equitable access to effective health and social welfare services irrespective of socioeconomic status, origin, ethnicity, gender, age and geographic location" as a priority goal. Access is fundamentally related to the *distribution* of health infrastructure (determining an individual's ability to reach a facility) as well as *design* (determining an individual's ability to obtain and navigate health services within the facility).

Efficiency and effectiveness of medical care. Basic services, such as clean water and reliable electricity, are clearly vital to the safe and effective delivery of care. Optimized building layouts and room planning, however, are also critical for improving staff efficiency and patient monitoring. Supporting facilities such as staff housing have been shown to successfully improve staff retention and performance, especially in remote areas.

Improved utilization of health services. The physical condition of health facilities not only impacts the effectiveness of medical services, but the likelihood of patients to seek those services in the first place. A dignified, comfortable experience will encourage return visits and build confidence in formal health care. The integration of maternal waiting homes has proven to be a simple but effective measure for improving facility based deliveries.

Reduced transmission of infectious diseases. Patients go to facilities to get better, not get sick. Overcrowding, poor ventilation, and improper facility layouts are design problems that can lead to unnecessary health and safety risks. Examples of simple but effective infection control measures include strategically planned room adjacencies, failsafe ventilation systems, waste management infrastructure, and sanitary amenities.

Minimize construction, maintenance and operational costs. Good buildings do not have to be more expensive. Appropriately sized facilities permit more effective resource allocation, while contextually optimized designs limit construction costs. Well-designed and constructed buildings also perform better, minimizing long-term maintenance and operational costs.

Optimized standards for Liberia

The NHSWPP explicitly recognizes that the provision of quality health infrastructure is necessary for the effective, efficient delivery of health services. But to date, no definitions or criteria have existed for what "quality" entails.

Between 2008 and 2010, prototypical drawings were developed for a series of health facilities including Clinics and Health Centers. While this effort provided some degree of infrastructural standardization, it did not offer enough flexibility for a broad application.

The National Health Infrastructure Policy (NHIP) was developed in acknowledgement that a one-size-fits-all approach is neither appropriate nor cost-effective given the diversity of contexts and programs for health delivery across Liberia. In addition to recognizing the necessity of establishing building design, construction, and performance standards; the NHIP acknowledged the importance that these standards be "dynamic and flexible to meet the needs of a range of conditions as they develop over time."

"Not having standards has been a huge problem for the delivery of healthcare. We don't want just what's available now. We want what can serve."

--Watuku Z. Kortima, IU

The following document was developed under a important premise: That to enable the design and construction of health facilities optimized for Liberia, building standards had to be approached not as a universal prototype, but as a flexible tool for implementing efficient, effective, and sustainable change.

The NHSWPP identified target construction of 48 new PHC1 facilities, 90 new Health Centers, and 2 new hospitals over the next 10 years. This constitutes a scale of construction that would radically transform the landscape of Liberia's health infrastructure and offers the opportunity to create not only examples of high-performing facilities, but demonstrate a model globally of a better, more holistic process of doing so. Prioritizing choices we make can positively impact the communities we are serving. The opportunity is to demonstrate how better infrastructure can be linked to better health outcomes. By institutionalizing standards to deliver better health outcomes and dignity, Liberia has a chance to be a global leader in health infrastructure.

Objectives

This document focuses on the creation of successful health infrastructure that is community informed, contextually optimized, and aligned with the 10-year health targets. The Standards are underpinned by four primary objectives:

Provision of high quality infrastructure

For many Liberians, the quality of healthcare buildings is an indicator of the quality of care inside. High quality infrastructure requires proper planning, appropriate design, and quality construction—both for building structures as well infrastructural systems such as ventilation, lighting, electricity, water, and sanitation. Developing and maintaining high-quality infrastructure is achieved primarily by:

- Selecting systems, designs, and construction methods well-suited to local resources and contexts
- Following preventative maintenance to minimize long-term costs and maximize building lifespan
- Ensuring that infrastructure is consistently in good working order to meet performance criteria
- Making cost-effective decisions to allocate available funding to the most critical infrastructure needs

Focus on improved health outcomes

Better infrastructure can also improve health. The Health Infrastructure Standards have been developed to both ensure and improve health outcomes including:

- Locating and designing facilities to strategically respond to population needs
- Creating environments that promote patient healing and well-being
- Simplifying processes for care provision
- Focusing on the patient experience to encourage ongoing use of facilities

Inclusion of stakeholder participation in decision-making

The development of these Standards involved extensive research, field visits to health facilities, interviews of medical and CHSWT staff, public and private sector engagement, and continuous collaboration within the MoHSW, as well as participation with implementing partners. Correspondingly, this document recognizes that continued stakeholder participation will be vital for the successful implementation and maintenance of these standards. Stakeholder collaboration must be facilitated by:

- Clarifying who should be involved in decision-making processes related to infrastructure development, in alignment with the National Health Infrastructure Policy.
- Distributing responsibilities and establishing accountability amongst individuals with relevant skills, knowledge, and tools.

Institutionalization of capacity-building measures

Providing a framework where the delivery and oversight of health infrastructure can be leveraged as an opportunity for capacity building is seen as the surest form of the sustainability. This is achieved by:

- Providing information relevant to all groups or individuals who participate in design, construction, use, and upkeep of facilities
- Communicating connections between defined standards and guidelines and health outcomes
- Simplifying processes and procedures necessary for achieving desired infrastructure and health outcomes

Guiding Principles

International codes inherently limit the ability to leverage opportunities unique to a given context and constrain innovation. In development of the MOHSW Health Infrastructure Standards, the goal has been to be prescriptive enough to hold responsible parties accountable, while remaining flexible to adapt to project specific needs and produce optimized solutions.

Adaptive

"Using Architectural Building Standards, one can dissect the form and functions of such a facility and carefully articulate specific requirements based on the unique needs of the local community. Standards allow for a more flexible assembly of components to suit numerous contexts and needs."

- Health Infrastructure Policy

To fulfill the NHSWPP's target of providing all Liberians with equitable access to health facilities, a strategy of distributed community-based care has been developed. In order to address the various scales of facilities and sites, the Standards allow for flexibility, enabling cost effective and appropriate design that can be achieved, particularly in rural regions. This will also accommodate evolving needs as Liberia advances from EPHS to Comprehensive Package of Health Services (CPHS).

The Standards are written with performance-based criteria rather than prescriptive solutions, which allows for different approaches based on project needs. This focuses on the impact required to improve health as the overarching metric.

Outcomes-based

Users are less likely to apply and enforce standards when they are just abstract technical requirements and not grounded in outcomes and impact. In response, the Infrastructure Standards have been written to not just indicate *what* is required but *why* it is required. By being explanatory and instructive, the Standards serve as a teaching tool for users to understand the implications of infrastructural decisions on health outcomes, safety, and patient comfort. By understanding these implications, users are less likely to make decisions that subvert the goal of the standards, and also take greater ownership over their implementation because the link between infrastructure decisions and their role as health care providers becomes seen as linked.

Prioritized for Impact

Inevitably decisions about infrastructure come down to the cost-benefit analysis, particularly when financial conditions pose perhaps the largest constraint. To respond to this these Standards have included a Hierarchy of Needs to help make more conscious decision about prioritizing interventions. By illustrating the improvements that have the highest return on investment in terms of delivering better health outcomes and dignified environments for care, the Standards prioritize decision-making that is both efficient and effective.

1 Health Delivery in Liberia

1.1 Background

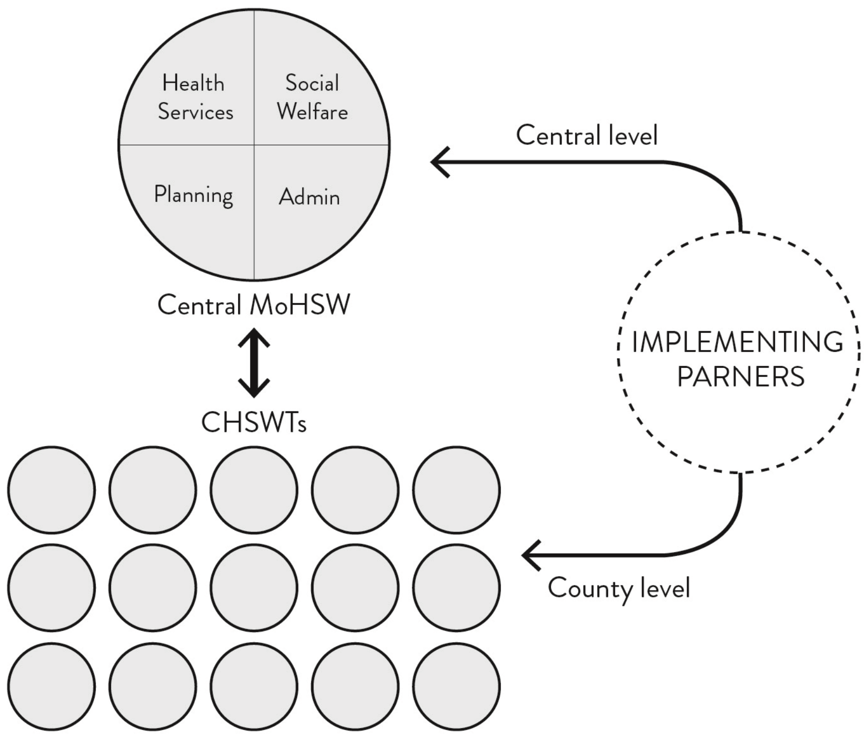
To facilitate the shift from short-term recovery to long-term national development, the Ministry of Health and Social Welfare (MOHSW) developed a holistic, evidence-based policy framework termed the National Health and Social Welfare Policy and Plan 2011-2021 (NHSWPP).The NHSWPP outlines three explicit objectives:

1) Increased access to, and utilization of, health and social welfare services
2) The development of more responsive, decentralized health systems
3) Equitable, accessible, and affordable healthcare for all Liberians.[1]

To achieve these goals, the MOHSW created an Essential Package of Health Services (EPHS). As the cornerstone of the NHSWPP, the EPHS underscores the GOL's commitment to improving the health status and social welfare of the population by prioritizing the delivery of essential health services.

1.2 Sector Organization

The implementation guidelines established in the NHSWPP emphasize community empowerment, decentralization, and partnership.[2]As Liberia's health sector is a dynamic, multifaceted system comprised of many actors and stakeholders, effective coordination and strong partnerships will be necessary to ensure the successful delivery of the EPHS and subsequent transition to a Comprehensive Package of Health Services (CPHS). Major stakeholders are briefly summarized below.



Central MOHSW

The Ministry of Health and Social Welfare (MOHSW) is the governmental entity responsible for health policy formulation, regulation, and coordination. The MOHSW is comprised of four departments: Health Services; Social Welfare; Planning, Research & Development; and Administration. Functions at the Central level are primarily focused on policy development, resource mobilization and allocation, aggregate planning, monitoring and evaluation, and research.[3]

County Health and Social Welfare Teams

Reflecting the GOL's commitment to decentralizing public systems and services, individual health and social welfare departments were formed in each of Liberia's 15 counties. County level implementation is overseen by County Health and Social Welfare Teams (CHTSWs) who are accountable for service delivery, management, partner oversight, and systems building.[4]On a day-to-day basis, CHSWT administrators develop and execute operational plans and budgets; oversee staffing, supply chain, and transportation logistics; prioritize infrastructural needs; and monitor health outcomes.

Implementing Partners

Over the past decade, international NGOs (implementing partners) have played a key role in the stabilization and reconstruction of Liberia, bringing funding, resources, and technical expertise. With Liberia's transition from post-conflict relief to long-term development, many NGOs have begun exit strategies; nevertheless, partners continue to play a vital role in health systems strengthening—particularly in terms of capacity building, project delivery, and implementation.

1.3 Levels of Service

The EPHS outlines the delivery of healthcare across three levels: primary care, secondary care, and tertiary care.

Primary Care

Primary care is intended to be the day-to-day point of contact for citizens with their healthcare system, focusing on basic outpatient treatment, maternal and child health, and preventative healthcare. Primary health services are both facility- and community-based—with the latter directed toward community outreach, health promotion and education, and referrals for facility-based services.[5]

Secondary Care

The secondary level of care supplements primary care with inpatient, emergency, and diagnostic services as well as comprehensive emergency obstetric care.

Tertiary Care

The tertiary level provides specialized consultative services and forms the pinnacle of healthcare delivery in Liberia. Tertiary health facilities are referral-based, receiving patients with the most serious or complicated conditions, and also offering opportunities for medical training and clinical research.

1.4 Health Targets

The MOHSW has developed specific national and county health targets to be reached in the next decade.[6] Fundamentally, every target—from improved access to facilities, to increased attendance of skilled professionals during childbirth, to newborn vaccinations—necessitates improved health infrastructure. To achieve an effective and efficient system of health delivery, healthcare facilities must be well designed and constructed.

Indicators for monitoring health system goals and performance have been summarized in the following chart.[7]

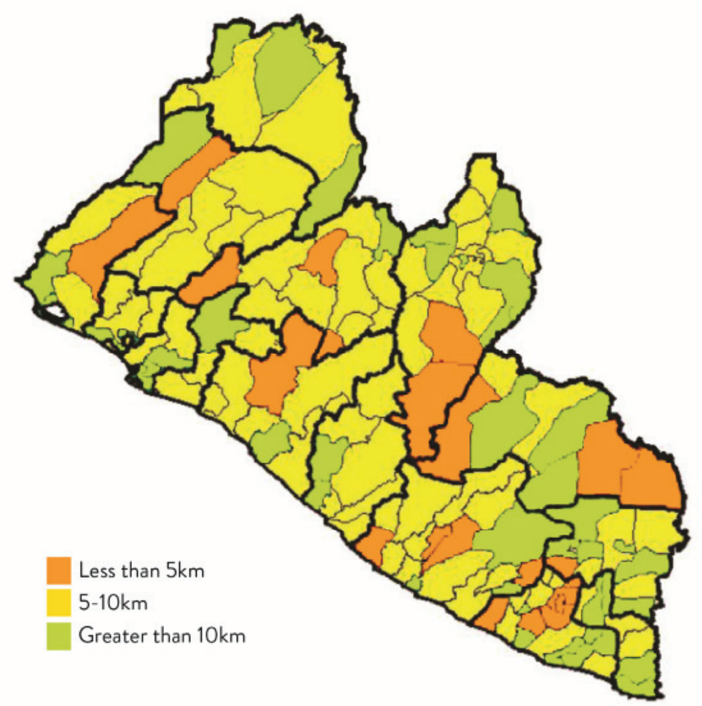
Goal/Objective	Indicator
Improved health status	Maternal mortality rate Child mortality rate Life expectancy at birth
Increased access and utilization of health services	Population living within 5 km of a health facility
Maternal health	Facility-based deliveries with a skilled birth attendant
Child health/EPI	Children under 1 year who received OPV3/Penta3
Service consumption	OPD consultations per inhabitant per year
Malaria	Pregnant women provided with 2nd dose of IPT for malaria
HIV/AIDS	Pregnant women tested for HIV and receiving a complete course of ARV prophylaxis
Tuberculosis	Smear positive TB cases notified
Human Resources	Skilled birth attendants/10,000 population
Drugs	Facilities with no stock-out of tracer drugs
HMIS	Timely, accurate and complete HIS reporting
Facility quality	Facilities with two star accreditation

2 Health Infrastructure in Liberia

2.1 Background

The 1989-2003 civil conflict resulted in the damage or destruction of 95% of Liberia's health facilities.[8] Over the last decade, rebuilding efforts have focused on expanding access to health services, as well as increasing the utilization and quality of healthcare settings. The 2008 Poverty Reduction Strategy (PRS) expressed the intention of the Government of Liberia (GOL) to rehabilitate health infrastructure. The stated goal of the PRS was to provide "a quality health facility within a 5km radius of every community."[9]

The 2008 National Population and Housing Census reported that 41% of all households must travel one hour or more to reach the nearest facility.[10] The below map (adapted from RBHS's 2010 Geographic and Demographic Distribution of Health Facilities) illustrates the proximity of the population to health facilities by district, highlighting currently underserved areas.

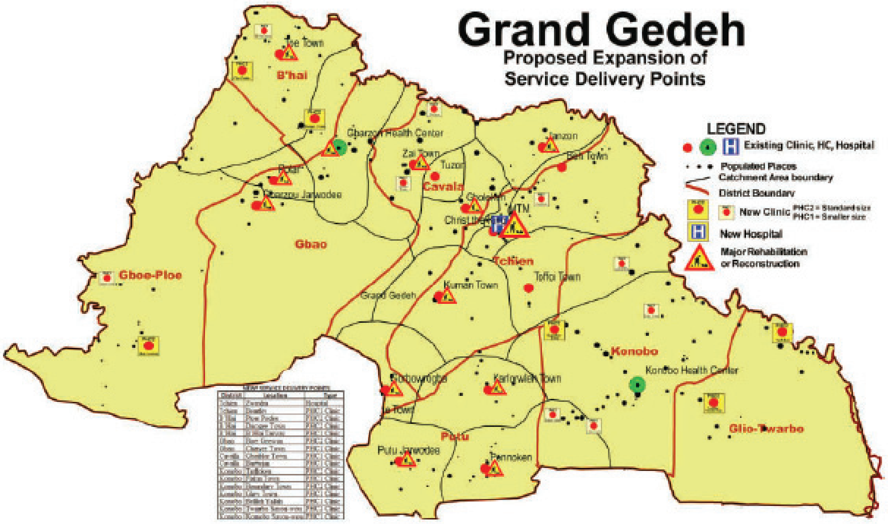


The rehabilitation of existing facilities will enhance the capabilities of healthcare workers to deliver safe and effective services; yet in planning for extended growth, new facilities will be needed in all areas of the country.

Ultimately, the expansion of health infrastructure will be closely tied to the capacity of Liberia's building sector. With the large-scale departure of skilled professionals during the war, the building sector was beset by the loss of significant design and management expertise. Through post-conflict economic recovery and reconstruction efforts, the building industry has experienced a significant expansion in recent years, but the capacity to regulate construction practices and project delivery is still inconsistent. The development of systematic practices for construction oversight, quality control, and stakeholder coordination will be necessary for projects to be planned, constructed, and maintained more effectively in the future.

2.2 Needs and Priorities

The County Plan Executive Summaries in the NHSWPP identify new facilities and service delivery points as well as major rehabilitation and reconstruction projects to be undertaken. In total, the county plans indicate 48 new PHC 1 facilities, 90 new PHC 2 facilities, 3 new Health Centers, and 2 new Hospitals.



While each county has established short- and long-term plans for the expansion of service delivery points, much of the infrastructure needed to fully roll out the EPHS and NHSWPP is not yet in place. Some existing facilities have suffered from poor construction, driving up maintenance costs and reducing the quality of care. The 2010 National Health Infrastructure Situational Analysis reported that basic building services continue to be lacking at many facilities. As of 2010,[11]

- 43% of facilities did not have a functioning incinerator
- 13% of facilities did not have drinking water available during all operating hours
- 45% of facilities did not have a primary power source

In addition to properly functioning building services, another ongoing challenge has been facility sizing and resource optimization. As noted in the NHSWPP,

> "50% of government clinics are serving catchment populations smaller (40%) or larger (11%) than catchment criteria established by the MOHSW. The absence of infrastructure design standards and building codes for construction, reliance on an expensive clinic prototype, and inadequate project delivery processes have constrained optimization of public facilities."[12]

2.3 Health Infrastructure Policy and Standards

The National Health Infrastructure Policy (NHIP) was developed in response to these challenges and priorities to guide the design, procurement, construction, management, and maintenance of health infrastructure. The NHIP&P has six main objectives:

1) To establish well define Building Standards for all health facilities and to ensure compliance to the standards based on the local conditions.
2) To establish a transparent Project Delivery Management System comprised of preconstruction reviews and approvals that apply the Building Standards, with flexibility, to local site conditions and project needs; transparent procurement and contracting; regular site supervision and quality control during construction, regular prompt progress payments and financial oversight; and final inspections and corrections, prior to building acceptance and turn over to the health care providers and users.
3) To define health infrastructure components.
4) To define roles and responsibilities of the Infrastructure Unit and all involved stakeholders.
5) To establish a process of regular management, monitoring, maintenance and evaluation of all health facilities.
6) To ensure collaboration and coordination of the Health Infrastructure Policy among all health infrastructure stakeholders and the National Health Policy and Plan 2011 - 2021.[13]

The following document establishes building standards to be used in the renovation, construction and maintenance of public and private health infrastructure. From outlining detailed requirements for proper ventilation and infection control, to creating parameters for facility layout, the Standards will guide the efficient implementation of health facilities and enable the delivery of safe, sanitary, and patient-centric spaces.

2.4 Infrastructure Unit (IU)

The Infrastructure Unit (IU) of the MOHSW is the primary point of contact for all building and infrastructure-related activities for Liberia's public health facilities.

The National Health Infrastructure Policy envisions a tiered, integrated network comprised of a central Infrastructure Unit and County-level Infrastructure Units. As of 2013, only the central IU is in place and is responsible for the process of overseeing design, construction, and maintenance of health facilities in Liberia. Amongst these duties, some of the key roles are as follows:

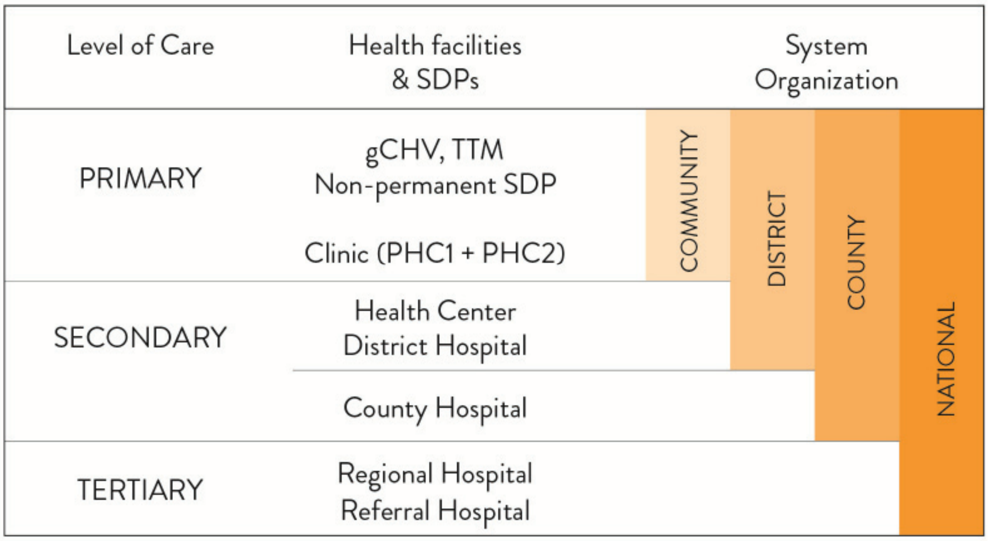
- Developing, disseminating and enforcing these building standards for health facilities.
- Providing local supervision of health infrastructure activities.
- Supervising maintenance and carrying out performance evaluations of existing health facilities.
- Developing and distributing a Project Delivery Management System.
- Building the capacity of the CHSWT to plan, budget, manage and maintain the County health facilities.
- Collaborating with all health infrastructure stakeholders in revising and developing new standards and management tools as circumstances change.

For each new design, construction, renovation or other relevant infrastructure project, the IU will assign a representative to oversee the project. This assigned IU representative will be responsible for issuing approvals where noted in the standards, holding all consultants and contractors accountable to the standards, and generally guiding the project process.

3 Facility Types

The MOHSW's Essential Package of Health Services (EPHS) assigns primary, secondary, and tertiary health services to specific facility types. This structure aims to offer complete primary care at the primary care level; secondary and tertiary care is available through referrals to Health Centers and Hospitals.[14] The following chapter gives a brief summary of the operating characteristics and services provided by each facility type. More detailed information is provided in Chapter 12, Program Adjacencies and Layout.

Figure 3.a. Relationship between facilities, level of care and system organization*



** Adapted from the NHSWPP*

3.1 PHC Level 1 and 2 Clinic

Serving small catchment populations, primary healthcare clinics (PHCs) are typically staffed by nurses and/or mid-wives, with an emphasis on maternal-child care. The two levels of clinics are intended to provide the same services at different scales and are essential mechanism for the distribution of healthcare, particularly in remote and hard-to-reach areas. Operational criteria defining PHC level 1 and 2 clinics are:

- Each PHC 1 facility serves a catchment population of up to 3,500, while each PHC 2 facility serves a population ranging from 3,500-12,000 people.
- PHC clinics are expected to be within a 1-hour walking distance or 5km from communities served.
- Facilities must be open 8 hours per day Monday-Friday, with birth attendants available 24 hours.

3.2 Health Center

Health centers are part of the secondary-care network, and receive referrals from PHC level 1 and 2 clinics.

- Each health center serves a population ranging from 25,000-40,000 people.
- Facilities must be open 24 hours per day, seven days per week.
- Facilities must have inpatient wards with up to 40 beds.

3.3 District Hospital

District hospitals are also part of the secondary-care network and receive referrals from PHC level 1 and 2 facilities and health centers. District hospitals are generally located in areas of higher population density when compared with health centers; in some cases, district hospitals may be developed in lieu of health centers, or health centers can be upgraded to become district hospitals.

- Each district hospital serves a population above 40,000 people.
- Facilities must be open 24 hours per day, seven days per week.

3.4 County Hospital

County hospitals are the largest facilities in the secondary-care network, and receive referrals from all smaller facility types.

- Each county hospital serves 1 county.
- Facilities must be open 24 hours per day, seven days per week.

3.5 Regional Hospital

Regional Hospitals and the John F. Kennedy Medical Center (JFK) in Monrovia form the tertiary-care network, and receive referrals from county hospitals.

- Each regional hospital serves 3-5 counties, and JFK serves the entire country
- Facilities must be open 24 hours per day, seven days per week.

Table 3.a Facility type operational characteristics

Services	Facility type					
	PHC 1	PHC 2	Health Center	District Hospital	County Hospital	Regional Hospital
Level of care	Primary		Secondary			Tertiary
Catchment Size	1,500-3,500 people	3,500-12,000 people	25,000-40,000 people	> 40,000 people	1 county	3-5 counties
Operating Hours	8 hrs	8 hrs	24/7	24/7	24/7	24/7

Table 3.b. Service offerings by facility type

X = Required
O = Recommended

Services	Facility type					
	PHC 1	PHC 2	Health Center	District Hospital	County Hospital	Regional Hospital
Maternal and Child Health	X	X	X	X	X	X
Outpatient Treatment	X	X	X	X	X	X
Expanded Program on Immunization (EPI)	X	X	X	X	X	X
Short Stay Monitoring	X	X	X	X	X	X
Laboratory		X	X	X	X	X
Inpatient Treatment			X	X	X	X
Operating Department			O	X	X	X
Emergency Department			O	X	X	X
Specialized Consultations				X	X	X
Morgue				X	X	X
Intensive Care Unit				O	X	X
Medical Imaging				O	X	X

4 Design Variables

While striving to adopt the highest international standards, locally optimized solutions must take into consideration Liberia's specific social, economic, and environmental contexts. No two counties will have the same health delivery needs or resources. The following chapter outlines important design considerations that will facilitate the appropriate design and efficient construction of health facilities.

4.1 Health Service Delivery

Proper assessment of demographic and epidemiological information is imperative to planning a well-functioning healthcare facility. Any facility planning process should begin not with the building design but with the population the building intends to serve.

Demographics

In addition to general health challenges, each region and community will have distinct public health characteristics. The prevalence and incidence of medical needs in the facility's catchment area will determine the size and ratio of related departments.

Catchment population

Population size affects spatial and programmatic requirements related to facility access. Generally, more dispersed populations must travel greater distances to obtain health services, resulting in more infrequent visits and longer stays. Larger-capacity waiting rooms must be provided, and supplementary facilities such as staff housing and Maternal Waiting Homes should be considered. Denser populations tend to have greater access to healthcare facilities, meaning more frequent visits and shorter stays.

It is important to anticipate projected population growth in any areas where facilities are planned. New hospitals and services can spur growth in a region due to increased jobs and health security; hence increases in population over time should be evaluated and assessed in terms of future needs for expanded capacity or additional services. Similarly, the planning and operation of facilities near international borders should reflect the realities of systemic loads to adequately provide essential care for catchment populations that will likely include non-Liberian patients.

Sector resources

Across Liberia, health facilities of all scales are located in vastly different settings and contexts. Ranging from urban, proximate, and accessible, to rural, distant, and inaccessible, access to facilities varies significantly. When planning for the construction of a new health facility, the local conditions which define access within the catchment area must be well understood. Access is not simply the physical distance from the user to the facility, though this is certainly a defining factor; access is also determined by the means of transportation available to reach the facility (foot, motorcycle, bus, car, ambulance, etc.), the quality of the road to get there (passable, impassable, wide enough for motor bike, wide enough for car), the time required for the journey, and seasonal conditions (dry or rainy).

The accessibility of a health facility depends also on the availability of reliable communication. For emergencies in remote areas with no access to cell networks or radios or a means of transportation, facilities can become inaccessible to patients in immediate need of care due to the impossibility of calling an ambulance. Improved transportation to health facilities is a critical need for better healthcare delivery in Liberia, but outside the purview of this document.

4.2 Local Conditions and Resources

Within Liberia's relatively small landmass, varying geographic, climatic, and environmental conditions influence how people and materials travel, as well as how buildings perform and age over time. Understanding these contextual conditions and constraints is essential to establishing responsive, appropriate approaches to infrastructure. The Standards in this document will seek to improve the performance and lifespan of health facilities, taking into account regional variations in environmental, material, and human resources.

Climate

Climate is a necessary factor in considering building layouts, program adjacencies, and design details. Torrential rains, for example, may affect how occupants circulate through the building and across the site, especially if walkways are exposed to the elements or buildings are separated from one another. Especially in rural areas, where more basic construction techniques are often used, properly detailed foundations, roof construction, and wall finishes are necessary to prevent damage from excess water exposure. Due to high daytime temperatures and constant sun exposure, buildings must also be appropriately oriented to the sun and prevailing winds. If they are not, interiors can be hot, poorly ventilated, and uncomfortable. The standards in this document address criteria and strategies for building orientation and passive cooling, in addition to facility layout and design details appropriate to Liberia's climate.

Construction activities are also significantly influenced by seasonal conditions. During the peak of the rainy season, construction work may be heavily impacted or stopped. Transportation during the rainy season is also a major challenge, especially in remote areas where quickly deteriorating road conditions prevent materials from being delivered to the site. Project managers must take these factors into account to ensure that projects are delivered efficiently and effectively.

Regional variation

To result in appropriate, durable, and high-performance buildings, designs must take into account a large range of environmental factors and other context-based factors. Among these are population density, soil conditions, topography, drainage patterns, solar exposure, and vegetation. Urban areas tend to have more restricted building sites and environmental pollution issues, but better access to municipal infrastructure, material suppliers, and labor. Construction projects in rural areas by contrast, do not face as many spatial restraints, but material transportation and limited skilled labor can significantly increase project costs.

Local resources

The availability of materials, technical resources, and human capacity must be assessed to determine appropriate building methods and infrastructural opportunities. Optimizing the use of locally available resources can reduce both initial construction costs and long-term operational costs.

The availability and quality of maintenance and repair services is critical to ensuring that building structures and systems last for their intended lifespans. Access to skilled technicians, tools, and replacement parts may present a particular challenge in more remote areas, and should be accounted for early on.

5 User Guide

5.1 Contents

Recognizing the variety of contexts in which facilities operate, the standards in this document have been written and organized to provide suitable strategies for constructing and maintaining health infrastructure that meet minimum performance criteria while being flexible to the individualized needs of each location.

Standards

Throughout the document, **standards** are identified in bold and marked with numbers and letters (e.g., 3.2.A, 10.1.C). The definition of a standard, as adapted from the World Health Organization's description, is as follows:

> *Standards are requirements that must be met to achieve minimum essential conditions in healthcare settings. They must be clear, essential, and verifiable statements, identifying quantitative or qualitative performance criteria for healthcare facilities.*

For certain standards, **supplementary requirements** have been provided to identify specific performance criteria or practices. Supplementary requirements are marked with roman numerals (e.g., 3.2.A.i, 10.1.C.iii). It should be noted that these are not optional recommendations but mandatory requisites; however there is some flexibility in the compliance path as long as the standard is achieved.

Standards provide mandatory, verifiable minimum requirements.

Supplementary requirements expand upon standards, and may include additional details, compliance paths, means of achieving the standard, or alternative options.

Figures illustrate typical or example means of achieving the standard.

39.2 Products

The following product requirements must be met for concrete in order to ensure proper construction quality.

Manufacturers

39.2.A **Manufactured products such as bonding agents, mortar, joint filler, crack injection adhesives must be purchased from a supplier who is experienced in manufacturing and has production facility guidelines in place for review. Contractor must receive approval from the assigned IU representative for use of products obtained from manufacturers where facility guidelines are not available.**

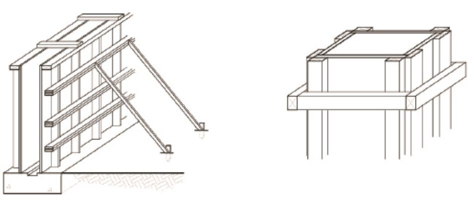
Formwork

39.2.B **For panel formwork, formsof the largest size possible must be usedto minimize joints. Sheets must not be damaged and must have clean, straight edges.**

i. The face of forms directly in contact with the concrete must be high grade lumber or plastic overlaid plywood. Refer to Standard39.2.E for acceptable wood types.

39.2.C **Acceptable formwork construction alternatives include board-formed concrete, or metal or plastic pans. Other formwork techniques must be approved bytheassignedIUrepresentative.**

Figure 39.b Formwork Layout



39.2.D **Bracing to ensure stability of all formwork must be provided. Shore or strengthen formwork subject to overstressing by construction loads.**

i. Forms for walls must be supported by studs, tied together by continuous wales, and diagonally braced to the ground.
ii. Forms for columns require liners, diagonal bracing to the ground and straps or clamps to hold the formwork together.

39.2.E **The wood for formwork must conform to the following requirements. The types listed in Table 39.dare acceptable for formwork.**

i. Timber used for forms must be durable and treatable.
ii. Timber must have sufficient strength characteristics.
iii. Timber forms must be light weight and well-seasoned without warping
iv. Timber for formwork must hold nails well.
v. Where plywood is used, it must be built up of an odd number of layers with the grain of adjacent layers perpendicular to one another. Refer to Section 43.2 for additional wood information.

Multiple options for design, building services, and other facility elements are presented for use in situations where location and local resources do not allow the use of uniform solutions.

Facility-specific recommendations

Many of the standards identified in this document establish minimum requirements that apply to every type of health facility in Liberia. Where necessary, standards particular to only specific facility types or programs are noted as such. Examples of areas that require particular attention include operating departments, inpatient wards, and labor and delivery rooms.

Key information

Technical information that is helpful to see in proximity to related standards has been placed in grey boxes throughout the document. Content in these boxes includes:

- Technical primers on the functionality of building services and systems
- Solutions to frequent operational challenges
- Best practices

More extensive technical content is presented in the appendix.

Table 39.d. Acceptable Wood Types – Formwork

Species	Local Name	English Name
Pentandra	Fromager	Silk Cotton
Guineensis	Rikio	-
Ivorensis	Pali	Sasswood
Africanus	Ilomba	-
Scledroxylon	Wawa	-

39.2.F Where steel formwork is used, the steel must have a minimum yield stress of 36 ksi (250MPa).

39.2.G Forms or bracing must not be removed until concrete has gained sufficient strength to carry its own weight and imposed loads.

Table 39.e. Shoring Removal Schedule

Structure	Removal Time
Bottom Forms: Slab, Beams, Girders	7 days
Side Forms: Beams and Girders	3 days
Columns and Walls	3 days
Footings, Pile caps, Grade Beams	2 days

Tables present detailed criteria or recommendations.

Concrete Mixtures

39.2.H Particles in concrete mixtures must be well graded or similar in size because strength is reduced when particle sizes vary.

39.2.I Select the appropriate concrete mix by volume according to location of concrete placement in structure. Refer to Table 39.f for mix appropriateness.

i. A concrete mix must be selected based on the intended application and is mixed by a ratio of Cement: Sand: Gravel: Water. The ratios are expressed by volume for ease of field measuring.

ii. Mix calculations may be performed per unit volume as an alternate process according to the following equations.

Mix Calculations

Volume of concrete = $1\ m^3$ (EQ. a)

Volume of cement = $\frac{\text{Mass of Cement}}{\text{Specific Gravity [SG] of Cement}} \times \frac{1}{1000}$ (EQ. b)

Volume of water = $\frac{\text{Mass of Water}}{\text{[SG] of Water}} \times \frac{1}{1000}$ (EQ. c)

Volume of chemical admixture (SG 2%by mass of cement) (EQ. d)

Volume of all aggregates = (EQ. a) − (EQ. b + EQ. c + EQ. d) (EQ. e)

Volume of course aggregates [CA] = (EQ. e) x Volume of CA x [SG] of CA (EQ. f)

Volume of fine aggregates [FA] = (EQ. e) x Volume of FA x [SG] of FA (EQ. g)

Key information including technical primers and best practices are summarized in grey boxes.

STRATEGIC PLANNING

CONTENTS

IMPACT

Because project conditions vary drastically from one another, there is no one-size-fits all approach. Strategic planning is necessary to not only ensure that what is needed is what gets built, but that all the resources are in place for facility operation and maintenance. Understanding a tiered approach to meeting minimum needs, and strategizing budgeting and project phasing will ensure that resources, effort, and time are invested in the most optimal way.

Proper planning helps increase the quality of design and construction, reduces delays, helps keep realistic project financing on track, and leads timely and efficient project initiation and completion.

PRIMARY USERS

Central MOHSW Administrators

Infrastructure Unit

County Health & Social Welfare Teams

MOHSW Implementing Partners

GUIDELINES FOR USE

Resource constraints require a prioritization of projects at any given time. Chapter 6: Hierarchy of Needs is intended to serve as a planning tool to help determine whether maximum impact can be made by renovating existing facilities to meet essential needs, building new facilities, or a combination of the two. Once a determination of resource allocation is made, a project plan may be developed by using Chapter 7: Project Planning for guidelines on project scope, budgeting, and strategies.

6 Hierarchy of Needs

This chapter establishes and highlights the most essential infrastructural needs for both new and existing facilities to help inform the prioritization of work needed at existing facilities and the planning of future facilities.

6.1 Minimum Requirements

A set of minimum requirements ensures that whenever work is planned, there is a checklist of items that must be fully functional across all facilities before additional improvements are developed. The standards and charts below were developed through rigorous assessment of existing facilities and meetings with stakeholders including CHTs, MOHSW administrators, implementing partners, and medical and support staff at facilities.

Structure & Space

6.1.A. A roof free of leakage is required for all existing and new facilities.

i. Refer to Section 36.1 for roof construction requirements.

6.1.B. A solid level surface floor is required for new primary facilities and new and existing secondary and tertiary facilities.

i. Refer to Section 44.2 for sanitary floor finish requirements.
ii. All tertiary care facilities must have level solid continuous surface floor finishes that meet the requirements for cleaning and maintenance as specified in Section 44.2.

6.1.C. Spaces where health services are provided must be accessible and navigable by all patients regardless of disability, gender, age, or literacy level.

i. Refer to Chapter 16 for spatial layout and design details that ensure equitable access.
ii. Refer to Chapter 17 for wayfinding and signage standards.

6.1.D. Room for future expansion must be incorporated into master plans for new secondary and tertiary facilities.

i. Refer to Section 9.8 for facility growth and expansion strategies.

Water &Sanitation

6.1.E. All existing and new facilities must be supplied with a clean, safe, and reliable source of water.

i. The water supply must meet the usage demands of the facility type and must be available on a consistent basis throughout the year. Refer to Sections 6.2 and 8.7 for facility water demands and Chapter 27 for water provision, storage and treatment requirements.
ii. Water quality must be tested and meet the safety requirements identified in Standards 8.7.D-E.
iii. If a clean, safe, and reliable ground or surface water source is not available, assess the potential for rainwater catchment and storage; otherwise consider relocating the facility.

6.1.F. New health centers and new and existing hospitals must have an internally piped water distribution system.

i. Building plumbing systems must meet the standards outlined in Chapter 30.

6.1.G. **All existing and new facilities must have functioning waste treatment and disposal infrastructure.**

i. Refer to Chapter 29 for standards on solid, medical, and human waste systems.
ii. Waste infrastructure must be used and managed appropriately.
iii. Existing primary facilities that lack waste infrastructure may alternatively ensure the safe and routine transfer of waste to a nearby health facility for treatment and disposal. Where this is not possible, primary health facilities must prioritize the construction of waste infrastructure.

6.1.H. **Sanitary facilities are required at all new and existing facilities, and must be accessible to both patients and staff.**

i. Refer to Section 50.5 for sanitary space requirements.
ii. Refer to Chapter 28 for standards on human waste management systems.

Electricity

6.1.I **All existing and new facilities must have a stable electrical supply for EPI cold chain storage.**

i. Prioritize the use of solar PV panels.
ii. Refer to Chapter 23 for electrical requirements.

6.1.J. **A primary power supply for general electrical use is required at all new primary facilities and new and existing secondary and tertiary facilities.**

i. Refer to Section 23.1-2 for power supply options and critical loads.
ii. Refer to Section 23.5 for power generation and storage requirements.

6.1.K. **An uninterrupted backup power supply is required at all new facilities level PHC2 and above, and all existing hospitals.**

i. Refer to Section 23.1-2 for power supply options and critical load.
ii. Refer to Section 23.5 for power generation and storage requirements.

6.1.L. **A safe, balanced electrical distribution system must be installed at all new facilities level PHC2 and above.**

i. Refer to Sections 23.3-4 for load analysis and power distribution requirements.

6.1.M. **A reliable communication system is required at all new facilities, and all existing hospitals.**

i. Refer to Section 26.1 on communication systems.

Lighting

6.1.N **All existing and new facilities must optimize the use of natural daylighting.**

i. Prioritize spaces where daylighting will improve task performance, increase occupant comfort, and decrease the need for electric lighting.

ii. Refer to Chapter 24 for daylighting requirements.

6.1.O. **All new facilities must have functioning electric lighting that allows visibility for nighttime functions and safe navigation on site. All new and existing secondary and tertiary facilities must additional have electric lighting for medical procedures.**

i. Refer to Chapter 25 for electric lighting requirements.

Ventilation

6.1.F **All new primary care facilities must be planned and designed to use natural ventilation for internal spaces. All secondary and tertiary care facilities, existing or new, must prioritize natural ventilation, especially in public spaces.**

i. Secondary and tertiary facilities may use mechanical ventilation to achieve the ventilation standards outlined in Chapter 20. Natural ventilation must be designed using the principles in Chapter 19.

6.1.H. **Covered open air waiting spaces are required at all new facilities, and are strongly recommended at existing facilities.**

i. Refer to Section 47.1 for waiting space design requirements.

6.1.I. **All new and existing tertiary healthcare facilities must provide mechanical ventilation systems in sterile areas and high clinical risk spaces, and mechanical cooling in spaces where climate control is essential for medical procedures.**

i. Refer to Chapters 20 and 22 for mechanical ventilation and cooling requirements.

Supporting Facilities

6.1.J. **Maternal waiting homes are required at all new PHC 2s and Health Centers, and are strongly recommended at existing PHC 2s and Health Centers**

i. Refer to Sections 7.3 and Chapter 51.1 for maternal waiting home siting and design requirements.

6.1.K. **Staff housing is required at all new PHC1s and strongly recommended at all facilities in rural or remote locations.**

i. Refer to Sections 7.3 and Chapter 51.2 for staff housing siting and design requirements.

6.2 Tiered Approach

Basic needs should be accommodated first at all facilities before additional facilities are constructed. Following a tiered approach of upgrading current facilities first before expanding helps ensure that all facilities meet basic minimum requirements. The tables below provide a decision-making tool for this planning process.

6.2.A Table 6.a must be used to assess needs and prioritize interventions for primary care facilities.

Table 6.a Hierarchy of Needs for Primary Healthcare Facilities

Item		Primary Care Facilities		Referenced Standards
		PHC 1	PHC2	
1	Leak-free roof	**X**	**X**	36.1
2	Clean, safe, and reliable water supply	**X**	**X**	27.1-27.9
3	Electricity supply for EPI cold chain storage	**X**	**X**	23.1-23.7
4	Waste management systems	**X**	**X**	28.1-28.4; 29.1-29.10
5	Naturally ventilated spaces	**X**	**X**	19.1-19.5
6	Naturally daylit spaces	**X**	**X**	24.1-24.2
7	Sanitary facilities	**X**	**X**	50.5
8	Covered open air waiting spaces	**X**	**X**	47.1
9	Primary power supply	X	X	23.1-23.7
10	Electric lighting	X	X	24.1-24.4
11	Level solid surface floor	X	X	44.2
12	Reliable communication system	X	X	26.1-26.2
13	Spaces accessible to all patients	X	X	16.2
14	Staff housing	X	O	51.2
15	Uninterrupted backup power supply	O	X	23.5
16	Safe, balanced electrical distribution system	O	X	23.3-23.7
17	Internal piped water	O	O	30.1-30.3
18	Room for expansion	O	O	9.4
19	Maternal waiting homes	–	X	51.1
20	Mechanical ventilation in high clinical risk spaces	–	–	20.2

X = *Required for Existing and New facilities*

X = *Required for New facilities; Strongly recommended for Existing facilities*

O = *Highly recommended for all facilities*

– = *Not required*

6.2.B. Table 6.b must be used to assess needs and prioritize interventions for secondary care facilities.

Table 6.b Hierarchy of Needs for Secondary Healthcare Facilities

Item		Secondary Care Facilities			Referenced Standards
		Health Center	District Hospital	County Hospital	
1	Leak-free roof	**X**	**X**	**X**	36.1
2	Clean, safe, and reliable water supply	**X**	**X**	**X**	27.1-27.9
3	Waste management systems	**X**	**X**	**X**	28.1-28.4; 29.1-29.10
4	Electricity supply for EPI cold chain storage	**X**	**X**	**X**	23.1-23.7
5	Naturally ventilated spaces	**X**	**X**	**X**	19.1-19.5
6	Naturally daylit spaces	**X**	**X**	**X**	24.1-24.2
7	Primary power supply	**X**	**X**	**X**	23.1-23.7
8	Electric lighting	**X**	**X**	**X**	24.1-24.4
9	Level solid surface floor	**X**	**X**	**X**	44.2
10	Sanitary facilities	**X**	**X**	**X**	50.5
11	Internal piped water	X	**X**	**X**	30.1-30.4
12	Uninterrupted backup power supply	X	**X**	**X**	23.5
13	Reliable communication system	X	**X**	**X**	26.1-26.2
14	Covered open air waiting spaces	X	X	X	47.1
15	Spaces accessible to all patients	X	X	X	16.2
16	Safe, balanced electrical distribution system	X	X	X	23.3-23.7
17	Room for expansion	X	X	X	9.4
19	Mechanical ventilation in high clinical risk spaces	O	X	X	20.2
18	Maternal waiting homes	X	O	–	51.1
20	Staff housing	O	O	O	51.2

X = *Required for Existing and New facilities*

X = *Required for New facilities; Strongly recommended for Existing facilities*

O = *Highly recommended for all facilities*

– = *Not required*

6.2.C. Table 6.c must be used to assess needs and prioritize interventions for tertiary care facilities.

Table 6.c Hierarchy of Needs for Tertiary Healthcare Facilities

Item		Tertiary Care Facilities		Referenced Standards
		Regional Hospital	Referral Hospital	
1	Leak-free roof	**X**	**X**	36.1
2	Clean, safe, and reliable water supply	**X**	**X**	27.1-27.9
3	Waste management systems	**X**	**X**	28.1-28.4; 29.1-29.10
4	Naturally ventilated spaces	**X**	**X**	19.1-19.5
5	Naturally daylit spaces	**X**	**X**	24.1-24.2
6	Electricity supply for EPI cold chain storage	**X**	**X**	23.1-23.7
7	Primary power supply	**X**	**X**	23.1-23.7
8	Electric lighting	**X**	**X**	24.1-24.4
9	Level solid surface floor	**X**	**X**	44.2
10	Sanitary facilities	**X**	**X**	50.5
11	Internal piped water	**X**	**X**	30.1-30.4
12	Uninterrupted backup power supply	**X**	**X**	23.5
13	Reliable communication system	**X**	**X**	26.1-26.2
14	Covered open air waiting spaces	X	X	47.1
15	Spaces accessible to all patients	X	X	16.2
16	Safe, balanced electrical distribution system	X	X	23.3-23.7
17	Mechanical ventilation in high clinical risk spaces	X	X	20.2
18	Room for expansion	X	X	9.8
19	Staff housing	O	–	51.2
20	Maternal waiting homes	–	–	51.1

X = *Required for Existing and New facilities*

X = *Required for New facilities; Strongly recommended for Existing facilities*

O = *Highly recommended for all facilities*

– = *Not required*

7 Project Planning

There are four categories of project intervention: renovation, expansion, upgrading, and new construction. Existing conditions and resources as well as anticipated services and needs will inform the development of the most appropriate type of intervention.

Budgets must be established early on to ensure that adequate funds are available not only for construction, but furnishings and equipment, and staffing and operation. A variety of stakeholders, including CHTs and community leaders, must also be engaged from the start of every project to optimize the use of resources, ensure that end users' needs are met, and build local stewardship of the project.

7.1 Renovation, Expansion, & Upgrading

Renovation

As buildings and infrastructure age or undergo wear and tear from normal use, renovations will be necessary to restore existing structures or make improvements or alterations reflecting the facility's service needs. By definition, renovations entail work that is performed to materially extend the useful life of a building or increase its performance. Three levels of renovation are defined as follows:

- **Minor renovations** include repairs or improvements to building finishes or non-structural elements. No fundamental alterations are made to walls, floors, or ceilings, or the physical layout of rooms; however the function and internal arrangement of rooms may or may not change.
- **Moderate renovations** include work performed to modify non-structural components such as walls, doors/windows, and fixtures. The physical layout of rooms may be altered within the existing footprint of the building.
- **Major renovations** include work that alters or improves structural building elements such as walls, ceilings, or floors. Changes may be made to electrical, mechanical, and/or plumbing systems, so work should be carefully planned to minimize negative impacts on service provision.

7.1.A. Minor renovations must be planned when building finishes or non-structural elements are damaged beyond routine maintenance repairs in such a way that compromises the hygiene or performance of medical services.

7.1.B. Moderate renovations must be planned when existing room layouts compromise the hygiene or the performance of medical services, and when interventions can be carried out without diminishing a building's structural integrity. Examples include but are not limited to:

i. Demolish and/or construct non-structural walls to maximize the use of available space, improve infection control, and facilitate the circulation of building occupants.

ii. Alter the placement, number, size, or qualities of doors and windows to improve accessibility and circulation, lighting and ventilation, and the use of internal spaces.

7.1.C. Moderate renovations must be planned when fixtures are damaged or compromising the hygiene or performance of medical services. Examples include but are not limited to:

i. Replace fixtures when their working lifespan come to an end or when their maintenance and condition are impeding building performance and/or leading to unnecessary operational costs.

7.1.E. Major renovations must be planned when existing building layouts or structural elements compromise the hygiene or the performance of medical services, and/or when interventions are necessary to maintain structural integrity. Examples include but are not limited to:

i. Repair or replace walls, ceilings, floors, or roofs to maximize the use of available space, improve infection control, and facilitate the circulation of building occupants.

7.1.F. Major renovations must be planned when existing building systems are damaged in such a way that compromises occupant safety or the quality of healthcare services. Examples include but are not limited to:

i. Repair or replace plumbing infrastructure to ensure the adequate delivery of clean water, and/or the removal of waste water and sewage. (See Chapter 30 on requirements for plumbing systems)

ii. Repair or replace mechanical infrastructure to reduce the risk of airborne infection and to improve indoor air quality and occupant comfort. (See Chapters 20 and 22 on requirements for mechanical ventilation and cooling systems)

iii. Repair or replace electrical infrastructure to reduce the risk of fire or electrocution, and to facilitate the balance of electrical loads. (See Chapter 23 on requirements for electrical systems)

Expansion

Unlike major renovations, expansions add to the existing building footprint, and typically involve extending spaces or adding new rooms to accommodate an increase in users or services.

7.1.G. Expansion projects must be planned under circumstances including but not limited to the following:

- There is an increase in the catchment population and the facility needs more space to perform the same services.
- There is a significant increase in daily patient load and the facility needs more space to accommodate users.
- There is a significant permanent increase in the number of staff assigned to the facility.
- The original building was never large enough.
- Additional or improved services are added requiring specialized equipment and/or spatial requirements.

Upgrading

Upgrading takes place when additional medical services are introduced that qualify the facility to upgrade its designation within the healthcare system. (e.g: An addition of a lab to PHC1 may qualify it to become a PHC2). Upgrades must be done in conformity with the norms and standards specific to each facility.

7.1.H. Upgrading projects must be planned under circumstances including but not limited to the following:

- The catchment population has surpassed the capacity the facility is intended to serve. (See Chapter 5 on Facility Types)
- The next facility of a higher level is located too far away to provide accessible or effective referral services.

Administrative Planning

All interventions performed on existing facilities must be carefully planned to minimize the disruption of health services, and to guarantee the safety and comfort of building occupants. Proper assessment must be carried out to ensure that the scope of the intervention reflects both the existing and future needs of the facility.

7.1.I. **A thorough inspection must be completed before contracts are signed and any renovation, expansion, or upgrading work begins. The degree of existing damage is often difficult to determine from observation or minimal wall demolition.**

i. Open walls and ceilings to the extent necessary to be certain which systems and structural elements need to be renovated or replaced.

ii. Perform necessary tests on existing systems (plumbing, electrical, mechanical) before construction begins to determine the scope of work that will be required for renovation.

7.1.J. **Make the necessary arrangements before construction begins if a portion of the health facility will remain in use during renovation so that the services can continue to function at the highest level possible.**

i. Work that will cause major noise disruptions or closures to the facilities in service must be done at low traffic times or after hours when possible.

ii. Schedule work in advance and inform administrators so that arrangements can be made in case of closures.

7.1.K. **Consider occupant safety when a portion of the building or adjacent buildings will remain in use during renovation or expansion.**

i. Identify the entire construction zone, including loading zone, access to street, material storage, etc., and block off with appropriate signage and barriers.

ii. Close off entrances, hallways or circulation in existing structures as needed in order to physically separate the construction zone from facilities in use.

7.1.L. **Prepare a strategy for site management before any materials or machinery are transported to the site**

i. Identify and block off an area for trash/debris that will not be a hazard to people or obstruct facilities in use.

ii. Identify and remove as needed any electrical and telephone lines that may be in the way of construction and subsequently a danger to occupants or workers.

7.2 New Construction

In addition to renovating, expanding, and upgrading existing health facilities, new facilities must be planned and strategically located to enable the expansion of health services as set forth by the EPHS. Each project presents an opportunity to build local capacity as well as local project stewardship. Alignment among stakeholders is necessary from the start of a project to guarantee that development runs smoothly and that end users' needs are met. A well planned community engagement process not only has the potential to generate jobs and add skill sets within nearby communities, but can be effective in creating a strong sense of community ownership for the facility.

7.2.A. New construction must be planned in areas where there are significant populations lacking access to health services.

i. Determine facility types and sizes based on anticipated catchment populations and proximity to other facilities of each level.

7.2.B. New construction must replace existing facilities when buildings are jeopardizing the safety and wellbeing of their occupants and are beyond repair or renovation.

7.2.C. New facilities must be carefully located to maximize effectiveness of healthcare delivery and accessibility to services.

i. Maximize the use of human and financial resources by considering how the facility fits into existing health infrastructure and service delivery networks.
ii. Maximize user accessibility by considering the expected distance and nature of patient travel.

7.2.D. The site selection process must be coordinated with the CHT and engage local community leadership.

i. Communicate the need for a new facility site to community leadership, and provide site selection criteria.
ii. Select a site that conforms to requirements outlined in Chapter 8.
iii. Conduct water quality and any additional environmental tests, as outlined in Chapter 8.

7.2.E. The land title and/or other property ownership documents must be obtained and filed with the MOHSW prior to the start of facility design.

i. Engage the community in which a new facility is planned to coordinate the procurement of a land title for the site.
ii. The site survey and all documentation that provides information on the site must be obtained and filed with the IU.

7.2.F. A staffing and equipment plan must be created before any new facility can undergo design and construction to ensure that buildings are operational upon completion.

i. Establish written confirmation of the number and qualifications of staff who will be working in the new facility.
ii. Establish written confirmation of the source of funding for furniture and medical equipment for each new facility. This should be done regardless of who is funding the construction of the building, as the two sources of funding may be different.

7.2.G. Consulting architects and/or engineers must seek to engage a committee of community members, facility staff, and the CHT in their programming and design phases.

7.2.G. The CHT must be engaged in the design and construction process of any new facility to ensure that the facility design meets local needs and constraints, and to provide confirmation of construction progress.

i. Prior to design and construction, a designated CHT representative must visit the site with the IU project representative and provide feedback regarding site-specific design concerns and determine required design criteria.

ii. The CHT representative must provide periodic confirmation of construction progress and communicate any problems to the IU. While the IU project representative must routinely visit the site during construction to supervise quality control and conformance with the Standards; the CHT must be engaged in reporting contractor presence on site, and the general status of work.

7.3 Supporting Facilities

Supporting facilities include infrastructure types that are not direct settings for the provision of medical services but have proved to be crucial to the effective and efficient delivery of healthcare. These facilities are essential for the wellbeing of patients and facility staff, in addition to the achievement of the national health objectives described in Chapter 1.

Maternal Waiting Homes

The primary role of maternal waiting homes is to reduce maternal and infant mortality by enabling expecting mothers immediate access to health services in the late stages of pregnancy. In areas where populations are dispersed, transportation is limited, and facilities are spaced widely apart, maternal waiting homes can be instrumental in increasing facility-based deliveries overseen by a skilled birth attendant. By reducing the need for mothers to travel long distances close to their delivery dates—which can present a potential threat to the mother or baby, especially when road or weather conditions are poor—and offering mothers with potential birth complications temporary accommodation close to health services, maternal waiting homes are a simple yet effective alternative to other infrastructural measures for reducing maternal infant mortality.

Staff Housing

Staff housing addresses two major challenges that affect the efficiency and quality of healthcare delivery: staff retention and intervention time. Particularly in rural or remote areas, staff retention remains difficult because qualified staff are reluctant to live and work in areas where there are unable to secure quality housing and live comfortably. Providing well-designed and constructed staff quarters on or near health facility sites can be a cost-effective measure that significantly improves the willingness of medical staff to provide services where most needed.
Intervention times also remain a problem when medical staff live relatively long distances away from the facilities in which they work. Especially under emergency circumstances, such as when patients arrive needing critical care in the middle of the night, not only are patient lives put at risk, but the general effectiveness of health services are impeded. The provision of staff housing can successfully prevent such circumstances by allowing staff to live in close proximity to facilities.

7.3.A. **Maternal waiting homes must be prioritized in locations where there are facilities that are well equipped and staffed to handle deliveries, and serve communities that live relatively long walking distances (>10km) from the facility.**

i. Maternal waiting homes must be fully functioning and designed to maintain the same standards as other health facilities, and should have spaces and amenities for sleeping, cooking, bathing, and laundry.

ii. See Section 51.1 for maternal waiting home requirements.

7.3.B. **As much as possible, staff housing must be planned for facilities in remote locations.**

i. To maintain staff satisfaction, staff housing must adequately meet the level of quality and living standards expected by healthcare workers.

ii. Staff housing must be located on-site if possible or within short walking distance from healthcare facilities.

7.4 Budgeting and Phasing

Proper budgeting is necessary to ensure that construction can be accomplished with the funds available, and that the facilities can be occupied, operated, and maintained as intended. In cases where all the funds for a full facility build-out may not be available initially, a phasing plan should be established to strategize how construction may be staged in phases over time. Project phasing can be very beneficial if the scope and the expected results of work in every phase are determined in advance.

7.4.A. An initial estimated budget must be developed in consultation with the assigned IU representative before the project proceeds to site selection or design phases, and must include the cost of construction; furniture, finishes, and equipment; and operations.

i. The construction budget must include the construction materials, cost of labor and contingencies.

ii. The furnishing, furniture, and equipment (FF&E) budget must include all expected expenditures for furnishing and equipping the facility to an operational level.

iii. The operations budget must include staff salaries, medical, office, operations supplies as well as projected regular maintenance costs. The purpose of including operations in this initial budget is to ensure that the necessary funds will be available to run the facility following construction.

iv. Reference in costs and comparison to project costs from facilities of the same scale in similar locations can be used as a baseline for estimating total project cost.

7.4.B. Once design is completed, a final budget must be established for every new healthcare facility, and must include a construction budget and a furniture, furnishing, and equipment budget (FF&E).

i. The construction budget must include the construction materials, cost of labor and contingencies, as indicated on the project Bill of Quantities (BOQ).

ii. The furnishing, furniture, and equipment (FF&E) budget must include all that is necessary to have the healthcare facility running before it is commissioned by the MOHSW.

7.4.C. In cases where the budgets submitted cannot be financed to complete the project all at once, the project must be phased in accordance to the Hierarchy of Needs in Chapter 6.

7.4.D. Budgets for renovation, expansion, and upgrading projects must also be established prior to design and construction, and must include a construction budget and a furniture, furnishing, and equipment budget (FF&E).

SITE PLANNING

CONTENTS

IMPACT

Proper site selection and planning are essential for facilities to be able to function efficiently and safely, to serve as appealing places for patients to seek health services, and to accommodate the long-term growth of the facility.

A well-selected and planned site can support infrastructure while a poorly selected and planned site can frustrate infrastructure. Ideal site development provides conditions that promote efficient and safe health care delivery.

Careful site selection and planning not only reduce the need for added resources, but make the most of the natural and built environment to create a safe, effective, and dignified setting for the delivery of health care.

PRIMARY USERS

Central MOHSW Administrators

Infrastructure Unit

County Health & Social Welfare Teams

Architects & Designers

Civil Engineers

GUIDELINES FOR USE

The site selection process should begin with an assessment of site options and evaluation of their favorability; important features to look out for are listed in Site Selection. Once a site is chosen, users may refer to the Masterplanning Chapter in order to strategize an overall project plan before any building design decisions are made.

For specific site features during design, consult Chapter 10: Landscaping & Outdoor Space. Chapter 11: Stormwater Management and Erosion Control may be used as a means of determining detailed design factors for the site, and should be used in conjunction with Chapters 27-26 Water & Sanitation during planning and with Chapter 32: Site Preparation during implementation.

8 Site Selection

Once the facility type and the target community for a new health facility have been determined, selecting a site for construction is the next step. Environmental conditions, topography, existing infrastructure, and accessibility all must be considered, as these elements impact building design, cost, utilization and the effectiveness of services offered.

Definitions

- **Drilled Well**: A well constructed by either cable-tool or rotary methods usually to depths exceeding a 50 ft with capacities to provide for industry, irrigation, or municipalities.
- **Dug Well**: A shallow, large-diameter well constructed by excavating with hand tools or power machinery instead of drilling or driving, typically for individual domestic water supplies and yielding considerably less than 100 gal/min (380 L/min).
- **Fill:** Dirt, rock or other material added to level or raise the elevation of a land feature.
- **Leach Field**: Area where septic-tank effluent is distributed for natural leaching.
- **Peat:** Compressed dead vegetation that has been preserved from decay by acidic groundwater in low-lying areas.
- **Penetrometer:** A device to test the strength of a material such as soil.
- **PV panel**: Photovoltaic panel.
- **Septic Tanks:** Typically two or three chambered concrete tanks that are constructed just below ground level and receive excreta and all other wastewater from the facility.
- **Soakaway Tanks:** Rectangular two compartment tanks commonly constructed just below ground level that receive both excreta and flush water from flush toilets and other waste flows.
- **Spring**: A place where ground water flows naturally from a rock or the soil onto the land surface or into a body of surface water.

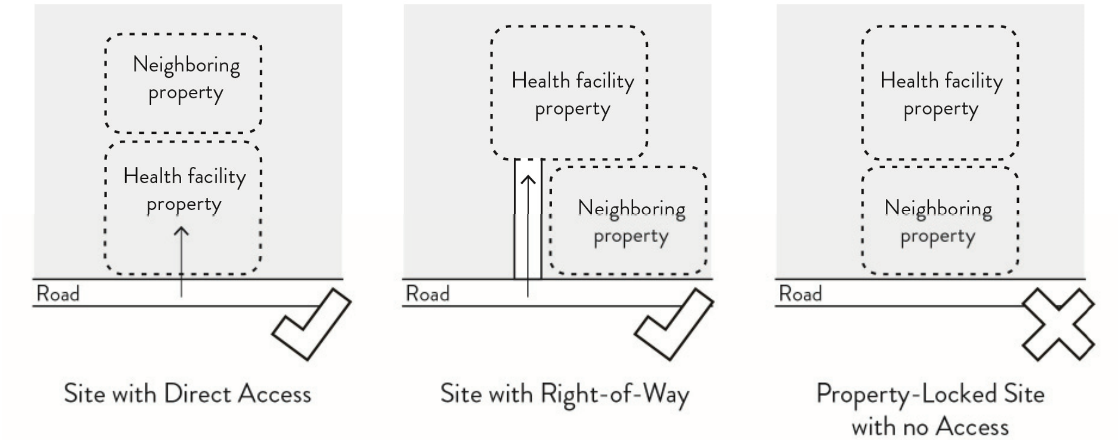
8.1 Access and Proximity

Residents are more likely to visit primary healthcare facilities that are conveniently located and easy to access; these factors should therefore be considered in order to maximize services provided, especially for unwell patients and pregnant women. However, Hospitals with Clinics and Health Centers in close proximity maybe less centrally located to minimize foot traffic from patients seeking primary care.

8.1.A. New PHC clinics and Health Centers must be placed on sites that are easily accessible to the public.

i. Sites that require long roads (over 100ft (30.5m) from the main road) or steep roads (over 20% slopes) must be avoided. Such roads are expensive to build and maintain, and unless they are paved, can limit access during the rainy season.
ii. Sites requiring bridges must be avoided as crossings may be impassable during the rainy season.
iii. Facilities may be co-located with other institutions or local civic and commercial facilities to optimize use especially when service infrastructure can be shared with other buildings.[1]
iv. Sites must enable privacy and quiet for patients during visits.
v. Sites that are property-locked and inaccessible to vehicles must be avoided. (Refer to Figure 8.a.)

Figure 8.a. Site position relative to major roads



8.1.B. New Hospitals must be placed to optimize their use for referral care by allowing efficient access by ambulance and other means of transportation.

i. Sites must be selected that are easy to access from the primary care facilities referring patients.
ii. Given that many referrals travel long distances by ambulance or private vehicle, special attention must be given to making the facility accessible by road, even in the rainy season.
iii. Prioritize sites that are less central to community centers to minimize congestion and allow for future growth.

8.1.C. The siting and planning of facilities must optimize the referral network and available resources by distributing primary, secondary, and tertiary services.

i. Patients living in proximity to primary care facilities should only visit Hospitals if referred for secondary or tertiary services.
ii. In areas where there are no primary care facilities in proximity to a Hospital, primary services can be provided at the Hospital for the immediate catchment population, but must be clearly distinguished from secondary and tertiary services.

8.2 Site Hazards

Facilities should not be located on sites that are known to be at risk of environmental damage or contamination from hazardous land uses nearby. Sites that could put patients, visitors, or staff at risk are not appropriate locations for healthcare infrastructure.

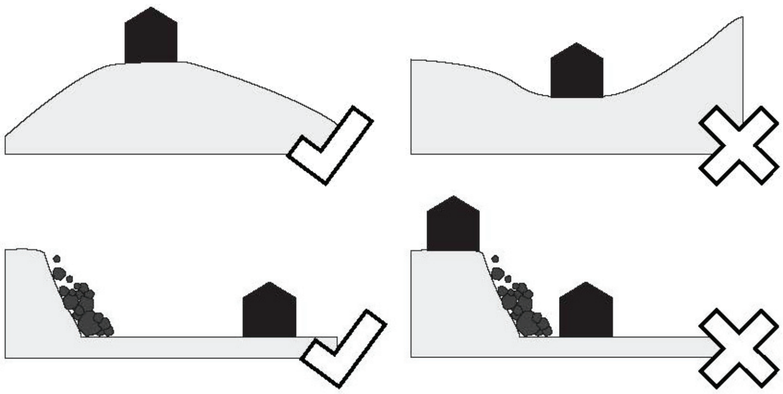
8.2.A. **New healthcare facilities must be placed on sites that are at minimal risk of flooding or landslides.**

i. Facilities must not be sited in known or potential flood zones or low-lying areas that are prone to flooding, inundation, or poor drainage. Infrastructure must be able to be set back from drainage, river, and stream courses.

ii. Sites selected must not be at risk of landslides or soil liquefaction. Infrastructure must be able to be set back from cutbacks and slopes over 30%. (Refer to Figure 8.b.)

iii. Sites must be elevated relative to their surroundings to allow drainage to naturally flow away from buildings and to promote better air quality from consistent airflow.

Figure 8.b. Minimizing risk of flooding and landslides



8.2.B. **Healthcare facilities must not be placed on sites adjacent to garbage dumps, industrial zones, or other areas that are potential sources of air and water pollution.**

i. Sites must not be exposed to air and particulate pollutants, such as those from highly congested motorways or unpaved roads that are sources of pollution, including dust.

ii. Sites must not be near industrial zones or commercial activities that emit harmful airborne substances (e.g., heavy dust, corrosive or salt air, airborne industrial byproducts, burning of waste). Prevailing wind direction and intensity must be evaluated to assess potential of harmful particle migration to the site.

iii. Sites must not be near industrial zones or commercial activities that generate and/or dispose of wastes (wastewater, contaminated stormwater runoff, solid and hazardous wastes) that impact surface and groundwater.

Figure 8.c. Minimizing exposure to health hazards

8.3 Topography and Erosion

Topography must be taken into consideration, particularly for sloping sites, to limit unnecessary excavation, retaining walls, and other site improvements (such as accessibility ramps and stairs), which increase cost. Erosion of the ground surfaces on sites threatens the stability of site improvements and structures, complicates drainage, and contributes to siltation and turbidity of adjacent properties, nearby streams, lakes and drainage courses. The costs associated with the control and repair of erosive surfaces can be significant and sometimes directly impact the safety of a site and/or structures. Erosion problems should be prevented by integrating the site improvements fitting to the terrain and keeping within recommended slopes. Refer to Chapter 11 on erosion control and Chapters 32-33 for site grading standards.

8.3.A. **Sites selected must be below the maximum slope for specific uses.** (Refer to Table 8.a.)

i. Avoid sites on steep slopes (1.5 horizontal to 1 vertical and steeper), as these areas are most susceptible to erosion associated with embankments and drainage channels. Embankments often receive concentrated runoff from pavement surfaces that, depending on soil and slope conditions, may lead to significant erosion problems leading to more engineering and higher construction costs.

ii. Consider the following factors during the site selection process:
- Whether site improvements can be implemented in a manner that minimize site disturbances and cut slopes
- Whether existing vegetation (trees and other natural landscaping) can be preserved or restored to protect slopes and undeveloped areas of the site
- Whether passive drainage improvements can be used to manage runoff and site drainage to minimize erosion and sedimentation.

Table 8.a. Maximum allowable slopes

Site Improvement	Maximum Slope
Building Sites	25%
Access Roads	
▪ Paved roads	20%
▪ Unpaved roads	10%
Sanitary Improvements	
▪ Septic tank	20%
▪ Leaching devices	30%
Water Wells	15%

8.3.B. **Sites selected must not require substantial grading or retaining walls in order to accommodate proposed improvements so as to minimize development costs.**

i. Refer to Appendix A for a range of construction costs based on grading and other site development work.

8.4 Soil Conditions and Ground Stability

A thorough investigation and assessment of soil conditions and stability are essential to determine whether a site is suitable for building on, where the best place may be to locate a building, and what type and size of foundations are required. Inadequate bearing or ground instability may result in minor or major building failure and preliminary screening from a structural or geotechnical engineer is required before a site is selected.

8.4.A. **For new projects, a preliminary site assessment must be conducted and provided to the MOHSW Infrastructure Unit for review and approval.**

Preliminary Site Assessment

A preliminary site assessment must include the following:

- A characterization of the general landforms
- Mapping and documenting and evidence of a risk of landslide or subsidence
- A map of general soil types for load-bearing capacity
- A map of drainage and runoff conditions
- A determination of the highest anticipated water table, and presence of natural springs or waterlogged soils
- The proximity of the site or proposed building to excavations or exposed banks
- The presence of expansive clays
- Previous use of the site such as buried structures; and contamination, earthworks and un-compacted and organic fill

8.4.B. **The bearing pressure of soil must be determined and only deemed acceptable if it has the ability to carry the load of the building without settlement of more than 1in (2.5cm) with an ultimate bearing pressure of at least 6 kips/square foot (300 kpa).**

i. Employ a dynamic cone penetrometer or scala penetrometer test to establish the bearing pressure of the soils. If the soil does not meet the bearing pressure from the penetrometer test, the soil condition should be assessed by an experienced geotechnical engineer.

ii. Determine circumstantial evidence of good ground, including where:
    - Foundations of adjacent buildings show no signs of settlement or inadequate bearing
    - There is no evidence of landslides in the vicinity
    - There is no evidence of buried services
    - Soil drains well to allow for infiltration of runoff and sanitary waste;
    - There is no organic soil, peat or soft clay.

Soil Types of Insufficient Bearing Pressure

Soil types that have insufficient bearing pressure include peat, sand and expansive clay.

Peat: Peat occurs in low-lying areas and consists of compressed dead vegetation that has been preserved from decay by acidic groundwater. Although the surface of the ground can appear stable and dry, peat may be present below the surface in a deep layer that will compress under the weight of a building. If the presence of peat is suspected, consult a geotechnical engineer. The extent and depth of the peat will need to be determined by drilling boreholes or excavating test pits. Where there is only a thin layer of peat, it may be able to be removed to expose firmer soil below. Alternatively, a specifically designed raft foundation and floor slab may be needed.

Sand: Sands vary in particle size and in compaction, and some types of sand have low bearing capacity, and if saturated by shallow groundwater are highly liquefiable, and should be evaluated by a geotechnical engineer. If the soil type is sand, piles driven down to a good bearing layer may be required in conjunction with a concrete slab.

Expansive clay: Expansive clay increases significantly in volume when wet and shrinks again when dry. When expansive clay extends a significant depth below the surface and particularly if it occurs at a depth where the water level fluctuates, substantial uplift of the ground's surface may occur during wet periods, followed by subsidence during dry periods. The amount of uplift will vary according to the clay content of the soil but may be up to 2in (5cmm). Building on a clay soil will affect the ground moisture content and result in a different pattern of expansion and contraction. Moisture content will also be reduced by large paved areas, tree planting and subsoil drainage. If expansive clay is present, soil conditions should be evaluated by a geotechnical engineer.

Fill: If the building site contains areas of fill, whether excavated and relocated on the site or imported from another location, it should be evaluated for suitability and bearing capacity by an experienced geotechnical engineer. Generally, fill is unlikely to meet the required bearing capacity so it should either be removed, compacted, or foundations must pass through the fill down to solid bearing below.

8.4.C. At new sites, the water table must be more than 3ft (91.4cm) below grade.

i. Check the site for a high water table, which means the water pressure in the soil is high and that the soil is likely to be correspondingly weaker.
ii. Consider whether areas of higher ground surround the site. If so, underground water can tend to flow to the site.
iii. Consider implications of a high water table, which is likely to make construction more difficult. It may be necessary to pump excavations and provide drainage to remove the water, which generally results in additional costs. To the extent practical, areas of high groundwater should be avoided if other building sites are available that do not have high groundwater conditions.

Water Pressure and Groundwater Tables

High water pressure adversely affects the stability of sloping ground and increases the loading on a wall retaining the sloping ground.
High groundwater tables may cause pressure beneath a concrete floor slab or increased moisture levels beneath a timber floor. It can also cause water to be driven into timber piles. In this situation, subsoil drainage may be necessary. Indicators of a high groundwater table include:

- Reeds or other wet land vegetation;
- Surface water or boggy ground; and
- Springs and seeps.

8 / Site Selection

8.5 Drainage

Locating natural and manmade drainage courses, stream and river channels, as well as their respective flood ways, is part of the site selection process. Refer to Chapter 11 on Stormwater management.

8.5.A. **Site improvements must be set back 100ft (30.5m) from the top of the banks of all year-round water courses and 50ft (15.2m) from seasonal unmapped streams.**

i. Designate the setback area as a "no build" zone, which preserves the natural functions of the floodplain and stream.

8.5.B. **Sites with good natural drainage must be selected to convey runoff away from the building locations and to effectively convey run on from adjacent properties and hill slopes. Water must move easily away from building site, making high points preferable.**

8.6 Water Quantity and Quality

Health facilities must have reliable and abundant sources of clean and safe water, which is vital to the effective and safe delivery of care. Clean water is used as part of an infection control and prevention plan, including hand washing, facility cleaning, treatment procedures, sterilization of instruments, dialysis, and other functions. It is important to assess local water conditions to determine beforehand that there is capacity to meet the facility's needs. If municipal water is not available (which is the case in most areas in Liberia) a local water supply needs to be developed. Rainwater can serve as an option if rainfall patterns are suitable and water is effectively collected for year-round needs, otherwise rainwater catchment may be considered as a supplementary or back-up method for shorter term situations. Refer to Chapter 27 for standards on water provision, storage, and treatment.

8.6.A. **The site must have access to a reliable and sufficient source of water that meets the daily water demand of the facility.**

i. Refer to Table 27.a. for estimated water needs for Clinics, Health Centers, and Hospitals.

ii. Water usage in large facilities may be higher than requirements noted in Table 27.a. and so should be quantified according to needs based on the facility's expected size.

8.6.B. **Water source capacity by type of potential collection method must be determined by the corresponding flow tests. Wells must have a sustainable yield of at least 264 gallons (1000 liters) per hour to be used.**

Water source capacity testing

Hand Dug Well: The sustainable yield of a hand-dug well must be established by measuring the well's rate of discharge (in gallons or liters/hour) over at least a four-hour period at the point where the dynamic water level stabilizes at the level where the pump's intake will be installed. Care must be taken to dispose of pumped water away from the well in order to minimize the chance of recharge/infiltration which would reduce the validity of the results – a distance of >100m is recommended. Yield is measured using a flow meter on the pump's discharge pipe; or volumetrically by timing how long it takes to fill a container of known volume. Water levels can be measured using an electronic dip meter, or a chalk covered tape with a weighted end.

Drilled Wells: Drilled wells must be tested using a step-draw-down test in conformance with procedures established in the National Guidelines for Well and Latrine Construction.
Springs: The flow of a spring must be measured volumetrically by installing at least a 3ft (91.4cm) length of pipe (or longer) into the spring source. Packing the pipe with clay to direct the flow into the pipe and measuring the flow volumetrically by timing how long it takes to fill a container of known volume.

8.6.C. Potential on-site sources of surface and groundwater contamination must be clearly identified when considering a water source to determine whether it is possible to place a well on-site.

Water contamination sources

Likely sources of pollution on or near sites include:

- Pit latrines
- Soakaway and septic tanks
- Leachfields
- Sewage lines
- Garbage or hazardous waste dumpsites
- Animal lots
- Open and/or abandoned wells
- Old and/or existing cemetery or burial sites
- Buried or surface mounted fuel tanks (diesel, gasoline, kerosene)
- Maintenance building, and other chemical depots or industrial sites

8.6.D. Water quality of potential sources must be screened to assure that the source is safe for the proposed facility. If the water source is not yet developed, then one of two testing methods must be employed to screen the water:

i. A test well must be installed to collect water samples (Refer to Standard 8.8.B.); and/or
ii. Water samples must be collected from developed sources on adjacent properties, if available.

8.6.E. Samples from a representative water source must be collected in clean and sterile bottles and taken to the MOHSW's Environmental Health Department or a water quality-testing laboratory that has been approved by the MOHSW.

i. Test water for all parameters listed in the most current "Liberian Water Quality Standards/Guide" adopted by the MOHSW and/or other guidelines required by the MOHSW. (Refer to Appendix B).
ii. Store and transport water samples on ice to maintain temperatures below 100 F or 40 C, if feasible.
iii. Identify alternative sources of water on-site and repeat the testing process if the results of the initial water tests indicate that the source water quality may not be a safe potable supply.
iv. Follow required documentation methods and keep records with the County Health Team.
v. For approved sources, submit a Well Completion Form to the Ministry of Public Works, District Commissioner and community for all completed wells.

8.7 Solar Access

When selecting a site it is important to evaluate the amount of sunlight available to the building for photovoltaic (PV) panels to be considered as an energy source. The benefits of using PV panels for power generation are both economic and environmental, and so determining whether a site has the appropriate solar access that permits the use of PV panels is an important part of site selection. Refer to Chapter 23 for PV system design.

8.7.A. A site evaluation must be completed and submitted to a MOHSW-approved solar engineer[2] for assessment to determine whether the site permits the use of PV panels.

i. Observations from the site evaluation must include:
   - Seasonal and daily shade patterns from surrounding trees, buildings, and other objects that could obstruct the panels from solar exposure.
   - Orientation of proposed building in reference to the site. PV panel orientation is greatly impacted by which direction the panels are facing, so this must be taken into consideration. (Refer to Section 23.5 for PV installation and orientation standards.)

8.8 Existing Infrastructure

When sites considered for new facilities already contain infrastructure, the impact of pre-existing buildings or utilities on a new facility requires evaluation.

8.8.A. Patient health, safety, comfort, and privacy must be prioritized when determining how to co-locate facilities with existing buildings.

i. Sufficient space, ventilation, light, and safe patient access must be accommodated on sites with pre-existing buildings so that the delivery of care is not compromised.

ii. Existing buildings should be converted for clinical or supporting uses only when they can be renovated to conform to health infrastructure standards; otherwise, they must be removed.[3]

8.8.B. New healthcare facilities must be placed on sites where they can safely make use of or co-exist with any existing utility infrastructure.

i. Sites should incorporate existing electrical infrastructure, where available. Access to an electrical grid or alternative energy sources should be utilized to provide consistent power for mechanical and electrical systems.

ii. Sites should incorporate existing water and waste infrastructure, where possible. Systems that can service new and existing buildings with minimal reconfiguration should be used to simplify design and reduce costs. Infrastructure that is incompatible with site requirements should be shut off or removed.

9 Masterplanning

A masterplan is necessary for buildings and services to operate as a unified system for efficient and effective healthcare delivery. Designing sites to accommodate programmatic, contextual, and climatic needs involves the strategic placement of spaces and services, well-designed site circulation, and provisions for future growth, while limiting risk factors that can confound infection control and service delivery.

Definitions

- **Anaerobic Baffled Reactor (ABR):** An improved septic tank in which the configuration of the tank inlet and outlet baffling or piping forces the wastewater to flow vertically upwards through the sludge.
- **Berm:** A mound or wall of earth or sand.
- **CWMA**: Central Waste Management Area.
- **Generator**: Diesel or gasoline-fired engine that produces energy by the turning of a piston.
- **Leach Field**: Area where septic-tank effluent is distributed for natural leaching.
- **LEC:** Liberia Electric Corporation.
- **Septic Tanks:** Typically two or three chambered concrete tanks that are constructed just below ground level and receive excreta and all other wastewater from the facility.
- **Soakaway Tanks:** Rectangular two compartment tanks commonly constructed just below ground level that receive both excreta and flush water from flush toilets and other waste flows.
- **PV panel**: Photovoltaic panel.
- **Waste Management:** The handling, storage, treatment and disposal of wastes and their residuals.
- **Waste stabilization ponds (WSPs):** Large, shallow ponds that use a combination of natural processes involving bacteria and algae to treat the wastewater.
- **WMA:** Waste Management Area.

9.1 Functional Zones

Masterplanning begins with dividing the site into functional zones so that public areas are easy to reach and areas requiring privacy or clinical isolation are restricted. This is particularly relevant when programs are spread across multiple buildings. More detailed information on program adjacencies and circulation is located in Chapters 12 and 13.

9.1.A. **Patient and visitor entry, waiting, and other public areas must be located near the most accessible entry point to the site.**

i. Check-in and waiting areas must be visible and/or have signage directing patients and visitors that is visible from all access points.

9.1.B. **Clinical programs must be separated from public areas onsite and require managed access by staff.**

i. Clinical areas must be easily accessed from waiting areas and check-in, but only through designated, controlled routes. Patients and visitors should have access to these parts of the site, but only with staff approval.

9.1.C. **Non-clinical support (e.g., Kitchen, Staff Housing, Maternal Waiting Homes, etc.) must be located away from general traffic through the clinical areas of the site.**

i. Associated residential and other non-clinical programs must be placed away from public access. These programs and buildings require greater privacy, but should still be easily accessible from clinical areas. (Refer to Chapter 12 on Program Adjacencies).

Figure 9.a. Site zones showing progression from entry/public areas to rear/private areas

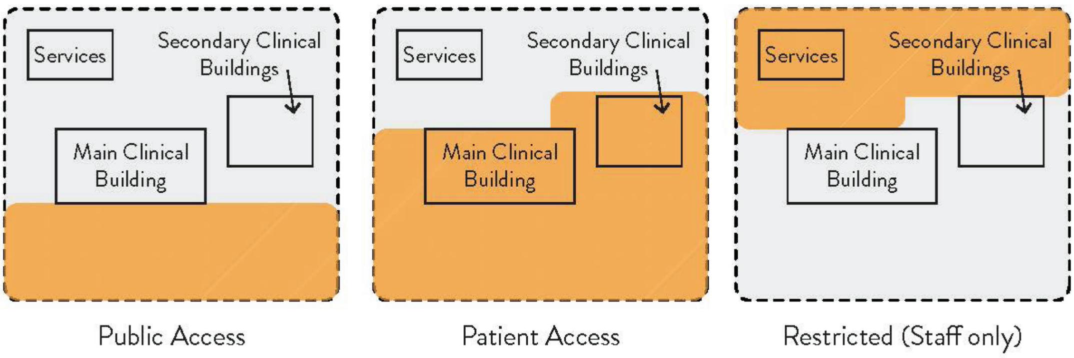
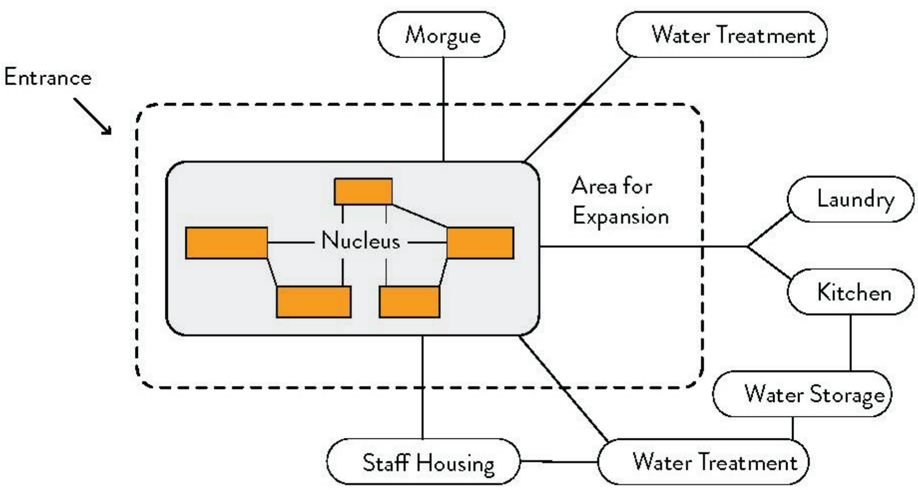


Figure 9.b. Site planning of core and peripheral programs



9.2 Building Services and Utilities

Building services form the backbone of any healthcare facility infrastructural operation. These services encompass wet and dry utilities lines, water system components (wells, storage tanks and other appurtenance), human waste, medical waste and solid waste treatment (incinerator) and disposal facilities, electrical power stations, telecom and radio systems, and maintenance facilities.

During the site planning process it is critical that several factors be considered to properly locate these facilities on the site, so that they do not pose a threat to human health and the environment, as well as to install them in a manner that creates an effective barrier to infection.

9.2.A. Building service facilities must be sited such that they are accessible for ongoing cleaning, service, maintenance, and waste disposal.

9.2.B. Utility planning must provide corridors or routes, able to be reached by vehicles where necessary, that allow for ongoing servicing and access to utility lines without inhibiting operation of the clinical operations.

Medical and Solid Waste Management

Effective confinement of waste and safe handling measures provide significant health protection. Management of hazardous and medical waste includes the handling, storage, treatment and disposal of wastes and their residuals. Chapter 29 provides technical parameters for the layout, configuration, design, and operation of medical and solid waste infrastructure; however basic requirements for the placement and relationship of medical and solid waste infrastructure are outlined below.

9.2.C. An effective masterplan must consider and plan for the following:

- How wastes are collected and transported across or through a site to minimize exposure or contact to the waste
- Where these materials are stored to reduce exposure to potentially infectious or hazardous wastes
- Where these materials are stored or disposed of so they do not impact groundwater and the environment
- Safe measures, such as a secure building or fenced area to prevent scavenging and access to the waste
- Provisions to access (roads, driveways and paths) to transfer the wastes to a vehicle for final treatment and disposal at a regional waste management facility

9.2.D. Each healthcare facility must establish and operate a waste treatment and/or storage area.

i. Ensure that the design and construction of this area permits the following tasks to be carried out:
   - Maintenance and cleaning for waste logistic equipment (water and sewage connection)
   - Interim storage and transfer place (interface) for domestic waste
   - Post-sorting and storage place for valuable materials (waste for recycling) if recycling is carried out (simple shed attached to existing buildings)
   - Documentation and record keeping of the waste streams
   - Secure storage in the case that the waste will be treated in a central facility (e.g. County Hospital)

ii. Secure storage for hazardous waste must be located near any on-site treatment facility, sited on a well-drained impervious hard base, and have available wash down facilities, adequate lighting, ventilation and clear warning signs.

9.2.E. For Health Centers and Hospitals, local collection points for solid and infectious waste must be set up in conjunction with a Central Waste Management Area (CWMA), which must be a stand-alone building complex at least 500 feet from treatment, patient, staff residential areas, and neighboring properties.[4]

i. If the size or conditions of the site do not allow for this distance, provisions must be made to prevent smoke from the incinerator from infiltrating the facility and to address any other potential health or safety hazards resulting from waste management activities.
ii. Refer to Section 29.5 for siting, design, and construction requirements for CWMAs.
iii. Standard 29.5.A identifies core elements to be included in CWMAs. The sizing and layout of these elements must be taken into account in the master plan.

9.2.F. For Clinics, provisions must be made for a basic Waste Management Area (WMA) to be constructed on site to carry out basic waste management functions; this must be situated at least 500ft (152.4m) from treatment, patient, staff residential areas, and neighboring properties.

i. If the size or conditions of the site do not allow for this distance, provisions must be made to prevent smoke from the incinerator from infiltrating the facility and to address any other potential health or safety hazards resulting from waste management activities.
ii. Refer to Section 29.5 for siting, design, and construction requirements for WMAs.
iii. Standard 29.5.J identifies core elements to be included in WMAs. The sizing and layout of these elements must be taken into account in the master plan.

Water Supply

The majority of healthcare facilities rely on on-site water systems to fulfill the daily water demands. During master planning, a site the designer needs to consider the placement of the water system relative to other improvements and features on the site.

9.2.G. Wells must be sited at least 100ft (30.5m) away and up-slope from potential sources of contamination.

i. Consider all potential sources of contamination, including: laundry washing facilities, waste storage and disposal facilities, onsite gray water and sanitary waste system (latrines, soakaways or septic systems), fuel storage tanks, industrial sites, and maintenance buildings.
ii. Calculate the radius around the well, particularly where facilities are designed in campus or other multi-building structures.
iii. Where possible, include two wells on-site to provide redundancy in the case that one becomes contaminated. Other backup sources of water (particularly rainwater) may be preferred where site space is constrained.

9.2.H. A 10ft (3m) horizontal separation between water distribution lines and sanitary sewers must be maintained.

9.2.I. If an electric well pump is used, provisions for a pump house that is at least 4ft (1.2m) by 6ft (1.8m) must be provided.

Human Waste

Effective master planning anticipates and prevents potential conflicts between the placement of sanitary systems and potable water systems or other site conditions.

9.2.J. Pit latrines, soakaway tanks and leaching trenches must be separated from other site elements as per criteria outlined in Table 9.a.

Table 9.a. Pit latrine, soakaway tank, and leaching trench distances from site elements

Element	Minimum Permitted Distance
Property Line	5 ft
Foundation, structure bearing weight	5 ft
Water Line	10 ft
Stream, well, spring, water course	100 ft
Seasonal drainage	25 ft
Steep slope (greater than 50%)	25 ft
Paved Area or Driveway	5 ft
Edge of road easement or right of way	5 ft
Septic Tank	3 ft

9.2.K. Septic tanks, anaerobic baffled reactors, waste stabilization ponds and other engineered wastewater treatment systems must be separated from other site elements as per criteria outlined in Table 9.b.

Table 9.b. Engineered wastewater treatment system distances from site elements

Element	Minimum Permitted Distance
Leaching device	3 ft
Property line	5 ft
Building foundation or structure	5 ft
Water Line	10 ft
Stream, well, spring, water course	100 ft
Paved Area or Driveway	5 ft
Edge of road easement or right of way	5 ft

9.2.L. Site planners must identify potential future expansion areas (calculated to be 100% of the existing leaching system) to replace failed systems and/or to install new sanitary facilities to serve future development.

Electrical Services

Electrical service to all healthcare facilities is necessary for sustaining the life of the patients. There are several building electrical service sources, including the utility, Liberia Electric Corporation (LEC), power generators, and solar PV. At least two of these three options need to be provided for a new healthcare facility, with one serving as back-up for critical functions. Chapter 23 on Electrical Systems addresses these options and their design in detail.

9.2.M. Consideration must be given to the following key factors when locating the electrical service for a facility:

- Proximity of the electrical service panel to the key electrical loads
- The relationship between the generator, utility connection, PV system and the electrical service panel
- Security and maintenance access

Electrical Service Considerations

Locating the service panel at the opposite end of the building from the majority if the electrical loads such as medical equipment and the air conditioning system will increase the cost of the electrical system and could cause introduce voltage drop problems.

Access for routine maintenance and repair is a key factor when locating equipment. A poor location can lead to longer than necessary outages and directly affect patient care.

9.2.N. The generator must be located near an access road so it can be readily fueled, maintained, and removed when replacement is necessary.

9.2.O. Electrical equipment must be located in a safe area where it cannot be tampered with or damaged as part of normal operation of the facility.

9.2.P. The utility connection point must be made in an area not overrun by trees and not in the middle of a parking area where it can be damaged by vehicles. It should be on the perimeter of the site near the generator and main electrical service equipment.

9.3 Building Types

An appropriate building design can improve delivery of care, health outcomes, and the patient experience by creating a usable and dignified environment. Responding to the clinical needs and the context with the right building type can also reduce infection risks by minimizing interaction between potentially infectious patients, immune-compromised patients, and other facility occupants.

9.7.A. Facility planners must select building types that are appropriate for the facility type, taking into account the scale and type of services needed.

9.7.B. Facility planners must select building types that are appropriate for the site context (e.g. urban vs. rural sites, flat vs. sloped sites) to establish optimal onsite program distribution.

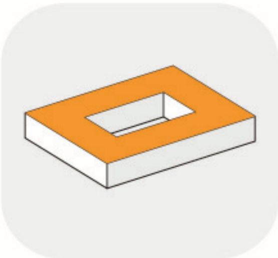
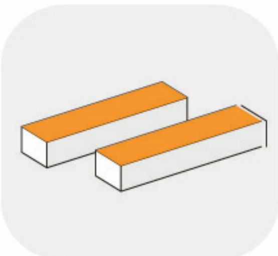
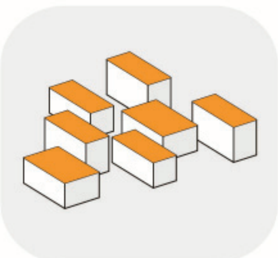
i. Selected building typologies must accommodate expected expansion on the site, either through additions to existing buildings or construction of new buildings.

ii. As much possible, a variety of facility arrangements must be explored to make use of irregularly shaped sites that meet other performance criteria.

9.7.C. Selected building types must be acceptable to users and local communities.

i. Building designs should be approved by community groups and County Health Teams.

Table 9.c. Building typologies and their expected uses, benefits, and drawbacks[5]

Typology	Primary Uses	Pros	Cons
Multistory *Vertical structure* 	• Urban settings with limited space • Large-scale facilities	• Compact • Simplifies isolation of specific programs	• Can be more expensive for both design & construction • Requires large-scale ramps or reliable electricity for lift • Requires more skilled workmanship than single story typologies
Courtyard *Building surrounds protected outdoor space* 	• PHC 2 Clinics • Health Centers • Hospitals • Sites where inward views are nicer than outward views	• Shields patients in outdoor spaces from surrounding sites and roads • Increases travel efficiency • Increases access to natural ventilation and lighting • Allows for a range of configurations for different site shapes • Large roof area for rainwater collection or solar panels • Compact building can lower costs	• Courtyard can be impacted by inclement weather • Requires larger site than more compact typologies
Bar *Long, single-story structure* 	• PHC 1 and 2 Clinics • Health Centers	• Provides large roof area for rainwater collection or solar panels • Simple structure and roof construction • Compact building can lower costs	• Poses challenges to co-locating programs due to linear flow • Cross ventilation can be problematic if program is back to back.
Campus *Programs broken into smaller, separate buildings* 	• Large sites • Health Centers • Hospitals	• Simplifies isolation of specific programs • Increases access to natural ventilation and lighting • Provides large roof area for rainwater catchment • Allows for a wide range of configurations for different site shapes	Requires more space • Requires replication of equipment across buildings • Longer utility runs can be more expensive • Can require more observation staff if patient monitoring is not carefully designed • Site & landscape planning must be carefully designed to make circulation clear & efficient • May require outdoor circulation during inclement weather

9.4 Growth and Expansion

The communities that facilities serve are not static. Some of the most significant problems that occur with health facilities over time are due to inadequate planning for growth and evolution. Often, buildings and services are retrofitted or added to the core facility in such a way that compromises the functionality of the original design. The strategic siting and masterplanning phase should look beyond the scope and budget of the first phase of building to account for and anticipate future needs. Consider embedding flexibility within the design to accommodate evolving services and priorities.

9.4.A. Site masterplanning must account for expected growth trends in the region that is served by the facility.

i. Sites must accommodate expected regional population changes over a 10-20 year period. Typical reasons for expansion of healthcare facilities, and their implications, are outlined in Table 9.d.

Table 9.d. Reasons for expansion of healthcare facilities[6]

	Description	Required Response
Population growth	Increase in local population due to shifts in settlement patterns or birth rates	Expansion of general outpatient programs and inpatient wards, as well as specific programs that respond to population growth (e.g., labor and delivery)
Accumulated needs and requirements	Deferral of needed expansion until budget is available	Expansion of programs that do not sufficiently serve the existing catchment population
Shifting epidemiological factors	Increase in prevalence of certain diseases in particular regions	Expansion or introduction of programs that serve specific conditions of concern
Changing medical methods and technology	Technological advancements or introduction of new equipment or processes	Changes to programs to accommodate new equipment or processes
Changing standards and codes	Shifts in regulation, zoning, or construction standards	Changes to programs required by standards to be larger or differently located
Changing licensure or care regulations	Updates to regulatory or facility licensing requirements	Expansion or changes required to meet care and/or licensing regulations

9.4.B. Growth and expansion must be planned and implemented in deliberate phases.

i. The scale of expansion must be based on anticipated population growth or required functional changes to facilities (Refer to Table 9.d.). Placement of future facility wings or buildings should be included in master plans (Refer to Figure 9.c.).

ii. Building typologies that are well-suited to the level of expansion expected for each facility must be used in initial design. For example, campus buildings accommodate expansion easily because many programs run along the exterior of the buildings. (Refer to Section 9.3 on Building Typologies)

iii. Inpatient facilities must be expanded by ward, not bed-by-bed, and new programs must be introduced in their entirety instead of piecemeal. An exception to this strategy is when the need for a new service or piece of equipment precedes available funding for development of a full program. In such a case, small renovations may be required to accommodate the change.

iv. The model for expansion must be appropriate for the site and building typology. (Refer to Table 9.e.)

Table 9.e. Expansion strategies[7]

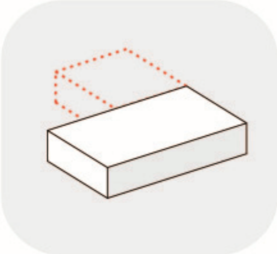
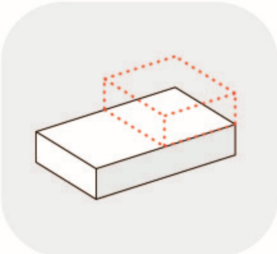
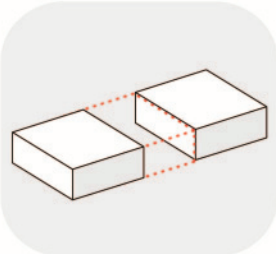
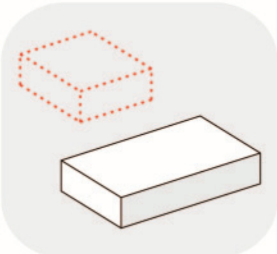
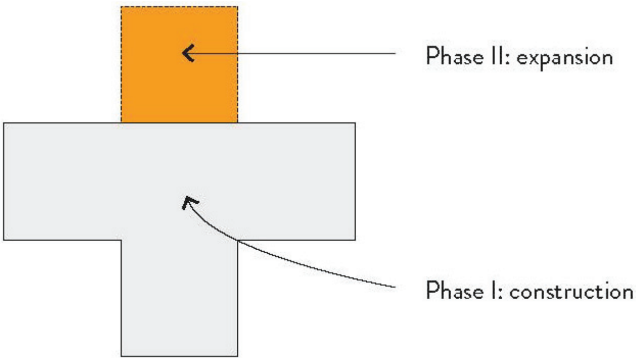
Expansion Model	Primary Uses	Pros	Cons
Outward growth *New facilities attached to existing facilities* 	• Preferred in most cases • Multiple-building facilities • Single-story sites	• Simple • Least disruptive • Does not require program rearrangement	• Challenging on small sites • Increases distances/travel times between programs
Upward growth *Additional levels built on top building* 	• Small sites	• Compact	• Requires sufficient foundation strength to support new levels • Requires strong roof slab on original building or replacement of existing roof • Disrupts operations and systems and compromises water tightness during construction • Infection control may be more difficult to maintain
Inward growth *Filling in void spaces in plan* 	• Small sites • Facilities with no additional space on site	• Minimizes new construction costs	• Complicates building/ program flow • Can inhibit natural ventilation & daylighting
Additive Growth *Detached new buildings* 	• Large sites • Sites with multiple buildings	• Maintains spaciousness of individual programs	• Increases distances/ travel times between programs • Introduces supervision or management challenges • Poses challenges to expansion of infrastructure (e.g., water, electrical)

Figure 9.c. Phased facility growth



9.5 Building Orientation and Adaptation

Optimized building placement allows facilities to take advantage of solar exposure, prevailing winds, and existing vegetation to control interior ventilation, cooling, and lighting. On some sites, however, aligning all of these elements while working within topographic constraints may not be possible. In such cases, placing buildings based on solar exposure and prevailing wind should be prioritized since these heavily influence patient comfort and well-being.

9.5.A. To the extent possible, buildings must be oriented according to sun and wind patterns and sit along natural contour lines.

i. As much as possible, orient long facades of buildings face north or south to minimize solar gain but maximize use of natural light. (Refer to Chapter 23 on Daylighting for details on optimizing solar exposure)

ii. As much as possible, orient buildings to maximize the use of prevailing wind for ventilation. Where winds are inconsistent or weak, wind patterns may not influence orientation. (Refer to Chapter 19 on Ventilation for details on optimizing natural ventilation)

iii. As much as possible, orient buildings to run parallel with contour lines to minimize work or materials required to level the site. This has less impact on the interior environment, but may have notable cost implications. (Refer to Figure 9.e. and Section 8.3. on Topography and Erosion)

iv. Position buildings on less steep parts of the site to reduce the need for grading or additional site work.

v. Use pre-existing vegetation, when suitable, to lessen or enhance effects of sun or wind. (Refer to Chapter 13 on Landscaping and Outdoor Spaces for shading and planting strategies)

Figure 9.d. Building orientation based on sun and wind

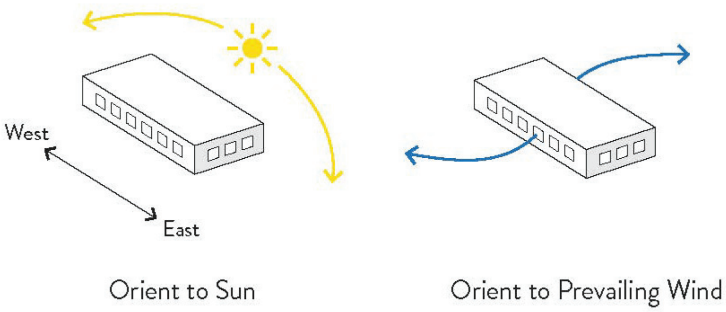
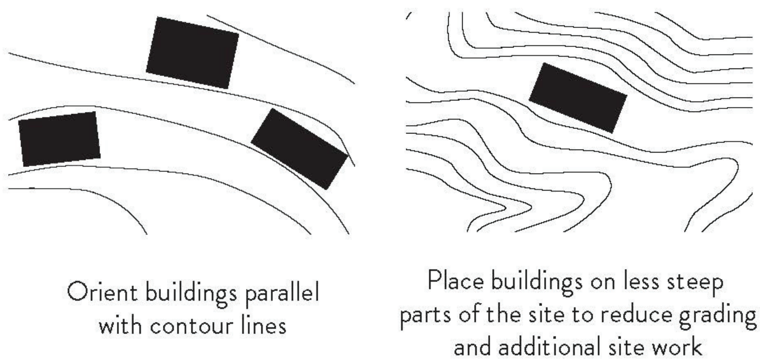


Figure 9.e. Building positioning based on topography



9.6 Access and Circulation

Clear travel patterns on sites support efficient healthcare delivery, particularly important in emergencies, and decrease the likelihood of patients and visitors entering unsafe or sensitive areas. Being able to monitor entrances and pathways is not only important for patient well-being, but also for general site security.

9.6.A. Sites must separate entrances for people (patients, visitors, staff) from exits for waste and other potentially hazardous or contaminated material.

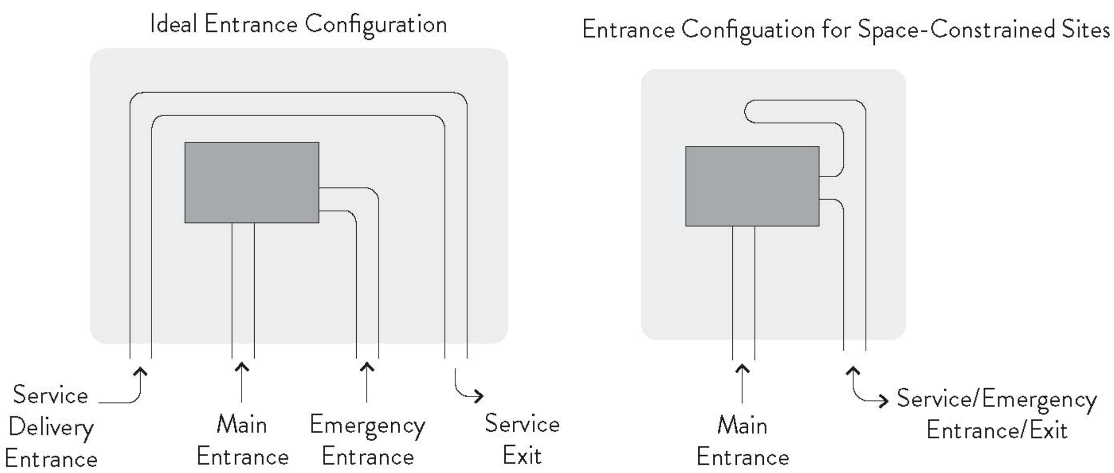
i. Where possible, separate points of entry must be provided for each type of traffic expected on-site.

ii. Create points of entry for each type of movement expected on-site, or at least separate paths for traffic that moves at different paces (i.e., separate entrances for ambulances and foot traffic). Four recommended discrete access points include:

- **Emergency:** entry point for ambulances and individual patients going straight to emergency department
- **Main:** primary public access point for vehicular and foot traffic
- **Service – Delivery:** entry point for supply delivery
- **Service—Exit:** exit point for waste and morgue

iii. For small sites, sub-divide entrances to separate traffic types if the space to accommodate multiple entrances (or the personnel to monitor them) is not available.[8] This strategy increases security by reducing the number of entry points to be monitored.

Figure 9.f. Entrance configurations for large or space-constrained sites



9.6.B. Circulation patterns must be designed to suit building typologies, program placement and site conditions.

i. Routes must prioritize connections between critical functions. Refer to Chapter 12 for recommended program adjacencies.

ii. In multi-building facilities, outdoor circulation must reflect the circulation and occupant flow principles described in Chapter 13, and programs that are required to be in close proximity should be in the same building or covered.

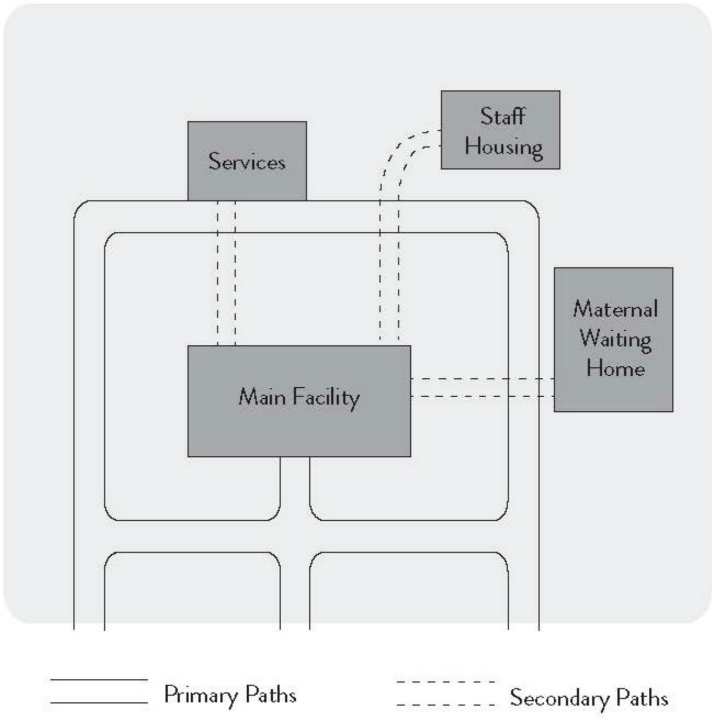
iii. As much as possible, routes must follow natural grade changes and other site features to minimize work required to cut and finish walkways and roads.

iv. Evaluate all circulation paths based upon overall function, accessibility, and naturally occurring walkways. The most direct routes (the shortest distance between points) are what will be utilized.

9.6.C. **Circulation patterns must communicate a clear hierarchy of access to various site areas.**

i. Circulation must be designed to incorporate a main route with access to patient and visitor areas, and smaller paths off of the main route to private and limited-access areas.[9]

Figure 9.g. Diagram of main circulation and secondary paths to less accessible parts of site



9.6.D. **Pedestrian walkways must be clearly separated from vehicular roads and parking areas to reduce traffic safety risks.**

i. As much as possible, pedestrian and vehicular paths must not cross. If intersection is unavoidable, clear signage must be used for safety purposes.

9.6.E. **Vehicular entry and parking areas must be incorporated into site planning.**

i. For secondary and tertiary level facilities, a designated place for ambulance entry and parking must be provided, and must not be impeded by other flows of pedestrian or vehicular traffic.

ii. More vehicular roads and parking must be provided in areas with higher levels of automobile and motorcycle traffic. Rural PHC level 1 and 2 Clinics should not require many parking spaces.

iii. Parking near the facility must not be directly in front of the door in order to minimize dust, dirt, and noise entering facilities from cars and motorcycles.

iv. Consider placing a planted area between parking lots and buildings.[10]

9.6.F. **Entrances to emergency departments must be sheltered so that patients are covered when being transferred from ambulances.**

i. The height of the covered canopy must take into account the size of vehicles utilized. Ambulances typically need 10-14ft (3-4.3m) of clearance.

9.6.G. **Spatial provisions must be incorporated to allow police and fire safety vehicles adequate access to buildings under emergency circumstances.**

i. Fire safety and police vehicles must be able to turn around to exit the site.

10 Landscaping and Outdoor Spaces

Outdoor spaces play a critical role in the creation of dignified environments for treatment, as well a role in infection control. Landscape should be considered and integrated into any facility design to produce well-planned exterior environment. These open spaces encourage patients and visitors to congregate outside of the facility, where risk of airborne infection is significantly lower. Additionally, landscape strategies assist with passive heating and cooling and water and waste management. A dignified center for treatment can also reduce stress and pain perception, as well as assist to retain staff. Orienting and connecting interior spaces to the surrounding environment, such as patio areas where patients can sit, can create a calming effect in the wards and has been shown to promote faster recovery.

Definitions

- **Hardscape:** Paved exterior areas.
- **Impervious:** Resistant to penetration by fluids or by roots.
- **Softscape:** The elements of a landscape that comprise live, horticultural elements.

10.1 Landscape Planning

Well-planned exterior spaces support facility disease control strategies, improve administrative control of patient flow and way finding, and provide for needs of patients, families and attending clinicians in a dignified manner.

Outdoor Spaces and Waiting Areas

In climates that allow, utilizing outdoor waiting areas and gathering spaces is one of the simplest and most cost efficient steps to the reduction of airborne disease, avoiding the challenges of properly ventilating indoor spaces.

10.1.A. Landscape must be designed in conjunction with covered waiting areas, taking into account proximity of waiting areas to check-in and diagnostic consultation areas.

i. Adjacent, uncovered overflow must be provided in addition to the covered waiting area.
ii. Built in benches must allow ample space between patients to minimize transmission of undiagnosed airborne disease.

10.1.B. Accessible exterior landscape space with seating for inpatient use must be provided adjacent to inpatient treatment areas and wards.

i. Accessible, shaded and un-shaded areas must be provided for patient recovery and respite.
ii. Ample seating must be provided for patients and patient attendants and allow for group and solitary seating configurations.
iii. Ideally these areas should provide views to existing landscape or designed garden areas.

Play Areas

For recovering children or those accompanying sick parents—especially long-term patients—access to the outdoors, sunshine, and opportunities for play have been shown to support improvements in health. While play elements will vary based on community values, site constraints, and location; all play areas should be safe and comfortable for both children and their caregivers.

10.1.C. Play areas for children must be provided adjacent to the pediatric ward or children's treatment areas.

i. Where possible, dedicated play areas for pediatric inpatients must have one main entry /exit directly accessible from one door of the pediatric ward. There must be a second, emergency egress for the area.
ii. The play area must provide visual observation from all points to allow the caregivers to easily monitor children playing.
iii. Ample seating must be provided for children and their caregivers/parents to comfortably observe and monitor children, and patient attendants and allow for group and solitary seating configurations.
iv. Accessible, shaded and un-shaded areas must be provided for patient recovery and respite.

10.1.D. Ground surfaces and equipment in play areas must be safe and accommodate children of all ages and abilities.

i. Grade changes can be great opportunities for play but must not exceed 18in (45.7cm) without soft surfacing. Soft surfacing includes grass and wood chips.

ii. All ground surfaces in the play area must be soft to minimize any injury due to falling. Some surfaces to consider are sand, grass, and gravel less than 1cm in diameter. These 'flexible' surfaces must have a properly prepared sublayer to allow for drainage and prevent settling.

iii. Consider the abilities of children of all ages when designing play areas and selecting equipment. Equipment that is appropriate for an older child may not be safe in an area with mixed age groups. Depending on area available, it may be useful to consider separating play for very young children (1-4) from areas of play for older children (5-15).

10.2 Landscape Design

The designed landscape can support climatic, environmental, and programmatic functioning of health care facilities. Landscape design should be part of the site master plan because of the central role it plays on every site. In addition to providing a dignified environment conducive to patient healing and clinician well-being, a well-integrated planting approach can provide wind, dust, heat and noise mitigation, all supporting a cleaner, safer and more comfortable facility. A thoughtful hardscape strategy provides the network of paths and waiting areas that supports efficient way finding, airborne disease prevention for patient and clinician safety, and the functioning of an efficient medical facility.

Softscape: Planting Strategies

Planting can reduce energy use and provide helpful climate modification through provision of shade for thermal control, air purification and dust reduction, and noise reduction.

10.2.A. As much as possible, planting and design strategies for shading and climate modification must be utilized to minimize thermal gain.

i. Consider nearby vine screens or tree planting for all facades that are east-west facing to provide shading to reduce thermal gain.

ii. Consider easy-to-maintain water features, coupled with shading, for certain outdoor waiting areas or outdoor patient areas for both their calming effect and ability to provide some thermal cooling.

Figure 10.a. Diagram of shading principles

10.2.B. As much as possible, planting strategies for air purification and dust reduction must be utilized to ensure adequate indoor air quality.

i. Incorporate landscaping and wind breaks around the perimeter of sites to reduce dust accumulation on-site and inside the building.
ii. Plant mixed tree and shrub buffers along all unpaved roads adjacent to site.
iii. Plant mixed tree and shrub buffers between the parking area and the facility.

10.2.C. Landscape and planting strategies for noise reduction must be utilized to mitigate noise pollution where noise levels are at levels that might disturb patient recovery.

i. Hard surfaces and walls provide the most effective noise barriers and should be used in dense urban environments. Increasing the height of the wall increases the area of protection. (Refer to Figure 10.b)
ii. In urban sites, sources noise pollution should be identified and freestanding or retaining walls must be used to reduce noise disturbance where needed. (Refer to Figure 10.c.)
iii. In rural areas, planted buffers or earth berms should be included in the site design if a facility is located along a busy vehicular thoroughfare and where space allows. (Refer to Figure 10.d.)

Figure 10.b. Effective noise barrier, decibel reduction related to increasing height

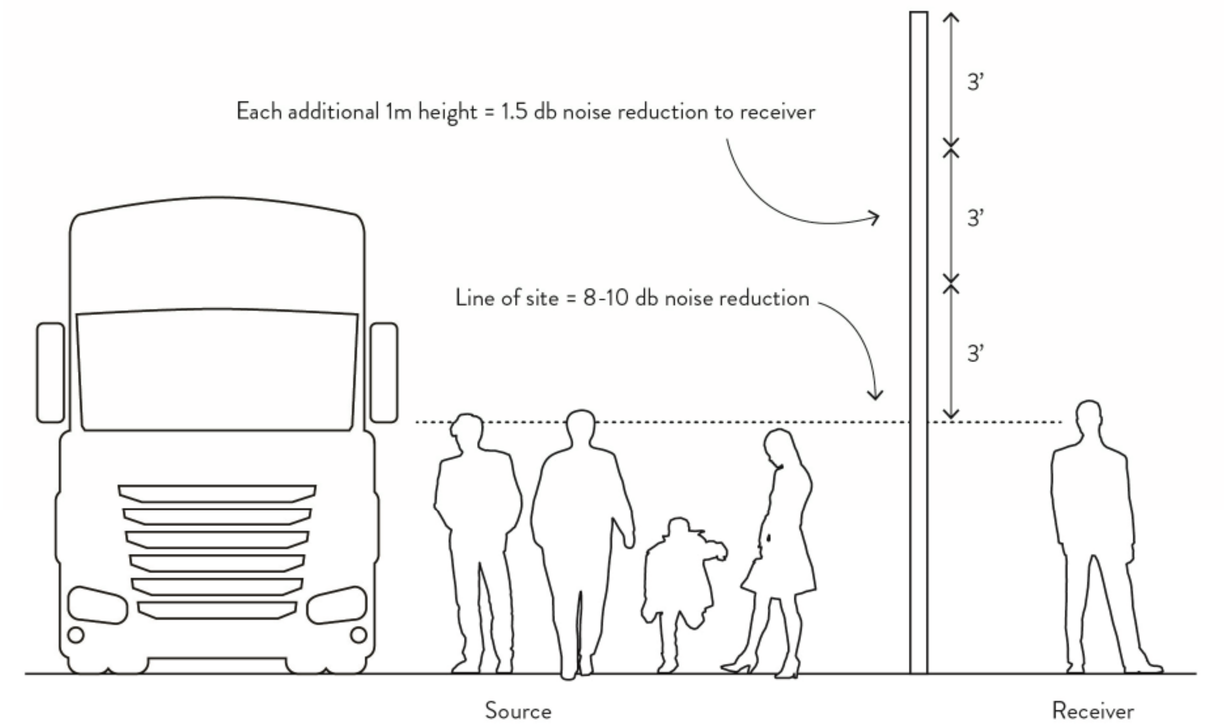


Figure 10.c. Principles of sound travel and sound shadow area

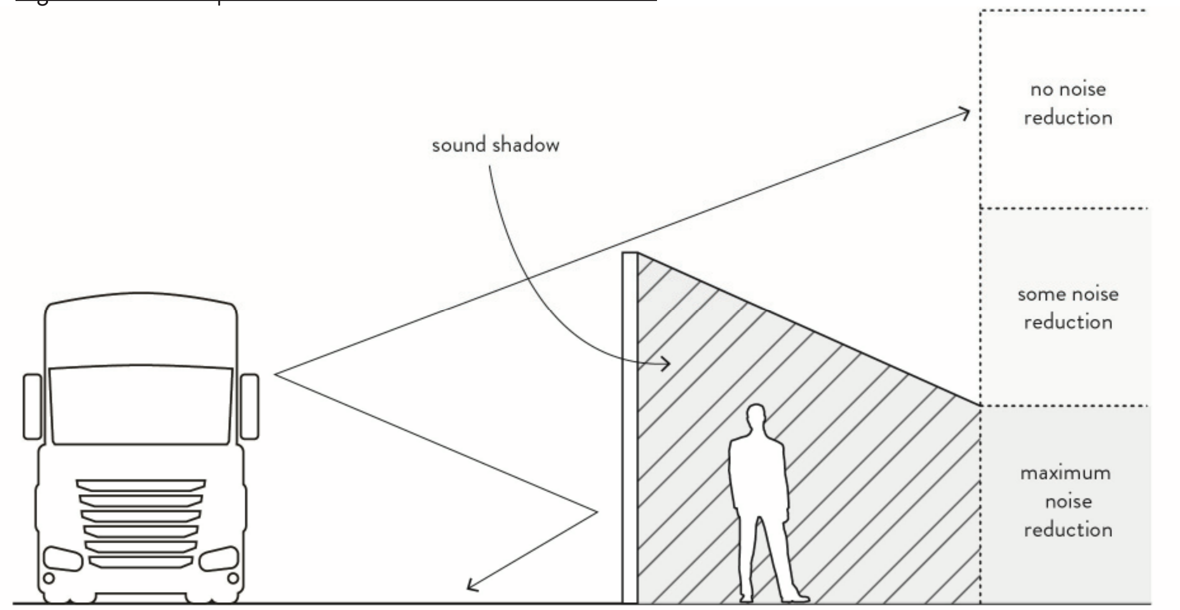
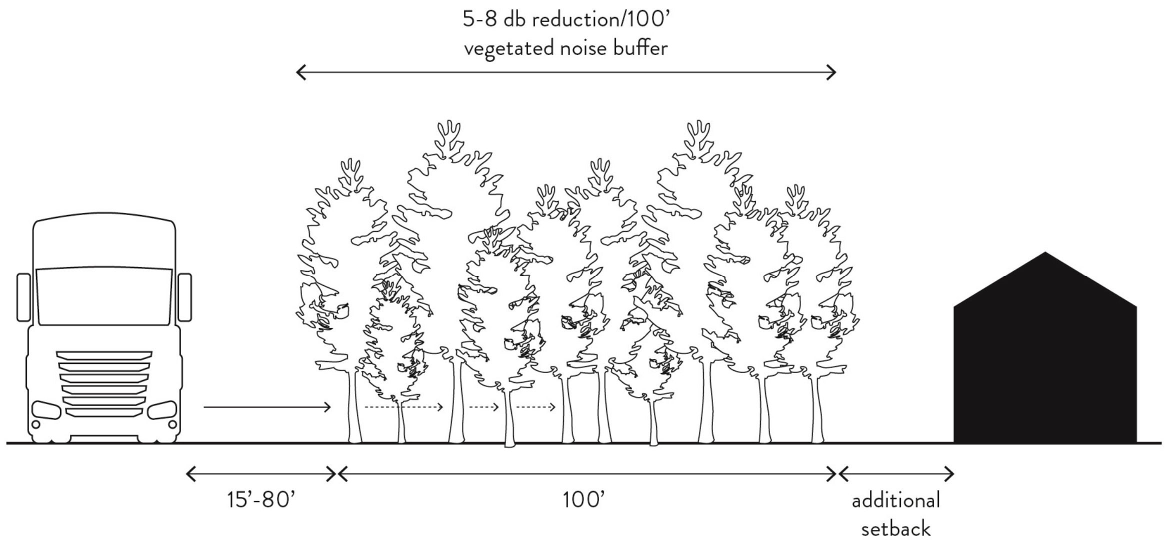


Figure 10.d. Planted sound buffer



Softscape: Planting Selection

The landscape design and planting selection for each facility should not only be climatically appropriate, but can also support the clinical programs, education and demonstration of nutritional gardening in areas where malnutrition or a lack of nutritional diversity is contributing to poor health. Native and climate appropriate plants reduce the need for irrigation, and locally available and culturally familiar and appropriate planting selections will aid in the long-term maintenance of the landscape.

10.2.D. Native and climate appropriate plants must be used in all landscape design.

i. Turf grass, plants and trees must be able to withstand dry season without excessive watering.

10.2.E. Where appropriate, planting and landscape design must support Hospital programs and reflect the specific clinical needs of the local community as much as possible.

i. Productive landscapes including edible nutritional gardens should be planned and as much as possible can be used as an educational tool in areas where poor nutrition is a problem due to lack of crop diversity.

10.2.F. Planting design must be part of overall campus design, and the type and quantity of plants must be part of the project Bill of Quantities.

i. Generally plant quantities can be calculated using 4 plants per square meter for the Liberian climatic conditions. Some groundcovers or grasses may be more dense.

ii. Plants must be procured in advance or if possible, propagated and maintained on site during construction by a gardening technician to ensure strong and healthy plants.

Hardscape: Paths, Gathering Areas and Site Furnishing

The appropriate design of the hardscape will promote ease in access and movement for patients and clinicians, assist in minimizing day-to-day and long term maintenance, and contribute to the dignified and appropriate appearance of a health facility or campus. Durable and appropriate furnishing can be easily integrated into the landscape approach to create comfortable and low cost outdoor gathering areas that contribute to infection control as well as staff and patient comfort.

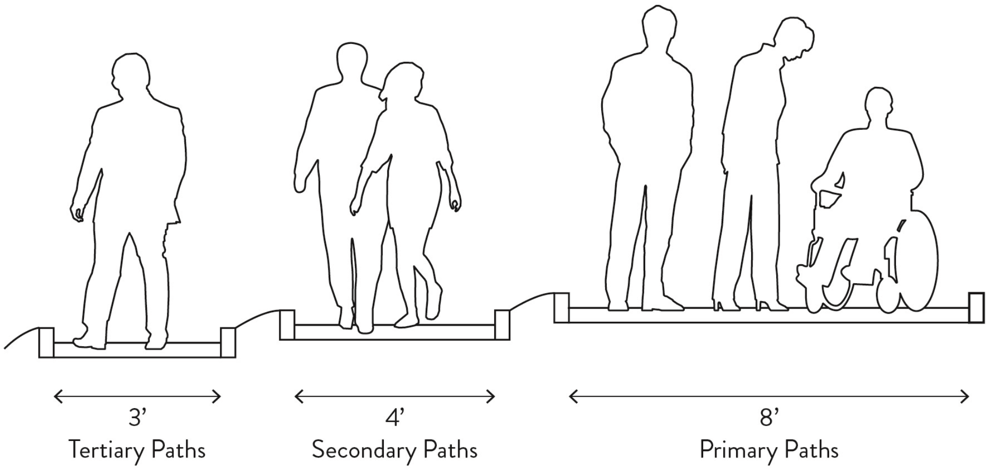
10.2.G. Path sizing must be appropriate for each area of a facility and the expected patient load in that area. (Refer to Figure 10.e)

i. Primary paths at entry, between main areas of care and near buildings must be a minimum of 8'wide to accommodate groups as well as passage of wheelchairs, gurney, dollies, etc.

ii. Secondary paths connect between buildings that are less intensively used and must be a minimum of 4ft (1.2m) wide to accommodate passage of 2 people walking in opposite directions, or 1 person and 1 wheel chair side by side.

iii. Tertiary paths connect outlying support structures, and can be 3ft (91.4cm) wide, except where material deliveries must be made.

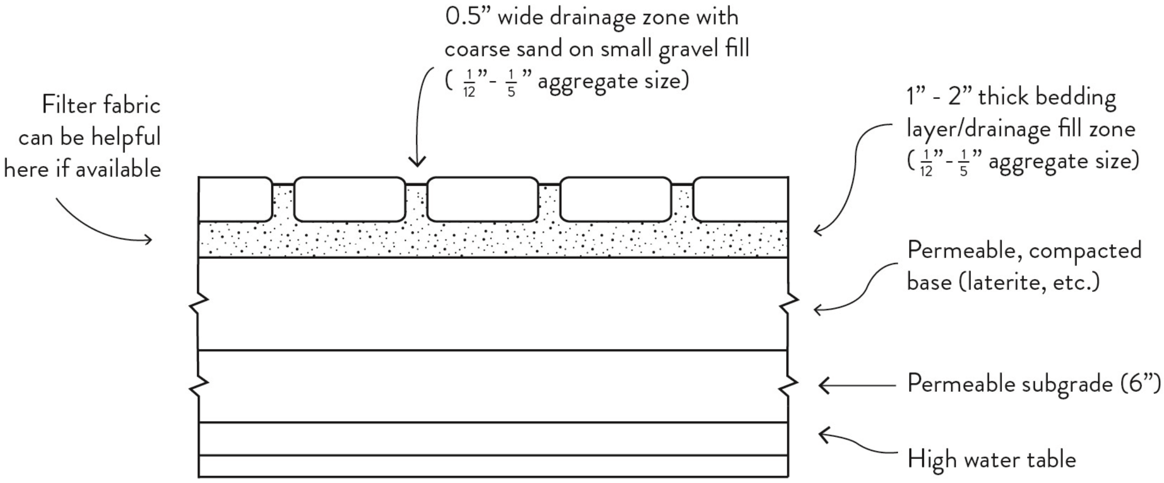
Figure 10.e.   Appropriate Path sizing



10.2.H. Path material should be impermeable where adjacent to buildings or beneath covered verandas, and permeable when there is landscape on both sides.

i. Impermeable paths can be concrete or pavers laid without space between or mortared.
ii. Permeable paths can be compacted gravel less than 1cm in diameter, or pavers laid with drainage spacing and filled with a locally available drainage aggregate. (Refer to Figure 10.f.)

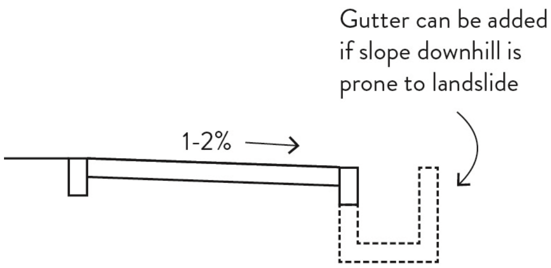
Figure 10.f.   Permeable Paving Detail



10.2.I. All paths must be designed with proper grading to be well drained and handicap accessible, and must have handrails where needed.

i. All paths must have a 1-2% grade to shed water. (Refer to Figure 10.g.) Gutters must be provided along paths adjacent to hillsides that may be unstable.
ii. All paths must have a minimum of 5% grade where possible for ease of circulation, and not more than 12% ramping, with landings every 30ft (9.1m). (Refer to Figure 10.h.)
iii. In any location where there is a grade change over 30in (76.2cm) a railing must be provided. (Refer to Figure 10.i.)

Figure 10.g. Cross grade at paths grades



1-2% Cross grade at path

Figure 10.h. Acceptable path and ramp

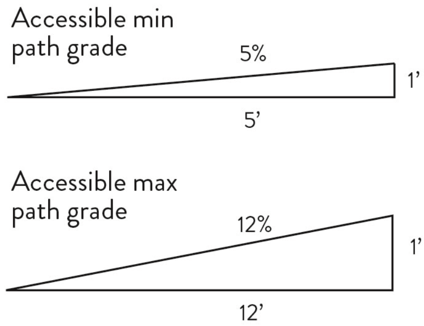
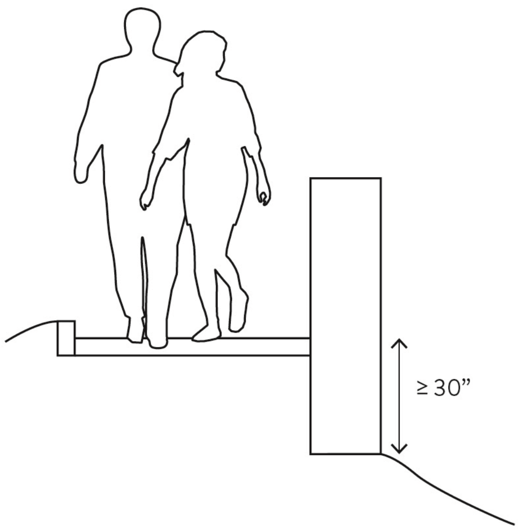


Figure 10.i. Railing requirements

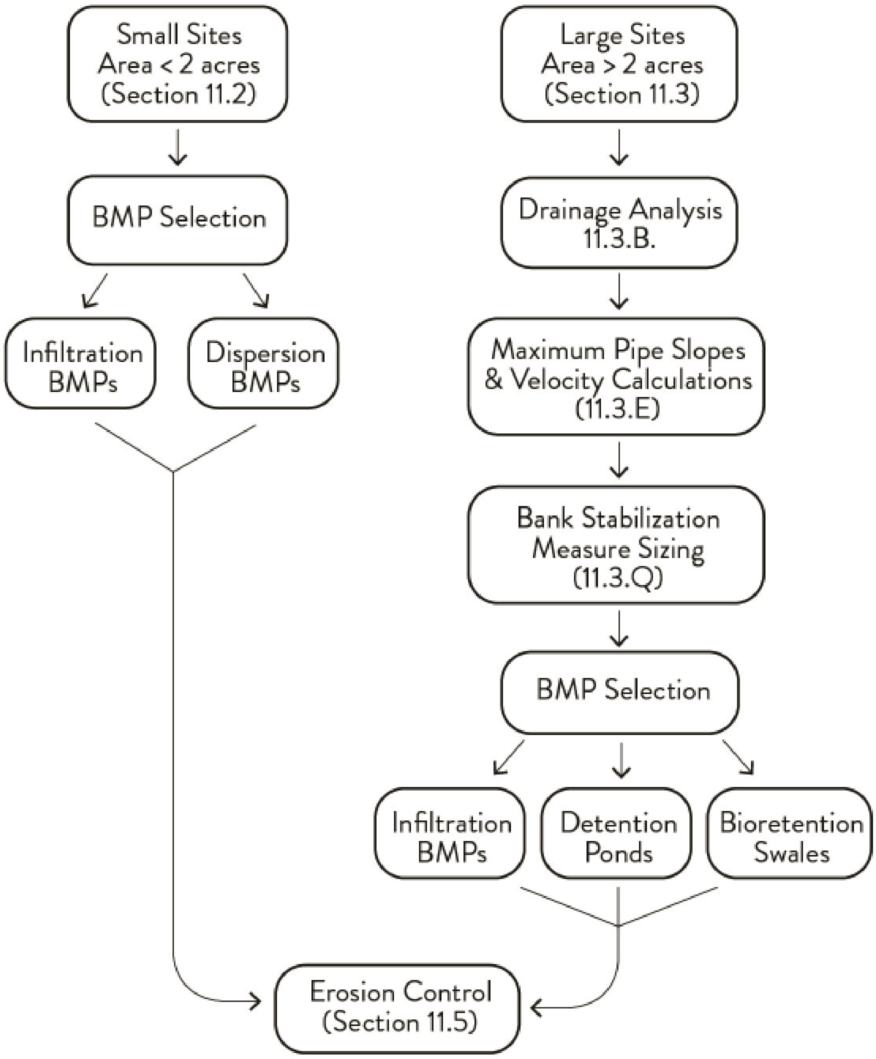


Hand rails should be minimized but must be used when grade change exceeds 30"

11 Stormwater Management & Erosion Control

Site development alters drainage conditions on a site by increasing the amount of impermeable surfaces from roofs, roads, parking areas and other hardened surfaces. These modifications increase the rate and volume of runoff and, if not properly managed, can impact the site by creating severe erosion problems that can interfere with the use of the facility by patients and staff. Effective stormwater management is important to prevent localized flooding and erosion of critical infrastructure, such as roads and pedestrian paths, which are needed to allow reliable and easy access to medical services.

The majority of healthcare facilities are located on relatively small sites that are less than 2 acres in area. On these small sites, relatively simple storm water Best Management Practices (BMPs) can be used onsite to effectively retain or disperse runoff in an effective and safe manner. For larger and/or more complex sites, many of the storm water and erosion control BMPs prescribed for small sites may be appropriate; however, a more through drainage analysis should be completed by qualified civil engineer and the storm drainage improvements must be sized applying standard hydrologic and hydraulic methods.



Definitions

- ASTM/AASHTO: A private non-profit organization that oversees the development of standards for products, services, processes, systems, and personnel in the United States.
- Best Management Practices (BMP): A method, activity, maintenance procedure, or other management practice for reducing the amount of pollution entering a water body.
- Bioretention: A technique that uses parking lot islands, planting strips, or swales to collect and filter storm water.
- Catch Basin: A receptacle with a sediment bowl or sump, diverting surface water to a subsurface pipe.
- Conveyance: The process of transporting wastewater from one place to another.
- Culvert: Any structure not a bridge that provides a waterway or opening under a road.
- Detention Pond: An impoundment, normally dry, for temporarily storing storm runoff from a drainage area to reduce the peak rate of flow.
- Discharge: Flow rate in a culvert, pipe, or channel.
- Dispersion: The process of distributing water over a wide area.
- Downspout: A pipe to carry rainwater from a roof to a drain or to ground level.
- Drainage: Interception and removal of ground or surface water by artificial or natural means.
- Drainage Area: The area drained by a channel or sub-surface drain.
- Drywell: An underground structure that disposes of unwanted water, most commonly stormwater runoff, by dissipating it into the ground.
- Erosion: Detachment and movement of soil or rock fragment by water, wind, ice, and gravity.
- ECPs: Erosion control plans.
- ESC: Erosion and sediment control.
- Filter Fabric: Textile of relatively small mesh or pore size used to (a) allow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable).
- Geosynthetics: Degradable and nondegradable products used for a variety of purposes, including soil and slope stabilization, erosion and sediment control, soil reinforcement, and subsurface drainage.
- Headwall: A vertical wall at the end of a culvert to support the pipe and prevent earth from spilling into the channel.
- High-Density Polyethylene (HDPE): Polyethylene thermoplastic made from petroleum that is commonly used for corrosion-resistant piping and geomembranes.
- Infiltration: The downward entry of water into the surface of a soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.
- Mulch: Materials such as leaves, bark, or compost, spread around a plant to enrich or insulate the soil.
- Peak Flow: The maximum instantaneous discharge rate resulting from a given storm condition at a specific location.
- Percolation: Movement of soil water toward the water table.
- Rain Garden: A planted depression that allows rainwater runoff from impervious areas the opportunity to be absorbed.
- Runoff: Precipitation or surface discharge carried off from the area on which it falls.
- Sedimentation: The act or process of depositing sediment.
- Sheet Flow: Flow over plane, sloped surfaces in a thin layer.
- Silt Fence: A temporary sediment control device used on construction sites to protect water quality in nearby streams, rivers, lakes and seas from sediment in stormwater runoff.
- Splash block: A masonry block with its top close to the ground surface, which receives roof drainage and prevents erosion below the spout.
- Swale: A constructed or natural grassed or vegetated waterway.
- Water Table: The level below which the ground is saturated.
- Watershed: A drainage basin, or area contributing to the supply of a stream or lake.

11.1 General Stormwater Control Requirements

In general, stormwater management consists of collecting, retaining (infiltrating) and/or detaining runoff before it is released to a natural drainage course. Simple and effective management strategies are employed to either infiltrate or disperse the runoff on site. However, in some sites, such as, steep sites or sites receiving substantial runoff from adjoining properties more extensive drainage improvements may be necessary to collect and convey runoff in pipes in a safe manner to protect the healthcare facility and property as well as the downstream drainage course or neighboring properties. On large sites excessive runoff may need to be detained in a detention pond to protect a downstream watercourse or an adjacent property.

11.1.A. Drainage and erosion control plans must be prepared for all new healthcare facilities, and plans must be prepared under the direct supervision of a qualified civil engineer with at least 3 years' experience in the field of storm water management and drainage engineering.

11.1.B. The drainage and erosion control plans must prescribe Best Management Practices (BMPs) that are appropriately sized and engineered for site.

i. For small sites described in Section 11.2 BMPs must be sized in accordance with the standards and guidelines presented in this section.
ii. For larger and/or sites with significant drainage issues drainage and erosion control measures must be sized based on the following criteria:

Table 11.a. Drainage and Erosion Control Measures for Large Sites

Drainage Measure	Design Storm	Intensity	Depth (24 hr)
Storm drain piping	10 year	10in/hr (13mm/hr)	--
Open channel swales	10 year	10in/hr (13mm/hr)	--
Infiltration Systems	1 year	--	3.3in
Retention/Detention Ponds	2 year	--	4.0in

11.1.C. Drainage improvements sites over 2 acres (0.8ha) must employ stormwater BMPs to reduce the off-site discharge of stormwater runoff to pre-project runoff rates.

11.1.D. Stormwater and erosion control BMPs chosen for implementation must be safe, reliable, and manageable.

11.1.E. For large or complex sites (in floodways, on slopes greater than 20% and with existing drainage courses through the site), before a BMP is selected, a drainage analysis must be conducted to evaluate physical conditions of the site and to estimate pre- and post-development runoff rates. Based on this drainage analysis, appropriate BMPs must be selected to effectively manage and control runoff.

i. The drainage analysis must evaluate the following site conditions:
   - Site topography and existing drainage pattern
   - Geology and soil conditions where the BMP would be implemented
   - Groundwater conditions where the BMP would be implemented
   - Proximity of buildings, roads, and property boundaries
   - Proximity of drainage and floodways
   - Pre-and Post-project runoff rates from developed areas on the site
   - Engineering calculation to size the proposed stormwater BMPs.
ii. The drainage analysis must be prepared under the supervision of by a qualified civil engineer with at least three (3) years' experience in drainage engineering projects.

11.1.F. All stormwater BMPs must be situated in areas that remain accessible for routine maintenance and repair work. Stormwater BMPs must not be installed under buildings or under underground utility trenches.

11.1.G. Erosion control BMPs must be planned for all areas where soil will be disturbed during the construction and remain bare during and after construction. Erosion control measures must remain installed and maintained to effectively protect the site and prevent erosion of soils and drainage ways.

11.2. Stormwater Management for Small Sites

For sites less than or equal to 2 acres (0.8ha), the following stormwater management standards have been developed to address stormwater runoff and erosion control requirements area. The standards prescribe simple BMPs to mitigate drainage impacts without the construction of expensive stormwater facilities (i.e. storm drain piped networks and detention ponds). If the site have significant drainage issues, such as being located in a flood plain, includes a natural drainage course (stream or river) and/or drainage measures are to be located on slopes over 20%, additional drainage analysis and engineering is required by a qualified engineer.

The following sections contain standards for small site drainage and erosion control BMPs. Drainage control BMPS area divided into two basic types: infiltration and dispersion BMPs. Infiltration BMPs act to capture and percolate runoff into the underlying soils and are appropriate if soil, groundwater and geologic conditions area suitable. Dispersion BMPs act to slow and spread out the runoff over the natural vegetated areas to dissipate the erosive energy of the runoff to protect site.

Infiltration Best Management Practices (BMPs)

11.2.A. **If site conditions are appropriate, infiltration trenches or shallow dry wells must be used to capture and retain runoff from impermeable surfaces. Impermeable surfaces include roofs, parking lots, driveways, and paved areas.**

i. Infiltration BMPs (infiltration trenches and dry wells) must be used where soil conditions are suitable including sands, sand and gravels, gravels and cobble and other soils measured to have percolation rates greater 0.5 hours per inch. At least two percolation tests must be conducted in the vicinity of the proposed infiltration BMP and must be conducted in the soil strata that will be used to absorb the water.

ii. Infiltration BMPs must be used at sites that have a minimum of three feet of vertical separation between the bottom of the infiltration system (trench or pit) and the highest anticipated groundwater or hardpan/bedrock.

iii. Infiltration BMPs must not be placed on or above landslide hazard areas slopes over 20% without the review and approval from a qualified geotechnical engineer. Infiltration BMPs must be setback at least 50ft (15.2m) from a landslide hazard area or steep slope.

iv. Infiltration BMPs must be installed downslope or cross slope and at least 25ft (7.6m) away from an onsite wastewater disposal system (seepage pit, soak-away tank/pit or drainfield trench).

v. Infiltration BMPs used to retain runoff from parking lots or roads that may be polluted must include a sediment trap styled catch basin to minimize sediment from entering the infiltration BMP. This will prolong the life of the BMP.

vi. Infiltration BMPs must be placed down slope and set back at least 5ft from a building foundation or other structural improvements on the site.

vii. Infiltration BMPs must not be installed in fill materials except as approved by a qualified geotechnical engineer.

11.2.B. **Infiltration trenches must be designed to conform to the following standards:**

i. There must be 20ft (6.1m) of trench per 1,000ft^2 (92.9m^2) of impervious surface (i.e. roof surface, parking lot) for coarse sands and gravels; 30ft (2.8m) of trench per 1,000ft^2 (92.9m^2) of impervious surface for medium sands; and 40ft (12.2m) of trench per 1,000ft^2 (92.9m^2) of impervious surface in soils with percolation rates greater or equal to ½in (13mm) per hour. Infiltration trenches must not be used in soils that have a percolation rate slower than ½in (13mm) per hour.

ii. Trench lengths must not exceed 100ft (30.5m) long. If multiple trenches are planned, a distribution box must be used to distribute runoff to the trenches equally.

iii. The trenches must be spaced 6ft (182cm) apart from the centerline of the trenches.

iv. Filter fabric or 6in (15cm) of straw must be installed over the drainrock before the trenches are backfilled/covered with soil. Filter fabric can be installed on the sidewalls of the surrounding soils to prevent soil from migrating into the infiltration trench reducing its storage capacity.

v. Figure 11.a. and Figure 11.b. illustrate the requirements for infiltration trench systems as outlined in the following subsections.

Figure 11.a. Typical Downspout Infiltration System

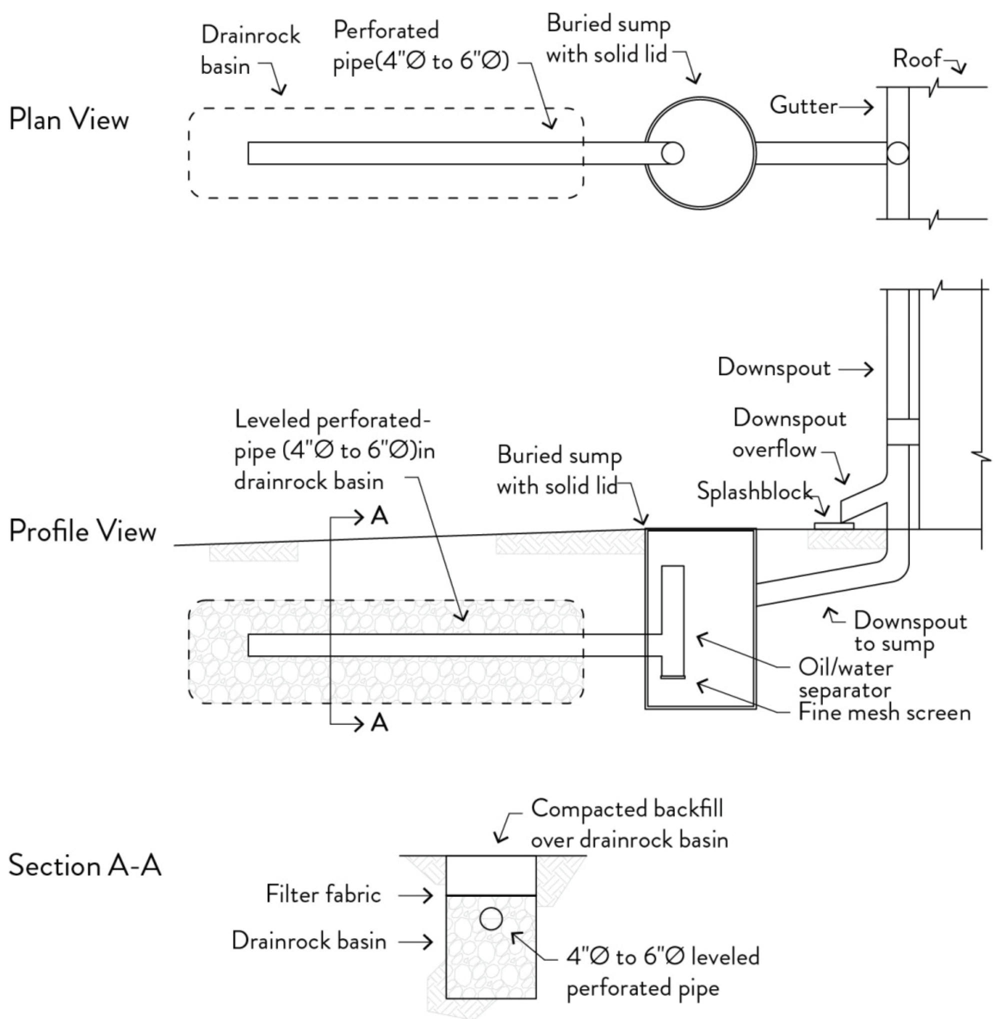
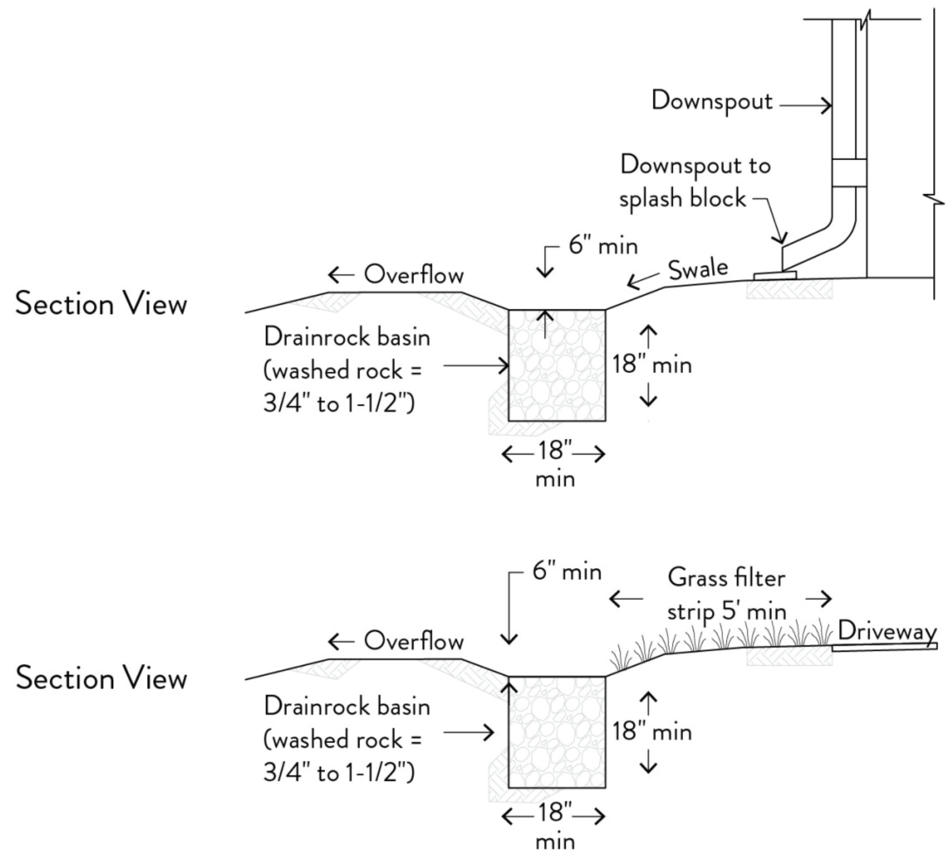


Figure 11.b. Alternative Downspout Infiltration System



11.2.C. **Infiltration Drywells must be designed and installed in conformance with the following standards:**

i. Each drywell must serve up to 750ft^2 (69.9m^2) of impervious area in sandy and gravelly soils. Each drywell must serve 500ft^2 (46.6m^2) of impervious areas when the percolation rate is greater than or equal to ½in (13mm) per hour. Drywells must not be used in soils that have a percolation rate slower to ½in (13mm) per hour.

ii. Drywells must be a minimum of 48in (1.2m) in diameter and have a depth of 5ft (1.5m) [4ft (1.2m) of gravel and 1ft (30.5cm) of suitable solid cover]. A layer of filter fabric or straw must be placed between the gravel and soil cover.

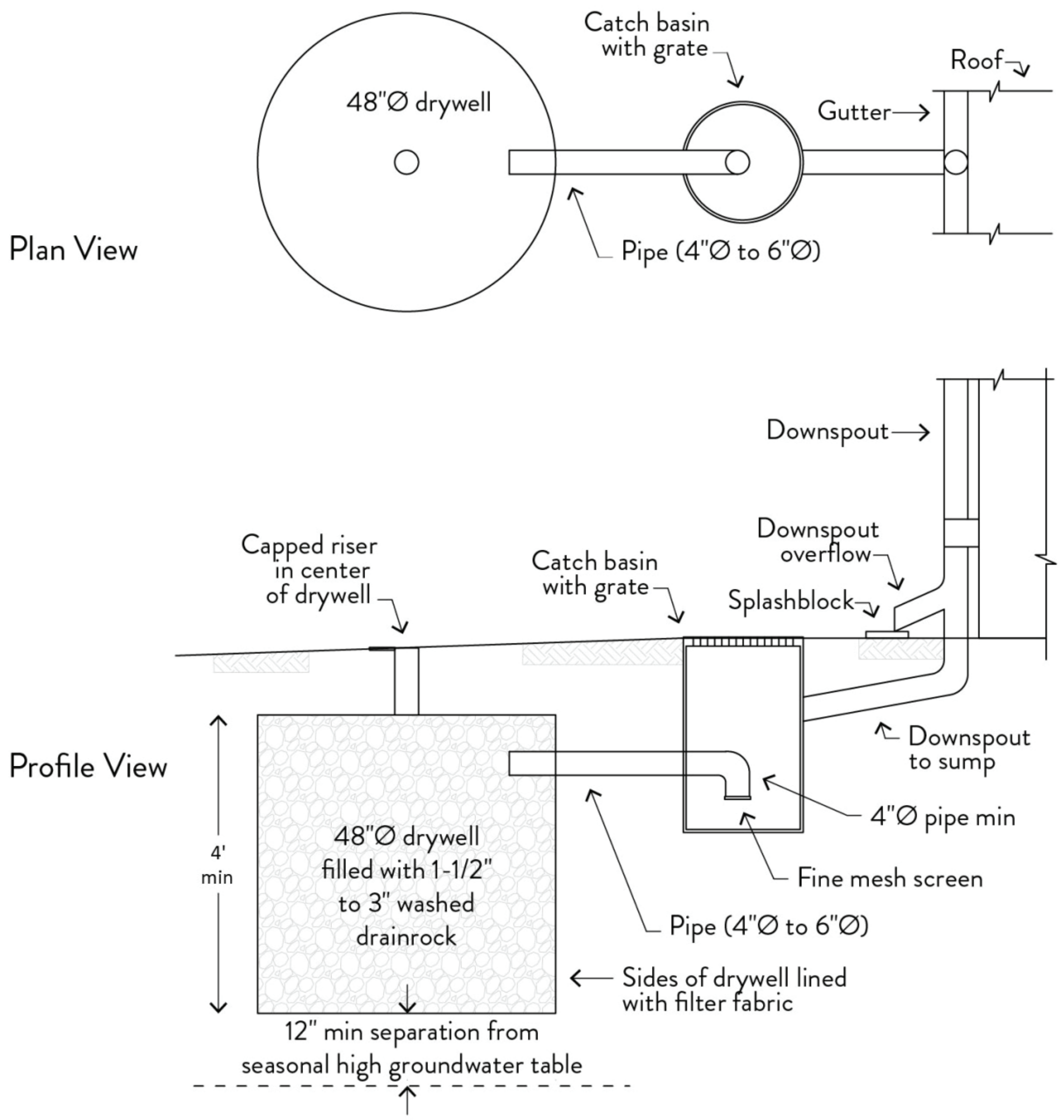
iii. Drywells must be spaced at least 4ft (1.2m).

iv. Drywells must be placed down slope and at least 5ft (1.5m) from a building foundation or any other surface improvement.

v. Infiltration BMPS must be placed down slope and set back at least 5ft (1.5m) from a building foundation or other structural improvements on the site.

vi. Figure 11.c. illustrates the requirements for drywell infiltration systems outlined in the following subsections.

Figure 11.c. Typical Drywell Infiltration System



Dispersion Best Management Practices (BMPs)

The dispersion and spreading out of runoff is the simplest and least cost method of flow control BMPs available. Common dispersion BMPs include splash blocks, vegetated swales or retention basins, a vegetated and rock lined dispersion swales.

Splash Blocks

Splash blocks are the simplest way to disperse flows from a roof area. Downspouts splash blocks or downspout/drain extensions with splash blocks are often the only BMP required to spread runoff out into a landscaped or naturally vegetated area. The vegetated area downstream of the splash block does the work of slowing and infiltrating the runoff.

11.2.D. Splash blocks must be designed and installed according to the following standards:

i. A vegetated area or flow path of at least of feet must be maintained between the discharge point and any property line, structure, steep slope, stream or other impervious area.

ii. A maximum of 700ft^2 (65m^2) of roof area may be drained to each splash block.

iii. A splash block or a pad of crushed rock 2ft wide by 3ft long by 6in deep (60cm wide by 90cm long by 15cm deep) must be placed at each downspout discharge point.

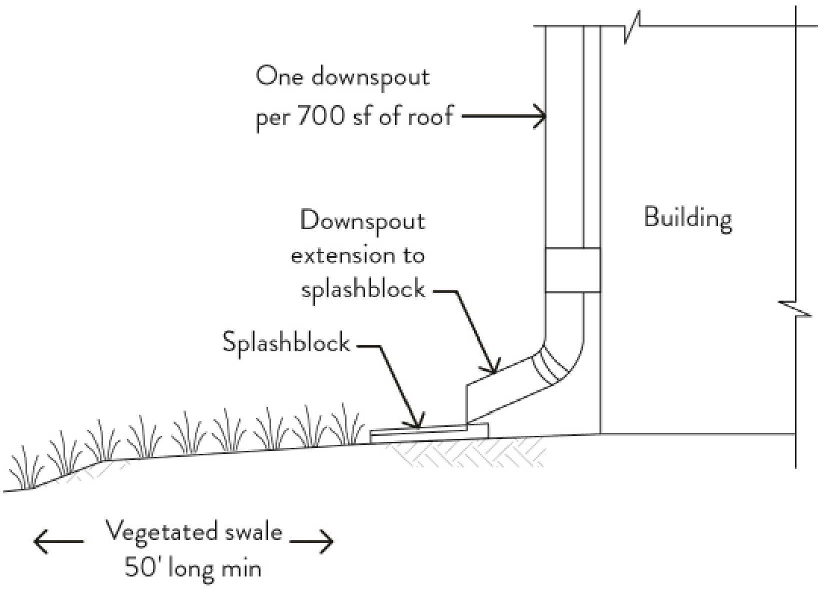
iv. The splash block or pad must discharge to a stabilized and vegetated area that is not prone to erosion of flooding.

v. Runoff must not be directed to a landslide hazard area.

vi. Splash blocks and pads must not be installed on slopes over 20%.

vii. The discharge point of a splash block/pad must be at least 25ft (7.6m) cross or downslope from a latrine, soak-away tank and drainfield/ leachfield.

Figure 11.d. Typical Splash Block Installation Detail



11 / Stormwater Management

Vegetated and Rock-lined Swales and Shallow Rocked Trenches

Concentrated flow from driveways, small parking lots and roofs can be directed to shallow vegetated or rock lined swales or shallow rock trenches.

11.2.E. Vegetated dispersion areas must be designed and installed according to the following standards:

i. The vegetated dispersion area must be sized to provide 50ft^2 (4.6m^2) dispersion area for 500ft^2 (46.4m^2) of impervious area.
ii. A pad of crushed rock 2ft wide by 3ft long by 6in deep (60cm wide by 90cm long by 15cm deep) must be placed at the inlet of the vegetated swale.
iii. Vegetated dispersion areas must not be installed on slopes over 20%.
iv. Vegetated dispersion areas must be at least 25ft (7.6m) cross or downslope from a latrine, soak-away tank and drainfield/ leachfield.
v. Vegetated dispersion area must discharge to a stabilized and vegetated area that is not prone to erosion of flooding.
vi. Runoff must not be directed to a landslide hazard area.

11.2.F. Vegetated and rock-lined swales must be designed and installed to the following standards:

i. The vegetated swale flow length must be at least 50ft (15.2m) long by 3ft (91.4cm) wide and 6in (15.3cm) deep for each 1,000ft^2 of impermeable surface drained. The rock-lined swale must be at least 25ft (7.6m) long by 3ft (91.4cm) wide by 6in (15.3cm) deep for each 1,000 square feet of impervious surface drained.
ii. A pad of crushed rock 2ft (61cm) wide by 3ft (91.4cm) long by 6in (15.3cm) deep must be placed at the inlet of the vegetated swale.
iii. Vegetated and rock-lined swales must not be installed on slopes over 20%.
iv. Vegetated dispersion area must be at least 25ft (7.6m) cross or downslope from a latrine, soak-away tank and drainfield/ leachfield.
v. Vegetated dispersion area must discharge to a stabilized and vegetated area that is not prone to erosion of flooding.
vi. Runoff must not be directed to a landslide hazard area.

Sheet Flow Dispersion

In many instances, such as roads, driveways and parking lots can be graded to have a uniform cross slope (typically 2%) that avoids concentrating runoff. Because flow is already dispersed as they leave the impervious surface, they need only traverse a narrow band of adjacent vegetation or a shallow rock-lined swale for effective attenuation and control of the runoff. This BMP is used on relatively flat or moderately sloping surfaced (<15% slope) such as driveways, small roads, parking lots, and roofs without gutters.

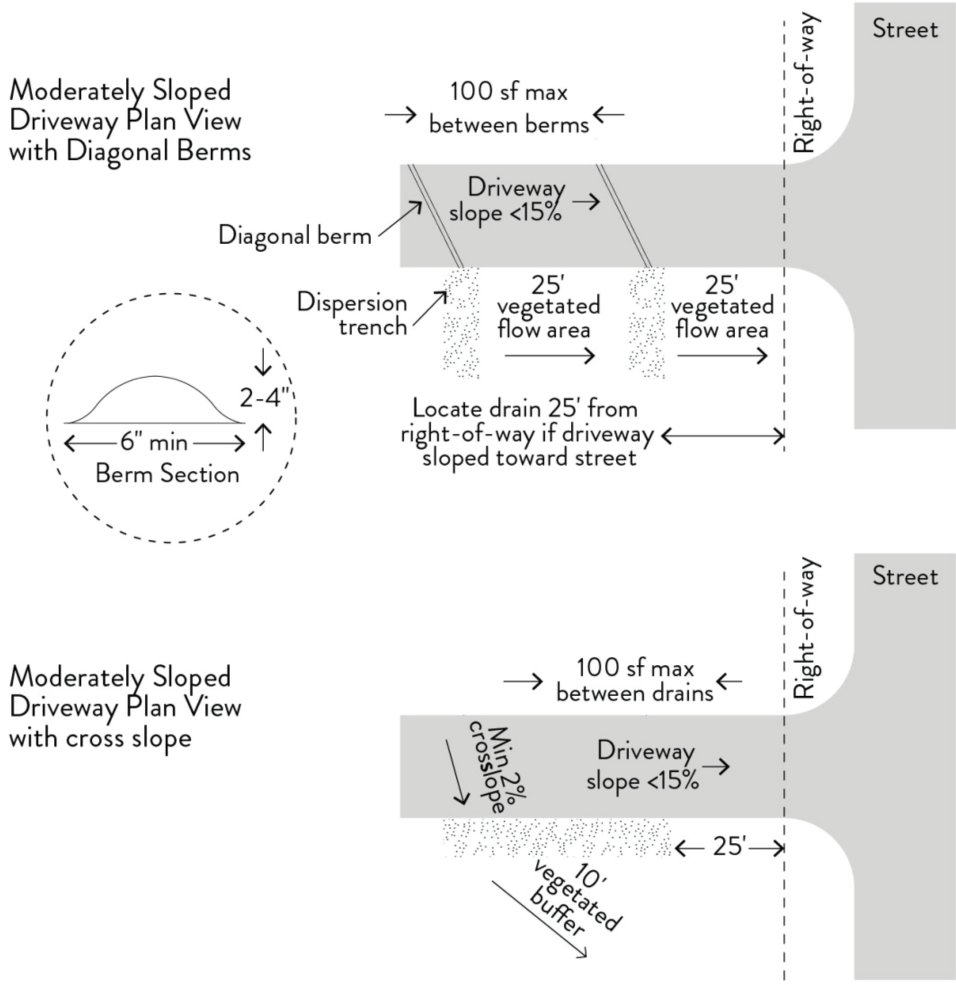
11.2.G. Sheet flow dispersion BMPs must be designed and installed in conformance with the following standards:

i. A 2ft (61cm) wide transition zone must be installed between the impervious surface and the dispersion BMP. The transition material must be a 6in (15.3cm) bed of crushed rock, crushed concrete, or drain rock or equivalent material.
ii. A vegetated buffer width of 10ft (3m) must be provided for up to 20ft (6.1m) of width of paved or impervious cover. An additional 5ft (1.5m) of width must be added for each additional 20ft (6.1m) width.
iii. The vegetated buffer must not be installed on slopes over 20%.
iv. The vegetated buffer must be at least 25ft (7.6m) cross or downslope from a latrine, soak-away tank and drainfield/ leachfield.

v. The vegetated buffer must discharge to a stabilized and vegetated area that is not prone to erosion or flooding.

vi. Runoff must not be directed to a landslide hazard area.

Figure 11.e. Sheet Dispersion Detail



11.3. Stormwater Management for Large Sites

Designing and installing stormwater management practices for larger sites larger than 2acres (0.8ha) or sites that are located in flood prone areas or on steep slopes typically requires more in-depth drainage analysis, planning and engineering to properly manage runoff. A larger project, such as a regional health center or hospital campus may require the installation of a piped stormed drain network to collect, convey and manage runoff in a safe and effective manner. The following standards present the minimum requirements for conducting a drainage analysis, designing runoff conveyance systems, outfall structures and stormwater BMPS.

Drainage Analysis

11.3.A. **A drainage analysis must be completed to properly size drainage collection, conveyance, storage and treatment systems. The drainage analysis must be completed by a qualified civil engineer with a minimum of 3 years' experience in drainage engineering.**

Runoff Collection and Conveyance Systems

Stormwater runoff from buildings, roads and other improved areas must be collected in stormwater collection and conveyance systems. Roof gutters and down spout or pipes are commonly employed to collect and convey runoff off of roofs and away from buildings. In some instances rain chains can be used to safely convey rainfall off of roof into landscaped areas or drainage swales. Runoff may be directed to infiltration systems that are in close proximity to a building and parking area to recharge groundwater and to minimize runoff leaving the site. In other instances runoff from buildings, parking lots and other improved areas may be collected in surface drainage swales or piped storm drainage system (which are more costly to construct and maintain). This section presents standards and guidelines of alternative runoff conveyance BMPs.

11.3.B. **Roof runoff collection systems must be designed to accommodate the peak flows from the 2-minute, 10-year rainfall equivalent to 15in (38.1cm) per hour.**

Roof Runoff Calculation

The peak runoff from a 5,000ft^2 (464.5m^2) roof is calculated with the rational formula using a runoff coefficient C of 0.95 and a rainfall intensity of 15in (38cm) per hour.

$Q = (0.95)(15in/hr)(0.083ft/in)(5{,}000ft^2)/(3600s/h) = 1.64\ ft^3/sec$ or

$Q = (0.95)(38cm/hr)(1L/1{,}000cm^3)(464.5m^2)(10{,}000cm^2/m^2)/(3600s/h) = 46.4\ L/s$

The total runoff will typically be routed to two or more gutters and downspouts and the flow in each will be proportional to the area of roof it serves. By way of example, a rectangular building with a 50ft by 100ft (15.2m by 30.4m) roof with its peak in the center might divide the runoff into 4 equal portions with the gutters running to downspouts at the 4 corners of the building. In this case each gutter must be designed to carry a peak flow of 0.41 ft^3/s (11.6L/s). Galvanized iron gutters having a cross sectional profile of 6in by 6 n (15cm by 15cm) and positioned to fall 2 in (5cm) over 50ft (15.2m) will each have a capacity of 0.43 ft^3/ s (12.2L/s). Downspouts of half this size, i.e. 3in by 3in (7.5cm by 7.5) would be adequate if there are no flow impediments at the discharge end.

11.3.C. **The following pipe materials must be used in constructing stormwater conveyance systems at Liberian health facilities:**

- Plain concrete pipe (12in (30cm) diameter only, and only as a driveway culvert)
- Reinforced concrete pipe (must meet ASTM C76-11 or AASHTO M170-09)
- Corrugated aluminum pipe
- Galvanized corrugated iron or steel pipe
- Solid wall high density polyethylene (HDPE) pipe

11.3.D. **Pipes must be laid true to line and grade with no curves, bends, or deflections in any direction. Any break in grade or change in pipe material must occur only at catch basins.**

11.3.E. **Pipe slopes and maximum water velocities must conform to Table 11.b.**

Table 11.b. Maximum Pipe Slopes and Velocities

Maximum Pipe Slopes and Velocities			
Pipe Material	Pipe Slope above which Pipe Anchors Required & Min. Anchor Spacing	Max. Slope Allowed	Max. Velocity at Full Flow
CMP	20% (1 anchor per 100 LF of pipe	30%	30 fps
Concrete	10% (1 anchor per 50 LF of pipe)	20%	30 fps
HDPE	20% (1 anchor per 100 LF of pipe)	None	None

11.3.F. **The three following criteria must be adhered to in designing pipe systems:**

i. The minimum velocity at full flow in any stormwater pipe must be 3ft/s (0.9m/s).

ii. The minimum slope for 8in (20cm) pipes must be 0.5% and the minimum slope for 12in (30cm) and larger pipes must be 0.2%

iii. The maximum distance between catch basins (manholes) must be 300ft (91.4m) except for watertight lines down steep slopes, which do not require maintenance because they are self-cleaning.

11.3.G. **Pipe cover, measured from the finished grade elevation to the top of the outside surface of the pipe, must be 2ft (61cm) minimum.**

i. Under driveways, parking stalls, or other areas subject to light vehicular loading, pipe cover may be reduced to 1ft (30cm) minimum if the design considers expected vehicular loading and the cover is consistent with pipe manufacturer's recommendations.

ii. Pipe cover in areas not subject to vehicular loads, such as landscape planters and yards, may be reduced to 1ft (30cm) minimum.

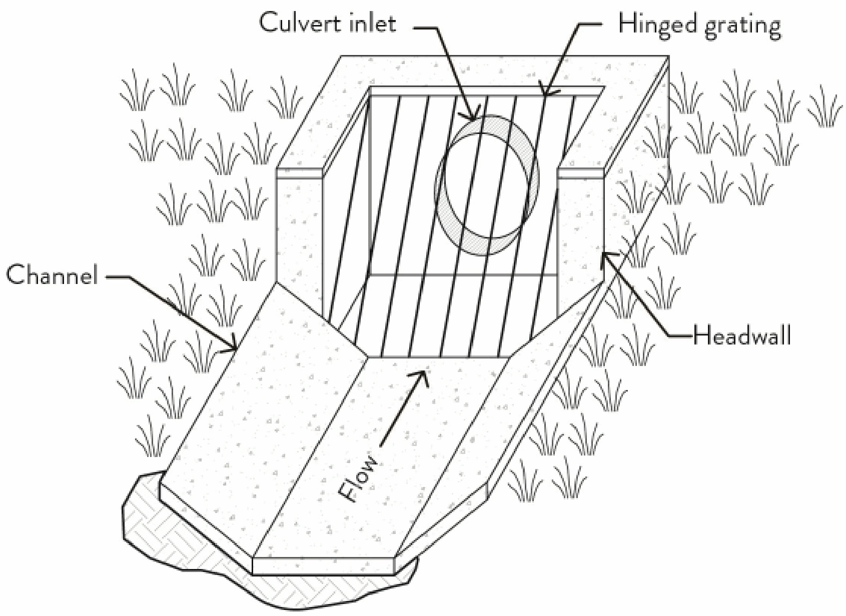
iii. If site conditions call for a pipe to be buried more than 10ft (3m) deep guidance from the pipe manufacturer must be obtained.

11.3.H. **A minimum of 6in (15.3cm) vertical and 3ft (91.4cm) horizontal (outside surfaces) must be provided between storm drainpipes and other utility pipes and conduits.**

11.3.I. **Connections to a pipe system must be made only at catch basins. No wyes or tees are allowed except on roof/footing/yard drain systems involving pipes 8in (20cm) in diameter or less, with clean-outs upstream of each wye or tee.**

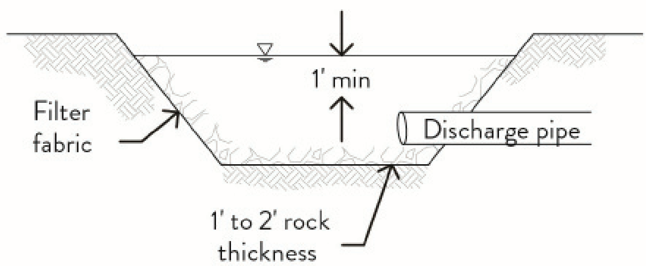
11.3.J. **Debris barriers (trash racks) must be installed on all pipes 12in to 36in (30cm to 90cm) diameter entering a closed pipe system.** (Refer to Figure 11.f. for a typical trash rack installation)

Figure 11.f. Typical Debris Barrier



11.3.K. All storm drain pipeline must have a stabilized outfall that is constructed as an energy dissipater using rock splash pad or roughened concrete channel. (Refer to Figure 11.g. for a typical outfall configuration.)

Figure 11.g. Typical storm drain outfall configuration



11.3.L. For outfalls with a velocity at design flow greater than 10ft/s (3m/s) a gabion dissipater or engineered energy dissipater must be designed and installed.

11.3.M. Open channels conveyance systems must be designed to provide required conveyance capacity while minimizing erosion.

11.3.N. Channel cross-section geometry must be trapezoidal, triangular, parabolic, or segmental. Side slopes must be no steeper than 3:1 for vegetation lined channels and 2:1 for rock-lined channels.

11.3.O. Vegetation-lined channels must have bottom slope gradients of 6% or less and a maximum design velocity of less than or equal to 5ft/s (1.5m/s).

11.3.P. Rock-lined channels or bank stabilization of natural channels must be used when design flow velocities exceed 5ft/s (1.5m/s).

11.3.Q. **Bank stabilization protection measures must be selected and sized in accordance with Table 11.c.**

i. Rock lining must be well graded as follows:
- Maximum size stone: 12in (30cm)
- Median size stone: 8in (20cm)
- Minimum size stone: 2in (5cm)

ii. Riprap must be well graded as shown below. Note that riprap sizing is governed by side slopes on channel, assumed to be approximately 3:1.
- Maximum size stone: 24in (60cm)
- Median size stone: 16in (40cm)
- Minimum size stone: 4in (10cm)

Table 11.c. Guidelines for Selecting Bank Stabilization Protection Measures

Velocity at Design Flow				Required Protection				
Greater than		Less than or equal to		Type of Protection	Thickness		Min. Height Above Design Water Surface	
ft/s	m/s	ft/s	m/s		ft	cm	ft	cm
0	0	5	1.5	Grass or bioengineered lining	N/A			
5	1.5	8	2.4	Rock or bioengineered lining	1	30	1	30
8	2.4	12	3.7	Riprap	2	60	2	60
12		20		Slope mattress gabion, etc.	varies		2	60

Stormwater Management Best Management Practices

11.3.R. **Drainage improvements must employ best management practices (BMPs) to reduce the off-site discharge of stormwater runoff to pre-project quantity and quality levels.**

i. BMPs chosen for implementation must be safe, reliable, and manageable.

ii. Before a BMP is selected physical conditions of the site must be documented to show which BMPs are feasible given these conditions. A drainage study must be conducted to avoid any conflicts that would render the BMP ineffective, evaluating:
- Site topography and drainage pattern
- Pre-project peak stormwater runoff flow
- Pre-project stormwater quality characteristics
- Geology and soil conditions where the BMP would be implemented
- Groundwater conditions where the BMP would be implemented
- Proximity of buildings, roads, and property boundaries
- Proximity of drainage and floodways
- Community acceptance

11.3.S. **All stormwater best management practices must be accessible for routine maintenance and repair, necessary.**

i. Any ponds or traps requiring periodic removal of accumulated sediment must be accessible by vehicle.

ii. Maintenance access roads must be at least 12ft (3.6m) wide and have a maximum slope of 15% and be appropriately stabilized to withstand maintenance equipment and vehicles.

Infiltration BMPs

11.3.T. Soils underlying an infiltration device must meet minimum permeability requirements to allow infiltration.

i. Underlying soils must have an infiltration rate of $^1/_2$ in (13mm) per hour or greater. The minimum soil testing to confirm compliance is one test hole per 5000ft^2 (464.5m^2) with a minimum of two test holes per facility.

ii. Underlying must have a clay content of less than 20% and a silt/clay content of less than 40%.

iii. There must be a minimum of three feet of permeable soil between the bottom of any infiltration device and the highest anticipated groundwater level or bedrock.

11.3.U. Infiltration devices must not be installed on slopes greater than 15%.

11.3.V. The maximum area contributing to an individual infiltration device must be less than 1acre (0.4ha).

11.3.X. An overflow conveyance system must be included in the design of all infiltration devices to ensure that excess flow is discharged at non-erosive velocities.

11.3.Y. All infiltration systems must be designed to fully de-water the input from a 24-hour, one-year storm of 3.3in (83mm) within 12 hours after the storm ends.

11.3.Z. All infiltration systems must be designed to employ an effective pre-treatment technique to prevent clogging.

i. A dense and vigorous vegetative cover must be established over the contributing pervious drainage areas before runoff can be accepted into the infiltration device.

ii. Infiltration trenches must not be constructed until all of the contributing drainage area has been completely stabilized.

iii. An observation well must be installed in every infiltration trench, consisting of an anchored two-inch diameter perforated PVC pipe with a lockable cap.

11.4 Detention Ponds and Bioretention Swales

Stormwater Detention Ponds

This section presents requirements for stormwater detention ponds, which are used to temporarily detain runoff to reduce the rate at which stormwater flows off the developed site so that it doesn't cause erosion or flash flooding down slope of the site. Stormwater ponds are designed to drain dry in under 24 hours, so that they do not become breeding habitats for mosquitoes.

11.4.A. Surface water storage devices (detention ponds) must not be constructed within 25ft (7.6m) of a property line. A 25ft (7.6m) buffer zone must be maintained around the pond.

11.4.B. Woody plants and/or wetland vegetation must not be planted on the embankments or in the pond basin and must be removed if it becomes established by natural recruitment.

11.4.C. The pond must be designed to have a pilot channel connecting the pond inlet to the pond outlet so that the pond is totally dewatered during periods of low or no flow.

11.4.D. The design and construction of stormwater ponds must include provisions for maintenance access.

i. Equip the principal spillway of a stormwater pond with a trash rack that provides access for maintenance.
ii. Ensure that the low flow orifice on the outlet from a stormwater pond has a minimum diameter of 6in (15cm) and that it is adequately protected from clogging by an external trash rack.
iii. Locate the riser within the embankment for maintenance access, safety, and aesthetics.

11.4.E. The design and construction of stormwater ponds must include provisions for drainage and sediment removal.

i. The pond must be designed and installed with a drainpipe that can completely drain the pond within 24 hours.
ii. The pond drain must be sized one pipe size larger than the calculated design diameter.
iii. The pond drain must be equipped with an adjustable valve.
iv. Valve controls must be located inside of the riser at a point where they will not normally be inundated and they can be operated in a safe manner.

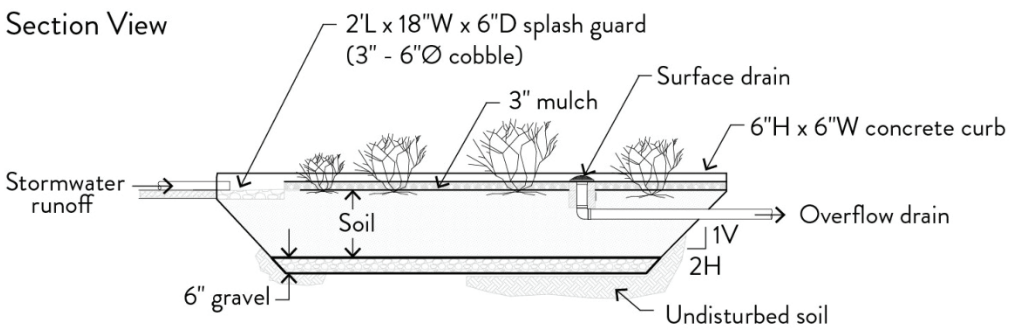
Bioretention Swale/Rain Garden BMP

This section concerns practices that capture, treat, and infiltrate in part or all of the runoff through an engineered vegetated bioretention swale or rain garden.
The bioretention swale and rain garden include an engineered bed that treats the runoff as it flows vertically through the bed that consists of a layer of "bioretention" soil, sand and a gravel underdrain. The bioretention soil is typically:

- 24in to 36in (60cm to 90cm) layer of a sand, loam and compost or mulch
- 6in to 12in (15cm to 30cm) thick layer of sand is under the soil layer
- 6in to 12in (15cm to 30cm) layer of ¾in to $1^1/_2$in (2 to 6cm) gravel

In some instances the swale is unlined and runoff that percolates through the bed infiltrates into the underlying soils. In some instances where the soils are not well draining an underdrain or collector pipe is installed to discharge the stored and treated runoff. The following sections present the general standards for sizing a bioretention swale/rain garden system.

Figure 11.h. Typical Bioretention Swale Design



11.4.F. The entire treatment system must temporarily hold 75% of the runoff from the design storm prior to filtration.

11.4.G. The bioretention swale or rain garden must be sized using the following permeability coefficients:

- Sand 3.5ft/day (106cm/day)
- Peat 2.0ft/day (60cm/day)
- Leaf compost 8.7ft/day (264cm/day)
- Bioretention Soil 0.5ft/day (15cm/day)

11 / Stormwater Management

11.4.H. Bioretention Swales and rain gardens that require outlets must be equipped with a minimum 4in (10cm) perforated pipe underdrain located at the top of the gravel layer.

11.4.I. Bioretention swales and rain gardens must be sized to fully drain within 12 hours to prevent the breeding of mosquitoes.

Bioretention Area Sizing

The required filter bed area is computed according to:

A_f	=	(V) $d_t/[k(h+d_t)t_f]$
A_f	=	Surface area of filter bed (ft^2)
V	=	Runoff volume from design storm (ft^3)
d_f	=	Filter bed depth (ft)
k	=	coefficient of permeability (ft/day)
h	=	average height of water above filter bed (ft)
t_f	=	design filter bed drain time (days)

11.5 Erosion Control Plans and Measures

Erosion and Sediment Control (ESC) is necessary because erosion rates associated with uncontrolled construction sites are much higher than normal rates—often a thousand or more times that of undeveloped land. The erosion rates increase during construction due to the removal of soil cover, alteration of soil characteristics, and changes in site topography. These vastly accelerated erosion rates result in excessive deposition of sediment in water resources and drainage facilities. This excessive erosion and consequent sediment deposition can result in devastating impacts to surface waters such as flooding due to obstruction of drainage ways. Excessive erosion can also cause severe impacts to a site by creating gullies, slope failure (landslides and slumps) and sedimentation on paths, roads, parking areas. Repairing erosion problems can be expensive and sometimes difficult to fully repair.

The majority of erosion problems occur when construction related activities disturb the site and exposed fill or cut slopes or areas void of vegetation become erodible during rainfall event. Common causes of erosion and sediment control failure include:

- Improper scheduling of construction activities (i.e. construction during rainy season)
- Poor site analysis
- Design is incompatible with the site
- Inadequately sized facilities
- Wrong materials specified or used
- Poor installation
- Poor maintenance
- Failure to compensate for seasonal differences or extreme weather conditions

Applying erosion and sediment controls to construction sites can greatly reduce the delivery of sediment to downstream properties or surface waters.

11.5.A. The following general erosion control principles must be considered during the site selection and design process.

Erosion Control Principles

Design the project to fit the site and terrain to minimize grading and site disturbance requirements. Through such practices as limiting disturbance of steeper slopes, avoiding disturbance of natural drainage ways, or using soils with a high infiltration rate to treat polluted runoff, the characteristics of the site can be used to minimize erosion and sediment transport.

Protect and retain existing vegetation to the extent practical. Restricting clearing to only those areas necessary for construction is probably the single most effective form of erosion control. Additionally, exposing areas only as long as necessary reduces the risk of erosion substantially. This can be accomplished by planning the project so that areas are disturbed only when construction is imminent, and by mulching or seeding disturbed areas as soon as grading is completed.

Keep runoff velocities low. While erosion of exposed soil begins with a single raindrop or the wind, the largest volumes of eroded materials are typically associated with concentrated runoff forming rills and gullies. One of the best ways to minimize erosion, therefore, is to reduce the possibility of concentrated runoff by intercepting runoff and conveying it in a non-erosive manner to a sediment pond or trap. This can include the use of dikes, swales, and benches to intercept runoff on slopes and ditches or drains to convey the intercepted runoff.

Schedule major earthwork and construction to occur during the dry season to the extent practical to minimize soil exposure and enhance stabilization.

Protect and stabilize both new and existing drainage swales and channels for increased flows and velocities.

Trap sediment on site. Sediment can be retained by allowing it to settle out in ponds and traps or by filtering runoff from small areas through vegetation or use of a silt fence. Note that settling and filtration typically only remove sand-sized and coarse silt particles. Fine silts and clays cannot be removed in these ways unless the runoff is released to vegetated areas.

Thoroughly monitor the site and maintain all ESC measures. Maintenance and vigilance are the most vital components of effective ESC management. All measures require regular maintenance, monitoring, and inspection. The overall site also needs to be frequently examined to ensure that all areas are protected, that the measures are working together to provide maximum protection, and that all areas are mulched and/or vegetated as soon as possible.

Develop contingency plans before they are needed.

11.5.B. Erosion Control Plans (ECPs) must be prepared as part of the site improvement plans by a qualified civil engineer, landscape architect, geotechnical engineer or architect.

i. The ECP must include a scaled erosion control plan for the site that accurate shows the layout of proposed temporary erosion control measures, such as the installation of silt fences, sand bags, mulch cover, bank and channel stabilization measures, sediment traps and other potential erosion control best management practices (BMPs).

ii. The ECP must include typical details and notes showing the installation methods for all specified BMPs.

iii. The ECP must include an implementation schedule for the installation of the BMPs.

iv. The ECP must contain specifications for temporary runoff control measures that control runoff from equipment and material storage/staging areas and soil stockpile areas to prevent contaminated runoff from entering streams or adjacent properties.

v. The ECP must contain specifications directing the contractor to monitor, maintain and repair BMPs as required to assure good erosion and sediment control at the site.

11.5.C. Erosion and Sedimentation Controls (ESC) must include the following strategies considered for application to the project site.

Erosion and Sediment Control Strategies

Clearing Limits: Prior to any site clearing or grading, areas to remain undisturbed during project construction must be delineated on the project's ESC plan and physically marked on the site.
Cover Measures: Temporary and permanent cover measures must be provided when necessary to protect disturbed areas. The intent of these measures is to prevent erosion by having as much area as possible covered during any period of precipitation.
Perimeter Protection: Perimeter protection to filter sediment from sheet flow must be provided downstream of all disturbed areas prior to upslope grading.
Traffic Area Stabilization: Unsurfaced entrances, roads, and parking areas used by construction traffic must be stabilized to minimize erosion and tracking of sediment offsite.
Sediment Retention: Surface water collected from all disturbed areas of the site must be routed through a sediment pond or trap prior to release from the site, except those areas at the perimeter of the site small enough to be treated solely with perimeter protection. Sediment retention facilities must be installed prior to grading any contributing area.
Surface Water Collection: Surface water collection measures (e.g., ditches, berms, etc.) must be installed to intercept all surface water from disturbed areas, convey it to a sediment pond or trap, and discharge it downstream of any disturbed areas. Areas at the perimeter of the site, which are small enough to be treated solely with perimeter protection, do not require surface water collection. Significant sources of upstream surface water that drain onto disturbed areas must be intercepted and conveyed to a stabilized discharge point downstream of the disturbed areas. Surface water collection measures must be installed concurrently with or immediately following rough grading and shall be designed, constructed, and stabilized as needed to minimize erosion.
Dust Control: Preventative measures to minimize wind transport of soil must be implemented when adjoining property or neighborhood will be impacted by dust pollution.
Flow Control: Surface water from disturbed areas must be either contained on site or routed through a flow control system to protect downstream channels or properties.

11.5.D. Erosion and sediment control (ESC) measures must include the following:

Erosion and Sediment Control Measures

Rock construction entrance helps to prevent transport of sediment away from the site on tires or undercarriage of vehicles.
Mulching prevents erosion by dissipating the energy of rainfall and helps to adsorb the water. Mulching also enhances plant establishment by conserving moisture, holding fertilizer, seed, and topsoil in place and protects soils from drying out.
Minimizing clearing - As previously noted, minimizing clearing and site disturbance are the most effective methods of erosion control. Undisturbed vegetation intercepts and slows rainwater.
Silt fencing uses low fabric fences to catch sediment that has been mobilized by water flowing over the site. Fabrics used in the construction of silt fencing must have openings specifically sized to allow water to flow through while retaining the majority of sediment.
Rainy season stabilization is employed to protect disturbed areas or to cover stockpiled soils to minimize sediment-laden runoff from leaving the site.
Final stabilization involves installing landscaping, mulch and other measures that will stabilize soils after the site construction has been completed.

11.5.E. Rock construction entrances must be installed at all entranceways to a cleared construction site from a public or private road.

i. Rock construction entrances must be at least be 12ft wide by 50ft long by 1ft deep (3.6m wide by 15.2m long by 0.3m deep); however, for small projects the pad may be reduced to 12ft by 25ft (3.6m by 7.6m).

ii. The rock aggregate must be 3in to 6in (7cm to 15cm) in diameter and if the site soils have a clay content over 50% a geotextile fabric must be placed between the rock and the underlying soil.

11.5.F. As much as possible, mulch must be installed for the following applications.

i. Mulch should be installed in disturbed areas that will remain unworked for more than 1 days during the rainy season and 14 days during the dry season.

ii. Mulch should be applied as a cover for seed year around, and on disturbed slopes steeper than 3H:1V with more than 10ft (3m) of vertical relief.

iii. Mulch should be applied at the application rates indicated in Table 11.c and should completely cover the areas resulting in no visible bare soil being exposed.

Table 11.c. Application Rates for Different Mulch Material

Mulch Material	Application Rate
Straw	2in – 3in (5cm - 8cm) thick, 2 -3 bales per 1000ft^2 (92.9m^2), 2 -3 tons per acre (0.7 - 1.1 metric tonnes per hectare)
Compost	2in (5cm) thick, 100 tons per acre (36.7 metric tonnes per hectare)
Wood Chips	2in (5cm) minimum thickness

11.5.G. Erosion control plans must specify minimizing clearing requirements that must be incorporated into the site design, and clearing limits must be marked on both the site plan and erosion control plans. On the ground clearing limits must be marked and clearing minimize on any site where significant areas of undisturbed vegetation will be retained.

11.5.H. Erosion control plans must specify that silt fencing must be installed to protect the perimeter of the site. The silt fencing must be installed in conformance with the following standards:

i. Silt fencing must be installed parallel to the topographic contours.

ii. The bottom of the silt fence must be towed-in to a shallow trench and then staked and reinforced to effectively trap sediment during runoff events.

iii. Silt fencing must be inspected regularly for damage and sediment that collects behind the fence must be removed so that this material does not push the fence over.

11.5.I. Erosion control plans must specify wet weather stabilization measures that conform to the following standards:

i. During the rainy season slopes and stockpiles 3H:1V or steeper must be covered if they are to remain unworked for more than 12 hours. Other disturbed areas must be covered or mulched if they are to remain unworked for more than two days.

ii. The plans must include maintenance specifications that state the site must be inspected weekly and immediately before, during, and after storms. Cover and other erosion control measures must be repaired and enhanced as necessary to prevent or minimize erosion and sedimentation.

11.5.J. Erosion control plans must specify final stabilization measures that will be installed to stabilize the site once construction is completed, such as landscaping, paving, mulch or other drainage improvements.

BUILDING LAYOUT

CONTENTS

IMPACT

The layout of a facility has a direct impact on patient well-being. Not only does it influence the efficiency of health care delivery, but it also plays a central role in controlling the spread of infection. A facility's "program," which is a list of its constituent elements (functions, rooms, or spaces) that together compose the building, needs to be thoughtfully designed to maximize its effectiveness. This section addresses three aspects of building layout that require attention prior to design.

PRIMARY USERS

Infrastructure Unit

County Health& Social Welfare Teams

Facility Staff

Architects & Designers

GUIDELINES FOR USE

For designers to gain a basic understanding of proximity needs for medical services, Chapter 12: Program Adjacencies presents diagrammatic illustrations of adjacencies. Note that these are not facility plans but functional proximity diagrams. Plans themselves will also be informed by the way patients, staff and equipment move through facilities, which can be determined by consulting Chapter 13: Circulation & Occupant Flow.

Having an understanding of the overall programmatic arrangement, Chapter 14: Facility Sizing may be used during early schematic design to get a handle on the rough size of the facility being planned; as the design progresses and more detailed spatial information is needed, users should consult Chapters 46-51: Room Planning.

12 Program Adjacencies and Layout

Relationships between program elements affect the flow of people and materials through the building. Well-designed adjacencies maximize efficiency and reduce risks like the spread of infection, while also ensuring patient privacy. To achieve these outcomes, a hierarchy of spaces that accommodates necessary adjacencies needs to be developed for each new facility.

Definitions

- **Adjacency:** Placement next to or with direct access to another program element.
- **Program:** A list of the constituent elements (functions, rooms, or spaces) that compose a building.
- **Program element:** The individual functions, rooms, or spaces in a building.
- **Proximity:** Close placement in terms of space, time, or relationship.

12.1 General Program Element Requirements

Levels of service, and therefore building space requirements, depend on the care level of the facility. Primary care facilities function with outpatient services only. Secondary facilities have both outpatient and inpatient facilities, with much clinical support and more sophisticated services at the Hospital level. Tertiary care facilities are predominantly specialty facilities with special services, and inpatient services for severe cases.

Table 12.a Recommended Categorization and Placement of Facility Functions[1]

Category	Description of Spaces[a]	Placement / Spatial Configuration
Entry and Reception	• Patient &Visitor Entry • Registration and Records • Waiting Area • Triage& Vital Signs	• At primary access point of building • Check-in point (Registration & Records) near entry, with access to Waiting Area • Triage & Vital Signs adjacent to Waiting Area, with access to Outpatient Department (OPD) • Visible from staff areas for patient supervision • Separate queue spaces for Registration and Dispensary (if adjacent to Waiting Area)
Outpatient Department (OPD)	• Examination Rooms • Short Stay • OPD Laboratory	• Proximal to Entry and Reception • More secure and private than Entry, controlled through Registration • Lab proximal to Examination Rooms and OPD bathrooms
Maternal & Child Health (MCH)	• Expanded Program Immunization (EPI) visits • Family Planning and Antenatal Care • Labor Room • Delivery Room • Post Partum Ward • Post C-Section Ward	• EPI proximal to main waiting area • Separate from general OPD • Privacy and acoustical separation desired • Labor and Post-Partum may be shared in small facilities
Emergency Room (ER)	• Emergency Room	• Entrance from exterior (either through Records and Registration or as its own entrance)
Internal Medicine	• Men's Inpatient Ward • Women's Inpatient Ward • Pediatrics Inpatient Ward	• Private areas, accessible to visitors but not general public
Infectious Disease Unit (IDU)	• Infectious Disease Consultation Rooms • Isolation Rooms	• Isolated from all other spaces; separate and controlled access
Intensive Care	• Intensive Care Unit (ICU) • Neonatal Intensive Care Unit (NICU)	• Private areas, not immediately accessible to general public. Proximity to wards preferred. • NICU proximity to Delivery and Surgery required • Proximity to a staff lounge is recommended.

continued on next page

Category	Description of Spaces[a]	Placement / Spatial Configuration
Surgery	• Pre-Op • Sterile Access System (Scrub Rooms, Transit) • Operating Rooms • Post Anesthesia Care Unit (PACU) • Post Operation Ward	• Set apart as its own department to maintain sterile conditions • Controlled access to all spaces • Proximity to Delivery and ER required • Proximity to ICU preferred
Diagnostics & Clinical Support	• Diagnostic testing • Laboratory services • HIV counseling & testing • Drug Dispensary& Pharmacy Stock	• Proximal to OPD, but self-contained • Lab may be combined with OPD Lab if necessary • Drug Dispensary accessible to general public with separate queue space
Infectious Disease	• Treatment for TB or other highly infectious diseases	• Isolated from all other spaces; separate and controlled access
Staff Areas	• Nursing Stations • On-Call Areas • Break Rooms • Staff Offices • Meeting & Training Rooms	• Nursing Stations within or immediately adjacent to inpatient wards • On-Call Rooms near ICU, Surgery, ER • Break Rooms for larger facilities near clinical areas but accessed separately • Staff Offices and Meeting Rooms in administrative area with its own entrance in larger facilities
Non-Clinical Support	• Laundry • Kitchen and Cafeteria • Storage& Maintenance • Equipment& Communication Rooms • Public Bathrooms	• Laundry and Kitchen back of house; separate from clinical and administrative areas • Storage dispersed throughout the facility in relevant locations • Equipment & Communication Rooms isolated in back-of-house areas but accessible to maintenance staff • Bathrooms adjacent to major public areas and as required for service

[a]Not all spaces listed are required for all facilities. Refer to Table 12.b. for details.

12.1.A. Each facility must contain, at minimum the program elements outlined in Table 12.b. Additional program elements must be included per specific facility needs.

Table 12.b Program Element Requirements by Facility Type

X = Required
O = Recommended

Program element	Facility Type					
	Primary Care		Secondary Care			Tertiary Care
	PHC 1	PHC 2	Health Center	District Hospital	County Hospital	Regional Hospital
Entry and Reception						
Waiting Area	X	X	X	X	X	X
Registration	X	X	X	X	X	X
Medical Records			X	X	X	X
Triage& Vital Signs	X	X	X	X	X	X
Outpatient Department (OPD)						
Consultation Rooms	X	X	X	X	X	X
Dressing Room		X	X	X	X	X
Specialist Consultation Rooms				X	X	X
Short stay	X	X	X			
Maternal & Child Health (MCH)						
Antenatal Care		X	X	X	X	X
Immunization (EPI)	X	X	X	X	X	X
EPI Storage	X	X	X	X	X	X
Labor Room	X	X[a]	X	X	X	X
Delivery Room		X	X	X	X	X
Post-Partum Ward		X[a]	X	X	X	X
Post-C-Section Ward				X	X	X
Internal Medicine						
Male Inpatient Ward			X	X	X	X
Female Inpatient Ward			X	X	X	X
Pediatric Inpatient Ward			X	X	X	X
Emergency						
Emergency Room			O	X	X	X
ER Storage			O	X	X	X
Emergency Procedure Room				X	X	X
Intensive Care Unit						
ICU Rooms				O	X	X
NICU				X	X	X
Surgery						
On-Call Suite				X	X	X
Pre-Op				X	X	X
Clean Material Storage			O	X	X	X
Scrub Room			O	X	X	X
Pre-Op Transit				X	X	X
Operating Room			O	X	X	X
PACU Transit				X	X	X
Dirty Linens / Sluice Room				X	X	X
Post Anesthesia Care Unit (PACU)				X	X	X
Post Operation Ward				X	X	X

continued on next page

<table>
<tr><th rowspan="3">Program element</th><th colspan="6">Facility Type</th></tr>
<tr><th colspan="2">Primary Care</th><th colspan="3">Secondary Care</th><th>Tertiary Care</th></tr>
<tr><th>PHC 1</th><th>PHC 2</th><th>Health Center</th><th>District Hospital</th><th>County Hospital</th><th>Regional Hospital</th></tr>
<tr><td colspan="7">Infectious Disease Unit (IDU)</td></tr>
<tr><td>IDU Consultation</td><td></td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Isolation Rooms</td><td></td><td></td><td>O</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="7">Diagnostics and Clinical Support</td></tr>
<tr><td>Drug Dispensary</td><td rowspan="2">X</td><td rowspan="2">X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Pharmacy Stock Room</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>General Laboratory</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Biosafety Laboratory</td><td></td><td></td><td></td><td></td><td>X</td><td>X</td></tr>
<tr><td>Radiology</td><td></td><td></td><td></td><td>O</td><td>X</td><td>X</td></tr>
<tr><td>Advanced Diagnostics</td><td></td><td></td><td></td><td></td><td></td><td>X</td></tr>
<tr><td>Sterilization</td><td></td><td></td><td>O</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="7">Staff Areas</td></tr>
<tr><td>Nursing Stations</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Staff Room</td><td></td><td></td><td></td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Staff Offices</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Meeting Room</td><td></td><td></td><td></td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Education Rooms</td><td></td><td></td><td></td><td></td><td>X</td><td>X</td></tr>
<tr><td colspan="7">Non-Clinical Support</td></tr>
<tr><td>Bathrooms</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Laundry</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Kitchen</td><td></td><td></td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Cafeteria</td><td></td><td></td><td></td><td></td><td>O</td><td>X</td></tr>
<tr><td>Storage</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Equipment Rooms</td><td></td><td></td><td rowspan="2">X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Communications Room[b]</td><td></td><td></td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Morgue</td><td></td><td></td><td></td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Generator House / Electrical Supply Room</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Incineration</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="7">Supplemental Facilities</td></tr>
<tr><td>Staff Housing[c]</td><td>X</td><td>X</td><td>O</td><td>O</td><td></td><td></td></tr>
<tr><td>Maternal Waiting Homes[d]</td><td></td><td>O</td><td>O</td><td></td><td></td><td></td></tr>
</table>

[a] *In PHC 2 facilities, Labor and Post-Partum Wards may be combined into a single ward.*

[b] *In PHC 1 and 2 facilities, Communication Rooms may be combined with storage.*

[c] *Staff Housing is strongly required for rural health facilities only.*

[d] *Maternal Waiting Homes are strongly recommended for PHCs and Health Centers with long walking distances from the community members' homes to the facility.*

12.1.B. The arrangement of program elements within facilities must be based on infection control, patient privacy, and efficient service provision.

i. Refer to Figures 12.c. - 12.f. for guidance on optimal program element adjacencies in Clinics, Health Centers, and Hospitals.

ABBREVIATIONS KEY

CM	Clean Materials
Comm.	Communication Room
DL	Dirty Linens
EPI	Extended Program for Immunization
ER	Emergency Room
ICU	Intensive Care Unit
IPD	Inpatient Department
MCH	Maternal Child Health
N	Nurses Station
NICU	Neonatal Intensive Care Unit
OPD	Outpatient Department
OR	Operating Room
PACU	Post-anesthesia Care Unit
Pre-op	Pre-operative Room
WC	Water Closet (bathroom)

Figure 12.c. Program Element Adjacencies for PHC 1

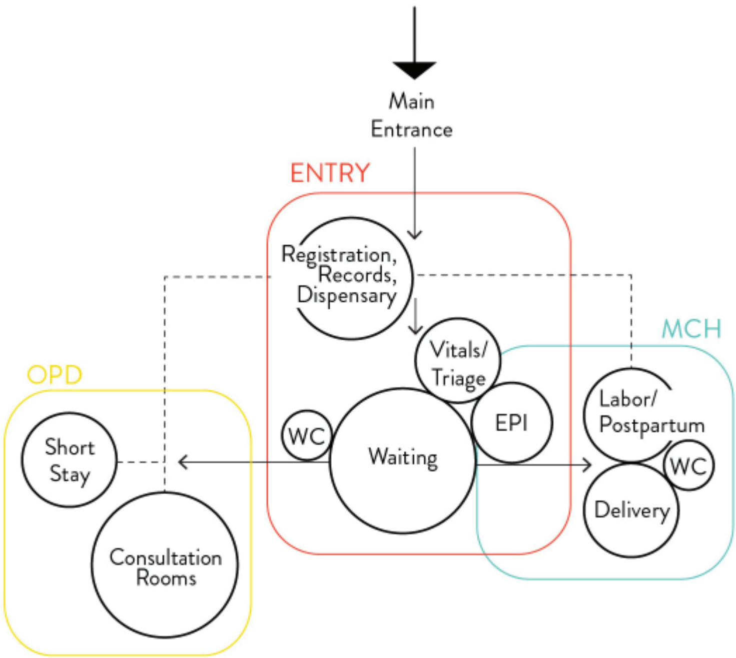


Figure 12.d. Program Element Adjacencies for PHC 2

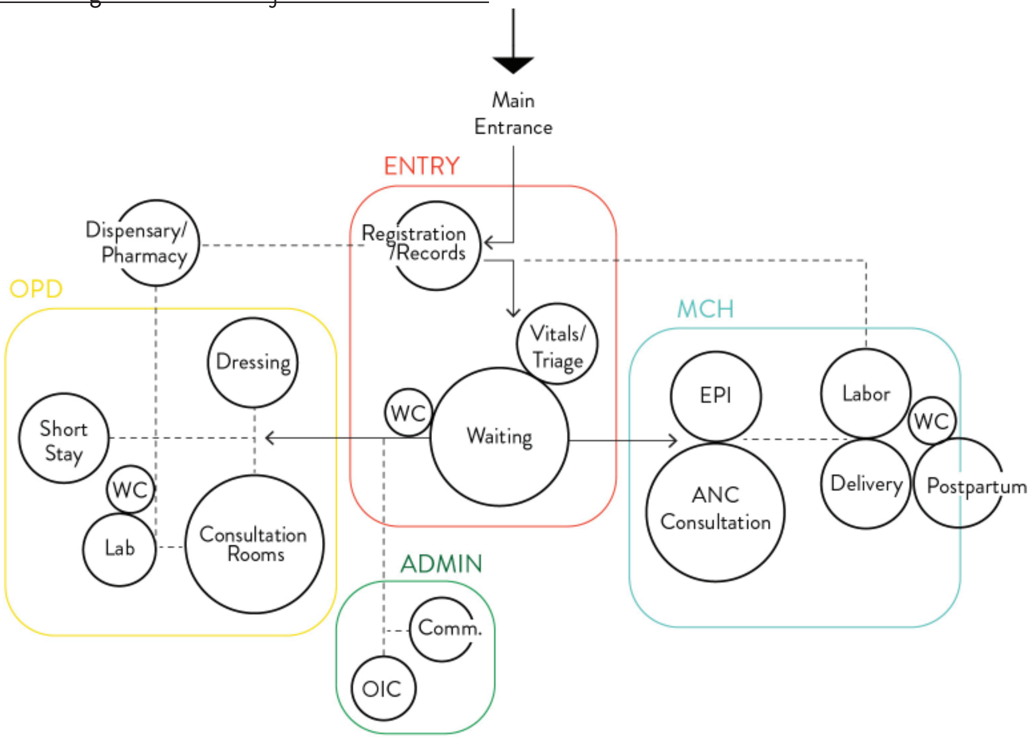
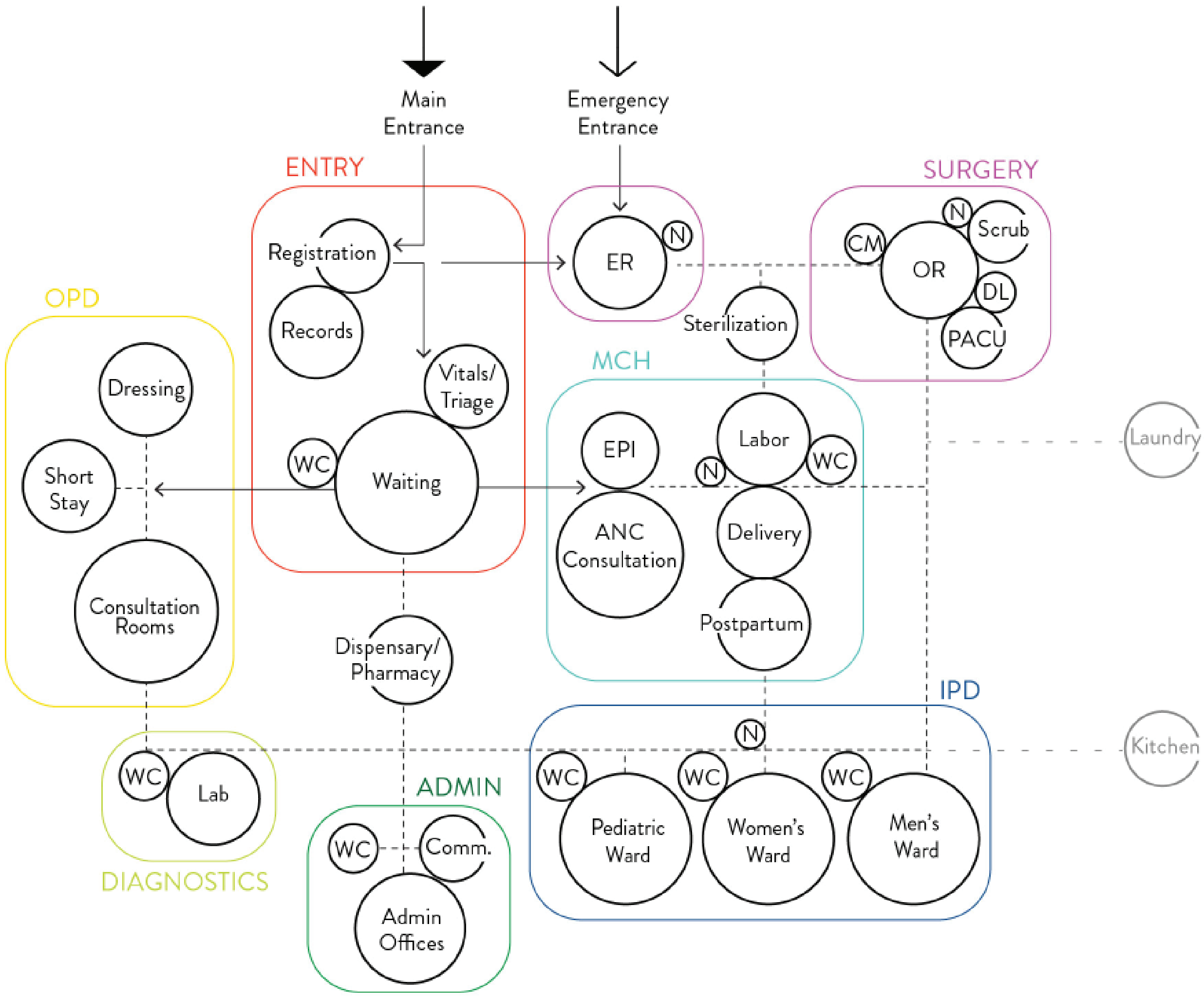
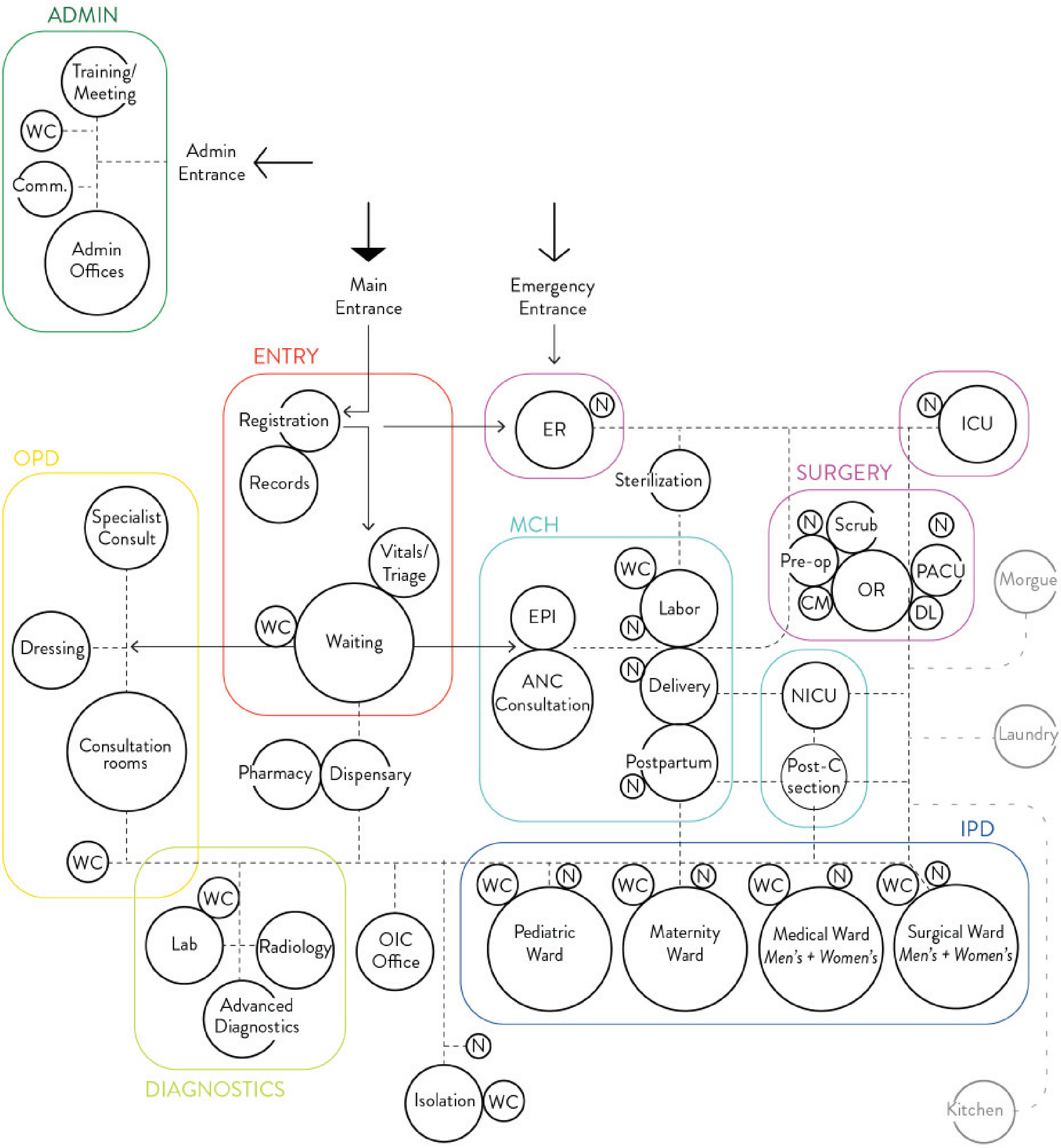


Figure 12.e. Program Element Adjacencies for Health Centers



12 / Program Adjacencies

Figure 12.f. Program Element Adjacencies for Hospitals



12.2 Minimizing Infection Transmission

The idea of 'do-no-harm,' from the Hippocratic Oath taken by physicians, also applies to buildings. First, keeping healthy patients well and helping sick patients recover is top priority. Isolating program areas that contain waste or patients with infectious illnesses limits exposure to airborne and waste-related infection. Second, carefully controlling hazardous materials contributes to patient safety.

12.2.A. Areas accessible to the general public must be physically and environmentally separated from treatment, diagnostic, support, and staff areas.

i. Boundaries between public and restricted spaces must be marked and supervised to avoid confusion about access to each area; this spatial separation also reduces movement of contaminants through the air or underfoot.

12.2.B. In Health Centers and Hospitals, isolation for diagnosis and treatment of infectious diseases must be provided.

i. Treatment rooms for infectious patients must be physically and environmentally separate from inpatient wards, surgery, ER, ICU, and other areas where vulnerable patients are located.

ii. If naturally ventilated, isolation areas must be a minimum of 65ft (20m) from other treatment areas.

12.2.C. Support areas including food preparation areas, waste management areas, and a morgue must be separated from treatment areas.

i. These areas must be physically separated by a full-height wall with independent access for interior spaces, or at least 65ft (20m) from treatment areas if sheltered exterior spaces.

ii. Windows to naturally ventilate these spaces must not be within 50ft (15m) of windows to clinical areas.

iii. Refer to Chapters 28 and 29 for waste treatment requirements.

12.3 Optimizing Medical Services

Arranging program elements to support the flow of patients through the facility, and the workflow of staff, improves patient and staff experiences alike. In some cases, program elements have competing adjacency requirements that require judgment on the part of the architect or facility planner.

12.3.A. Program elements that are used jointly during single patient visits must be clustered.

i. Program elements with related functions, access levels, and security must be co-located.

ii. Functional 'zones' must be arranged based on who requires access to them. Spaces that allow visitors or require limited public access must be grouped accordingly. Refer to Table 12.g.

Table 12.g. Expected Users of Facility Program Elements by Category

Category	Accessibility		
	Patients	Staff	Visitors
Entry & Reception	X	X	X
OPD	X	X	
MCH	X	X	X
Emergency	X	X	
Internal Medicine	X	X	X
Intensive Care	X	X	X
Surgery	X	X	
Infectious Disease Unit	X	X	
Diagnostics & Support	X	X	
Staff Areas		X	
Non-Clinical Support	X (bathrooms only)	X	X (bathrooms only)

12.3.B. Program elements requiring similar levels of patient privacy must be located in areas further removed from public areas.

i. Sensitive program elements requiring greater patient privacy must be located away from public spaces and main entrances. Labor and Delivery, Internal Medicine, ICU, Surgery, and Psychiatric Departments must be considered private.

12.3.C. Environmental conditions must be considered when locating program elements.

i. Quiet areas such as inpatient wards, ICU and NICU must be located and/or designed in a way to maintain acoustical separation from potentially loud areas such as Entry & Reception, ER, Labor and Delivery.

ii. If mechanical ventilation is used, program elements requiring it must be grouped to make installation, use, and maintenance of systems more efficient. This includes Operating Rooms and ICUs.

12.3.D. In Health Centers and Hospitals, Surgery must be located near the ER, Delivery Room, and NICU

i. Distances between critical care functions must be minimized in case a C-section or emergency surgery is required.

12.3.E. Pharmacy and Drug Dispensaries must be located near the Entry and Reception area for ease of outpatient access and deliveries.

Program element placement assessment

While there is no universal solution to how every facility should be set up, understanding the functional requirements of each program element helps to optimize the layout of new and upgraded facilities of all scales. Points that may be useful to determine program arrangements during the facility design phase include the following:[1]

- Name of function:
- Types of users (list by type and number involved):
- Major activities (list chief functions, tasks, or activities that must be accommodated in this area):
- Proximity and access (determine what areas this space must relate to directly):
- Special requirements (natural and artificial ventilation and lighting, sanitary systems, electrical considerations, materials, windows):
- Major furnishings and equipment (list by type, permanent or moveable placement, special characteristics):

13 Circulation and Occupant Flow

"Circulation" refers to the way people and equipment move or "flow" through a building. Usually this relates to the design of corridors, walkways, and door openings, but it can also include elevators and stairs. Being intentional about the flow of people, equipment, and supplies through the facility optimizes service delivery and minimizes risks.

13.1 General Circulation

Different types of circulation apply to different occupants in a facility, which include:

- People: patients, visitors, staff
- Equipment and supplies: clinical and support supplies
- Specimens: biological matter for lab testing

13.1.A. Circulation patterns must minimize or eliminate the crossing of patients, staff, and visitors with potential health hazards, including patients with highly contagious illnesses, as well as waste and other potentially harmful equipment and supplies.

i. Separate entrances and routes for the passage of sensitive or hazardous constituents must be maintained, whenever possible.

13.1.B. Circulation patterns must be designed to allow staff to monitor visitors and control access to restricted or hazardous areas.

13.1.C. Corridors for non-sterile areas must be located on the exterior of facilities or outfitted with appropriate ventilation provisions per Chapters 19 and 20.

i. Single-loaded corridors (corridors with program elements on only one long side and unenclosed on the other) must be prioritized and situated on the exterior of buildings to maximize benefits from natural light and ventilation.

13.2 People

Patients, visitors, and staff require clear instructions of where to go in facilities to maximize efficiency, avoid crowding, reduce risks and otherwise and enable effective provision of care.

Patient circulation

Most patients are not familiar with the facilities they visit. Signage indicating clear points of entry and straightforward referral routes are essential. Patient-centric circulation is designed to control infection, maintain sterile conditions, provide privacy, and ensure patient safety.

13.2.A. Facilities must be designed to optimize patient referral routes, minimize travel time between program areas, maintain levels of sterility, and control access to restricted areas.

13.2.B. Women in labor and patients requiring emergency care must have clear and direct access to the Labor and Delivery Rooms and ER.

i. Clearly marked, direct and visible entrances from Registration to the ER and Labor Ward must be provided in Health Centers and Hospitals. If facility capacity allows, a separate ER entrance with its own registration may be provided at County and Regional/National Referral Hospitals.

ii. In all facilities, the MCH department must have a separate spatial flow from Registration that is not used by general patients and allows direct access to the Labor Room.

13.2.C. In hospitals with separate treatment areas for highly contagious illnesses, patients known to have such conditions must have separate entrances so as to avoid circulating through the main facility with other patients, staff, or visitors.

i. Where possible, secondary entrances for patients who are known to require isolation should be established; these should lead directly to isolation rooms. Refer to Table 12.a. for notes on adjacencies.

ii. Care must be taken so as not to stigmatize patients entering these spaces. Discrete signage and private entry out of view of public areas of the facility must be incorporated.

13.2.D. A clear progression from unclean to sterile conditions must be adopted in program elements requiring a sterile environment.

i. For requirements on the surgical sequence of spaces, refer to Sections 49.1 - 49.3.

13.2.E. Delivery Rooms must be directly connected to Labor Rooms, and have close access to ORs and NICU.

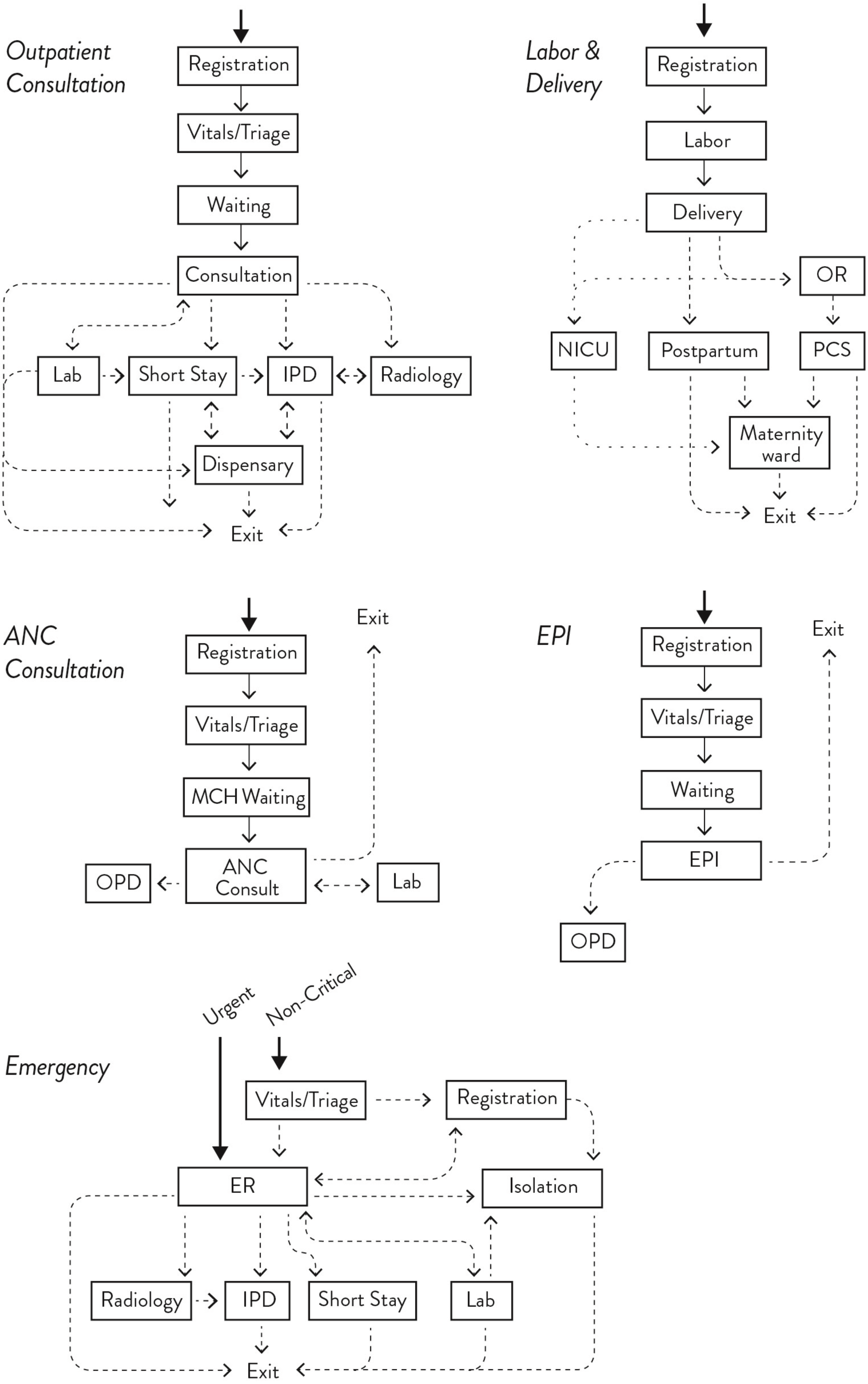
Visitor circulation

Family members or attendants often accompany patients, particularly children, pregnant women, the elderly, and those requiring intensive or long-term care. When visitors are not adequately accommodated, overcrowding, infection transmission, poor patient experiences, reduced operational efficiency, and the loss of a beneficial caretaker's role during treatment can all occur. (See Chapter 14 on Program Sizing for detailed accommodation requirements for visitors.)

13.2.F. Public access within facilities must be limited to Entry, Waiting, and designated Visitor Areas; access for caretakers and visitors must be provided in wards according to patient needs and terms decided by facility staff.

i. Areas restricted to staff must either have doors separating them from other areas or clearly indicated signage restricting access.

Figure 13.a. Patient Referral Routes



Staff circulation

Staff circulation patterns vary by facility type. In Hospitals, staff members are specialized and do not move around the entire building. In Clinics and Health Centers, the breadth of work required of medical staff means that they must use many parts of the facility.

13.2.G. Facilities must be designed to provide convenient routes for staff members that minimize travel time between program areas, maintain levels of sterility, and control access per Table 13.e.

Table 13.e. Access and Circulation Requirements by Staff Type

Staff Type	Primary Role	Work Locations	Design Priorities
Clinical	• Directly treat patients	• OPD • Inpatient Wards • Nursing Stations • Staff Offices	• Minimize distance to destinations • Incorporate nurses' stations into travel paths
Diagnostic & Clinical Support	• Manage diagnostic and laboratory operations • Oversee pharmacy	• OPD • Diagnostic Rooms • Laboratory • Pharmacy • Staff Offices	• Provide direct route to workplace • Develop clean-to-dirty flow for work areas • Controlled access to Pharmacy Stock, Lab Storage, and areas with consumables
Administrati ve	• Check-in patients • Manage records • Receive deliveries	• Registration • Staff Areas • Storage	• Provide direct route to workplace
Maintenance	• Service buildings and equipment • Conduct scheduled assessments	• Entire facility excluding controlled consumables areas for routine maintenance (not consistently)	• Coordinate work to minimally disrupt patient services
Cleaning	• Clean facility	• Entire facility excluding controlled consumables areas for routine cleaning(not consistently)	• Provide storage for cleaning products on each floor if multiple floors • Incorporate multiple janitors' closets and waste disposal outlets
Other support	• Prepare and serve food • Clean linens • Monitor facility	• Kitchen • Laundry • Wards (serving) • Facility grounds	• Provide direct route to workplace (potentially with separate entrance) • Provide direct route between kitchen/laundry and wards or other places where food and linens are delivered • Develop clean-to-dirty flow

13.3 Equipment and Supplies

Equipment and supplies generally fall within four categories:

- **Clinical equipment:** IVs, oxygen tanks, wheelchairs, patient beds, gurneys, operating beds, trolleys
- **Disposable clinical supplies:** medicine, vaccinations, bandages, disposable syringes
- **Supporting supplies and goods:** food, laundry, cleaning supplies
- **Biological material and specimens:** blood, stool, sputum, solid and medical waste

Equipment and supply circulation plans should take into account the safety and cleanliness of materials, their required modes of transportation, and how often they must be transported to various parts of the facility.

13.3.A. Facilities must be designed for wheeled equipment to travel to points of use without risk of disruption or damage.

i. Travel paths must include sufficient space for wheelchairs, beds, gurneys, and trolleys. Refer to Section 16.2 for corridor accessibility requirements.

13.3.B. Facilities must be designed with sterile storage spaces for sterile supplies in areas distant from sterilization.

i. Sterile equipment must not be exposed to public or patient spaces.

13.3.C. Facilities must be designed to allow unclean materials to be disposed of without exposing patients or clean equipment and supplies to contamination.

i. Distances that exposed, unclean materials need to travel through facilities must be minimized. Multiple disposal points or sealed methods of transport are advisable to mitigate challenges with trying to avoid disrupting activities within facilities.

14 Facility Sizing

Room and total program element sizes are determined by purpose, the furniture and equipment that they contain, and the number of people that use them on a consistent basis.

14.1 Facility Sizing Inputs

Generally, facilities of the same type contain the same program and are therefore comparable in size. Spatial requirements vary with catchment population, however; such variation is explicitly defined for PHC 1 and 2 facilities (see Chapter 3 on Facility Types), which may contain the same programs but with different numbers of rooms. Size differences also occur among Health Centers and Hospitals that serve dramatically different population segments. Calculating total spatial requirements for each facility is possible and is useful for ensuring that each is large enough to serve its catchment population without being wasteful.

It should be noted that it is crucial to look beyond official demographics to fully understand the patient load on a facility. Facilities in counties that border other countries at times face extra pressure from refugees from nearby Guinea, Sierra Leone, or Côte d'Ivoire. Even without an unexpected influx of refugees into Liberia, facilities near the border regularly receive patients from the neighboring country. Final facility sizing should be determined in consultation with facility staff and the MOHSW.

14.1.A. Total facility floor area must be based on the sum of individual program element needs and expected circulation space.

i. All sizes to be designed for must be checked against facility statistics, relevant health care planning, and staff recommendations. Final program element sizes must be approved by the assigned IU representative.

ii. Individual program element spatial requirements must be summed to attain the net usable area within a facility. In new buildings, programs must not be forced into pre-defined building shapes that have been designed without thought to individual program element requirements.

iii. Gross building area must be obtained by multiplying the net usable area by 1.3. The additional 30% should be designated for corridors and service spaces not included in listed program elements. Refer to Tables 14.a, 14.b, and 14.c. for standard program sizing for PHC1, PHC2, and Health Center facilities, respectively.

Table 14.a. Approximate Minimum Spatial Requirements for a PHC1 Clinic[a]

Program element	Size (ft^2)	Size (m^2)	Notes
Entry and reception			
Waiting Area[b]	155 to 470	14.4 to 43.6	Refer to Standard 14.2.A. for sizing requirements
Registration, Records& Dispensary	100 to 120	9.3 to 11.1	
Triage& Vital Signs	92	8.5	May be an extension of the Waiting Area
Outpatient Department (OPD)			
Examination Room	100	9.3	
Short Stay	220	20.4	
Maternal & Child Health (MCH)			
Immunization (EPI)	May be shared with Waiting/Triage& Vital Signs area		
EPI Storage	16	1.5	
Antenatal Care	OPD Examination or Delivery Room to be used		
Labor & Delivery Room	130	12.1	
Diagnostics & Clinical Support			
Dispensary & Pharmacy	May be shared with Registration/Records		
Non-Clinical Support			
Men's Bathroom	35	3.3	
Women's Bathroom	35	3.3	
Storage	26	2.4	3% of total size
Non-Clinical Support outside main building			
Generator Shelter/ Electrical Supply Room	60	5.6	To be sized based on equipment
Circulation	270	25.1	30% of total
TOTAL	**1,242 to 1,477**	115.4 to 137.2	Estimated minimum

[a] *This table assumes a minimum adjusted primary catchment population of 2,000 and a maximum of 4,200. If a PHC 1 facility is built to serve a larger catchment population, some adjustment is needed. Refer to Sections 14.2-11 for further details on sizing relative to adjusted catchment population.*

[b] *Sizing depends on adjusted catchment area or expected patient load.*

Table 14.b. Approximate Minimum Spatial Requirements for a PHC2 Clinic[a]

Program element	Size (ft^2)	Size (m^2)	Notes
Entry and reception			
Waiting Area[b]	470 to 1,860	43.6 to 172.8	Refer to Standard 14.2.A. for sizing requirements
Registration & Records	150	14.0	Conjoined spaces
Triage& Vital Signs[c]	92 to 184	8.5 to 17.1	Refer to Standard 14.2.E. for sizing requirements
Outpatient Department (OPD)			
Examination Room 1[c]	100	9.3	Refer to Standards 14.3.A. and 14.3.B. for required number of Examination Rooms and sizing
Examination Room 2[c]	100	9.3	
Examination Room 3[c]	100	9.3	
Dressing Room	100	9.3	
Short Stay[b]	220 to 330	20.4 to 30.7	Refer to Standards 14.3.A. and14.3.C. for sizing requirements
Maternal & Child Health (MCH)			
MCH Waiting & EPI	110	10.2	
EPI storage	16	1.5	
ANC Consultation	130	12.1	
Labor and Post-Partum Room[b]	220 to 550	20.4 to 51.1	Refer to Standards 14.4.A. and 14.4.E. for number of beds and sizing requirements
MCH Bathroom	50	4.6	
Delivery Room[c]	330 to 495	30.7 to 50.0	Refer to Standards 14.4.A and 14.4.D for number of bays and sizing requirements
Diagnostics and Clinical Support			
Dispensary & Pharmacy Stock[b]	120 to 180	11.1 to 16.7	Refer to Standard 14.9.A. for sizing requirements
General Laboratory[d]	135 to 225	12.5 to 20.9	Refer to Standard 14.9.B. for sizing requirements
Staff Areas			
OIC Office	100	9.3	
Staff Office	100	9.3	
Non-Clinical Support			
Men's Bathroom	35	3.3	
Women's Bathroom	35	3.3	
Storage	78	7.3	3% of total
Non-Clinical Support outside main building			
Generator Shelter / Electrical Supply Room	60	5.6	To be sized based on equipment
Incineration	60	5.6	To be sized based on equipment
Circulation	805	74.8	30% of total
TOTAL	3,450 to 5,950	320.5 to 552.7	Estimated minimum

[a] *This table assumes a minimum adjusted primary catchment population of 4,200 and a maximum of 16,800. Refer to Sections 14.2-11for further details on sizing relative to adjusted catchment population.*
[b] *Sizing depends on adjusted catchment area or expected patient load.*
[c] *Quantity depends on adjusted catchment area or expected patient load.*
[d] *Sizing depends on number of planned staff.*

Table 14.c. Approximate Spatial Requirements for a Health Center

Program element	Size (ft^2)	Size (m^2)	Notes
Entry and reception			
Waiting Area[b]	1,580 to 3,310	146.8 to 307.5	Refer to Standard 14.2.A. for sizing requirements
Registration	80	7.5	
Medical Records	150	14.9	
Triage& Vital Signs[c]	92 to 276	8.5 to 25.6	Refer to Standard 14.2.E. for sizing requirements
Outpatient Department (OPD)			
Examination Room 1[c]	100	9.3	Refer to Standards 14.3.A. and 14.3.B. for required number of Examination Rooms and sizing
Examination Room 2[c]	100	9.3	
Examination Room 3[c]	100	9.3	
Examination Room 4[c]	100	9.3	
Examination Room 5[c]	100	9.3	
Dressing Room	100	9.3	
Short Stay[b]	330 to 440	30.7 to 40.9	Refer to Standards 14.3.A. and14.3.C. for sizing requirements
Maternal & Child Health (MCH)			
MCH Waiting & EPI	110	10.2	
EPI Storage	16	1.5	
ANC Consultation	130	12.1	
Labor Room[b]	330 to 440	30.6 to 40.8	Refer to Standards 14.4.A. and 14.4.E. for number of beds and sizing requirements
MCH Bathroom	50	4.6	
Delivery Room[b]	495 to 660	46.0 to 61.3	Refer to Standards 14.4.A. and 14.4.D. for number of bays and sizing requirements
Post-Partum Ward[b]	440 to 660	40.8 To 61.3	Refer to Standards 14.4.A. and 14.4.E. for number of beds and sizing requirements
Internal Medicine			
Male Inpatient Ward[b]	330 to 550	30.6 to 51.1	Refer to Standards14.6.A. and 14.6.B. for required number of ward beds and sizing requirements
Female Inpatient Ward[b]	330 to 650	30.6 to 51.1	
Pediatric Inpatient Ward[b]	440 to 770	40.9 to 71.6	
Emergency (if included)			
Emergency Room[b]	320 to 400	29.7 to 37.2	Refer to Standards14.5.A. and 14.5.B. for required number of ER bays and sizing requirements
Nursing Station	80	5.6	
ER Storage	12	1.1	
Surgery			
Scrub Room	65	6.0	Presence of full OR depends on available staff and equipment
Operating Room	360	33.4	
Infectious Disease Unit (IDU)			
Isolation Rooms	76	7.0	One room

continued next page

Program element	Size (ft^2)	Size (m^2)	Notes
Diagnostics and Clinical Support			
Drug Dispensary	80	7.5	
Pharmacy Stock Room[b]	120 to 180	11.2 to 16.7	Refer to Standard 14.9.A. for sizing requirements
General Laboratory[d]	180 to 270	16.8 to 25.1	Refer to Standard 14.9.B. for sizing requirements
Staff Areas			
Nursing Station[b]	80	7.4	
OIC Office	100	9.3	
Staff Office 1	100	9.3	Both may not be necessary depending on staffing levels.
Staff Office 2	100	9.3	
Non-Clinical Support			
Men's Bathrooms[c]	155	14.4	Refer to Standards14.11. A. and 14.11.B. for number of toilets and sizing requirements
Women's Bathrooms[c]	155	14.4	
Staff Bathroom	35	3.3	1 Unisex
Laundry	25	2.3	Sink + exterior space for drying
Storage	230	21.4	3% of total size
Non-Clinical Support outside main building			
Generator Shelter/ Electrical Supply Room	200	18.6	To be sized based on equipment
Incineration	60	5.6	To be sized based on equipment
Circulation[1]	2460	228.5	30% of total
TOTAL	**10,663 to 14,065**	990.6 to 1,306.7	Estimated minimum

[a] *This table assumes a minimum adjusted primary catchment population of 14,400 and a maximum of approximately 35,00; and a minimum adjusted referral catchment population of up to 56,000. Refer to Sections 14.2 - 14.11for further details on sizing relative to adjusted catchment population.*
[b] *Sizing depends on adjusted catchment area or expected patient load.*
[c] *Quantity depends on adjusted catchment area or expected patient load.*
[d] *Sizing depends on number of planned staff.*
[e] *Laundry for Health Centers consists only of an area with an appropriate washbasin and drying area.*

14.1.B. **For primary care program elements which vary in size and quantity based on the number of people to be served, the adjusted primary catchment population of the facility must be calculated according to the following formula:**

$P_p \times F_p = C_p$

where: P_p *= the current primary catchment population*
F_p *= growth rate factor of 1.2 for rural areas or 1.4 for urban areas*
C_p *= adjusted primary catchment population*

i. Primary care program elements which will depend on population include: all OPD consultation and examination rooms; Short Stay; Antenatal Care facilities; and Labor and Delivery Wards at PHC 1 and PHC 2 facilities.
ii. The adjusted primary catchment population is the product of the current primary care catchment area (excluding referral catchment area) and a cumulative growth rate factor (figured over 10 years) to account for projected growth as indicated in Table 14.d. Refer to Appendix T for more information.
iii. Urban areas, defined in this standard as contiguous settlement areas with a population greater than 250,000, are likely to grow faster than rural areas. As a result, its growth rate factor is higher than that of rural areas.
iv. The methodology for these requirements is outlined in Appendix T. Refer to it for greater detail.

14.1.C. **For referral care program elements which vary in size and quantity based on the number of people to be served, the adjusted referral catchment population of the facility must be calculated according to the following formula:**

$P_r \times F_r = C_r$

where: P_r *= the current referral catchment population*
F_r *= growth rate factor of 1.2 for rural areas or 1.3 for urban areas*
C_r *= adjusted referral catchment area*

i. Referral care program elements which will depend on population include: Referral Consultation Rooms; Labor and Delivery Wards at Health Centers and Hospitals; Emergency Rooms; all Inpatient facilities; ICUs at Hospitals; NICUs at Health Centers and Hospitals; and Operating Rooms.
ii. The adjusted referral catchment population is the product of the current referral care catchment area (including all areas which may be referred to the facility) and a cumulative growth rate factor (figured over 10 years) to account for projected growth as indicated in Table 14.d. Refer to Appendix T for more information.
iii. Referral facilities in urban areas, defined in this standard as contiguous settlement areas with a population greater than 250,000, are likely to grow faster than rural areas, but also generally serve some rural locations with slower growth rates as well. As a result, its growth rate factor is higher than that of rural areas but lower than purely urban areas.
iv. The methodology for these requirements is outlined in Appendix T. Refer to it for greater detail.

14.1.D. **Expected peak outpatient loads must be calculated according to the following formula:**

$0.0092 \times C_p = V_t$

where: C_p *= adjusted primary catchment area from Standard 14.1.B.*
V_t *= total peak OPD visitors per day*

i. Peak outpatient loads will be used to determine the size of Waiting Areas.
ii. Methodology and rationale for this formula is outlined in Appendix T. Refer to it for more details.

14.2 Entry and Reception

Good healthcare begins when patients enter facilities. Particularly in rural areas, where most patients tend to arrive in the morning (increasing waiting periods), appropriately sized waiting areas paired with good administrative measures reduce the spread of infection and increase the efficiency of service delivery.

14.2.A. Waiting areas must be sized to safely seat the volume of patients and visitors expected during peak periods using the following formula:

$$12x\ V_t = A_f\ (ft^2)$$

$$1.125\ x\ V_t = A_m\ (m^2)$$

where: V_t = *total peak OPD visitors per day from Standard 14.1.D.*
A_f = *required floor area in* ft^2
A_m = *required floor area in* m^2

i. For detailed methodology on this calculation, refer to Appendix T.
ii. In small facilities where space is limited, waiting, vital signs, and EPI may be arranged as separate zones within a single room or area.

14.2.B. Registration and Medical Records Rooms must be positioned near facility entry points, but be only accessible to staff members.

i. Patients must be able to complete registration upon arrival and while waiting in the general Entry Area without entering the Staff Area.

14.2.C. At minimum, Registration and Medical Records must be sized for each facility type according to Table 14.d.

i. Sizes in Table 14.d. must be checked against facility needs. The final sizes to be designed for must be approved by the assigned IU representative.
ii. In PHC facilities, Registration and Medical Records may be housed together in one room.
iii. Patients must be able to complete registration upon arrival and while waiting in the general Entry Area without entering the room where records are stored.
iv. The Medical Records Room must include enough space for staff to manage registration and records management. Storage must accommodate all patient records, meaning that more space is required for facilities that serve larger catchment populations, as per Table 14.d.

Table 14.d. Minimum Registration and Medical Records Size Requirements

Facility Type	Minimum Space Required
PHC 1	One room at 100ft^2 (9.3m^2); or minimum of 120ft^2 (11.2m^2) if combined with Dispensary
PHC 2	One room at 150ft^2 (14m^2) (can be combined with Dispensary in smaller facilities)
Health Center	One Registration Area at 80ft^2 (7.5m^2) One Medical Records Room at 120ft^2 (11.2m^2)
District Hospital	One Registration Area at 100ft^2 (9.3m^2) One Medical Records Room at 150ft^2 (11.2m^2)
County Hospital	One Registration Area at 120ft^2 (11.2m^2) One Medical Records Room at 200ft^2 (18.6m^2)
National Referral Hospital	One Registration Area at 120ft^2 (11.2m^2) One Medical Records Room at 240ft^2 (22.3m^2)

14.2.D. **An area for Triage& Vital Signs must be designated as part of the general Waiting Area.**

i. Hygiene and patient privacy must be prioritized when planning the space in relation to the broader Waiting Area.

14.2.E. **Triage & Vital Signs Areas must have a minimum total area of 92ft^2 (8.5m^2). The quantity of designated Triage& Vital Signs areas must be calculated per expected patient load according to Table 14.3.**

i. Sizes in Table 14.g. must be checked against facility needs. The final sizes to be designed for must be approved by the assigned IU representative.
ii. Refer to Appendix T for methodology on how these figures are obtained.
iii. The number of Triage& Vital Signs Areas must be compared to available and planned staff members for this role. If fewer staff are available or planned than triage area quantity, the quantity may be reduced with approval from the assigned IU representative.

Table 14.3. Minimum Quantity of Designated Triage Areas by Expected Patient Load

Expected Patient load (from 14.1.d.)	Number of Triage & Vital Signs Areas
<130	1
130-240	2
>240	3

14.3 Outpatient Department (OPD)

Outpatient facility sizing depends greatly upon the adjusted catchment population to be served and, in turn, on the expected patient load.

14.3.A. OPD program element sizes must align with sizes in Table 14.f.

Table 14.f. Clinical Program Spatial Requirements

Program	Minimum Space Required
Consultation Room(s)	100ft^2 (9.3m^2) per room
Dressing room	100ft^2 (9.3m^2) per room
Short stay	110ft^2(10.2m^2) per bed

14.3.B. The quantity of OPD Consultation Rooms must be calculated according to the adjusted catchment population as shown in Table 14.g.

i. Quantities in Table 14.f must be checked against facility statistics and staff recommendations. The final number of OPD Consultation Rooms to be designed must be approved by the assigned IU representative.

ii. For secondary and tertiary level referral facilities, the number of Consultation Rooms must be determined only by the facility's primary care catchment area, not its entire referral catchment area.

iii. The calculated number of Consultation Rooms must be compared with staff availability. If the number of Consultation Rooms is less than the number of available medical staff and the number of medical staff planned for in a 5-year period, this number may be reduced with approval from the assigned IU representative.

iv. Methodology for these quantities is outlined in Appendix T. Refer to it for more details.

Table 14.g. Number of Consultation Rooms per adjusted primary catchment population

Adjusted primary catchment population	Number of Examination Rooms
<4,200	1
4,200 - 12,599	2
12,600 - 17,599	3
17,600 - 22,600	4
>22,600	5

14.3.C. The quantity of beds in a Short Stay room must be calculated according to the adjusted primary catchment population as shown in Table 14.h.

i. Quantities in Table 14.h. must be checked against facility statistics and staff recommendations. The final number of beds in a Short Stay Room must be approved by the assigned IU representative.

Table 14.h. Number of Beds for Short Stay Based on Adjusted Primary Catchment Population

Adjusted primary catchment population	Number of beds
<12,000	2
12,000 - 16,800	3
>16,800	4

14.4 Maternal and Child Health (MCH)

Maternal and Child Health's prioritized status in national health policy make MCH departments the central program in PHC clinics, health centers, and hospitals alike. Related spaces therefore need to be appropriately sized to promote mothers' and children's well-being before, during, and after birth.

14.4.A. MCH program spaces must align with sizes in Table 14.i.

Table 14.i. MCH Program Spatial Requirements

Program	Space Required
ANC consultation	130ft^2(12.1m^2) per room
Immunization (EPI)	110ft^2 (10.2m^2) as extension of waiting area plus 16ft^2 (1.5m^2) of storage; or 125ft^2(11.6m^2) for combined EPI provision and storage room.
Delivery room	80ft^2 (7.4m^2) plus circulation for PHC 1 facilities 100ft^2(9.3m^2) per bay plus circulation for PHC 2 and above
Labor / postpartum room(s)	110ft^{2}per bed

14.4.B. An area for Immunization (EPI) provision and area for EPI storage must be designated as part of the MCH waiting area.

i. EPI supplies and photovoltaic equipment used for refrigeration must be securely stored. If a designated room for EPI dispensing is provided, then equipment and supplies must be contained within it; otherwise, a designated storage space must be built.

14.4.C. MCH departments must have a minimum number of Consultation Rooms for Antenatal Care (ANC) as designated by facility type in Table 14.j.

i. Quantities in Table 14.j. must be checked against facility statistics and staff recommendations. The final number of ANC consultation rooms to be designed must be approved by the assigned IU representative.

Table 14.j. Minimum Number of ANC Consultation Rooms per Facility Type

Facility type	Number of ANC Consultation Rooms
PHC 1	1 (shared with Delivery or Consultation Room)
PHC 2	1
Health Center	1
District Hospital	2
County Hospital	3
Regional Referral Hospital	4

14.4.D. Delivery Wards must accommodate the minimum number of delivery bays as expressed for the relevant adjusted catchment population in Table 14.k.

ii. Quantities in Table 14.k must be checked against facility statistics and staff recommendations. The final number of delivery bays to be designed for must be approved by the assigned IU representative.

iii. Methodology for the calculation behind these requirements is outlined in Appendix T. Refer to it for greater detail.

Table 14.k. Minimum Number of Delivery Bays per Adjusted Catchment Population

Adjusted primary catchment population	Facility Type	Number of Delivery Bays
<4,200	PHC 1	1
4,200 - 16,799	PHC 2	2
>16,800		3
Adjusted referral catchment population	**Facility Type**	**Number of Delivery Bays**
<56,000	Health Center	3
>56,000		4
all populations	District Hospital	4
<110,000	County Hospital	4
>110,000		4-5
all populations	Regional/National Referral Hospital	4-5

14.4.E. Labor, Post-Partum and Post C-Section Wards must be provided based on an adjusted catchment population as indicated in Table 14.l.

i. Quantities in Table 14.l. must be checked against facility statistics and staff recommendations. The final number of delivery bays to be designed for must be approved by the assigned IU representative.
ii. In PHC 1 facilities Labor and Post-Partum may be combined into one room and shared with Short Stay. No Post C-Section Ward is needed.
iii. In PHC 2 facilities, Labor and Post-Partum may be combined into one room but must not be shared with other functions. No Post C-Section Ward is needed.
iv. In Health Centers, Labor and Post-Partum must be separated but Post C-Section may be a part of Post-Partum.
v. In Hospitals, Labor, Post-Partum, Post C-Section and Kangaroo Care must be in separate rooms
vi. Methodology for these calculations is outlined in Appendix T. Refer to it for more detail.

14.4.F. In Health Centers and Hospitals, Post-Partum facilities must have beds divided between a Post-Partum Ward and Kangaroo Care as recommended by facility staff and planners.

Table 14.I. Minimum Number of Rooms and Beds for Labor, Post-Partum, and Post C-Section Wards

Adjusted primary catchment population	Facility Type	Minimum Space Required
<4,200	PHC 1	One room with minimum 1 bed
4,200 - 16,799	PHC 2	One room with minimum 2 beds
>16,800		One Labor Ward with minimum 2 beds One Post Partum Ward with minimum 3 beds
Adjusted referral catchment population	**Facility Type**	**Minimum Space Required**
>38,000	Health Center	One Labor Ward with minimum 3 beds One Post Partum Ward with minimum 4 beds
38,000 - 48,000		One Labor Ward with minimum 3 beds One Post Partum Ward with minimum 5 beds
>48,000		One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 6 beds
<72,000	District Hospital	One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 5 beds
72,000 - 80,000		One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 6 beds
>80,000		One Labor Ward with minimum 5 beds One Post Partum Ward with minimum 6 beds One Post C-Section Ward with minimum 7 beds
<72,000	County Hospital	One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 5 beds
72,000 - 79,999		One Labor Ward with minimum 5 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 6 beds
80,000 - 110,000		One Labor Ward with minimum 5 beds One Post Partum Ward with minimum 6 beds One Post C-Section Ward with minimum 7 beds
110,000 - 149,999		One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 7beds One Post C-Section Ward with minimum 9beds
150,000 - 249,999		One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 8beds One Post C-Section Ward with minimum 10 beds
>250,000		One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 10 beds One Post C-Section Ward with minimum 12 beds
all populations	National Referral Hospital	One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 10 beds One Post C-Section Ward with minimum 12 beds

14.5 Emergency

The size of emergency departments is contingent on both the catchment population and the number of medical professionals who treat emergency patients.

14.5.A. Emergency Rooms must have a minimum size as indicated in Table 14.m.

i. For details on major and minor bays, and isolation rooms, refer to Section 48.4.

Table 14.m. Emergency Room sizing

Program element	Minimum Space Required
Minor ER bays	72ft^2(6.7m^2) per treatment bay plus circulation
Major ER bays	128ft^2 (11.9m^2) per treatment bay plus circulation
Isolation rooms	76ft^2 (7m^2) per room plus exterior circulation
Circulation	30% of total area

14.5.B. The minimum number of Emergency Room bays must be determined by adjusted referral catchment population per Table 14.n.

i. Quantities in Table 14.n. must be checked against facility statistics and staff recommendations. The final number of delivery bays to be designed for must be approved by the assigned IU representative.

ii. Refer to Appendix T for the methodology calculation of ER bays.

Table 14.n. Minimum number of ER bays required per adjusted referral catchment population

Adjusted Referral Catchment Population	Facility Type	Minimum ER Bays Required
<30,000	Health Center	2
30,000 - 56,000		3
>56,000		4
all populations	District Hospital	4
>130,000	County Hospital	4
130,000 - 199,999		5
200,000 - 249,999		6
250,000 - 550,000		7
<550,000		8
all populations	National Referral Hospital	8

14.6 Inpatient Wards

14.6.A. Inpatient program spaces must align with minimum sizes in Table 14.o.

<u>Table 14.o.Minimum Internal Medicine Spatial Requirements per Unit</u>

Program	Minimum Space Required
Male and female inpatient wards	110ft^2 (10.2m^2) per bed
Pediatric inpatient wards	110ft^2 (10.2m^2) per bed
Isolation rooms	76ft^2(7m^2) per room

14.6.B. Total male, female, and pediatric and surgical inpatient wards must include a recommended minimum number of beds based on adjusted referral catchment population as designated in Table 14.p.

i. Quantities in Table 14.p must be checked against facility statistics and staff recommendations. Facility OICs have this data and must be consulted regarding typical patient volumes and lengths of stay. The final number of ward beds to be designed for must be approved by the assigned IU representative.

ii. It is advisable to provide more space in female and pediatric wards than in male wards, as female and pediatric patients tend to visit health facilities more frequently.

iii. Methodology for these calculations is outlined in Appendix T. Refer to it for greater details.

iv. For Maternity Wards, refer to Standard 14.4.E.

Table 14.p.Minimum Inpatient Bed Recommendations by Adjusted Referral Catchment Population

Adjusted Referral Catchment Population	Facility Type	Minimum Space Required
>30,000	Health Center[a]	One Men's Ward with minimum 3 beds One Women's Ward with minimum 3 beds One Pediatrics Ward with minimum 4 beds
30,000 - 47,999		One Men's Ward with minimum 4 beds One Women's Ward with minimum 4 beds One Pediatrics Ward with minimum 5 beds
48,000 - 56,000		One Men's Ward with minimum 4 beds One Women's Ward with minimum 5 beds One Pediatrics Ward with minimum 6 beds
>56,000		One Men's Ward with minimum 5 beds One Women's Ward with minimum 5 beds One Pediatrics Ward with minimum 7 beds
all populations	District Hospital	One Men's Ward with minimum 5 beds One Women's Ward with minimum 6 beds One Pediatrics Ward with minimum 7 beds
<80,000	County Hospital	One Men's Ward with minimum 6 beds One Women's Ward with minimum 6 beds One Pediatrics Ward with minimum 8 beds One Surgical Ward with minimum 3 beds
80,000 - 110,000		One Men's Ward with minimum 7beds One Women's Ward with minimum 8 beds One Pediatrics Ward with minimum 9 beds One Surgical Ward with minimum 4 beds
110,000 - 149,999		One Men's Ward with minimum 9 beds One Women's Ward with minimum 10 beds One Pediatrics Ward with minimum 12 beds One Surgical Ward with minimum 5 beds
>150,000		One Men's Ward with minimum 12 beds One Women's Ward with minimum 14 beds One Pediatrics Ward with minimum 16 beds One Surgical Ward with minimum 6 beds
all populations	Regional/National Referral Hospital	One Men's Ward with minimum 20 beds One Women's Ward with minimum 23 beds One Pediatrics Ward with minimum 27 beds One Surgical Ward with minimum 10 beds

[a] *In Health Centers, inpatient wards may be separated by curtains or partitions and do not necessarily need to be independent rooms*

[b] *In Hospitals, Men's and Women's Wards comprise the Medical Ward. The Surgical Ward would have separate spaces for men and women patients.*

14.7 Intensive Care Unit (ICU) & Neonatal Intensive Care Unit (NICU)

14.7.A. ICU rooms must be a minimum size of $76ft^2$ ($7m^2$) per room.

14.7.B. The quantity of ICU rooms must be determined in conjunction with facility staff, MOHSW planning, and approved by the assigned IU representative.

14.7.C. A Neonatal Intensive Care Unit (NICU) must be present in Hospitals. Rooms must be a minimum size of $53ft^2$ ($4.9m^2$) per equipment station.

i. Equipment stations may include placement of incubators, warming tables, or infant resuscitation tables.

14.7.D. At Hospitals, Neonatal Intensive Care Unit (NICU) rooms must be designed for the minimum number of equipment stations shown in Table 14.q.

i. Quantities in Table 14.t. must be checked against facility statistics, staff recommendations, and planned equipment. The final number of ward beds to be designed for must be approved by the assigned IU representative.

Table 14.q.Minimum Number of NICU Equipment Stations

Facility type	Number of equipment stations
District Hospital	2
County Hospital	4
Regional Referral Hospital	6

14.7.E. Proximity of the ICU and NICU to a staff lounge is recommended

14.8 Surgery

Spatial requirements for operating departments are determined based on the need to treat and move patients through efficiently and to maintain sterile conditions. Refer to Chapter 49 for specific sequencing and requirements.

14.8.A. At minimum, Surgery department program spaces must meet the sizes indicated in Table 14.r.

i. For Surgery departments in Health Centers, only a Scrub Room, Clean Material Storage, and Operating Room must be included.

Table 14.r. Minimum Surgery Department Program Spatial Requirements

Program	Minimum Space Required
Pre-Operating Room	$70ft^2$($6.5m^2$) per gurney plus $60ft^2$($5.5m^2$) Nursing Station
Clean Material Storage	$70ft^2$ ($6.5m^2$)
Patient Transit Room	$48ft^2$ ($5.5m^2$) per room
Scrub Room	$48ft^2$ ($5.5m^2$) per room
Operating Room	$360ft^2$($33.4m^2$) per room
Clean Material Storage	$10ft^2$ ($0.9m^2$) for Health Centers (if included) $100ft^2$ ($9.2m^2$) for Hospitals
Dirty Linens / Sluice Room	$50ft^2$ ($4.6m^2$) per room
PACU	$120ft^2$($11.1m^2$) per bed plus $60ft^2$ ($5.5m^2$) Nursing Station

14.8.B. Health Centers and Hospitals must be designed with the minimum number of Operating Rooms as designated in Table 14.s.

i. Quantities in Table 14.s must be checked against facility statistics and staff recommendations. The final number of Operating Rooms to be designed for must be approved by the assigned IU representative.

Table 14.sMinimum Number of Operating Rooms by Facility Type

Facility type	Number of Operating Rooms
Health Center	1 (optional; if needs permit)
District Hospital	1
County Hospital	2
Regional Referral Hospital	3

14.8.C. Space for two beds per operating room must be provided in the Post-Anesthesia Care Unit.

14.9 Diagnostics and Clinical Support

Providing sufficient space for clinical support activities ensures that procedures can be followed correctly and that staff can work efficiently and safely.

14.9.A. A Drug Dispensary must be provided at sizes based on adjusted primary catchment population for PHC facilities, and adjusted referral catchment population for Health Centers and Hospitals as indicated in Table 14.t. In Health Centers and Hospitals, the Dispensary must be connected to a Pharmacy Stock room for storage.

i. Sizes in Table 14.t. must be checked against facility needs. The final sizes to be designed for must be approved by the assigned IU representative.
ii. Dispensaries must include space for a pharmacist to work and storage for the full volume of drugs required by PHC clinics at any given time.
iii. Dispensaries and Pharmacy Stock rooms in PHC facilities may be part of the same room.

Table 14.t. Minimum Dispensary and Pharmacy Stock Size Requirements

Adjusted Primary Catchment Population	Facility Type	Minimum Space Required
<4,200	PHC 1	One room at 80ft^2 (7.4m^2); or combined with Registration & Records
4,200- 7,999	PHC 2	One room at 120ft^2 (11.1m^2)
8,000 - 16,799		One room at 150ft^2 (11.2m^2)
>16,800		One Dispensary booth at 80ft^2 (7.4m^2) One Pharmacy Stock room at 100ft^2 (9.3m^2)
Adjusted Referral Catchment Population	**Facility Type**	**Minimum Space Required**
>30,000	Health Center	One Dispensary booth at 80ft^2 (7.5m^2) One Pharmacy Stock room at 120ft^2 (11.2m^2)
30,000 - 52,000		One Dispensary booth at 80ft^2 (7.5m^2) One Pharmacy Stock room at 150ft^2 (13.9m^2)
>52,000		One Dispensary booth at 80ft^2 (7.5m^2) One Pharmacy Stock room at 180ft^2 (16.7m^2)
<52,000	District Hospital	One Dispensary booth at 100ft^2 (9.3m^2) One Pharmacy Stock room at 180ft^2 (11.2m^2)
>52,000		One Dispensary booth at 100ft^2 (9.3m^2) One Pharmacy Stock room at 220ft^2 (20.4m^2)
<72,000	County Hospital	One Dispensary booth at 100ft^2 (9.3m^2) One Pharmacy Stock room at 250ft^2 (23.2m^2)
72,000 - 149,999		One Dispensary booth at 120ft^2 (11.1m^2) One Pharmacy Stock room at 300ft^2 (27.9m^2)
150,000 - 550,000		One Dispensary booth at 150ft^2 (9.3m^2) One Pharmacy Stock room at 400ft^2 (37.2m^2)
<550,000		One Dispensary booth at 150ft^2 (9.3m^2) One Pharmacy Stock room at 500ft^2 (46.5m^2)
all populations	National Referral Hospital	One Dispensary booth at 150ft^2 (9.3m^2) One Pharmacy Stock room at 600ft^2 (55.7m^2)

14.9.B. **At minimum, diagnostic and clinical support program spaces must meet sizes in Table 14.u.**

i. Sizes in Table 14.u. must be checked against facility statistics, needs, and staff recommendations. The final size of clinical support program must be approved by the assigned IU representative.

Table 14.u. Diagnostic and Clinical Support Program Spatial Requirements

Program Element	Minimum Space Required
Laboratory	$90ft^2$ ($8.3m^2$) plus $45ft^2$ ($4.2m^2$) per expected lab employee at a time
Radiology Exposure room	$220ft^2$ ($20.4m^2$) per equipment room[2]
Radiology Office/Consult	$100ft^2$ ($9.2m^2$) per room
Radiology Darkroom	$65ft^2$ ($6.0m^2$)
Radiology and Advanced Imaging Diagnostics Changing Room	$65ft^2$ ($6.0m^2$) per room; One room for each Exposure or Advanced Equipment Room
Advanced Imaging Equipment Rooms (CT scan, MRI)	$540ft^2$ ($50.2m^2$) per room[3]
Radiology and Advanced Imaging Diagnostics Storage	$5ft^2$ ($0.5m^2$) per Exposure Room or Advanced Equipment Room

14.9.C. **Laboratories must accommodate work for inpatient and outpatient services and anticipate a workload that can double within 5-8 years.**[4]

14.9.D. **Sterilization rooms must meet minimum sizes by facility type as shown in Table 14.v.**

i. Sizes in Table 14.v. must be checked against facility statistics, needs, and staff recommendations. The final size of Sterilization rooms must be approved by the assigned IU representative.

Table 14.v. Diagnostic and Clinical Support Program Spatial Requirements

Facility Type	Minimum Size of Sterilization
District Hospital	$90ft^2$ ($8.3m^2$)
County Hospital	$110ft^2$ ($10.2m^2$)
Regional Referral Hospital	$165ft^2$ ($15.3m^2$)

14.10 Staff Areas

Staff areas provide places of respite and locations for medical professionals to complete and store administrative work. Staff offices and meeting rooms should be designed to aid clinical work without interference from patient movement; Nursing Stations should be designed to enable patient oversight.

14.10.A. **Minimum staff program spaces must meet sizes in Table 14.w.**

i. Sizes in Table 14.w. must be checked against current and planned facility staffing requirements, staff-to-patient ratios, and staff recommendations. The final size of staff areas must be approved by the assigned IU representative.

Table 14.w. Staff Area Program Spatial Requirements

Program	Minimum Space Required
Nurses' stations	60ft^2 (5.5m^2) per Nursing Station
Staff offices	100ft^2 (9.3m^2) per office
Meeting and Training rooms	200ft^2 (18.5m^2) per room

14.10.B. In Health Centers and Hospitals, at least one nurses' station must be provided for every 40 inpatient ward beds, and an additional station must be provided in the Emergency Room.

14.10.C. Staff offices and meeting rooms must accommodate full-time staff and community health workers.

i. In PHC 2 clinics, at least one office for the OIC and other full-time staff must be provided.
ii. In Health Centers and Hospitals, at least one meeting room, one private office for the OIC, and additional staff offices for each department head must be provided.

14.11 Non-clinical Support

Supporting functions need to be sized to accommodate the number of patients served by facilities on a regular basis.

14.11.A. Minimum non-clinical support program spaces must meet sizes in Table 14.x.

Table 14.x . Non-clinical Support Program Spatial Requirements

Program	Minimum Space Required
Sanitary Spaces	35ft^2 (3.3m^2) per toilet plus 18ft^2 (1.7m^2) per shower
Laundry	None for PHC facilities(sheltered space for patient attendants is recommended); For Health Centers area with sink of 25ft^2 (2.3m^2); For Hospitals 100ft^2 (9.2m^2) or 1.5ft^2 (0.14m^2) per inpatient bed, whichever is greater.
Kitchen	None for PHC facilities or Health Centers (sheltered space for patient attendants is recommended); For Hospitals 100ft^2 (9.2m^2) or 1.5ft^2 (0.14m^2) per inpatient bed, whichever is greater.
Storage	51% of total facility size
Equipment and Communications rooms	To be determined with equipment specs
Morgue	None for PHC facilities or Health Centers; For Hospitals 90ft^2 (8.4m^2) plus85ft^2 (7.9m^2) per stack of refrigerators.

14.11.B. Minimum number of toilets must be provided in each facility according to requirements in Table 14.y.

Table14.y.Minimum Number of Toilets for each Facility Type

Facility Type	PHC 1	PHC 2	Health Centers	Hospitals
Entry / Reception & General Public	Shared with OPD	Shared with OPD	1 Men's 1 Women's	1 Men's 1 Women's per 1,000 ft^2 of waiting area [minimum of 1 each]
OPD	1 Men's 1 Women's	1 Men's; 1 Women's	1 Men's 1 Women's	1 Men's 1 Women's per 5 consult rooms
MCH	Shared with OPD	1 Women's	1 Women's per 5 Labor ward beds	1 Women's per 5 Labor ward beds
ER	N/A	N/A	1 Men's + 1 Women's per 5 bays	1 Men's + 1 Women's per 5 bays; 1 Men's 1 Women's for staff
Inpatient Wards	N/A	N/A	1 per 5 beds	1 per 5 beds
ICU	N/A	N/A	1 per 2 beds	1 per 2 beds; 1 Men's 1 Women's for staff
NICU	N/A	N/A	N/A	none
Surgery	N/A	N/A	none	1 Men's 1 Women's for staff
Diagnostics & Clinical Support	N/A	N/A	none	1 Men's 1 Women's for staff
Staff Areas	none	1 for all staff	1 Men's 1 Women's	1 per 50 expected employees

PATIENT CENTRICITY

CONTENTS

IMPACT

Patient-centric design considers how the health care environment contributes to the physical and psychological well-being of the patient. All design decisions should prioritize the patient experience when not in conflict with the delivery of care. Consideration must be given to cultural, religious, and gender preferences, as well as general privacy. Accessibility - allowing universal access for the handicapped and children - is essential, as well as making graphic provisions to increase legibility and function. Behind each of these considerations is a universal standard of safety. Encouraging people to visit facilities for healing, childbirth, and preventative care becomes much simpler when patients can be assured that they will be treated with dignity and respect.

PRIMARY USERS

Infrastructure Unit

County Health & Social Welfare Teams

Facility Staff

Architects & Designers

GUIDELINES FOR USE

These Chapters present both conceptual level criteria for patient centric design and design details for equal access and patient dignity. Users may move back and forth between large-scale thinking and specific design details to ensure an accessible and safe facility.

15 User Preferences

Health facilities are more than sites for patients to receive care; they are also their temporary homes. Studies suggest that a patient's perception of his or her environment has an effect on health outcomes. As a result, designs prioritizing infection control and environmental quality must take patient dignity and comfort into consideration.

15.1 Privacy

Privacy communicates respect for patients, enabling a positive experience and increases trust in healthcare professionals. At the same time, patient privacy needs to be balanced with staff oversight to avoid impeding care.

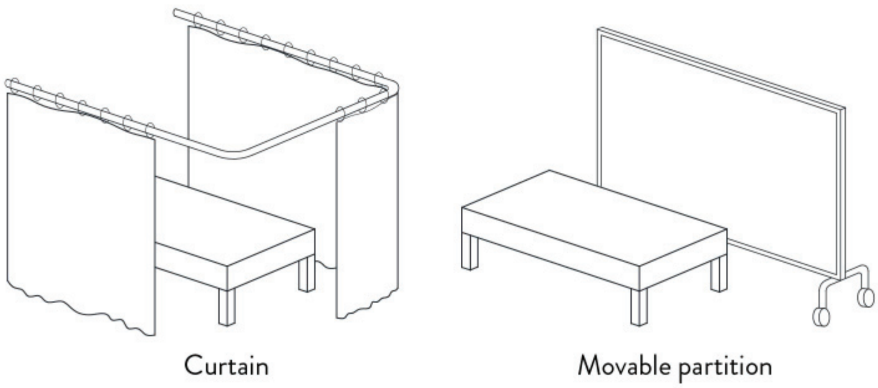
15.1.A. Facilities must include spatial provisions for privacy for patients seeking consultation or treatment for stigmatized conditions and diseases.

i. When space allows, provide separate, discreetly marked rooms for patients receiving screening or treatment for HIV/AIDS, STDs, GBV, or other stigmatized conditions.
ii. Consider separate entrances for patients receiving treatment for stigmatized conditions, as long as it does not conflict with the security or staff oversight of the facility.

15.1.B. Facilities must include spatial provisions for privacy for patients undergoing sensitive treatment.

i. Place programs requiring patient privacy (e.g. labor and delivery, inpatient wards) away from main circulation routes and public areas. Refer to Chapter 12 for more details on program adjacencies.
ii. Move hospice patients to secluded wards to provide them and their visitors with a quiet environment during their final days.
iii. Provide privacy screens or movable curtains to visually separate patients undergoing treatment in the same room. This should only be done if the visual obstructions will not impede airflow or staff oversight.

Figure 15.a Privacy Screens



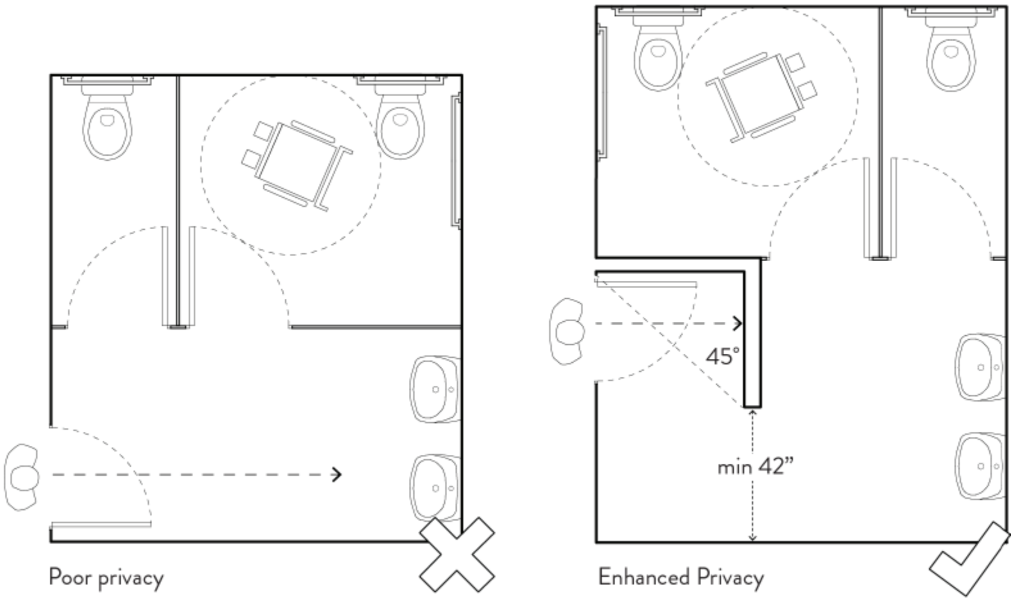
15.1.C. Restrooms must be placed to allow patients with discomfort and sensitive conditions access without passing through public areas.

i. Pregnant women in labor rooms must have direct access to a restroom without needing to pass through public areas.
ii. Inpatients must have access to a restroom without having to leave the general ward.
iii. Restrooms must be designed for single occupancy or have individual stalls.
iv. Appropriate doors and windows must be selected for bathrooms that ensure privacy while still allowing ventilation. Refer to Standard 15.1.D.

15.1.D. **Doors to common sanitary facilities must be positioned so as not to provide a direct view into the room when opened.**

i. Common sanitary facilities include those that may be used by one or more person at the same time. Patient and user privacy must be ensured through door placement.

Figure 15.b. Door Placement to Common Sanitary Facilities



15.1.E. **Windows must be designed with privacy in mind.**

i. Certain spaces will require special consideration, such as bathrooms and operating rooms. When selecting and placing windows in such spaces, the desire for natural daylight must be balanced with provisions for privacy. Options include opaque glass, higher window placement, and operable blinds.

15.2 Access to Views

Providing views of trees and plants enables building occupants to maintain a visual connection to the outdoors. If increasing building window area, however, consider the effects on cooling and solar gains.

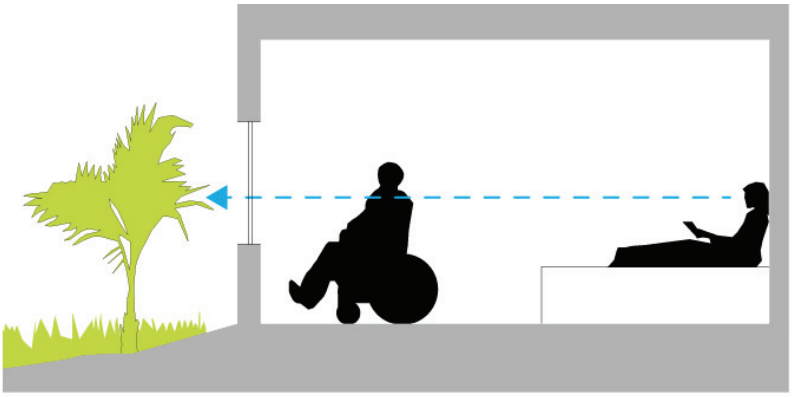
15.2.A. **Views to nature must be available in all inpatient wards, waiting areas, and offices.**

15.2.B. **In ward spaces, windowsills should be low enough for someone lying down in bed to see outside.**

15.2.C. **In all waiting areas, corridors, and therapy spaces, windows should be low enough for children and the disabled to gain access to views.**

15.2.D. Where privacy is an issue, landscaping and site orientation can be used to maintain views while protecting the privacy of the patient.

Figure 15.c. Access to Views



16 Accessibility

Mobility limitations affect a variety of patients, including children, pregnant women, the elderly, and handicapped individuals. Providing access for mobility-impaired patients can also greatly benefit fully mobile patients. Buildings and sites need to be designed so that all patients can move around safely and share access to medical services.

16.1 Spatial Layout

Program adjacencies and circulation patterns should be designed with optimized travel paths for the mobility-impaired in mind.

16.1.A. **Building layouts must be designed to minimize distances between functions regularly used by the mobility impaired.**

i. Programs must be designed in a logical flow from entry to treatment areas to wards to reduce distances that people need to travel at any one time. Refer to Chapter 13 for details on circulation and occupant flow.
ii. Patients must not travel more than 100ft (30m) from their bed to reach a lavatory.
iii. Patients must not have to move from one department (i.e. Maternity) to another (i.e. Neonatal Care Unit (NICU)) to access a lavatory.
iv. Patients must not have to travel up or down stairs to access a lavatory. If a change in elevation is required, it must be traversed by means of a ramp. (See Section 16.2.C on ramps)

16.1.B. **Building layouts must be designed to minimize exposure to the elements for the mobility-impaired in order to reduce the risk of slipping.**

i. Patients must not have to travel through uncovered outdoor areas that may be uneven or wet to reach restrooms or treatment areas.
ii. Assuming proper ventilation can be achieved; toilets must be placed inside or close to buildings to be accessible to mobility-impaired patients.

16.2 Design Details

Thoughtful design of circulation routes, surfaces, furniture, and fixtures can increase safety, accessibility, and improve patient comfort.

16.2.A. **All occupiable spaces must include a clear space of at least 5ft (150cm) in diameter for the turning of a wheelchair, and must include clear spaces for linear circulation of at least 3ft (90cm).**

i. For toilets, training rooms, and meeting halls at least 1 accessible stall or seat with this access must be included for every 50 occupants, but not less than 1 total.
ii. Expected occupancy must be calculated according to Section 18.2.

16.2.B. **All corridors must be at minimum 5ft (150cm) wide. Any corridor with expected gurney traffic must be at minimum 6ft (180cm) wide.**

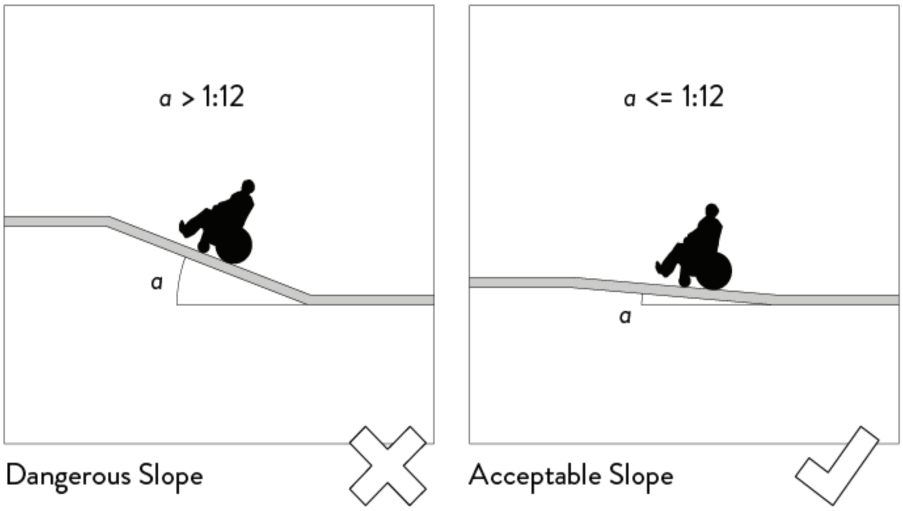
16.2.C. **Walkway or corridor corners must be a minimum of 6ft (180cm) wide to facilitate the turning of wheelchairs, gurneys, and wheeled equipment.**

16.2.D. **Ramps must be provided between all changes in floor levels.**

16.2.E. **Ramps must have a slope not exceeding 1:12 rise to run.**

i. Exterior walkways must be designed to be as level as possible, never to exceed a 12% slope, and with a 1-2% cross slope for drainage.
ii. Exterior walkways must be designed to follow natural site topography to prevent the need for significant site grading.

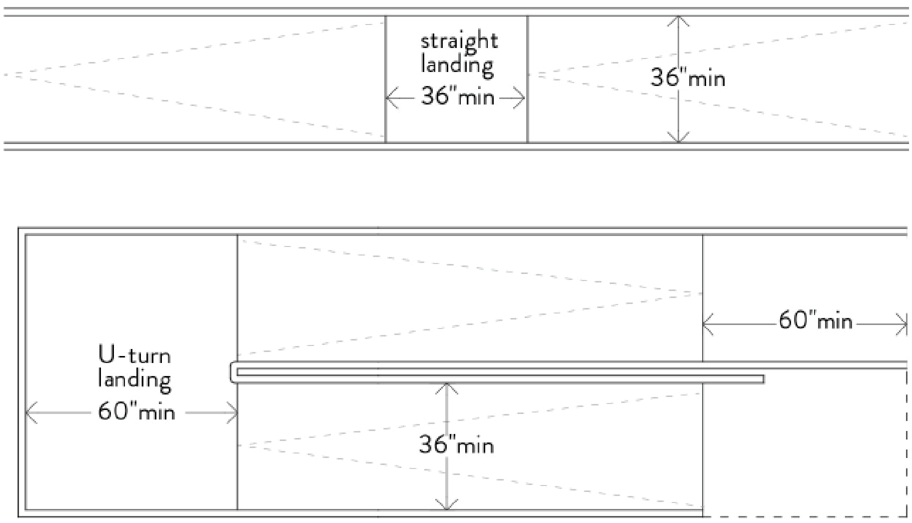
Figure 16.a. Acceptable and Unacceptable Ramp Slopes



16.2.F. **Ramps must have flat landings for every 40in (100cm) of vertical rise, and must not contain steps or stairs along the path of the ramp.**

i. Landings must be at least 36in (90cm) in length on straight runs.
ii. Landings must be at least 60in (152cm) in length where ramps turn.

Figure 16.b. Ramp Requirements

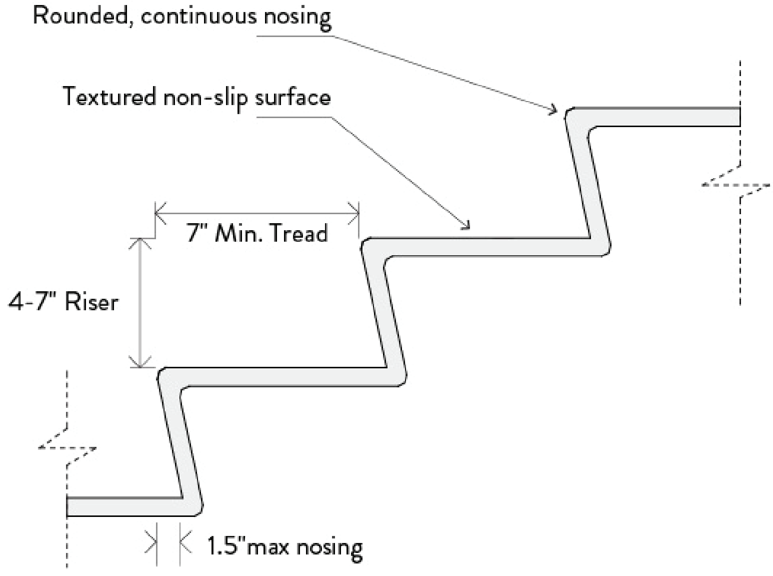


16.2.G. **Stairs must be at least 3ft (90cm) wide.**

16.2.H. **Stairs must be constructed with minimum riser heights at 4in (10cm); maximum riser heights at 7in (18cm), and a riser/tread ratio of 17:29 to allow safe movement for most users. The height of all risers must be identical from the bottom to the top of each staircase.**

i. Because heights above 7in (18 cm) become difficult for less agile users, the required number of stairs to ascend a particular height change must be calculated accordingly and an appropriate horizontal distance should be designed to achieve them.

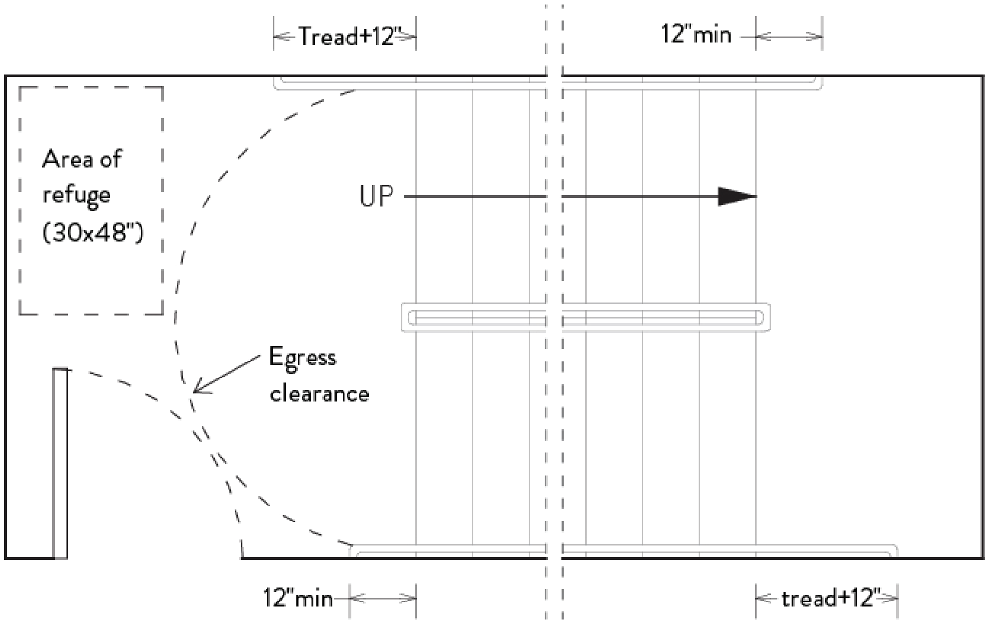
Figure 16.c. Stair Requirements



16.2.l. Stairs must be provided with landings for every 12ft (365cm) of vertical rise at minimum.[1]

i. The width of the landing must not be less than the width of the stair.
ii. The length of the landing must be at least the width of the stair but not to exceed 48in.
iii. When a doorway is provided onto the landing, the door swing shall not restrict the clear width by more than one half.

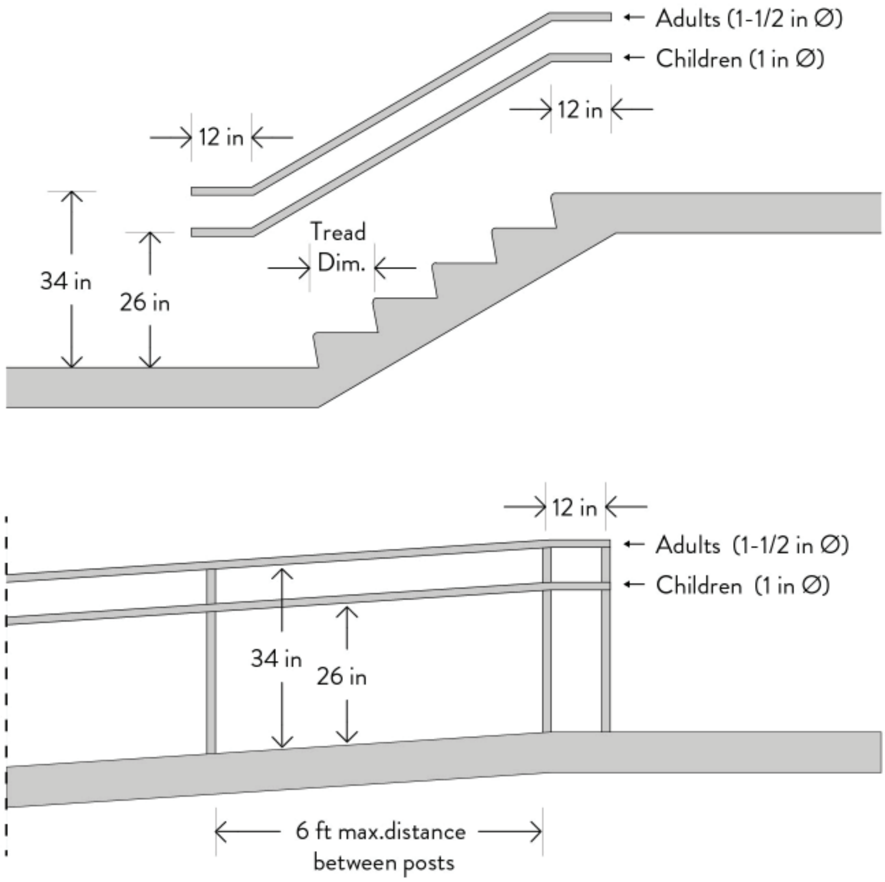
Figure 16.d. Stair Landing & Refuge Area



16.2.J. **Handrails must be installed that are accessible to both adults and children. As such, two handrails must be used at all level changes greater than 5in, including ramps and stairs. Such rails must be provided on both sides of ramps and stairs. (See Figure 16.e.)**

i. The height of the two handrails must be 26in (66cm) and 34in (86cm) from the level of the floor, ramp, or stair tread. The handrails must be circular in profile and have an outside diameter of 1in and $1^1/_2$in respectively.
ii. Handrails must allow at least $1^1/_2$in (4cm) clearance from the inside of the rail to the wall.
iii. Placement of handrails must not block other circulation routes or entrances.
iv. All handrails must be free from sharp edges.
v. Railings must continue horizontally for a minimum of 12in (30cm) beyond the top and bottom of the level changes to provide mobility assistance at each end of the level change.
vi. At the bottom of stairs, the railing must continue to slope for the depth of one tread beyond the bottom riser.
vii. Railing supports must not impede the movement of the hand along the rail. Recommended supports are those situated at the bottom of the railing and away from the side of the user.

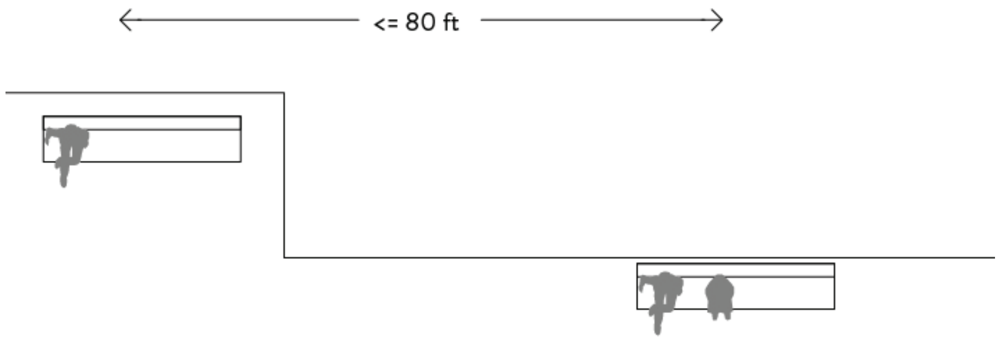
Figure 16.e. Railing Requirements



16.2.K. **Fixtures and furniture that ease patient movement must be provided.**

i. Distances between seating areas in corridors must not exceed 80ft (24.4m).

Figure 16.f. Seating Frequency in Circulation



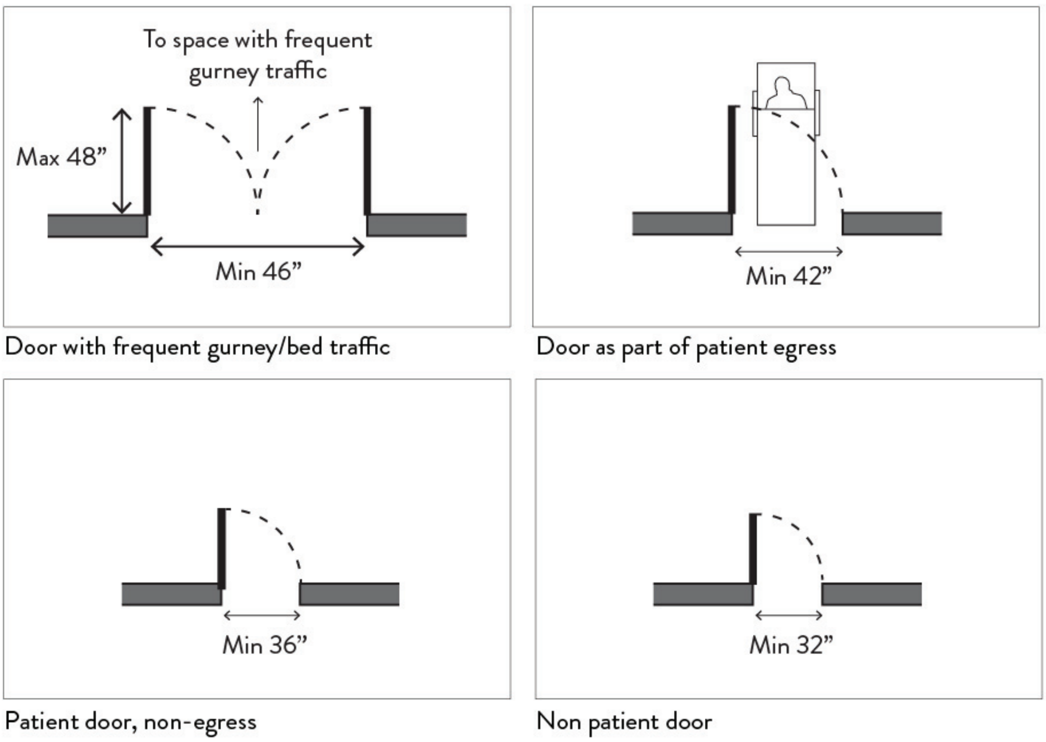
16.2.L. Fixture selection and placement must maximize patient accessibility and autonomy.

i. Sinks, light switches, and other essential operational fixtures must be placed within reach of children and patients in wheelchairs.
ii. Sinks in pediatric wards must be lower and shallower than those in adult wards.

16.2.M. Door openings must be sized to maximize accessibility and ease of passage.

i. Door openings to rooms in which gurneys and equipment are regularly wheeled in/out must be at least 46in(116cm) wide (not including door frames) to accommodate beds and equipment without the risk of damaging the equipment or the doors. This is especially important for surgical and maternity spaces.
ii. Doors to all major public or patient access spaces must be at 36in (90cm) or greater.
iii. All other doors must be at 32in (80cm) or greater for normal access.
iv. The maximum width of any single door leaf must not be greater than 46in (116cm).
v. Doors must be at least 80in (200cm) in height.
vi. See Section 45.2 for additional door standards.

Figure 16.g. Door Widths



17 Wayfinding

A clear wayfinding or signage system in a healthcare facility represents a transparent and approachable administrative structure. The more nebulous and difficult the circulation of a medical facility is, the more likely the patient's medical experience is to be frustrating and even ineffective. By making visible the pathways to available services, signage systems are an opportunity for not only guidance but also improved care.

Literacy rates and language differences significantly affect the way patients and families are able to navigate healthcare services. Patients and visitors who cannot read or speak English need to be able to find their way around the facility and understand the services provided to them. Well-designed and strategically placed signage and wayfinding components minimize confusion, reduce the risk of unsafe behavior, and promote patient dignity.

17.1 Signage Strategies

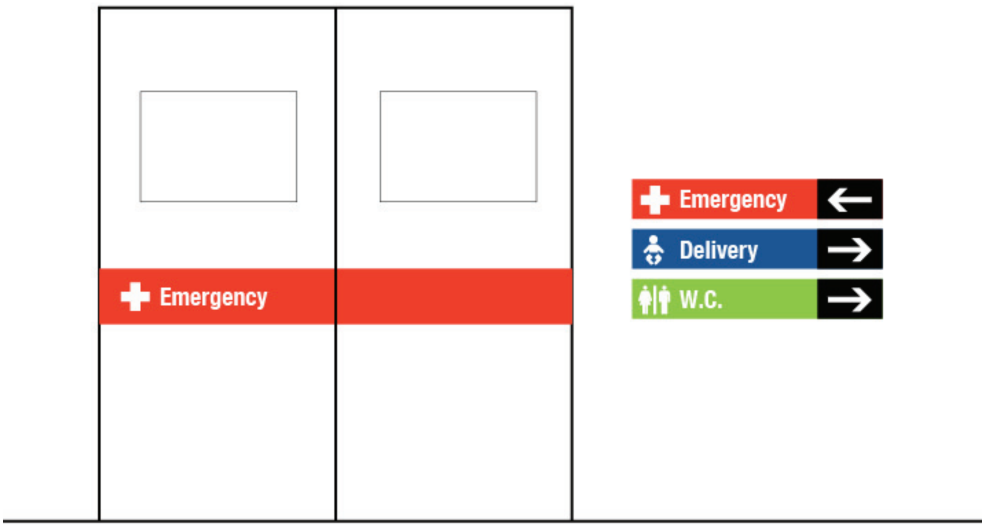
The design of signage impacts its effectiveness: graphic techniques that are understood by a wide variety of people maximize the likelihood that signs will serve their intended purposes. The level of language comprehension should inform the design of signage and wayfinding. In areas with high illiteracy rates, graphic communication techniques such as icons or color-coding may be useful alternatives to text-based communication.

17.1.A. Signage and communication methods must be accessible to all patients and visitors regardless of literacy levels and language spoken.

i. In addition to text, signage must utilize graphic techniques to accommodate patients unable to read. Examples include icons, images, or color-coding.

ii. Visual hierarchy must be taken into consideration. The most important messages on signs should be the clearest; signs or sign-posting areas should not be cluttered with outdated or less relevant information.

<u>Figure 17.a. Example Sign Illustrating Use of Graphics to Guide Patients</u>



17.1.B. A hierarchy of graphic materials, signage, paint and color must be maintained.

i. Room labels and other signage must be consistently positioned where they are used throughout the facility (i.e. always label rooms above the door, always place directional signage at eye-level) so that they are easy to locate.

ii. Signage must be positioned so as to be legible based upon the sightlines of both children and adults.

iii. Signage and wall postings must not graphically overwhelm patients: Directional signage should be prominently placed and large, while room labels should be smaller and visible at a close distance. Public service announcements and other posters should be concentrated in waiting areas where they are visible but not distracting to the public.

Figure 17.b. Icons for various medical services

17.2 Signage Types

Three primary types of signage ease the movement of patients and visitors to and throughout facilities and minimize patient entry in restricted or private areas.

17.2.A. Building signage must be placed at building entrances and circulation junctures.

i. The name of the facility and its hours must be marked on or near the exterior of the building.
ii. Each wing within the facility must be marked near its entrance.

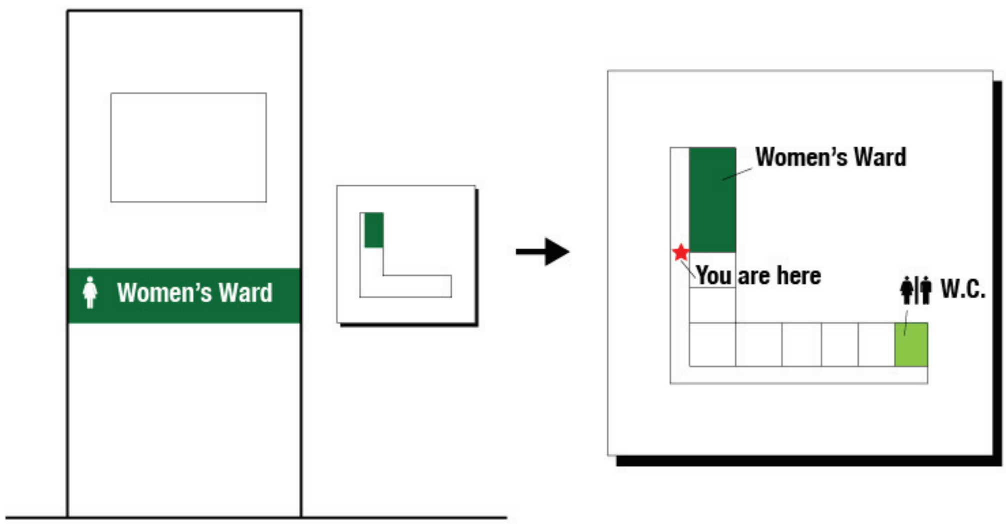
17.2.B. Directional signage must be placed at the entrance to the site, at road junctures leading up to the site, and throughout the facility.

i. Pathways to the facility's public entrance must be clear from the site's primary access point.
ii. Direct routes to emergency treatment areas must be noted separately from other primary signage.
iii. Interior facility routes, or outdoor routes between buildings within the facility must have pathways marked.

17.2.C. Departments and rooms must be labeled with names, access information, and logical numbers (in facilities where numbering systems are used).

i. When abbreviations are used, use a distinct prefix for rooms in different departments (e.g., outpatient rooms may be numbered OP1, OP2, OP3, etc.).
ii. Restricted access rooms or departments must be clearly marked as such to deter patients and visitors from entering without permission.
iii. Where rooms are numbered within a department, order the numbers consecutively.

Figure 17.c. Diagram of Facility Map



18 Safety

Theft, vandalism, and fire are among the risks faced by health facilities. Protecting patients, visitors, staff, equipment and medicines is a central concern. Safe facilities not only reassure patients and staff, but also reduce costs associated with fixing or replacing damaged or stolen equipment. Additionally, secure storage of medicines may prevent theft and the health repercussions of misuse and abuse.

18.1 Security

Security measures are necessary to prevent theft and vandalism. Physical measures primarily include provision of locks, fencing, and security lights.

18.1.A. Site and building entrances must be in locations visible to security and staff oversight so that they can be monitored easily.

i. The reception area must be oriented to overlook entrances and waiting areas, enabling staff members to watch public activity during hours of operation.

18.1.B. Dark or secluded public areas must be minimized through the use of lighting and site and building design.

i. Sites and buildings must be designed so that public areas are open, have clear sight lines, and are easily monitored at all times.
ii. Security lighting must be placed to illuminate otherwise dark corners, corridors, or other areas to deter undesirable activity.

18.1.C. Facilities must include secure storage for valuable equipment and supplies.

i. Designated storage should include security bars and/or door locks to restrict access.
ii. Medicines, generators, PV panels, and other equipment and supplies that may attract theft or vandalism should be secured as well as possible.

18.2 Fire Safety

Routine fire prevention and response features are an essential part of design best practices. Facilities all need to comply with national fire codes in addition to the standards below.

18.2.A. Expected occupancy must be calculated according to Table 18.a.

Table 18.a. Expected Occupancy Rates by Room Size

Type of Space	Occupancy Rate
Waiting Areas	1 per 7ft^2 (0.6m^2)
Lecture Halls / Training Rooms	1 per 7ft^2 (0.6m^2)
Conference Rooms / Offices	1 per 20ft^2 (1.8m^2)
Nursing Stations	1 per 20ft^2 (1.8m^2)
Consultation Rooms	1 per 50ft^2 (4.6m^2)
Physiotherapy Rooms	1 per 50ft^2 (4.6m^2)
Wards and Short Stay Rooms	1 per 80ft^2 (7.4m^2)
Radiology	1 per 100ft^2 (9.3m^2)
Storage Areas	1 per 200ft^2(18.6m^2)
All other spaces not listed	1 per 100ft^2 (9.3m^2)

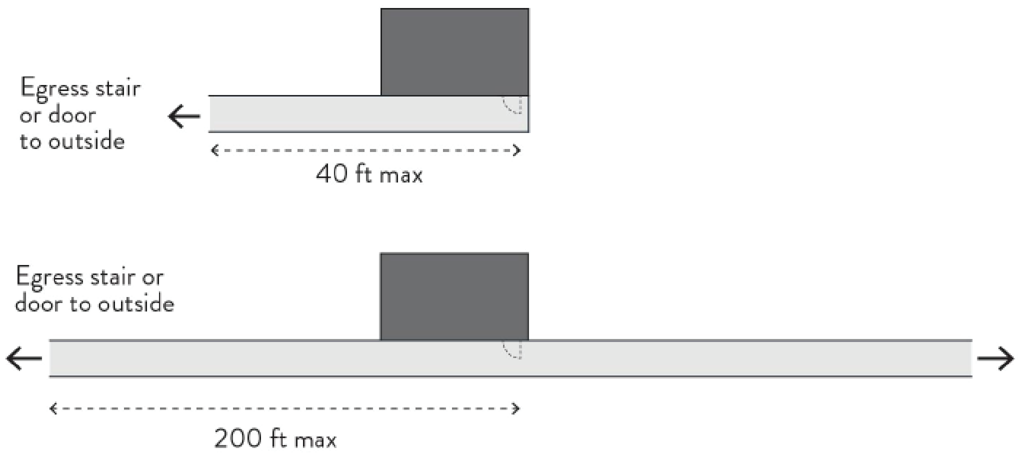
18.2.B. Directional exit placards must be posted in any non-exterior corridor or circulation space, or in any space with an expected occupancy of greater than 50 people at a time, indicating the direction to the nearest 1or 2 exits to an unenclosed exterior area.

i. Directional exits placards must be consistent with international standards with a green background, white 'running man' icon, and a white arrow indicating the direction(s) of exit(s).
ii. Placards must be hung between 6ft 8in (200cm) and 10ft (300cm) above the floor.
iii. At exit doors a directional arrow is not needed.

Egress (Exit) Paths
An egress path is defined as a continuous, unobstructed way of egress travel from any accessible point in a building or facility to a public way eventually leading to the exterior of the building.

18.2.C. **All spaces must have access open to an egress path either less than 40ft (12m) from an egress stair or door to the exterior, or have more than 1 egress path, with the shortest exit stair or door not more than 200ft (60m) away. Spaces with an expected occupancy of 200 or more must have 2 direct means of egress to the exterior.**

Figure 18.a. Access to Egress Paths



18.2.D. **Egress paths must be of a width as calculated by the expected occupancy of all rooms conjoining it according to Table 18.b, and must not have any permanent or semi-permanent obstructions or furnishings, including doors when swung open, protruding into the width indicated in Table 18.b.**

i. Ceilings in an egress path must be at least 7ft 6in (2.3m) high.
ii. When calculating the occupancy load of an egress path, it must also include the occupancy load of all tributary egress paths in addition to its own occupancy load.
iii. To count as an egress stair, stairways must meet the requirements in standards 18.2.E. and 18.2.F. Other stairways may not be used for compliance with this standard.
iv. Elevators do not count as egress stairs or part of an egress path.
v. Rooms within a sterile sequence, such as Operating Rooms and Neonatal Care Unit (NICU) are exempt from this requirement.

Table 18.b. Width of Egress Paths by Expected Occupancy of Conjoined Rooms

Occupancy Load of All Conjoined Rooms	Minimum Width
0-50	4 ft (1.2m)
50-100	6 ft (1.8m)
100-200	7ft (2.1m)
200-300	8ft (2.4m)
300-400	9ft (2.7m)
400-500	10ft (3.0m)
500 or greater	12ft (3.6m)

18.2.E. Egress stairs must be at least 36in (90cm) wide or $^{3}/_{5}$ the width of the egress path as determined by Standard 18.2.C, whichever is greater.

18.2.F. Egress stairs more than 2 stories in height must be fully enclosed in brick or concrete walls, with openings or windows only to the exterior. Exit stairs must have a landing at any point a minimum of 5ft (1.5m) wide before the beginning of any stair up or down.

i. Egress stairs must either lead directly to the building exterior or to a semi-exterior space within the building with immediate access to a non-enclosed exterior area.

18.2.G. Interior doors along an egress path must be at least 32in (82cm) wide from hinge to frame and must swing out in the direction of the path to the exterior. Exterior egress doors must be a minimum 36in (90cm) wide. Door frames and doors accessing egress stairs must be made of metal and be equipped with an automatic door closer.

i. All doors in rooms with an expected occupancy greater than 50 must also swing out in the direction of the path to the exterior.

18.2.H. Door sizes must meet requirements listed in Standard 16.2.Mor be at least 60in (150cm) wide if the room's expected occupancy is greater than 150, whichever is greater.

18.2.I. Carbon dioxide or chemical fire extinguishers with a minimum capacity of 1gallon (3.8L) must be mounted in unlockable, easily accessible areas at a minimum rate of 1 extinguisher per 4,000ft^2 (370m^2), or at the rate of 1 for level 1 Primary Health Clinics; 2 for level 2 Primary Health Clinics; and 3 for Health Clinics, whichever is greater.

i. At least one fire extinguisher must be mounted on every floor of the building.
ii. A fire extinguisher must be mounted within 15ft (4.5m) of any oxygen system manifolds or cylinder storage areas and/or electrical generators.
iii. A fire extinguisher must be mounted inside or within 15ft (4.5m) of any nursing station servicing a ward of 4 beds or more.
iv. A fire extinguisher must be mounted in any room with an expected occupancy of greater than 200 people, including waiting areas.
v. A fire extinguisher must be provided for an oxygen generation plant.
vi. Fire hoses may be substituted for extinguishers provided that the supply systems meet the requirements of Standard 27.9.D. If all criteria are met, hoses may be installed at a rate of 8,000ft^2 (740m^2) per hose.

18.2.J. An evacuation plan illustrating routes of travel along egress paths must be permanently posted in all waiting areas, wards, and any spaces with an expected occupancy greater than 200.

18.2.K. An exterior assembly point for building occupants in case of fire must be identified and signposted at least 150ft (45m) from the building. The assembly point must be labeled in posted evacuation plans.

18.2.L. Any space greater than 30ft (9m) in height open to multiple floors of the building must either have direct ventilation at the top for smoke exhaust, or have all adjacent habitable spaces contained behind metal doors that remain closed.

VENTILATION & THERMAL COMFORT

CONTENTS

IMPACT

The primary objective in ventilation is to provide air for breathing and promoting health by diluting and removing pollutants. The importance of adequate air exchange where needed should not be understated, as poor ventilation puts both patients and staff at risk of nosocomial infection.

Adequate thermal comfort also promotes healing and reduces stress in patients, since illness can interfere with the body's ability to regulate heat. Maintaining thermal comfort influences whether patients seek services at the facility and improves the productivity of staff.

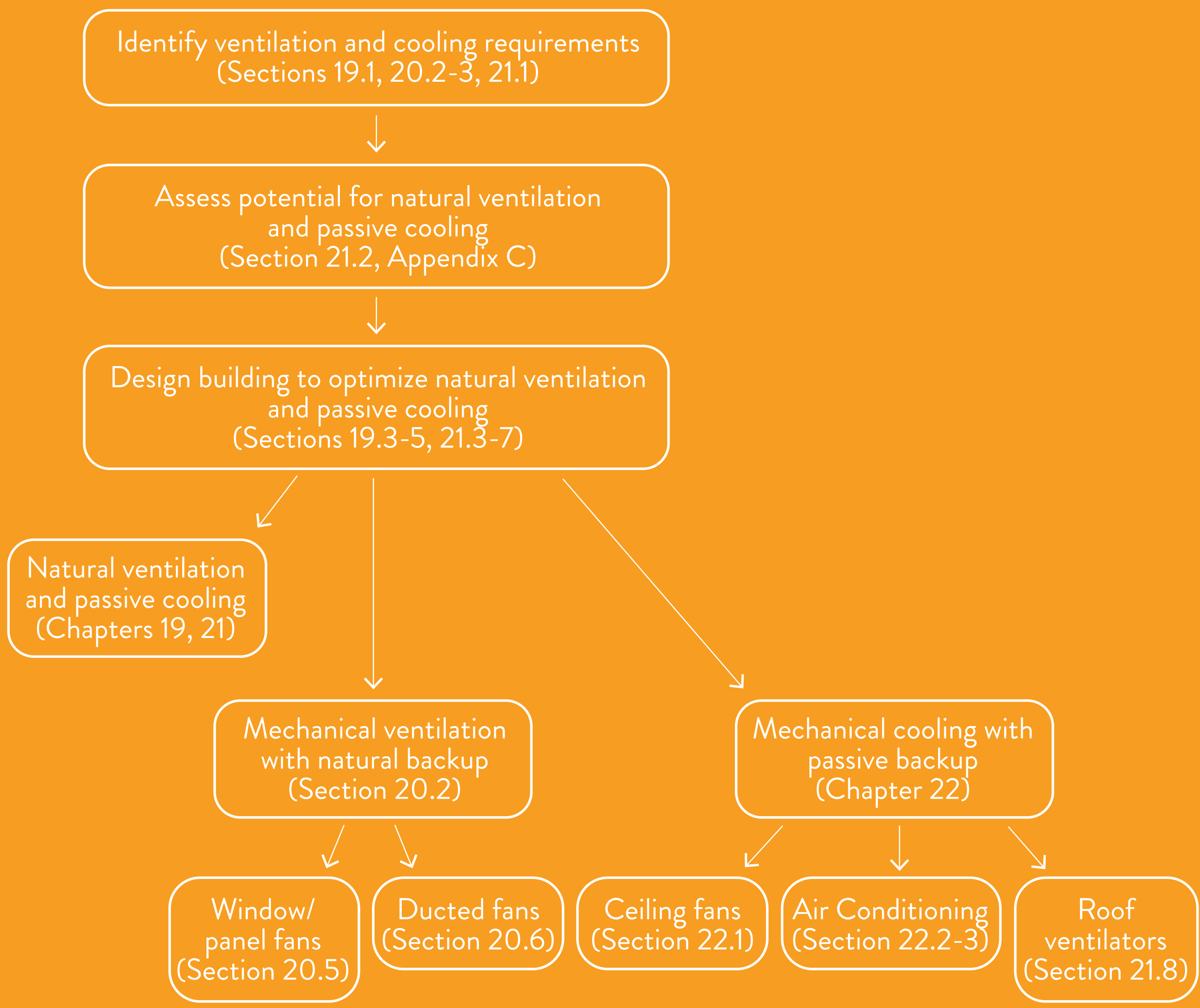
PRIMARY USERS

Infrastructure Unit

Architects & Designers

Mechanical Engineers

GUIDELINES FOR USE



19 Natural Ventilation

Natural ventilation can provide many benefits over mechanical ventilation in that it typically requires lower costs, has lower maintenance, and can be more reliable under certain climatic conditions. The challenge with using natural ventilation is that it is not always guaranteed to work and it may not be possible to achieve desired ventilation rates, airflow direction, and air distribution patterns to maintain thermal comfort and support infection control. For natural ventilation to work effectively, specific climatic conditions must exist, staff must be educated on its use/operation, and regular maintenance is needed to ensure its effectiveness and reliability. Given its advantages over purely mechanical driven solutions, its use should be maximized whenever appropriate climactic conditions exist to make it possible to provide adequate ventilation to maintain thermal comfort and indoor air quality to support infection control.

Definitions

- **Air changes per hour (ACH):** The metric for air change rate, or the amount of air that must be circulated in the room in one hour.
- **Air distribution pattern:** The manner in which air is supplied and exhausted from a space.
- **Airflow direction:** The general direction air flows through building spaces.
- **Clerestory:** Any high windows or openings above eye level.
- **Stack effect:** the movement of air into and out of buildings driven by buoyancy which occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences.
- **Short-circuiting:** Situation in which exhaust air is brought back in through intake.
- **Ventilation rate:** The amount of outside air that enters a space within a given period of time.

19.1 Ventilation Requirements

Ventilation is achieved by introducing clean outdoor air into a space and distributing it to control temperature, humidity, air motion, and air purity. See Appendix C for a primer on natural ventilation principles based on the WHO guidelines on Natural Ventilation for Infection Control. The amount of air delivered, the means in which it is delivered, the need for filtration, the pressure relationship to adjacent spaces, and the suitability of recirculating the air in the room depends on the function and acuity of care of the space.

19.1.A. A risk assessment must be performed for each space type to determine if minimum ventilation (and air filtration/treatment) is required for infection control beyond what is needed to maintain adequate thermal comfort.

i. A risk assessment must include evaluation of Population Risk which considers:
   - **Infection potential** – whether there are potentially infectious patients that should be isolated.
   - **Contamination risk** – whether there is a concern for protecting contamination of immunosuppressed patients and invasive procedures.

ii. The risk assessment must also include an evaluation of Clinical Risk which considers what level of protection is needed for each particular space type based on its function.
   - **Non-clinical** – spaces occupied by patients and staff where there is a low risk of exposure to potentially infectious patients and where there is not a concern for protecting against patient contamination.
   - **Low clinical risk** – spaces where there is a low risk of exposure and contamination.
   - **Medium clinical risk** – spaces where there is a moderate risk of exposure and contamination.
   - **High clinical risk** - spaces where there is a high risk of exposure and contamination.

19.1.B. Natural ventilation must be used whenever possible to achieve ventilation requirements to reduce energy costs, limit maintenance requirements, reduce need for expensive/complex equipment, and support resiliency of the building during power outages.

19.1.C. The use of natural ventilation must satisfy minimum ventilation requirements for clinical spaces for facilities that have an infection potential or contamination risk.

i. See Table 19.a. for ventilation requirements by each space type when using natural ventilation.[1]

ii. Generally, air must be directed from contamination sources to areas where there is sufficient dilution, and preferably to the outdoors.[2]

iii. Increased ventilation must be used for spaces with excessive heat generation, moisture, odors, or pollutants.[3]

Air Changes per Hour (ACH)

ACH is the metric for air change rate, or the number of times the air is circulated in the room in one hour. This ventilation rate, or amount of air needed for ventilation (in terms of cubic feet per minute or CFM), is calculated by multiplying the volume of the room by the air change rate (in ACH) and dividing by 60.

Q = (ACH X V) / 60

where: *Q = ventilation rate (cubic feet per minute)*
ACH = air change rate (air changes per hour)
V = volume of the room (cubic feet)

Table 19.a. Minimum ventilation requirements when using natural ventilation

Space Type	Examples	Minimum Average ACH	Absolute Minimum ACH
Non-Clinical	Staff Rooms	2	2
	Medical Records	2	2
	Staff Offices	2	2
	Meeting/Education	2	2
	Staff Bathrooms	6	2
	Laundry	6	2
	Kitchen	6	2
	Storage	2	2
	Equipment Rooms	2	2
	Morgue	6	2
Low Clinical Risk	Patient/Public Bathrooms	6	2
	Consultation Room	2	2
	Immunization (EPI)	2	2
	Dressing Rooms	2	2
	Family Planning/Antenatal	2	2
	Consulting	2	2
	Pharmacy & Drug Storage	2	2
	Advanced Diagnostics	2	2
	General Laboratory	2	2
	Sterilization (Clean)	2	2
Medium Clinical Risk	Emergency Room	8	8
	Labor Ward	8	8
	Short Stay	8	8
	Inpatient Wards	8	8
	X-ray	8	8
	Nursing Stations	8	8
	Sterilization (Dirty)	8	8
High Clinical Risk	Triage & Vital Signs[a]	10	10
	Waiting Areas[a]	10	10
	Registration[a]	10	10
	Clinical Corridors[a]	10	10
	PACU	24	12
	Post-Operative Ward	24	12
	ICU/NICU/Nursery	24	12
	High Risk Emergency Rooms[b]	24	12
	Operating Rooms	24	12
	Delivery Rooms (C-section)	24	12
	Isolation Rooms[c]	-	-
	Biosafety Laboratory[c]	-	-

[a] *When exposed to a high population risk*
[b] *Emergency rooms where operations or invasive procedures are expected*
[c] *Infection risk is too high for natural ventilation*

19.1.D. **For health centers and hospitals located on sites where natural ventilation cannot meet the minimum ventilation requirements and where there is a population risk of infection potential or contamination, hybrid (mixed-mode) or mechanical ventilation must be used.**

i. See Chapter 20 on Mechanical Ventilation.

ii. Ultraviolet Germicidal Irradiation (UVGI) systems can supplement natural ventilation for spaces where there is only a risk of infection potential, but there is not a need to prevent contamination of immunosuppressed patients and also where invasive procedures are not expected to be performed. (See Section 20.4 on UVGI systems.)

19.2 Airflow Distribution

Airflow distribution is important for maximizing the effectiveness of the ventilation system in minimizing the risk of airborne disease transmission and controlling contaminants. Proper airflow distribution can ensure that potentially contaminated air is managed such that occupants and visitors at the facility are protected.

19.2.A. **Airflow must be configured such that clean outside air is brought into the space and potentially contaminated indoor air is exhausted to the outdoors away from occupants.**

i. Generally, direct air from clean to dirty areas.

ii. Vent air from rooms directly outside and not to hallways unless the program specifically calls for positive pressure (e.g. Nurse Stations in some cases).

iii. Vent air as high in the room as possible and away from circulation areas.

19.3 Building Configuration

The overall geometry of the building can be configured to maximize the amount of natural ventilation potential via wind and stack effect. Refer to the primer on natural ventilation in Appendix C for additional background on wind and stack effect. The building design has a significant impact on the potential for using natural ventilation in addition to climate conditions. If well designed and sited, buildings can potentially be completely naturally ventilated if favorable climate conditions exist. If poorly designed, buildings can become a health hazard if relying only on natural ventilation.

Note on Renovations

When renovations or alterations are made to an existing building, care must be taken to ensure that the redesign does not interfere with how air flows across the building and through spaces. Common problematic changes include when openings are obstructed, building footprints are expanded, or windows are sealed shut—which can disrupt or stop air from flowing through the building as designed.

19.3.A. **Building geometry must be configured to maximize the potential for natural ventilation.**

i. Generally, naturally ventilated buildings must be narrow in the dimension parallel to the direction of airflow. See Figure 19.a.

ii. Buildings must be sited where wind obstructions are minimal. See Figure 19.b.
The maximum floor plan depth of the building that should be considered for cross ventilation is 45ft (13.7m).

Figure 19.a. Building orientation to maximize wind-driven natural ventilation

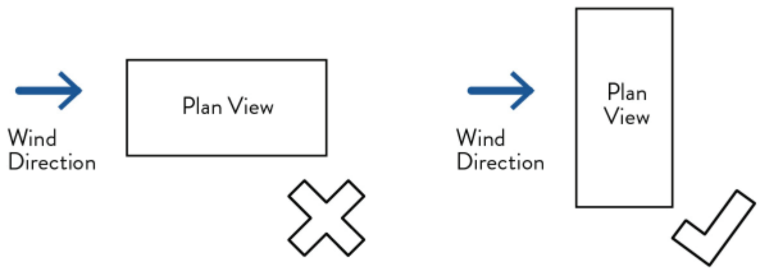
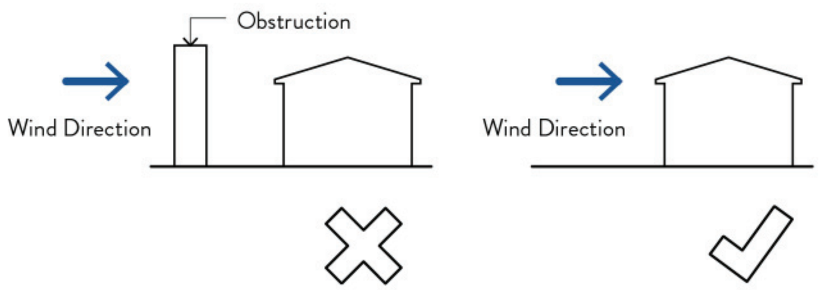


Figure 19.b. Minimizing obstructions that inhibit wind-driven natural ventilation



19.4 Room Geometry

Room geometry can be configured to support adequate ventilation in the space through cross ventilation and to take advantage of stack effect when climactic conditions allow.

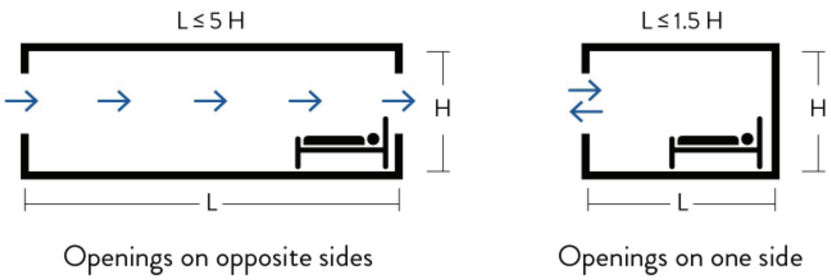
19.4.A. **Room geometry design must maximize the potential for natural ventilation even when a hybrid (mixed-mode) ventilation system is used.**

i. Minimize obstructions to airflow within the room (e.g. bookshelves and other furniture) when using cross ventilation.

ii. For wind-driven ventilation in a room with windows or openings on only one side of the space, the plan depth must not exceed 1.5 times the ceiling height. This system is not appropriate for infection control.

iii. For wind-driven cross ventilation in a configuration with openings placed on opposite sides of the room, the plan depth must not exceed 5 times the ceiling height.

Figure 19.c. Room geometry ratios for natural ventilation



19.5 Openings

Openings in perimeter walls as well as walls connecting to adjacent spaces can be configured to promote good airflow distribution.

19.5.A. Room openings must be sized, placed, and distributed to maximize the potential for natural ventilation even when a hybrid (mixed-mode) ventilation system is used.

19.5.B. Openings must be sized such that the total openable area is not less than 10% of the floor area.

i. For sliding windows, the openings must be sized such that the open area with the window fully open is at least 10% of the floor area.

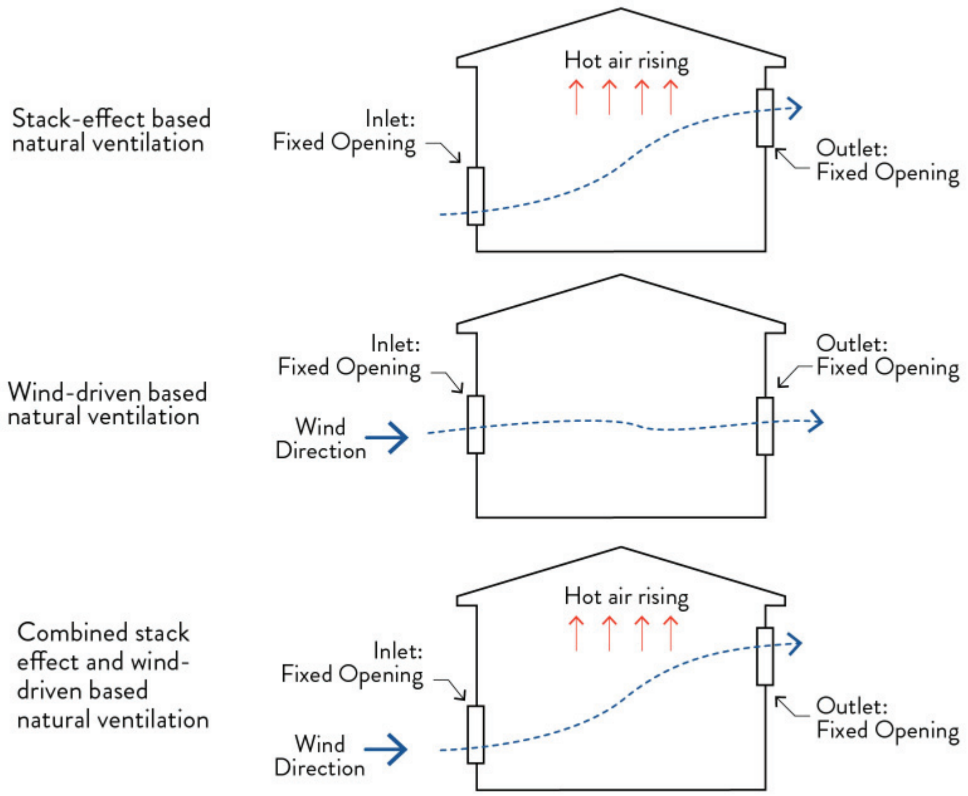
ii. Non-operable windows should not be included in this calculation.

19.5.C. Each room must have separate supply and exhaust openings.

i. Locate exhaust high above the inlet to maximize stack effect.

ii. Orient windows across the room and offset from each other to maximize mixing within the room and to prevent short-circuiting.

Figure 19.d. Recommended strategies for natural ventilation



19.5.D. When possible, window openings must be a combination of operable types to allow control by the occupants, and also fixed open vents or window types to ensure that the minimum ventilation requirements are always achieved.

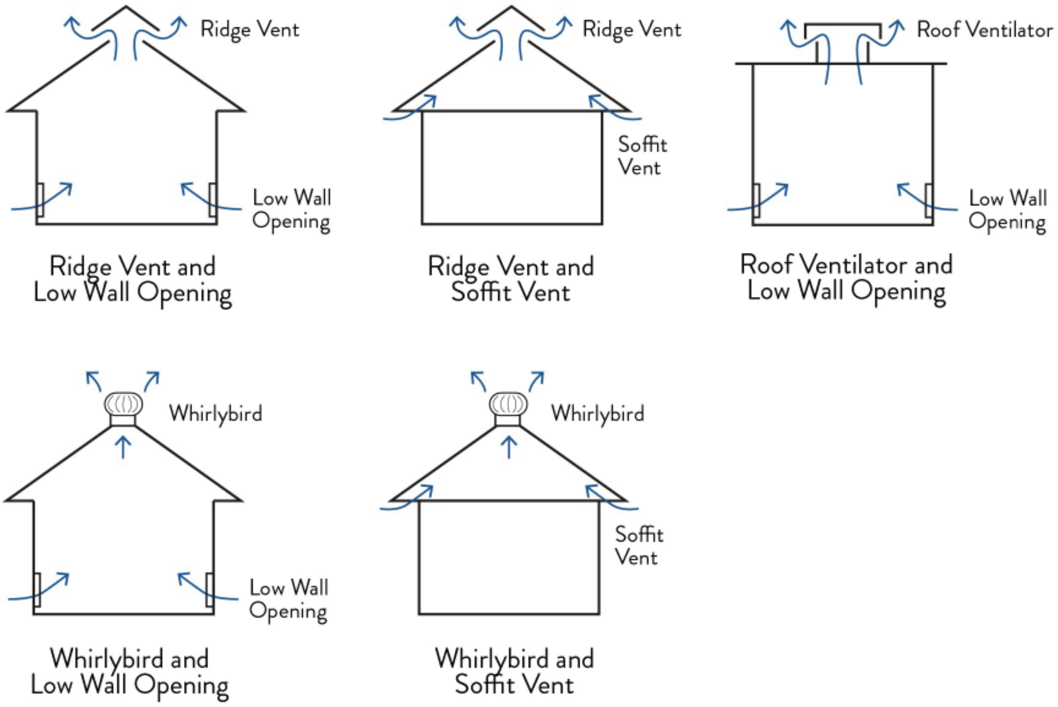
19.5.E. When natural ventilation systems are used, failsafe systems must be put in place to ensure that the system is operated as intended.

i. Facility staff should be trained on the intended use of the system to make sure that windows are not closed and that openings are not obstructed when being used for natural ventilation.

19.5.F. Provide ridge vent openings, roof vents, or whirlybirds at the highest point in the roof to offer a good outlet for both buoyancy and wind-induced ventilation. The opening must be free of obstructions to allow air to freely flow out of the building while providing rain protection.

i. See Standard 21.8.A. for whirlybird placement and installation requirements.
ii. See Standard 21.8.B. for ridge and roof vent placement and installation requirements.

Figure 19.e. Ridge vent, roof vent, and whirlybird configurations

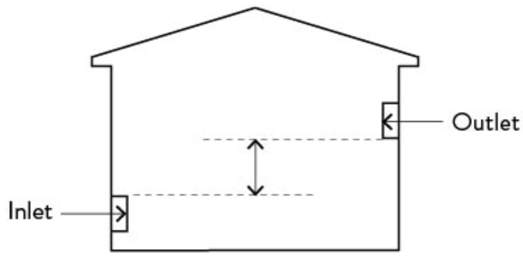


19.5.G. When possible, interior doors must be designed to be open to encourage whole-building ventilation. If privacy is required, ventilation exhaust can be provided through high louvers.

19.5.H. Consider the use of clerestories or vented skylights with rain protection to allow for stale, hot, potentially contaminated air to escape in a stack ventilation strategy.

19.5.I. Lower openings must be provided to complete the ventilation system such that there is a low opening for air intake and a high opening for air exhaust. The top of the inlet must be below the height of the bottom of the outlet.

Figure 19.f. Opening placement for air intake and exhaust



19.5.J. Maximize the distribution of openings to improve air flow effectiveness. Multiple, distributed, smaller openings are better than one large opening.

20 Mechanical Ventilation

Mechanical ventilation systems are often needed to augment and support natural ventilation to maintain minimum environmental comfort and enhance infection control. Dependence on mechanical systems, however, can represent a high-risk solution as mechanical systems will ultimately fail, eliminating their ability to support environmental comfort and infection control. In short, a mechanical system that is an asset becomes a liability when it fails.

Definitions

- **Airborne precaution room:** A room with >12 air changes per hour (ACH).
- **Ducted fans:** Fans that are connected to air ducts for supplying and exhausting air to and from spaces.
- **HEPA filter:** A high efficiency particulate air filter that is effective at removing a high percentage of airborne contaminants.
- **Immunosuppressed patient:** Patients lacking a natural immune response.
- **Nosocomial infection:** A new infection that develops in a patient during hospitalization.
- **Redundant Fans:** Secondary duplicate fans that are sized for 100% airflow that are normally off when the primary fan is being used, but are capable of being used in the event of failure of the primary fan.
- **Ultraviolet Germicidal Irradiation (UVGI):** A sterilization method that uses ultraviolet (UV) light at a sufficiently short wavelength to break down microorganisms.
- **Window fans and panel fans:** Propeller fans installed in either windows or walls for exhausting air from spaces for ventilation and supplemental cooling.

20.1 Mechanical System Reliability

Systems with moving parts are inherently susceptible to failure and breakdown due to repetitive and cyclic use. Mechanical systems are useful for many applications, though they should be designed with mechanisms to deal with potential reliability issues.

20.1.A. When required, mechanical system components must be selected for high reliability throughout the life of the facility.

i. Select equipment that is readily available via local supply chains; use common sizes with on-site spares.
ii. Select equipment that can be maintained or replaced by locally available services.
iii. Design power-serving equipment to be reliable. (See Chapter 23 on electrical system design.)

20.1.B. Hybrid and/or mechanical systems must incorporate backup natural ventilation systems in the event of equipment failure.

20.1.C. Whenever mechanical systems are used, they must be commissioned to ensure the specified ventilation and cooling requirements and specifications are met.

20.1.D. An operations and maintenance budget must be provided with all mechanical systems designs.

i. Training should be provided to staff for proper operation and maintenance of mechanical equipment.

20.2 Supplemental Mechanical Systems (Mixed Mode)

A supplemental mechanical system should be used for conditions where a reliable natural ventilation system is not capable of meeting the minimum requirements and for facilities where there is an infection or contamination risk.

20.2.A. Facilities must be designed to meet the minimum requirements for mechanical ventilation according to Table 20.a.

i. Use variable-speed, manually-controlled ceiling fans to improve environmental comfort for all space types where possible.
ii. Provide exhaust fans for odor generating or contaminant storage areas such as toilet or food preparation rooms.
iii. Use Ultraviolet Germicidal Irradiation (UVGI) systems to mitigate airborne pathogens for high clinical risk spaces. (See Section 20.4 on UVGI systems.)
iv. Use HEPA filters for the supply air for Operating Rooms, Delivery Rooms (where C-sections may be performed), ICUs, NICUs, and Nurseries.
v. Use HEPA filters for exhaust air for Isolation Rooms and Biosafety Laboratories.
vi. Use redundant fans for ICUs, NICUs, Operating Rooms, Delivery Rooms (with C-sections), Isolation Rooms, and Biosafety Laboratories.

Table 20.a. Minimum ventilation requirements for mechanical or mixed mode systems

Space Type	Examples	Min. Total ACH[a]	Min. OSA ACH	Filters	Pressure[b]
Non-Clinical	Staff Rooms	2	2		
	Medical Records	2	2		
	Staff Offices	2	2		
	Meeting/Education	2	2		
	Staff Bathrooms	6	2		
	Laundry	6	2		
	Kitchen	6	2		
	Storage	2	2		
	Equipment Rooms	2	2		
	Morgue	6	2		
Low Clinical Risk	Patient/Public Bathrooms	6	2		
	Consultation Room	2	2		
	Immunization (EPI)	2	2		
	Dressing Rooms	2	2		
	Family Planning/Antenatal	2	2		
	Consulting	2	2		
	Pharmacy & Drug Storage	2	2		
	Advanced Diagnostics	2	2		
	General Laboratory	2	2		Negative
	Sterilization (Clean)	2	2		Positive
	Sterilization (Dirty)	2	2		Negative
Medium Clinical Risk	Emergency Room	6	2		
	Labor Ward	6	2		
	Short Stay	6	2		
	Inpatient Wards	6	2		
	X-ray	6	2		
	Nursing Stations	6	2		Positive
High Clinical Risk	Triage[c]	6	2		
	Waiting Areas[c]	6	2		
	Registration[c]	6	2		
	Clinical Corridors[c]	6	2		
	PACU	6	2		
	Post-Operative Ward	6	2		
	ICU/NICU/Nursery	6	2	Yes	Positive
	High Risk Emergency Rooms[d]	6	2	Yes	Positive
	Operating Rooms	12	2	Yes	Positive
	Delivery Rooms (C-section)	12	2	Yes	Positive
	Isolation Rooms	12	2	Yes	Negative
	Biosafety Laboratory	12	2	Yes	Negative

[a] *Refer to shaded box in 19.1.C for a definition of ACH*

[b] *Refer to shaded box below for definition of pressurization*

[c] *When exposed to a high population risk*

[d] *Including emergency rooms where operations or invasive procedures are expected*

High Efficiency Particulate Air (HEPA) Filters

HEPA filters are used where there is concern for protecting contamination of immunosuppressed patients and where invasive procedures are performed.

HEPA filters must meet the efficiency standards set by the United States Department of Energy (DOE) which requires that the filter must remove 99.97% of particles that have a size of 0.3 micrometers or larger.

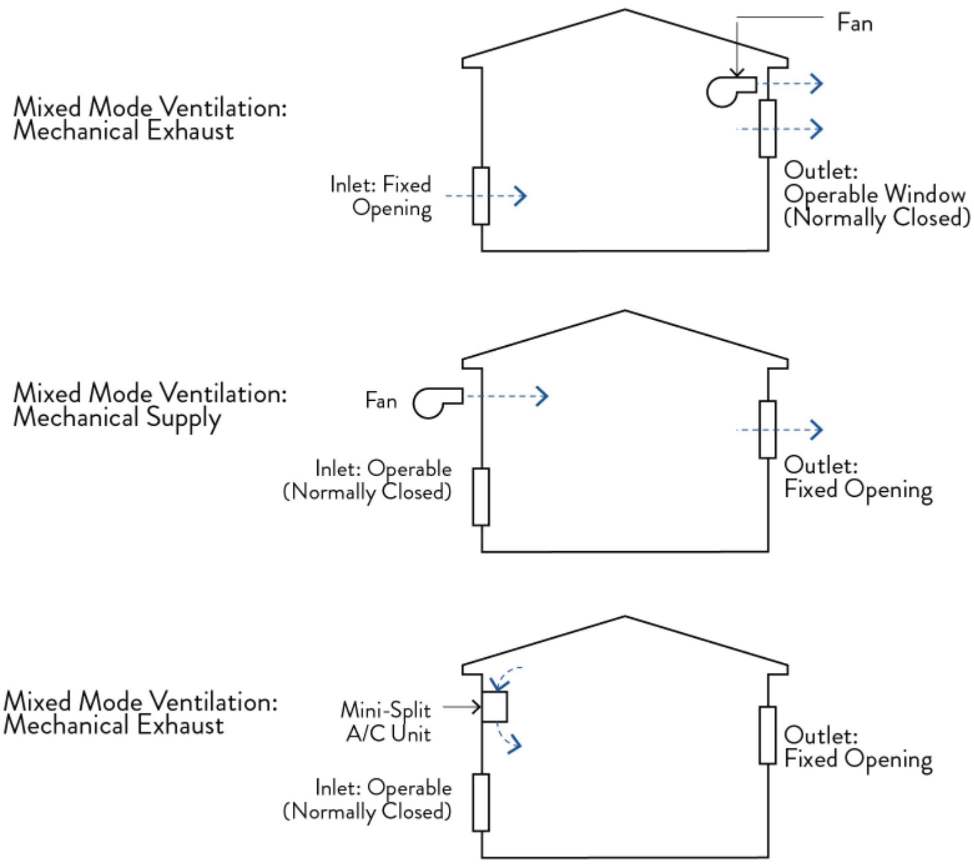
Pressurization

Positive pressure is achieved when there is more air supplied to a room than is being extracted. Negative pressure is achieved when there is more air being exhausted from a room than is being supplied.

Pressure measurement

Water gauge measured in inches of water is an imperial unit of measure for pressure that is used for measuring small pressure differentials between two spaces.
It can be measured using an instrument referred to as an anemometer.

Figure 20.a. Recommended strategies for mixed mode ventilation



20.3 Isolation Practices

Isolation may be required for patients that are known to be contagious, or who need a protective environment due to immunosuppression or high susceptibility to infection during an invasive medical procedure. Infectious patients need a negative pressure environment to prevent infectious particles from being transmitted to others whereas immunosuppressed patients need a positive pressure environment for preventing contaminants from entering their space. Refer to the shaded box in Section 20.2.A. for a description of pressurization.

20.3.A. Patients who require airborne isolation precautions must be placed in an airborne precaution room.[4] An airborne precaution room is a room with >12 air changes per hour (ACH).

i. The requirement for 12 ACH applies to new construction. Renovations must achieve a minimum of 6 ACH.

ii. Directional airflow is needed to ensure that air moves from clean to dirty areas and ultimately to spaces where there is sufficient dilution, preferably outdoors.

20.3.B. Infectious patients with diseases that have a high potential for nosocomial transmission must be placed in an airborne precaution room with a negative pressure differential of 0.01in water gauge.

i. The exhaust air must include a HEPA filter before being exhausted outdoors if it is near potentially occupied areas where sufficient dilution is not feasible.

ii. The pressure differential may also be achieved by maintaining an inward velocity of 100fpm (feet per minute) or exhausting 50 CFM (cubic feet per minute) more than the supply.

iii. UVGI systems may be used in conjunction with, or in place of, HEPA filters when used with ceiling fans to assist in air mixing to improve their effectiveness. (See Section 20.4.)

Figure 20.b. Negative pressure configuration

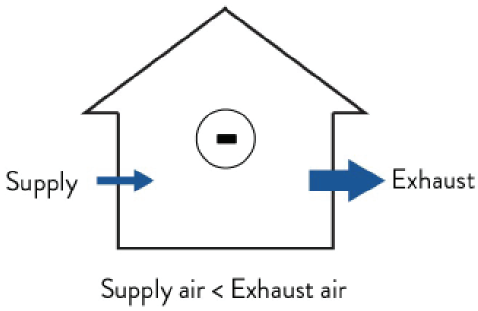
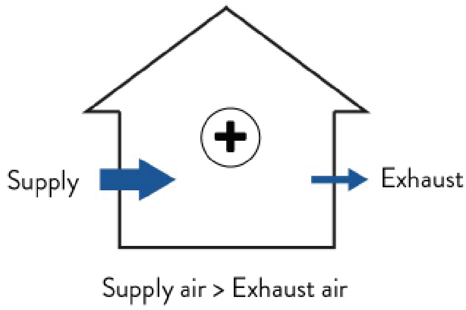


Figure 20.c. Positive pressure configuration



20.3.C. Patients that require a protective environment must be placed in an airborne precaution room with a positive pressure differential of 0.01in water gauge and a HEPA filter must be provided where air is introduced to the space.

i. The supply air should include a HEPA filter located such that it filters air before being introduced to the space.

ii. The pressure differential may also be achieved by maintaining an outward velocity of 100 fpm or supplying 50 CFM more than the exhaust.

iii. UVGI systems may be used in conjunction with, or in place of, HEPA filters when used with ceiling fans to assist in air mixing to improve their effectiveness.

20.4 UVGI

Ultraviolet germicidal irradiation (UVGI) can be a very effective means of preventing transmission of infections particularly when used to supplement ventilation systems. UVGI fixtures contain an ultraviolet light that kills microorganisms and can be mounted to ceilings or walls in a space. UVGI is especially effective at killing bacteria and other harmful organisms, though not necessarily effective at eliminating all contaminants (such as fungal and bacterial spores) that can present problems for immunosuppressed patients and in areas where invasive procedures are performed. Typical applications of UVGI include isolation wards and rooms, waiting rooms, emergency rooms, surgical suites, and general hospital areas.

20.4.A. **UVGI must be considered as a complement to mechanical filtration for areas where there is a high risk of infection transmission.**

i. UVGI systems should not be used as the primary means of contaminant control for immunosuppressed patients or where invasive procedures are performed.

20.4.B. **When UVGI systems are used, they must be designed and installed such that occupants' eyes and skin are protected from harmful exposure to the lamp.**

i. Select fixtures with louvers to protect occupants' eyes and skin from exposure.
ii. Place fixtures in a location in the room that achieves sufficient distribution and coverage for the space.
iii. Place fixtures in a location in the room such that the light is blocked from direct exposure to occupants' eyes and skin.

20.4.C. **When UVGI systems are used, ceiling fans must be considered to help mix the upper air in the room with the lower occupied region.**

20.4.D. **When UVGI systems are used, they must be tested and commissioned to ensure proper effectiveness and protection of building occupants.**

20.5 Window and Panel Fans

Window fans and panel fans are propeller fans installed in either windows or walls that exhaust air from spaces for ventilation and supplemental cooling. These types of fans use relatively lower energy than other types of fans such as cabinet and inline duct fans and can provide effective ventilation and cooling for Liberian climates when designed as part of a complete system and operated properly.

20.5.A. When window and panel fans are used, a low air intake should be provided in the space.

i. Refer to Section 19.5 for opening placement guidelines.

20.5.B. When possible, window and panel fans must be installed on facades facing away from prevailing winds.

i. Panel fans can also be used in attic spaces for ventilation and as part of a mechanical cooling strategy.

20.5.C. When panel fans are used, a variable speed controller must be installed whenever possible to provide comfort control.

20.6 Ducted Fans

Ducted fans are fans that are connected to air ducts for supplying and exhausting air to and from spaces. They can be an effective way of ventilating and cooling a space by moving a specific controlled amount of air to and from targeted areas. Ducted fan systems can be either centralized (serving multiple spaces) or dedicated for individual rooms. Centralized systems can be more efficient and cost effective, but can also be more unreliable as the entire system is dependent on a single fan.

20.6.A. When ducted fans are used, a variable speed controller must be used whenever possible to provide ventilation and comfort control.

i. The speed controller should be located such that access is only allowed by staff to prevent unauthorized adjustment.

20.6.B. When ducted fans are used, a redundant fan must be used whenever possible to improve system reliability.

i. The secondary fan should be sized for 100% of the required airflow as provided by the primary fan, but should be normally off.

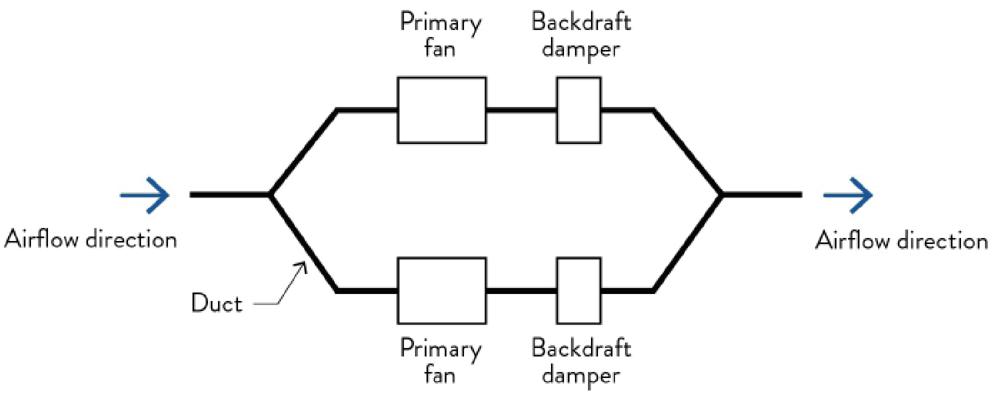
ii. The controls of both fans should be easily accessible by staff to be able to turn on the secondary fan when the primary fan fails.

iii. A backdraft damper should be provided for each fan to prevent air from short-circuiting the duct path. A backdraft damper is a device in a duct that allows air to travel in only one direction. Refer to Figure 20.a. for recommended redundant fan configuration.

20.6.C. When ducted fans are used, direct-drive types should be used instead of belt-driven types

i. Belt-driven fans can be more unreliable than direct-drive types due to extra moving parts that require additional maintenance.

Figure 20.a. Recommended redundant fan configuration



21 Passive Cooling

Passive cooling is a strategy that can be more reliable, less expensive, and require less operation and maintenance than mechanical systems under certain conditions. A climate analysis should be performed to determine if passive cooling is appropriate or adequate for the site conditions and proposed program. Though Liberia is generally hot and humid the majority of the year across the country, specific microclimates do exist that warrant evaluating climate and wind patterns to assess the appropriateness of using natural ventilation. Passive cooling will not be able to provide the needed space conditioning in all applications. Due to its advantages over mechanical systems, it should be used wherever possible and supplemented with mechanical systems when needed for specific spaces.

Definitions

- **Diurnal swing:** the variation in temperature that occurs during the high daytime temperature and the low night temperature.
- **Earth coupling:** The practice of building into the ground to take advantage of the vast thermal mass of the earth, which typically remains a constant temperature at a certain depth below grade (depending on the climate).
- **Earth berming:** Using a mound or bank of earth as a barrier or to provide insulation.
- **Fenestration:** The arrangement of windows and doors on the elevations of a building.
- **Heat island:** A surface which is significantly warmer than its surrounding areas, typically due to absorption of solar radiation.
- **Heat sink:** A device or substance for absorbing excessive or unwanted heat.
- **Passive cooling:** Technologies or design features used to cool buildings without power consumption.
- **Night flushing:** Drawing cooler outside air into a space during the night for cooling. This strategy is typically coupled with high thermal mass materials such that they can provide cooling during the day from the night flushing.
- **Thermal bridging:** Heat transfer that occurs when materials that are poor thermal insulators come into contact, allowing heat to flow through the path of least thermal resistance (R-value).
- **Thermal mass:** The ability of a solid to absorb heat which typically occurs during the day and can be released at night.

21.1 Temperature

The need for temperature control varies by space type. Although maintaining adequate thermal comfort is important for all occupants, the need for tighter control of indoor air temperature is most essential in critical spaces.

21.1.A. **Facilities must be designed to meet the temperature requirements for critical spaces according to Table 21.a.**

Table 21.a Acceptable temperature ranges for critical spaces

Space Type	Temperature (°C)	Temperature (°F)
Operating Room	21-25	70-77
Delivery Room (C-section)	21-25	70-77
Recovery Room	24-26	75-79
Nursery	24-26	75-79
Intensive Care	24-26	75-79

21.1.B. **As much as possible, all other spaces in the facility must be kept within 22-27°C (71-81°F).**

21.1.C. **As much as possible, all spaces must maintain a humidity of less than 70%.**

21.2 Passive Cooling vs. Mechanical Cooling

Because Liberia's climate is mostly hot and humid throughout the country, the opportunity to use passive cooling to provide adequate comfort for all applications is somewhat limited. Mechanical cooling should therefore be considered for critical high clinical risk spaces where maintaining adequate thermal comfort is necessary.

21.2.A. **Passive cooling must be used wherever possible to minimize the reliance on mechanical systems that require maintenance and consume energy.**

21.2.B. **For conditions where passive cooling cannot meet the minimum thermal comfort requirements, supplemental mechanical systems must be used.** (See Chapter 22 on Mechanical Cooling.)

21.3 Building Design and Layout

Building design and layout plays a major role in leveraging the opportunity to use passive cooling. Simple design elements can have a significant impact on thermal comfort through passive cooling. By designing the building to maximize the use of passive cooling, the facility can be more resilient and able to satisfy thermal comfort requirements even when mechanical systems fail or power is lost.

21.3.A. Building design and layout strategies must be considered to optimize the opportunity for passive cooling.

i. Minimize the surface area to volume ratio (S/V) to reduce solar gain.
ii. Configure building layout to maximize cross ventilation (maximize area perpendicular to prevailing wind, minimizing depth of floor plate undergoing cross ventilation).
iii. Utilize reflective surfaces and light colored paints to help prevent solar gain.
iv. Minimize heat islands near outside air intakes and openings. Consider planting vegetation as a strategy.
v. Minimize direct solar exposure year round (no passive heating necessary).
vi. Utilize vestibules and air lock spaces.
vii. Minimize east and west exposures and glazing when not in conflict with building configuration to maximize cross ventilation.

21.4 Shading

The use of shading devices can help significantly reduce cooling requirements by minimizing the amount of direct solar gain from entering the building. They can help strike the balance between promoting daylighting strategies via diffuse light while simultaneously mitigating direct solar gain. Shading devices can help also support ventilation by allowing larger openings while still maintaining protection from rain.

Figure 21.a. Recommended horizontal shading device strategies

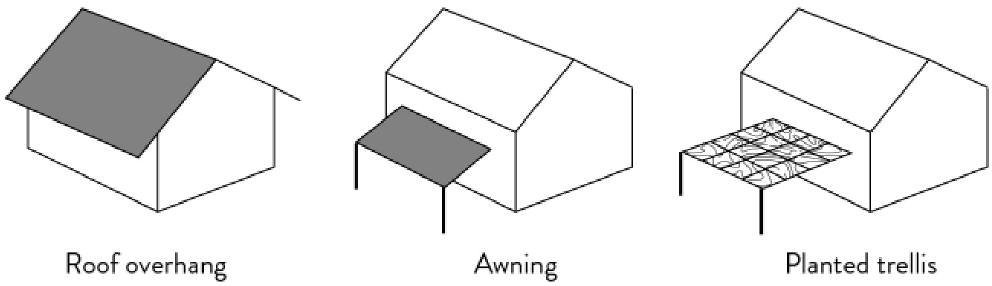
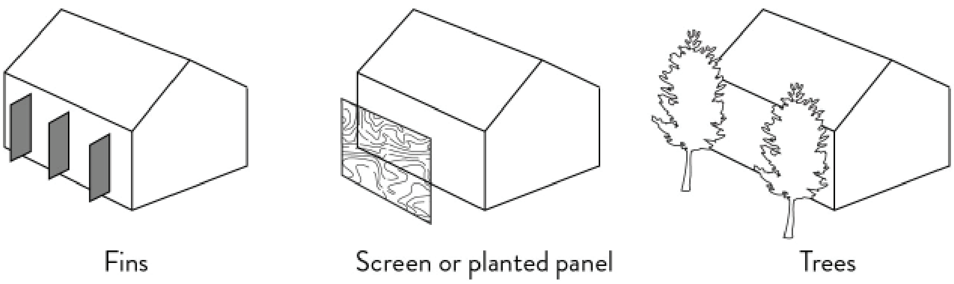


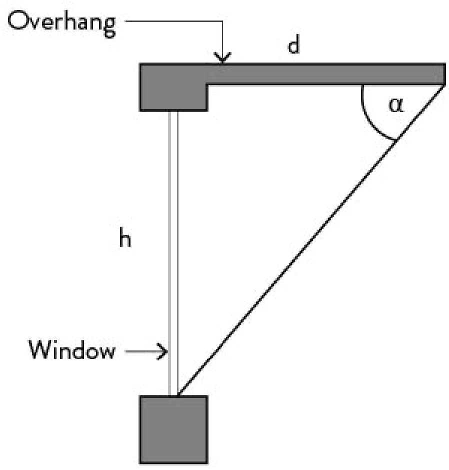
Figure 21.b. Recommended vertical shading device strategies



21.4.A. **Shading strategies must be considered to optimize the opportunity for passive cooling.**

i. For Southern facades, use the winter solstice altitude angle ~ 60°; h/d ≤ 1.75.
ii. For Northern facades, use the summer solstice altitude angle ~75°; h/d ≤ 2.75.
iii. Overhang depth vs. window height can be calculated using the following formula: $h/d \le tangent(\alpha)$ where: h = window opening height , α = sun angle , d = overhang (shading device) depth

Figure 21.c. Recommended shading device depth calculation



21.5 Thermal Mass

Thermal mass in conjunction with night flushing can help balance the need for cooling by taking advantage of the temperature fluctuations between night and day.

21.5.A. **Thermal mass strategies must be considered to optimize the opportunity for passive cooling.**

i. Consider using materials with a high thermal mass to take advantage of Liberia's mild diurnal swing.
ii. Consider earth coupling or berming as a heat sink.

21.6 Fenestration

Building fenestration, which is the design and placement of windows in a building, has a significant impact on regulating cooling loads that result from direct solar radiation and conduction. Balancing the need for natural daylight and reducing the need for mechanical cooling is key for minimizing total building energy use.

21.6.A. Fenestration elements must be selected to minimize building heat gain.

i. See Table 21.a. for temperature requirements.
ii. Choose operable windows where occupant controllability of thermal comfort is desired.
iii. Use permanently fixed openings (as opposed to operable windows) when a minimum amount of outside air is required at all times. A hybrid strategy can be used to meet minimum ventilation requirements while also providing controllable thermal comfort.
iv. Reduce heat islands near openings to prevent excess heat buildup near air intakes.
v. Prioritize the selection of windows that meet the parameters in Table 21.b. Window properties (U-value and SHGC) can be obtained from the manufacturer.
vi. Minimize east and west un-shaded windows when not in conflict with prevailing winds.

Table 21.b Window property requirements

Building Element	Maximum U-value	Minimum SHGC
Windows	0.25	0.40
Skylights	0.25	0.35
Door windows	0.25	0.45

21.7 Insulation

Building insulation can be used to minimize the heat entering the building via conduction. Un-insulated walls and roofs can be a major source of heat gain to spaces. Particularly for roofs, which in Liberia are typically metal, excess heat conduction can occur, causing excessive build-up and thermal discomfort for occupants. Heat gain through roofs can be significantly greater than through walls given the high sun angles in Liberia. Selecting materials with high insulating properties can significantly reduce heat build-up and the need for mechanical cooling.

21.7.A. **Exterior walls and roofs must be designed to minimize heat gain via conduction.** (See Table 21.c. for minimum insulation requirements.)

i. Minimize thermal bridging which can occur when there are gaps in insulation and where the R-value is the smallest.

ii. Refer to Appendix D for typical R-values for building materials. Building material elements can be combined additively to meet the requirements listed in Table 21.c. An example is shown in Appendix D.

Table 21.c. Minimum insulation requirements

Building Element	Minimum R-value
Exterior walls	11
Roofs	17
Floors	N/R

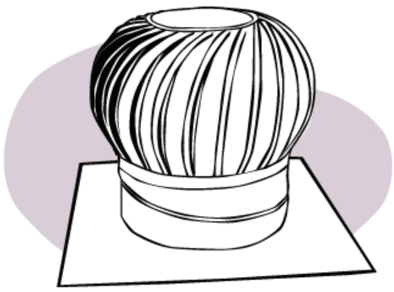
21.8 Roof Ventilation

As roofs can be a major source of heat gain in buildings, and hot interior air naturally rises to collect at the top of spaces, roof ventilation is a practical strategy for passive cooling. Roof ventilation systems include whirlybirds, ridge vents, and roof vents. Care must be taken to ensure that these components are well installed to prevent water from leaking into the building.

Whirlybirds

Whirlybirds, also known as turbine ventilators, are a type of ventilation system that can be installed on roofs to help remove heat from a ceiling cavity or upper portion of a room. They are cylindrical domes with fins that spin in the wind to create a vacuum, sucking up air from below. They can also work when there is little or no wind as they provide a means for rising heat to escape through a roof, causing the whirlybird to spin. Whirlybirds can be an effective means for removing heat and providing some ventilation as part of a natural ventilation strategy, but are not a reliably consistent means for ventilating critical or high-risk spaces. They can be used as a complement to a passive ventilation strategy.

Figure 21.d. Whirlybird illustration



21.8.A. **Whirlybirds can serve as a means for supplemental cooling, but must not be used as the sole means for achieving minimum ventilation requirements.**

i. Whirlybirds should be installed at the highest possible point in a roof to allow heat to escape.
ii. Obstructions that may block the wind should not be placed on roofs near the whirlybirds.
iii. When whirlybirds are used, a low opening must be provided in the ceiling cavity or room to allow air to enter the space that is being ventilated. For ceiling cavities, a soffit vent can be used to allow the air to enter the space. When used to ventilate a room, a low opening should be provided as part of a proper natural ventilation design. (See Figure 19.e.)
iv. Whirlybirds should be designed and installed with proper flashing to prevent roof leaks.
v. Whirlybirds should be checked regularly to ensure that debris does not block the fins or prevent the device from spinning.

Ridge vents and roof vents

Ridge vents and roof vents are passive devices which are installed in roofs to allow excessive heat to escape ceiling cavities and upper portions of rooms. Heat trapped in ceiling cavities and the upper portions of rooms will rise due to buoyancy and when a high and low opening is provided, roof openings can help promote this heat to escape. When used properly, they can be an effective means of passive cooling, though should not be the single option used for ventilation of critical or high-risk spaces.

21.8.B. Ridge vents and roof vents can be considered a means for supplemental cooling, though must not be used as a means for achieving minimum ventilation requirements.

i. Ridge vents and roof vents should be installed at the highest point of a roof ridge to allow heat to escape.

ii. When ridge vents and roof vents are installed, a low opening must be provided in the ceiling cavity or room to allow air to enter the space that is being ventilated. For ceiling cavities, a soffit vent can be used to allow the air to enter the space. When used to ventilate a room, a low opening should be provided as part of a proper natural ventilation design. (See Figure 19.e.)

iii. Ridge vents and roof vents should be designed and installed with proper flashing to prevent roof leaks.

iv. Ridge vents and roof vents should be checked regularly to ensure that debris does not block the openings.

22 Mechanical Cooling

Mechanical cooling systems are often needed to augment and support passive cooling systems to maintain minimum environmental comfort and enhance infection control. Dependence on mechanical systems, however, can be a liability due to the inherent reliability issues of systems with moving parts. Consequently, backup passive systems should always be used to ensure functionality even in the event of failure. The serviceability and repair of systems should be considered when selecting mechanical equipment, in addition to determining a consistent supply chain in the event of the need for equipment replacement.

Definitions

- **Centralized Packaged Air Conditioner:** An air conditioning system in which a single housing contains the condensing unit, compressor and evaporator, ducting conditioned air to the serviced spaces.
- **Condensing Unit:** Part of an air conditioning unit that cools and condenses incoming refrigerant vapor into liquid.
- **Ductless Split Air Conditioner:** An air conditioner with an exterior condensing unit and an interior fan unit, connected by refrigerant and electrical lines.
- **Refrigerant Line:** Tubing which connects the interior and exterior units of a ductless split air conditioner.
- **Window Air Conditioner:** A single-unit air conditioning system which fits into a window.

22.1 Ceiling Fans

Ceiling fans can be very effective in improving occupant comfort by moving air over occupants and improving air circulation within spaces. The temperature that is perceived by occupants when air is moving across the skin's surface can be lower than the actual temperature and therefore will be more comfortable to occupants under high temperature conditions. Ceiling fans are not a reliable form of ventilation; however, they should be used to improve thermal comfort for occupants. A ceiling fan can provide an equivalent level of cooling as compared with an air conditioner for up to 5°F temperature decrease while consuming only 1/20th the amount of power. Fans can also be an effective means of providing air mixing which can help improve indoor air quality particularly when coupled with air disinfection systems like Ultraviolet Germicidal Irradiation (UVGI) fixtures.

22.1.A. Ceiling fans must be used wherever possible to improve the thermal comfort of occupants for non-critical spaces.

i. Refer to Table 22.a for suggested ceiling fan sizing.

22.1.B. Ceiling fans must be installed in the middle of the room when a single fan is used or equidistantly in the room when multiple fans are used.

i. Multiple fans should be used for rooms greater than 300 ft^2 or longer than 18 ft.
ii. Refer to Figure 22.a for optimal placement of multiple fans.

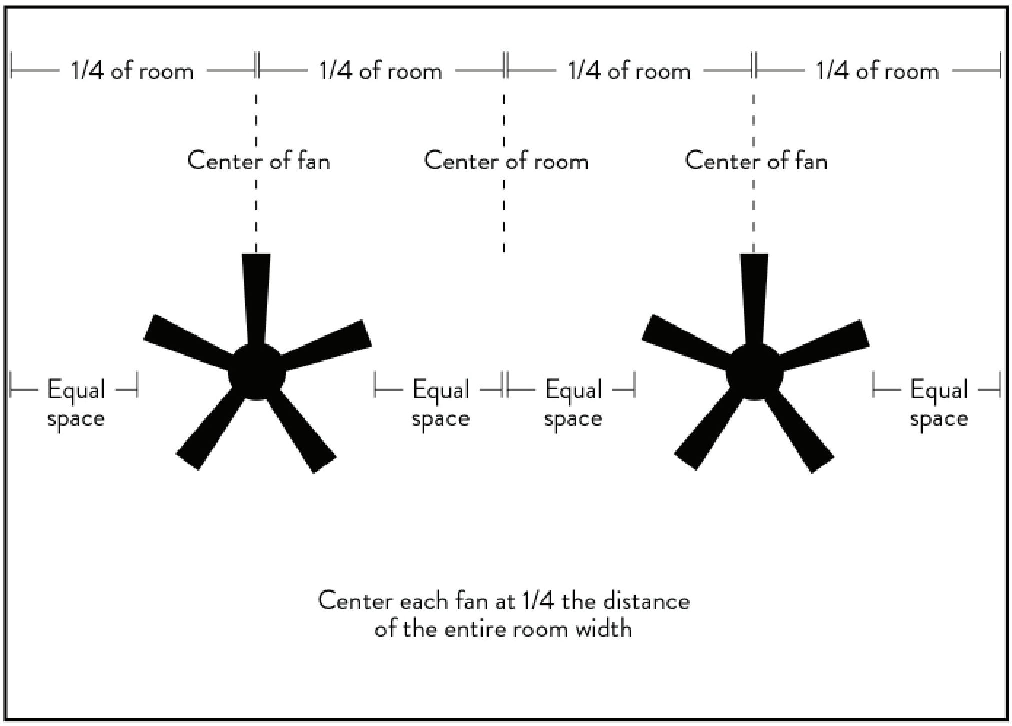
22.1.C. Ceiling fans must be installed at least 7 feet above the floor, 8 inches below the ceilings, and 18 inches from the walls.

i. Ceiling fans work best at 10-12 inches below the ceiling.
ii. If the ceiling height allows, the fan must be installed 8-9 feet above the floor for optimal flow.

Table 22.a. Suggested ceiling fan sizing

Room Dimensions	Suggested Fan Size (inches)
Up to 75 ft^2	29-36
76-144 ft^2	36-42
144-225 ft^2	44
225-300 ft^2	50-44
Above 300 ft^2	Use multiple fans

Figure 22.a. Optimal placement of multiple fans



22.2 Air Conditioning Applications

Air conditioning systems are commonly available in Liberia, particularly ductless mini-split types. When correctly installed and maintained, they can be very effective in space conditioning; however, they require electricity to work. Mechanical air conditioning systems are not required for all spaces, though are needed for critical spaces that have temperature requirements and when climatic conditions are inadequate for utilizing natural ventilation. Air conditioning systems can be either centralized or dedicated for individual rooms. Centralized air conditioning systems can be more efficient and cost effective, but can also be more unreliable as the entire system is dependent on a single unit.

22.2.A. Mechanical air conditioning systems must be used in spaces listed in Table 21.a when natural ventilation is not capable of meeting the requirements.

22.2.B. The provision for air conditioning in spaces not listed in Table 21.a must be determined by facility planners.

22.2.C. A reliable power supply must be provided for facilities with spaces requiring air conditioning.

i. The use of air conditioning for non-critical spaces must be minimized, particularly when a reliable power supply is not available.

22.3 Air Conditioning Systems

Mechanical cooling is most commonly provided via ductless split air conditioners, though other systems may be considered for larger facilities such as packaged central air conditioning units and heat pumps. Ductless split air conditioning systems are typically the best option, particularly in smaller healthcare facilities given their relative reliability, the availability of replacement parts, and the availability of personnel with servicing experience. Centralized packaged systems can also be used, though the ability to obtain replacement parts or have servicing performed is limited in Liberia. A packaged central air conditioner has the evaporator coil, condenser, and compressor all located in one unit as opposed to a split system where the components are placed in different locations. Packaged systems are typically placed on a roof or on a concrete slab adjacent to the building. Air supply and return ducts come from indoors through the building exterior wall or roof to connect with the packaged air conditioner, which is usually located outdoors.

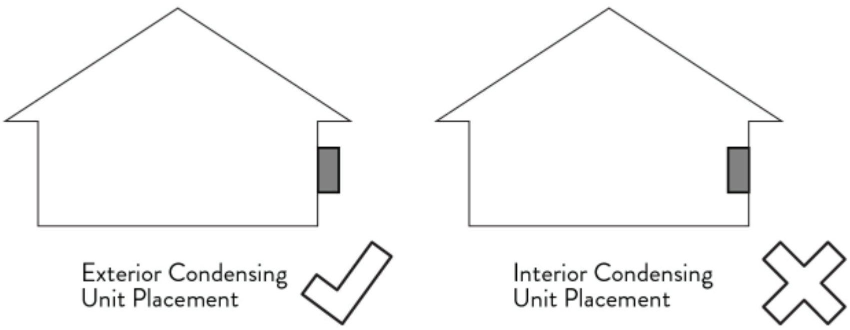
22.3.A. When mechanical cooling systems are used with refrigerants, the refrigerant type and charge must match the manufacturer's specifications for the equipment.

i. Select equipment that uses a refrigerant with a low ozone depletion potential (ODP) and global warming potential (GWP). Refrigerant R410a meets these requirements.

22.3.B. When ductless split air conditioners are used, the outdoor condensing unit must be placed in an area where the rejected heat will not cause discomfort to occupants.

i. As much as possible, condensing units should be placed on the exterior to avoid heating interior or other occupied spaces. This may require easily configured custom extensions to extend the connection to the indoor component. (Refer to Figure 22.b. for proper condensing unit placement.)

Figure 22.b. Condensing unit placement



22.3.C. Condensing units must be located in a way that avoids undesirable noise in healing areas.

22.3.D. Condensing units must be located at a minimum height of 6ft above the finished floor height in occupied areas.

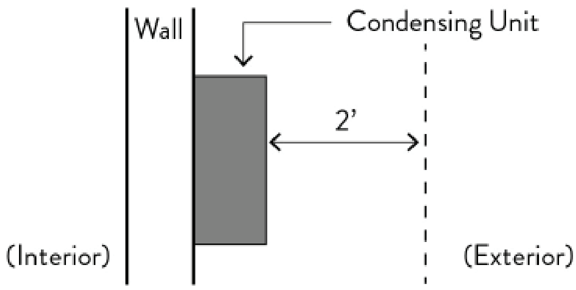
22.3.E. Unless otherwise stated in the manufacturer's specifications, the refrigerant line length between the indoor and outdoor unit of mini-split air conditioners must be less than 50ft with a maximum lift (height difference between the units) of 25ft.

22.3.F. When ductless split air conditioners are used, the outdoor condensing unit must be placed in an area where dirt and debris can be prevented from entering the unit.

i. To the best degree possible, a minimum 2ft clearance must be maintained around the outdoor condensing unit. Refer to Figure 22.c. for a diagram illustrating proper condensing unit clearance requirements.

ii. Locate mechanical cooling equipment in an accessible location for ease of maintenance.

Figure 22.c. Condensing unit clearance requirements



22.3.G. When ductless split air conditioners are used, a condensate drain must be provided with a collector or routed to the exterior away from occupants.

22.3.H. When window air conditioners are used, an adequate seal must be provided between the air conditioner and the window frame.

22.3.I. When centralized packaged air conditioners are used, the ventilation requirements of section 22 must be maintained at all times.

i. As with split-systems, central air conditioning units should be placed on the exterior to avoid heating interior or other occupied spaces as much as possible.

22.3.J. When centralized packaged air conditioners are used, access for maintenance and servicing must be provided. A minimum clearance of 3ft must be maintained on all sides of the unit.

22.3.K. When mechanical cooling is used with ventilation, the additional cooling load of the introduced outside air must be considered when sizing the unit, ensuring that the minimum thermal comfort and ventilation requirements are both met.

22.3.L. When mechanical cooling is used, the system must be tested and commissioned to ensure that the cooling and ventilation requirements (when using centralized packaged systems) are being met.

Other fan types for cooling

Window fans, panel fans, and ducted fans, as discussed in Section 20, can provide cooling in addition to ventilation by moving air throughout spaces and introducing cooler outside air.

22.3.M. When using fans for cooling, the ventilation requirements for each space type must be met.

i. Refer to Section 20 for ventilation standards and guidelines.

ELECTRICITY, LIGHTING & COMMUNICATIONS

CONTENTS

IMPACT

Properly designed and well-installed building systems are critical for health facility operation. Electrical systems must be carefully sized so that all systems powered in the facility can remain consistently operational while ensuring user safety.

Providing appropriate lighting in health care facilities is critical for task completion, and the health, safety, and comfort of patients and staff. Natural lighting should be optimized as a priority and then supplemented by artificial lighting where needed.

Communication systems are key for facilities to be able to exchange information within and outside the facility. Integrating safety systems such as security and fire alarms are also an important precaution for minimizing safety risks to building occupants in case of emergency.

PRIMARY USERS

Infrastructure Unit

Architects & Designers

Electrical Engineers

Contractors

GUIDELINES FOR USE

Chapters 23-26 include process diagrams to guide the user through critical electricity and lighting design decisions.

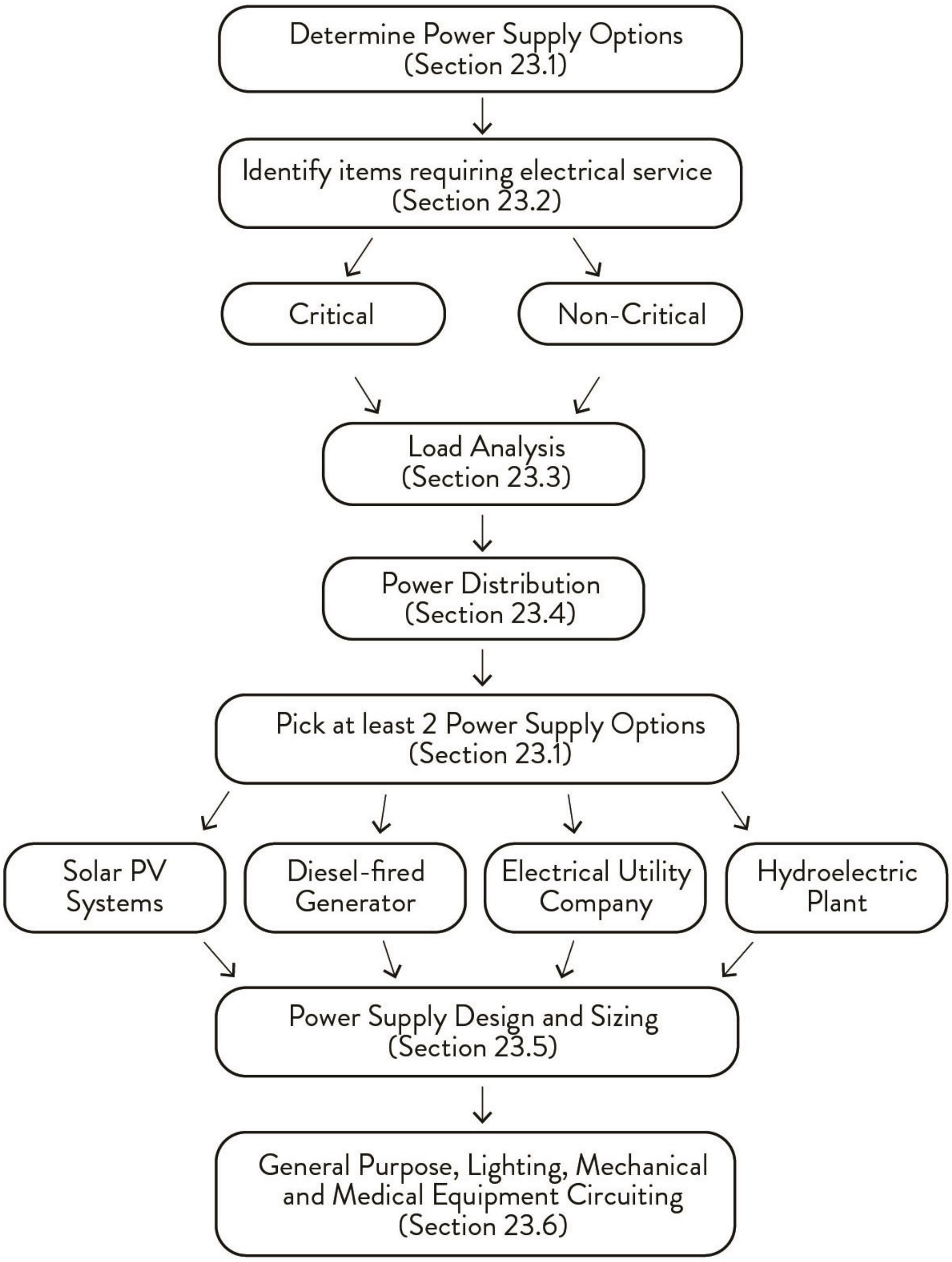
23 Electrical Systems

Building electrical systems must be properly designed and installed to prolong the life of the facility and maintain a safe environment for all users. For electrical systems to perform reliably, more than one source of power should ideally be utilized to ensure that power is always available for patient care.

In most cases, the degradation of an electrical system comes over time as modifications are made to the system. Therefore, the best way to prolong the life of an electrical system is to keep it simple. Key steps include:

- Evaluation of existing site conditions, including available electrical sources and electrical service options.
- Analysis of the proposed new facility as it pertains to electrical loads, and sizing of the new electrical service to accommodate those loads.
- Identification of critical and non-critical loads to ensure patient care is maximized when power supply is limited.
- Selection of systems that can be simply designed based on accepted industry standards, efficiently installed, and readily maintained.

Designing electrical systems can be a confusing process, but when broken down into simple steps it becomes very manageable. A step-by-step process for designing an efficient and functional system is provided below in Figure 23.a.


Determine Power Supply Options (Section 23.1)
Identify items requiring electrical service (Section 23.2)
Critical
Non-Critical
Load Analysis (Section 23.3)
Power Distribution (Section 23.4)
Pick at least 2 Power Supply Options (Section 23.1)
Solar PV Systems
Diesel-fired Generator
Electrical Utility Company
Hydroelectric Plant
Power Supply Design and Sizing (Section 23.5)
General Purpose, Lighting, Mechanical and Medical Equipment Circuiting (Section 23.6)

Definitions

- **Ampere(AMP):** Unit of electric current, or electric charge passing a point in an electric circuit.
- **Automatic transfer switch (ATS)**: A device that switches electrical load from one power source to another.
- **Battery**: Stores energy for supplying to electrical appliances when there is a demand.
- **Charge controller**: Regulates the voltage and current coming from the PV panels going to the battery, prevents battery overcharging, and prolongs battery life.
- **Critical loads**: Loads associated with building occupant safety and patient life support systems
- **Earthing/grounding**: Low resistance path to earth which allows electrical faults to flow safely to earth without harming users or equipment.
- **Equipotential**: The same voltage or no voltage between 2 points. A good grounding system eliminates voltage differences between 2 objects that may be simultaneously touched by a person, causing shock.
- **Fault current**: A fault on the electrical system is any abnormal electrical current. A fault typically occurs as a "short circuit" where phase-to-phase or phase-to-ground current bypasses the load and an enormous amount of current is released.
- **Franklin Lightning Protection System:** A lightning rod designed by Benjamin Franklin in 1749 and still used today around the world to protect buildings from lightning strikes.
- **Full Load Amps (FLA).** The current drawn by equipment after startup when running at full capacity.
- **Generator**: Diesel or gasoline-fired engine that produces energy by the turning of a piston.
- **Ground Fault Circuit Interrupter:** An electrical wiring device that disconnects a circuit whenever it detects that the current is not balanced between the energized conductor and the neutral conductor.
- **Horsepower (HP):** A unit of power approximately equal to 746 watts.
- **HVAC: Heating, ventilation, and air conditioning.**
- **Inverter**: converts DC output of PV panels into a clean AC current.
- **Minimum circuit amps (MCA):** The min. size conductor suggested by the manufacturer to feed equipment.
- **LEC**: Liberia Electricity Corporation.
- **Load shedding**: Manual or automatically turning off noncritical circuits to enable a standby system to cover all critical loads. Also used to prolong the runtime of critical loads for a given amount of backup power fuel.
- **Maximum overcurrent protection (MOCP):** The largest circuit breaker or fuse recommended by the manufacturer to protect a piece of equipment.
- **National Electric Code (NEC):** An international document with instructions for safely installing electrical systems.
- **NFPA**: National Fire Protection Agency.
- **Noncritical loads**: Loads associated with normal facility operation where power loss does not affect patient care.
- **One-line diagram**: A representation of an electrical system by means of single lines and graphic symbols showing the major components of the electrical system.
- **Power (Watt):** The rate energy is transferred in an electric circuit. Power (Watt) = Volts * Amps.
- **PV module**: Photovoltaic module, converts sunlight into DC electricity.
- **PV panel**: Photovoltaic panel.
- **Service panel**: Electrical panelboard where the building's point of service is established. Panelboards have earthing connections to an earth rod, steel structure, cold water pipe, etc. The neutral bus is bonded to ground bus to establish a zero potential for neutral wire.
- **Surge Protection Device (SPD):** Equipment designed to capture power surges, thereby protecting electrical distribution systems and equipment.
- **Underwriters laboratory (UL):** International company testing electrical equipment for safe operation.
- **Volt**: Electric potential between two points.
- **Voltage Drop**: The difference in voltage between two points in a circuit. Too much voltage drop leads to dim lights, poorly operating equipment, and early failure.
- **Weatherhead**: An electrical device that keeps water from entering a conduit.

23.1 Power Supply Options

Power is supplied to health facilities by the electric utility company or from on-site power producing systems such as generators. Available power options for each facility will differ; however there are generally 5 electrical system options:

- Service from a public electric utility company
- Diesel/Gasoline-fired generator
- Solar photovoltaic systems
- Hydroelectric plant
- Wind generation

23.1.A. **All facilities must have at least 2 sources of power for critical systems to ensure they remain energized. See Table 23.a for more information on critical systems.**

23.1.B. **Power sources must be selected based on site location and capacity requirements.**

i. As much as possible, all facilities must be provided with a diesel or gasoline powered generator. Reference Section 23.5 for generator sizing criteria.

ii. As much as possible, solar PV must be provided for selective systems as identified in Table 23.a. Methods for sizing solar PV systems are identified in Section 23.5.

iii. When LEC is available at a health facility site, it must be considered as one of the sources of electricity.

23.1.C. **In order to design the best energy system for a specific facility, existing site conditions must be thoroughly investigated and analyzed.**

i. Refer to Sections 8.7 and 9.2 for more information regarding electrical factors in site selection and master planning including:
   - Unobstructed solar access without significant areas of the roof shaded with trees, other structures or hillsides.
   - Easy access to potential generator areas for services and fueling.
   - Line of sight for HF radio communications.

Available Power Options

Electric Utility Company

The utility company in Liberia is the Liberia Electricity Corporation (LEC). Prior to the civil war, LEC provided electrical service to highly populated areas of the country and to some remote areas. After the destruction of the main hydroelectricity plant and subsequent looting of the plant and transmission lines, the LEC currently provides power to less than 10% of the Monrovia population.

When LEC is available at a health facility site, it should be considered as one of the sources of electricity. Even if the utility is the last choice for service due to high energy cost and power surges, it will be needed when solar PV and generators are not available due to weather conditions, darkness, fuel interruption, or equipment failure. The utility system can experience prolonged outages, however, so it should not be the only energy source for the facility.

If the LEC distribution system is not close to the selected location, it is often cost prohibitive to have it extended into the site. As part of the initial site analysis, the location of the LEC system needs to be identified.

Diesel or Gasoline Fired Generator

Diesel and gasoline fired generators are a common solution for powering a facility. These systems are reliable when properly installed, operated, and maintained. When any of these 3 factors are not properly addressed, the generator will fail prematurely. A generator can last 50,000 hours (over 5 years) when properly used. Typical items contributing to early failure include overloading, improperly installed intake and exhaust systems, lack of maintenance (spare parts not available or technical expertise is not available locally), fuel shortages, and bad fuel.

A generator's life will be shortened when the unit is lightly loaded. When sizing, understand which equipment will operate simultaneously and calculate the maximum load accordingly. In hospitals where loads can fluctuate a great deal, consider multiple generators to allow for staged operation.

Solar Photovoltaic Systems

Solar PV systems are an excellent alternative to both utility service and generators. A PV system requires little maintenance, has no moving parts, and is fueled by the sun.

Small Hydroelectric Plant

Another option to generate electricity is the use of water for hydroelectricity. By using the kinetic energy of moving water instead of diesel or gasoline to drive a generator, electricity can be generated by using a natural resource without producing carbon emissions.

Wind Generation

Wind generation is not readily used and is not considered a good energy solution. It has been selectively used in conjunction with a storage battery for exterior lighting. It is not a recommended source for healthcare facilities.

23.2 Electrical Applications

All equipment requiring electrical service can be placed into one of two categories: critical or non-critical. Non-critical loads are often referred to as normal power loads. Critical loads are those identified as lifesaving or life sustaining, such as blood bank refrigerators. This section describes the methods necessary to identify and design both critical and non-critical power systems.

23.2.A. Prior to the design of an electrical system, all items requiring electrical service must be identified.

i. Lighting, general purpose power (e.g. receptacles), medical equipment, mechanical equipment (e.g. fans and air conditioners), and plumbing systems (e.g. well pumps) must all be considered.

ii. The designer should interview all project stakeholders including the eventual owner/operator/users of the facility, the mechanical, plumbing and civil engineers, architect, medical equipment planner, and all other groups that may be providing equipment and systems needing electricity.

23.2.B. Identified electrical loads must be separated into noncritical and critical loads. (See Table 23.a.) The table identifies loads that may be encountered in all facility types, Hospitals, Health Centers and Clinics. Not all these loads will be present in each facility, but when they are, they shall be connected to the critical power system.

Table 23.a. Typical Critical Loads

Critical Lighting Loads	Critical Equipment Loads
<u>All Facilities</u> - All exit pathways and exit signs where applicable - Labor and delivery rooms <u>Health Centers + Hospitals</u> - Surgical, Post-Operative, Intensive Care Units (ICU) and Emergency Rooms - Lifts, if applicable - Nursing Stations - Communications/Equipment Rooms	<u>All Facilities</u> - Vaccine refrigerator - Well pump, if electric - Communication systems including HF radio and cell phone charging stations - Lab refrigerators for cultures, blood work, etc. <u>Health Centers + Hospitals</u> - All pharmaceutical refrigerators - Blood bank refrigerator - Suction pump - Equipment in the operating rooms - Cooling and ventilation in surgical rooms - Ventilation in Labor and Delivery, Post-Operative, ICU and Emergency Rooms if applicable - One lab work station <u>Hospitals only</u> - Sterilizer (autoclave) - One x-ray machine - Critical Care Patient Rooms where life support is provided

23.3 Electrical Load Analysis

Proper sizing of electrical equipment is required to maintain proper facility operation, minimize fire hazards, maximize safety, and account for future expansion.

23.3.A. A full load analysis must be calculated prior to the design of electrical systems to ensure the power distribution equipment is properly sized for the facility.

i. Reference Appendix E for typical electrical loads in healthcare facilities, and an example load analysis.

ii. Refer to Appendix O for calculation examples.

<u>Electrical Load Categories</u>

Loads are typically broken out into four categories: lighting, HVAC, medical equipment, and plug loads:

Lighting loads are easily calculated by taking the load per fixture and summing all lighting fixtures in a space. For preliminary design, a power density (W/SF) should be used since a detailed lighting plan will be developed later in the process.

HVAC loads vary depending on the final system being designed by the mechanical engineer. It is important to know both the equipment size and location. Although the overall load for a facility may be similar, a "centralized" HVAC system which concentrates most of the equipment in one location will require additional power in that same central location. Again, for preliminary design, a power density (W/SF) may be used to start equipment selection and space planning.

Medical equipment is often hard to secure at the time of design, but is still easy to predict. The loads can vary from a few watts to several kilowatts, and the voltage can vary from single phase to three phase. A list of typical medical equipment loads has been assembled in Appendix E.

Plug loads are very difficult to predict as a wide range of equipment can be supported off an outlet. Additionally, most equipment that is plugged into an outlet only uses its nameplate power when the device is in use. The continuous load can be only 10% of the nameplate.

23.4 Power Distribution

A well-designed electrical system will safely deliver power to end users and equipment. The system needs to be adequately sized to ensure proper operation as well as minimize safety risks to the facility and users. A well-organized system will allow for easy troubleshooting and maintenance.

23.4.A. Liberia is transitioning to a uniform service voltage and frequency. A 400/230 Volt, 3 Phase, 50 Hertz service voltage must be utilized for all medical facilities.

i. The service voltage for Health Centers and Hospitals must be 400/230 Volt, 3 Phase, 4 wire, 50 Hertz.

ii. Since Clinics are smaller and do not use much power, they can be served with a 230 Volt, 1 Phase, 3 wire, 50 Hertz service. This voltage is a derivative of the 3 phase system, which uses less expensive equipment.

23.4.B. All electrical distribution systems must comply with the latest edition of NFPA 70, National Electrical Code.

i. Key NFPA 70 tables have been summarized in Appendix F. They must be referenced as necessary to ensure safe and functional installations.

23.4.C. All electrical receptacles shall be rated for 230 volt, 50 hertz.

ii. Type A and B receptacles and plugs shall not be used.

iii. Type C and D shall be the default style, but this needs to be confirmed with the user prior to the completion of the design and final selection.

23.4.D. Electrical system hierarchies and load transfers must be determined prior to the initiation of any detailed electrical design.

Electrical System Hierarchies & Load Transfers

Electrical system hierarchies will be dictated by reliability, initial costs, and operating costs.

- Clinics and Health Centers: As a general rule, solar PV will be the primary energy system for Clinics and Health Centers. It has a higher first cost but is the most cost effective system to operate and very reliable when minimal maintenance is performed as recommended. The secondary choice of either generator or utility will vary based on the cost of utility service (kWh) and utility availability versus the cost of the generator, fuel, and maintenance of the generator.
- Hospitals: Hospital loads are too large to be served by a solar PV system. The primary source will either be generators or the public utility system, depending on availability and cost. Solar PV shall be considered for isolated loads such as the blood bank refrigerators.

Transferring loads from one source to another can be done manually or automatically. Ideally all transfers occur automatically to minimize downtime of key systems. Automatic load transfers can be an expensive installation and require a higher than normal understanding of electrical systems to safeguard the equipment and more importantly prevent injuries. Load transfers in Clinics and Health Centers are normally done manually, while Hospital load transfers are done automatically. See Figures 23.a.-d. for electrical one line diagram examples.

Figure 23.a. Generator/Utility

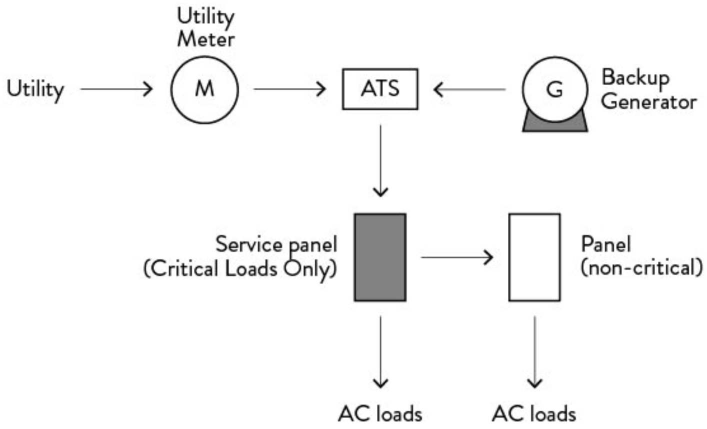


Figure 23.b Generator/Utility/Grid-Tied PV with Batteries

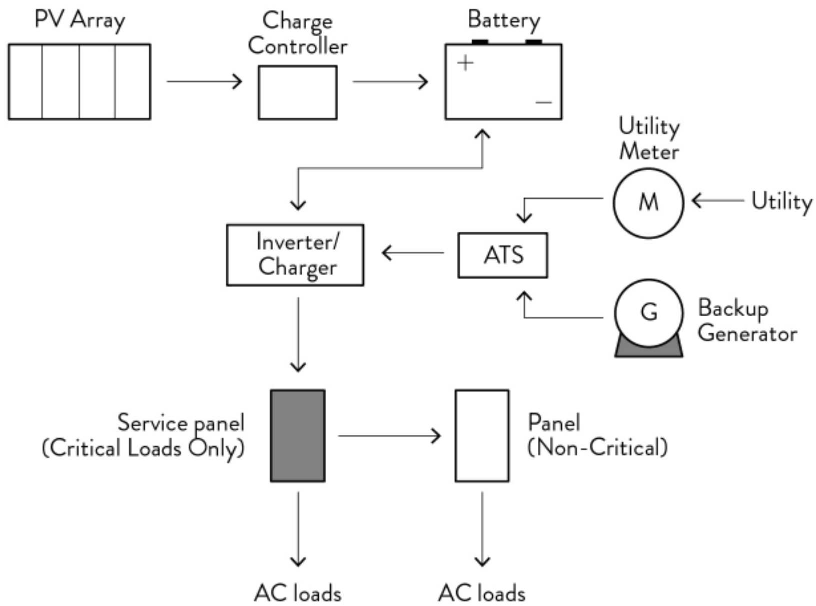


Figure 23.c. Generator/Utility/Grid-Tied PV without Batteries

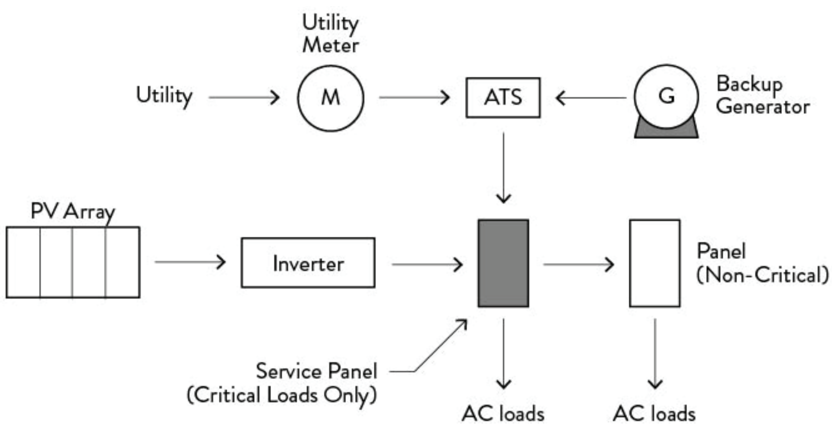
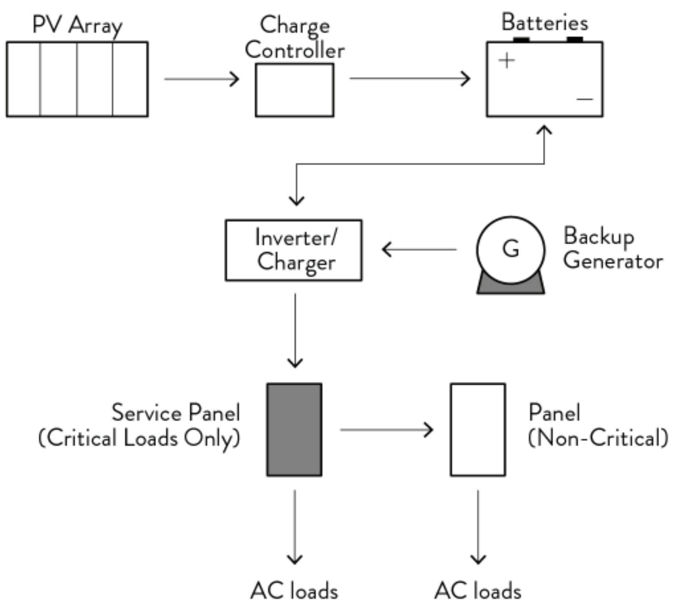


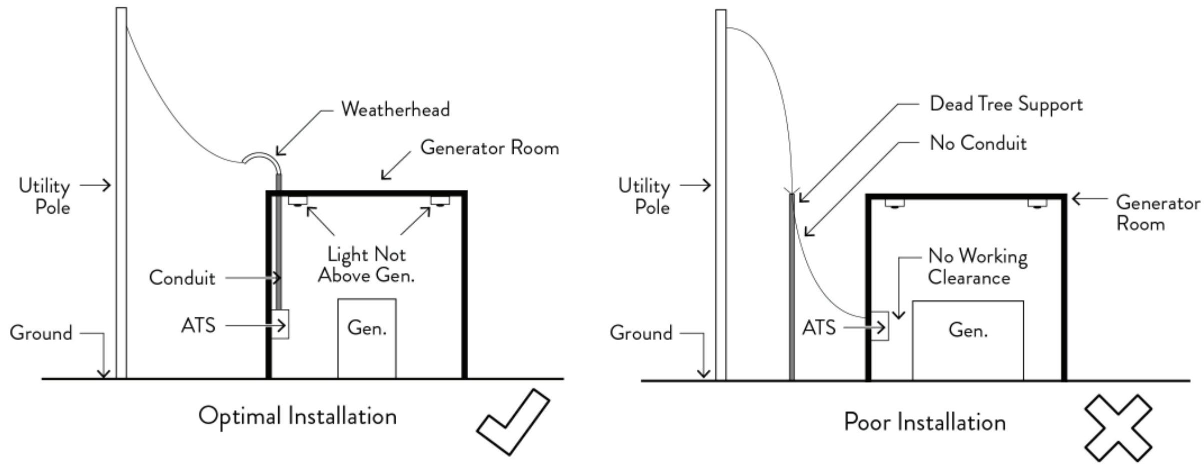
Figure 23.d. Generator/Off-grid PV System



23.4.E. Electric utility connections must comply with the requirements of the utility company.

i. Utility connections must be installed in a manner that prevents damage to equipment and minimizes safety risks. If utility connections are improperly installed, the chance for early equipment failure, fire, and injury to operators is very high. Reference Figure 23.e. for installation examples.

Figure 23.e. Electric Utility Connection



23.4.F. Electrical equipment must be selected to withstand the calculated available fault current.

i. Electrical equipment (panelboards, circuit breakers, transfer switches, etc.) must be rated to withstand the available fault current on the system. Refer to Appendix E for the calculation method used to establish the available fault current.

23.4.G. A load shedding scheme must be determined as part of the electrical design.

Load shedding

At times the energy required by a facility exceeds the available power source. This can occur when the only available source is the solar PV system, during a period when the utility is not available, and when the generator is down for maintenance. The electrical distribution system needs to be designed to keep the critical loads on-line during these conditions.

The one line diagrams in Figures 23.a.-d. identify two electrical panels labeled 'Service Panel (critical loads only)' and 'Panel (non-critical).' During periods of limited power availability, the non-critical panel can be isolated from the critical panel, allowing for these key critical loads to remain energized. It is vital that the designer identifies all critical loads and connects them to the critical panel.

Equipment energy requirements are designated in Amps and Volts or Watts. In order to properly size an electrical distribution system, the energy required for each device needs to be serviced from the system. Often times, the exact equipment is not known at the time of design so an estimate needs to be generated.

23.4.H. **The placement and location of electrical equipment must minimize cabling distance.**

Electrical Equipment Placement

The cost of electrical installations is greatly affected by the proximity of equipment. Placing a generator at the opposite end of a site from the utility connection point will increase cost and can introduce voltage drop problems. As can be observed in the typical one-line diagrams above, the following equipment relationships need to be carefully considered when designing a distribution system.

- Utility feeder and generator
- Generator and main distribution center
- Service panel and panelboards
- Panelboards and load

Figure 23.f. Typical Site Plan

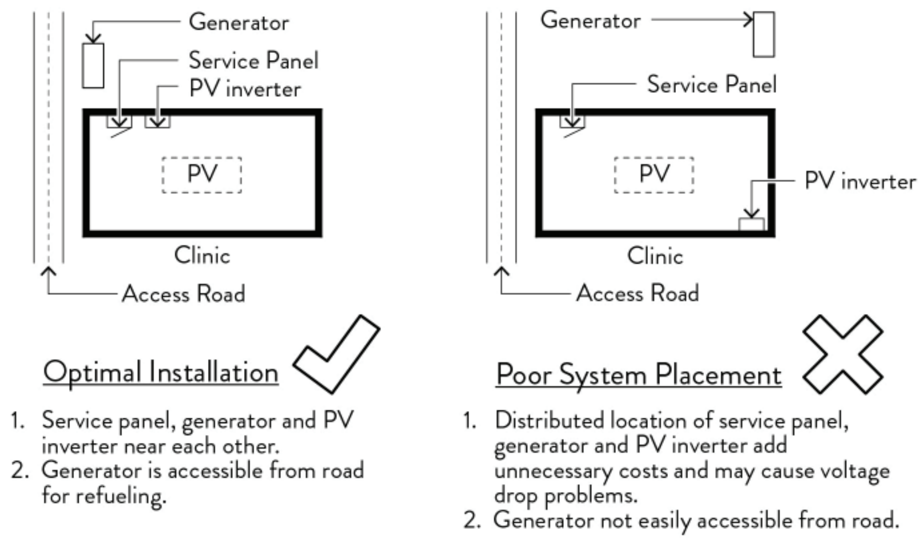
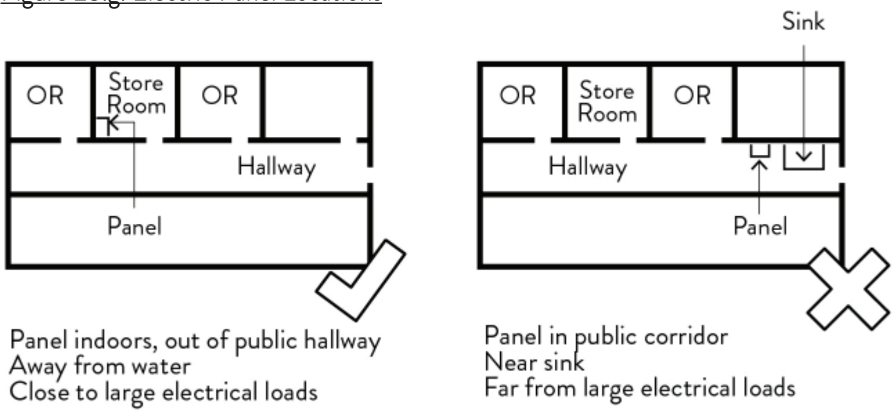


Figure 23.g. Electric Panel Locations



23.4.I. **Wiring must be sized properly to minimize voltage drop, which affects equipment performance and power loss.**

i. A maximum allowable voltage drop of 5% must be maintained from the service panel to the final outlet.

ii. If a sub panel is present, the voltage drop should be divided so that a maximum of 2% is maintained from the service panel to the sub panel and the remaining maximum of 3% is maintained from the sub panel to the final outlet. The chart in Appendix H provides the necessary information for conducting a voltage drop calculation and provides conductor sizes for typical loads and distances for 50-500 ft.

23.4.J. **Ground fault protection must be provided to protect users from low current ground faults.**

i. All receptacles with close proximity (20ft) to water must be equipped with ground fault interruption.

ii. Hospitals must contain ground fault protection per NEC 517.17 requirements.

23.4.K. **Overcurrent protection (circuit breakers) must be sized correctly to minimize fire hazards, damage to equipment, and to protect users.**

i. Use the following minimum size circuit breakers and conductors for general purpose loads, including receptacle and lighting circuits:
   - Hospitals: 20A breaker with 12 AWG conductors
   - Health Centers: 15A breaker with 14 AWG conductors
   - Clinics: 15A breaker with 14 AWG conductors

23.4.L. **Use nameplate ratings to size conductors and overcurrent protection on circuits feeding equipment.**

i. Size feeders based on MCA (minimum circuit ampacity). Refer to chart in Appendix I to select the next largest conductor that meets the minimum ampacity requirements.

ii. Size circuit breakers based on the MOCP (maximum over current protection). The MOCP is the manufacturer's recommended breaker used to operate the equipment.

iii. If the nameplate does not contain MCA/MOCP information and is only given in horsepower (hp), calculate MCA using the equation found in Appendix J. Refer to chart in Appendix I to select the next largest conductor that meets the minimum ampacity requirements.

23.4.M. **An earthing (grounding) system must be provided to protect people, structures, and equipment.**

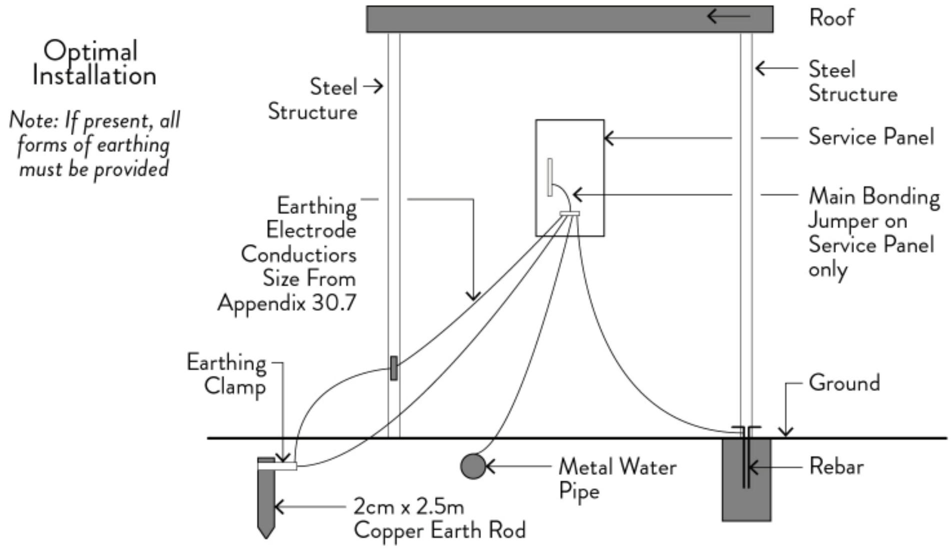
i. Where the electrical system enters a building, the following items must be bonded to the earthing bus: Earth rod, Steel structure, Rebar in foundation, Metal water pipe

ii. The size of the earthing electrode conductor must be based on the size of the incoming service conductors. Refer to chart in Appendix K to size the earthing electrode conductor.
iii. All other components in the power distribution system must be connected to the service panel earthing bus.
iv. All conduits must contain an earthing conductor along with power conductors. The size of the earthing conductor is based on the size of the overcurrent protection (circuit breaker) feeding the circuit). Refer to chart in Appendix K to size the earthing conductor.
v. Critical equipment must also have a connection to the earthing system. At the point of electrical connection to the equipment, provide an earthing jumper to the equipment structure itself to effectively earth the equipment.

Earthing Systems

Earthing and grounding shall be considered the same in this document.
The leading cause of equipment failure is the lack of an earthing system. The proper design and installation of an earthing system is a fundamental requirement for all structures and electrical systems. Effective earthing systems protect people from electrical shock and provide an effective route to earth for electrical currents. All electrical equipment requires an earthing system. The most important feature of an earthing system is establishing an equipotential point at the service panel. Figure 23.h. depicts the key elements in a properly installed earthing system.

Figure 23.h. Key elements in earthing systems



23.4.N. **A lightning protection system must be provided for all Hospitals and a surge protection system must be provided for all Hospitals and Health Centers.**

i. Liberia is in a high lightning flash density area, subjecting the electrical distribution system to extreme damage and interruption of life sustaining electrically operated medical equipment.
ii. The system shall be a Franklin style and designed to comply with UL 96A.
iii. A Type 1 surge protective device (SPD) shall be provided on the electrical service entrance at Hospitals and Health Clinics. The SPD shall be UL 1449 compliant.
iv. Both of the Underwriter Laboratory (UL) references are international standards. If the systems do not comply with UL, they may be substandard and may not provide the necessary protection of the electrical distribution system.

23.5 Power Generation and Storage

It is imperative that the correct procedures are understood and followed to ensure that power generation systems are properly designed and specified. Undersized systems will lead to early failure while oversized systems can fail early and waste construction and operating resources.

Generators

Improper installation of generators always leads to early failure of the equipment. Care must be taken during the design to provide the equipment the best possible chance to last as long as possible.

23.5.A. Generators must be sized based on calculated demand load including anticipated future loads (within 24 months) plus 25%. Use the chart provided in Appendix L.

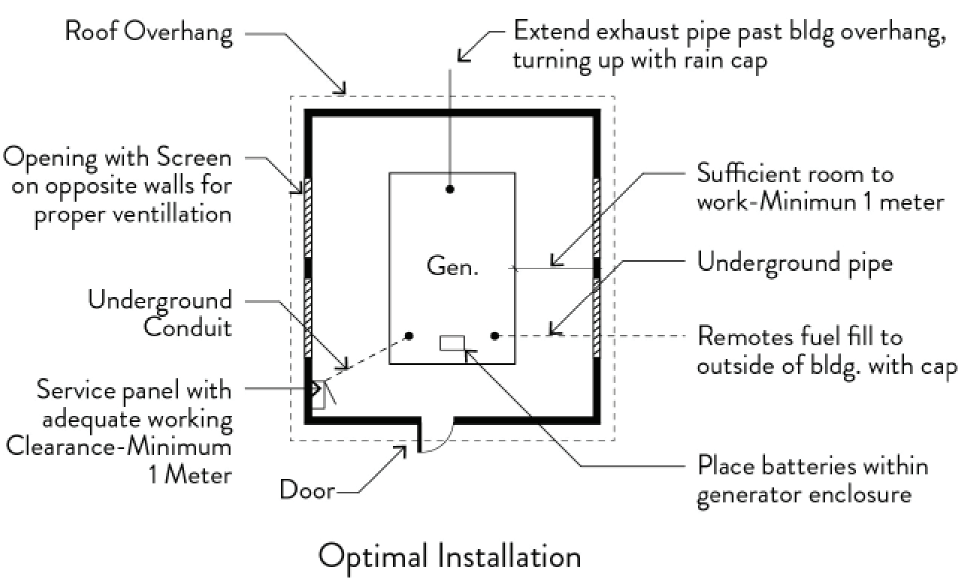
i. Fuel tank size must be carefully considered when specifying a generator. It is recommended that a base tank be provided and an elevated standalone tank sized for 14 days of fuel and positioned for gravity flow into the base tank.
ii. The elevated tank must auto fill the base tank.

23.5.B. Generators must be installed to all of the following standards:

i. The exhaust system must be sized as required by the manufacturer, must extend out of the enclosure past all rooflines, and must have a rain cap.
ii. Fixed intake air vents sized per manufacture instructions must be provided.
iii. Batteries must be installed in manufacture approved enclosure.
iv. Conduits must be installed underground or overhead, not across the floor.

23.5.C. Generator rooms must be properly ventilated to avoid overheating and equipment failure.

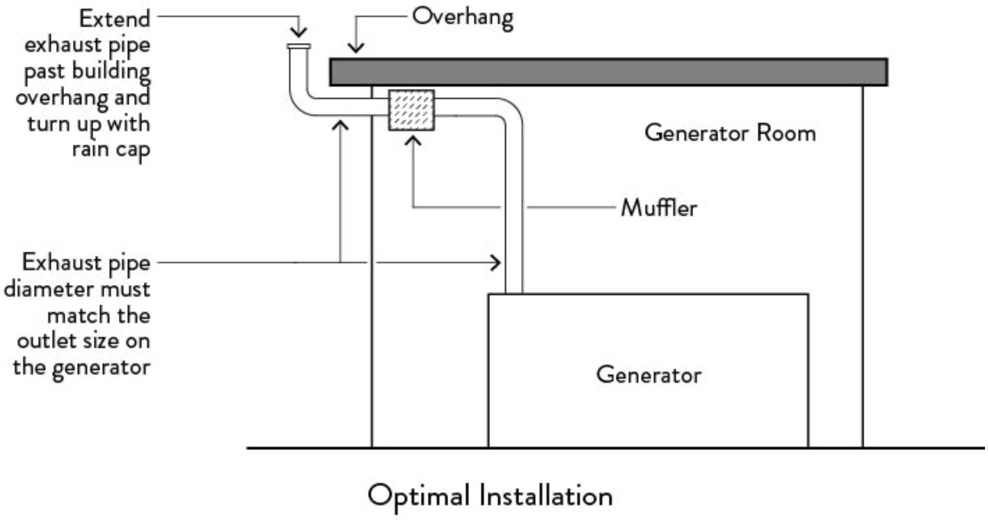
Figure 23.i. Recommended generator room layout



23.5.D. **At a minimum, generator exhaust pipe diameter must match the outlet size on the generator.**

i. Do not reduce size of exhaust piping. See Figure 23.j. for proper generator exhaust piping.

Figure 23.j. Generator Exhaust Piping



Photovoltaic Systems

Solar PV is essential for the operation of life-sustaining systems in healthcare facilities. When properly installed and maintained, a PV system should operate for at least 25 years. Batteries will need to be replaced after 5-7 years and the charge controller may fail after 10 years. Because the electrical grid is currently very limited throughout Liberia, PV systems are especially important for rural facilities. PV systems can be arranged to power individual loads (like EPI vaccine storage in clinics) or grouped together in a larger system to power an entire facility.

A PV system is very desirable because it has no moving parts and requires very little maintenance. However, to ensure proper operation for the life of the system, a few minor maintenance procedures should be followed on an annual basis.

23.5.E. **A solar PV system must be provided for all critical systems in Clinics and Health Centers.**

i. Identify critical medical equipment such as blood bank refrigerators and suction pumps.
ii. Locate key areas where lighting is necessary to maintain basic healthcare such as Operating Rooms, Labor and Delivery, ICU, and Post-Operative Care.
iii. Reference Appendix M for Solar PV sizing criteria.

23.5.F. **Solar PV panels may only be roof mounted when the following conditions are met:**

i. PV panels may be roof mounted on new facilities only if the roof is specifically designed for the load and proper details are developed for sealing all mounting points and penetrations.
ii. When a solar PV system is provided for an existing facility, it can be roof mounted only if a structural engineer determines that the roof can support the system, or that the roof can be modified to support it, and details are developed for the mounting points and penetrations.
iii. When PV panels cannot be roof mounted, they must be mounted on poles.
iv. Ground mounted systems are not acceptable due to security concerns.

23.5.G. Solar PV systems must be designed to the following standards:

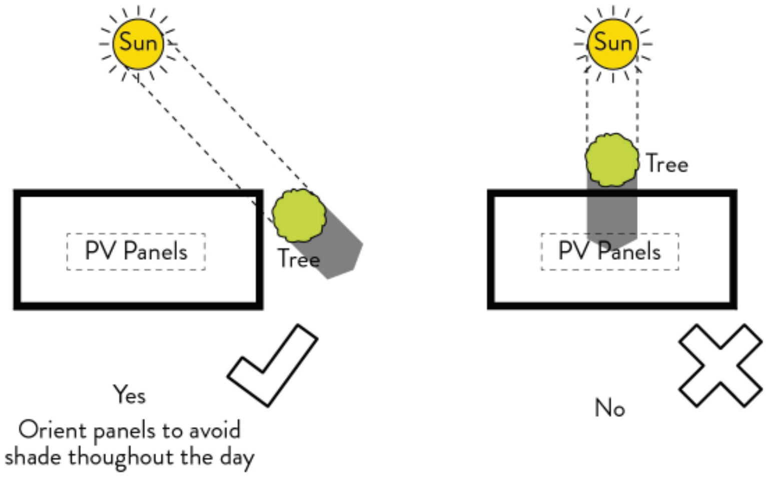
i. Place panels to minimize shading incident on the panel. Even a small amount of shade on a portion of a panel will affect the power production of the entire system. See Figure 23.k. for PV orientation.

ii. Estimate the maximum allowable rated system size for a given area of roof.
System size (W) = Roof Area (m^2) x (100 W/ m^2)

iii. Estimate the rated power produced by the system.
Rated annual output (kWh) = Roof Area (m^2) x (sunhours/m^2/day) x (365 days/year)
(Use 4.8 sunhours/m^2/day for Liberia)

iv. Compare the maximum allowable system based on the calculation for required electrical service size. Reduce the plant size if the system produces more energy than required. If the maximum system size calculated is not adequate, consider additional panels mounted on poles.

Figure 23.k. Solar PV Orientation



23.5.H. Solar PV systems must be installed to the following standards:

i. Install panels so there is at least a 5% slope up to 25% to ensure rainfall or washing can properly flow off the panel.

ii. Install panels at least 6in off of roof surfaces to allow proper ventilation around panels for adequate cooling.

iii. All panels in the array must have the same orientation and tilt. Mixing panel orientation and tilt affects the string's combined voltage and reduces the amount of power produced by the system.

iv. The system output shall be 230 volt, 50 hertz.

PV Placement and Orientation

In Liberia, which is located near the equator, the optimal orientation for solar PV panels is a 5% south-facing angle. If the building roof lines do not face south, east or west facing at 5% are the next best options. A northern orientation will work with a small drop off in performance, but it should not be disregarded if it is the only option.

23.5.I. Solar PV systems must be maintained to the following standards.

i. Clean the surface of all PV modules every 6 months during the wet months and every month during the dry dusty season..

ii. Ensure earthing system is continuous and maintained.

iii. Clean all battery terminals every year.

iv. Ensure inverter and battery room is well ventilated.

Storage Systems

Incorporating an on-site power storage system (battery plant) will allow a facility to fully utilize all the power generated from its photovoltaic system. Storage systems allow the facility to remain operational beyond daytime hours.

23.5.J. At a minimum, Clinics and Health Centers will need adequate storage to continuously operate the EPI refrigerator and minimal interior and exterior lighting for nighttime deliveries.

23.5.K. Battery systems must be placed in a temperature controlled environment.

i. As much as possible, batteries must be stored in spaces kept under27 degrees C. The rated capacity of a battery is based on an ambient temperature of 25 degrees C. Battery life is greatly reduced when the ambient temperature exceeds this. Place the battery plant in a ventilated room away from all heat generating equipment to get as close the 27 degrees as possible.

23.5.L. Zero maintenance sealed batteries shall be utilized for all facility types. When not available, utilize a wet battery.

Battery Characteristics

A sealed battery has the electrolyte completely enclosed within its case while a wet battery allows access to the electrolyte for maintenance.

Advantages of sealed batteries:

- Electrolyte is completely enclosed and will not spill acid if tipped.
- Minimal maintenance.
- Can be placed in any position.

Advantages of wet batteries:

- Lower cost.
- Larger capacity per pound.
- Good ability to dissipate heat.

23.5.M. Select a battery charger based on the battery type used.

i. Battery chargers must be compatible with the selected battery type to avoid battery damage caused by overcharging and overheating. Dual mode chargers are preferred as they provide a fast charge, but will not cause an overvoltage situation resulting in battery failure.

23.6 Systems Circuiting

Each space within the facility has its own unique needs to ensure proper devices (receptacles, lighting, HVAC, equipment, etc.) are provided to meet the uses of the space. Knowing the demands of the building will help designers provide the proper amount of power to the appropriate spaces in the building.

23.6.A. At a minimum, provide receptacles and circuiting to each room as shown in Table 23.b. For information on requirements by program element, see Standard 46.2.A.

Table23.b. Receptacle locations

Class	Description	Receptacle Quantity	Circuiting	Normal Power	Critical Power
Class 1	Public Areas & Stockrooms	2 total, both at 12in above the floor, located on opposite walls.	12 receptacles per circuit	X	
Class 2	General Clinical	Minimum 1 per wall or 1 every 26ft, whichever is greater, at 12in above the floor, plus program specific requirements.	8 receptacles per circuit	X	
Class 3	Nursing Stations	1 every 10ft at 12in above the floor, plus program specific requirements.	8 receptacles per circuit		X
Class 4	Intensive Clinical	2 every 10ft at 12in above the floor, plus program specific requirements.	12 receptacles per circuit		X
Class 5	Administrative	2 total located on opposite walls of the room at 12in above the floor.	6 receptacles per circuit	X	
Class 6	Special Circumstances	Determined by room. (See Chapters 47-50.)	12 receptacles per circuit		X

23.6.B. A portion of the lighting system must be placed on critical power to ensure users can safely exit the building in an emergency.

i. Illuminated exit signs must be provided throughout each facility and connected to critical power to assist in proper building egress.

23.6.C. Each room in a facility must have local lighting controls to turn lights off when sufficient daylight is present.

i. Refer to Section 24.4 for additional requirements.

23.6.D. Dedicated circuits must be provided to all HVAC equipment. This includes, but is not limited to air conditioning, exhaust fans, pumps, etc.

23.6.E. Provide a local disconnect switch next to each piece of HVAC equipment.

Local Disconnects

A local disconnect ensures that maintenance can be safely conducted while knowing the power has been disconnected to the equipment. If a local disconnect is not provided, equipment may be unknowingly energized when someone is working on the system. Local means of disconnect include:

- Plug and cord to nearby receptacle; and
- Disconnect switch adjacent to equipment.
- Circuit breakers feeding equipment are not considered a means of disconnect unless they can be locked in the off position while conducting maintenance.

23.7 Equipment Selection and Installation

Properly selected equipment will drastically prolong the life of the installation and ensure correct operation of the system. Equipment that is not properly selected or installed can also lead to unsafe conditions including fire hazards and electrical hazards.

23.7.A. All electrical equipment must be approved for its intended application.

i. Use equipment and material that is certified by a testing agency built to industry standards (UL, NEMA, etc.).

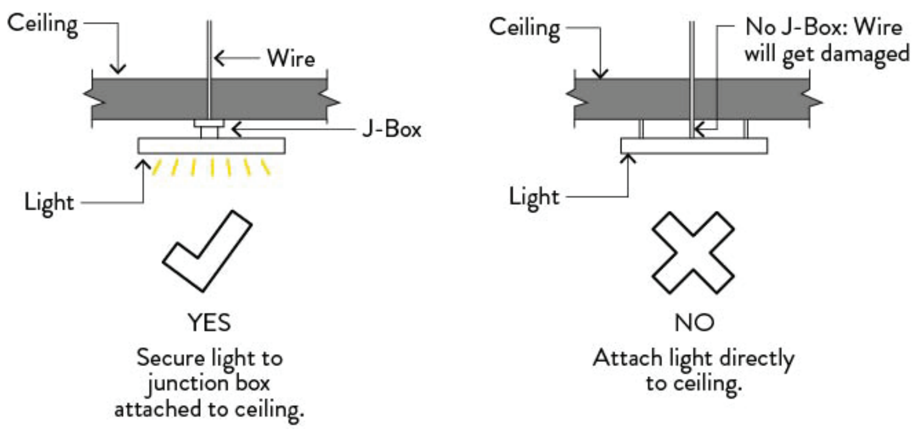
ii. Where possible, select equipment that is backed by a manufacturer warranty. Equipment with warranties must be installed per manufacturer's requirement to ensure the warranty is not voided. Standard warranties include:
   - Light fixtures and ballasts: 1 year
   - Generator: 5 years
   - PV panels: 25 years
   - PV inverters: 5 years

iii. Ensure junction box fill is not exceeded. See Appendix N for junction box fill information.

23.7.B. All electrical equipment must be installed as directed by manufacturer instructions.

i. Pay careful attention to the correct application and installation of a product or device. See Figure 23.I. for device installation examples. Electrical equipment is often misused, leading to a diminished useful life and creating electrical hazards.

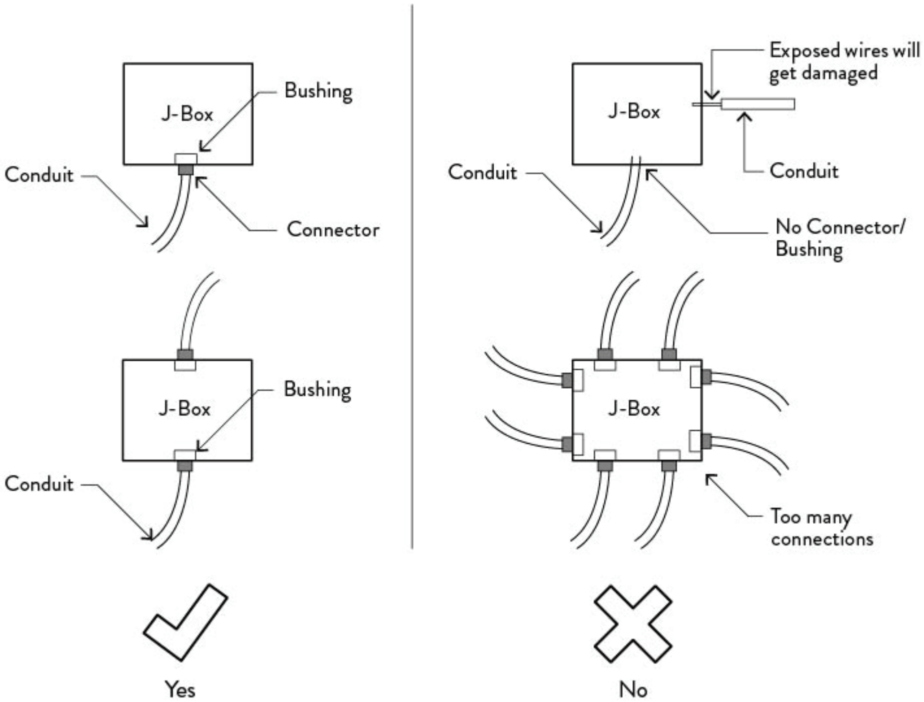
Figure 23.I. Typical Lighting Device Installation Requirements



23.7.C. **There must be a maximum of 4 conduits entering a junction box.**

i. To ensure that the conductor bending radius and conductor fill is not exceeded , the number of conduits entering a junction box must be limited.
ii. The use of proper connectors and bushings will eliminate conductor damage at junction box entry.
iii. See Figure 23.m. for device installation examples.

Figure 23.m. Typical junction box connectors



23.7.D. **Electrical installations must be installed in a safe, neat, and organized manner to minimize electrical hazards.**

i. Electrical conductors must be installed in conduit.
ii. Conductors must be properly sized to avoid overloading and premature failure, and they must be installed in conduit.
iii. Electrical conduit must be properly sized and used as intended by the manufacture.
iv. Conductors must be properly terminated and enclosed.
v. Equipment must have adequate fault current rating. See Section 23.3 for fault current calculation methods.

23.7.E. **Ensure spare parts are accessible for future system maintenance.**

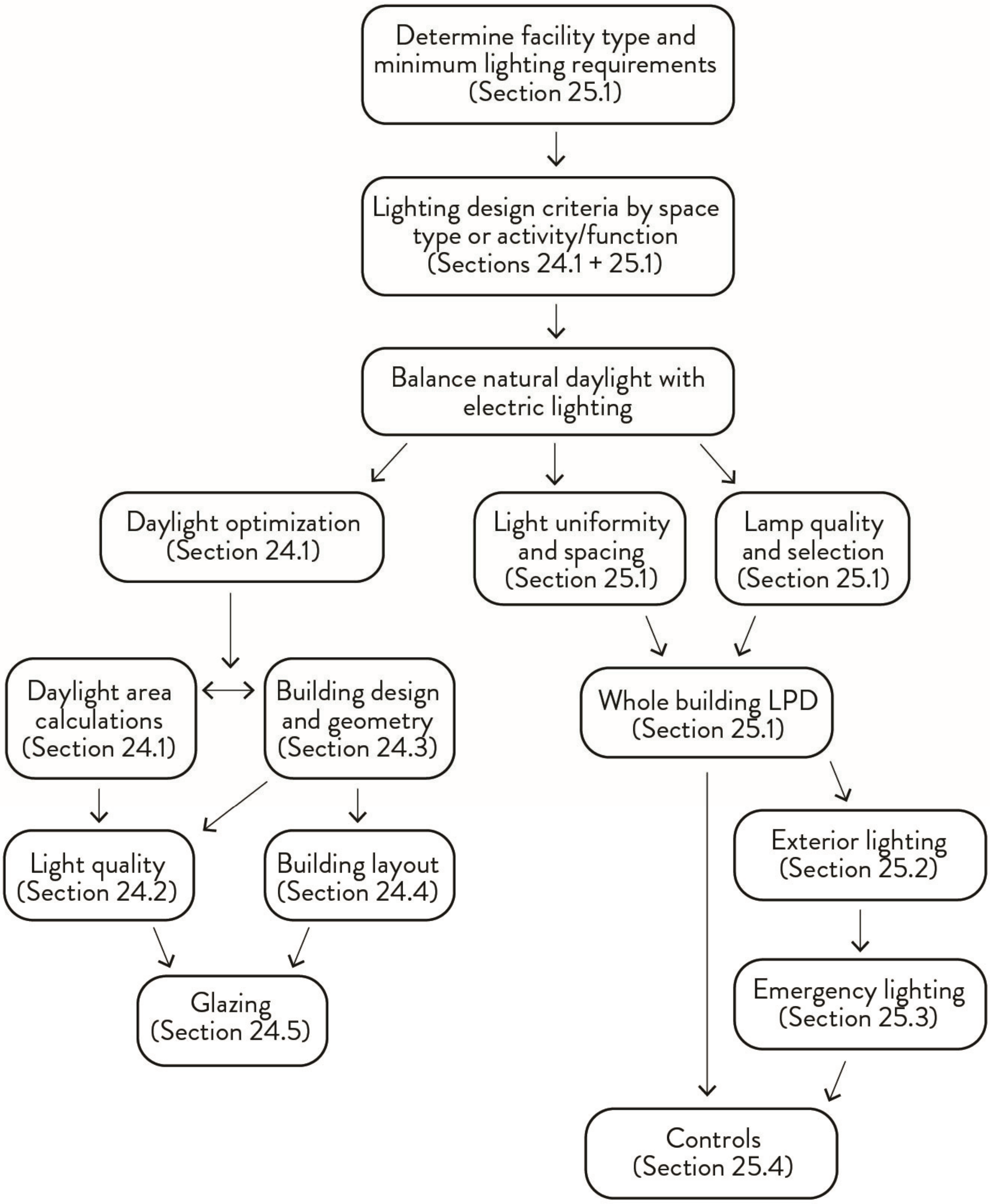
i. The following spare parts must be provided:
   - Lighting equipment: lamps and ballasts
   - Overcurrent protection devices: circuit breakers and fuses
   - Generator components: filters (air, oil, gas) and spark plugs

24 Daylighting

Natural daylighting design allows visible light from the sun to enhance a building's interior illumination, eliminating or complementing electrical lighting, reducing electrical energy costs and grid reliance, and improving occupant health and comfort. Studies have shown that effective use of daylighting can improve productivity, enhance moods, boost morale, lower fatigue, reduce eyestrain, and hasten healing.

Definitions

- **Glare**: A very harsh, bright light causing discomfort.
- **Glazing**: Panes or sheets of glass set or made to be set in frames for windows, doors or skylights.
- **Illuminance:** The amount of luminous flux per unit area measured in lumens per square feet [1 lumen/ft^2 = 1 footcandles (fc), 1 lumen/m^2 = 1 lux].
- **Solar gain (solar load):** The amount of thermal heat energy (temperature) on a surface or in a space caused by solar radiation from the sun.
- **Solar heat gain coefficient (SHGC):** The amount of solar thermal energy passing through glass.
- **Visual Light Transmittance (VLT)**: The proportion of visible light that passes through a glazing system relative to the incident light on that glazing system, expressed as a percent


Determine facility type and minimum lighting requirements (Section 25.1)
Lighting design criteria by space type or activity/function (Sections 24.1 + 25.1)
Balance natural daylight with electric lighting
Daylight optimization (Section 24.1)
Light uniformity and spacing (Section 25.1)
Lamp quality and selection (Section 25.1)
Daylight area calculations (Section 24.1)
Building design and geometry (Section 24.3)
Whole building LPD (Section 25.1)
Light quality (Section 24.2)
Building layout (Section 24.4)
Exterior lighting (Section 25.2)
Emergency lighting (Section 25.3)
Glazing (Section 24.5)
Controls (Section 25.4)

24.1 Daylight Optimization

Daylight optimization is a process that accomplishes a balance between sufficient light from the sun combined with electric lighting where needed, while minimizing solar heat penetration which results in increased cooling demands. This balance is very important to consider, because while both daylighting and solar load reduction are desirable, they can contradict one another. Windows, skylights, and shading devices are generally the most important elements to consider when designing daylight systems for a building. Space use, building location/orientation, and project budget are also important elements to consider.

24.1.A. When designing new facilities a daylight optimization process must be established that addresses the need for lighting.

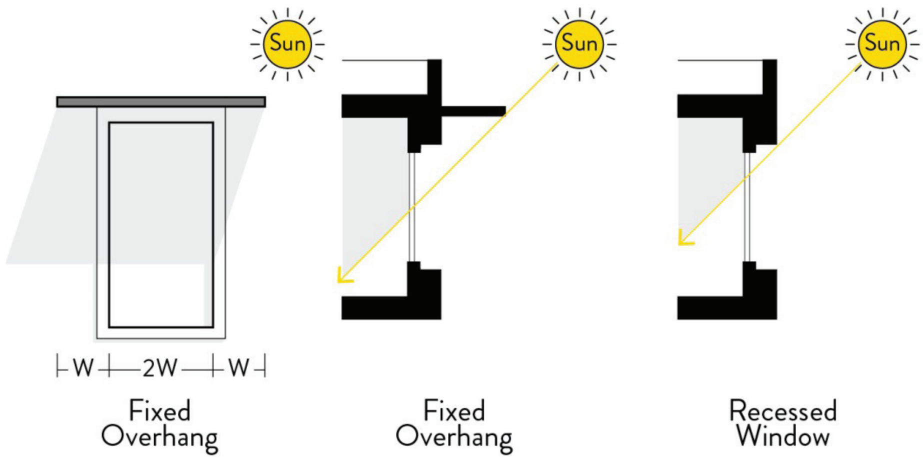
i. Windows and skylights must be selected in order to balance their daylight and thermal properties.

ii. Shading devices must be designed to optimize daylight allowance while blocking or redirecting as much direct solar penetration as possible (Refer to Figure 24.a.). Since Liberia is so close to the equator, direct sunlight will primarily come from the east and west as the sun rises and sets. Facilities should avoid direct solar penetration on the east and west facades, which will lead to increased solar gains, increased cooling loads, and increased glare and visual discomfort.

iii. Light colored interior (e.g. wall and ceiling color) and exterior (roof color) finishes must be selected so that light is easily reflected off of surfaces.

iv. Lighting and daylighting controls must be integrated such that electric lighting is on when natural light levels are not sufficient, and either dimmed or turned off when natural light levels are sufficient. For light levels by space function, refer to Table 24.b.

Figure 24.a. Shading Device Depth Calculation



24.1.B. The balance between daylight optimization and solar load reduction must be considered.

i. Space conditions must provide enough light for occupants to easily see their task without laboring, while also maintaining thermal comfort so that occupants are not too hot or too cold.

ii. Refer to Table 24.a. for lighting design criteria and Chapters 21-22 for thermal comfort design criteria.

24.1.C. Prioritization must be given to utilizing daylighting where possible before incorporating supplemental electrical lighting to meet specific operational standards.

24.1.D. **Daylighting levels must be appropriate to the usage of the space and expected activity level. A desired illuminance level is one which allows the occupant to comfortably see his or her task without straining the eyes.**

i. Refer to Table 24.a. for equivalent outdoor illuminance levels, which may be used in the absence of a daylight measuring tool.
ii. Refer to Table 24.b. for typical illuminance levels based on activity.

Table 24.a. Typical Exterior Illuminance Levels

Exterior Condition	Illuminance (fc)
Direct Sunlight	10,000
Full Daylight (blue sky)	1,000-2,000
Overcast Day	100-500
Twilight	1-10
Full Moon	0.01
Quarter Moon	0.001
Starlight	0.0001

Table 24.b. Typical Interior Illuminance Levels

Activity/Function	Illuminance (fc)
Working areas where visual tasks are occasionally performed	5-15 fc
Easy visual tasks	25 fc
Moderate visual tasks	50 fc
Detailed visual tasks	100 fc
Very detailed visual tasks	200 fc

24.1.E. **75% of spaces with recommended illuminance values greater than 50 fc must be within primary daylit areas.**

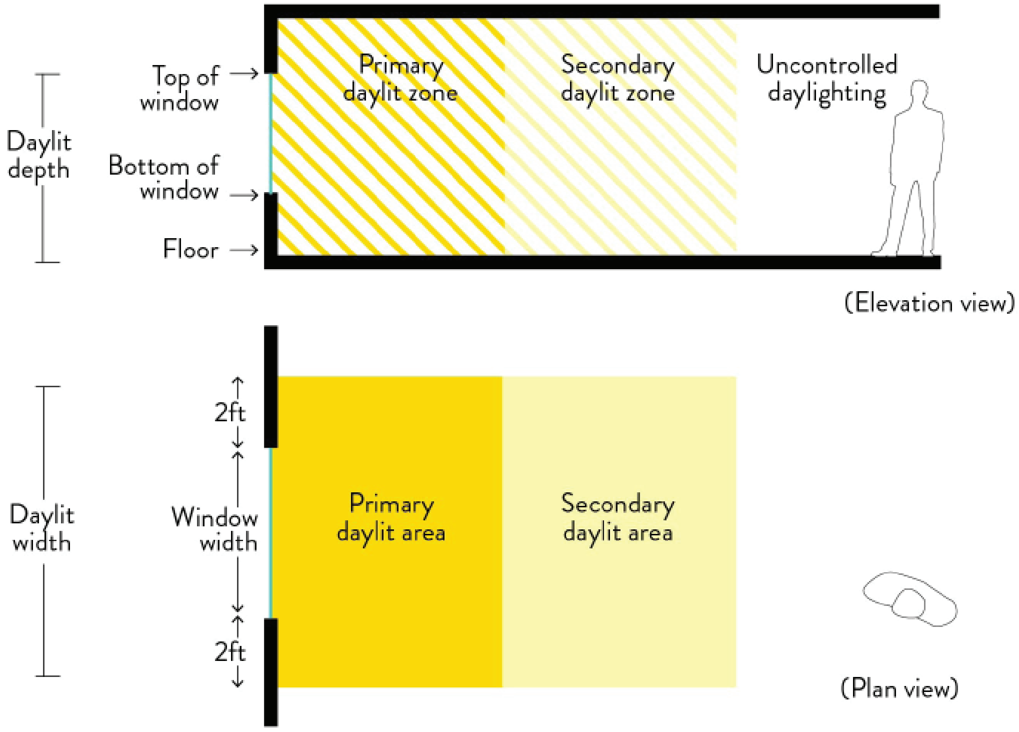
24.1.F. **75% of spaces with recommended illuminance values greater than 10 fc must be within either primary daylit areas OR secondary daylit areas.**

Daylit area calculations

Primary daylit areas can be measured using the following calculation:
Primary Daylit Area = Daylit Width x Daylit Depth
Secondary daylit areas can be measured using the following calculation:
Secondary Daylit Areas = Daylit Width x Daylit Depth x 2

where Secondary Daylit Width = width of the window plus 2ft (61cm) on each side of the window, and Daylit Depth = distance from the floor to the top of the window.*
**This calculation assumes that the distance from the floor to the bottom of the window is no greater than 3.25ft (99cm), and that there are no permanent vertical obstructions higher than 5ft (1.5m) in the daylit area.*

Figure 24.b. Primary and Secondary Daylit Area



24.2 Light Quality

While high levels of natural daylight in buildings is desirable, the quality of light is also very important to consider. Occupant discomfort may be reported if certain characteristics of the natural light are either in excess or otherwise undesirable. Sky conditions contribute to the color, intensity and distribution of light. In general, indirect ambient natural daylight under clear sky conditions will present quality interior illumination levels.

24.2.A. **Space function must be considered, as some space types require higher levels of lighting than others.** For light levels by space function, refer to Table 24.b.

24.2.B. **Glare reduction must be considered by minimizing the contrast in luminance between the glare source and its surroundings.**

Glare reduction

Discomfort due to glare is caused by a high or non-uniform luminance distribution within the visual task area or by high contrasts of luminance between the glare source (usually the window) and its surroundings. The recommended solution for glare reduction entails balancing light sources with adjacent surfaces

24.3 Building Design and Geometry

There are very effective ways to manipulate building geometry in order to maximize natural daylight while minimizing direct solar gain. Window location, light shelves, sloped ceilings and shading devices can help to achieve this balance.

24.3.A. Optimize the building geometry in such a way that minimizes direct solar gain while admitting daylight.

i. When possible, allow daylight penetration high in a space. Windows located high in a wall or in roof monitors and clerestories will result in deeper light penetration and reduce the likelihood of excessive brightness.

ii. Reflect daylight within a space to increase room brightness. A light shelf, if properly designed, has the potential to increase room brightness and decrease window brightness. (Refer to Figure 24.c.)

iii. Consider sloping ceilings to direct more light into a space. Sloping the ceiling away from the fenestration area will help increase the surface brightness of the ceiling further into a space and reflect light down into occupied areas. (Refer to Figure 24.d.)

iv. Avoid direct beam sunlight on critical visual tasks such as treatment areas or nurse stations. Poor visibility and discomfort will result if excessive brightness differences occur in the vicinity of critical visual tasks.

v. Filter daylight. The harshness of direct light can be filtered with vegetation, curtains, louvers, or the like, and will help distribute light.

vi. Understand that different building orientations will benefit from different daylighting strategies; for example, light shelves—which are effective on south facades—are often ineffective on east or west elevations of buildings. In general, overhangs are most effective on North and South exposures, and vertical fins are most effective on East and West exposures. If applicable, coordinate natural daylighting design and building orientation with natural ventilation design and prevailing wind direction.

Figure 24.c. Light Reflection and Light Shelves

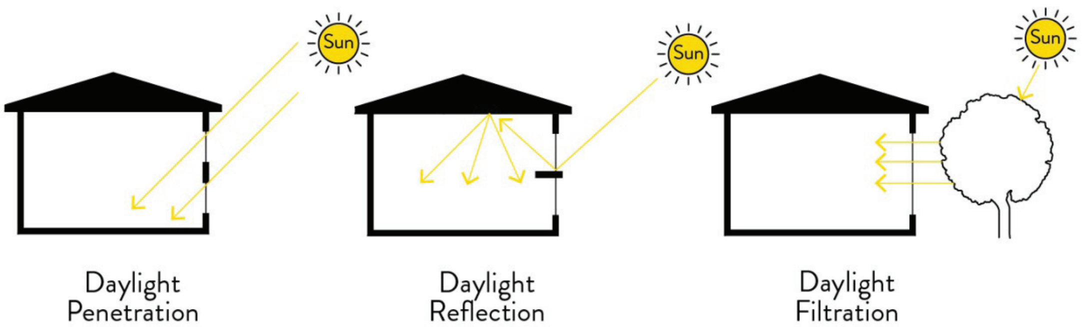
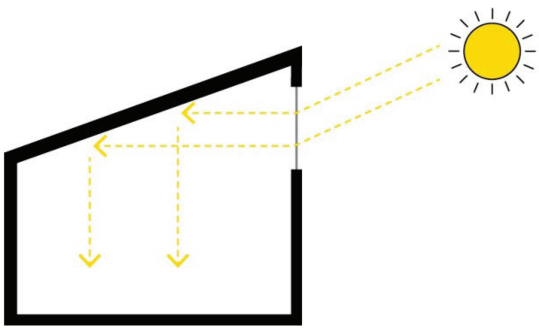


Figure 24.d. Sloped Ceilings for light reflection



24.4 Building Layout

As with its orientation, a building's layout greatly affects its daylighting performance. Spaces requiring natural daylight should be placed at the perimeter, and interior surfaces should be minimized in order to allow more light into the interior.

24.4.A. **Room areas, locations, and interiors must be carefully placed in order to optimize natural daylighting.**

i. Building floor plans must be developed to allow all rooms access to natural daylight unless specific room uses prohibit use of daylight (e.g. x-ray).

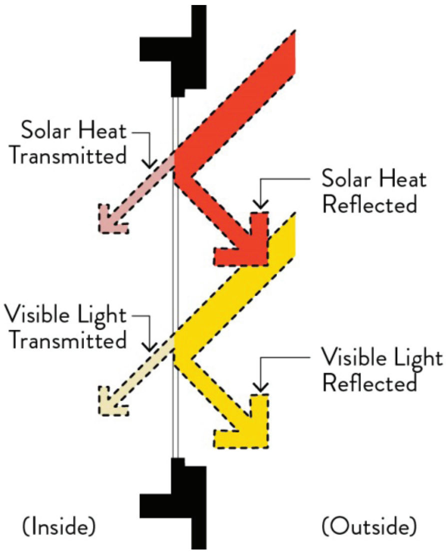
ii. Place spaces requiring the most natural daylight at the building perimeter, unless it is assumed that daylight from a skylight will suffice to light an interior space.

iii. Position interior surfaces such as partitions and furniture such that daylight is able to pass through. Do not block windows or openings with furniture.

24.5 Glazing

When selecting glass to incorporate into natural daylighting design it is very important to know that all windows and skylights have an associated Visible Light Transmittance (VLT), which is a value characterizing the amount of visible light allowed to pass through the glass. The difficulty is finding the desirable VLT (too high can result in glare, too low can result in low light and reduced views) and balancing it with the associated Solar Heat Gain Coefficient (SHGC), which indicates the amount of solar thermal energy also passing through the glass (Refer to Figure 24.e.). In the absence of available VLT and SHGC information for glass selections, double-pane windows have a more balanced visual and thermal performance when compared to single-pane windows, and wood-frames, when appropriate, have a better thermal performance when compared with metal frames.

Figure 24.e. Window Solar Performance



24.5.A. Glazing must be selected according to visible light and thermal properties.

i. For daylighting purposes, select glazing with a minimum VLT value of 60% to the degree possible (per manufacturer's published performance data). In the absence of available glass selections, double-pane, wood frame windows are preferable from a thermal standpoint; however adequate termite protection must be ensured.

24.5.B. Glazing placement must be considered to allow maximum daylighting while mitigating solar heat gains.

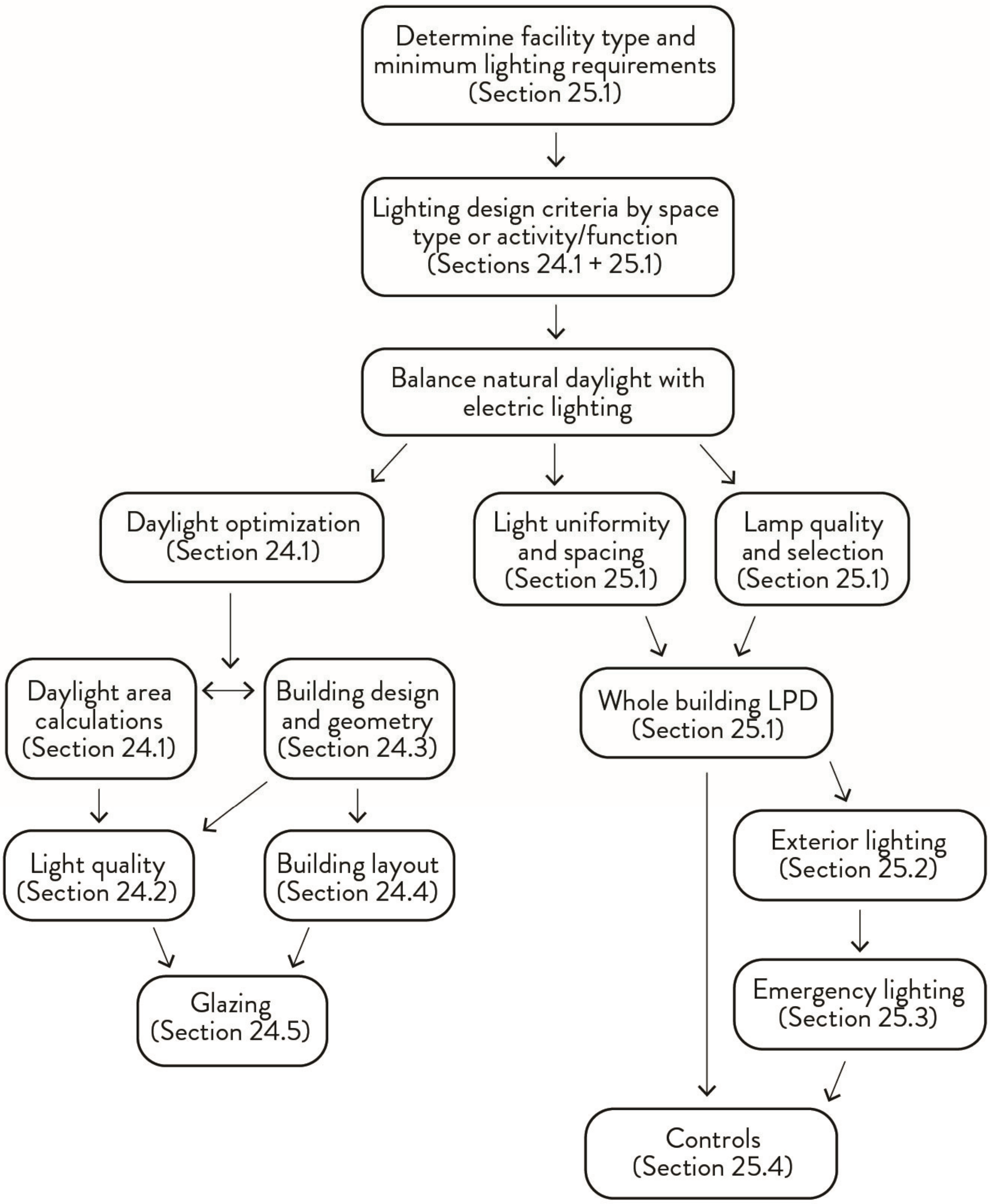
i. Place glazing on Northern and Southern exposures as much as possible.
ii. Minimize glazing on Eastern and Western exposures as much as possible, while considering spaces where lighting is needed most (see Table 24.a)
iii. Coordinate window placement with natural ventilation design and prevailing wind direction.

25 Electric Lighting

While efficient daylighting design can reduce the need for artificial lighting, electric lighting is necessary for certain functions. In instances where rooms may not have access to daylight, or weather conditions limit the amount of natural light able to reach spaces, or facilities need to operate during the night, electric lighting is critical to ensuring the effective performance of medical tasks and the safe movement of people around the facility.

Definitions

- **CCT**: Correlated color temperature measured in degrees Kelvin. The higher the number the more cool or blue the light appears. The lower the number the more warm or amber the light appears.
- **CRI**: Color rendering index is given in a range from 0 to 100. The closer the number is to 100 the better the lamp's ability is to render true color in comparison to incandescent or daylight.
- **CFL**: Compact fluorescent lamp.
- **LED**: Light emitting diode.
- **Illuminance:** The amount of luminous flux per unit area measured in lumens per square feet or footcandles [lm/ft^2 or fc].
- **Light Trespass**: Light falling where it is not needed or wanted.
- **Lighting Power Density (LPD)**: The amount of power produced by the lighting per the unit area measured in watts per square feet (W/ft^2).
- **LPW:** Lumens per watt.


Determine facility type and minimum lighting requirements (Section 25.1)
Lighting design criteria by space type or activity/function (Sections 24.1 + 25.1)
Balance natural daylight with electric lighting
Daylight optimization (Section 24.1)
Light uniformity and spacing (Section 25.1)
Lamp quality and selection (Section 25.1)
Daylight area calculations (Section 24.1)
Building design and geometry (Section 24.3)
Whole building LPD (Section 25.1)
Light quality (Section 24.2)
Building layout (Section 24.4)
Exterior lighting (Section 25.2)
Emergency lighting (Section 25.3)
Glazing (Section 24.5)
Controls (Section 25.4)

25.1 Interior Lighting

Varying levels and forms of lighting are appropriate for different types of spaces within healthcare facilities. Critical medical procedures, for instance, may require bright direct lighting; whereas lower-level, indirect lighting may be better for general circulation spaces like corridors. When designing interior lighting, desired illuminance values for different space types must be carefully considered.

25.1.A. Electric lighting must be provided in spaces types based upon the healthcare facility type.

i. Refer to Table 25.a for minimum electric lighting requirements by space type and facility type. In spaces where electric lighting is not required, electric lighting is still highly recommended.

Table 25.a. Minimum Electric Lighting Requirements by Facility Type

Space Type	Hospital	Health Center	Clinic
Entry & Reception			
Waiting Areas & Registration	X	O	-
Triage	X	X	-
Corridors & Stairways	X	X	O
Clinical Areas			
Examination and Consultation Rooms	X	X	O
Immunization (EPI) and Dressing	X	X	O
Emergency Room	X	X	N/A
Labor and Delivery	X	X	X
Short Stay	N/A	X	X
All Inpatient Wards & Isolation Rooms	X	X	N/A
ICU and NICU	X	N/A	N/A
Surgery, Diagnostics & Clinical Support			
Pre-Operation	X	N/A	N/A
Scrub Rooms & Operating Rooms	X	X	N/A
Post-Operation Wards	X	N/A	N/A
Pharmacy and Drug Storage	X	X	O
Laboratory	X	X	X
Radiology and Advanced Diagnostics	X	N/A	N/A
Sterilization	X	N/A	N/A
Staff Areas & Non-Clinical Support			
Nursing Stations	X	X	O
Medical Records	X	X	O
Staff Offices	X	O	O
Meeting and Training Rooms	X	N/A	N/A
Sanitary Spaces	X	O	O
Laundry and Kitchen	X	O	N/A
Equipment & Communication Rooms	X	X	X
Morgue	X	N/A	N/A

X *Required*
O *Highly recommended*
– *Not required*
N/A *Not applicable*

25.1.B. Desired illuminance values must be provided for the main types of spaces found in healthcare facilities. Approximate equivalent lighting power densities or LPDs can be used as a guide to achieve the desired illuminance values.

i. Illuminance or footcandle (fc) values must meet the design criteria within+/-20%. Approximate LPD values are given based on lamp and space type and no natural daylight to achieve the indicated illuminance values.

ii. Refer to Table 25.b. and Figures 25.a-b. Illuminance values can also be quantified by using an illuminance equivalence table. (Refer to Table 24.a.)

iii. To achieve these desired values, natural daylighting must be prioritized, and supplemented with electric lighting where necessary.

iv. For full daylighting requirements by program element, refer to Standard 46.3.B.

Table 25.b. Lighting Design Criteria for Typical Spaces in Healthcare Facilities

Lighting Class	Sample Space Types	Floor Illuminance (fc)	Approximate EquivalentLPD[a] (Watts/ft^2)				
			LED[b,c]	CFL[c]	T12[c]	T8[c]	T5HO[c]
Class 1	Storage, Records	5	0.125	0.25	0.25	0.125	0.125
Class 2	Waiting Areas, Corridors, Bathrooms, Staff rooms, Pharmacy Stock	10	0.25	0.5	0.5	0.25	0.25
Class 3	Examination Rooms, Wards, Nursing Stations, Offices, Meeting/Education Rooms	30	0.75	1.5	1.5	0.75	0.75
Class 4	Emergency Room (ER), NICU, ICU, Laboratory,	50	1.25	2.5	2.5	1.25	1.25
Class 5	Operating Room (OR), Delivery Room	100	2.5	5	5	2.5	2.5

[a]*Approximate Equivalent LPD based on a 10ft. ceiling height and electric lighting only. Daylighting was not taken into consideration for these values.*

[b]*Based on LED replacement lamp for compact fluorescent lamp.*

[c]*Based on bare bulb lumen output. Assume 20% light loss when installed in a fixture.*

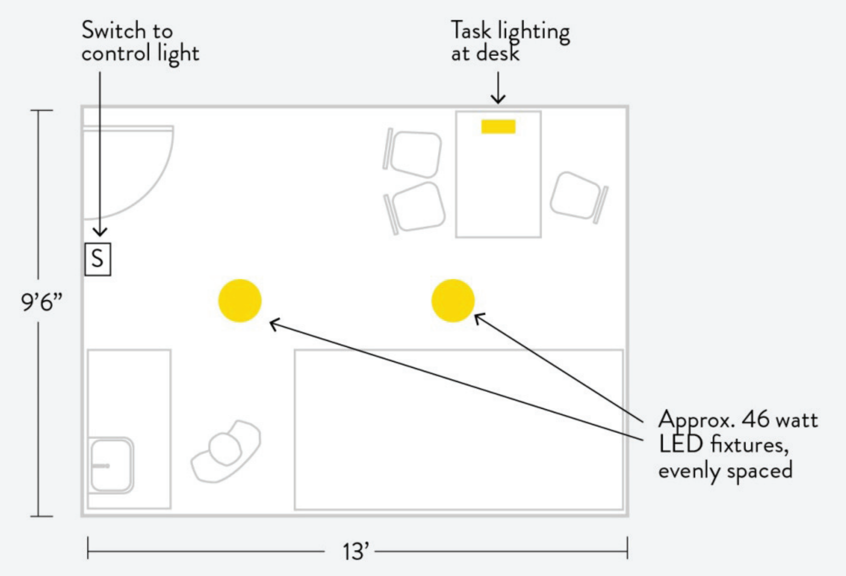
Sample Lighting Design Calculations

Table 25.b. can be used to size lighting fixtures in a space. Use the following formula:

Total required watts = Room area (ft^2) x Approximate equivalent LPD(W/ft^2)

Class 3 Example:

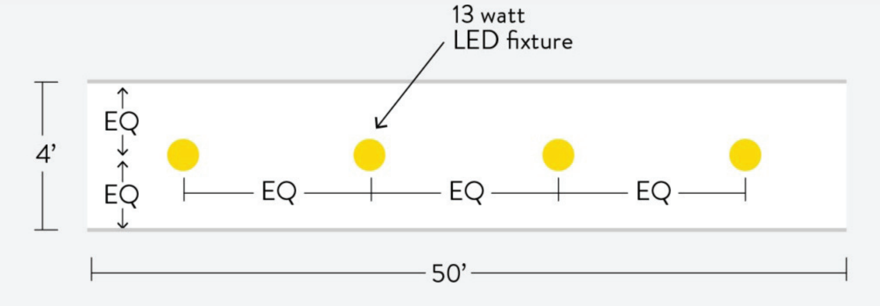
Figure 25.a. Exam Room



Target floor illuminance = 30fc (from Table 25.b., for Class 3)
Lamp source = LED
Approx. equivalent LPD (W/ft^2) = 0.75
Room area = 9.5'x13' = 123.5 ft^2
Total required LED watts = 123.5 ft^2 x 0.75 = 92.6W

Class 2 Example:

Figure 25.b. Corridor



Target floor illuminance = 10fc (from Table 25.b, for Class 2)
Lamp source = LED
Approx. equivalent LPD (W/ft^2) = 0.25
Room area = 4'x50' = 200 ft^2
Total required LED watts = 200 ft^2 x 0.25 = 50W

25.1.C. Lighting power density or LPD for the entire healthcare facility must not exceed the LPD thresholds indicated in Table 25.c. to prevent excessive power from being consumed.

Table 25.c. Allowable Lighting Power Density (LPD)

Building Type	Allowable LPD[1a] (Watts/ft^2)
Hospital	1.2
Health Center	1.2
Clinic	1.0

[a] *Actual LPD must not exceed Allowable LPD. To calculate the Actual LPD for a building, add the wattage of all the fixtures in the facility and divide that number by the total facility area.*

25.1.D. Uniformity and spacing must be considered when designing the lighting for healthcare facilities. Some exceptions may include task lights that are provided for detailed procedures.

i. Provide fixture layouts such that the light will be evenly distributed throughout the space. (Refer to Figures 25.c.-d.)

Figure 25.c. Light distribution in hallways

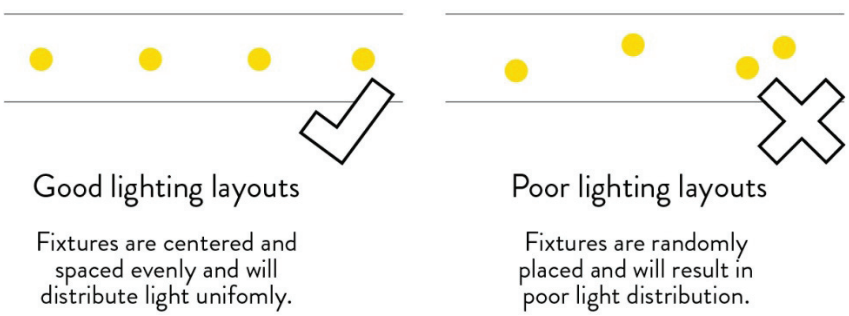
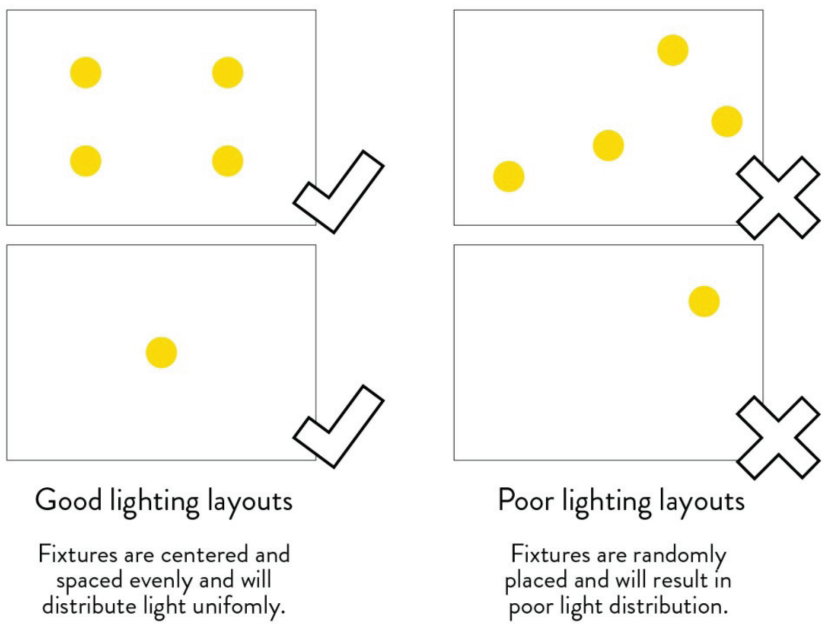


Figure 25.d. Light distribution in hallways



25.1.E. **Lamp quality must be considered when designing the lighting for healthcare facilities provided that lamp data is available.**

i. Provide lamps with a CCT value ranging between 2700K and 6000K. Lamps with higher CCT values are more acceptable in exterior applications, while a CCT value of 3000K to 4000K would be more ideal for interior spaces.
ii. Provide lamps with a CRI value ranging between 80 and 100. Spaces with more critical tasks should consider using a CRI value of 90 or greater.

Lamp Color Tone

The color temperature of lightbulbs affects the perception of color including the appearance of skin tone, which can be an indicator of patient health.

25.1.F. **Power and wiring requirements must be considered when designing lighting systems.**

i. Provide proper wiring requirements. Refer to Section 23.4 for specific wiring requirements.
ii. Provide lamps with power requirements that match the power supply.

25.2 Exterior Lighting

Exterior lighting is important for security and occupant safety, particularly for facilities operating 24/7. Critical areas requiring electric lighting include the building's entrance and exit as well as other areas that may need to be accessed at night. Other areas may include, but are not limited to, supply loading/unloading areas and electrical or generator room exterior entrances.

25.2.A. **Exterior lights must be provided for hospitals and health centers at minimum at the main entrance/exit to the building and for any exterior areas that will be used during the night. Exterior lights at the main entrance/exit for clinics are recommended for added security and safety.**

i. Provide exterior lights at every entrance/exit to the building for increased safety.
ii. Take into consideration light trespass when selecting exterior fixtures. Exterior fixtures should be aimed primarily down towards the ground.

25.3 Emergency Lighting

It is important to determine what lighting should be placed on emergency power versus normal power. Areas like stairs, corridors and exit passageways should have some lighting placed on emergency power to ensure the ability to exit the building in the case of power loss and an emergency where all occupants are required to exit quickly. Other areas to consider placing the lighting on emergency power would be rooms such as the Electrical, Generator, Surgical, Labor and Delivery, Post-Operative, ICU and Emergency Rooms. Refer to Section 23.2 for more information on critical loads versus noncritical loads.

25.3.A. In hospitals and other facilities with interior corridors, lighted exit signs must be provided to navigate from interior corridors to the exterior.

i. As much as possible, lighted exit signs must be placed at all exits, stairways and corridors for increased safety.
ii. Lighted exit signs must be placed on critical power (Refer to Sections 23.1 and 23.2).

25.3.B. Stairways, corridors and exit passageways must maintain a minimum horizontal illuminance level of 1fc at all times.

i. For stairways, one light fixture per level must be provided for sufficient lighting and should be placed on emergency power.
ii. For corridors and exit passageways every third or fourth fixture must be on emergency power.

25.4 Controls

The placement and design of controls influence the effective operation of lighting systems. The standards in this section are required for all facility types, including clinics, health centers and hospitals. When considering control locations and the grouping of fixtures to be controlled by a switch, it is important to think about who will be in control of its operation and function.

25.4.A. For all corridors and main public spaces there must be a minimum of one master switch in order to manually switch on and off the light fixtures.

i. Place corridor and main public space master switches at a reception or nurse's station location for easy access.

25.4.B. Patient, exam, nurse station, restrooms, storage and electrical rooms must have a minimum of one switch per room in order to manually switch on and off the light fixtures.

25.4.C. Light switches must be placed appropriately to enable user access.

i. Locate wall switches near the entrance of rooms.
ii. Place wall switches on the door handle side of the door if a room has a door.
iii. Place light switches between 34in-48in (86.4cm-1.2m) above the finished floor surface.

25.4.D. Exterior lights must have a minimum of one master switch to manually switch on and off the light fixtures.

i. Place exterior master switches in an electrical or control room or a space with limited public access.

26 Communication and Safety

Providing adequate communication between communities and healthcare facilities, from facility to facility, as well as within a single facility can save lives. Although there are currently only limited opportunities available for communication systems, Liberia's infrastructure continues to develop and expand. Cell phone service is available in some locations, but never guaranteed; and while vehicle transportation (automobile, motorcycle or bicycle) is at times an option, it is limited by road conditions and can be hampered during the rainy season. The use of High Frequency radios has proven to be a fast and cost effective method of communication. This solution is required at all facility types, in addition to the other available options.

In health facilities, staff and patient safety is often overlooked, as the focus tends to be on immediate patient care. Where fire alarm and detection systems have been installed, they are often in a state of disrepair. These standards will support the continued the use of central fire alarm systems for hospitals, as the newer intelligent systems are easier to maintain and have fewer failures. In clinics and health centers, there should be single station smoke and fire detectors in patient areas, as these are easy to maintain and will provide and excellent level of protection.

26.1 Communication Systems

A reliable communication system is crucial for staff to communicate within a facility as well as to other sites where additional expertise and consultation is needed. Key considerations include:

- Access
- System selection
- Installation and operational space requirements
- Maintenance

26.1.A. Communication systems must be provided at each facility regardless of facility type. Examples include high frequency radio and cell phone charging stations.

i. Even when landlines are available for telephone service, a second service must be provided as a backup.

26.1.B. Communication systems must be selected based on local assets as well as needs.

i. Identify the local infrastructure for communication systems and determine the ability to utilize existing systems based on the facility's needs.
ii. In addition to the current local assets, planners should also anticipate the technology and infrastructural changes that will occur over the next decade.

Common Communication Systems

While currently limited in rural areas, Liberia's communication infrastructure continues to expand. Available technologies fall into the following general categories:

Radio: Radio systems can be arranged as either one-way (broadcast only) or two-way if each facility is equipped with its own power station and/or antenna.

Pager: Similar to radio communication but instead of audible communication, text messages are sent over the system.

Wireless Local Area Network (WLAN or Wi Fi): Data and voice capabilities using wifi hotspots.

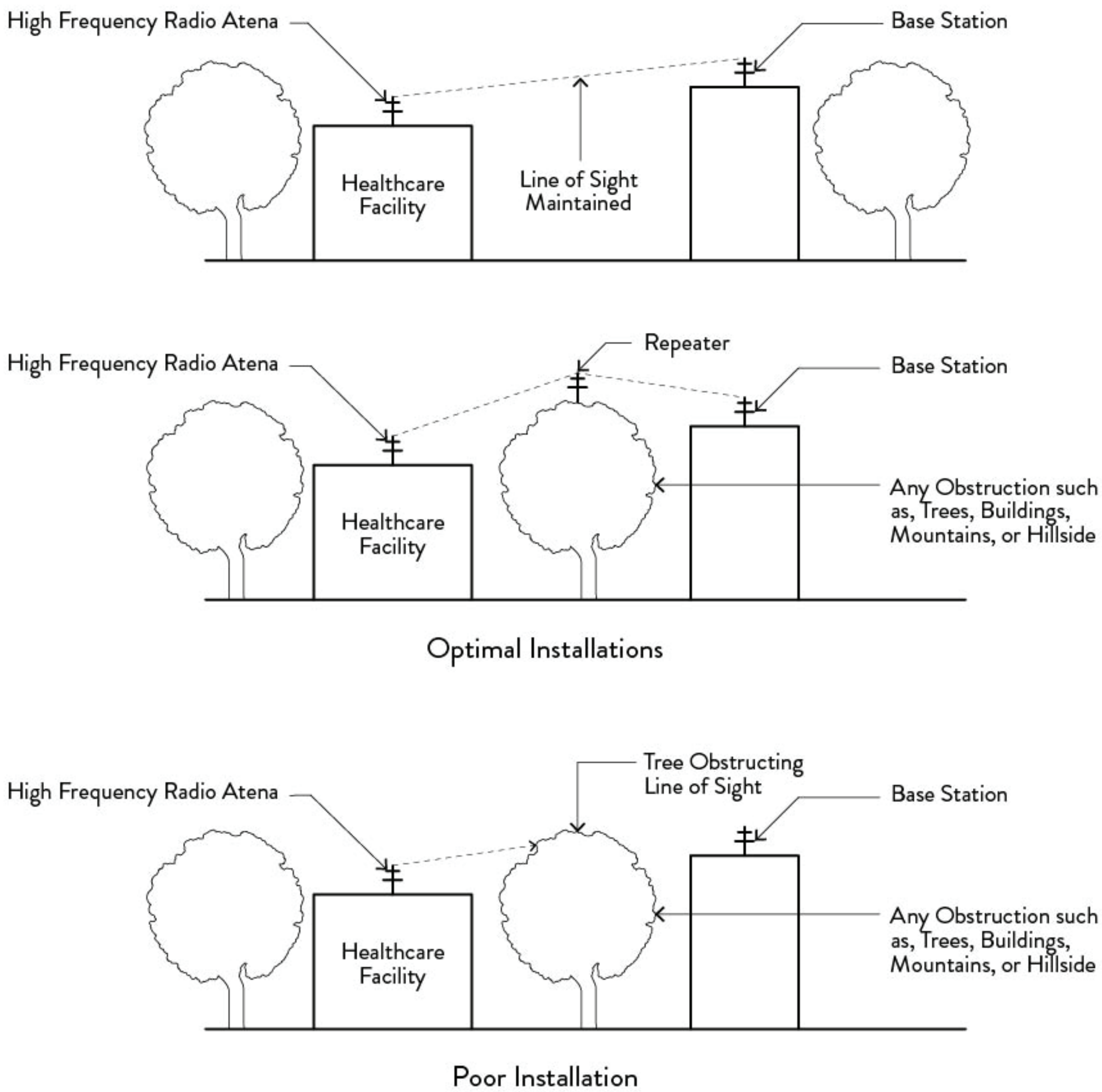
Digital Cellular Network (GSM): Cell networks offer the best opportunities for data and voice; however, they are not available in all locations.

Table 26.a. Comparison of Common Communication Systems

	Communication System			
Communication Type	Radio	Pager	Wifi	GSM
Community to Facility	Good	Poor	Good	Good
Facility to Facility	Medium	Good	Good	Good
Within Facility	Good	Medium	Good	Good
Criteria				
Power Usage	Medium	Low	High	High
Cost	Low	Low	High	High
Ability to withstand environment	Medium	Medium	Medium	Medium
User Interface	Good	Medium	Medium	Good
Network Maintenance	Poor	Poor	Medium	Poor
Device Maintenance	Medium	Poor	Medium	Good

26.1.C. High frequency radio antennas must be placed as high as possible on the roof of a building or be pole mounted in an accessible location. The antenna must have a direct line-of-site view to the base station or provide repeaters to avoid obstructions.

Figure 26.a. Recommended HF Radio Installation



26.1.D. All nurse stations within a hospital facility must be equipped with a communication device.

26.1.E. Head end equipment for all communication systems must be installed in a dedicated telecommunication room.

26.1.F. The telecom room must meet the following requirements:

i. The telecom room must be secured by lock or security system.
ii. The telecom room must have adequate ventilation to maintain a maximum temperature of 27 degrees C. Excess heat buildup in the room will greatly shorten the life of the equipment.
iii. The space can be shared with the electrical room, but be cautious if transformers are present as they add heating load to the room.
iv. An earthing system reference bar must be provided near the telecom equipment.
v. Telecom equipment must be mounted to the wall or within an open style rack. Do not enclose the equipment in a confined space without any ventilation.
vi. All ambulances must be equipped with high frequency radios to ensure good communication between the ambulance and the healthcare facilities.

26.2 Security Systems

Security systems are used to deter vandalism and theft of property as well as maintain protection for building occupants.

26.2.A. Where installed, onsite security systems must transmit a local audio/visual alarm when activated by automatic intrusion detection.

i. To the degree possible, equip the following areas with intrusion detection:
   - Rooms with key equipment
   - Pharmacy or pharmaceutical distribution center
   - Rooms housing key patients or personnel

26.3 Fire Alarm Systems

Fire alarm systems are a life-saving measure. They are used as an early indication to building occupants when they must egress a facility in an emergency.

26.3.A. A central fire alarm system must be provided in all facilities powered 24/7 by the LEC utility grid.

i. A fire alarm system will go into alarm mode upon loss of power. Therefore only facilities with reliable utility service should be equipped with a fire alarm system.
ii. Provide a minimum of 48 hours of battery back-up in the fire alarm control panel to accommodate utility outages.

WATER & SANITATION

CONTENTS

IMPACT

Appropriate water and waste management prevents the contamination of groundwater and protects access to potable water. Overloaded systems run the risk of creating significant environmental and safety hazards, threatening patient health as well as the health of nearby communities.

PRIMARY USERS

Infrastructure Unit

Faculty Staff

Architects & Designers

Civil & Plumbing Engineers

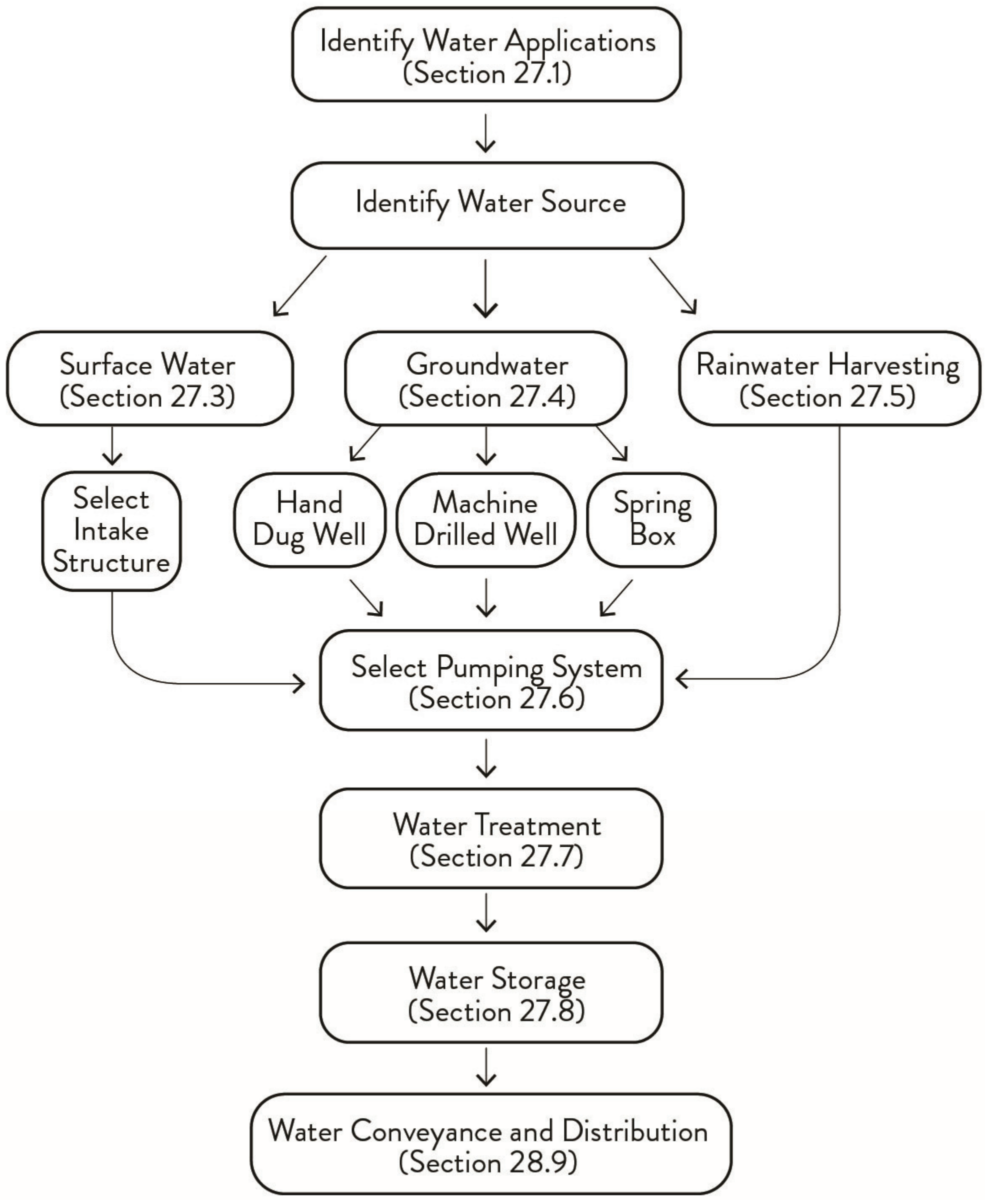
Contractors

GUIDELINES FOR USE

Before sizing and selecting systems, it is important to map out expected water and waste applications and loads. Chapters 27-29 include process diagrams to guide the user through water and waste design decisions.

27 Water

Water is one of the most critical infrastructural needs for healthcare facilities in Liberia, and is essential for medical services as well as building functions. Clean, sterile water is required within every healthcare facility for hand washing, equipment cleaning, cleansing wounds, compounding medicines, and for all the human uses of clean water such as drinking, bathing, cooking and food preparation. Additional non-potable water uses include flush toilets, laundry washing, cleaning and landscape irrigation. Water is especially critical in health facilities in Liberia, where sources of water are not always readily available. Therefore, identifying a source of water, clean or requiring treatment should be one of the first steps in the creation of a new health facility.



Definitions

- **Aggregate**: A group of soil particles cohering so as to behave mechanically as a unit.
- **Air Relief Valve**: A brass or plastic, manually operated valve located at the top of a filter tank for relieving the pressure inside the filter and for removing the air inside the filter.
- **American National Standards Institute/National Science Foundation (ANSI/NSF)**: Organization that oversees the development standards for products, services, processes, systems, and personnel in the United States.
- **American Society for Testing and Materials (ASTM)**: International standards organization that develops and publishes technical standards for a wide range of materials, products, systems, and services.
- **American Water Works Association (AWWA)**: Association founded to improve water quality and supply.
- **Annulus**: The void space between well rings.
- **Bacteria**: Unicellular microorganisms that feed upon and consequently degrade organic matter.
- **Chemical-Feed Pump**: A mechanical device that introduces chemicals into a water system at a rate proportional to the water flow. Also called a chemical feeder.
- **Chlorination**: The use of chlorine gas or solutions to disinfect water or as an oxidizing agent.
- **Chlorine Demand**: A measure of the amount of chlorine which can be consumed by organic matter.
- **Cistern**: An artificial reservoir or tank for storing water.
- **Conveyance**: The process of transporting water from one place to another.
- **Disinfection**: Killing pathogenic microbes in or on a material without necessarily sterilizing it.
- **Dissolved solids (TDS)**: Solids present in solution.
- **Distribution**: Entire set-up consisting of procedures, methods, equipment, and facilities, designed and interconnected to facilitate and monitor the flow of water from the source to the end user.
- **Drilled Well**: A well constructed by either cable-tool or rotary methods usually to depths exceeding a 50 ft with capacities to provide for industry, irrigation, or municipalities.
- **Dug Well**: A shallow, large-diameter well constructed by excavating with hand tools or power machinery instead of drilling or driving, typically for individual domestic water.
- **Filtration**: The act or processing of passing water through a filter in order to remove solid particles.
- **Groundwater**: Water found in pore spaces in the subsurface below the water table.
- **Grouting**: A cementitious fluid poured or injected into a borehole during well-drilling to seal crevices.
- **Hand Pump**: A pump worked by hand that can serve a structure with water.
- **Impervious**: Resistant to penetration by fluids or by roots.
- **Landscape Irrigation**: Water used for watering plants or landscaped areas.
- **Percolation**: The flow or trickling of a liquid downward through a contact or filtering medium.
- **Permeability**: The ease with which gases, liquids, or plant roots penetrate or pass through soil.
- **Potable**: Water suitable for human consumption.
- **Priming**: The process of introducing fluid into a pump to improve the sealing of the pump.
- **PVC**: Polyvinyl chloride, used in sewage pipe due to its low cost, chemical resistance, and ease of jointing.
- **Rainwater Harvesting**: The method of collecting runoff from rainwater for use as water for human consumption.
- **Saturated zone**: The area below the water table where the soil pores are fully saturated with water.
- **Spring**: A place where groundwater flows naturally from a rock or the soil onto the land or a water body.
- **Submersible Pump**: A pump designed to fit into a well and operate below the water level.
- **Subsoil**: In general, that part of the soil below the depth of excavation.
- **Surface Water**: Water on the surface of the planet, such as in a stream, river, lake, wetland, or ocean.
- **Suspended Solids**: Solids physically suspended in water, sewage, or other liquids.
- **Total Suspended Solids (TSS)**: The solids remaining as residue after water has been evaporated from a sample.
- **Water Table**: The surface of a body of unconfined ground water.

27.1 Water Applications

27.1.A. **Water must be provided in every health facility for at least the following uses: drinking, hand washing for toilet/latrine users, hand washing for health care providers before and after treatment, treatment/operating room sanitation, and equipment cleaning/sterilization.**

i. Refer to Table 27.a-c. for the required and site specific uses of water to be provided at healthcare facilities.

Table 27.a. Required and Optional Uses of Water at PHC 1 + 2 Clinics

Use	Required	Optional
Drinking	X	
Toilets (Pour flush pit latrine or flush toilet)	X	
Hand washing for toilet/latrine users	X	
Sanitation in treatment rooms	X	
Hand washing for staff members before and after providing treatment	X	
Showers for staff members (Bucket shower)	X	
Laundry (Hand-washing sink)		X
Kitchen		N/A
Wards		N/A
Equipment cleaning and sterilization	X	
Fire suppression		X
Landscape irrigation		X

Table 27.b. Required and Optional Uses of Water at Health Centers

Use	Required	Optional
Drinking	X	
Flushing toilets	X	
Hand washing for toilet/latrine users	X	
Sanitation in treatment rooms	X	
Hand washing for staff members before and after providing treatment	X	
Showers for staff members (Bucket shower)	X	
Laundry (Hand-washing sink)	X	
Kitchen		X
Wards	X	
Equipment cleaning and sterilization	X	
Fire suppression		X
Landscape irrigation		X

Table 27.c. Required and Optional Uses of Water at Hospitals

Use	Required	Optional
Drinking	X	
Flushing toilets	X	
Hand washing for toilet/latrine users	X	
Sanitation in treatment rooms	X	
Hand washing for staff members before and after providing treatment	X	
Showers for staff members	X	
Laundry (Washing machines)	X	
Kitchen	X	
Wards	X	
Equipment cleaning and sterilization	X	
Fire suppression	X	
Landscape irrigation		X

27.2 Water Provision

Access to a clean, safe, and reliable supply of water is critical for all healthcare facilities. In rural settings, most health facilities will rely on onsite wells, rainwater collection, springs and/or streams to meet the demands of patients and staff. In some urban areas, a health facility may be connected to a centralized water system; however, even in these settings, providing an onsite supply of water either as the primary or secondary supply can be critical as a backup and secure source of water at all times.

27.2.A. **The infrastructure supplying water to a health care facility must be under the administrative control of the health facility.**

27.2.B. **In selecting the source of water to be developed, the designing engineer must prove to the satisfaction of the assigned IU representative that an adequate quantity of water will be available to satisfy required water uses at the facility , and that the water will meet the water quality standards presented in Standard 8.6.E.**

i. Table 27.d may be consulted as a guide, but water demand must be calculated for each facility, taking into account the uses identified in Section 27.1, taking into account the size of the facility and the level of services offered.

Table 27.d Recommended water demand estimates

	Facility			
Activity	PHC1 (gallons/day)	PHC2 (gallons/day)	Health Center (gallons/day)	Regional Hospital (gallons/day)
Bathing	150	300	500	2500
Toilet Flushing	100	125	200	500
Drinking Water	40	75	150	500
Cooking	-	-	100	500
House Keeping	30	30	100	300
Laundry	30	30	50	400
Medical Procedures	75	150	500	1500
Total Water Use	425	710	1600	6200

27.2.C. **Every healthcare facility must have a minimum of one reliable source of water.**

ii. Two sources of water are preferable to provide redundancy or backup supply during an emergency or equipment failure. The smaller of these must have the capacity to meet the water needs of the facility.

iii. The water source must be connected to the storage and distribution system.

iv. If water treatment facilities are required the source must be connected to the treatment system.

v. If two sources of water are available backflow prevention devices (such as double check valve assemblies must be installed on each source water line) must be installed to prevent water from one source flowing into another.

vi. Prioritize the installation of rainwater harvesting systems at all health facilities, and use harvested water for at least non-potable uses. The rainwater harvesting system can be used as a backup source of drinking water as long as the water is treated before use. This can count as one source.

27.2.D. **Each water supply must take its raw water from the best available source that is economically reasonable and technically possible.**

27.2.E. **If a municipal supply system is utilized, an additional dedicated backup source must be installed to provide for a continuous supply of water.**

Water Sources

The particular manner in which the source water is supplied to the healthcare facility will depend on the type of source that is available at or near the location of the facility. Possible sources of water supplied to a healthcare facility include:

- Pumping water from a cistern which captures and stores rainwater into a pipeline leading to the facility
- Pumping water from a hand-dug well into a pipeline leading to the facility
- Pumping from a machine-drilled well into a pipeline leading to the facility
- Diversion of part of a stream into a pipeline leading down slope to the facility
- Diversion of the discharge of a spring box into a pipeline leading down slope to the facility
- Pumping water directly from a lake and/or stream into a pipeline leading up or over to the facility

27.3 Surface Water Sources

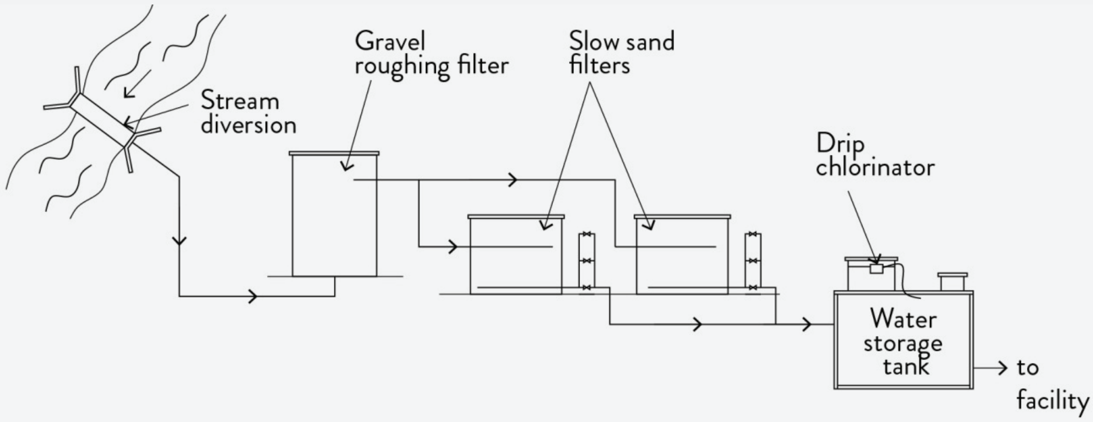
Surface water sources include all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments accessible to the facility. Surface water sources situated at locations topographically higher than the facility are preferable to those at equal or lower elevation because they offer the possibility of gravity flow. Sites at equal or lower elevations and requiring delivery pumps also require power supplies.

The main advantage for using a year round surface water source is that typically there is a more abundant supply of water. If the surface water supply is located at a higher elevation, water can be supplied by gravity. However; surface water sources are never free of microbiological contamination and those near cities and towns are particularly vulnerable to domestic and industrial pollution. Surface water sources will always require multi-barrier treatment consisting of filtration and disinfection to be a safe source of drinking water. Constructing and maintaining a multi-barrier treatment system may be costly and unmanageable for many small clinics. It is important to note that some surface water sources may not be available during the dry season and if they do so they may not be a reliable source of water for a healthcare facility.

Surface Water Intake Structures

The preferred filtration system for rural sites includes a coarse media gravel or roughing filter to reduce sediment from the stream followed by a dual chamber slow sand filter and a simple drip chlorination system set on top of the domestic water storage tank. A schematic of this surface water treatment system is shown in Figure 27.a.

Figure 27.a. Multi-Barrier Surface Water Treatment System

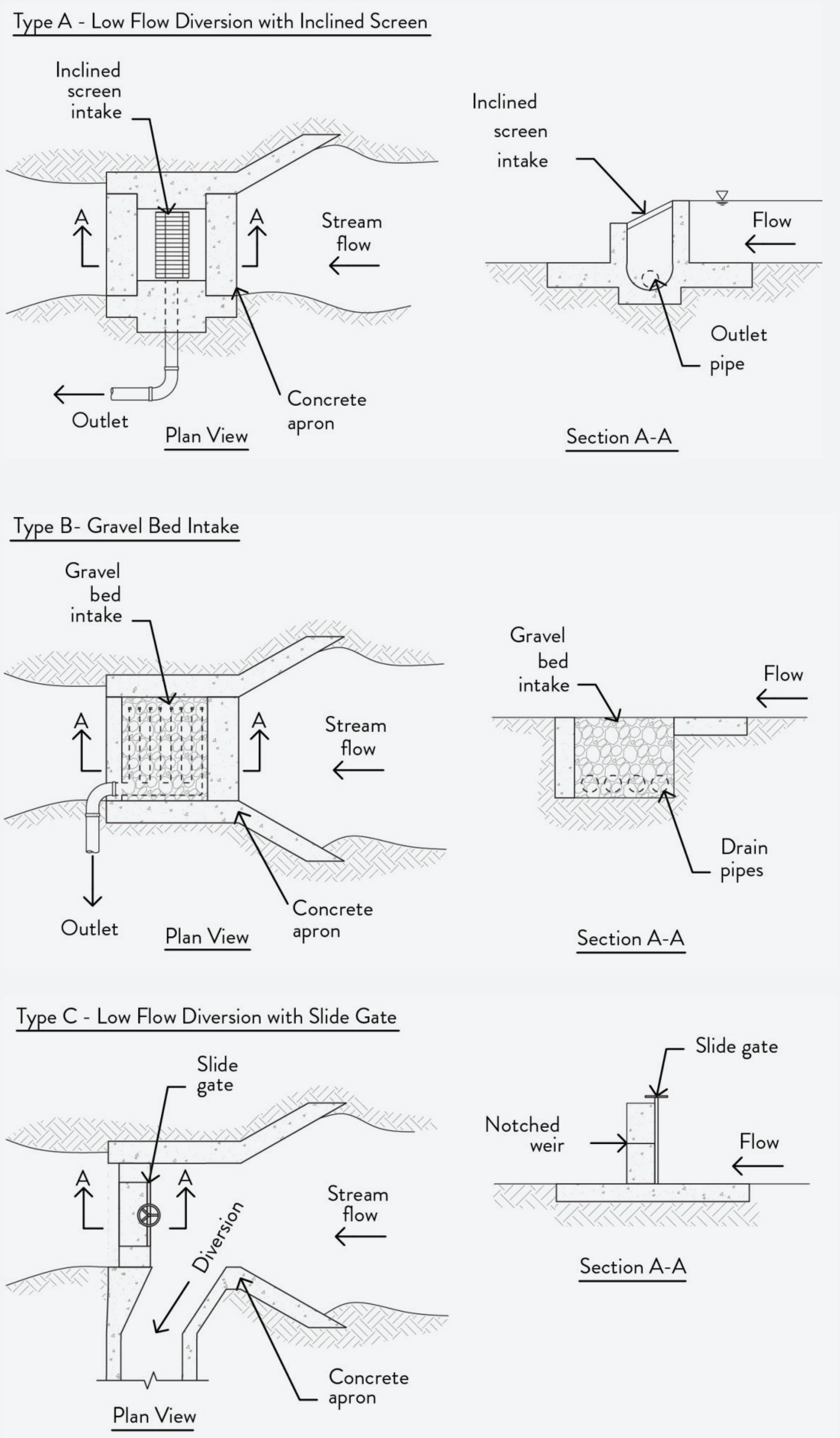


During storm events surface water quality can become impacted from sediment laden runoff causing the suspended solids and bacterial load to increase substantial. During these events the surface water may be difficult to treat and under extreme conditions the best strategy may be to temporarily shut off the inlet to protect the water treatment system and healthcare system users.

Desirable surface water sources are streams flowing through undeveloped terrain at a higher elevation than the health facility. A portion of the water from small streams can be diverted using a very low profile dam with an overshooting screen intake. Often the roughing filter can be installed at or near the point of water intake to reduce suspended solids entering the water system, which will make it easier for subsequent treatment prior to final use and human consumption.

Surface water supplies are also vulnerable activities in the upper watershed areas. If a surface water source is selected as the primary source of water for the health facility, the MOHSW should develop a watershed protection plan to develop and implement strategies to protect the watershed area and water quality and to restrict activities in the watershed. Figure 27.b. shows alternative configurations for intake structures installed in a body of surface water. Note that there is no configuration, which simply places an unprotected submersible pump or suction pipe into the water body directly. Flood flows in streams and sedimentation in lakes and swamps can severely impact unprotected water intake devices.

Figure 27.b. Alternative Surface Water Intake Structures



As noted above, one intake structure (Type A) that is easy to maintain includes a low profile dam with an inclined screen that is installed on the downstream side of the dam. In this simple configuration the screen intake is self-cleaning by the surface water running over the screen and not prone to clogging. Once the water it is collected it can enter a simple grit chamber that is designed to trap sand gravel and leaves.

For the second intake (Type B) raw water enters the intake system through an engineered gravel bed and horizontal perforated pipe leading to a pumping sump with a top higher than any historical or anticipated flood level. Usually the pumping sump is constructed in an excavation on dry land next to the surface water body. The bottom of the pumping sump is taken to a depth below the bed of the surface water body and a channel is cut connecting the two. A perforated pipe is laid in the channel and the channel is refilled with clean gravel. This alternative is prone to clogging and if the stream carries a high sediment load these intakes area commonly abandoned once the gravels are silted over. To improve the performance, a low dam or barrage may be constructed just upstream of the intake structure to constrict the width of the channel that increases the velocity of water crossing the intake and thus lessens deposition of fine sediments in the gravel filter surrounding the intake pipe.

Another approach (Type C) is to install a small diversion dam and side channel that directs the water to a simple baffled sedimentation box, which can be easily cleaned by the water system operator.

27.3.A. Design of intake structures must provide for withdrawal of water from more than one level if quality varies with depth.

27.3.B. Provisions must be made for routine cleaning of the inlet line, and bar screens to prevent large debris from entering the intake.

27.3.C. When buried surface water collectors are used, sufficient intake open area must be provided to minimize inlet head loss. Particular attention must be given to the selection of backfill material in relation to the collector pipe slot size and gradation of the native material over the collector system.

27.3.D. Raw water pumping sumps must be designed with appropriate provisions:

i. Motor, electrical controls and splice boxes must be located above grade, and protected from flooding.
ii. All equipment must be easily accessible for routine operation and maintenance.
iii. All intake structures must be well anchored and designed against flotation.
iv. Intakes must be equipped with removable screens before the pump suction well.

27.4 Groundwater Sources (Wells and Springs)

Developed groundwater sources include dug, drilled, bored and driven wells, and constructed spring boxes. Groundwater from sparsely populated areas and/or from properly constructed deeper wells are less prone to surface contamination and water quality impacts; however, in many locations groundwater from deeper wells is more likely to be enriched in naturally occurring iron and manganese and other potentially toxic metals.

Many dug wells—even properly constructed ones—suffer from the annual oscillation of the water table between wet and dry seasons. There can commonly be as much as 15ft (4.6m) difference in the elevation of the water table between its highest point in the cycle and its lowest. This can result in some shallow wells becoming waterless in the dry season. The obvious mitigation—deepening the well as the dry season approaches—is not accessible if the well bottoms on hard rock. This problem will be avoided by adhering to the standards listed below.

In the following sections hand dug wells are discussed first, then machine drilled wells, and finally constructed spring boxes. Regardless of the type of groundwater source one rule is paramount: Never locate a well or spring box within 100ft (30.5m) of a septic tank or pit latrine.

Hand Dug Wells

27.4.A. A well must be sited at least 100 ft (30.5m) and up slope from any potential source of groundwater contamination. The local community and local authorities must concur with the selection of the site.

i. Potential sources of contamination include: pit latrines; septic tanks; sewage lines; garbage dump sites; animal lots; unprotected open or abandoned wells; old and/or existing cemeteries or burial sites; underground fuel storage tanks; and any other sources of contamination such as chemical depots or industrial waste.

27.4.B. A hand dug well must be fully lined with concrete rings fabricated (usually on site) with a concrete mixture of 1:2:3 (cement:sand:stone) and reinforced with wire mesh.

ii. The inside diameter of the rings must be a minimum 48in (1.2m).

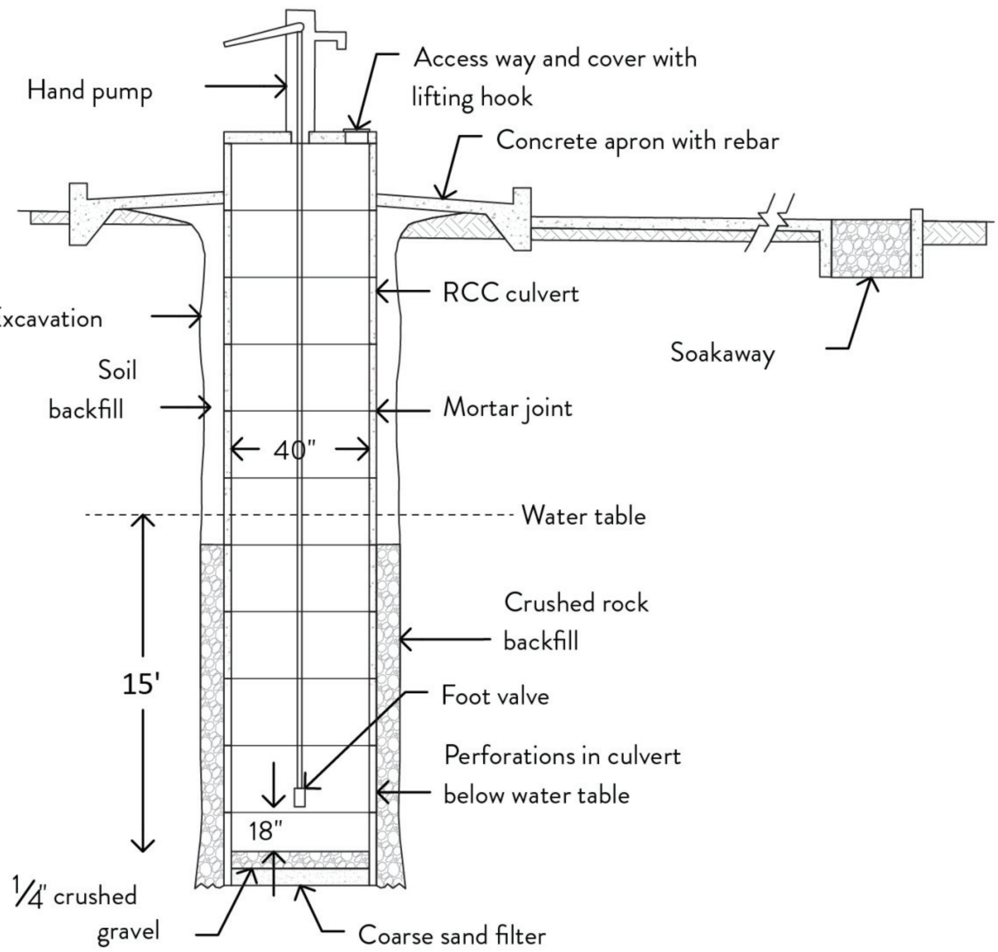
iii. The first ring installed in the well must have an outside diameter 4in (10.2cm) larger than the rings that rest on it and its bottom surface should be tapered rather than flat as are all the others

Well Ring Construction

The first ring is cast in an excavation at the well site and is never removed from it. Excavation of the well commences by excavating within the first ring and allowing it to descend. The inside diameter of the first ring is the same as the overlying rings. All the other rings are taller (usually 24in (61cm)) and are cast in a steel mold that produces a 24in (61cm) tall ring with a 2in (5cm) wall thickness.

In low yielding stable consolidated formations perforated culverts or rings can be used at the intake section of the well to increase well recharge rates. The seepage holes can be fashioned by inserting lengths of oiled re-bar or wooden pegs into the rings as they are cast. The rods or pegs should be inserted at an upward angle to lessen the invasion of sand into the well bore. Remove the rods or pegs before the concrete is completely set.

Figure 27.c. Typical Hand Dug Well



27.4.C. Well cover construction must meet the following requirements:

i. When the well reaches its total depth the uppermost ring must extend 12in (31cm) above grade.
ii. A 4in (10.2cm) reinforced concrete slab must be placed over the uppermost ring and cemented to it with 1:2 mortar.
iii. The slab cover must include a 14in by 14in or 16in diameter manhole situated off center. The manhole cover must be on a $^{1}/_{2}$in high plinth to prevent water entering the well. The manhole cover must be secured and hidden with a 1in (2.5cm) thick blanket of 1:2 mortar troweled smooth. The manhole is for access to the well if pump maintenance or repair is required. Opening the manhole requires destroying the mortar blanket hiding it. The blanket must be reinstalled when access to the well is no longer required.
iv. The slab cover must also include a length of 4in (10.2cm) PVC pipe at its center and extending 12in (31cm) above its upper surface and 2in (5.1cm) below its lower surface. The length of 4in (10.2cm) PVC pipe at the well's center is for installation of a pump. If the pump is not installed immediately the PVC pipe must be closed with a cap secured with PVC cement.

27.4.D. The upper 10ft (3m) of annulus between the upper rings and the surrounding soil must be filled with 1:1 grout.

Well Annulus Construction

The bottom ring should be intentionally made 4in (10.2cm) larger in diameter than the overlying rings. Hypothetically that is expected to leave a 2in (5.1cm) wide annulus for the entire length of the well bore. In practice, the annulus may not be continuous to the well bottom because of sloughing of the excavation walls.

Follow the following steps:

1. Probe the annulus using a sufficient length of 0.5in (1.3cm) PVC pipe securely glued end to end and having a glued on cap at the bottom. If the annular cavity extends more than 10ft (3m) below grade it must be filled up to the level 10ft (3m) below grade with very dry pea gravel (⅛in – ¼in (3mm – 6mm)).
2. Add the gravel slowly and prod it into place with the 0.5in (1.3cm) PVC pipe. When the target level is achieved pour clean water into the annular space and prod the gravel again. Add more gravel if needed.
3. When the gravel is in place mix the grout with enough water to make it barely pourable. Pour the grout into the annulus intermittently punctuating the grout placement with prodding with the 0.5in (1.3cm) PVC pipe. The intention is to leave no air pockets in the grout curtain and to bring the level of grout flush with the ground surface.

27.4.E. A 30in (76.2cm) layer of washed gravel at ¼in (6mm) to ½in (1.3cm) diameter must be placed as a filter on the well bottom.

27.4.F. A circular apron of reinforced concrete must surround the well and be sloped to direct spilled water and rainwater to a drainage channel leading to a soakaway.

i. The apron must extend 5ft (1.5m) beyond the outer perimeter of the well in every direction.
ii. The apron must be at least 4in (10.2cm) thick with wire mesh reinforcement and be made from 1:2:3 concrete.
iii. The well head (i.e. the top most ring) must be attached to the apron with 1:2 mortar to assure a sanitary seal.
iv. If concrete blocks are used to define the outer rim of the apron the voids in the blocks must be filled with 1:3 mortar.
v. The drainage channel leading from the apron to the soakaway must be excavated 10in (25.4cm) wide and 6in (15.3cm) deep and must be plastered with 1:3 mortar troweled smooth.
vi. The minimum dimensions of the soakaway pit are 3ft (91.4cm) in diameter and 6ft (1.8m) deep. It must be filled with 6in (15.3cm) to 10in (25.4cm) rock and it must have a cover. The minimum dimensions apply only if the soil permeability allows the pit to drain completely and rapidly. If water accumulates in the pit it must be enlarged.
vii. On completion of the well, the date of completion, the name of implementing agency, total depth of well, and static water level must be clearly inscribed on the apron. The inscription should be done in an area that will not be disturbed by well users.

27.4.G. A submersible dewatering pump capable of delivering 20 gallons per minute (gpm) with a total dynamic head of 30ft (9.1m) and suitable for pumping water with high solids content must be available during well digging.

Dewatering

An acceptable hand dug well will contain at least 15ft (4.6m) of water when it is not being pumped. As it is not possible to effectively dig in water deeper than about 6in it is necessary to continuously pump water from the excavation once the water table has been penetrated. 2-horsepower pumps operable with a portable generator are commercially available. If, in the course of well digging during the dry season (1 November through 30 April), the dewatering pump delivering 20 gpm fails to empty the well, the objective of having 15ft (4.6m) of water may be waived and the well deemed suitable as to yield. Failure to empty the well during the wet season will not earn this exemption. The well digging would merely be postponed until the next dry season.

27.4.H. A hand dug well shall be considered acceptable as to yield if it can deliver at least 4 gpm continuously for 4 hours during the period 1 November through 30 April.

Acceptable Yield

Hand dug wells falling slightly short of this standard may still have utility provided they always produce some acceptable quality water. A flow rate of 4 gpm for 4 hours is nearly 1,000 gallons and this exceeds the daily water requirements of many small outpatient health care facilities.

A 4ft (1.2m) diameter well contains nearly 100 gallons of water for each foot of water depth. A well which accumulates 6ft (1.8m) of water over the pump intake during an overnight shutdown has 600 gallons to deliver the next morning. It may run dry in 2 or 3 hours pumping at 4 to 6 gpm but later in the day it will be ready to deliver 100s of gallons more. It would not be useless if the demand were modest.

27.4.I. Before it can be used, every hand dug well must be disinfected after it is constructed or after any repairs are performed.

i. Disinfection must be accomplished by adding 1 liter of 0.2% strength chlorine solution for every 100 liters of water in the well (about 3in (7.6cm) of water) and allowing at least 30 minutes of contact time before dewatering the well and allowing the chlorine concentration remaining to be less than 5.0 mg/l. Assuming complete mixing the initial chlorine dose is equivalent to about 20 mg/l.
ii. Discharge of the highly chlorinated water following disinfection must be done with care. In particular it should not be discharged directly to a stream or dry water course that enters a flowing stream nearby. If it is sprayed on living vegetation it will probably kill it.

27.4.J. Chemical and bacteriological tests of the water must be done on all wells during and after construction.

i. The chemical tests must include iron as well as other constituents and shall be done when the new well reaches its static water level and again after 6 months of use.
ii. The bacteriological tests must include total coliform and fecal coliform. The results should be negative immediately after sterilization but the six-month findings will reveal the true condition of the aquifer.
iii. If testing reveals a source is unfit for human consumption the well must be sealed off and a sign posted as non-potable until corrective actions can be implemented.
iv. Copies of all water quality testing (positive or negative) must be made available to community and county health authorities.

27.4.K. An electronic and printed Well Completion Form must be submitted to the Ministry of Public Works, District Commissioner, and community for all completed wells.

Machine Drilled Wells

This sub-section presents standards that are pertaining to machine drilled wells. However, all the standards for hand dug wells also apply, where relevant, to machine drilled wells. Machine drilled wells have the advantage of being constructed deeper and draw water that may be of a higher quality and less prone to surface contamination. However, machine drilled wells are generally more expensive required skilled labor to install properly and drilling equipment may be hard to get to rural sites. In some areas deeper wells may be prone to elevated levels of iron, manganese and other naturally forming contaminants that make the water unsuitable or undesirable as a source of drinking water.

27.4.L. Every drilled well must be tested for plumbness and alignment upon completion of construction.

i. The casing must be sufficiently plumb so as not to interfere with the installation and operation of the pump.
ii. The test method and allowable tolerance must be clearly stated in the specifications. If the well fails to meet these requirements, it may be accepted by the engineer if it does not interfere with the installation or operation of the pump or uniform placement of grout.

Well Plumbness

An unplumb or poorly aligned well may not be usable or will not necessary accept the required pump for the application. A well that is tending to go out of plumb can be recognized while the well is still under construction and can be corrected during the drilling process. It is the responsible of the drilling supervisor to keep informed about this issue and to make corrections as the well is being drilled.

27.4.M. Drilling fluids and additives must not impart any toxic substances to the water or promote bacterial contamination.

27.4.N. Screen opening sizes must be based on sieve analysis of formation and/or gravel pack materials. They must also have sufficient length and diameter to provide adequate specific capacity and low aperture entrance velocity.

i. The entrance velocity must not exceed 0.1 feet per second.
ii. Screens must be installed so that the pumping water level remains above the screen under all operating conditions.
iii. The annulus adjacent to the screened interval and at least 5ft (1.5m) above the screen must be filled with clean coarse sand or pea gravel as a filter pack. If the annular opening is less than 4in (10.2cm), the filter pack should be installed through a tremie pipe extending to the well bottom and slowly raised as the annulus fills with the filter pack material.
iv. A clay seal at least 4ft (1.2m) thick must be placed in the annulus above the filter pack.

27.4.O. All permanent well casing must be surrounded by a minimum of $1^1/_2$in (3.8cm) of grout to the depth required to exclude surface water seepage (minimum 10ft (3m)) or entrance of water from contaminated or otherwise undesirable aquifers.

i. When the annular opening is less than 4in (10.2cm), grout must be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled.
ii. When the annular opening is 4in (10.2cm) or greater and less than 100ft (30.5m) in depth, and concrete grout is used, it may be placed by gravity through a grout pipe installed to the bottom of the annular opening in one continuous operation until the annular opening is filled.

iii. When the annular opening exceeds 6in (15.3cm), is less than 100ft (30.5m) in depth, and a clay seal is used, it may be placed by gravity.

27.4.P. After cement grouting is applied, work on the well must be discontinued until the cement or concrete grout has properly set.

27.4.Q. Temporary steel casing used for construction must be capable of withstanding the structural load imposed during its installation and removal.

27.4.R. The minimum casing diameter is 4in and all casings must be constructed of PVC.

i. PVC casing must be new pipe meeting ASTM F480 and ANSI/NSF Standard 61 and be appropriately marked.
ii. It must have a minimum wall thickness equivalent to SDR (standard dimension ratio) 21; however, diameters of 8in (20.3cm) or greater or deep wells may require greater thickness to meet collapse strength requirements.

27.4.S. PVC casing must be properly stored in a clean area free from exposure to direct sunlight; must be assembled using couplings or solvent welded joints; all couplings and solvents must meet ANSI/NSF Standard 14, ASTM F480, or similar requirements; and must not be driven.

27.4.T. Packers must be of material that will not impart taste, odor, toxic substances or bacterial contamination to the well water. Lead packers must not be used.

27.4.U. Permanent casing for all groundwater sources must project at least 12in (30.5cm) above the pump house floor or concrete apron surface and at least 18in above final ground surface.

27.4.V. Where a well house is constructed, the floor surface must be at least 6in (15.3cm) above the final ground elevation.

27.4.W. Sites subject to flooding must be provided with an earth mound to raise the pump house floor to an elevation at least 2ft (61cm) above the highest known flood elevation, or other suitable protection.

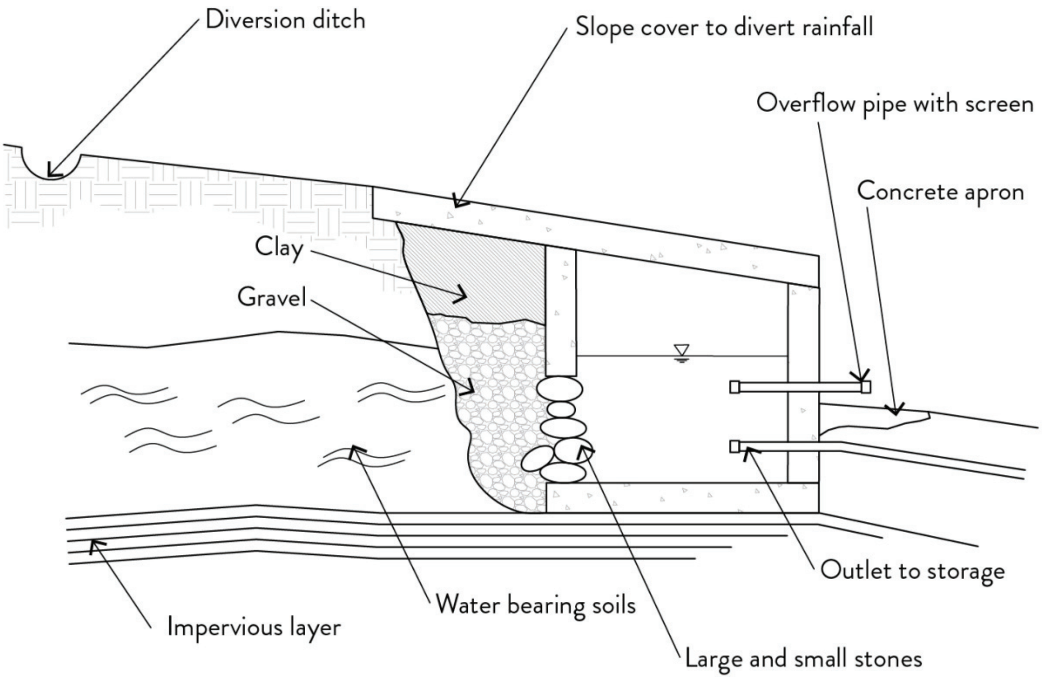
27.4.X. The top of the well casing at sites subject to flooding must terminate at least 3ft (91.4cm) above the 100 year flood level or the highest known flood elevation, whichever is higher.

27.4.Y. A PVC sump of at least 3ft (91.4cm) and bottom cap must be used to seal the bottom of drilled wells to collect silt that may enter the casing.

Spring Boxes

A spring box is a method used to capture groundwater at the surface in a manner that protects it from contamination. Spring boxes are desirable sources of water because they provide groundwater, which is somewhat more likely than surface water to be of good quality. Generally they are cheaper to build than hand dug wells. Springs are most often located on hillsides. If one exists on a hillside above the site of a healthcare facility it may provide the facility with raw water by gravity flow, saving the cost of a pump and power supply.

Figure 27.d. Typical Spring Box Configuration



27.4.Z. A spring to be used as a water source must have a dry season (1 November through 30 April) flow rate of at least 100 gallons per hour

i. Springs flow constantly so a rate of flow less than an intermittently operating pumped well is acceptable.
ii. A spring box may serve as an auxiliary source of water for a facility that also draws water from a well or surface water body.

27.4.AA. The area upslope of a spring must not contain any potential source of pollution such as a latrine, septic tank, sewer line, rubbish tip, underground fuel tank, cemetery, or industrial operation within 300ft of the spring.

27.4.BB. The spring box must be constructed in a manner that the groundwater is protected from surface water contamination.

i. The spring box must be installed so that groundwater flow is captured in a cast-in-place diversion box that is sealed on the sidewalls and top to direct the flow to outlet pipes that are sealed into the box.
ii. The spring box outlet must be installed so that it is lower than the flow line of the spring water to prevent water from backing up in the box and creating backpressure in the box. Backpressure in the spring box may lead to the spring flow to flow out of the sidewalls of the spring and not into the outlet pipe.
iii. The spring box must have an overflow pipe that is placed above the outlet pipe, but lower than the spring flow line to provide for a secondary outlet in case the main outlet line is closed or obstructed.
iv. The outlet of the overflow line must be screened to prevent insects and vermin from entering the spring box. The screen should be at least 1/16" stainless steel mesh.
v. A drainage diversion ditch must be installed at least 25ft (7.6cm) above the spring box to divert surface runoff around the box. The width, depth and length of the diversion ditch must be long enough to effectively capture and convey runoff away from the spring box.

27.5 Rainwater Harvesting

Rainwater harvesting can be a supplemental and high source of water to healthcare facilities. Rainwater is well suited for non-potable uses and with additional treatment is adequate for potable uses. The following standards pertain to rainwater catchment systems that capture runoff from roofs and other hardened surfaces that are not prone to substantial surface contamination. The standards include collection, pre-treatment, storage, final treatment and distribution.

Collection Surface

Collection surfaces are sloped horizontal surfaces including roofs and concrete slabs where rainfall lands and flows off usually as sheet flow and is intercepted by gutters on the downslope edge of the collection surface.

27.5.A. Rainwater collection surfaces must be above-ground, hard surfaces constructed of impervious material.

i. Proximity to airborne pollution sources, such as waste incinerators, must be avoided.

27.5.B. For potable water applications the collection surface must be as noted above, but must also be made of non-toxic material.

i. Painted surfaces are only acceptable if paint has been certified to ensure the toxicity level of the paint is acceptable for drinking water contact. Lead, chromium or zinc based paints are not permitted.
ii. Enameled Steel roofs are acceptable surfaces.
iii. Collection of water from vehicular parking surfaces is prohibited.
iv. Materials <u>not</u> approved for potable water applications include:
  - Galvanized, Zinc or Copper roofing materials.
  - Lead flashing is not approved for potable water.
  - Bitumen / Composition roofing

27.5.C. All surfaces, tanks and equipment must be washed clean before they are put into service.

Conveyance System

Conveyance systems include the rainwater gutters that collect the rainfall off of a roof and typically include debris screens (Refer to Figure 27.f.) and a first flush diverter (Refer to Figure 27.e.) that are used to intercept organic matter and debris that is washed off of the collection surface (roof).

27.5.D. Gutters, piping, fittings, valves, screens, down spouts, leaders, flushing devices, tanks, and liners, must be appropriate for the intended use.

i. Gutters and down spouts must be manufactured of PVC, HDPE or other material safe for non-potable and potable use.
ii. Copper or zinc gutters and down spouts must not be used.
iii. All piping and plumbing component materials used in the installation of a rainwater harvesting system must be as approved for the specific use by the MOHSW.

27.5.E. Screen and pre-filtration systems must meet the following requirements:

i. All collected rainwater must pass through a first flush diverter and debris screen system before the water enters the cistern(s).
ii. Debris screens and first flush divert system must be designed as follows:

- The inlet to the first flush divert should be provided with a debris screen that prevents debris and vermin from entering the cistern. The debris screen must be made of corrosion resistant material and must have openings no larger than $^{1}/_{2}$in (1.3cm) and no smaller than $_{1/4}$in (6mm) nominal.
- At the onset of a rainstorm a sufficient amount of rainwater should be wasted, and not allowed to enter the cistern, to wash accumulated debris from the collection surface (i.e. roof). This should be accomplished using first flush diverter system.
- The amount of rainfall to be wasted should be adjustable as necessary to minimize cistern water contamination.
- Water drained from the first-flush diverter should be piped away from the storage tank and terminate in a location which will not cause damage to property or cause erosion.

iii. If more than one cistern is used a screen and pre-filtration system must be provided for each cistern. Exception: Where cisterns are interconnected to supply water in series, a single pre filter can be employed.

iv. First flush diverters must be provided with an automatic or manual means of draining between rain events.

v. Screen and first flush diverters must be readily accessible for regular maintenance.

Figure 27.e. First Flush Diverter Layout

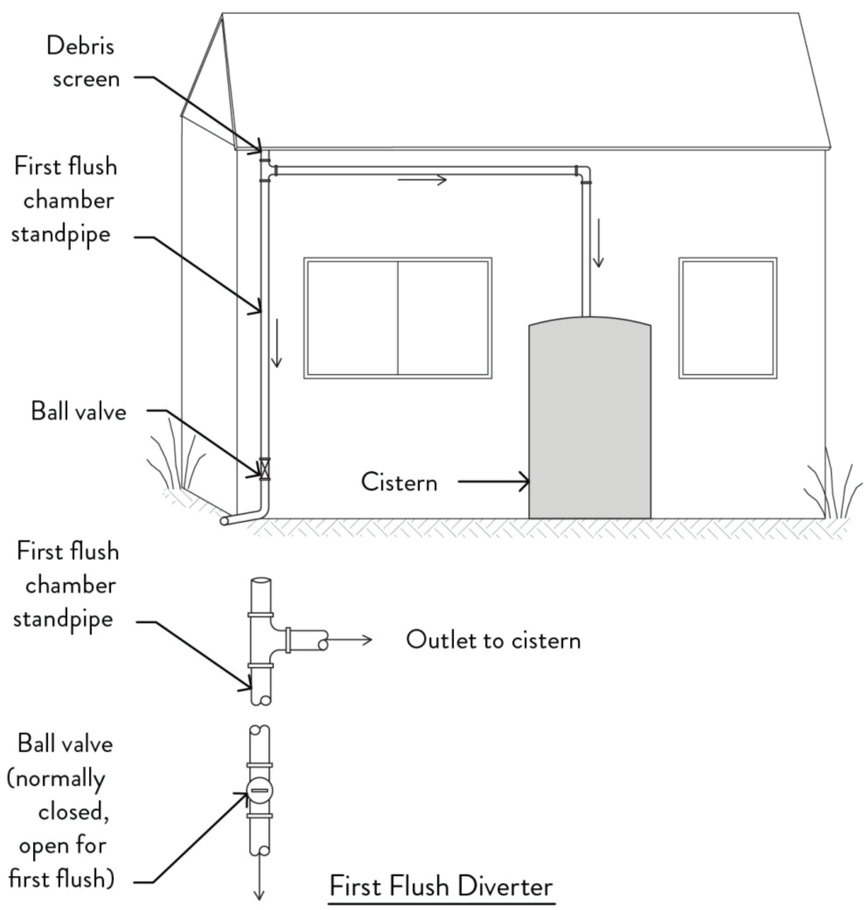
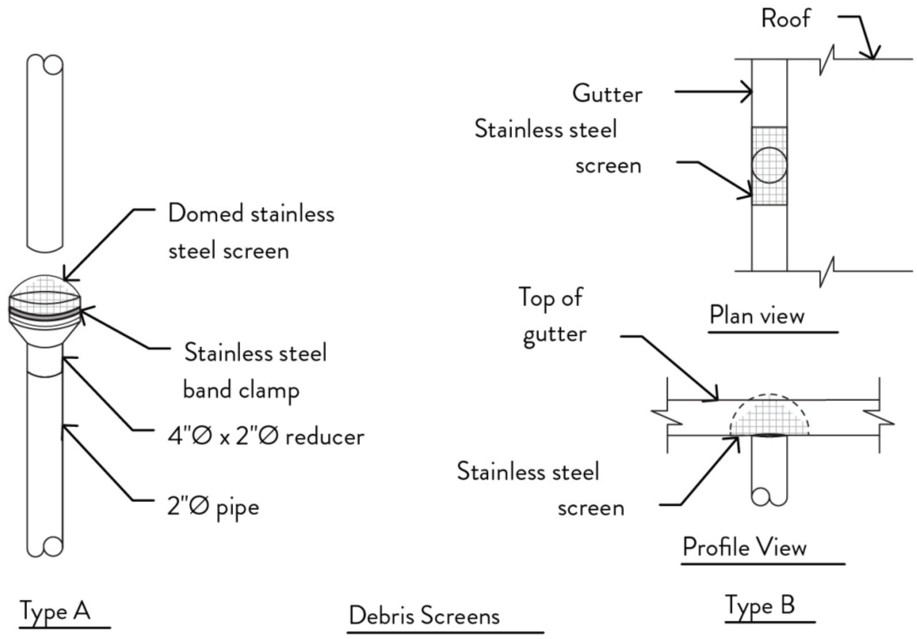


Figure 27.f. Typical Debris Screen Configurations



Rainwater Storage

Cisterns are used as stormwater collection points providing a water reservoir for later use. Cisterns should have access to allow inspection and cleaning. Cisterns can be installed either above or below grade. The following are the minimum requirements for cisterns.

27.5.F. Above grade cisterns must be protected from direct sunlight and must be constructed using opaque, UV resistant, materials.

27.5.G. Below grade cisterns, located outside of the building, must be provided with manhole risers a minimum of 4in (10.2cm) above surrounding grade and/or installed in such a way as to prevent surface or ground water from entering through the top of any fittings.

27.5.H. Where the installation requires a foundation, the foundation must be flat and designed to support the cistern weight when the cistern is full and consistent with bearing capability of adjacent soil.

27.5.I. Above grade tanks must be installed on a sturdy and level foundation or platform, adequately secured with adequate drainage.

27.5.J. In a situation where the soil can become saturated, underground tank(s) must be ballasted, or otherwise secured, to prevent the tank from floating out of the ground when empty.

i. The combined weight of the tank and hold down ballast must meet or exceed the buoyancy force of the tank, calculated as follows:

Example Buoyancy Calculation

Buoyant force of Cistern (lbs) = Cistern Volume (cubic ft) x 62.4 (lbs/ ft^3)

E.g. for a 1000 gallon tank, Buoyant force will be 1000 gallons x (1 ft^3 */ 7.48 gallons) x 62.4 (lbs/*ft^3*) = 8342 lbs*

If concrete used as ballast, the volume needed will be:

Volume (ft^3*) = 8342 lbs x* ft^3 */ 165 lbs = 50.6* ft^3 *(1.9 cubic yards)*

27.5.K. Cisterns must be provided with a means for draining and cleaning.

27.5.L. All cistern openings must be protected from unintentional entry by human or vermin. Manhole covers must be provided and must be secured to prevent tampering.

27.5.M. The cistern inlets and outlets must meet the following requirements:

i. The pipe entering the cistern must terminate in a return bend elbow pointed upward, or equivalent calming device, at the bottom of the tank to minimize splashing and disturbance of accumulated sediment on the bottom of the tank.
ii. The overflow outlet must be protected with a screen having openings no greater than 1/4in (6mm), or as otherwise appropriate, for preventing entrance of insects or vermin entering the cistern.
iii. Overflow outlet must be sized to accommodate the maximum flow conveyed the gutters
iv. Water from the cistern overflow must be discharged in a safe and non-erosive manner, or allowed to infiltrate into the soil using an infiltration basin.

27.5.N. Cisterns intended to be used for potable water storage must be approved by the assigned IU representative for this use.

27.5.O. Cisterns and storage tanks must not be connected directly to a public or community water supply without approved back-flow protection.

i. Make up water to rainwater storage tank(s), when provided, must be made so that an air gap is provided between the supplemental water inlet and the overflow pipe to assure untreated water does not flow into the potable water system.
ii. Cisterns for potable water application the outlets must be provided with floating inlet to draw water from the cistern just below the water surface or the outlet should be located at least 4in (10.2cm) above the bottom of the cistern.

Rainwater Treatment

Where rainwater is used for non-potable use and for non-critical operations, such as irrigation, wash down, etc., a final stage filtration system is not required. Where rainwater is used for non-potable use, interior to an occupied facility, for makeup for laundry, toilets, process, etc.; the water should be filtered as a safeguard against sediment or discoloration, and for proper operation of valves or other devices. Rainwater catchment systems used for potable water applications must use a multi-barrier treatment system to remove pathogens, sediment and other potential contaminants and the multi-barrier treatment system should at a minimum include filtration and disinfection treatment systems.

27.5.P. Non-potable interior reuse of rainwater must be filtered prior to entering the building. The water filter must be rated to remove particles to less than or equal to 20 microns.

27.5.Q. For water storage volumes less than 200 gallons, or intended for minor utility, irrigation and garden use, no treatment is necessary.

27.5.R. For non-potable water applications harvested rainwater must be filtered or treated to an appropriate quality suitable for intended use. No treatment is necessary for general washing, landscape irrigation or garden use.

27.5.S. Potable reuse of rainwater must be treated using a multi-barrier treatment system.

i. The treatment system must include the following components:
   - A pre-filter including a gravel roughing filter, a cartridge filter or disc filter rated to remove coarse and fine suspended particulate matter to 20 microns or less.
   - A final filter system consisting of a slow sand filter, a pressure sand filter, cartridge filters approved by the assigned IU representative, or other advance filtration technique rated to remove particles less than 1 micron and as is approved by the Ministry of Health and Social Welfare (MOHSW).

ii. Carbon filtration can be provided for reduction of taste, odor and organic chemicals and shall comply with the requirements of the MOHSW.

iii. All filters must be of adequately size to extend service time.

iv. A disinfection system must be installed after the final filtration system using either chlorination, ozone or ultra-violet (UV) disinfection processes.
   - Chlorination may be used with an automated demand feed system, and if used, shall enable adequate contact time and residual according to local health authorities.
   - Ozone may be used with an approved ozone system ensuring adequate contact time with the ozone. Provision must be made to off- gas ozone to a safe environment.
   - Ultra-violet disinfection may be used and shall be provided between filtration (30 micron or less) and final point of use.

v. Filtration and Disinfection systems must be located as close to the final point of use as possible.

Rainwater Distribution

27.5.T. There must be no direct connection of any rainwater harvesting pipe system and sanitary sewer system.

27.5.U. Separation must be maintained between potable and non-potable water systems at all times and cross connections, without proper protection must not be permitted.

27.5.V. When rainwater non-potable pipe and potable water pipe are installed in the same trench, wall cavity, or other location, the potable water pipe must be separated by a minimum distance of 12in (30.5cm) above the rainwater harvesting pipe.

Piping Materials

27.5.W. Rainwater distribution water piping, fittings and other related system components must be suitable for domestic water application.

27.5.X. Plastic piping must be protected from UV radiation by a factory apply protective coating, or painted with a compatible latex paint. Piping and solvent cements shall be approved for the intended use.

Rainwater System Labeling

27.5.Y. All rainwater supplied fixtures, not specifically treated for potable water use, must be prominently labeled "NON-POTABLE - DO NOT DRINK".

27.6 Water Supply Pumps

One or multiple pumps may be required to convey water to an elevated storage tank, to pressurize a water distribution system or to pump water through a treatment system. Pump systems require vigilant attention and maintenance to be able to operate reliably. Pump systems tend to have a high rate of failure due to several reasons, including mechanical failures, electrical power problems (such as voltage drops and spikes), a lack of maintenance and other problems. Many different types of pumps are put to the task of moving water and each type is subject to its own assortment of failures.

Pumps may be categorized according to their driving force (manually-operated, AC electricity, DC electricity, or internal combustion engine) or their pumping action (suction lift, Venturi ejector, or positive displacement by either rotary or reciprocating action). This section will first present general standards for pumping stations applicable to all types of pumps and specify that the pumps are situated in lockable enclosures situated on or next to hand or machine-dug wells or on constructed pumping sumps adjacent to surface water bodies.

Pumping Systems

Pumping systems are used to pump surface water, groundwater and rainwater to elevated cisterns for water distribution purposes. Pumps are also used in certain locations to maintain pressure in the water distribution system and to operate a water treatment system. The following standards apply to all pump systems related to the domestic water system serving the healthcare facility.

27.6.A. PHC 1 and PHC 2 may have hand pumps only. Health Centers and above must have an electric pump. All PHC and Health Center facilities with an electric pump must have a hand pump to provide redundancy and serve as a backup during emergencies or in case of equipment failure.

27.6.B. All pumps and their components must be rated and approved for use with potable water systems.

i. Any components in contact with the water supply must be mercury-free devices. This includes level float controls controlling pumps and makeup water valves.

27.6.C. The electric pump system must be capable of delivering a minimum of 15 psig residual pressure at the highest and/or most remote outlet served.

i. Minimum pump pressure must allow for friction and other pressure losses.
ii. Maximum pressures must not exceed 80 psig.
iii. A pressure-reducing valve must be provided at water branch distribution piping if the pump is capable of exceeding 75 psig.

27.6.D. Pumping systems must be designed to be easily accessible for routine maintenance and repairs and in a manner to maintain the sanitary quality of pumped water. Subsurface pits or pump rooms and inaccessible installations must not be used.

27.6.E. Pumping systems must not be subject to flooding or other potential hazards.

i. The pumping systems must be located so that the proposed site will meet the requirements for sanitary protection of water quality, hydraulics of the system and protection against interruption of service by fire, flood or any other hazard.
ii. The pumping system must be elevated to a minimum of 3ft (91.4cm) above the 100-year flood elevation, or 3ft (91.4cm) above the highest recorded flood elevation, whichever is higher, or protected to such elevations.
iii. The pumping system must be readily accessible at all times unless permitted to be out of service for the period of inaccessibility.

iv. The site for the pumping system must be graded around the system, so as to lead surface drainage away from the station.
v. The pumping system must be protected to prevent vandalism and entrance by animals or unauthorized persons. The pump station should be located within a secure area such as a locked building or fenced area.
vi. The pumps and valves in the system must be tagged to correspond to the maintenance record and for proper identification.
vii. The pumping system must have adequate space for the installation of additional units, if needed, and for the safe servicing of all equipment.
viii. The pumping system must be of durable construction, fire and weather resistant, and with outward-opening doors if enclosed in a building.
ix. The pumping system must have floor or pad elevations of at least 6in (15.3cm) above finished grade.
x. If the pumping system is enclosed in a building the building must have a floor drained to assure that water on the floor does not enter the pump system and impact the quality of the potable water.
xi. Pump systems must be provided with crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors or other heavy equipment; openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment; a convenient tool board, and/or other facilities as needed, for proper maintenance of the equipment.
xii. As much as possible, pump systems must be fitted with a rate and totalizing flow meter.
xiii. Adequate ventilation must be provided for all pumping systems to protect the motors and dissipation of excess heat from the equipment. Forced ventilation of at least six changes of air per hour shall be provided for all confined rooms, compartments, pits and other enclosures below ground floor.
xiv. If electric power is provided, pump systems must be adequately lighted to deter vandalism and facilitate maintenance.

27.6.F. At least two pumping units (duplex) must be provided for each raw water source. With any pump out of service, the remaining pump or pumps must be capable of providing the maximum pumping demand of the system.

i. Pumping units must have a means for measuring the discharge.
ii. Pumping units must have ample capacity to supply the peak demand against the required distribution system pressure without dangerous overloading.
iii. Pumping units must be driven by prime movers able to meet the maximum horsepower condition of the pumps.
iv. Be provided with readily available spare parts and tools.
v. Be served by control equipment that has proper heater and overload protection for air temperature encountered.
vi. Include at least one manual-powered pump if such a pump is able to meet the required demand.

27.6.G. When a pump requires priming (e.g. suction lift pumps or Venturi ejector pumps), appropriate practices must be followed:

i. Priming water must not be of lesser sanitary quality than that of the water being pumped.
ii. Means must be provided to prevent either back-pressure or back-siphoning into the water source.
iii. When an air operated ejector is installed, the screened intake must draw clean air from a point at least 10ft (3m) above the ground or other source of possible contamination, unless the air is filtered by an apparatus acceptable to the MOHSW. Vacuum priming may be used.

27.6.H. When a suction lift pump is installed the appropriate practices must be observed.

i. The source water level must not be more than 15ft (4.6m)below the pump.

ii. The suction line must have a rigid section (PVC or stainless steel) passing vertically through the concrete slab covering the water source and having a water-tight seal with the slab. An air-tight flexible connector should join the pump to the top of the rigid section.
iii. A screened foot valve at the intake end of the suction line must have a net valve area of at least 2 ½ times the area of the suction pipe.

27.6.I. When a reciprocating positive displacement hand pump is installed, appropriate practices must be observed:

i. The pump base must have a water-tight seal with the concrete slab covering the water source.
ii. The seals on the reciprocating piston must be inspected at least once every 90 days and replaced as necessary.
iii. The seals on the pump head that allow the pump to raise water to elevated storage must not leak water on the pumping station floor.

27.6.J. When an electric submersible pump is installed in the water source (hand-dug well or bored well), appropriate practices must be observed:

i. The riser pipe and electrical cable from the pump must pass through a steel and rubber well seal making a water tight connection with the length of PVC casing installed at the center of the concrete slab covering the water source.
ii. The pump motor must be protected from overheating by an approved method (either float switches or thermal overload circuit).
iii. Float switches must be installed in the elevated storage tank to disallow the pump to overfill the tank.

27.6.K. When an electric turbine pump is installed in the water source, appropriate practices must be observed.

i. The pump base must have a watertight seal with the concrete slab covering the water source.
ii. The annulus between the pump riser and the casing penetrating the concrete slab over the water source must be made watertight.
iii. The pump motor must be protected from overheating by an approved method (either float switches or thermal overload circuit).
iv. Float switches must be installed in the elevated storage tank to disallow the pump to overfill the tank.
v. The seals on the pump head that allow the pump to raise water to elevated storage must not leak water on the pumping station floor.

27.6.L. If booster pumps are installed in the water distribution system, appropriate practices must be observed.

i. Booster pumps must be located or controlled so that they will not produce negative pressure in their suction lines.
ii. Pumps installed in the distribution system must maintain inlet pressure at a minimum of 15psi under all operating conditions. Pumps taking suction from storage tanks should be provided adequate net positive suction head.
iii. Automatic shut-off or low pressure controller must maintain at least 15psi in the suction line under all operating conditions, unless otherwise acceptable to the MOHSW and/or the Ministry of Public Works. Pumps taking suction from ground storage tanks should be equipped with automatic shutoffs or low pressure controllers, as recommended by the pump manufacturer.
iv. Automatic or remote control devices must have a range between the start and cutoff pressure, which will prevent excessive cycling.
v. Where possible, a bypass line must be available.

Appurtenances

Appurtenances include the parts that must be installed up and downstream of the pumping equipment, such as valves and fittings that assure that the pumping system works properly as well as can be shut off and be removed for routine maintenance, repair and/or replacement.

27.6.M. Each pump must have an isolation valve on the intake and discharge side of the pump to permit satisfactory operation, maintenance and repair of the equipment.

27.6.N. Each pump system must be designed to include a positive-acting check valve on the discharge side between the pump and the shut-off valve and surge relief valves or slow acting check designed to minimize hydraulic transients.

27.6.O. Pump piping must be of high quality standards.

i. Pump piping assemblies must be designed so that the friction losses will be minimized.
ii. Piping must be designed and installed so it is not be subject to contamination.
iii. All piping must have watertight joints.
iv. All piping must be securely anchored, where necessary to protect against surge or water hammer.
v. All piping must be designed such that each pump has an individual suction line or that the lines shall be so connected in a manifold that they will insure similar hydraulic and operating conditions.

Controls

27.6.P. Pumps, their prime movers and accessories, must be controlled in such a manner that they will operate at rated capacity without dangerous overload.

27.6.Q. Where two or more pumps are installed, provisions must be made for alternations.

27.6.R. Provision must be made to prevent energizing the motor in the event of a backspin cycle.

27.6.S. Electrical controls must be located above grade.

27.6.T. Equipment must be provided with voltage regulation to protect motors when there is a shift in line voltage and or other arrangements made to prevent surge pressures from activating controls which switch on pumps or activate other equipment outside the normal design cycle of operation.

Standby Power

27.6.U. A power supply must be provided from a standby or auxiliary source to ensure continuous service when the primary power has been interrupted.

i. If standby power is provided by onsite generators or engines, the fuel storage and fuel line must be designed to protect the water supply from contamination. (Carbon monoxide detectors are recommended when generators are housed within pump stations.)

Lubrication

27.6.V. When automatic pre-lubrication of pump bearings is necessary and an auxiliary power supply is provided, the design must assure that pre-lubrication is provided when auxiliary power is in use, or that bearings can be lubricated manually before the pump is started.

27.6.W. All oil or grease lubricants which come into contact with the potable water shall be listed in ANSI/NSF Standard 60.

27.7 Water Treatment

Water supplies to health facilities must conform to the Liberian water quality standards for potable water (see Section 8.6). In some cases water extracted from the ground or captured hygienically from a spring may meet these standards. More often, the raw water will require treatment to remove pathogens and particulate matter. Many water sources will provide water that has additional treatment needs: reduction of iron and manganese, elimination of odor and/or color, or reduction of toxic metal concentrations.

Design of Water Treatment Processes

The design of treatment processes and devices depend on an evaluation of the nature and quality of the source of water to be treated, seasonal variations, the desired quality of the finished water and the mode of operation planned.

27.7.A. Water treatment works must be constructed with cross-connection controls to assure that the service water lines discharging to liquid storage tanks are absolutely protected from backflow.

27.7.B. The treatment works must be designed and constructed so that chemical solutions or slurries cannot be siphoned through liquid chemical feeders into the water supply.

27.7.C. There must be no direct connection between any sewer and a drain or overflow from the liquid chemical feeder, liquid storage chamber or tank.

27.7.D. All drains must terminate at least 6in (15.3cm) or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, conduit or waste receptacle.

27.8. Storage Facilities

Once water has been taken from a source and treated to the suitable standard it must be stored until it can be used. A weak or deficient storage system can undo all the benefits instilled by the preceding processes. Inadequate storage facilities are commonly the cause of unsatisfactory water being delivered to consumers. Disease outbreaks are frequently traced to failures in the storage system.

27.8.A. The materials and designs used for finished water storage structures must provide stability and durability as well as protect the quality of the stored water.

27.8.B. Porous material, including wood and concrete block, must not be used for potable water contact applications.

HDPE Tanks

For small to medium-sized health facilities the preferred choice is a manufactured HDPE tank of an appropriate size (1.5 times daily water use). All HDPE tanks are not of equal quality and the method of tank installation seriously affects tank performance.

27.8.C. HDPE water storage tanks must meet the following requirements:

i. HDPE tanks must be manufactured from virgin UV protected HDPE resin.
ii. The HDPE tank must be mounted on an absolutely level rigid surface larger than the tank bottom circumference. The entire bottom of the tank must be supported.
iii. Piping connections on HDPE tanks must be adequately supported with pipe supports and expansion joints or flexible connections to allow for thermal expansion and normal flexing of the tank wall.

27.8.D. Ground level storage tank(s) must be fenced, locks must be provided on access manholes, and other necessary precautions must be provided to prevent trespassing, vandalism, and sabotage.

Sizing

27.8.E. Storage facilities must have sufficient capacity, as determined from engineering studies, to meet water use demands, including, where fire protection is provided, fire flow demands.

27.8.F. The minimum storage capacity for systems not providing fire protection must be equal to 1.5 times the average daily consumption.

Location of Storage Tanks

27.8.G. The lowest elevation of the floor and sump floor of ground level storage tanks must be placed above the elevation of the highest flood of record and at least 2ft (61cm) above the groundwater table.

27.8.H. Water storage tanks must be kept at least 10ft (3m) from buried sewer line, storm drain lines, and potential sources of contamination.

27.8.I. The bottom of ground level storage tanks and standpipes must be placed at the normal ground surface.

i. If the bottom of a storage tank must be below the normal ground surface, at least 50 percent of the water depth must be above grade.
ii. The top of a partially buried storage structure must not be less than 2ft (61cm) above normal ground surface.

Protection from Contamination

27.8.J. All finished water storage structures must have suitable watertight roofs, which exclude birds, animals, insects, and excessive dust.

27.8.K. The installation of appurtenances, such as vents, antenna, must be done in a manner that ensures no damage to the tank, coatings or water quality, or corrects any damage that occurred.

Drains

27.8.L. No drain on a water storage structure must have a direct connection to a sewer or storm drain.

27.8.M. The design must allow draining the storage facility for cleaning or maintenance without causing loss of pressure in the distribution system.

Overflow

27.8.N. All water storage structures must be provided with an overflow.

i. Overflows must be brought down to an elevation between 1 ft (30.5cm) and 2ft (61cm) above the ground surface, and discharge over a drainage inlet structure or a splash plate.
ii. Overflow must not be connected directly to a sewer or a storm drain.
iii. All overflow pipes must be located so that any discharge is visible.
iv. The overflow pipe must be located on the outside of the structure.

27.8.O. The overflow for a ground-level storage reservoir must open downward and be screened with 24-mesh non-corrodible screen.

i. The screen must be installed within the overflow pipe at a location least susceptible to damage by vandalism.

27.8.P. The overflow for an elevated tank must open downward and be screened with a 4-mesh, non-corrodible screen or mechanical device, such as a flap valve or duckbill valve, to keep out animals or insects.

i. The screen must be installed within the overflow pipe at a location least susceptible to damage by vandalism.
ii. The overflow pipe must be of sufficient diameter to permit spillage of water in excess of the filling rate.
iii. When a flapper or duckbill valve is used, a screen must be provided inside the valve.

Access

27.8.Q. Finished water storage structures must be designed with reasonably convenient access to the interior for cleaning and maintenance.

27.8.R. All water tanks must have access manways.

i. The access manways must be framed at least 4in (10.2cm) above the surface of the roof at the opening.
ii. They must be fitted with a solid water tight cover which overlaps the framed opening and extends down around the frame at least 2in, (5cm) must be hinged on one side, and must have a locking device.

Vents

27.8.S. **Finished water storage structures must be vented. The overflow pipe cannot be considered a vent. Open construction between the sidewall and roof is not permissible. Vents must be installed tithe following requirements:**

i. Vents must prevent the entrance of surface water and rainwater.
ii. Vents must exclude birds and animals.
iii. Vents must exclude insects as much as this function can be made compatible with effective venting.
iv. Vents on ground-level tanks must open downward with the opening at least 2 feet above the roof and covered with 24-mesh non-corrodible screen.
v. Vent screen must be installed within the pipe at a location least susceptible to vandalism.

Roof and Sidewall

27.8.T. **The roof and sidewalls of all water storage structures must be watertight with no openings.**

i. Exceptions include properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow. This standard applies as well to the sealing of roof structures, which are not integral to the tank body.

27.8.U. **Any pipes running through the roof or sidewall of a metal storage structure must be welded, or properly gasketed.**

i. In concrete tanks, these pipes must be connected to standard wall castings, which were poured in place during the forming of the concrete.
ii. Wall castings in concrete tanks should have seepage rings imbedded in the concrete.

27.8.V. **Openings in the roof of a storage structure designed to accommodate control apparatus or pump columns must be curbed and sleeved with proper additional shielding to prevent contamination from surface or floor drainage.**

27.8.W. **Valves and controls must be located outside the storage structure so that the valve stems and similar projections do not pass through the roof or top of the reservoir.**

27.8.X. **The roof of the storage structure must be well drained.**

i. Downspout pipes must not enter or pass through the reservoir.
ii. Parapets, or similar construction which would tend to hold water on the roof, are not allowed.
iii. The roof of concrete reservoirs with earthen cover must be sloped to facilitate drainage and require installation of an impermeable membrane roof covering.

27.8.Y. **Reservoirs with pre-cast concrete roof structures must be made watertight with the use of a waterproof membrane or similar product.**

Safety

27.8.Z. **Safety must be considered in the design of the storage structure. The design must conform to pertinent laws and regulations of the area where the water storage structure is constructed.**

27.8.AA. **Ladders, ladder guards, balcony railings, and safely located entrance hatches must be provided where applicable.**

i. Elevated tanks with riser pipes over 8in in diameter must have protective bars over the riser openings inside the tank.
ii. Railings or handholds must be provided on elevated tanks where persons must transfer from the access tube to the water compartment.

Silt Stop

27.8.BB. **The discharge pipes from water storage structures must be located in a manner that will prevent the flow of sediment into the distribution system.**

27.8.CC. **An up turned elbow must be installed on the outlet pipe of the storage structure and the outlet pipe must be installed 2in above the bottom of the floor of the reservoir.**

Site Preparation and Grading

27.8.DD. **The area surrounding a ground-level structure must be graded in a manner that will prevent surface water from standing within 30 feet of it.**

Painting and Cathodic Protection of Metal Tanks

27.8.EE. **Proper protection must be given to metal surfaces by paints or other protective coatings.**

27.8.FF. **A cathodic protection system must be installed on the tank if the tank will be subjected to corrosive soils or site conditions.**

i. Cathodic protection, if used, must be designed and installed by competent technical personnel, and a maintenance contract must be provided.

27.8.GG. **Paint systems must not create a risk for any adverse health effects.**

i. Interior paint must be applied, cured, and used in a manner consistent with not causing adverse health effects.
ii. After curing, the coating must not transfer any substance to the water, which will be toxic or cause taste or odor problems.
iii. If possible, only use 100% solids coatings.

Disinfection and Testing

27.8.HH. **Finished water storage structures must be disinfected before use.**

i. Fill the structure with water and add chlorine solution to achieve a concentration of 200 mg/l free chlorine.
ii. This mixture must remain in the structure for a minimum of 30 minutes.

27.8.II. **Following disinfection, water samples must be taken for determination of bacteria to indicate microbiologically satisfactory water before the facility is placed into operation.**

27.8.JJ. Disposal of heavily chlorinated water from the tank disinfection process must be in accordance with the requirements of the appropriate regulatory agency. Under no condition may it be discharged directly to a surface water body or stormwater sewer.

27.8.KK. Smooth-nosed sampling tap(s) must be provided to facilitate collection of water samples for both bacteriological and chemical analyses. The sample tap(s) must be easily accessible.

Pressures

27.8.LL. The maximum variation between high and low levels in storage structures providing pressure to the distribution system must not exceed 35ft (10.7m).

27.8.MM. As much as possible, the minimum working pressure in the distribution system must be 5 pounds per square inch (psi) and the normal working pressure must be approximately 30 to 60psi.

27.8.NN. When static pressures exceed 60psi, pressure-reducing devices must be provided on mains or as part of the meter setting on individual service lines in the distribution system.[1]

27.8.OO. Finished water storage structures that provide pressure directly to the distribution system must be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without causing a loss of pressure in the distribution system.

Level Controls

27.8.PP. Adequate controls must be provided to maintain levels in distribution system storage structures.

i. Level indicating devices must be provided at a central location.
ii. As much as possible, pumps must be controlled from tank levels with the signal transmitted by telemetering equipment when any appreciable head loss occurs in the distribution system between the source and the storage structure.
iii. Prioritize the location of level warnings or alarms where they will be under responsible surveillance 24 hours a day.
iv. Altitude valves or equivalent controls may be required for a second and subsequent structures on the system.
v. Prioritize the location of overflow and low-level warnings or alarms where they will be under responsible surveillance 24 hours a day.

27.9 Water Conveyance and Distribution

Once water is diverted from its source it must be conveyed by a system of pipes to a storage tank or to a treatment system followed by a storage tank. The water line from the source to the storage/treatment system is referred to as a water conveyance line. From the storage tank/reservoir water is distributed through another series of pipes and thus is called the water distribution piping. In some instances water sources such as deep wells may be connected directly to the water distribution system and use this system to supply the users directly and/or to fill the water distribution system. At some larger installations there may also be a separate system for distributing raw water for fire protection and/or for landscape irrigation. Each and all of these distribution components must be designed and constructed to proper standards to assure long working life, to prevent the loss of water and contamination of treated water intended for human consumption or medical use.

27.9.A. Water distribution systems must be designed to convey raw water through a treatment system and into elevated treated water storage. The portions of the distribution system conveying treated water must maintain treated water quality.

i. Water distribution systems for healthcare facilities in Liberia will normally utilize both pumping and gravity to move the water through the system. The only exception will be facilities with a water source that delivers water to the facility by gravity and with a pressure equivalent to at least 27ft (8.2m). These exceptional systems require no pumping.

ii. Most frequently raw water will enter the treatment system with pressure imparted by a pump. The pump must impart sufficient pressure to compensate head losses in the treatment system and deliver the treated water to elevated storage at a sufficient rate to meet average demand.

iii. The height of the inlet to elevated storage depends on the height of the health facility:
  - 1 story building = 33ft (10.1m)
  - 2 story building = 50ft (15.2m)
  - 3 story building = 66ft (20.1m)

27.9.B. All materials including pipe, fittings, valves and fire hydrants must conform to the latest standards issued by the ASTM, AWWA and ANSI/NSF, where such standards exist, and be acceptable to the MOHSW and MPW.

i. In the absence of such standards, materials meeting applicable Product Standards and acceptable to the MOHSW and MPW may be selected.

ii. Special attention must be given to selecting pipe materials which will protect against both internal and external pipe corrosion.

iii. Water mains which have been used previously for conveying potable water may be reused provided they meet the above standards and have been restored practically to their original condition.

iv. Packing, gluing, and jointing materials used in the joints of pipe shall meet the standards of AWWA and the MOHSW and MPW.

v. Pipe having threaded joints or slip-on joints with rubber gaskets or glue is preferred.

vi. Gaskets containing lead shall not be used.

vii. Manufacturer approved transition joints shall be used between dissimilar piping materials.

Common Pipe Materials

The requirement to protect against internal and external corrosion eliminates or severely restricts the use of galvanized iron pipes (GIP). Exceptions may be made when the mechanical strength of GIP is required, the length of pipe is trivial, and the accessibility to the pipe for replacement is easy. For example, a short outside GIP standpipe with faucet could be connected to a buried PVC pipe provided the standpipe is isolated from the surrounding soil by at least 4in (10.2cm) of 1:2:3 concrete.

Unplasticized Polyvinyl Chloride (uPVC or commonly just PVC) pipe is commonly available with internal diameters from ½in (1.3cm) to 8in (20.3cm) and fittings such as elbows, tees, and threaded adapters are easily found. The pipe is joined end to end or to fittings with dissolved PVC glue to make very strong, leak-proof joints. It is manufactured in various wall thicknesses, which give varying resistance to internal pressures. Only wall thicknesses equivalent to Schedule 40 or Schedule 80 are suitable for water distribution systems.

27.9.C. Special consideration must be given to distribution main sizing, providing for design of multi-directional flow, adequate valving for distribution system control, and provisions for adequate flushing. Systems must be designed to maximize turnover and to minimize residence times while delivering acceptable pressures and flows.

i. Generally, small health facilities with peak water demand of 18 gpm or less (e.g. with 6 faucets each capable of delivering 3 gpm) must be designed with default minimum pipe sizes (2in (5cm) main, 1in (2.5cm) long (≥10ft (3m)) laterals, and ¾-inch short (<10 feet) laterals) without analysis of flows, diameters, and pressures.

ii. Dead ends must be minimized by making appropriate tie-ins whenever practical, in order to provide increased reliability of service and reduce head loss.

iii. Dead end mains must be equipped with a means to provide adequate flushing. Flushing devices must be sized to provide flows, which will give a velocity of at least 2.5ft (76.2cm) per second in the water main being flushed. No flushing device should be directly connected to any sewer.

iv. A sufficient number of valves must be provided on water mains to minimize inconvenience and sanitary hazards during repairs. Valves must be located at not more than 200ft (61m) intervals on the main and on each lateral where it joins the main.

v. Water mains not designed to carry fire-flows must not have fire hydrants connected to them. It is recommended that flushing hydrants be provided on these systems. Flushing devices should be sized to provide flows which will give a velocity of at least 2.5ft (76.2cm) per second in the water main being flushed. No flushing device shall be directly connected to any sewer.

27.9.D. A fire protection system must have 20,000 gallons of stored raw water and the means (either pump or elevation) to deliver 100 gpm to the fire protection main at a pressure of 60psi (140ft).

i. If a fire protection system is installed the minimum inside diameter of the pipe supplying it must be 6in (15.3cm).

ii. Fire protection systems and potable water systems must not be connected unless a double backflow protection assembly is installed on the fire line to prevent backflow conditions from occurring the and negative pressures and flow to occur in the domestic water system.

27.9.E. At high points in water mains where air can accumulate provisions must be made to remove the air by means of air relief valves. Automatic air relief valves must not be used in situations where flooding of the manhole or chamber may occur.

i. Use of manual air relief valves is recommended wherever possible.
ii. The open end of an air relief pipe from a manually operated valve must be extended to the top of the pit and provided with a screened, downward-facing elbow if drainage is provided for the manhole.
iii. The open end of an air relief pipe from automatic valves must be extended to at least one foot above grade and provided with a screened, downward-facing elbow.

27.9.F. Chambers, pits or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system, shall not be located in areas subject to flooding or in areas of high groundwater.

i. Such chambers or pits must drain to the ground surface, or to absorption pits underground.
ii. The chambers, pits and manholes must not connect directly to any storm drain or sanitary sewer.
iii. Blow-offs must not connect directly to any storm drain or sanitary sewer.

27.9.G. Specifications for installation of water mains shall incorporate the provisions of the AWWA standards and/or manufacturers' recommended installation procedures.

i. Where possible, the minimum trench depth must be 6in (153cm) + D +12in (30.5cm) + ≥30in (76.2cm) where D is the outside diameter of the pipe, 6in (15.3cm) is the bedding thickness, 12in (30.5cm) is the compacted overburden thickness, and the remaining is backfilled compacted thickness.
ii. Where possible, the minimum trench width must be 18in (45.7cm).
iii. A continuous and uniform bedding, 6in (15.3cm) thick, shall be provided in the trench for all buried pipe. Backfill material shall be tamped in layers around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Stones found in the trench shall be removed for a depth of at least 6in (15.3cm) below the bottom of the pipe.
iv. Flow through all tees, bends, plugs and hydrants shall be analyzed to determine if reaction blocking, tie rods or joints designed to prevent movement are required.
v. Installed pipe shall be pressure tested and leakage tested in accordance with the appropriate AWWA Standards.

27.9.H. New, cleaned and repaired water distribution systems must be disinfected.

i. Follow the following disinfection steps:
   - Fill the water distribution system with water having a free chlorine concentration of at least 50 mg/L.
   - The chlorinated water should remain in the pipe for a minimum of 24 hours. At the end of 24 hours no less than 25 mg/L chlorine should be remaining.
   - If the latter condition is not met the system must be re-dosed with 50 mg/L chlorine and allowed to remain another 24 hours.
   - Following disinfection the chlorinated should be flushed to waste with potable water.
ii. Microbiological testing is required before the system is put back in use.

27.9.I. Water mains must be installed with adequate separation from other utilities such as electrical, telecommunications, and stormwater or sanitary sewer lines for the ease of rehabilitation, maintenance, and repair of water main, and for protection from contamination.

i. Water mains must be laid at least 10ft (3m) horizontally from any existing or proposed gravity sanitary or storm sewer, septic tank, or subsoil treatment system. The distance must be measured edge to edge.
ii. Water mains crossing sewers must be laid to provide a minimum vertical distance of 18in (45.7cm) between the outside of the water main and the outside of the sewer. This must be the case where the water main is either above or below the sewer with preference to the water main located above the sewer.
iii. At crossings, one full length of water pipe must be located so both joints will be as far from the sewer as possible. (Special structural support for the water and sewer pipes may be required.)
iv. No water pipe must pass through or come in contact with any part of a sewer manhole. Water main should be located at least 10ft (3m) from sewer manholes.
v. Design engineers must exercise caution when locating water mains at or near certain sites, such as, sewage treatment plants or industrial complexes. On site waste disposal facility including absorption field must be located and avoided. The engineer must contact the reviewing authority to establish specific design requirements for locating water mains near any source of contamination.

27.9.J. For above-water crossings of streams the pipe must be adequately supported and anchored, protected from vandalism, damage and accessible for repair or replacement.

27.9.K. For underwater crossing of streams a minimum cover of 5ft (1.5m) must be provided over the pipe unless otherwise approved by the MOHSW and/or MPW. When crossing water courses which are greater than 15ft (4.6m) in width, the following shall be provided:

i. The pipe must be of special construction, having flexible, restrained or welded watertight joints.
ii. Valves must be provided at both ends of water crossings so that the section can be isolated for testing or repair; the valves shall be easily accessible, and not subject to flooding.
iii. Permanent taps or other provisions to allow insertion of a small meter to determine leakage and obtain water samples must be provided on each side of the valve closest to the supply source.

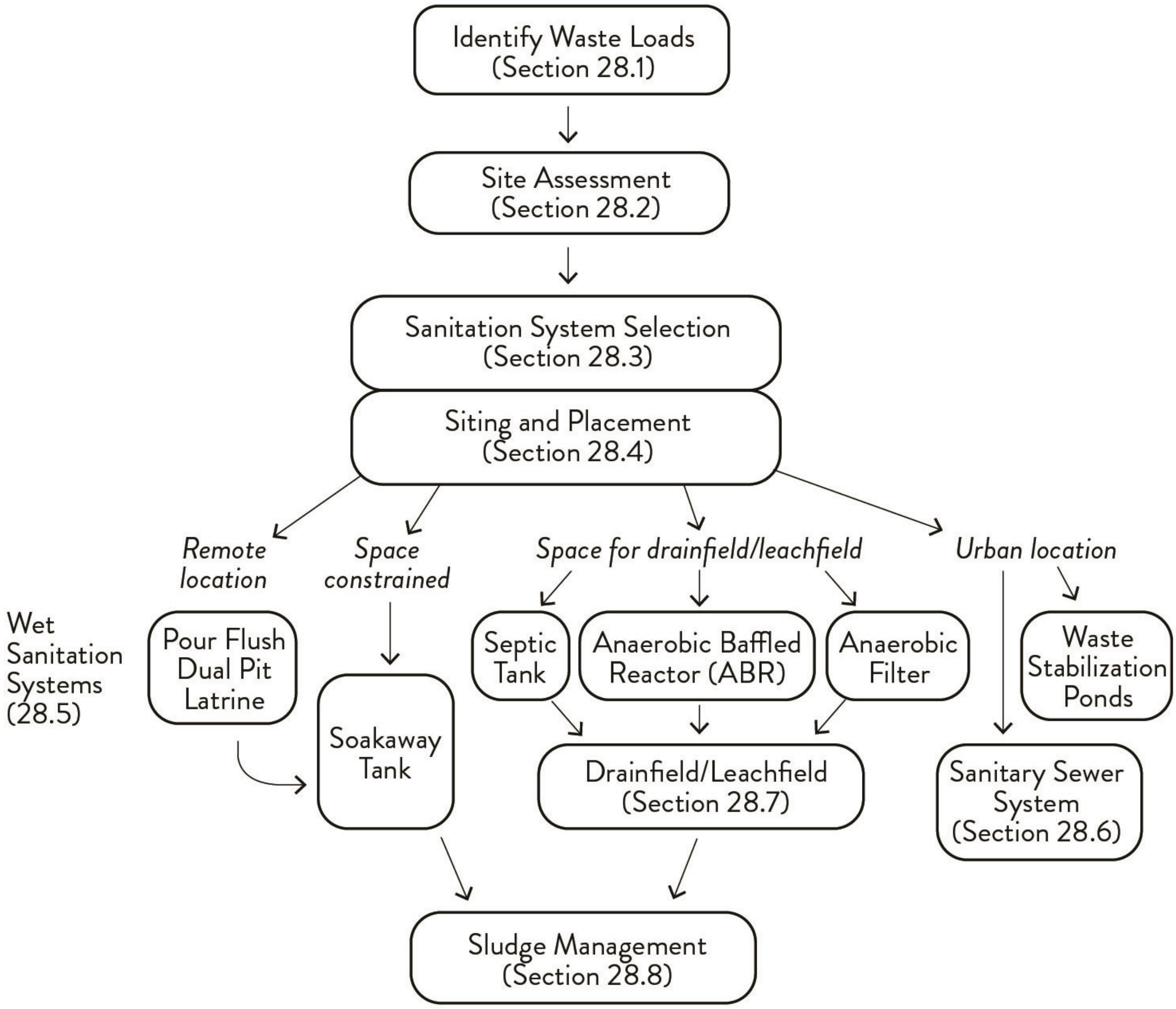
27.9.L. All water entering the distribution system must be metered by a totalizing meter.

28 Human Waste

Appropriate waste planning prevents groundwater contamination, protects access to potable water, and reduces health risks. Outbreaks of highly infectious diseases such as cholera or typhoid can place far higher-than-normal demands on a small health facility's water supply and sanitation systems. If these systems are designed only to meet "normal" demands, they may be overwhelmed, increasing the risk of additional and severe infections and posing further threats to community health.

Health facilities produce two categories of human wastes: fecal wastes and graywater wastes. Each should be disposed of properly to ensure safety over the long term. Anticipating the number of facility users with anticipated growth ensures that the waste management system will not be overloaded, which can cause system failures such as spills and overflows, clogging of soils, creating significant health hazards. With careful planning, waste management could also be an opportunity for recycling the resources to reduce long-term costs, minimize environmental impact, and potentially generate sustainable sources of fertilizer and water for the facility.

If an existing sewage system is not available, some alternatives include latrines, septic systems or other sanitary system will be required to properly manage, dispose and reuse these wastes in an effective manner. A civil or environmental engineer or other experienced expert must be consulted when designing a waste or water management system to ensure viability and supervision during installation to avoid inadvertent contamination.



Identify Waste Loads (Section 28.1)
Site Assessment (Section 28.2)
Sanitation System Selection (Section 28.3)
Siting and Placement (Section 28.4)
Remote location
Space constrained
Space for drainfield/leachfield
Urban location
Wet Sanitation Systems (28.5)
Pour Flush Dual Pit Latrine
Soakaway Tank
Septic Tank
Anaerobic Baffled Reactor (ABR)
Anaerobic Filter
Waste Stabilization Ponds
Drainfield/Leachfield (Section 28.7)
Sanitary Sewer System (Section 28.6)
Sludge Management (Section 28.8)

Definitions

- **Aerobic**: Using molecular oxygen. Growing or occurring only in the presence of molecular oxygen, such as aerobic organisms.
- **American National Standards Institute/National Science Foundation (ANSI/NSF)**: Organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States.
- **American Society for Testing and Materials (ASTM)**: International standards organization that develops technical standards for a wide range of materials, products, systems, and services.
- **American Water Works Association (AWWA)**: International association founded to improve water quality and supply.
- **Anaerobic Baffled Reactor (ABR)**: An improved septic tank because of the configuration of the tank inlet and outlet baffling or piping that forces the wastewater to flow vertically upwards through the sludge.
- **Anaerobic filter (AF)**: A fixed-bed filter.
- **Bacteria**: Unicellular microorganisms which feed upon and degrade organic matter.
- **Baffle**: A deflector at the inlet (top) of a typical water softener which disperses the water over the top of the resin bed.
- **Biochemical Oxygen Demand (BOD)**: Measure of the concentration of organic impurities in wastewater. The amount of oxygen required by bacteria while decomposing organic matter under aerobic conditions, expressed in mg/L.
- **Blackwater**: Liquid and solid human waste and the waters generated through toilet usage.
- **Chemical-Feed Pump**: A mechanical device designed to introduce chemicals into a water system at a rate proportional to the water flow. Also called a chemical feeder.
- **Chlorination**: The use of chlorine gas or solutions of its compounds to disinfect water or as an oxidizing agent.
- **Chlorine Demand**: A measure of the amount of chlorine which can be consumed by organic matter and other oxidizable substances in water without chlorine residual.
- **Clarifiers**: Settling tanks that remove settleable solids by gravity, colloidal solids by coagulation following chemical flocculation, or floating oil and scum through skimming.
- **Conveyance**: The process of transporting water from one place to another.
- **Digestion**: The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.
- **Dissolved solids (TDS)**: Solids present in solution.
- **Dissolved solids**: Theoretically, the anhydrous residues of the dissolved constituents in water. Actually, the term is defined by the method used in determination.
- **Effluent**: Sewage, water, or other liquid, partially or completely treated or in its natural state, flowing out of a reservoir, basin, or treatment plant.
- **Filtration**: The processing of passing water through a filter in order to remove solid particles.
- **Graywater**: Wastewater generated by water-using fixtures and appliances, excluding the toilet and possibly the garbage disposal.
- **Groundwater**: Water found in pore spaces in the subsurface below the water table.
- **Grouting**: A cementitious fluid poured or injected into a borehole during well drilling to seal crevices and prevent contamination , to provide a protective wall , or to improve the strength and elastic properties of the rock.
- **HRT**: Hydraulic residence time.
- **Impervious**: Resistant to penetration by fluids or by roots.
- **Influent**: Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant.

- **Leach Field (LF):** Area where septic-tank effluent is distributed for natural leaching.
- **Loading Rate:** The amount of effluent that is applied to the soil, usually in liters/square meter or gallons/square feet.
- **Particle Size:** The effective diameter of a particle usually measured by sedimentation or sieving.
- **Percolation:** The flow or trickling of a liquid downward through a contact or filtering medium. The liquid may or may not fill the pores of the medium.
- **Permeability:** The ease with which gases, liquids, or plant roots penetrate or pass through soil.
- **Pour Flush (PF) dual pit latrines:** Simple, low cost, easy to construct and maintain sanitation system.
- **PVC:** Polyvinyl chloride is used extensively in sewage pipe due to its low cost, chemical resistance, and ease of jointing.
- **Saturated zone:** The area below the water table where the soil pores are fully saturated with water.
- **Septic Tanks:** Typically two or three chambered concrete tanks that are constructed just below ground level and receive excreta and all other wastewater from the facility.
- **Settleable Solids:** That matter in wastewater which will not stay in suspension during a preselected settling period, but either settles to the bottom or floats to the top.
- **Soakaway Tanks:** Rectangular two compartment tanks constructed just below ground level that receive both excreta and flush water from flush toilets and other waste flows.
- **Subsoil:** In general, that part of the soil below the depth of excavation.
- **Subsurface wastewater infiltration systems (SWIS):** Common systems for the treatment and dispersal of onsite wastewater.
- **Suspended Solids:** Solids physically suspended in water, sewage, or other liquids.
- **Total Suspended Solids (TSS):** The solids remaining as residue after water has been evaporated from a sample.
- **Ventilated Improved Pit (VIP):** A type of latrine that reduces odors and flies.
- **Volatile Solids:** The quantity of solids in water, sewage, or other liquid lost on ignition of total solids.
- **Waste Activated Sludge (WAS):** Excess sludge removed from the treatment process.
- **Waste Stabilization Ponds (WSPs):** Large, shallow ponds that use a combination of natural processes involving bacteria and algae to treat the wastewater.
- **Water Table:** The surface of a body of unconfined ground water.

28.1. Waste Loads

The volume of human waste—particularly wastewater generated— will influence the selection of the sanitary solution for the site. Where there are only small quantities of wastewater, infiltration may be appropriate even in low-permeability soils, or these may be removed rapidly through evaporation. Where larger volumes are involved, disposal systems must be selected and sized accordingly. Existing systems may become inappropriate if water use increases greatly, and will need upgrading or replacing.

28.1.A. When calculating the wastewater flows for a health facility, the following factors must be considered:

- Available water supply
- Number of patients and staff
- Type of Health Facility (Rural Clinic to Regional Hospital)
- Level of services provided (Outpatient versus full service Hospital)
- Support services (kitchen, laundry and other facilities)

Sources and Forms of Human Waste

Human waste can be in a dry or waterborne form depending on the type and level of services provided.

Human waste sources at health facilities include:

- Urine
- Feces
- Toilet flush water

Graywater waste generated from human activities include:

- Food preparation
- Laundry wash water
- Bathing
- Wash water

It is important to note that all sanitation systems generate residual that need to be managed. Human waste residuals include both fecal sludge and treated sludge depending on the type of waste management practices employed at the health care facility. Residual management requirements are discussed in Section 28.8.

Table 28.a. Wastewater/graywater flow estimates from different sources and/or fixtures

Activity	Facility			
	PHC 1 (gallons/day)	PHC 2 (gallons/day)	Health Center (gallons/day)	Regional Hospital (gallons/day)
Bathing	145	275	475	2,375
Toilet Flushing	100	125	200	500
Cooking	-	-	75	400
House Keeping	25	25	90	250
Laundry	20	20	35	325
Medical Procedures	70	130	450	1,425
Total Wastewater Flows	**360**	**575**	**1,440**	**5,650**

** The above estimates are based on the water demand estimates in Table 27.d.*

Wastewater Generation Rates

Typical wastewater generation rates for public institutions from the WHO (1999) are as follows:

- Regional hospital: 15 – 30 gallons/person/day
- Cholera treatment center: 25 – 45 gallons/person/day
- Regional health center: 10 gallons/person/day
- Out-patient clinic: 1 to 3 gallons/person/day

See **Appendix Q** for guidelines for calculating facility waste load estimates.

28.2 Site Assessment

The selection, design, size and long-term reliability of an onsite sanitation system depends on the site conditions. Site factors include the area, topography, geology, soil and groundwater conditions, level of water service provided, and the amount of land available for the sanitation system. Before the sanitation system is selected a site assessment should be done to evaluate soil and groundwater conditions on the site. Test pits should be installed to determine the depth to groundwater and percolation tests should be conducted to determine the permeability of the soils where a soil disposal system (soakaway or leachfield system) would be installed. The following sections present the standards and guidelines for completing the site assessment study.

28.2.A. **Before an appropriate sanitary system can be selected, physical site conditions must be determined to make sure the sanitation system selected will function as designed. A site assessment study must be conducted that evaluates the following criteria:**

- Site topography
- Geology and soil conditions for the leaching system,
- Groundwater conditions in the vicinity of the leaching system
- Proximity of drainage and floodways

Site Assessment Procedures

Test Pits, soil percolation tests and determination of groundwater conditions are important parameters to determine the suitability and size of the subsurface disposal system.

Test pits: Test pits are used for the purpose of observing soil structures, texture, formations; the presence of seasonal groundwater; impervious rock formations, etc. Profiles are essential in the evaluation of any parcel for soil suitability for private sewage disposal systems.

Percolation tests: Percolation tests are used to evaluate soil conditions and determine the permeability of the soil.

Limitations: Soils or formations containing continuous channels, cracks, or fractures are not acceptable for sewage leaching unless there is a setback distance of at least 250ft (76.2m) to any domestic water supply well, potential domestic water supply well site, or surface water.

28.2.B. **One or more soil excavations must be performed for each individual sewage disposal system to demonstrate the suitability of soil conditions to serve the project. The test pit must extend to at least 5ft (1.5m) below the bottom of the proposed leaching system to demonstrate the suitability of soil conditions.**

i. When installing a test pit, the following factors are to be observed and documented in a report to the MOHSW Infrastructure Unit from ground surface to a depth corresponding to at least 5ft (1.5m) below the leaching system:

   - Thickness and coloring of soil layers

- Depth to and type of bedrock, hardpan, or impermeable soil layer
- Depth to observed ground water, saturated soil layers and areas of water infiltration.
- Depth to soil mottling
- Depth of other prominent soil features such as structure, stoniness, roots and pores, dampness, soil boundaries, etc.

28.2.C. Percolation tests must be conducted to evaluate soil conditions and to determine the permeability of the soil.

i. See Appendix P for Percolation Test Procedures. This information is required to size the following subsurface disposal systems:
   - Pits for pour flush latrines
   - Soakaway pits
   - Leachfield trenches

ii. Percolation tests must be performed by trained contractors or civil engineers.

iii. Percolation tests must be conducted at the location of the proposed subsurface disposal system.

28.3 Sanitation System Selection

There are wide arrays of sanitation management systems that can be employed to properly treat, dispose and in some instances reuse treated wastes at health care facilities. In rural areas, sanitation solutions are typically on-site dry and/or wet systems. In urban setting sanitary systems may be on-site or off-site. Table 28.b. outlines the various on-site, off-site, dry, and wet sanitary solutions that may be employed at a health facility. Table 28.c. presents a descriptive comparison of the different sanitation systems. A description and the standards for many of these systems is presented in Sections 28.5 through 28.8 below.

Table 28.b. Classification of Sanitary Systems

On-Site Sanitation Systems	
Wet	Dry
• Pour flush (PF) latrine – double pit • Soakaway septic tank • Septic tank+Leachfield (LF) or Evaporative bed (ET Bed) • Anaerobic baffled reactor (ABR)+LF or ET bed • Waste stabilization pond (WSP) • Enhanced treatment system • Graywater system	• Pit latrine • Ventilated improved pit (VIP) latrine • Composting latrine • Urine diverting composting latrine

On/Off-Site Systems
Wet
• Small bore sewers • Community septic tank + LF or ET Bed • Community ABR + LF or ET Bed • Waste activated sludge (WAS) • Enhanced wastewater treatment system • Graywater system • Holding tank and vacuum truck (haul-away)

Off-Site Sanitation Systems	
Wet	Dry
• Small bore sewers • Community • Community septic tank + LF or ET Bed • Community ABR = LF or ET Bed • WAS • Enhanced wastewater treatment system	• Holding tank and vacuum truck • Sludge treatment - Drying bed - Reed drying bed

28.3.A. The sanitation system must be selected to adequately serve the anticipated facility use (staff, patient, other users) load of the healthcare facility including projections for growth.

28.3.B. The selection of a sanitation system must be based on three sets of criteria:

- Technical considerations— costs, available and level of labor for construction and long-term maintenance and repairs, available water source.
- Cultural considerations—whether the sanitary system is one that people are accustomed to using or willing to use. For example, composting toilets in a particular region of Liberia may not be a culturally acceptable sanitation system and may not be properly maintained if installed.
- Environmental considerations—particularly relevant to the installation of on-site systems.

28.3.C. Environmental sanitation criteria must be assessed, including:

- Type of water supply and level of service
- Existing facilities for human waste management
- Environmental site conditions (See Section 28.2 for Site Assessment requirements)
  - Permeability of soil for leaching systems (PF latrines, soakaways, leachfields)
  - Location and setbacks to water supply wells
  - Location of pit latrines and other sanitary wastewater systems with regards to odor mitigation
  - Protection from insects and rodents
  - Adequate separation between the seepage bed and groundwater
  - Difficulty of repairs and replacement

Table 28.c. Descriptive Comparison of Sanitation Technologies

Sanitation Technology	Rural Clinic Application	Urban Application	Construction Cost	Operating Cost	Ease of Construction	Water Required	Soil Conditions
Pit Latrine	Suitable	Suitable	Low	Low	Easy	No	Stable permeable
Ventilated Improved Pit (VIP) Latrine	Suitable	Suitable	Low	Low	Easy	No	Stable permeable
Composting Latrine	Suitable	Suitable	Low	Med	Moderate	No	Not Applicable
Urine Diverting Composting Latrine	Suitable	Suitable	Med	Med	Moderate	No	Not applicable
Pour Flush (PF) Latrine – Double pit	Suitable	Suitable	Low	Low	Easy	Yes	Stable permeable
Soakaway Septic Tank	Suitable	Suitable	Med	Low	Moderate	Yes	Stable permeable
Septic Tank+ Leachfield (LF) or Evaporative (ET) Bed	Suitable	Suitable	Med	Low	Moderate	Yes	Stable permeable
Anaerobic Baffled Reactor (ABR)+ Leachfield (LF) or Evaporative (ET) Bed	Suitable	Suitable	Med	Low	Moderate	Yes	Stable permeable
Waste Stabilization Pond (WSP)	Not suitable	Suitable	High	Med	High	Yes	Not applicable
Enhanced Wastewater Treatment	Not suitable	Suitable	High	Med	High	Yes	Stable permeable
Graywater System	Suitable	Suitable	Med	Med	Moderate	Yes	Stable permeable
Small Bore Sewers	Not suitable	Suitable	Very High	Med	High	Yes	Not applicable

28.4 Siting and Placement

The following section describes the general siting and placement requirements for sanitation systems and in particular leaching systems. Leaching systems are typically onsite systems that are used to dispose of the wastewater into the subsoil at the facility. The soil acts to filter the wastewater and remove pathogens and other pollutants in the water. Adhering to the below standards will assure that the sanitation system and associated leaching system are installed in a manner that protects shallow groundwater conditions and that the healthcare staff to can effectively maintain the system by providing good access to the system.

28.4.A. Sanitary systems must be located so as to be accessible for maintenance and repairs. Any tanks that need periodic pumping (e.g. soakaway and septic tanks) must be located to allow vacuum pumping of fecal sludge.

28.4.B. There must be a minimum of 5ft (1.5m) of permeable soil beneath any leaching device.

28.4.C. Location selection for effluent leaching systems (leachfield trenches) for black and/or graywater disposal must be done in a manner to avoid contaminating the site.

i. Leaching devices including latrine pits must not be installed in areas of high groundwater. There must be a minimum of 5ft (1.5m) of separation from the bottom of the leaching device to highest anticipated groundwater level.

ii. Leaching areas must not be located in low-lying areas receiving storm water drainage, or within one-year flood zones or identified flood areas. Leaching devices or latrine pits should be at a minimum 25ft (7.6m) from any seasonal drainage way.

iii. Leaching areas must be separated from streams, creeks, wells, springs and water courses by a minimum horizontal distance of 96ft (29.3m).

iv. A leaching area or pit latrine must be located at least 100ft (30.5m) downslope or downstream from a well.

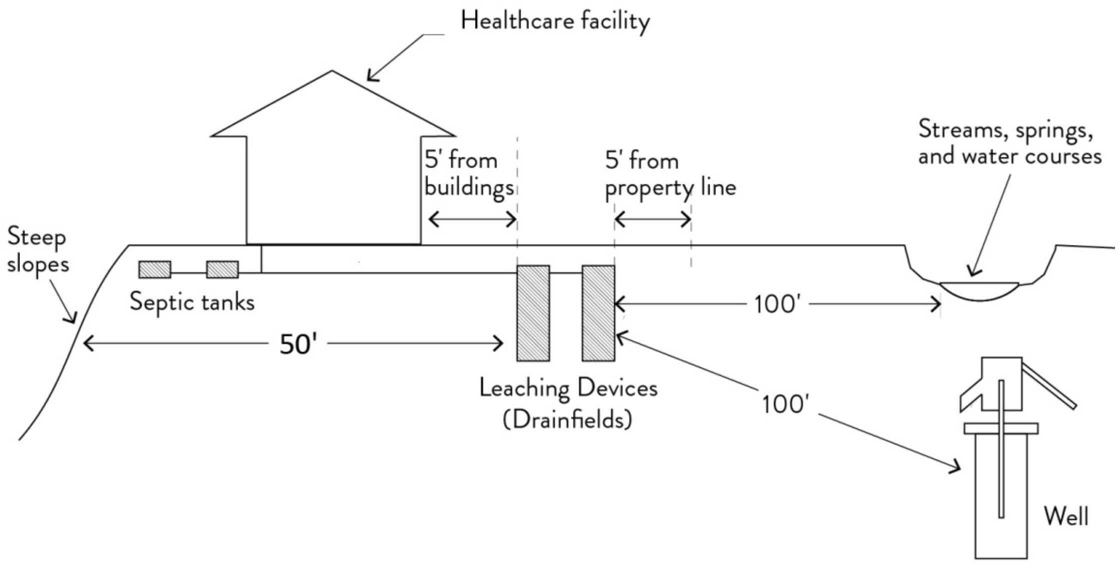
28.4.H. Leaching devices, including latrine pits, soakaway tanks, leachfields and other subsurface disposal systems must be constructed in conformance with the minimum distances per Table 28.d.

These distances align with the 2010 Guidelines for Water and Sanitation Services in Liberia, as developed by the Ministry of Public Works in conjunction with WASH.[2]

Table 28.d. Minimum Distances between Leaching Devices and Site Components

Site Component	Min. Permitted Distance to Leaching Device
Property Line	5ft
Foundation, structure bearing weight	5ft
Water Line	10ft
Stream, well, spring, water course	100ft
Seasonal drainage	25ft
Steep slope	50ft

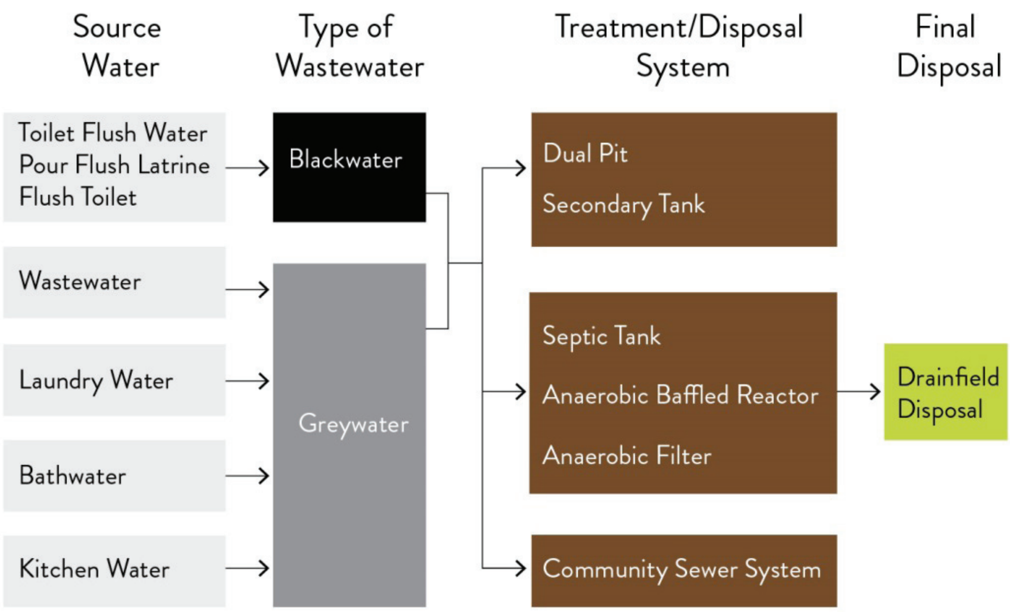
Figure 28.a. Siting and placement parameters for sanitary systems



28.5 Wet Sanitation Systems

All new healthcare facilities will include waterborne or wet sanitation systems that will rely on water to flush the excreta into a pit, a sanitary sewer, a soakaway tank, a septic tank, an anaerobic baffled reactor or other sanitation system design to treat and dispose of the waste. Alternative toilet systems may be used such as simple pour flush style latrines, which use a small amount of water poured in by hand to flush the excreta into a pit or sewer. Conventional flush style toilets will also be installed in many facilities. Figure 28.b. shows how a wet sanitation system is used to manage different sources of wastewater from a healthcare facility.

Figure 28.b. Wet Sanitation System Types



Wet Sanitation Treatment and Disposal Systems

Once the excreta is comingled with water it is commonly referred to as sanitary wastewater or sewage. To effectively treat and dispose of the wastewater and residuals generally involves a multi-stepped process, including the collection, treatment and disposal of the wastewater and the residual solids from the treatment system.

Waterborne sanitation systems generally rely on a two-stage treatment and disposal system to safely manage this waste stream and effectively remove pathogens and infectious agents from the environment. All of these systems must be designed so that the waste is contained and the users do not come into contact with any of the wastewater or disease causing pathogens prior to disposal.

In very simple sanitation systems, such as a pour flush latrine, which includes a pour flush toilet connected to a dual pit disposal system, a properly installed and sited system provides a means to store the water and the soils underlying the pit provide the treatment mechanisms to reduce pathogens and the potential environmental health impacts from the wastewater. In more advanced wastewater systems, such as, an anaerobic baffled reactor (ABR) the wastewater from the toilet(s) enters a multi-chambered tank and undergoes several days of anaerobic digestion, reducing solids, organic matter and pathogens before the water from the tank is discharged to a subsurface disposal system.

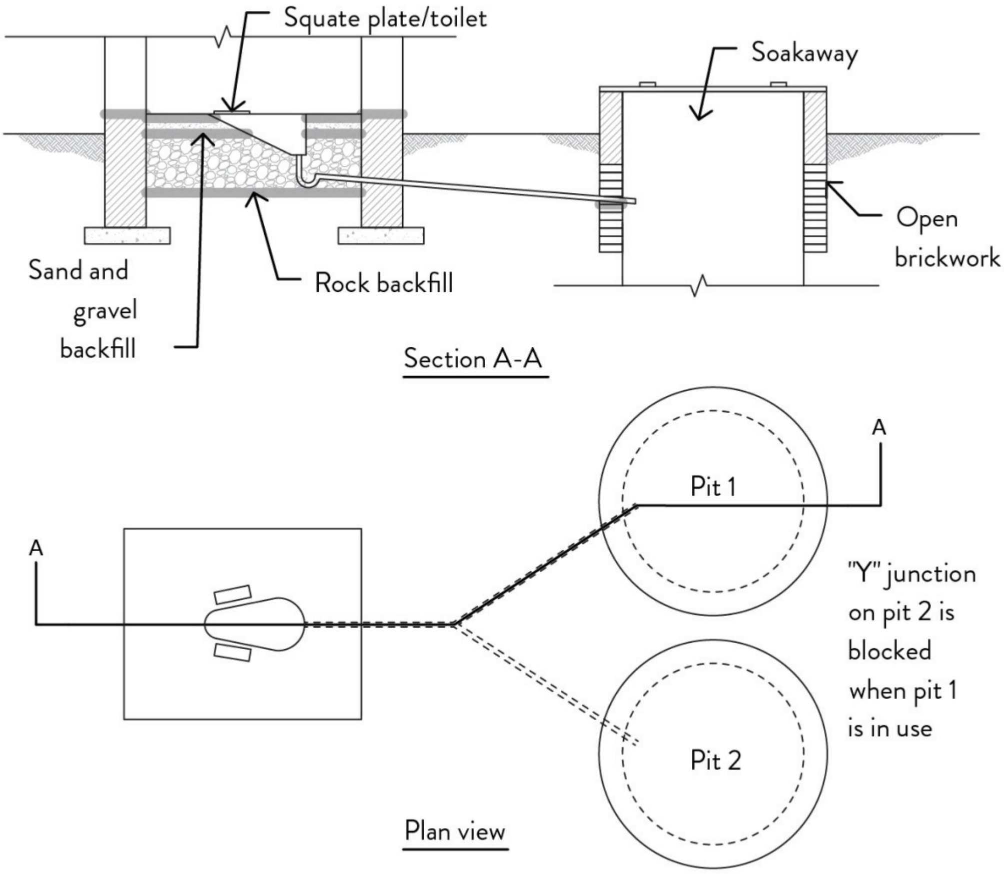
The following sections provide general standards for several sanitation treatment, collection, and disposal systems appropriate for healthcare facilities in Liberia, including:

- Pour flush latrines
- Soakaway tanks
- Dual chamber septic tanks
- Anaerobic Baffled Reactors and Anaerobic Filters
- Waste Stabilization Ponds
- Sanitary sewer systems, including small diameter (bore) sewer systems and effluent sewers
- Subsurface Disposal Systems, including gravity drainfield/Leachfield trenches

Pour Flush Dual Pit Latrines

Pour Flush (PF) dual pit latrines are simple, low cost, easy to construct and maintain sanitation system. The PF latrine consists of a PF squat plate that commonly uses a pre-cast porcelain toilet bowl that is cast into a reinforced concrete slab that is fabricated onsite. The toilet bowl is connected via a short gravity line to either disposal pits, a septic tank, or a sanitary sewer. The effectiveness of a PF latrine is dependent on the permeability and depth of the soil receiving the waste and the maintenance of the system (switching of pits). The PF are already in use in Liberia in various regions and are appropriate for the climate and many soils found in Liberia.

Figure 28.c. Dual Pit Pour Flush Latrine



28.5.A. The PF toilet must have a water seal beneath the squatting plate or pedestal seat to prevent odors from entering the room and to prevent mosquitoes from breeding.

28.5.B. The PF toilet must be connected to a short length of 3in (7.6cm) minimum diameter, Schedule 40 PVC pipe, or equivalent connected to the pit. The slope of the connecting pipe should not be less than 2%.

28.5.C. The PF toilet must be connected to two pits, or to a septic or sanitary sewer.

28.5.D. The volume of the PF latrine pits must be determined using the following formula:

V = 1.33 CPN

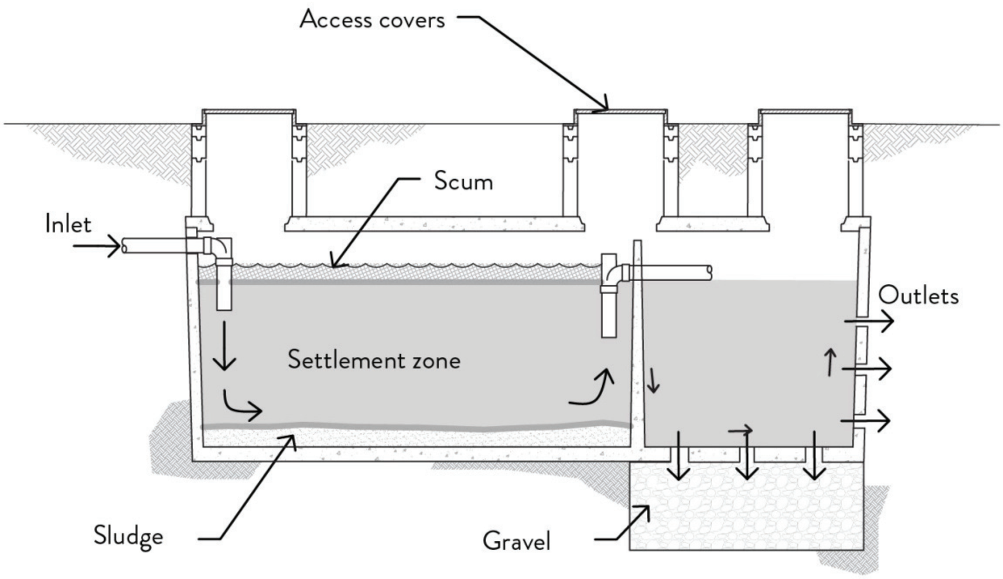
Where: *V = equals pit volume in cubic meters*
C = Pit design capacity (cubic meters per person per year)
P = Number of people using the latrine
N= Number of years the pit is to be used

Soakaway Tanks

Soakaway tanks are rectangular two compartment tanks commonly constructed just below ground level that receive both excreta and flush water from flush toilets and other waste flows. The tanks are commonly constructed in place using pre-cast concrete blocks and reinforced concrete slabs on the top and on the floor of the first chamber of the tank. The first compartment of the tank is designed to retain the wastewater for a sufficient time period to capture solids and the second chamber is porous chamber surrounded by rock to allow for the disposal of effluent to the surrounding and underlying soils. The effectiveness of a soakaway tank depends on the residence time in the first chamber to settle out and retain solids and the permeability of the underlying soils to adsorb water. Soakaway tanks are already in use at many healthcare facilities in Liberia.

Solids settle to the bottom of the first chamber of the tank where they can digest anaerobically, and a thick layer of scum is formed at the surface. Through digestion some solids will reduce over time; however, the tank will need to be desludged at regular intervals usually one to three years depending on usage.

Figure 28.d. Soakaway Tank



28.5.E. The soakaway tank must be sized so that the first chamber of the tank provides at least 3 days of residence time of the mean daily flow (liquid flow) plus solids storage volume 2 additional days.

i. Generally, the tank must be sized so that the liquid depth is 5ft (1.5m) to 8ft (2.4m) deep and the overall length-to-width ratio is 2 to 3 to 1.

ii. An access hatch must be installed in each chamber and should allow for good access to clean and inspect the chambers. The minimum hatch dimensions should 18in (45.7cm) by 18in (45.7cm) square.

28.5.F. The second chamber, the soakaway chamber, must be sized so that the sidewall area of the chamber provides sufficient area to infiltrate the effluent from the tank based on a minimum infiltration rate of 0.25 gallons per minute per square feet (gpm/ft2) or based on actual percolation rates measured at the site.

i. The soakaway tank must be surrounded by 6in (15.3cm) of clean $^{3}/_{4}$in to $1^{1}/_{2}$in drainrock with a 24in (61cm) layer of rock on the bottom.

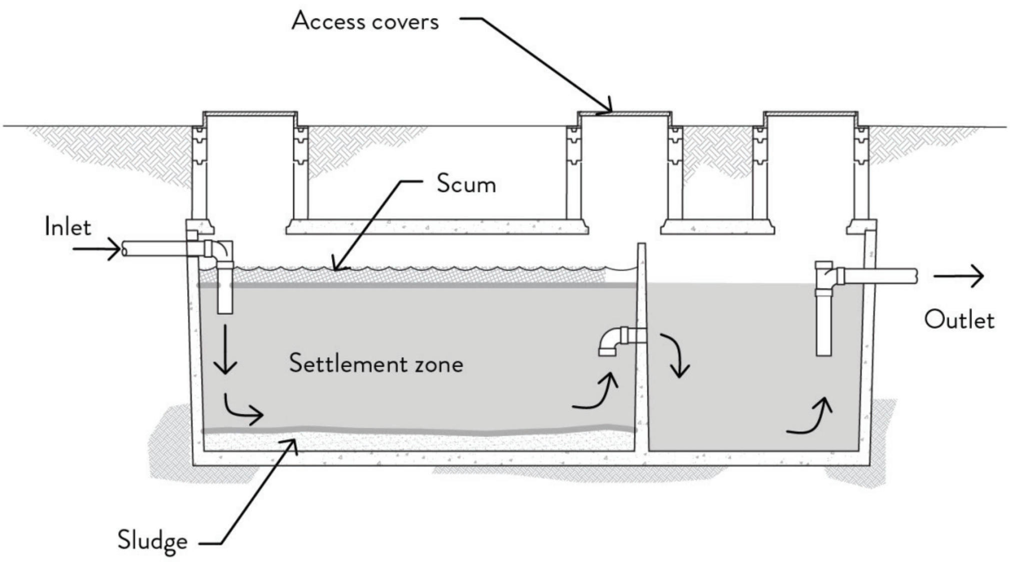
28.5.G. The first chamber of the soakaway tank must be watertight and sealed with an impermeable sealant compatible with sanitary wastewater.

Septic Tanks

Septic tanks are typically two or three chambered concrete tanks that are constructed just below ground level and receive excreta and all other wastewater from the facility. Septic tanks are commonly built onsite with pre-cast concrete block and reinforced concrete slabs on the top and bottom of the tank. Similar to soakaway tank sizing, the first chamber of the septic tank should be sized to accommodate the mean daily flow plus two days of accumulated solids.

The wastewater flow in a septic tank is horizontal through each chamber. A properly maintained septic tank is effective at removing approximately 30% of the organic matter. As it will not remove high concentrations of pathogens, effluent must be disposed into a subsurface soil disposal system to effectively remove pathogens. The septic tank will need to be desludged at regular intervals, usually ever one to three years depending on usage. Septic tanks are commonly used at healthcare facilities in Liberia.

Figure 28.e. Septic Tank



28.5.H. The septic tank must be sized so that the first chamber of the tank is $^{2}/_{3}$ the volume of the overall tank and is sized for a minimum hydraulic residence time of 3 days of the estimated mean daily flow.

i. Generally, the tank must be sized so that the liquid depth is 5ft (1.5m) to 8ft (2.4m) deep and the overall length-to-width ratio is 2 to 3 to 1.

ii. An access hatch must be installed in each chamber and should allow for good access to clean and inspect the chambers. The minimum hatch dimensions should 18in (45.7cm) by 18in (45.7cm) square.

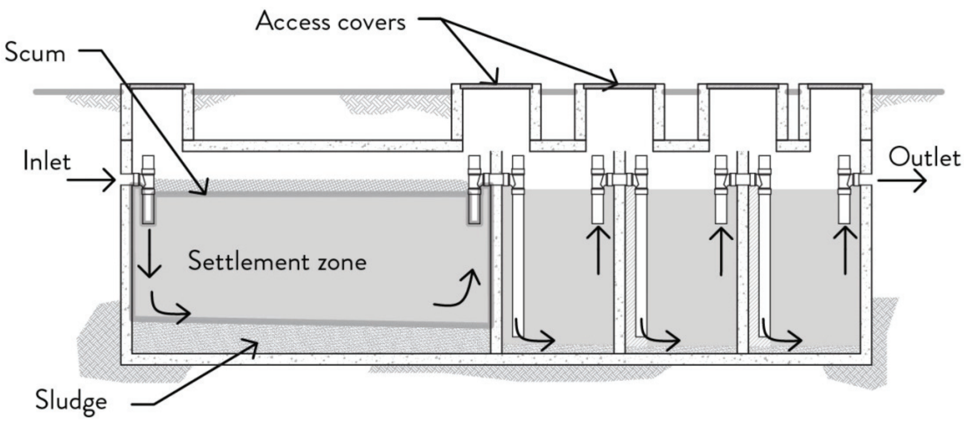
28.5.I. The septic tank must be watertight and sealed with an impermeable sealant compatible with sanitary wastewater.

Anaerobic Baffled Reactors

An anaerobic baffled reactor (ABR) is an improved septic tank because of the configuration of the tank inlet and outlet baffling or piping that forces the wastewater to flow vertically upwards through the sludge. Similar to the soakaway and septic tank, the ABR contains a sedimentation chamber as the first compartment in the tank followed by a series of smaller vertical upflow chambers that provide enhanced treatment of the wastewater. The construction of the ABR is similar to the soakaway and septic tanks and is commonly built onsite using pre-cast reinforced concrete block with reinforced concrete slabs for the floor and roof. The tanks are buried and just below ground surface and each compartment has an access hatch to allow for routine inspection and maintenance.

The majority of the settleable solids (50%) accumulate in the sedimentation tank and upflow chambers provide additional removal and digestion of the organic matter. A properly sized and maintained ABR can provide superior treatment of the wastewater and remove over 90% of the organic matter.

Figure 28.f. Anaerobic Baffled Reactor



28.5.J. **The ABR must be sized so that the first chamber of the tank is 1/2 the volume of the overall tank and is sized for a minimum hydraulic residence time of 3 days of the estimated mean daily flow.**

i. The tank must be sized so that the liquid depth is 8ft (2.4m) to 10ft (3m)deep.

ii. An access hatch must be installed in each chamber and must allow for good access to clean and inspect the chambers. The minimum hatch dimensions should 18in (45.7cm) by 18in (45.7cm) square.

28.5.K. **The ABR must be designed with at least 3 vertical flow chambers. Each chamber shall be designed to provide a minimum hydraulic residence time of 9 hours with an up-flow velocity of the wastewater less than 2ft (61cm) per hour based on the cross sectional area of each chamber.**

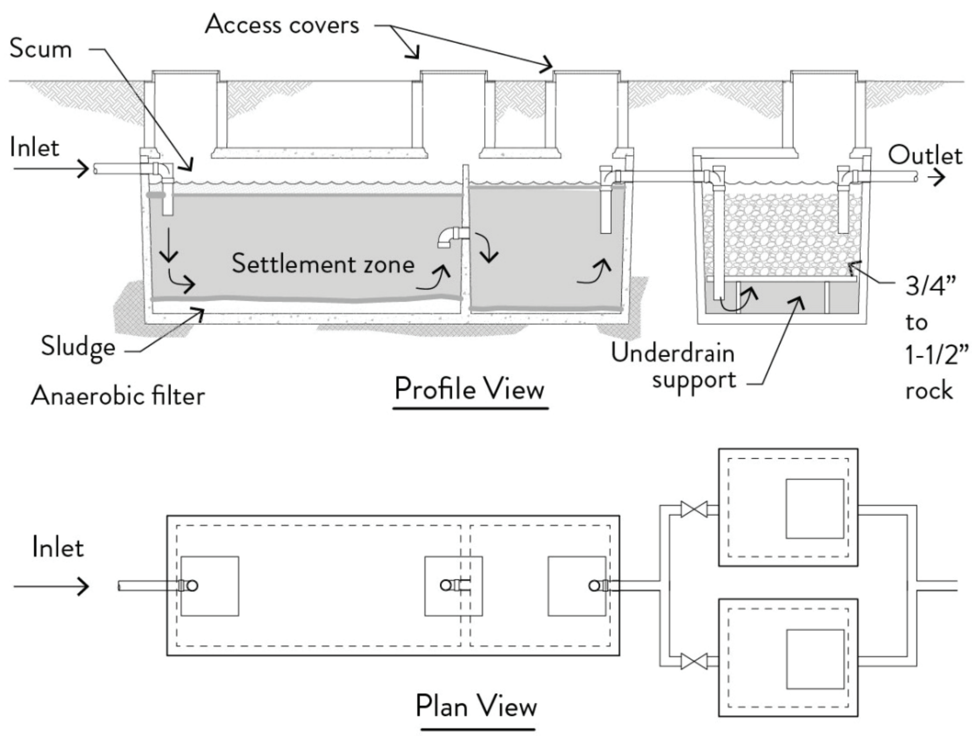
28.5.L. **The inlet and outlet baffles or piping must be designed so that the wastewater enters the bottom of each vertical flow chamber and exits from the top of each chamber to create vertical upflow conditions. Flows from the top of the previous chamber to the bottom of the ABR must be designed.**

28.5.M. **The ABR tank must be watertight and sealed with an impermeable sealant compatible with sanitary wastewater.**

Anaerobic Filter

An anaerobic filter (AF) is a fixed-bed filter. As the water flows through the filter, media particles are trapped and degraded by the biomass that establishes in the filter. An AF is usually designed to follow a septic tank or an ABR and is a tank filled with filter media such as gravel, crushed rock, or plastic media. The construction of the AF is similar to a septic tank or ABR and can be built onsite using pre-cast reinforced concrete blocks for the wall and cast-in-place reinforced concrete slabs for the roof and bottom slabs. The AF can be operated in either upflow or downflow mode; however, the upflow mode is recommended because there is less rick that the fixed biomass will be washed out. AF can reduce the organic matter and solids in the wastewater by 85 to 90% following a septic tank. AF are an appropriate technology for Liberia healthcare facilities.

Figures 28.g. Anaerobic Filter



28.5.N. The anaerobic filter must be designed in accordance with the following requirements:

i. Generally, the filter media must range in size from ¾in (1.9cm) to $1^1/_2$in (3.8cm) in diameter and should provide 30ft^2 (91.4cm^2) of effective surface area per cubic foot of media.
ii. The filter media must be supported by a filter support, which should consist of a media support plate or tile support and graded media support (Refer to Figure 28.g. above).
iii. The hydraulic residence time (HRT) of the AF must range from a minimum of 1 to 1.5 days. (The longer the HRT the better the filters typically perform.)
iv. To the degree possible, the filter media must be submerged at all times with a minimum of 12in (30.5cm) of water over the filter media to assure an even flow regime.
v. The AF compartment must have an access hatch (18in (45.7cm) by 18in (45.7cm) square) to allow for routine inspection and maintenance.
vi. Two AF should be installed to allow for system redundancy and allow for one to be taken offline and serviced while the other remains in service.

28.5.O. The AF tank must be watertight and sealed with an impermeable sealant compatible with sanitary wastewater.

Waste Stabilization Ponds

Waste stabilization ponds (WSPs) are large, shallow ponds that use a combination of natural processes involving bacteria and algae to treat the wastewater. WSPs are the most economical method of sewage treatment wherever land is available at relatively low cost. WSPs are appropriate technology for large healthcare facilities, such as Regional Hospitals or large regional Health Centers.

A WSPs system typically consists of a pretreatment system (bar screen and grit chamber) and three types of ponds constructed in series including: an anaerobic pretreatment pond; a facultative pond, and a series of aerobic maturation (or oxidation) ponds. Pretreatment systems typically include bar screens and shallow grit chambers. The purpose of the pretreatment system is to remove debris, garbage, sand and grit before this matter enters the biological treatment system.

The anaerobic ponds function similar to a septic tank or ABR tank to provide primary treatment of the wastewater and removal of the primary solids entering the system. The anaerobic pond typically has a hydraulic residence time (HRT) of two to five days and depths of 9ft (2.7m) to 12ft (3.7m). The facultative pond is design to treat the wastewater via bio-oxidation of the wastewater using oxygen supplied principally by photosynthetic algae that grow in them naturally. A facultative pond typically has a HRT of five to thirty days and depths of 3ft (91.4cm) to 5ft (1.5m). Aerobic maturation (oxidation) ponds, which receive facultative pond effluent are primarily responsible for the quality of the final effluent. They typically have HRTs of five to ten days and depths of 3ft (91.4cm) to 5ft (1.5m).

Anaerobic and facultative ponds are designed for removal of organic matter, whereas the function of oxidation ponds is the removal of excreted pathogens. A well-designed pond system, incorporating a minimum of three ponds in series and having a minimum overall HRT of 20 days, produce an effluent that that will be either be completely pathogen free or will contain only small numbers of enteric bacteria and viruses.

28.5.P. The pretreatment must be designed so that it can be easily cleaned manually.

i. Installing screens and grit chambers in deep concrete vaults is not recommended. These structures will not likely be maintained causing sewerage to backup in the main sewer lines resulting in poor drainage and potential breeding of vectors (i.e. mosquitoes) in the collection system.

28.5.Q. Manually raked bar screens must be designed to the following standards:

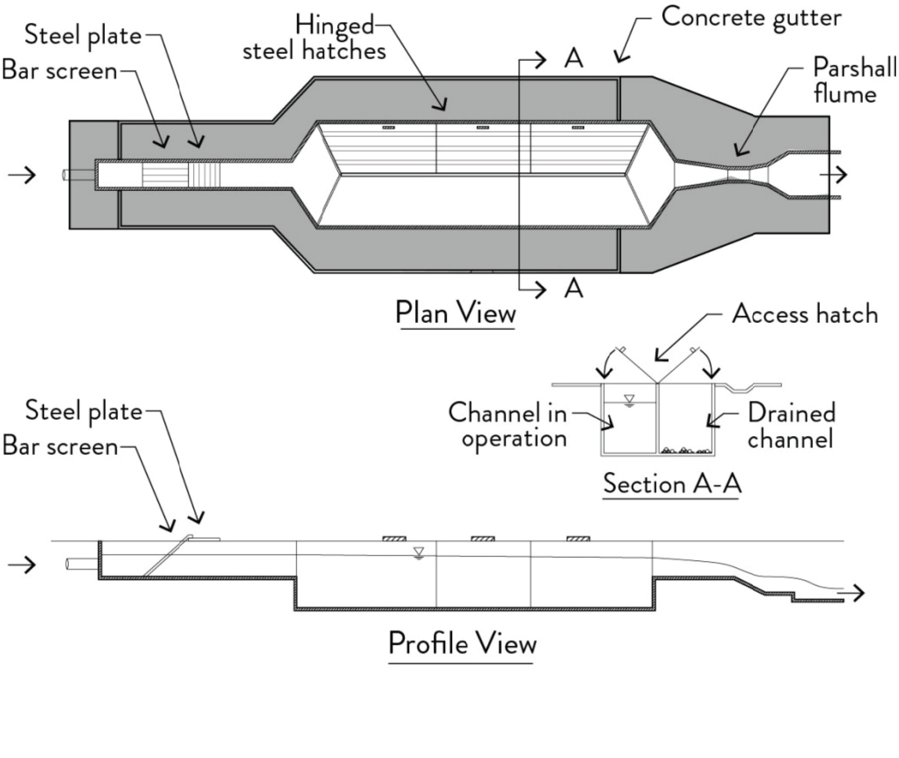
i. The approach velocity in the channel with the screen must be less than 3 feet per sec (fps).
ii. Where possible, the spacing of the bars must be 1/2in (1.3cm) to 3/4in (1.9cm)
iii. The bars must be inclined to 60 degrees to the horizontal.
iv. The submerged area of the screen must be 0.3ft (9.1cm) to 1ft (30.5cm) per 1000 people.
v. The screen must be designed to allow for daily cleaning.
vi. The screen system must be designed so that screenings may be removed and liquid can drain back to the entrance of the treatment works. (Refer to Figure 28.h. for Typical bar screen configurations)

Figure 28.h. Typical Bar Screen Installations

28.5.R. **Manually cleaned horizontal flow shallow grit chambers (Figure 28.i.) shall be designed according to the following criteria:**

i. The grit chamber must be designed with at least 2 channels so that 1 may be closed for grit removal.
ii. Generally the hydraulic residence time (HRT) must be between 45 to 90 seconds. An HRT of 60 seconds is typical.
iii. Generally, the horizontal velocity must be maintained between 0.25 to 0.4 m/s. 0.3 m/s is typical.
iv. Headloss through a downstream control section of 30 to 40% is required to create backflow conditions. 35% is typical.
v. The overall length of the grit chamber shall be added to reduce inlet and outlet turbulence. Typically 25 to 50% of additional length is added at both the inlet and outlet of the grit chamber.
vi. The minimum depth of the chamber must be 1.5ft (45.7cm) to provide adequate freeboard.
vii. The minimum width of the channels must be 1.5ft (45.7cm) to allow for easy access and cleaning.
viii. The grit chamber can be covered with a steel or fiberglass cover that can be opened or removed for routine cleaning.

Figure 28.i. Typical Dual Channel and Covered Grit Chamber



28.5.S. **Waste Stabilization Pond treatment systems must be designed by a qualified sanitary engineer who is qualified and experienced in the design and construction of WSPs.**

28.5.T. **Waste Stabilization Ponds must meet the following siting criteria:**

i. When choosing a site to construct a pond system, select an area where the water table is deep and the soil is heavy and impermeable. Silt or clay soils are ideal for pond foundations and construction.
ii. Avoid building ponds over coarse sands, gravels, fractured rock or other materials that will allow effluent to seep out of the pond or allow groundwater to enter in.
iii. No part of the system must be within 500ft (152.4m) of the healthcare facility or adjoining residences. If possible, ponds must be sited downwind from houses, roads and other public places.
iv. Soil must be suitable for pond stability. Geotechnical aspects, if not taken into consideration, may cause the WSP system to fail. A geotechnical investigation of the site should be made during the design stage to ensure correct embankment design and to determine whether the soil is sufficiently permeable to require the pond to be lined.
v. To minimize earthworks, the site must be flat or gently sloping.
vi. Adequate provision must be made to divert storm water runoff around the ponds and protect pond embankments from erosion.
vii. Site the WSP in an open area to take advantage of the sun and wind, which assist the efficient operation of the facultative and oxidation ponds and thus improve the quality of the discharge.
viii. Keep systems away from overhead or underground power lines and potable water lines.

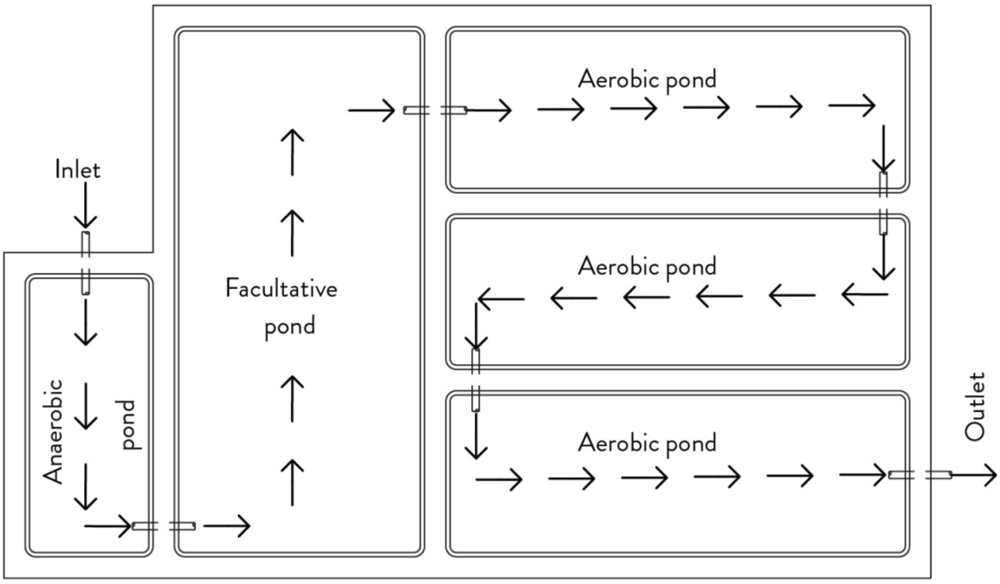
28.5.U. **A stable and impermeable embankment core shall be formed, whether chosen from an available local or imported soil. After compaction, the soil should have a coefficient of permeability of 10-8 ft/s. The following geotechnical considerations must be taken when constructing the embankment:**

i. Embankments must be well constructed to prevent seepage, excessive settlement and erosion over time.
ii. Slope stability should be ascertained according to standard soil mechanics procedures for small earth dams. Embankment slopes are commonly 1 (vertical) to 3 (horizontal) internally and 1 to 1.5-2 externally.
iii. External embankments must be protected from stormwater erosion by providing adequate drainage.
iv. Internal embankments must be protected from wave action erosion by using precast concrete slabs or stone rip-rap at top water level.

28.5.V. **Waste Stabilization Pond treatment systems must include a three-pond design that includes an anaerobic pretreatment pond, a facultative pond, and one or more oxidation ponds.**

i. Maintain a minimum separation of 4 feet (1.2 m) between the bottom of the pond and the maximum ground water elevation. A minimum separation of 10 feet (3.0 m) between the pond bottom and any bedrock formation is recommended.
ii. Orientate the longest diagonal dimension of the pond parallel to the direction of the prevailing wind.
iii. Install a bar screen and grit chamber be installed upstream of the anaerobic pond to remove garbage, debris, sand and non-degradable solids from entering the treatment ponds.

Figure 28.j.   Waste Stabilization Pond Layout



28.5.W. The WSPs must be sized according to the following criteria:

	Hydraulic Residence Time	Depth (ft)
Anaerobic Pond	2 to 5 days	9 to 12
Facultative Pond	5 to 30 days	3 to 5
Oxidation Pond	5 to 10 days	3 to 5

28.5.X. WSP designs must incorporate the following requirements:

i. The inlet pipe to the anaerobic pond must discharge well away from the embankment and into the center of the pond to avoid the development of sludge on the banks.

ii. The shape of all cells must be such that there are no narrow or elongated portions. Round, square or rectangular ponds (length not exceeding 3 times the width) are considered most desirable. No islands, peninsulas or coves shall be permitted. Dikes should be rounded at corners to minimize accumulations of floating materials. Common-wall dike construction, wherever possible, is strongly encouraged.

iii. Minimum freeboard shall be 3 feet except for very small installations 2ft (61cm) may be acceptable.

28.5.Y. Dikes must have a covered layer of at least 4in (10.2cm) of fertile topsoil to promote establishment of an adequate vegetative cover wherever riprap is not utilized.

i. Prior to prefilling, adequate vegetation shall be established on dikes from the outside to 2ft (61cm) above the pond bottom on the interior as measured on the slope. Perennial-type, low-growing, spreading grasses that minimize erosion and can be mowed are most satisfactory for seeding on dikes.

ii. In general, alfalfa and other long-rooted crops should not be used for seeding since the roots of this type are apt to impair the water-holding efficiency of the dikes.

28.5.Z. Waste Stabilization Ponds must be designed to permit access for routine maintenance and protection from unauthorized access.

i. A fence should be installed around the perimeter of the ponds to ensure that unauthorized people and animals stay out of the area.

ii. The design should lay out pipelines in access roads along straight runs for easy access.

iii. An all-weather access road shall be provided to the pond site to allow year-round maintenance of the facility.

iv. There should be sufficient space around the ponds to allow construction equipment and desludging vehicles to access the ponds.

Alternative Wastewater Treatment Facilities

28.5.AA. Any alternative sanitary system intended to be used at a healthcare facility must be designed by a sanitary or civil engineer with at least 3 years' experience in sanitary wastewater treatment.

28.5.BB. When approved by the MOHSW an alternative sanitary system may be used at a healthcare facility to treat and dispose of the sanitary wastewater. The project engineer must provide the MOHSW with the following technical information:

- A project description and conceptual plan that describes the proposed sanitary waste management system. The project description should provide the following information:
  - A description of the proposed wastewater system;
  - A description of the key design criteria;
  - Performance information for similar system used in Liberia or in other similar settings;
  - The operation and maintenance requirements of the system; and
  - The name of the person or organization that will operate and maintain the system.
- Engineering design plans and specifications for the alternative wastewater system.
- An Operation and Maintenance (O&M) Plan for the system.
- A letter of completion from the project engineer indicating the system has been constructed and is operating in conformance with the plans.

28.6 Sanitary Sewer Systems

Sanitary sewage collections systems are used to collect wastewater and graywater from healthcare facilities resulting from human water use, including wastewater from toilets, sinks, showers, baths, kitchens and laundry washing.

Most healthcare facilities, particularly in rural or semi-urban sites will generate small or low flows of wastewater and installing large diameter sewer pipes is not advantageous to maintain adequate flow conditions in the sewer pipe. At these sites small diameter (or small bore) sewer systems will be more appropriate and cost effective. Site conditions, such as very low gradient terrain, high ground water and potentially shallow bedrock may also require that sewers be installed at shallow depths or with minimum slopes to accommodate site conditions. The primary criteria for designing new sanitary sewer systems is based on providing sufficient velocity of flow in the sewer system to minimize deposition of solids in the pipes and to maintain sufficient ventilation in the pipes.

It is important to note that small diameter sanitary sewers are small are not designed to convey rainfall from roofs and other areas on properties. The rainwater piping from houses should not be connected to the sanitary sewer system.

Alternative Sanitary Sewer Systems

Two alternative types of small diameter sewer systems are recommended for healthcare facilities, including:

- Small diameter gravity sewer systems that convey raw sewage to the treatment and disposal system; and
- Small diameter gravity effluent sewers that utilize septic tanks located at the buildings to intercept solids from the wastewater before it is discharged to a sewer system. The purpose of the interceptor tank is to remove settleable solids before they enter the main low gradient sewer to prevent potential clogging of the sewer line.

Figure 28.k. Typical Small Diameter Gravity Sewer System Layout

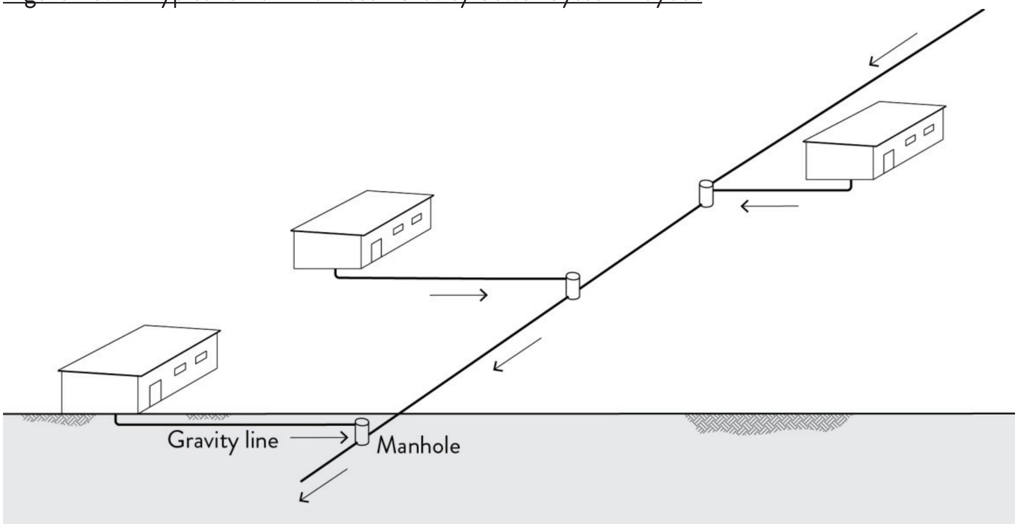
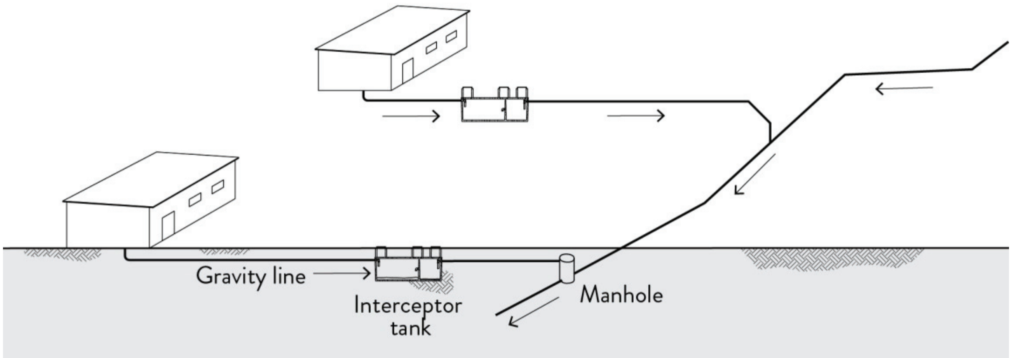


Figure 28.l. Typical Small Diameter Gravity Effluent Sewers with Interceptor (Septic) Tanks Before Sewers



28.6.A. The sanitary sewer system must be selected based on the following criteria:

i. Select small Gravity Sewer Systems when the minimum slope of the sewer pipes does not fall below 0.75% or 1ft (30.5cm) of fall for 135ft (41.1m) in length.

ii. Select small gravity effluent sewers with septic tanks when the slope of the main lateral sewer systems is less than 0.5% or 1ft (30.5cm) of fall in 200ft (61m) length. In these circumstances a septic tank should be installed on the branch line upstream of the low gradient main sewer line. The size of the septic tank shall be determined pursuant to the criteria presented above.

Small Gravity Sewers

28.6.B. The minimum pipe diameters for sanitary sewer must be 4in (10.2cm) for sewer laterals and 6in (15.3cm) for main sewer lines.

28.6.C. The sewer system design must ensure that an overall fall does exist across the system, and that the hydraulic grade line during the estimated peak flows does not rise above the outlet invert of the sewer lines or related facilities.

28.6.D. When there is insufficient gravity flow in the system is anticipated a lift station must be installed to overcome adverse elevation conditions either at the individual building connections or to raise collected wastewater from one location in the sewer system to another.

28.6.E. Cleanouts and/or manholes must be provided to allow for good access for cleaning and maintaining the sewers.

i. Cleanouts must be located in all lines between the building and the sewer mainline connections, at all upstream termini, and at 150ft (45.7m) intervals along the main sewer lines.
ii. Manholes must be installed at intersection of sewers, major changes in directions at intervals of 300ft (91.4m) to 500ft (152.5m) in long flat sections.

28.6.F. Minimum cover over pipelines must be provided as follows:

i. Under normal conditions the minimum required cover over a pipeline must be 24in (61cm) in locations with no vehicle traffic.
ii. Under normal conditions the minimum require cover over a pipeline shall be 36in (91.4cm) including 30in (76.2cm) of soil/sand and 6in (15.3cm) of base in locations with vehicle traffic. (In areas of shallow bedrock special provisions may be made to allow for shallow trench depths as approved by the MOHSW.)

28.6.G. The horizontal and vertical separation of sanitary sewers to domestic water lines must conform to the following standards:

i. The minimum horizontal separation between the sanitary sewer line and domestic water line must be 10ft (3m)
ii. The minimum vertical separation between the sanitary sewer and domestic water lines must be at least 12in (30 cm).
iii. Sewer lines and domestic water lines shall not be buried in the same trench.
iv. Sanitary sewer and domestic waterline intersections shall be perpendicular (90 degrees) to the extent practical.

28.6.H. Service connections that connect the buildings to the main sewer lines must conform to the following standards:

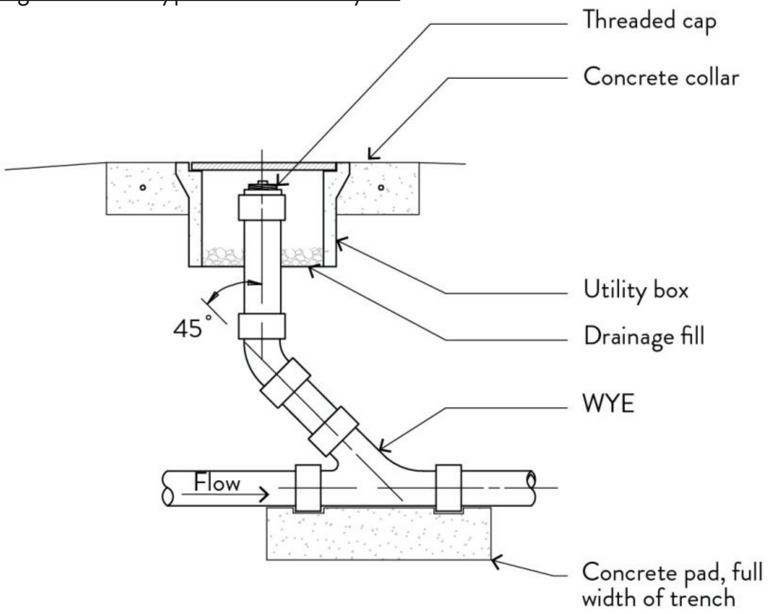
i. The sewers exiting the buildings must be a minimum of 3in (7.6cm) for graywater and 4in (10.2cm) for sewage.
ii. All pipes must be installed at a uniform negative gradient sufficient to transport fecal solids but not so great as to strand solids in the line. Minimum gradients for graywater lines are 2% for 3in (7.6cm) pipe and 2.5% for 4in 10.2cm) sanitary sewer pipe.
iii. Connections to the main must be made with Y or T fittings.

28.6.I. A cleanout must be installed in all service connection lines in conformance with the following standards:

i. Sewer cleanouts may be made of standard PVC fittings or they can be made as small inspection boxes in cement-rendered brick, pre-cast concrete vaults, or block work with sufficient care to be water tight, with lids that a sealed to prevent ingress of water into the sewer system.

ii. Cleanout piping shall be installed plumb and care shall be taken to maintain smooth transitions from up to dream flow in the sewer lines.
iii. Cleanouts installed in main sewer lines shall be installed in watertight valve boxes.
iv. Cleanouts installed in vehicle roads shall be installed with watertight vaults that are designed to accommodate loads from vehicles.

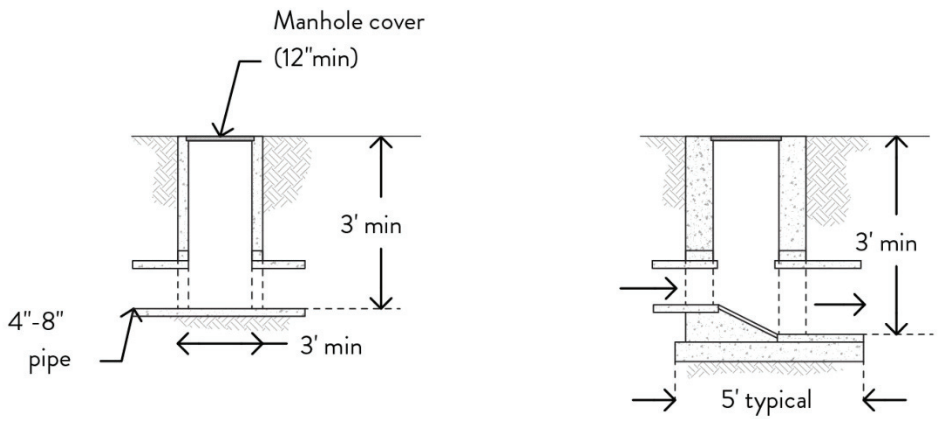
Figure 28.m. Typical Cleanout Layout



28.6.J. Small diameter manholes must conform to the following standards:

i. Manholes may be made of pre-cast concrete, cast-in-place concrete or brick and mortar, or block and mortar construction.
ii. Manholes shall be fitted with watertight covers to prevent infiltration of surface water.
iii. Manhole bottoms shall be grouted to provide for smooth flow conditions from the inlet and outlet pipe inverts to minimize sedimentation and standing water in the manhole, which can promote the breeding of vectors and generation or hydrogen sulfide and odor problems in the sewer system.

Figure 28.n. Typical Manhole Configurations for Small Diameter Sanitary Sewers



28.7 Subsurface Infiltration Systems

Subsurface wastewater infiltration systems (SWIS) are common systems for the treatment and dispersal of onsite wastewater. Infiltrative systems are installed in permeable, unsaturated natural soil or imported fill material so wastewater can infiltrate and percolate through the underlying soil. As water infiltrates and percolates through the soil, it is treated through a variety of physical, chemical, and biochemical processes and reactions. The physical characteristics of the applied wastewater, application rate, temperature, and the nature of the receiving soil affect the treatment processes. Treatment in the soil is obtained by the detention of solids, nutrients and microorganisms on or in the soil particles. Unsaturated conditions in the soil facilitate the detention of particles and increase oxygen favoring effluent treatment. Unsaturated conditions also improve the activity of soil macro fauna.

To improve dispersion and treatment in the soils receiving the effluent, SWIS are designed and installed to improve distribution to the infiltrative surface, and to reduce saturation below that surface. They are also installed to encourage oxygen penetration to the infiltrative surface and below. Subsurface Wastewater Infiltration Systems (SWIS) can be trenches, beds or drip dispersal areas. SWIS systems can be installed at various depths in ground or at grade to address vertical separation standards. The effluent can be distributed to the system by gravity or pressure.

Unsaturated conditions and unsaturated flow of effluent once applied to the infiltrative surface are essential to the proper functioning of the SWIS. In order to achieve this, the appropriate application of the daily design flow is essential to reduce the opportunity for saturated flow, achieve proper distribution and dosing of the effluent to the infiltrative surface is important.

Many different designs and configurations are used, but all incorporate soil infiltrative surfaces that are located in buried excavations. The primary infiltrative surface is the bottom and sidewalls of the excavation. Perforated pipe is typically installed to distribute the wastewater over the infiltration surface. A porous medium, typically gravel or crushed rock, is placed in the excavation below and around the distribution piping to support the pipe and spread the localized flow from the distribution pipes across the excavated trench or bed. The porous medium maintains the structure or the excavation, exposes the applied wastewater to more infiltrative surface and provides storage space for the wastewater within its void fractions during peak flows. A permeable geotextile fabric or other suitable material is laid over the porous medium before the excavation is backfilled to prevent the introduction of backfill soil into the porous medium. Natural soil is typically used for backfilling, and the surface of the backfill is usually slightly mounded and seeded with grass.

The following sections present the design and installation criteria for gravity drainfields or leachfield systems, which are considered to be appropriate for healthcare facilities in Liberia. There are several other methods of subsurface disposal and these may be an acceptable method of wastewater at these facilities; however, these should be approved by the MOH prior to completing the engineering design plans.

Soil Application Rates (SAR)

The subsurface infiltration system is sized based on the type of soil conditions encountered on the site and associated hydraulic loading or soil application rate (SAR), as presented in Table 28.d. below. Figure 28.o. presents the typical steps for sizing of a trench type disposal system based on the volume of wastewater and the appropriate SAR.

Table 28.d. Soil Application Rates (SAR) for different Soil Types

Texture	Structure		Hydraulic Loading (gal/ft2-day)	
	Shape	Grade	BOD=150	BOD=30
Coarse sand, sand, loamy coarse sand, loamy sand	Single grain	Structureless	0.8	1.6
Fine sand, very fine sand, loamy fine sand, loamy very fine sand	Single grain	Structureless	0.4	1.0
Coarse sandy loam, sandy loam	Massive	Structureless	0.2	0.6
	Platy	Weak	0.2	0.5
		Moderate, strong		
	Prismatic, blocky, granular	Weak	0.4	0.7
		Moderate, strong	0.6	1.0
Fine sandy loam, very fine sandy loam	Massive	Structureless	0.2	0.5
	Platy	Weak, mod., strong		
	Prismatic, blocky, granular	Weak	0.2	0.6
		Moderate, strong	0.4	0.8
Loam	Massive	Structureless	0.2	0.5
	Platy	Weak, mod., strong		
	Prismatic, blocky, granular	Weak	0.4	0.6
		Moderate, strong	0.6	0.8
Silt loam	Massive	Structureless		0.2
	Platy	Weak, mod., strong		
	Prismatic, blocky, granular	Weak	0.4	0.6
		Moderate, strong	0.6	0.8
Sandy clay loam, clay loam, silty clay loam	Massive	Structureless		
	Platy	Weak, mod., strong		
	Prismatic, blocky, granular	Weak	0.2	0.3
		Moderate, strong	0.4	0.6
Sandy clay, clay, silty clay	Massive	Structureless		
	Platy	Weak, mod., strong		
	Prismatic, blocky, granular	Weak		
		Moderate, strong	0.2	0.3

* *Adapted from Tyler, 2000. Table 4-3. Suggested hydraulic loading rates for sizing infiltration surfaces.*

Subsurface Disposal System Sizing Example

Use standard soil hydraulic application rates established by US EPA. Typical application rates are as follows:

Coarse sand: *Disposal of untreated water = 2.5 gal/ft2-d*
Disposal of treated water = 5 gal/ft2-d

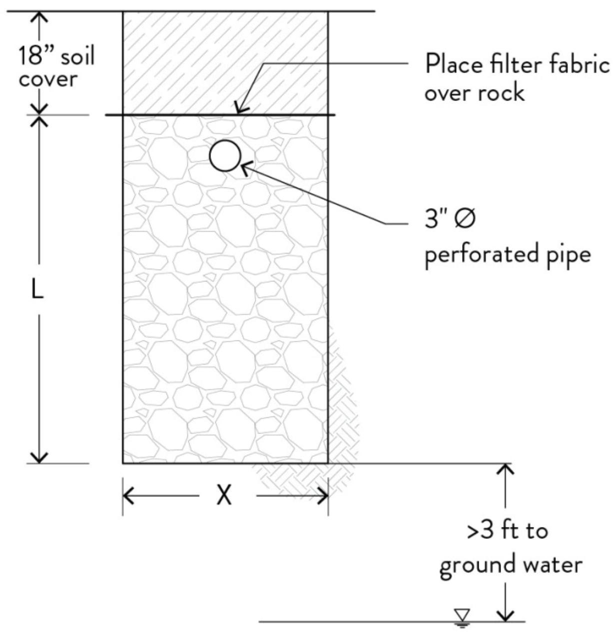
Clay: *Untreated wastewater = 0.5 gal/ft2-d*
Treated wastewater = 1 gal/ft2-d

Disposal area (ft2) of disposal trench required is the volume of wastewater divided by the application rate: *Disposal area (ft2) = volume (ft3)/sar*

Unit area of disposal trench is calculated based on the depth and width of trench multiplied by the length of trench: *Area (ft2)/unit length = [2lx] x [1 ft of trench]*

Total length of trench is calculated by disposal area (ft2) by the unit length:
Total length (ft) of disposal trench = [disposal area]/[area/unit length unit]

Figure 29.o. Subsurface Disposal System Sizing



Drainfield or Leachfield Trenches

A drainfield or leachfield is a network of perforated pipes that are laid in underground gravel-filled trenches to dissipate/dispose of the effluent from a water–based treatment system, such as a septic tank and ABR. Gravity flow trenches are appropriate for sites that do not have high groundwater or bedrock near the surface and also appropriate if the soil permeability is suitable for wastewater disposal purposes, as demonstrated by the field evaluation and testing.

28.7.A. **All trench systems must be sized such that the bottom area and sidewall area is at least equal to the daily design flow divided by the soil application rate for the type of soil conditions found at the site.** (Refer to Table 28.d. for appropriate soil application rates)

28.7.B. **The trench system must be designed to provide one primary trench system to accommodate 100% of the daily design flow and an expansion area that can provide an additional 100% disposal area for a total of 200% disposal capacity.**

28.7.C. **Gravity trench systems must conform to the following standards:**

i. Trench width must not be less than 12in (30.5cm) and not greater than 36in (91.4cm).
ii. Trench length must not be greater than 100ft (30.5m) for any one lateral in a gravity distribution system. Equally distribution gravity lines should preferably use shorter laterals (less than 50ft (15.2m)).
iii. Spacing must not be less than 6ft (1.8m) from centerline to centerline.
iv. Trench length must be level or with a positive slope in the direction of flow not exceeding 2in (5cm) in 100ft (30.5m). Pressure distribution system trenches can be designed specifically to be sloped.
v. As much as possible, trench length must be oriented parallel with contour (perpendicular to slope) and should follow the contour.
vi. Do not over dig and refill trenches. Scarify the trench base; do not polish or compact it with bucket or foot traffic.

28 / Human Waste

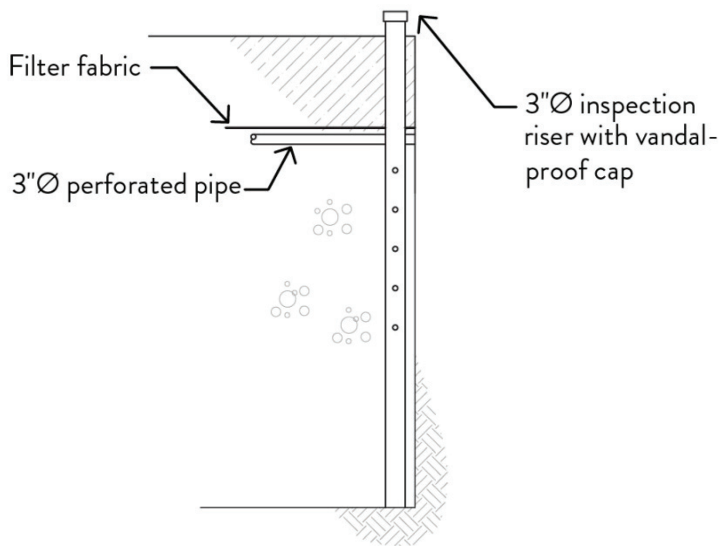
28.7.D. Gravity trenches must include the following provisions for aggregate:

i. Generally, gravel trenches must have not less than 9in (22.9cm) of drain rock depth between point of discharge and trench bottom.
ii. Generally, gravel trench must have a minimum of 2in (5cm) drain rock cover above effluent dispersal pipe.
iii. The effective aggregate sizes range from ½in – 2 ½in (13 mm – 63 mm). All aggregate must be washed and screened and contain less than 5% fines, silt or clay coating.

28.7.E. Gravity trenches must conform to the following cover requirements:

i. Cover drain rock with a breathable barrier to prevent soil mixing with the drain rock. This can be breathable, water permeable geotextile material or equivalent—for example, a biodegradable layer such as untreated building paper, marsh hay or straw 4in (10.2cm) depth or a graded aggregate filter). Where soil cover is uniform fine sand, this layer should be geotextile.
ii. Cover breathable barrier with not less than 6in of soil or sod. Soil cover should be air permeable and should be slightly crowned at installation to settle to level. Where marsh hay or straw is used as a barrier layer, cover soil mounding should take into account settlement of the barrier layer.
iii. Grade cover to provide ground water drainage away from the trench or bed. On a slope, an upslope swale should be installed to divert any surface flows.
iv. Install a 3in (7.6cm) diameter inspection riser at the end of the trench extending to the bottom of the trench to allow for routine inspection of the water level in the trench. The pipe should have ½in (1.3cm) perforations drilled in the pipe every 2in (5cm) from the bottom of the pipe until 3ft (91.4cm) from the bottom of the trench.

Figure 28.p. Trench Inspection Riser Detail



28.7.F. Distribution boxes must meet the following requirements:

i. A distribution box must be watertight.
ii. A distribution box must be structurally sound, and resistant to hydrogen sulphide.
iii. Generally, the distribution box must provide even flow to each individual lateral by adjustable outlet leveling devices.
iv. The distribution box must be placed on a compacted and level 1in (2.5cm) sand or gravel bed.
v. Provide a watertight riser access at grade to provide for maintenance (insulation may be necessary).

28.7.G. Piping must meet the following requirements:

i. As much as possible, piping must be placed on centerline in the trench.
ii. Piping grade must be level or with a positive slope in the direction of flow not exceeding 2in (5cm) in 100.
iii. Perforated pipe nominal size shall be not < 3in (7.6cm) for gravity distribution.
iv. Perforations shall not be <½in (1.3cm) for gravity distribution.
v. Generally, perforations must begin and end not less than one foot from trench end wall for gravity distribution.
vi. Dispersal piping must be capped at the end.
vii. Piping must be placed in such a way as to ensure the best and most even effluent dispersal along width and length.

28.8. Sludge Management

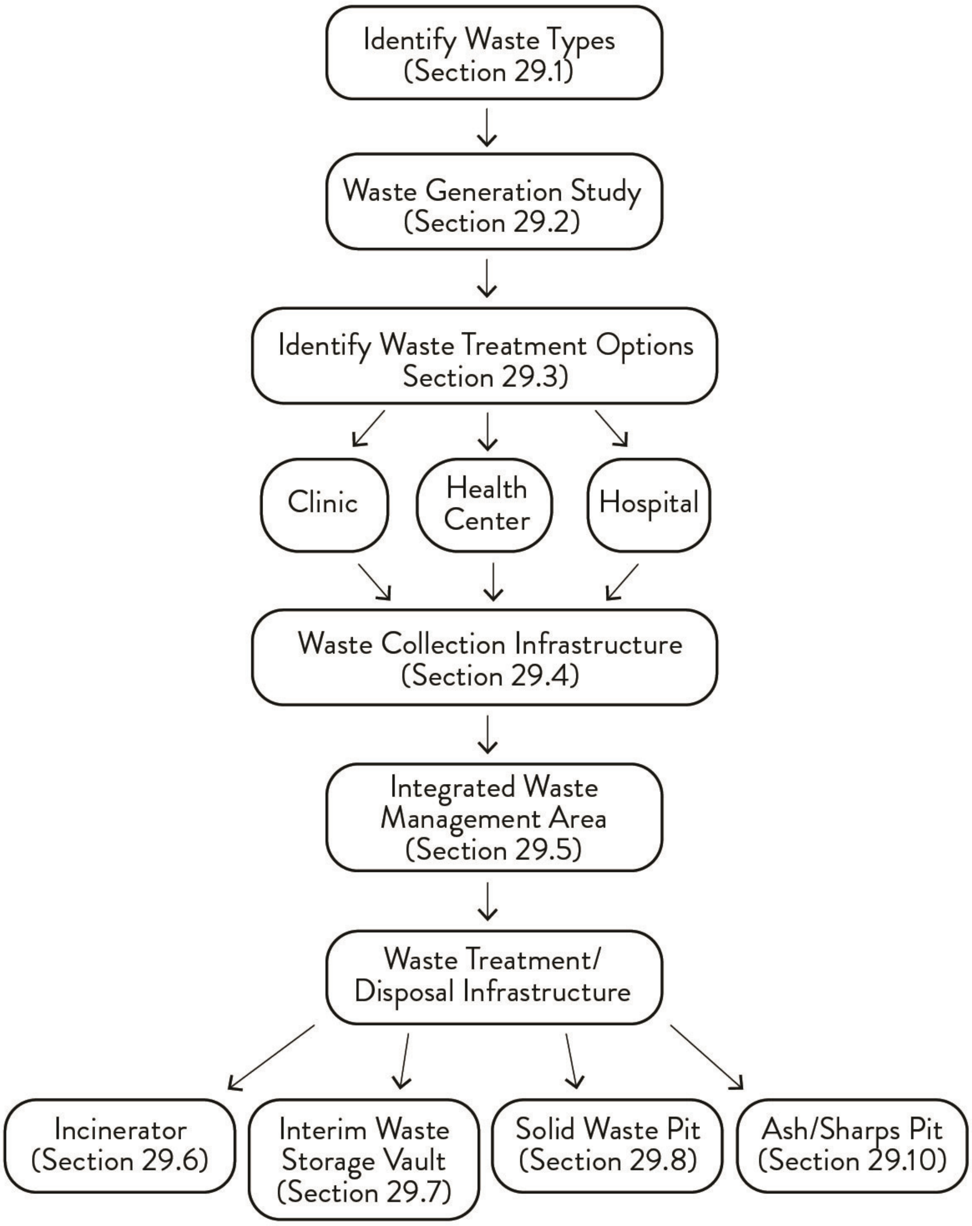
Onsite wastewater systems will require routine cleaning and removal of the residual solids that accumulate in the soakaway, septic, ABR and other waste treatment systems. A common practice in Liberia is to have the sludge hauled away by pump trucks and taken to a regional treatment facility. When sludge is hauled away it is commonly referred to as septage. A haul-away system usually relies on a vacuum truck or another vehicle equipped with a motorized pump and a storage tank for emptying and transporting septage to a regional treatment facility. If this haul-away system is going to be utilized, it is critical that the treatment system be located and designed so that a vacuum truck can access the site.

28.8.A. The onsite wastewater system must have good access for a septage pump truck to pump out the sanitation system on a routine basis, typically once every 1 to 3 years depending on the size and use of the facility.

i. To the degree possible, design the site to allow a truck access to the tank to be pumped within 98ft (30m). Accessibility is very critical because most vacuum pumps can only suck down tanks that are 6ft (1.8m) to 8ft (2.4m) deep.

29 Medical and Solid Waste

Medical and solid waste must be effectively managed and disposed of to protect human and environmental health. Effective waste management is critical to prevent the spread of infectious diseases in healthcare facilities. To achieve this, two principal goals need to be achieved. First, waste management systems must be properly designed, constructed and maintained. Equally importantly, an operations-based waste management program must be in place at every facility to ensure that waste is sorted, treated, and disposed of in a safe and efficient manner.



Definitions

- **Chemical Hazardous Waste**: Solid, liquid, and gaseous waste/chemicals from diagnostic and laboratory work, housekeeping and cleaning, disinfecting procedures, car/truck fleet management, and building operations.
- **Combustible:** A substance that is able to catch fire and burn easily.
- **Compost**: To make vegetable matter or manure into compost.
- **CWMA:** Central waste management area.
- **Encapsulate**: To enclose something in a sealed container.
- **Groundwater**: Water found in subsurface pore spaces below the water table.
- **Hazardous Waste**: Waste that poses substantial or potential threats to public health or the environment and includes pressurized containers and mercury-containing waste.
- **Incinerate**: To destroy waste material by burning.
- **Infectious Non-Sharp Waste**: Waste that includes soiled surgical dressings, cotton wool, gloves, swaps and all other contaminated waste from treatment areas. Also includes disposable plasters, bandaging, items significantly contaminated with blood, and materials from cases of infectious diseases (human biopsy materials, blood, urine, stools).
- **Interim Waste Storage Vaults**: Temporary storage for sharps waste prior to incineration on-site and/or taken to a higher-level facility for incineration.
- **Organic Waste**: Type of waste that can be broken down, in a reasonable amount of time, into its base components by micro-organisms and other living things. Examples include kitchen waste and yard waste.
- **Oxidation**: Deposition that forms on the surface of a metal as a result of contact with oxygen.
- **Pathological Waste**: Waste materials consisting of human or animal remains, anatomical parts, and/or tissue, the bags/containers used to collect and transport the waste materials, and animal bedding. Also includes lab waste or any other waste contaminated with blood and bodily fluids.
- **Permeability**: The quality of material or membrane that causes it to allow liquids or gases to pass through it.
- **Pharmaceutical Waste**: Waste that includes expired drugs and vaccines, drugs returned from wards, spilled or contaminated drugs, and cytotoxic wastes or other chemotherapy drug waste.
- **Pharmaceuticals**: Compounds manufactured for use as a medicinal drug.
- **Radioactive Waste**: Solid, liquid, or gaseous waste contaminated with radionuclides generated from "in vitro" analysis of body tissues, organ imaging and tumor localization, and therapeutic procedures.
- **Recycle**: To convert waste into reusable material and is applicable to materials such as metals, bottles, clothes, etc.
- **Relative Compaction**: The degree of compaction achieved, as a percentage of the laboratory compaction.
- **Sharps Waste**: Medical waste composed of discarded syringes, needles, cartridges, scalpel blades, and saws.
- **Solid Waste**: Refuse or rubbish consisting of everyday items that are discarded by the public, including paper, packing materials, cardboard containers, plastic bags, food wrappings/containers, metal cans, floor sweepings, non-infectious patient related waste, and bulky waste (debris).
- **Spillage Containment Equipment**: Equipment that aids in the containment of spills.
- **Waste Generation Study**: Determines waste types and generation amounts to size waste management infrastructure/operations accordingly.

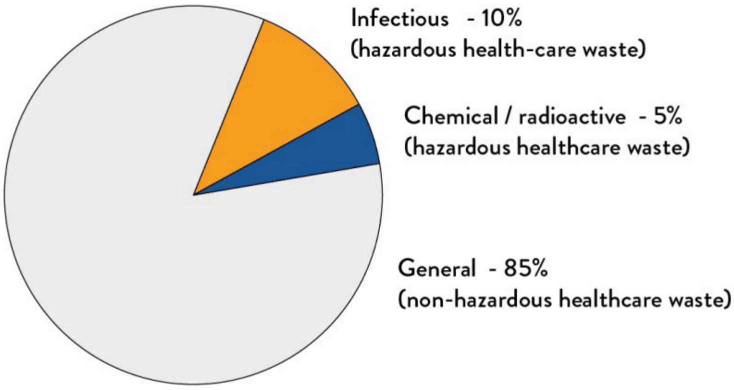
29.1 Waste Types

Healthcare facilities normally generate two categories of waste:

1) Non-risk/non-hazardous waste.
2) Risk/hazardous waste, such as infectious and biological waste, sharps, pharmaceuticals, chemicals and other potentially dangerous waste streams.

The following pie chart depicts the typical waste composition in healthcare facilities.

Figure 29.a. Typical waste composition in healthcare facilities[1]



Between 75% and 90% of the waste produced at healthcare facilities is non-hazardous.[2] Non-hazardous waste is defined as domestic solid waste that does not pose a specific significant risk of disease transmittal or that is not corrosive, toxic, or flammable. Some types of non-hazardous waste have the potential to be reused or recycled.

The remaining 10-25% of the waste produced at healthcare facilities is regarded as "hazardous" and may pose a variety of environmental and health risks. Hazardous waste includes both bio-hazardous (potentially infectious) waste and chemical waste. It is important to understand the types of waste generated and the implications around each.[3]

The following table outlines healthcare waste types with examples.

Table 29.a. Healthcare waste types and examples[4]

Waste Type	Examples
1) Solid waste	- Paper (documents, letters, newspapers) - Packing materials, cardboard containers - Plastic bags/films - Food wrappings/containers - Metal cans - Floor sweepings - Non-infectious, patient related waste (trash) - Bulky waste (debris)
2) Kitchen and organic waste	- Kitchen waste (food prep scraps, uneaten food, swills, paper products) - Yard waste
3) Infectious non-sharp waste	- Soiled surgical dressings, cotton wool, gloves, swabs and all other contaminated waste from treatment areas - Disposable plasters, bandaging, items significantly contaminated with blood - Material, other than reusable linen, from cases of infectious diseases (human biopsy materials, blood, urine, stools)
4) Pathological waste	- Pathological waste (human tissues, organs, body parts, placentas, human fetuses; animal carcasses and tissues from labs and related swabs/dressings) - Lab waste (e.g. pathology, hematology and blood transfusion, microbiology, histology, and postmortem room waste), or any other waste contaminated with blood and bodily fluids
5) Sharps waste	- Discarded syringes, needles, cartridges, scalpel blades, saws
6) Pharmaceutical waste	- Expired drugs and vaccines - Drugs returned from wards - Spilled or contaminated drugs - Cytotoxic wastes, or other chemotherapy drug waste

7) Chemical hazardous waste	- Solid, liquid and gaseous waste/chemicals from:
	  - Diagnostic and laboratory work
	  - Housekeeping and cleaning
	  - Disinfecting procedures
	  - Car/truck fleet management – oils, solvents
	  - Building operations (e.g. paints, adhesives, sealants, pesticides)

8) Radioactive waste	- Solid, liquid, and gaseous waste contaminated with radionuclides generated from "in vitro" analysis of body tissues and fluid, "in vivo" body organ imaging and tumor localization, and therapeutic procedures.
9) Other hazardous waste	- Pressurized containers (compressed gas cylinders, aerosol cans, disposable compressed gas containers) - Mercury-containing waste (highly hazardous)

29.2 Waste Generation

Knowing the types and quantities of waste produced in a healthcare facility is an important first step in safe disposal. Waste-generation data is used in estimating the required capacities for containers, storage areas, and transportation and treatment technologies. The following table outlines the typical types of waste generated by facility type and facility area/department.

Table 29.b. Healthcare waste generation sources[5]

Waste Type	Facility Type	Generation Sources
1) Solid waste	- Hospitals - Health Centers - Clinics	- Offices/public areas, medical ward, operating theatre, laboratory, pharmacy, radiology, chemotherapy, environmental services, engineering, food service
2) Kitchen and organic waste	- Hospitals - Health Centers - Clinics	- Food Service, Grounds/maintenance
3) Infectious non-sharp waste	- Hospitals - Health Centers - Clinics (minimal)	- Medical ward, operating theatre, laboratory
4) Pathological waste	- Hospitals - Health Centers - Clinics	- Medical ward, operating theatre, laboratory
5) Sharps waste	- Hospitals - Health Centers - Clinics	- Medical ward, operating theatre, laboratory, chemotherapy
6) Pharmaceutical waste	- Hospitals - Health Centers - Clinics (minimal)	- Medical ward, operating theatre, laboratory, chemotherapy, pharmacy, radiology
7) Chemical hazardous waste	- Hospitals - Health Centers - Clinics (minimal)	- Medical ward, operating theatre, laboratory, pharmacy, radiology, chemotherapy, environmental services, engineering
8) Radioactive waste	- Hospitals (minimal)	- Radiology
9) Other hazardous waste	- Hospitals (minimal)	- Medical ward, operating theatre, laboratory, pharmacy, radiology

Many factors affect the rate of waste generation including:

- Level of activity (often measured in terms of the number of occupied beds, number of patients per day, and/or number of staff);
- Type of department (e.g. general ward, surgical theatre, office);
- Type or level of facility (e.g. clinic, provincial hospital);
- Location (rural or urban);
- Regulations or policies on waste classification;
- Collection and segregation practices;
- Temporal variations (e.g. weekday versus weekend, seasonal);
- Level of infrastructure development of the country.

29.2.A. **A waste generation study must be conducted to determine waste types and generation amounts to size waste management infrastructure/operations accordingly.**

i. Perform a benchmark comparison to facilities of similar size and composition (e.g. kg/patient-day). See Appendix R for information on total and infection waste generation rates.

ii. Conduct a site assessment survey of a comparable healthcare facility. Take note of the following when conducting the site assessment:

- Determine type, size and color coding of internal waste collection containers;
- Understand how waste is internally handled/transported from point of generation to disposal;
- Assess options for hazardous waste treatment equipment (e.g. incinerator, autoclave and/or placenta pit)

29.3 Waste Treatment Options

Waste management in healthcare facilities should include provisions for the safe collection, storage, transport, treatment, and disposal of the various non-hazardous and hazardous waste streams. In all healthcare facilities the treatment and disposal of specific wastes including sharps, placentas or incinerator ash will be part of the internal waste management system.

Hospitals

Hospitals offer a wide and complex range of services. As a result, they generate not only large volumes of waste, but more varied waste streams, including forms of hazardous waste that may not be generated at primary or secondary level facilities. In some cases, hospitals may receive hazardous waste from smaller facilities that lack the infrastructure to treat or dispose of certain waste streams. The planning and design of waste treatment facilities at hospitals must account for these additional sources to ensure that systems are properly sized and utilized.

29.3.A. **Provisions must be developed at hospitals to properly treat solid waste.**

i. Treatment options must be considered in the following order of preference:

- Recycle applicable materials such as metals, bottles, clothes, etc.
- Incinerate at >1000°C with heat recovery if possible.
- Dispose of in burial pit with secure containment.

29.3.B. **Provisions must be developed at hospitals to properly treat kitchen and organic waste.**

i. All food, yard and organic wastes must be disposed of in an efficient manner.

ii. Compost food, yard, and organic waste if possible by establishing an on-site composting system or partnering with a commercial compost vendor.

29.3.C. **Provisions must be developed at hospitals to properly treat infectious non-sharp waste.**

i. Treatment options must be considered in the following order of preference:

- Incinerate at >1000°C with heat recovery if possible.
- Sterilize and/or disinfect prior to burial pit disposal.
- Dispose of in a solid waste pit with secure containment.

29.3.D. **Provisions must be developed at hospitals to properly treat pathological waste considered as minor and unrecognizable parts.**

i. Treatment options must be considered in the following order of preference:

- Incinerate at >1000°C with heat recovery if possible.
- Dispose of in a placenta pit with secure containment.

29.3.E. **Body parts that are results of amputations must be buried in authorized sites by recognized entities or institutions.**

29.3.F. **Provisions must be developed at hospitals to properly treat sharps waste.**

i. Treatment options must be considered in the following order of preference:
   - Encapsulate sharps in puncture proof container and then incinerate at >1000°C with heat recovery if possible. Dispose of ash in combined ash/sharp pit with secure containment. Ensure ash/sharp residue is managed as a potential sharps hazard.
   - Sharps waste that cannot be treated at the facility due to incinerator capacity or performance must be encapsulated then temporarily stored in an interim waste storage vault with secure containment.

Interim Waste Storage Vaults

An interim waste storage vault is meant to serve only as a temporary storage measure until the sharps waste is incinerated on-site and/or taken to a higher-level facility for incineration.

29.3.G. **Provisions must be developed at hospitals to properly treat pharmaceutical waste.**

i. Pharmaceuticals must be collected separately from all other wastes.
ii. Pharmaceuticals must not be flushed or disposed of down drains.
iii. Treatment options must be considered in the following order of preference:
   - Encapsulate then store in an interim waste storage vault with secure containment until pharmaceutical waste is transported to an offsite treatment facility.
   - Incinerate at >1000°C with heat recovery if possible.

29.3.H. **Provisions must be developed at hospitals to properly treat chemical hazardous waste.**

i. Chemical hazardous waste must be collected separately from all other wastes.
ii. Treatment options must be considered in the following order of preference:
   - Use all of the material to prevent disposal as a chemical hazardous waste.
   - Return unused material to suppliers to prevent disposal as a chemical hazardous waste.
   - Encapsulate then store in an interim waste storage vault with secure containment until chemical hazardous waste in transported to an offsite treatment facility.
   - Incinerate in a high temperature commercial incinerator, cement, lime or aggregate kiln or blaze furnace.

29.3.I. **Provisions must be developed at hospitals to properly treat cytotoxic and radioactive waste.**

i. Treatment options must be considered in the following order of preference:
   - Return unused material to suppliers to prevent disposal as a cytotoxic or radioactive waste.
   - Recycle empty non-returnable/refillable containers.
   - Encapsulate then store in an interim waste storage vault with secure containment until further disposal instructions are received from the MOHSW.

29.3.J. **If generated, highly infectious waste must be treated by thermal (steam) treatment methods close to the place of generation or directly in the laboratory. After treatment, the waste must be handled as infectious waste.**

29.3.K. **Fixing baths used for the photographical processes in radiology must be de-silvered (recovering silver) prior to disposal.**

29.3.L. **Liquid hazardous waste at hospitals must be neutralized prior to its disposal in the wastewater treatment system.**

29.3.M. **Liquid hazardous waste that cannot be neutralized must be stored in the interim waste storage vault until transported to an offsite treatment facility.**

29.3.N. **If a hospital is operating an on-site incinerator for waste treatment, the hospital must offer the treatment of infectious waste and sharps to other healthcare facilities in the surrounding area.**

Health Centers

Health Centers offer a more limited range of services than hospitals, but a greater range than clinics. Given the catchment populations they treat, they produce a sizable amount of waste, including some types of hazardous waste. In some cases, Health Centers may receive hazardous waste from nearby clinics. The planning and design of waste treatment facilities at Health Centers must account for these additional sources to ensure that systems are properly sized and utilized.

29.3.O. **Provisions must be developed at Health Centers to properly treat solid waste.**

i. Treatment options must be considered in the following order of preference:
  - Recycle applicable materials such as metals, bottles, clothes, etc.
  - Incinerate at >1000°C with heat recovery if possible.
  - Dispose of in burial pit with secure containment.

29.3.P. **Provisions must be developed at Health Centers to properly treat kitchen and organic waste.**

i. All food, yard and organic wastes must be disposed of in an efficient manner.
ii. Compost food, yard, and organic waste if possible by establishing an on-site composting system or partnering with a commercial compost vendor.

29.3.Q. **Provisions must be developed at Health Centers to properly treat infectious non-sharp waste.**

i. Treatment options must be considered in the following order of preference:
  - Pack in safe containers and store in an interim waste storage vault until transportation to an incinerator for treatment becomes available.
  - If external treatment is not possible, incinerate at >1000°C with heat recovery if possible.
  - Sterilize and/or disinfect prior to burial pit disposal.
  - Dispose of in a solid waste pit with secure containment.

29.3.R. **Provisions must be developed at Health Centers to properly treat pathological waste considered as minor and unrecognizable parts.**

i. Treatment options must be considered in the following order of preference:
  - Pack in safe containers and store in an interim waste storage vault until transportation to an incinerator for treatment becomes available.
  - If external treatment is not possible, incinerate at >1000°C with heat recovery if possible.
  - Dispose of in a placenta pit with secure containment.

29.3.S. **The body parts that are results of amputations must be buried in authorized sites by recognized entities or institutions.**

29.3.T. **Provisions must be developed at Health Centers to properly treat sharps waste.**

i. Treatment options must be considered in the following order of preference:
  - Pack in safe containers and store in an interim waste storage vault until transportation to incinerator for treatment becomes available.

- If external treatment is not possible, encapsulate in puncture proof container and then incinerate at >1000°C with heat recovery if possible. Dispose of ash in ash pit with secure containment. Ensure ash/sharp residue is managed as a potential sharps hazard.

29.3.U. Provisions must be developed at Health Centers to properly treat pharmaceutical waste.

i. Pharmaceuticals must be collected separately from all other wastes.
ii. Pharmaceuticals must not be flushed or disposed of down drains.
iii. Treatment options must be considered in the following order of preference:
   - Encapsulate then store in an interim waste storage vault with secure containment until pharmaceutical waste is transported to an offsite treatment facility.
   - Incinerate at >1000°C with heat recovery if possible.

29.3.V. Provisions must be developed at Health Centers to properly treat chemical hazardous waste.

i. Chemical hazardous waste must be collected separately from all other wastes.
ii. Treatment options must be considered in the following order of preference:
   - Use all of the material to prevent disposal as a chemical hazardous waste.
   - Return unused material to suppliers to prevent disposal as a chemical hazardous waste.
   - Encapsulate then store in an interim waste storage vault with secure containment until chemical hazardous waste is transported to an offsite treatment facility.
   - Incinerate in a high temperature commercial incinerator, cement, lime or aggregate kiln or blaze furnace.

29.3.W. If a Health Center is operating an on-site incinerator for waste treatment, the Health Center must offer the treatment of infectious waste and sharps to other surrounding health care facilities.

Clinics

Clinics offer basic outpatient services to small catchment areas, and as such do not tend to generate large volumes of waste. Hazardous waste generated at clinics is typically limited to sharps and a few other types of infectious waste. All new clinics will have waste treatment amenities (e.g. incinerators) to ensure proper disposal of the waste generated. Existing clinics will be required to include waste treatment amenities as part of any upgrades or remodels.

29.3.X. Provisions must be developed at clinics to properly treat solid waste.

i. Treatment options must be considered in the following order of preference:
   - Recycle applicable materials such as metals, bottles, clothes, etc.
   - Incinerate at >1000°C with heat recovery if an incinerator is available.
   - Dispose of in a burial pit with secure containment.

29.3.Y. Provisions must be developed at clinics to properly treat kitchen and organic waste.

i. All food, yard and organic wastes must be disposed of in an efficient manner.
ii. Compost food, yard, and organic waste if possible by establishing an on-site composting system or partnering with a commercial compost vendor.

29.3.Z. If a functional on-site incinerator is not available, sharps must be collected in puncture proof containers and stored in a waste storage vault until transported to another treatment facility.

29.3.AA. If chemical and pharmaceutical wastes are generated, and a functional on-site incinerator is not available, these must be separately packed and stored in a waste storage vault until transported to a treatment facility.

29.3.BB. If infectious waste is generated, and a functional on-site incinerator is not available, it must be disinfected by soaking for 12 hours in a .5% bleach solution. Afterwards it must be disposed of together with domestic solid waste.

29.4 Waste Collection Infrastructure

Waste segregation systems must be developed based on the types of waste generated in a specific healthcare facility. While in secondary and tertiary level healthcare facilities, a much wider spectrum of hazardous wastes must be expected, the classes of medical waste generated in primary healthcare settings is relatively limited.

General Standards

The following waste collection infrastructure standards and guidelines apply to all healthcare facility types.

29.4.A. Healthcare facilities must be designed to allow for the safe collection and storage of solid waste and hazardous healthcare waste.

29.4.B. Containers for waste collection must be durable and transportable.

i. Each bin must be of a manageable size.
ii. Bins must be relatively light and/or have wheels.
iii. Bins must be made of solid and waterproof materials such as plastic or stainless steel.
iv. Bins must be color-coded based on waste stream type. If color-coded bins are not available, label with appropriate signage.

29.4.C. Each healthcare facility must establish and operate at least a basic central interim storage point that will act as a waste function area.

i. In all instances, storage arrangements must:
   - Be robust and secure from unauthorized entry, animals, birds or other infestation
   - Be situated in a convenient place (away from patients and food preparation) for both healthcare workers and municipal workers
   - Allow for the safe handling of waste containers exclusively for healthcare waste (any clean unused containers should be distinctly separate from used/full containers)
   - Allow clear distinctions to be maintained between wastes intended for different disposal methods
   - Allow storage of wastes in designated and delineated areas, in a safe environment without offensive odor
   - Be provided with safety equipment and instructions (e.g. spillage procedures and blood and body fluids precautions)
   - Be of sufficient size to allow for delays in the onward transportation of waste
   - Have an impermeable hard standing floor with good drainage (away from watercourses); the floor should be easy to clean and disinfect
   - Have a water supply for cleaning purposes and a wash basin
   - Have a supply of cleaning equipment, protective clothing and waste bags or containers

29.4.D. **Each healthcare facility must establish an interim waste storage vault for the storage of any waste (pharmaceuticals, chemical hazardous, radioactive) that is to be transported offsite for treatment.** (See Section 29.7 for interim waste storage vault details)

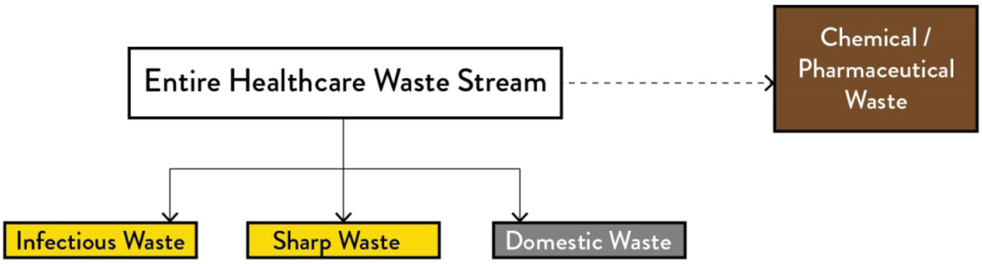
29.4.E. **A safe path of travel must be provided between the central interim storage point and the final transport or on-site treatment and disposal systems.**

i. The path must be at least 4ft (1.2m) wide and constructed of reinforced concrete or other equivalent stabilized material that will allow the use of a handcart to move the bins.

Hospitals

29.4.F. **The "three-bin system" must be setup in all medical areas throughout the Hospital to appropriately separate 1) infectious waste, 2) sharp waste, and 3) solid waste.**[6]

Figure 29.b. Three Bin Waste Collection System[7]



29.4.G. **Provisions must be developed to properly collect and transport waste within the hospital.**

i. Each ward and department must ensure that waste bins in the department are regularly emptied and that bins are cleaned and disinfected.
ii. Building services staff must be responsible for the emptying and maintenance of any local collection point containers.
iii. Waste must be transported in a secured manner to the central interim storage facility.
iv. To the degree possible, sharps and infectious waste must collected at the same time.
v. Waste bins for non-risk recycling (cardboard, plastic and glass) must be located throughout the Hospital, especially in non-medical areas.
vi. Pharmaceutical waste must be collected at the nursing station and should be brought back to the pharmacy. At the Pharmacy the pharmaceuticals should be sorted and stored in original packaging. Hazardous pharmaceuticals must be brought to the interim waste storage vault.
vii. Hazardous chemical waste must be collected in any areas where it is being generated (e.g. laboratory, radiology, pathology) and be brought to the interim waste storage vault.
viii. Pathological waste must be collected at operating theatres, pathology and labor rooms.
ix. One or more collection points must be established for heavy metal waste, especially amalgam (dentist,) batteries, and fluorescent lamps (that contain mercury.)

Health Centers

29.4.H. The "three-bin system" must be setup in all medical areas throughout the Health Center to appropriately separate 1) infectious waste, 2) sharp waste, and 3) solid waste.

29.4.I. Provisions must be developed to properly collect and transport waste within the Health Center.

i. Each department must ensure that waste bins in the department are regularly emptied and that the bins are cleaned and disinfected.
ii. Building services must be responsible for the emptying and maintenance of any local collection point containers.
iii. Waste must be transported in a secured manner to the central interim storage facility.
iv. Waste bins for non-risk recycling (cardboard, plastic and glass) must be located throughout the Health Center, especially in non-medical areas.
v. To the degree possible, sharps and infectious waste must be collected at the same time.
vi. One segregation point for pharmaceutical waste must be established at a secured area in the Health Center. Hazardous pharmaceuticals must be brought to the interim waste storage vault.
vii. One segregation point for the collection of hazardous chemical waste must be established at a secured area in the Health Center. The hazardous chemical waste must then be brought to the interim waste storage vault.

Clinics

29.4.J. The setup of the "three-bin system" may not be needed in clinics; however, provisions must be made for the collection and/or treatment of solid and sharps waste.

29.4.K. Provisions must be developed to properly collect and transport waste within the clinic.

i. Solid waste must be collected in a closable, large container and must be regularly picked up and disposed of.
ii. Infectious waste (if generated) must be disinfected on-site with adequate chemicals and disposed of afterwards together with solid waste.
iii. Sharps waste, small quantities of expired pharmaceuticals must be separately collected in safe containers and stored in an interim waste storage vault.
iv. Hazardous and toxic waste must be separately collected in safe containers and stored in an interim waste storage vault until transported to an offsite treatment facility.
v. To the degree possible, waste bins for non-risk recycling (cardboard, plastic and glass) must be located throughout the clinic, especially in non-medical areas.

29.5 Integrated Waste Management Areas

Developing integrated waste management areas for healthcare facilities are an effective means to consolidate, manage and dispose of wastes in a comprehensive and safe manner.

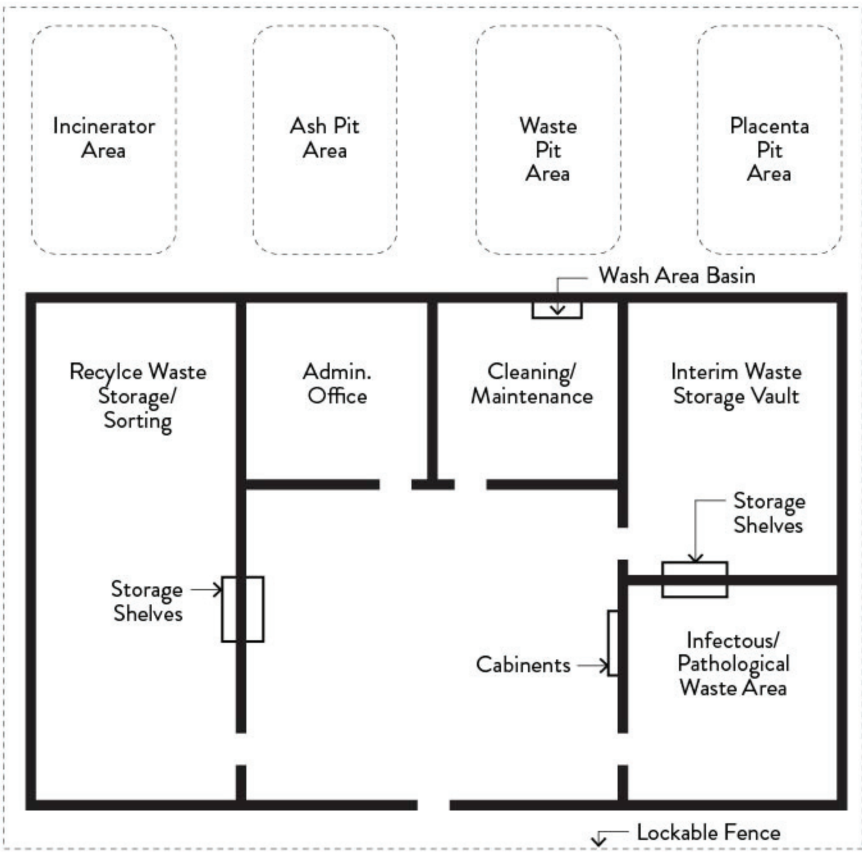
Hospitals and Health Centers

At county Hospitals and larger regional Health Centers, a central waste management area (CWMA) must be designed and constructed to store and/or treat medical and solid wastes. This facility is the central waste logistic center for the healthcare facility and is used as the main collection point for all medical-related (infectious and non-infectious) wastes.

29.5.A. Every Health Center and Hospital must have a designated CWMA for waste treatment and disposal systems.

i. The CWMA for a Health Center or Hospital must include the following core elements:
   - An area for an on-site incinerator
   - An area for ash pits
   - An area for waste pits
   - An area for placenta pits
   - An area for recycled wastes
   - An interim waste storage vault for sharps, chemical hazardous and pharmaceutical wastes
   - An area for cleaning and maintenance
   - A water supply for cleaning and wash basin purposes
   - A supply of cleaning equipment, protective clothing and waste bags
   - An administrative office and workshop (optional)

Figure 29.c. Example Hospital/Health Center CWMA



29.5.B. **The CWMA must be located at least 500ft (150m) away from main healthcare and treatment facilities.**

i. Refer to Standard 9.2.E for further CWMA siting requirements.

29.5.C. **The CWMA must have good vehicle and pedestrian access to facilitate the collection and transport of waste and the delivery of waste management equipment and supplies.**

ii. Access paths must be at least 6ft-8ft (1.58m-2.4m) wide.

29.5.D. **The CWMA must be enclosed in a secure and locked area for restricted access by authorized personnel.**

29.5.E. **All buildings and storage areas must be constructed on stable foundations and include floor drains that are connected to a sanitary sewer line and sanitary waste treatment/disposal system.**

i. As much as possible, all exterior waste storage areas must have 6in (15.3cm) thick reinforced concrete slabs that have at least a 6in (15.3cm) raised curb to contain spills.
ii. As much as possible, these areas must have a ramped access way to allow easy movement of bins and drums.
iii. As much as possible, all exterior waste storage areas must be covered by roofs to maintain the areas dry on a year round basis.

29.5.F. **As much as possible, the CWMA must incorporate critical utilities for staff use. Examples include electricity, telephones, water supply, and bathroom facilities.**

29.5.G. **The CWMA must have spillage containment equipment.**

29.5.H. **The CWMA must be adequately lighted and ventilated.**

29.5.I. **The space within the CWMA dedicated to infectious and pathological waste must have sealed or tiled floors and walls to allow easy disinfection.**

i. If possible, the space within the central waste collection area dedicated to infectious and pathological waste must be connected to a special sewage system for infectious hospital wastewater.

Clinics

As the waste generation in most Health Clinics is comparably small, the requirements for a Clinic Waste Management Area (WMA) are lower than what would be required to support a county Hospital or large regional Health Center. However, a small WMA is required to properly manage and dispose of medical and solid wastes in a safe manner. As a rule, hazardous and chemical wastes should not be disposed of at a small healthcare facility; however, this waste does need to be properly stored for future transport and off-site disposal.

29.5.J. **Every clinic must have a designated WMA for waste treatment and disposal systems.**

i. The WMA for a health clinic must include the following core elements:
   - Storage for infectious wastes
   - An interim waste storage vault for sharps, chemical, hazardous and pharmaceutical wastes
   - Storage for recycled wastes
   - An area for an on-site incinerator
   - An area for ash pits
   - An area for small waste pits

- An area for placenta pits
- An area for cleaning and maintenance
- A water supply for cleaning and wash basin purposes
- A supply of cleaning equipment, protective clothing and waste bags
- An administrative office and workshop (optional)

29.5.K. The WMA must be located at least 500ft (152.4m) away from main healthcare and treatment facilities.

i. Refer to Standard 9.2.F for further WMA siting requirements.

29.5.L. The WMA must have good vehicle and pedestrian access to facilitate collection and transport of waste and the delivery of waste management equipment and supplies.

i. The access path must be at least 6ft-8ft (1.58m-2.4m) wide.

29.5.M. The WMA must be enclosed in a secure and locked area for restricted access by authorized personnel.

29.5.N. All buildings and storage areas must be constructed on stable foundations and include floor drains that are connected to a sanitary sewer line and sanitary waste treatment/disposal system.

i. As much as possible, all exterior waste storage areas must have 6in (15.3cm) thick reinforced concrete slabs that have at least a 6in (15.3cm) raised curb to contain spills.
ii. These areas must have a ramped access way to allow easy movement of bins and drums.
iii. As much as possible, all exterior waste storage areas must be covered by roofs to maintain the areas dry on a year round basis.

29.5.O. As much as possible, the WMA must include critical utilities for staff use. Examples include electricity, water supply, and bathroom facilities.

29.5.P. The WMA must have spillage containment equipment.

29.5.Q. The WMA must have be adequately lighted and ventilated.

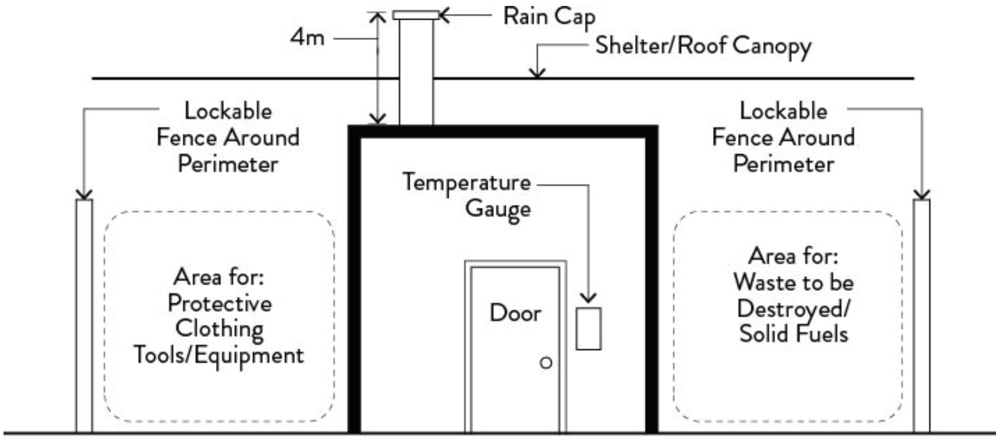
29.5.R. The space within the WMA dedicated to infectious waste must have floors and walls sealed or tiled to allow easy disinfection.

i. If possible, the space within the central waste collection area dedicated to infectious and pathological waste must be connected to a special sewage system for infectious Hospital wastewater.

29.6 Incinerators

Incineration is a high-temperature dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and results in a very significant reduction of waste volume and weight. This process is usually selected to treat wastes that cannot be recycled, reused, or disposed of in a landfill site. The combustion of organic compounds produces mainly gaseous emissions, including steam, carbon dioxide, nitrogen oxides, and certain toxic substances (e.g. metals, halogenic acids), and particulate matter, plus solid residues in the form of ashes. If the conditions of combustion are not properly controlled, toxic carbon monoxide will also be produced. The ash and wastewater produced by the process can also contain toxic compounds, which have to be treated to avoid adverse effects on health and the environment.

Figure 29.d. Example Incinerator



29.6.A. **Incinerators must be appropriately sized to accommodate the anticipated waste generated by the facility.** (Refer to Sections 29.1 and 29.2 to assist with estimating the type and generation of waste produced)

29.6.B. **Incinerators must be located at least 150ft (45.7m) from water sources and at least 200ft (61m) away from other incinerators and occupied or inhabited buildings.** (Refer to Section 9.3 for medical waste site planning standards.)

i. The prevailing winds at the incinerator location must blow in a direction away from occupied buildings.

ii. There must be no horticulture or leaf crops within 1000ft (300m) of the incinerator in the direction of the prevailing winds.

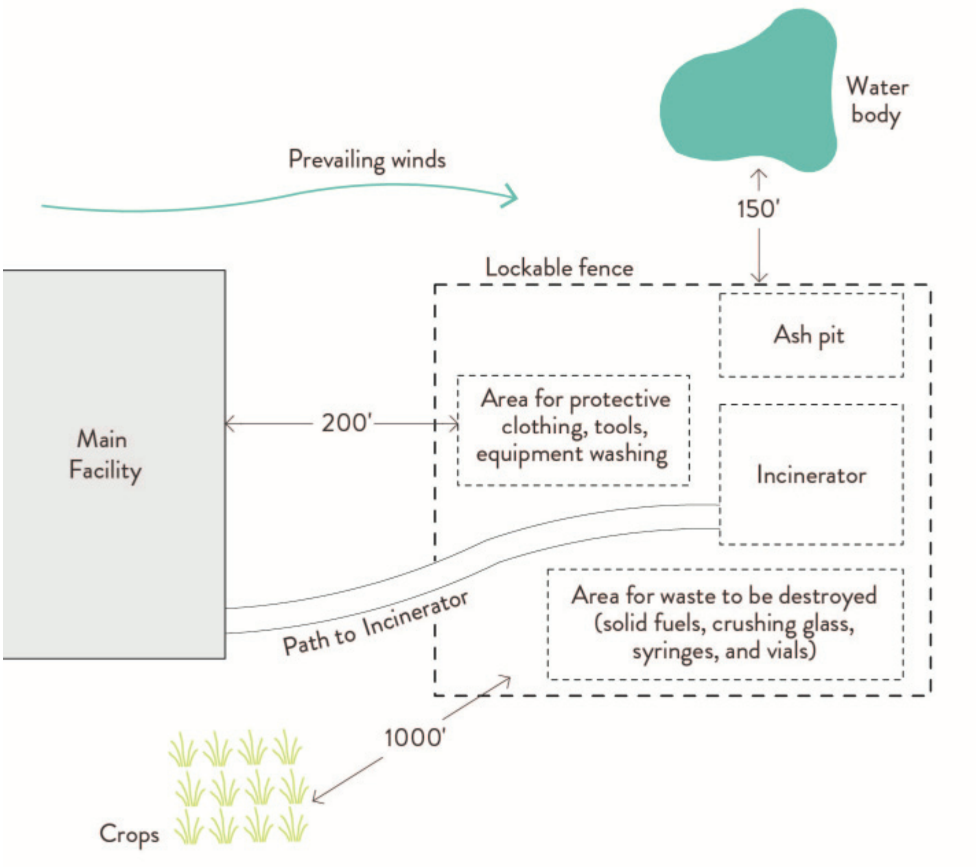
iii. There must be no regular public passage within the immediate proximity of the incinerator.

29.6.C. **The incinerator area must be accessible from the main building complex by a safe and stable path of travel so that waste can be delivered to the incinerator using a handcart or other mode of wheeled transport.**

29.6.D. **The incinerator site must be fenced with a lockable gate to restrict access.**

29.6.E. **The incinerator site must include an ash pit, arrangement for destruction of vials and glass syringes, a washing facility for reusable items and a secure storage facility for waste.**

Figure 29.e. Incinerator area



29.6.F. **The incinerator area must have provisions for water for both fire protection and washing down the area.**

i. If possible, the water supply (spigot) must be mounted above a concrete pad with either a gutter for runoff and percolation into the ground or connection to a drainage channel.

29.6.G. **Incinerators must be installed on a solid reinforced concrete foundation that can resist the final weight of the incinerator (about 2,200lbs. or 1,000kg).**

i. The foundations dimensions must be at least: 6.5ft x 6.5ft x 6in, (2m x 2m x 15cm) which includes immediately a small temporary storage area for the waste bins.

ii. For big healthcare facilities, a bigger platform may need to be constructed.

29.6.H. **A concrete apron must be constructed around the incinerator that includes a drain that is connected to a sanitary treatment/disposal system.**

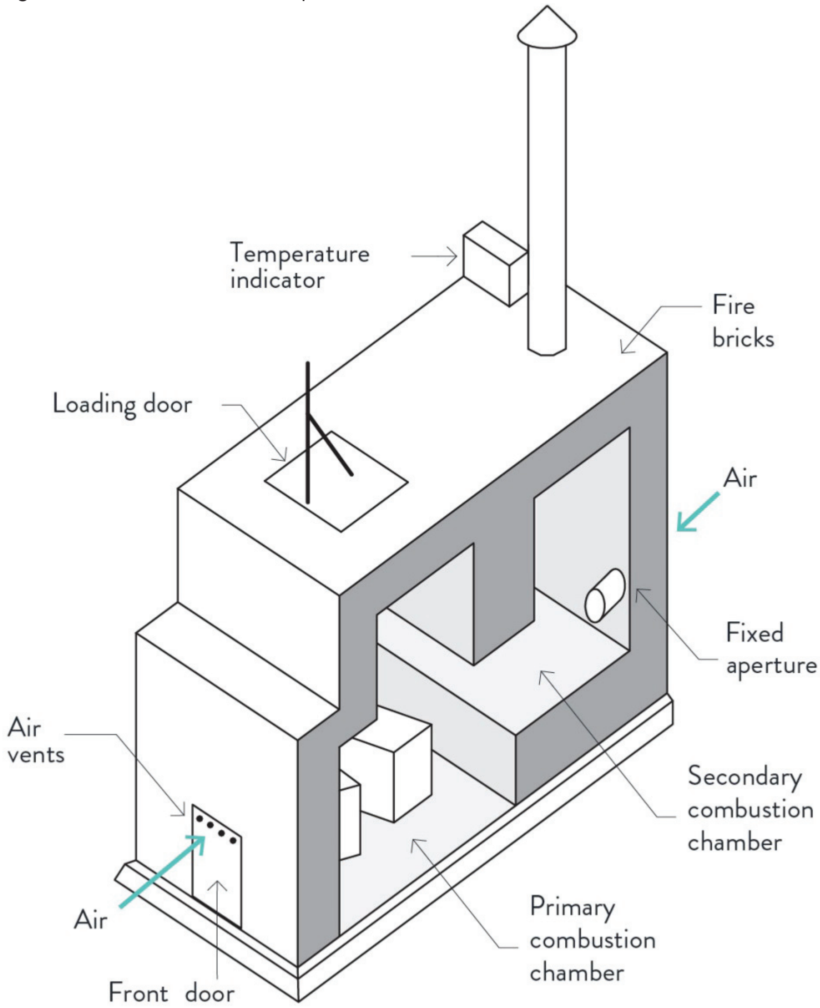
29.6.I. **The incinerator must be constructed of corrosion-resistant materials (all components stainless steel or case iron).**

29.6.J. **Incinerators must have a minimum of two burning chambers each with independent air intakes: one to combust solids and one to combust gases.**

i. The volume of the combustion chamber must be sufficient to receive the physical bulk of the waste and provide adequate gas residence time.

ii. For simple incinerators without burners and fans, however, it is better to have 2 small facilities than 1 large one or to increase the length of the cycles (loading more batches).

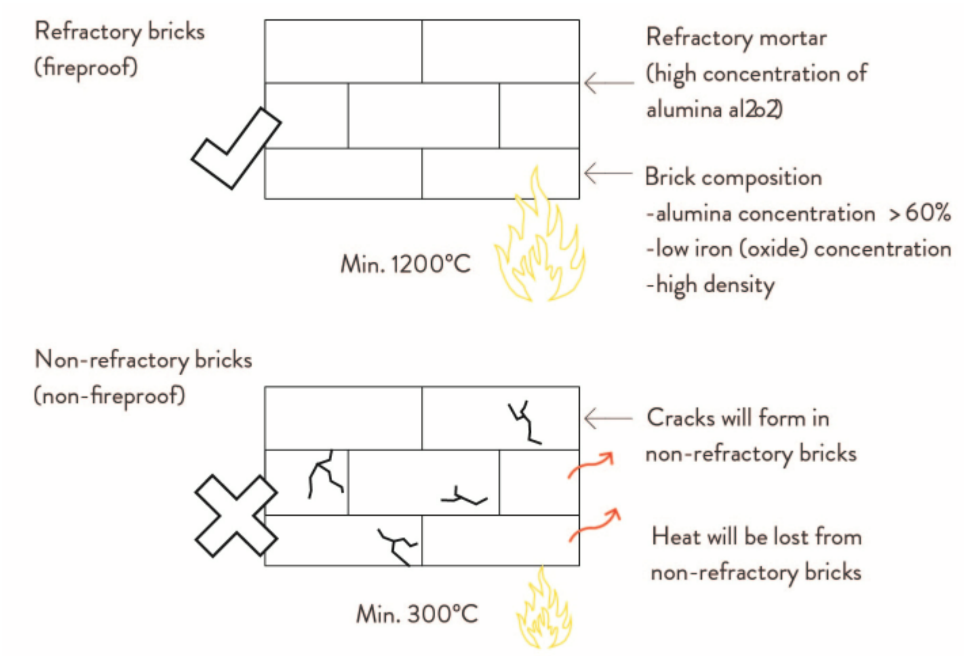
Figure 29.f. Incinerator components



29.6.K. The combustion chambers must be lined with fireproof refractory bricks that can stand temperatures up to 1200 °C and above, and have good isolating and heat buffer characteristics.

i. Normal bricks must not be used, as they will only resist temperatures up to 300 °C. Over time, normal bricks will crack, severely diminishing the operation of the incinerator.
ii. Ideally, the refractory brick composition must contain an alumina concentration of about 60% or above, an as low as possible iron (oxide) concentration and be high density.
iii. Refractory bricks must be jointed together with fireproof refractory mortar.
iv. Ideally, the refractory mortar must contain a high concentration of alumina AL203. Aludrite50 is the mixture recommended.
v. The incinerator must have joints that are as narrow as possible; in practice only 1/8in (3mm) thick.

Figure 29.g. Refractory vs. Non-refractory bricks



29.6.L. The incinerator must have an external hull / wall covering the refractory bricks.

i. A layer of vermiculite concrete must be applied between the refractory bricks and the external hull/ wall.

29.6.M. The incinerator must go through a curing process before initial use to prevent irreparable cracks.

i. Follow the following process:
   - Place red-hot charcoal or wood into the incinerator's ashtray.
   - Slide the ashtray inside the incinerator to heat the latter up slowly.
   - This process should be repeated several times, depending on the humidity of the incinerator.

29.6.N. The incinerator must receive sufficient oxygen supply.

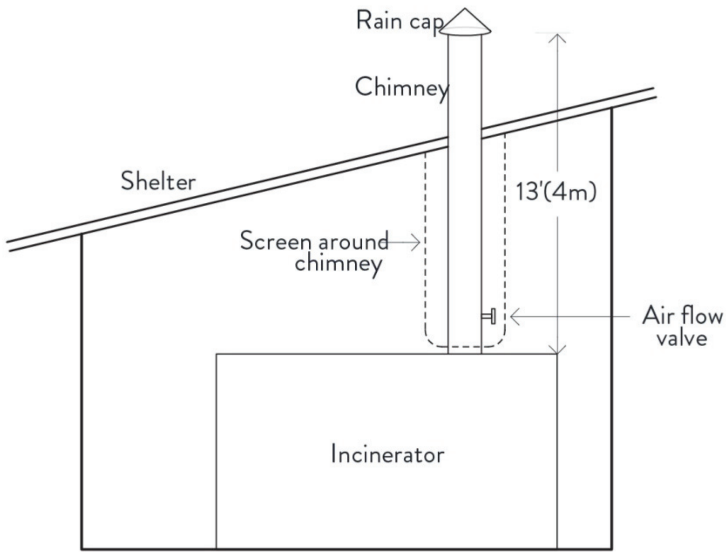
i. Air inlets must be of right size and location to allow a good mixture of air (oxygen) with the waste (gasses). (Refer to Figure 29.f.)
ii. Draught of the chimney should be away from obstacles like buildings and trees.

29.6.O. Incinerators must have a temperature or visual indicator to display heat status of equipment. (Refer to Figure 29.f.)

29.6.P. Provisions must be developed for a safe and effective chimney.

i. The chimney must be made out of stainless steel pipe at least 1/8in (3mm) thick and 13ft (4m) long.
ii. A rain cap must be installed on the chimney.
iii. Seals must not be used as they will melt or crack when the metal chimney expands due to heat.
iv. The bottom part of the chimney must be protected by a screen to avoid burn injuries.
v. An airflow valve must be installed in the chimney to buffer the residence time of gas in the secondary chimney when different waste types are loaded.

Figure 29.h. Chimney requirements



29.6.Q. The incinerator must be sheltered/roofed in a protective enclosure to prevent access by unauthorized persons and to protect the incineration equipment.

i. The roof must be single or double sloped. The former is easier to build and drains rainwater away from the waste zone.
ii. The shelter must be well ventilated and the stack emissions clear of the enclosure so that the operator is not exposed to fumes when the incinerator is in use.
iii. The shelter must be made of non-combustible materials, such as iron sheeting and poles.
iv. The shelter must be robust and corrosion resistant, and its design life is at least equivalent to the expected life of the incinerator.
v. The shelter must be high enough for the operator to be able to walk all around the incinerator without having to duck.
vi. Where possible, a channel must be provided to divert the rainwater away from the chimney.
vii. Where possible, a rainwater collection system must be installed on the roof. Collected rainwater can be used to clean and disinfect the waste bins.

29.6.R. The incinerator shelter must include adequate space for equipment operation and materials storage.

i. There must be space within the shelter to store the operator's protective clothing, tools and equipment required to operate the system.
ii. There must be sufficient space to conveniently store waste to be destroyed, as well as load and operate the incinerator.
iii. There must be storage space for solid fuels or a storage reservoir for fuel sufficient for at least one week of operation. This is best located within the incinerator enclosure to ensure adequate security.
iv. There must be provision of space within the shelter for equipment to crush glass syringes and vials.
v. The shelter must have a provision for waste to be deposited without allowing the waste handler to enter the shelter.
vi. There must be a provision for an emergency exit.

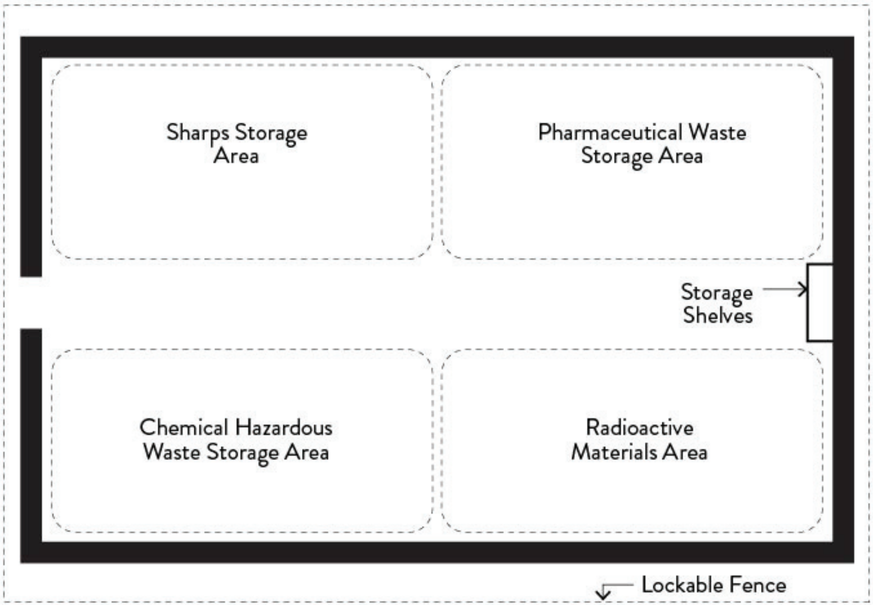
29.6.S. Incinerators must be operated by trained personnel, and have a maintenance and repair schedule.

i. The lifecycle of an auto combustible system is approximately 5-years and fuel assisted system should have a lifecycle of 10-year.

29.7 Interim Waste Storage Vaults

Many Health Centers and clinics will require interim waste storage vaults for sharps, pharmaceuticals, chemical hazardous waste and radioactive materials. These vaults are meant as temporary storage until on-site treatment becomes available or the waste is transported to an offsite treatment facility. These storage vaults provide a safe and secure method to temporarily store these wastes to prevent scavenging and access to these potentially infectious and dangerous materials.

Figure 29.i. Example interim waste storage vault



29.7.A. The vault must be constructed in a manner so that it can be easily filled and emptied.

i. Interim waste storage vaults must conform to the following minimum dimensions: 10ft x 16ft, with a height of 8ft (3m x 5m, with a height of 2.4m). However, the dimensions of this room will depend on facility type and the amount of waste being generated.

ii. The door must be suitable to the size of the waste containers.

29.7.B. The vault must be constructed on stable and compacted native soil.

29.7.C. The floor of the waste storage vault must be constructed of concrete and sealed to be waterproof.

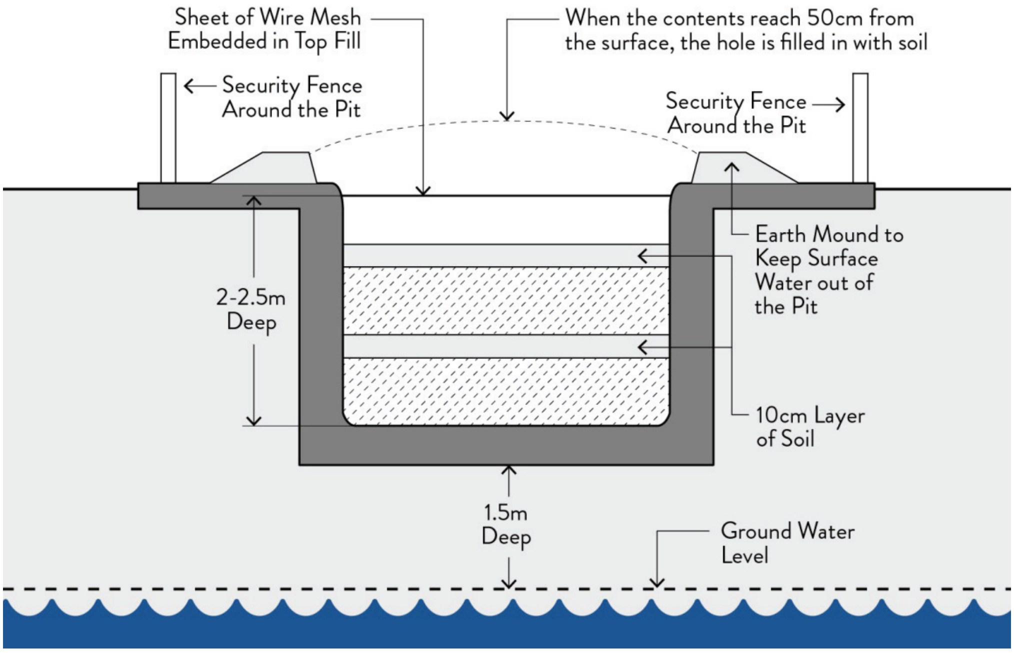
29.7.D. A 4in (2.5cm) thick reinforced concrete apron must be installed around the vault to allow for good access and cleaning of the vault.

29.7.E. Access to the vault must be restricted to authorized personnel only by having a lockable door (with ventilation) and placing the vault in a fenced and restricted area.

29.8 Solid Waste Pits

In healthcare facilities with minimal programs for waste management, particularly in rural locations, the safe burial of waste of healthcare facilities may be the only viable option available.

Figure 29.j. Solid Waste Pit Layout



29.8.A. Access to waste pits must be restricted to authorized personnel only by placing the pits in a fenced and restricted area.

29.8.B. The bottom of the waste pit must be lined with a material of low permeability, such as clay, to prevent pollution of any shallow groundwater that may subsequently reach nearby wells.

29.8.C. The burial site must be managed as a landfill, with each layer of waste being covered with a layer of earth (3-6in deep, or 7.6-15.3cm) to minimize odors, and to prevent the proliferation of rodents and insects.

i. If coverage with soil is not possible, lime may be deposited over the waste.

29.8.D. The bottom of the pit must be at least 5ft (1.5m) above the highest anticipated groundwater level.

29.8.E. The waste pit must be approximately 6-8ft (2-2.4m) deep and filled to a depth of 4-5ft (1.2-1.5m) before final cover is place over the pit.

29.8.F. Final cover placed over the pit must be compacted to at least 90% relative compaction and must be crowned slightly mounded at the center of the pit in a manner so that water does not pond over the pit and flows away from the pit.

i. The exposed soil over the pit must be seeded to allow vegetation to stabilize the soil over the pit.

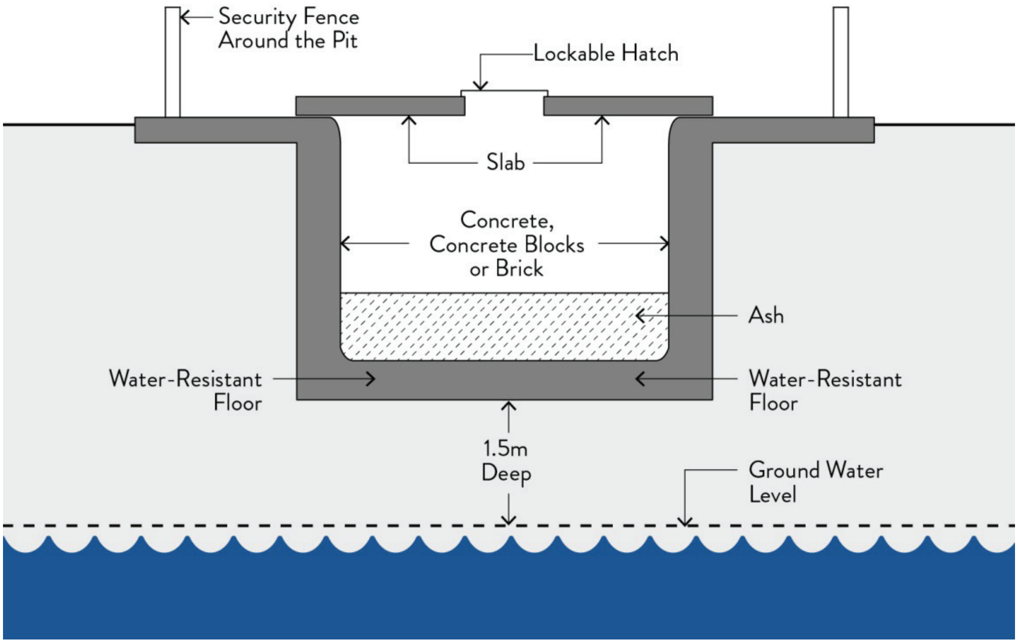
Waste Pit Usage

It should be kept in mind that safe on-site burial is practical only for relatively limited periods, say 1–2 years, and for relatively small quantities of waste, say up to 5 or 10 tons (4,500 to 9,000 kg) in total. Where these conditions are exceeded, a longer-term solution, probably involving disposal at a municipal solid waste landfill, will need to be found.

29.9 Placenta Pits

In many communities, burying placentas is an important ritual and one option for disposal. If it is done safely, burial can protect the community from pathogens while respecting cultural norms and religious traditions.

Figure 29.k. Placenta pit layout[8]



29.9.A. Once a pit is filled, it must be closed, marked and location recorded.

29.9.B. The site of the pits must be as far away as possible from publicly accessible areas and from hygienically critically areas (e.g. water wells, kitchens).

29.9.C. Placenta pits must not be built close to buildings due to possible odors.

29.9.D. The bottom of the pit must be at least 5ft (1.5m) above the highest anticipated groundwater level.

29.9.E. The top 20in (50.8cm) or more of the pit must be reinforced with concrete to prevent surface water infiltration.

29.9.F. The base of the pit must be made from concrete to stabilize the structure and to slow the downward movement of liquid towards the water table.

i. Placenta pits can also be constructed from a standard concrete ring with a diameter of about 3ft (91.4cm).

29.9.G. The top slab must be above ground level and made from watertight concrete to prevent surface water infiltration.

29.9.H. The top must be closed by a lockable hatch and a vent pipe installed to ensure that the generated gases can escape and air can get in.

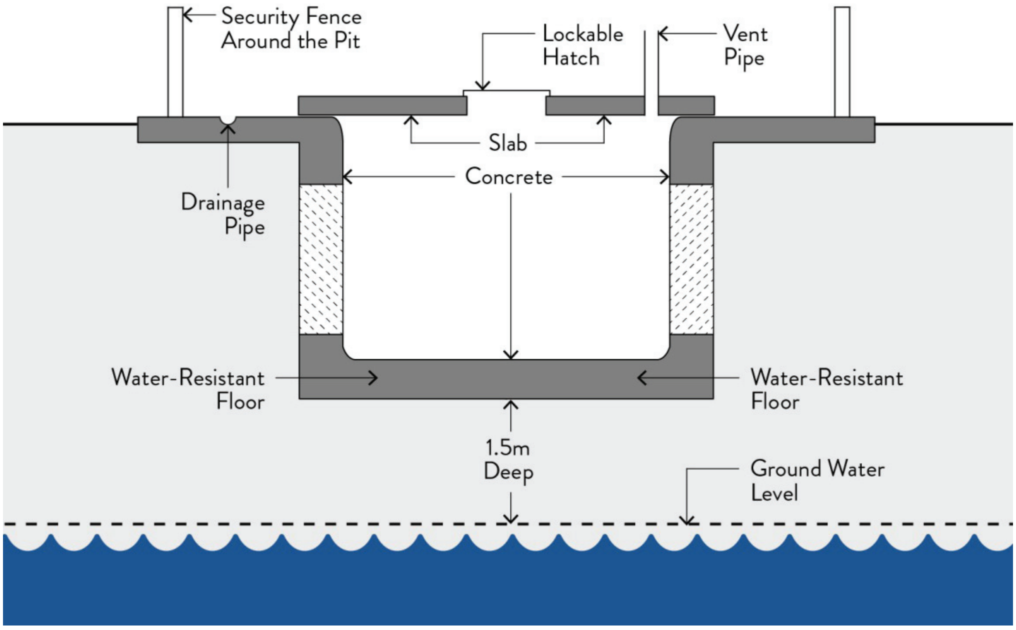
29.9.I. Where soil is particularly sandy, extra precautions must be taken to protect the water table and to prevent the pit from collapsing.

i. The sides should be reinforced with bricks, laid with gaps between them so that liquids can escape.

29.10 Ash/Sharp Pits

Any ash produced from the waste incineration process must be removed from the incinerator and disposed of safely. Ash pits must be constructed in close proximity to incinerators to encourage safe and expedient disposal.

Figure 29.I. Ash pit layout



29.10.A. All sites using incineration must be equipped with an ash pit that has sufficient capacity to store ash for a period of at least 5 years.

29.10.B. The bottom of the pit must be at least 5ft (1.5m) above the highest anticipated groundwater level.

29.10.C. The pit must be positioned to prevent risk of flooding.

29.10.D. The pit must be constructed of concrete, concrete blocks, or brick, with a water-resistant floor to ensure the pit will not collapse.

29.10.E. There must be provisional access to the pit for purposes of leveling or removal of accumulated waste and subsequent transfer to a municipal landfill.

29.10.F. The pit must be protected from access by unauthorized persons.

29.10.G. The pit must be located in the immediate proximity of the incinerator to ensure the convenient transfer of ash.

PLUMBING & MEDICAL GAS

CONTENTS

IMPACT

If designed and installed correctly, plumbing and gas systems will support the efficient and safe practice of medical procedures, hygiene and infection control, and life support. If designed and installed poorly, they may compromise the cleanliness and safety of these practices, endanger patients, and potentially add significant maintenance or repair costs over the lifespan of the facility.

PRIMARY USERS

Infrastructure Unit

Architects & Designers

Mechanical & Plumbing Engineers

Contractors

GUIDELINES FOR USE

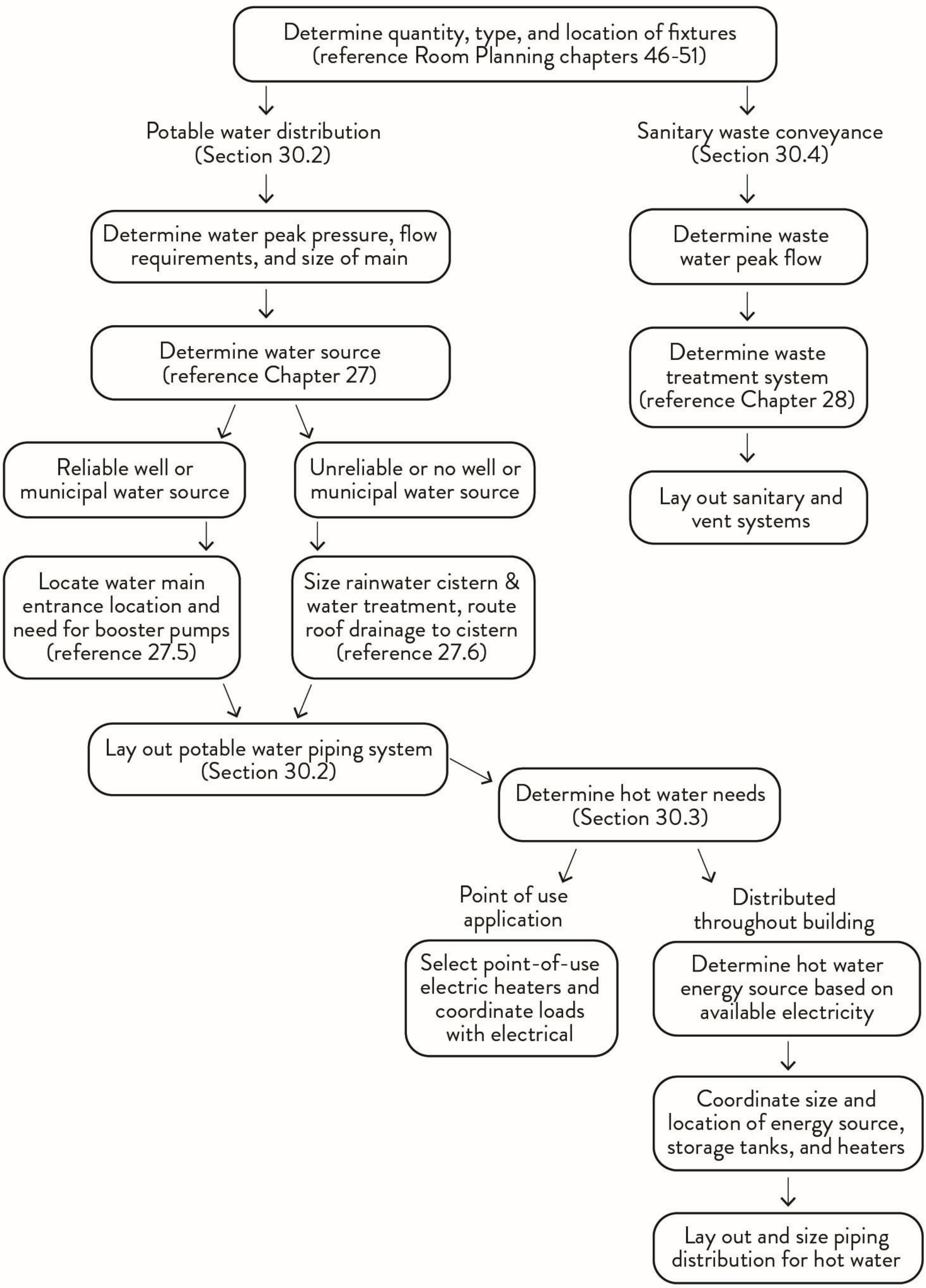
The design of plumbing and medical gas systems must take into account the other infrastructural systems available at the facility (including water and waste management systems) as well as the medical services offered at the facility. They must also be coordinated with the civil, architecture, structural, mechanical, and electrical designs to ensure that adequate provisions have been made for utility capacities, clearances, and space requirements of piping systems.

30 Plumbing

Water is especially important in healthcare settings because patients are often immune-deficient and extremely susceptible to water-borne pathogens. Patients may be exposed to water-borne pathogens by ingesting contaminated water, or by inhaling aerosolized water from flushing toilets, shower heads, or improperly-designed sink faucets and drains. With that in mind, the most important plumbing standards and guidelines are those aimed at prevention of cross-connection between potable water systems with any other building system, and those aimed at prescribing distribution and fixture designs that do not promote aerosolization of water or waste. This section shall address plumbing standards and guidelines necessary to understand and design appropriate internal water, sanitary waste, and storm drainage conveyance systems within healthcare facilities.

Definitions

- ASTM: American Society for Testing and Materials
- Air gap: The distance between a water outlet and a sink, tub, or other sanitary drain receptor's maximum water level.
- Backflow: The undesirable reverse flow of a liquid, gas or solid into potable water supply.
- Back-siphonage: Occurs when higher pressure fluids move to an area of lower pressure.
- Cistern: Waterproof receptacle for holding potable water.
- CPVC: Chlorinated polyvinyl chloride.
- Instantaneous Water Heater: An electric water heater that has little or no storage.
- GPM: Gallon/s per minute as a measure of flow rate.
- IPC: International Plumbing Code.
- ISO: International Standards Organization
- Flush Valve Toilet (also referred to as flushometer, or blowout toilets): A tankless toilet with a water-diverter that uses an inline handle to flush toilets or urinals. It uses water pressure from the water supply system.
- Flush Tank Toilet: A toilet with a water tank mounted on or near it. It uses water pressure from the weight of water in the raised tank to flush toilets or urinals.
- Fixture unit (FU): Equal to one cubic foot of water drained in a 1 1/4in pipe over one minute. A Fixture Unit is not a flow rate unit but a design factor. It is a value is assigned to each fixture based on its rate of water use, its likely use duration, and the average use frequency.
- Municipal Water: Water that is treated by a municipality to an established quality level and distributed by the municipality through a piping network to users.
- Potable Water: Water suitable for human consumption.
- Pressure Balancing Mixing Valve: A device used to mix hot and cold water to a desired temperature such as a shower valve.
- PSI: Pounds per square inch.
- PVC: Polyvinyl chloride is used extensively in sewage pipe due to its low cost, chemical resistance, and ease of jointing.
- Vacuum Breaker: A device used on a water outlet.


Determine quantity, type, and location of fixtures (reference Room Planning chapters 46-51)
Potable water distribution (Section 30.2)
Sanitary waste conveyance (Section 30.4)
Determine water peak pressure, flow requirements, and size of main
Determine waste water peak flow
Determine water source (reference Chapter 27)
Determine waste treatment system (reference Chapter 28)
Reliable well or municipal water source
Unreliable or no well or municipal water source
Lay out sanitary and vent systems
Locate water main entrance location and need for booster pumps (reference 27.5)
Size rainwater cistern & water treatment, route roof drainage to cistern (reference 27.6)
Lay out potable water piping system (Section 30.2)
Determine hot water needs (Section 30.3)
Point of use application
Distributed throughout building
Select point-of-use electric heaters and coordinate loads with electrical
Determine hot water energy source based on available electricity
Coordinate size and location of energy source, storage tanks, and heaters
Lay out and size piping distribution for hot water

30.1 Building Plumbing Systems

The primary requirements for plumbing systems are to distribute potable water to fixtures such as toilets and hand washing sinks at a functional pressure and temperature without creating conditions that can result in contamination of the water in the piping. Once the water is used at these fixtures, the used water and waste must be drained out of the building via a network of sanitary drainage and vent pipes that safely carry the waste without creating conditions that result in contamination of the built environment from overflowing fixtures, leaking pipes, or sewer gases.

30.1.A. **Building water must meet the water quality requirements defined in 27.2.B.**

i. Periodic water quality testing of the site water cistern or municipal water supply must include testing water samples from faucets on each floor of the building. Further treatment may be required.

30.1.B. **Water systems must be designed and installed to maintain adequate pressure to all fixtures.** (Refer to Standard 30.2.C.)

30.1.C. **Water distribution systems must be designed and installed in a way that discourages growth of pathogens within the system.** (Refer to Standards 30.2.J-K.)

30.1.D. **Plumbing water and waste systems must be designed and installed in a way that positively prevents cross-connection between the potable water distribution system and the waste conveyance system.** (Refer to 30.2.K.)

30.1.E. **Waste conveyance systems must be designed and installed so they will consistently convey waste out of the building – ideally by gravity via sloped piping to site sewer systems – and prevent sewer gases from entering into the building.** (Refer to Section 30.4)

30.2 Potable Cold Water

Potable cold water systems consist of a network of piping extending from the site potable water source, into the building, and connecting to plumbing fixtures. Potable water must be clean enough to be safely ingested as it is intended to be used for hand washing, bathing, food preparation and utensil cleaning. For most of these functions, water may be unheated, or "cold".

30.2.A. **All facilities designed with internal toilets, bathing, hand washing, and other fixtures requiring water and associated waste utilities must be provided with piped potable water conveyance systems.**

i. As much as possible, minimize piping buried below floor slabs because leaks can go undetected and water can undermine foundations.

Building Water Conveyance Systems

A typical potable water distribution system connects to the on-site water source with a pipe and extends into the building either below ground or above ground, depending on the source.

Distribution mains are typically run in ceiling spaces and provide branches with drops to connect to fixtures. For two-story buildings a single distribution network in the lower floor's ceiling space may feed up and down to serve fixture on both floors.

30.2.B. **Materials for pipe, pipe fittings, valves, faucets and accessories in contact with potable water must be resistant to corrosion, capable of handling the system pressure and temperature without leakage or deformation, and must not leach contaminants into the water at harmful levels.**

i. Availability of materials varies from region to region but it is extremely important to select pipe and fitting materials that are manufactured and certified as suitable for potable water. The designer should insist on receiving material samples and proof of such certification before allowing installation.

Table 30.a. Suitable Water Distribution Piping Materials (IPC Table 605.4)

Material	Standard
Brass pipe	ASTM B 43
Chlorinated polyvinyl chloride (CPVC) plastic pipe and tubing	ASTM D 2846; ASTM F 441; ASTM F 442; CSA B137.6
Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing (Type K, WK, L, WL, M or WM)	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 447
Cross-linked polyethylene (PEX) plastic tubing	ASTM F 876; ASTM F 877; CSA B 137.5
Cross-linked polyethylene/ aluminum/ cross-linked polyethylene (PEX-AL-PEX) pipe	ASTM F 1281; ASTM f 2262; CSA B 137.10M
Ductile iron pipe	AWWA C151/A21.51; AWWA C115/A21.5
Galvanized steel pipe	ASTM A 53
Polyethylene/aluminum/polyethylene (PE-AL-PE) composite pipe	ASTM F 1282
Polyethylene of raised temperature (PE-RT) plastic tubing	ASTM F 2769
Polypropylene (PP) plastic pipe or tubing	ASTM F 2389; CSA B137.11
Stainless steel pipe (Type 304/304L)	ASTM A 312: ASTMA A 778
Stainless steel pipe (Type 316/316L)	ASTM A 312: ASTMA A 778

[a] *See the World Health Organization's publication "Health Aspects of Plumbing," Part 10 for more detailed descriptions of suitable materials.*

30.2.C. **Potable water systems must deliver an adequate volume of water to all fixtures at a minimum pressure of 20psi and a maximum pressure of 70psi. If tankless, "flush-valve" blow-out or siphon-jet toilets are used, minimum pressure must be based on fixture manufacturer's requirements.**

i. Water pressure will be primarily determined by site water systems as described in Chapter 27. The designer of the building's internal water distribution system must determine the pressure and flow requirements and coordinate these with the design of the site water systems.

ii. The designer must total all of the pressure losses based on how many feet the water must be lifted to get to the highest fixture, and all of the pressure losses due to friction in the piping network experienced during peak flow rates – as well as pressure losses from valves and equipment.

Pipe sizing

Peak flow rates are not determined by summing the peak flow rate of each fixture because it is understood that fixtures are not in use simultaneously. A rational method of assessing the peak flow rate for multiple fixtures uses the fixture unit concept. A fixture unit (FU) Value is assigned to each fixture based on its rate of water use, its likely use duration, and the average use frequency. The table below shows fixture unit values for common fixtures.

Table 30.b. Fixture Unit Values for Common Fixtures

Fixture types	Domestic Water fixture units
Flush tank type toilet	2.5
Lavatory or sink	1.5
Shower	2

The following chart offers a rule of thumb for sizing pipes based on fixture units:

Table 30.c. Pipe sizing Recommendations based on Fixture Units

Fixture units	Minimum pipe size
0 - 5	¾in (1.9cm)
6-10	1in (2.5cm)
11-50	1-1/2in (3.8cm)
51-120	2in (5cm)
121-400	3in (7.6cm)

In some cases electric motor-driven pressure booster pumps may be needed in the building to supplement the available pressure.

30.2.D. **Design system to provide water at useable flow rates for fixtures.** (Refer to Table 30.d.)

Table 30.d. Usable Flow Rates (IPC Table 604.3)

Fixture Supply Outlet Serving	Flow Rate (gpm)	Flow Pressure (psi)
Bathtub, balanced-pressure, thermostatic or combination balanced-pressure/thermo-static mixing valve	4	20
Bidet, thermostatic mixing valve	2	20
Combination fixture	4	8
Dishwasher, residential	2.75	8
Drinking fountain	0.75	8
Laundry tray	4	8
Lavatory	2	8
Shower	3	8
Shower, balanced-pressure, thermostatic or combination balanced-pressure/thermostatic mixing valve	3	20
Sillcock, hose bibb	5	8
Sink, residential	2.5	8
Urinal, valve	12	25
Water closet, blow out, flushometer valve	25	45
Water closet, flushometer tank	1.6	20
Water closet, siphonic, flushometer valve	25	35
Water closet, tank, close coupled	3	20
Water closet, tank, one piece	6	20

[a] *For SI: 1 pound per square inch = 6.895 kPa*
[b] *1 gallon per minute = 3.785 L/m*

30.2.E. **Minimum water supply connection sizes for typical fixtures must be used to allow water to flow at a useable rate without excessive noise.**

Table 30.e. Typical water supply connection sizes (IPC Table 604.3)

Fixture Type	Minimum Pipe Size
Bathtubs	1/2in (1.3cm)
Bidet	3/8in (1cm)
Combination sink and tray	1/2in (1.3cm)
Dishwasher, domestic[2]	1/2in (1.3cm)
Drinking fountain	3/8in (1cm)
Hose bibbs	1/2in (1.3cm)
Kitchen sink[2]	1/2in (1.3cm)
Laundry, 1, 2 or 3 compartments[2]	1/2in (1.3cm)
Lavatory	3/8in (1cm)
Shower, single head[2]	1/2in (1.3cm)
Sinks, flushing rim	3/4in (1.9cm)
Sinks, service	1/2in (1.3cm)
Urinal, flush tank	1/2in (1.3cm)
Urinal, flushometer valve	3/4in (1.9cm)
Wall hydrant	1/2in (1.3cm)
Water closet, flush tank	3/8in (1cm)
Water closet, flushometer valve	1in (2.5cm)
Water closet, flushometer tank	3/8in (1cm)
Water closet, one piece[2]	1/2in (1.3cm)

[a]For SI: 1in = 25.4mm, 1 ft = 304.8mm.
1 pound per square inch = 6.895kPa.
[b]Where the developed length of the distribution line is 60ft or less, and the available pressure at the meter is 35psi or greater, the minimum size of an individual distribution line supplied from a manifold and installed as part of a parallel water distribution system shall be one nominal tube size smaller than the sizes indicated.

30.2.F. **Shut off valves must be provided to allow maintenance of the system without loss of water supply to all fixtures.**

i. Provide a main shutoff valve immediately after the main enters the building.
ii. Provide shut off valves to branches off the main to groups of fixtures or branches off the main to individual fixtures.
iii. Provide angle-stop shut off valves at water service to each fixture.

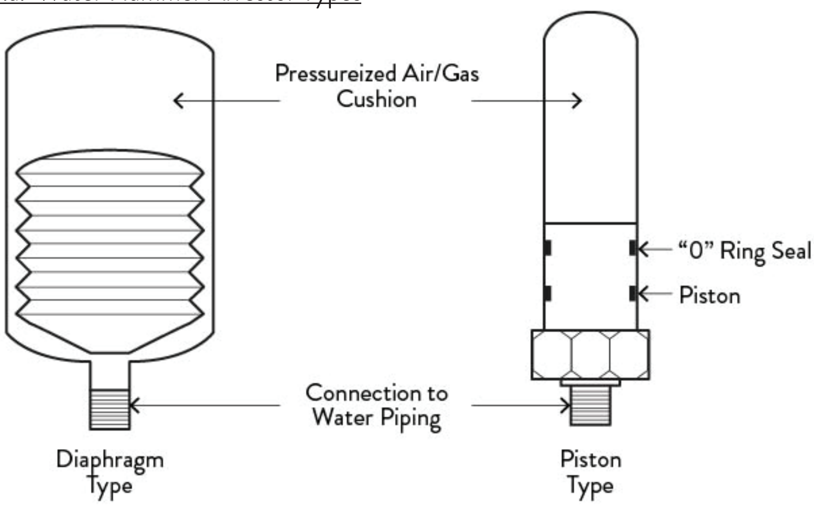
30.2.G. **Piping systems must include protection against water hammer which can damage piping and cause leaks.**

i. Water piping serving groups of two or more plumbing fixtures (such as a toilet, lavatory, or shower fixture group) should be designed with a sealed manufactured water hammer arrestor.

ii. These must be listed by the manufacturer as suitable for potable water, and should be maintenance-free types.

iii. Prioritize the use of simple 8in (20.3cm) tall capped air chambers in lieu of manufactured sealed chambers, which have been known to be ineffective in the long term as they eventually become water logged.

Figure 30.a. Water Hammer Arrestor Types



30.2.H. **Potable cold water piping must be insulated to prevent sweating and associated water damage.**

i. Acceptable insulation material must be used. Examples include mineral-fiber, cellular-glass, or closed-cell, sponge-type, or expanded-rubber flexible elastomeric thermal insulation.

ii. Insulation thickness must be ½in (1.3cm) minimum for pipes under 1in diameter and 1in (2.5cm) thick minimum for pipes over 1in (2.5cm) diameter.

30.2.I. **Potable water systems must be pressure tested after installation.**

i. Follow the following steps:
   - Flush piping system free of debris.
   - Fill system with potable water and pressurize to 75psi, or maximum design working pressure of the system. Pressure must be held for a minimum of 15 minutes.
   - For non-plastic piping systems, clean compressed air may be used in lieu of potable water, however water is preferred.

30.2.J. **Disinfect potable water systems after installation following method prescribed for potable water in Standard 27.9.H.**

30.2.K. **The potable water distribution system must prevent cross connection with non-potable water systems.**

i. All plumbing fixtures must ensure a minimum distance between the water outlet and the flood rim, as defined in Table 30.f.

ii. Provide a backflow preventer valve on main water service and any connections of potable water to equipment such as laundry machines, dialysis machines, water treatment equipment, or medical utensil washers.

iii. Provide vacuum breakers or anti-siphon valves on the outlets of any water outlets that can be connected to with a hose. (Refer to Figure 30.b.)

Table 30.f. Minimum Required Air Gaps (IPC 608.15.1)

Fixture	Minimum Air Gap	
	Away from wall[b] in (cm)	Close to wall In (cm)
Lavatories and other fixtures with effective opening not greater than ½in (1.3cm) in diameter	1in (2.5cm)	1-1/2in (3.8cm)
Sink, laundry trays, gooseneck back faucets and other fixtures with effective opening not greater than ¾in (1.9cm) diameter	1-1/2in (3.8cm)	2 1/2" (6.4cm)
Over-rim bath fillers and other fixtures with effective opening not greater than 1in (2.5cm) in diameter	2in (5cm)	3in (7.6cm)
Drinking water fountains, single orifice not greater than 7/16in (1.1cm) in diameter or multiple orifices with a total area of 0.150in^2 (area of circle 7/16in in diameter)	1in (2.5cm)	1-1/2in (3.8cm)
Effective opening greater than 1in (2.5cm)	2X the diameter of the effective opening	3X the diameter of the effective opening

[a]*For SI: 1in = 25.4mm.*

[b]*Applicable where walls or obstructions from the nearest of the spout opening a distance greater than three times the diameter of the effective opening for a single wall, or a distance greater than four times the diameter of the effective opening for two intersecting walls.*

Figure 30.b. Typical required air gaps

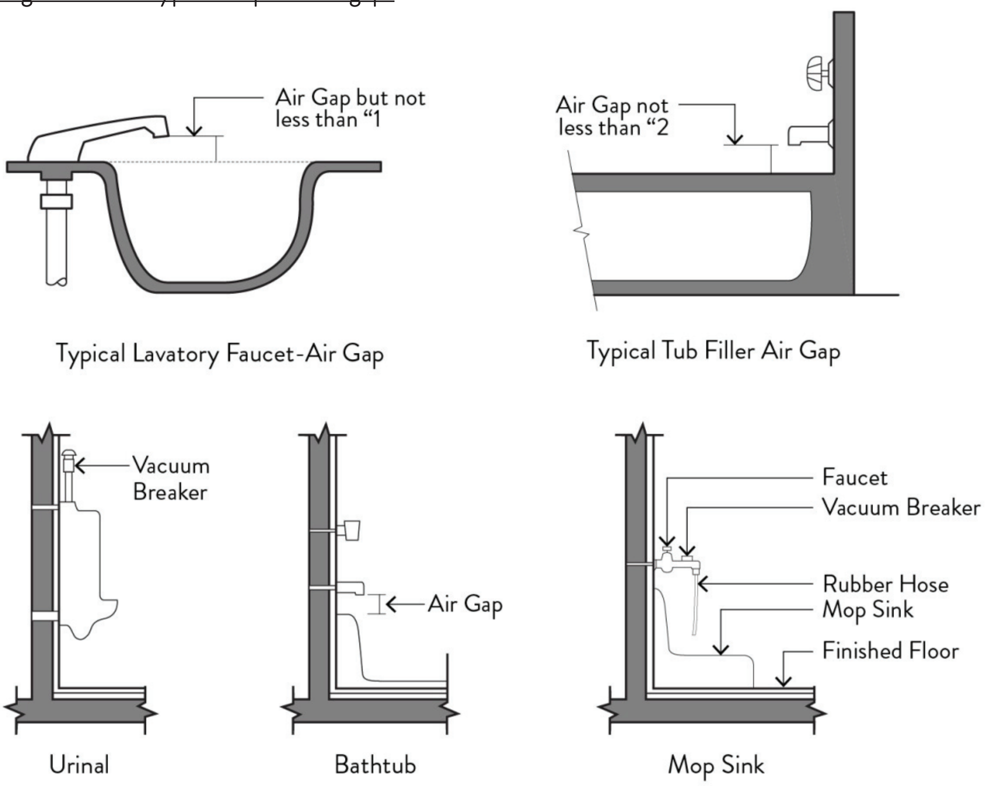
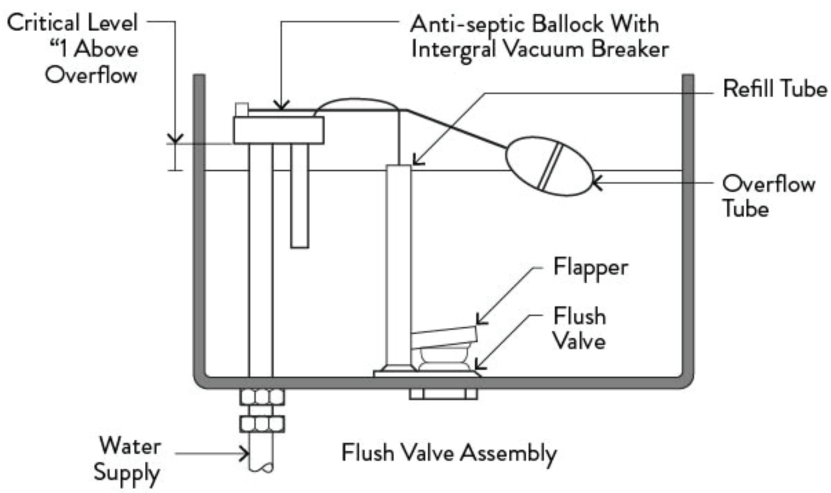


Figure 30.c.   Toilet water tank with back-siphonage protection



30.3 Potable Hot Water

Although potable hot water is not required at any fixture as a standard, some facilities desire hot water (average temperature over 40°C) to be delivered to all or some fixtures used for cooking, bathing, hand washing, medical equipment washing, and/or janitorial fixtures. It is important to note that hot water is not proven to be necessary for washing effectively.1 Hot water systems can be expensive, energy intensive, high-maintenance, and they can encourage growth of pathogens within the system. Therefore, the extent of hot water provisions and type of heating system must be carefully considered and determined by project stakeholders.

30.3.A. Where potable hot water is required by facilities, the source equipment must be suitable for domestic water use and the demand load.

i. Specify source equipment that is third-party certified to be suitable for potable water use.

Potable Hot Water Source Equipment

The source equipment may be designed as point-of-use heaters, or centralized water heating systems utilizing single or multiple storage tanks and piping networks distributing water to fixtures, and pumps to circulate water through the heater.

Central Storage Systems

A benefit of central storage systems is the ability to use a small amount of energy to heat water over a long period of time rather than using a large amount of energy to heat at the rate of use. Disadvantages to central storage systems include single point of failure, and inefficiencies due to heat loss through the tank and piping network. Options for centralized source equipment include:

- Solar water heating systems with storage tank, roof or site – mounted solar panels, a pump to circulate water through the tank and panels, and a control panel to automatically control water flow to the panels. These are complicated systems that cannot be pieced together by the designer but rather should be discussed with a reputable vender and specified as a complete package.

- Electric storage type water heaters – these are storage tanks with internal electrical heating elements.
- Natural gas or propane-fired storage type water heaters - these are not commonly used often enough in Liberia to warrant development of guidelines if a gas-fired heater is desired.

Point-of-use Water Heaters

These may be best if only a few fixtures are served. Advantages are no single point of failure, no hot water distribution piping or pumps, no inefficiencies due to heat loss. The disadvantage is large electrical load. Options for point-of-use water heaters include:

- Below counter electric instantaneous heater – these can be specified to feed up to three fixtures.
- Electric instantaneous heaters – these can be used for individual shower outlets.

30.3.B. Materials in contact with potable water must be resistant to corrosion, capable of handling the system pressure and temperature without leakage or deformation, and must not leach contaminants into the water at harmful levels.

30.3.C. Source equipment must be provided with safety relief valves to prevent damage or injury due to excessive pressure resulting in burst tanks or components.

i. Hot water storage tanks are pressure vessels and as such must have ASTM or ISO listings.

30.3.D. Source equipment must be sized to meet fixture demand.

Source Equipment Sizing

Sizing hot water source equipment requires balancing the amount of energy available to heat water with the storage capacity needed to make up for peak use periods. The less energy you have to heat water – the more storage you need to cover peak use periods. Typically discussing these factors with a heating equipment vender is the best way to determine the proper size.

30.3.E. For centralized potable hot water systems, a piped potable hot water distribution system from the water heating source, to all plumbing fixtures must be provided.

i. The standards for potable cold water systems regarding pipe sizing, cross-connection prevention, minimum pressure, isolation valves, and water hammer arrestors must also be applied to hot water systems.

30.3.F. Centralized hot water systems must maintain water temperature range desired by users (typically between 35°C and 44°C) throughout the system.

Hot Water Distribution

Accomplishing this will require designing the piping network in a loop format and providing a pump at the water heater to circulate the water back through the heater at a rate sufficient to make up for the heat lost in the piping network.

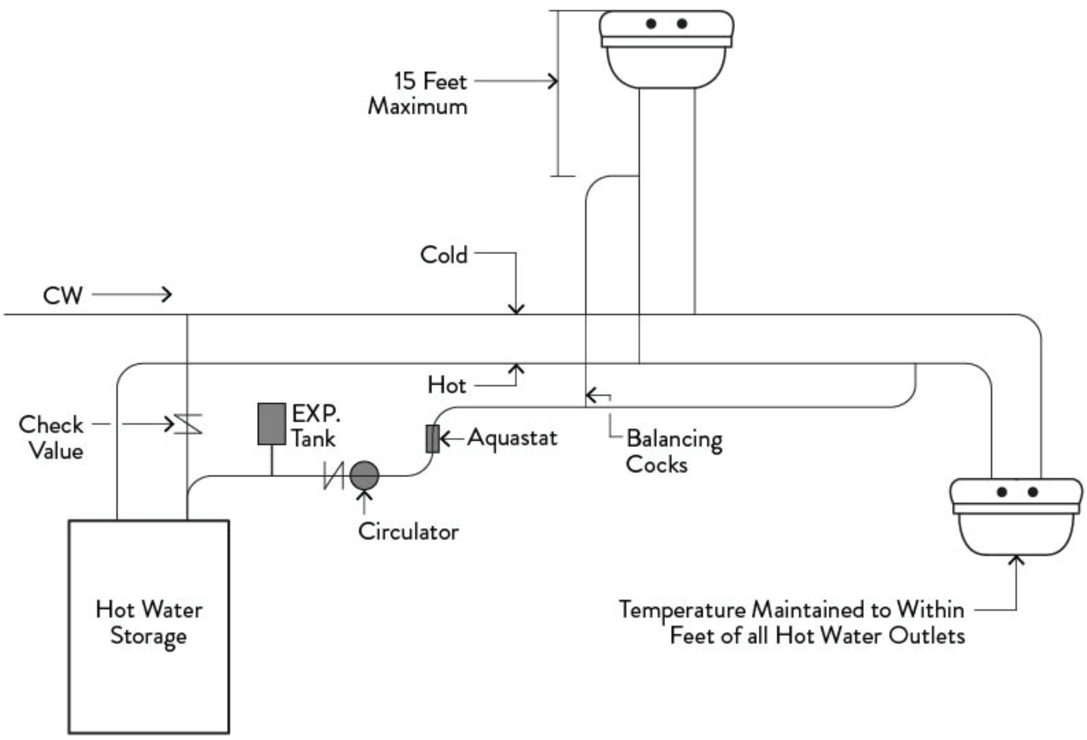
A rule of thumb for sizing circulation pumps is to provide one GPM circulation for every 10 hot water-using fixtures. A more accurate method is that pumps can be sized by measuring the total lineal feet of hot water piping between the last fixture served and the water heater, then multiplying the charted loss rates by the lineal feet of pipe. This figure results in a GPM rate required to make up the heat loss.

30.3.G. Piping for hot water systems must be insulated to minimize heat loss through the piping.

i. Acceptable insulation material must be used. Examples include mineral-fiber, cellular-glass, or closed-cell, sponge-type, or expanded-rubber flexible elastomeric thermal Insulation.

ii. Insulation thickness must be 1in (2.5cm) minimum for pipes under 1in (2.5cm) diameter and 1-1/2in (3.8cm) thick minimum for pipes over 1in (2.5cm) diameter.

Figure 30.d. Hot Water Temperature Maintenance



30.3.H. Potable hot water systems must include components to protect against scalding of users due to over-temperature water.

i. For centralized systems, include a thermostatic temperature control valve on the water heater outlet.

ii. For point-of-use instantaneous systems, consider application of a mechanical temperature-limiter on the water outlet. These devices restrict water flow relative to temperature increases beyond a safe level.

30.4 Sanitary Waste

Sanitary waste conveyance systems are networks of sloped drain pipes connected to plumbing fixtures and joining together in main building sewers that are routed out of the building to connect to site sewerage provisions described in Chapter 29 Medical & Solid Waste. When designed and installed properly, these systems will consistently convey waste out of the building by gravity via sloped piping, to site sewer systems, and they will prevent sewer water and sewer gases from entering back into the building.

30.4.A All facilities designed with internal toilets, bathing, hand washing, and other fixtures requiring water and associated waste utilities must be provided with piped sanitary waste drainage systems to convey waste from all plumbing fixtures to site sewerage provisions.

30.4.B Piping and fittings materials must be capable of carrying sanitary waste without corroding, leaking, sagging or deforming.

i. For above ground piping inside the building, cast iron or CPVC piping and drainage fittings systems may be used. CPVC piping must be certified as not-releasing toxic fumes if burned.
ii. For buried piping within the building footprint, cast iron, CPVC, or polyvinyl chloride (PVC) piping and drainage fittings may be used.

30.4.C Sanitary drainage piping must be sloped to ensure proper flow of waste water and solids.

i. Slope piping smaller than 3in (7.6cm) diameter at minimum ¼in (6mm) per lineal foot of run.
ii. Slope piping 3in (7.6cm) and larger at or between ¼in (6mm) and 1/8in (3mm) per lineal foot of run.

30.4.D Access must be provided to allow cleaning of piping buried below floor slab where horizontal waste lines change direction more than 45 degrees and at the base of drainage piping stacks serving multiple floors.

i. Install cleanouts by providing a full-size drainage fitting to extend from the buried sewer piping to terminate at the floor slab or wall surface with a flush, threaded plug.

30.4.E Water traps must be provided at each fixture connection to prevent sewer gasses from entering the building.

i. Traps must hold between 2in (5cm) and 3in (7.6cm) of water seal. Distance from fixture drain outlet to top of trap seal must not exceed 24in (61cm).
ii. Some fixtures such as toilets have internal traps. Additional traps are not required when connecting these fixtures to the drainage system. (Refer to Figure 30.f.)

Figure 30.e. Trap Seal Depth

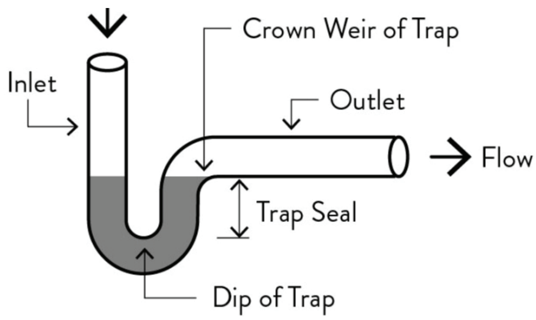
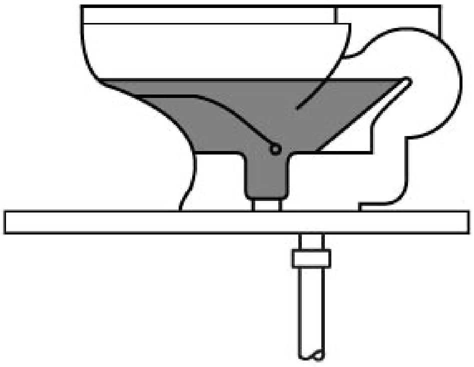


Figure 30.f. Fixture with integral trap



30.4.F **Fixture traps must be provided with vents to preserve water seal and conduct sewer gases to discharge above roof.**

i. Vents must be connected to trap outlet within the following distances in horizontal run from where the drain enters the trap inlet. (Refer to Table 30.g.)

ii. Air admittance valves are permitted in lieu of vented traps where piped venting cannot be installed due to structural conditions.

Figure 30.g. Distance from Trap to Vent

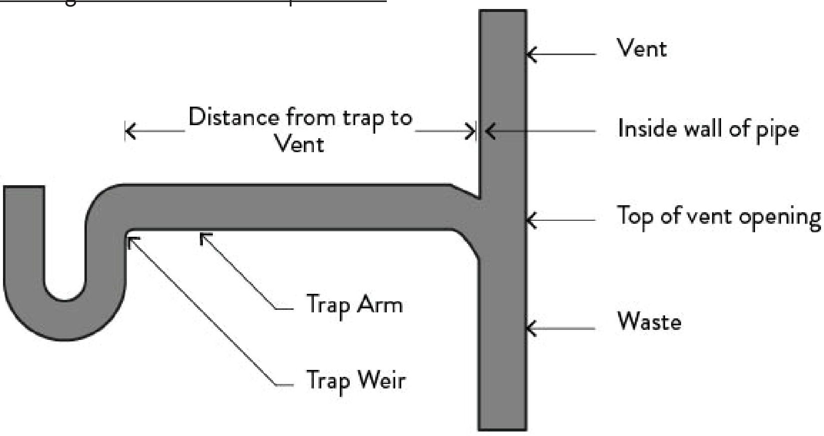


Table 30.g. Maximum Distance of Fixture Trap from Vent (IPC table 909.1)

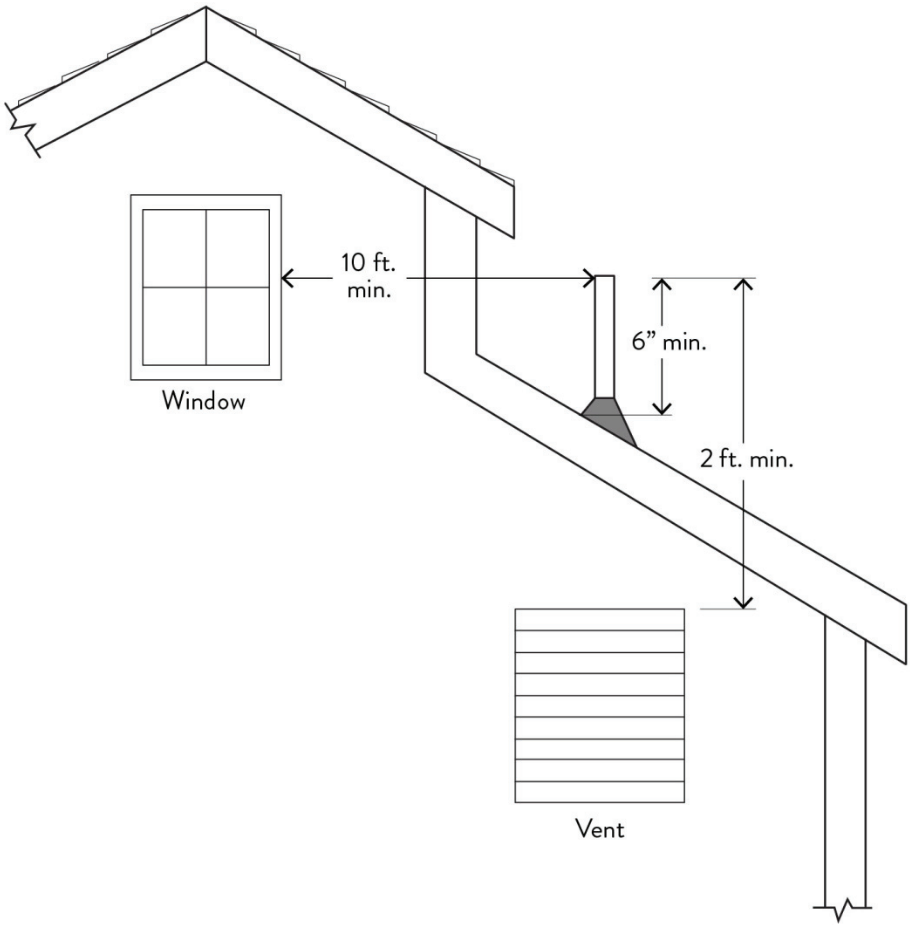
Size of Trap (inches)	Slope (inch per foot)	Distance from Trap (feet)
1-1/2in	1/4	5ft
1-1/2in	1/4	6ft
2in	1/4	8ft
3in	1/8	12ft
4in	1/8	16ft

[1] *For SI: 1 inch = 25.4mm, 1 foot = 304.8mm, 1 inch per foot = 83.3mm/m.*

30.4.G **Sanitary vent systems must be used to collect vents from several fixtures into common vent stacks and terminate vent stacks outside of building.**

i. Vent piping networks must be of the same materials and fittings as sanitary drainage. (Refer to Standard 30.4.B.)
ii. Drainage fittings in vent systems must be installed with the direction of flow being from the external vent termination to the fixture/s. (Refer to Figure 30.h.)
iii. Vent piping may be installed either with no slope, or with pipes sloped to drain back into fixtures.
iv. Vents from fixtures must not connect together until they are at least 6in (15.2cm) above the flood rim of the higher fixture.
v. As much as possible, vents must extend to minimum 6in (15.2cm) above roof and at least 2ft (61cm) from air intakes.
vi. Terminate vents with a stainless steel mesh screen to prevent debris or pests from entering.

Figure 30.h. Sanitary vent stack termination diagram



30.4.H **Sanitary drainage and vent systems must have adequate capacity for expected drainage loads.**

i. To size sanitary piping, use Tables 30.h. and 30.i. to determine drainage fixture unit loading on each section of the drainage and vent piping systems.
ii. The diameter of an individual vent shall be not less than 1 ¼in (3.2cm) nor less than 1/2 the diameter of the drain to which it is connected.
iii. A maximum of 1/3 of the total permitted length of any vent may be installed in a horizontal position. When vents are increased 1 pipe size for their entire length, the maximum length limitations in Table 30.i. do not apply.

Table 30.h. Waste Fixture unit loading

Fixture type	Fixture units per fixture[a]
Toilet with flush tank	5
Lavatory or sink	2
Shower	2

[a] *A rational method of assessing the peak flow rate for multiple fixtures uses the fixture unit concept. A fixture unit (FU) Value is assigned to each fixture based on its rate of water use, its likely use duration, and the average use frequency.*

Table 30.i. CPC table 7-5

Size of Pipe	1 ¼"	1 ½"	2"	2 ½"	3"	4"	5"	6"	8"	10"	12"
Max. Units Drainage Piping											
Vertical	1	2[b]	16[c]	32[c]	48[d]	256	600	1380	3600	5600	8400
Horizontal	1	1	8[c]	14[c]	35[d]	216[e]	428[e]	420[e]	2640[e]	4680[e]	8200[e]
Max. Length Drainage Piping											
Vertical	45'	65'	85'	148'	212'	300'	390'	510'	750'		
Horizontal[f]	∞	∞	∞	∞	∞	∞	∞	∞	∞		
Vent Piping, (Horizontal & Vertical)											
Max. Units	1	8[c]	24	48	84	256	600	1380	3600		
Max. Lengths	4'	60'	120'	180'	212'	300'	390'	510'	750'		

[a] *Excluding trap arm.*
[b] *Except sinks, urinals, and dishwashers - exceeding 1 fixture unit.*
[c] *Except six-unit traps or water closets (flush valve type).*
[d] *Only 4 water closets or six-unit traps allowed on any vertical pipe or stack; and not to exceed 3 water closets or six-unit traps on any horizontal branch or drain.*
[e] *Based on 1/4in per foot (20.8mm/m) slope. For 1/8in per foot (10.4mm/m) slope, multiply horizontal fixture units by 0.8*
[f] *Horizontal Lengths are unlimited. (∞ = unlimited)*

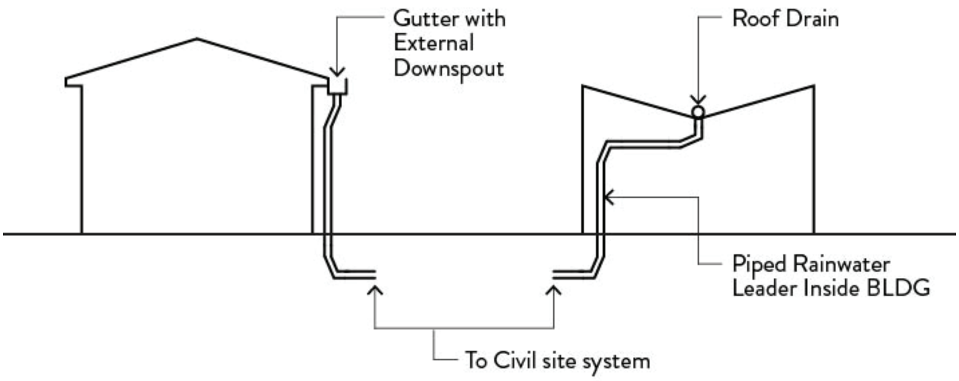
30.4.1 **A minimum positive air gap separation between equipment drains and sanitary drainage receptors must be provided.**

i. Refer to Standard 30.2.K. for cross-connection prevention for potable water systems.
ii. Any equipment draining to the sanitary drainage system must have a minimum 1in (2.5cm) air gap between outlet of the drain and the entrance into the sanitary drainage system.

30.5 Internal Roof Drainage

Some architectural roof designs may convey water from the roofs directly to site storm water systems without internal rainwater drainage piping. In other cases, it may be necessary to route these leaders inside the building in order to access an internal storage cistern etc.

Figure 30.i. Examples of internal roof drainage



30.5.A. All roofs and courtyards within the building footprint and open to the sky must have drainage systems to conduct rainwater out of the building. Rainwater may not drain into sanitary drainage systems unless combined sanitary/storm sewer systems are used on the site.

i. Pipe and drainage fittings materials must be the same as used for sanitary drainage and vent systems.

ii. Rainwater drainage piping must be sloped at 1% or more.

30.5.B. Design rainwater drainage systems with adequate capacity to handle minimum 6in (15.2cm) per hour rainfall rate.

i. Size piping by calculating the area served by each drain and applying this to Tables 30.j-k.

Table 30.j. Sizing of sloped Rainwater Piping

Size of Pipe (in)	Flow (gpm)[a]	Maximum Allowable Horizontal Projected Roof Areas (sq ft)[b]
3	34	548
4	78	1,253
6	222	3,566
8	478	7,670
10	860	13,800
12	1,384	22,200

[a] *Flow at 1/8in/ft. slope*

[b] *Square Feet at an assumed worst case Rainfall Rate of 6in (15.2cm) per hour*

Table 30.k. Sizing Roof Drains, Leaders, and Vertical Rainwater Piping

Size of Drain Leader or Pipe (in)	Flow (gpm)	Maximum Allowable Horizontal Projected Roof Areas (sq ft) [a]
3	67	1,073
4	144	2,307
6	424	6,800
8	913	14,667

[a] *Square Feet at an assumed worst case Rainfall Rate of 6in (15.2cm) per hour*

30.6 Plumbing Fixtures

Plumbing fixtures are intended to provide a clean and safe place for accessing water for drinking, washing, bathing, toiletry and cleaning. Plumbing fixtures also provide drainage of wastewater from these functions without splashing or leaking water into the surrounding area. Decisions about the location, type, and quantity of plumbing fixtures should incorporate feedback from facility administrators and staff.

30.6.A The determination of the type and quantity of plumbing fixtures for a facility must be determined by the architect or responsible Infrastructure Unit representative in collaboration with project stakeholders and end users.

i. Consider existing or planned infrastructure (what type of water and sanitation systems the facility will have) as well as the preferences of the intended users.

30.6.B. To reduce infection transmission and safety risks, plumbing fixtures must be of good quality such that they are durable, impervious to water, and free of cracks and crevices.

30.6.C. Plumbing fixtures must be constructed to maintain a minimum air gap between water outlet/s and fixture flood rim.

i. Refer to Figure 30.b. for typical required air gaps.

30.6.D. Seated toilets must include the following features:

- Floor mounted, vitreous china body and water cistern.
- Waste outlet through floor.
- Dual flush 1.6 gallon “high” flush and 1.1 gallon “low” flush.
- Hinged impervious seat and solid cover.
- Internal p-trap (refer to 30.4.E.).
- ½in (1.3cm) minimum potable water connection and minimum 3in (7.6cm) waste outlet.

30.6.E. Squat toilets must include the following features:

- Acid resisting fired porcelain enameled cast iron body with rotatable 4in (10.2cm) diameter 'P' trap. (Refer to 30.4.E.)
- Integral non-skid foot pads and bowl wash down non-splashing flushing rim.
- Mounting to be flush with finished floor, providing complete floor drainage into bowl.
- ½in (1.3cm) minimum potable water connection if flush valves are to be provided (flush valves for 2.4 or 3.5 gallons/flush are recommended).
- If piped flush valves are not being provided, a bucket of potable water, brackish or seawater may also be used for efficient flushing of entire bowl.
- The water closet must be completely self-supporting.

30.6.F. Urinals must include the following features:

- Wall mounted, vitreous china body.
- Non-corroding grid drain with minimum 1-1/2in (3.8cm) waste outlet.
- 0.125- gallons-per-flush piston type valve mounted on fixture.

30.6.G. Sinks for hand washing must include following features:

- Vitreous china body, with countertop or pedestal mounting.
- Faucet with manual wrist blade controls and laminar non-aerating type 0.5 gpm flow control located in the faucet base.
- Faucet outlet minimum 5in (12.7cm) above flood rim.
- Minimum 1-1/4in (3.2cm) drain outlet with p-trap, grid type non-corroding strainer.
- Water supply/s with shut off valve accessible below fixture.

30.6.H. Sinks for kitchen and/or medical utensil washing must include the following features:

- Counter mounting vitreous china, enameled cast-iron, or stainless steel body.
- Faucet with manual wrist blade controls and laminar non-aerating type 1.0 gpm flow control located in the faucet base.
- Faucet outlet minimum 5in (12.7cm) above flood rim.
- Minimum 1-1/2in (3.8cm) drain outlet, grid type non-corroding strainer.
- Sinks must be provided with a p-trap. (Refer to 30.4.E.)
- Water supply/s with shut off valve accessible below fixture.

30.6.I. Showers must include the following features:

- Pressure-balancing mixing valve.
- Wall-mounted 1.75gpm shower head.
- Minimum 3in (7.6cm) diameter removable grid drain with minimum 1-1/2in (3.8cm) dia. waste pipe connection.
- Shower enclosures and floor pan requirements per architectural design.

31 Medical Gas

Medical gases include oxygen, medical compressed air, medical vacuum, nitrous oxide, surgical tool air, and carbon dioxide. Medical gases are used to sustain life and facilitate medical procedures. These functions typically require that the gases enter the patient's body. The gases need to be extremely clean and must be delivered at a safe pressure or they may cause harm. It is crucial that pipe systems and gas source equipment be manufactured and installed by qualified contractors.

Definitions

- **Cylinder bank or Cylinder manifold**: A group of pressurized gas containers connected to a common pipe.
- **CFM**: Cubic feet per minute, used as a unit of medical gas volume.
- **LPM**: Liters per minute, used as a unit of medical gas volume.
- **Manifold Control Panel**: An assembly of devices intended to provide automatic switchover from a depleted cylinder bank to a full cylinder bank.
- **NFPA**: National Fire Protection Association, a US trade association that creates and maintains private, copyrighted, standards and codes for usage and adoption by local governments.

31.1 Gas Applications

Medical gas applications will vary by facility. Whether primary, secondary, or tertiary level services are provided will determine what type of medical gases may be needed, for what uses, and in what spaces. At most smaller facilities, the only medical gas used will be oxygen. Oxygen is extensively used for respiratory therapy and life support and is additionally used in anesthetic procedures. At larger facilities offering more invasive medical procedures, gases in addition to oxygen may be needed. These include: medical vacuum for removal of bodily fluids during procedures, medical air to mix with pure oxygen and to power ventilators, nitrous oxide for administration of anesthetics, surgical tool air for pneumatic-driven tools, and carbon dioxide to fill body cavities for some procedures.

31.1.A. Primary or secondary level facilities with mostly ambulatory patients must offer small portable cylinders of medical oxygen to support any necessary functions.

31.1.B. Secondary level facilities with non-ambulatory patients and mostly non-invasive procedures must be either have portable oxygen cylinders to support necessary functions or be outfitted with a central piped oxygen supply distributed to spaces per Room Planning Requirements in Chapters 46-50 and Table 31.a.

31.1.C. Tertiary level facilities offering invasive procedures, anesthesia recovery areas, and intensive care rooms must be provided with central sources and piped distribution systems for, at minimum, medical oxygen, medical air, and medical suction.

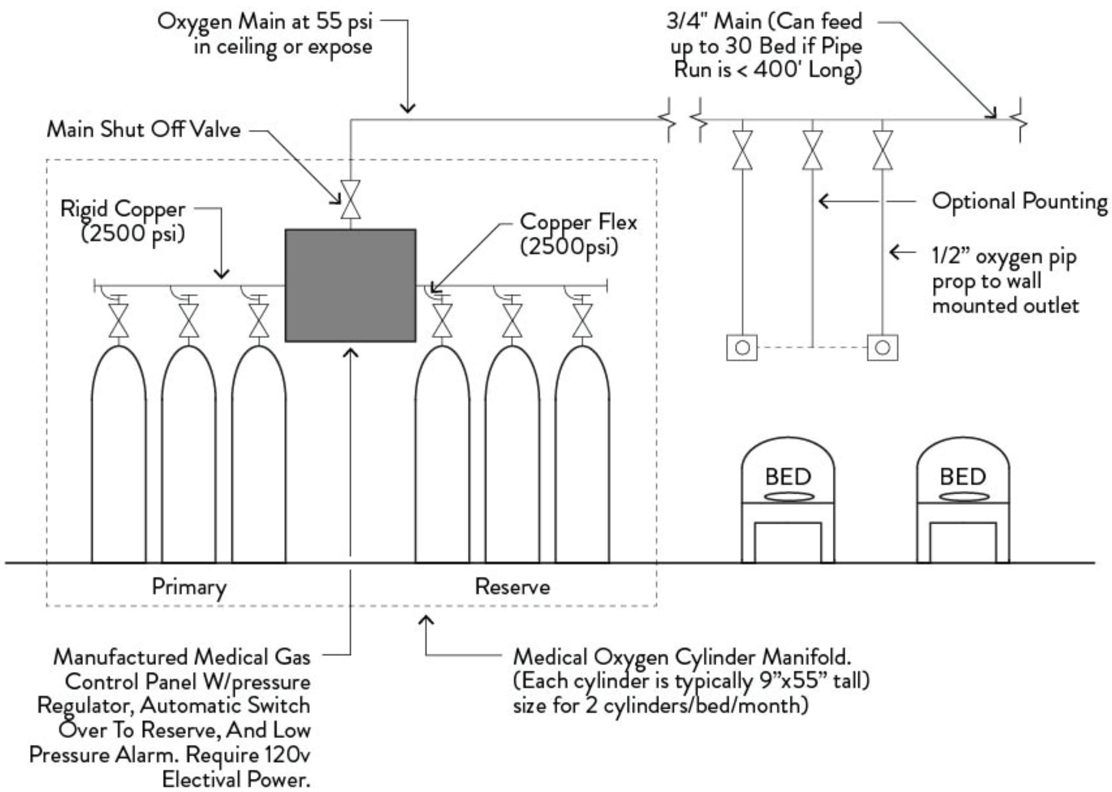
Table 31.a. Procedures and Services Requiring Medical Oxygen

Procedure	Space	Oxygen Supply
Surgical procedures Resuscitation	Operating Room	Required
Surgical recovery	PACU	Required
Heavy (chest) trauma Acute respiratory ailments Cardiovascular syndromes Resuscitation	ER	Required
Intensive care observation Assisted breathing / life support Resuscitation	ICU	Required
Neonatal incubation Resuscitation	NICU	Required
Acute respiratory ailments	Inpatient Wards	Recommended
Birthing recovery	Post Partum	Recommended
C-Section recovery	Post C-Section	Recommended
Birthing	Delivery	Optional

31.2 Gas Supply

Medical Oxygen is usually in the form of high-pressure gaseous oxygen cylinders provided by a vender. Alternatively, an on-site oxygen generation system may be used. Sources for medical air and vacuum are available in the form of pre-packaged pumps.

Figure 31.b. Central Oxygen Manifold



31.2.A. For facilities requiring piped oxygen, a central medical oxygen source with primary and reserve cylinders must be provided to allow change out of empty cylinders without interrupting the gas supply to patients.

i. The system must consist of a bank of cylinders piped together to serve as a primary supply where possible, and a separate equally-sized bank of cylinders tied together to act as a secondary supply.

ii. Cylinder banks must be sized so that one bank can last at least one week without being changed. The number of cylinders for each bank may be estimated based on an estimated use rate of (2) 9.5in (24cm) round x 55in (1.4m) tall cylinders per month for each patient bed or procedure room.

iii. Cylinders for these systems must be provided by a vendor specialized in delivery of medical grade oxygen. Contents must be medical-grade oxygen of at least 90% purity.

iv. Cylinders must be connected with copper or flexible stainless steel braided hose with a minimum 2,500psi (17.2MPa) burst rating. If an on-site oxygen generation system is used, the cylinders it produces must still be connected to a manifold system as shown in Figure 31.b.

v. Medical vacuum and air source equipment is only available as packaged equipment and is too complicated to assemble on site. Certified venders of this equipment must be contacted directly to determine suitable equipment.

vi. Consult the National Fire Protection Association, Chapter 99, 2005 Edition for all medical gas source equipment if possible.

31.2.B. **Medical gas cylinders and manifold control panels must be properly located and protected from damage due to heat and rain.**

i. If located outside, the manifold and cylinders must be protected from rainfall, shaded from direct sunlight, and safeguarded against theft or vandalism. Cylinders must not reach temperatures over the established maximum of 130˚F (54˚C). Cylinders left in direct sunlight are at risk of exceeding this temperature and bursting.

ii. If located inside the building, prioritize the placement of the manifold in a dedicated room with enough additional space for empty and full spare cylinders equal to or greater than the number of cylinders connected to the manifold.

iii. Cylinder manifolds must be provided with a level concrete pad or concrete floor for support, or flooring that meets the standards outlined in Section 44.2.

iv. Cylinder manifolds must be located to allow delivery and removal of cylinders with hand trucks. Access via stairs or ladders is to be avoided.

31.2.C. **Primary and reserve cylinder banks must be connected through a manifold controller to automatically switch to the secondary supply when the primary bank is depleted.**

i. These manifolds must include a pressure regulator to provide maximum 55psi oxygen to the distribution system.

ii. The manifold must include an audible alarm indicating switchover to reserve and low pressure in the main.

iii. The manifold controller must include a 3-piece ball valve as a main shut off.

iv. These manifold controllers are sophisticated and must be provided only by a manufacturer specialized in the manufacture of this equipment.

Oxygen Concentrators

On-site medical oxygen generation systems (oxygen concentrators) can be considered as an alternative oxygen source. These systems use a complex series of compressors, monitors and filters to produce 94% pure medical oxygen which is then automatically transferred into cylinders. These may either be used as portables, or they may be manifolded together as described above.

Oxygen concentrators are expensive, have large electrical loads, and require specialized maintenance. However, they provide a desirable level of independence from venders and they may eventually pay for themselves.

These are available only as packaged equipment from a small number of international manufacturers. Selecting the system is best done by contacting one of these manufacturers and tailoring the unit to the project needs.

31.3 Gas Distribution

Medical gas distribution systems are networks of piping that deliver gases to bedside outlets. Distribution systems must be properly sized and installed. If the piping is too small for the amount of gas needed, the pressure at the point of use may fall below a functional level. Oversized piping does not present a health risk but does add cost. Piping should be kept dry and be accessible for leak testing and visual inspection.

31.3.A. Piped medical gas distribution systems must be designed to deliver gas to use points if a central medical gas source is used.

i. Medical gas piping and component materials must be suitable for use with pressurized oxygen.
ii. Distribution piping, fittings and valves must be copper with brazed joints, cleaned and delivered capped by a certified reputable manufacturer. This is needed to ensure health and safety.
iii. Consult the National Fire Protection Association, Chapter 99, 2005 Edition for all medical gas distribution systems design if possible.

31.3.B. Oxygen distribution piping must be sized to the following requirements:

i. Size oxygen pipe based on a minimum of 20L/min flow per use point and a total system pressure loss of not more than 5psi at the most remote outlet so that a minimum of 50psi is always available at all outlets.
ii. Refer to Table 31.c. for oxygen line sizing information.

31.3.C. Medical vacuum piping must be sized to the following requirements:

i. Size medical vacuum pipe based on a minimum of 1 cubic foot per minute [cfm] (28.3L/s) flow per use point and a total system pressure loss of not more than 4in (10.2cm) mercury (Hg) at most remote outlet so that a minimum of 15in (12.5cm) is always available at all outlets.
ii. Refer to Table 31.c. for medical vacuum line sizing information.
iii. Rooms where invasive procedures are performed must have a 1in (2.5cm) minimum vacuum line for each room.

31.3.D. Medical air piping must be sized to the following requirements:

i. Size medical air pipe based on minimum 1CFM per minute flow per use point and a total system pressure loss of not more than 5psi at most remote outlet so that a minimum of 50psi is always available at all outlets.
ii. Refer to Table 31.c. for medical air line sizing information.
iii. Coordinate with users as to how to terminate medical gas services at patient-use points to ensure the user has the needed connector types available.
iv. Outlets at patient beds must be pre-manufactured for the intended gas service by a reputable manufacturer.

Table 31.c. Medical Gas Distribution Guidelines

Application	Line Diameter	Maximum Beds Served
Oxygen	½in (1.3cm) ¾in (1.9cm) 1in (2.5cm) 1-1/2in (3.8cm)	10 beds 30 beds 50 beds 200 beds
Medical vacuum	¾in (3.8cm) 1in (2.5cm) 1-1/2in (3.8cm) 2in (5cm) 4in (10.2cm)	3 beds 10 beds 30 beds 100 beds 200 beds
Medical air	½in (1.3cm) ¾in (3.8cm) 1in (2.5cm) 1-1/2in (3.8cm) 2in (5cm)	8 20 40 100 200

31.3.E. Medical gas piping must be installed in protected locations to prevent damage resulting in reduced flow rate, leaking, or contamination.

i. To the degree possible, avoid buried piping. If it is necessary to bury piping it must be enclosed in a PVC pipe and buried at least 24in (61cm) below grade.

ii. Medical gas piping within buildings must be run in ceiling spaces wherever possible.

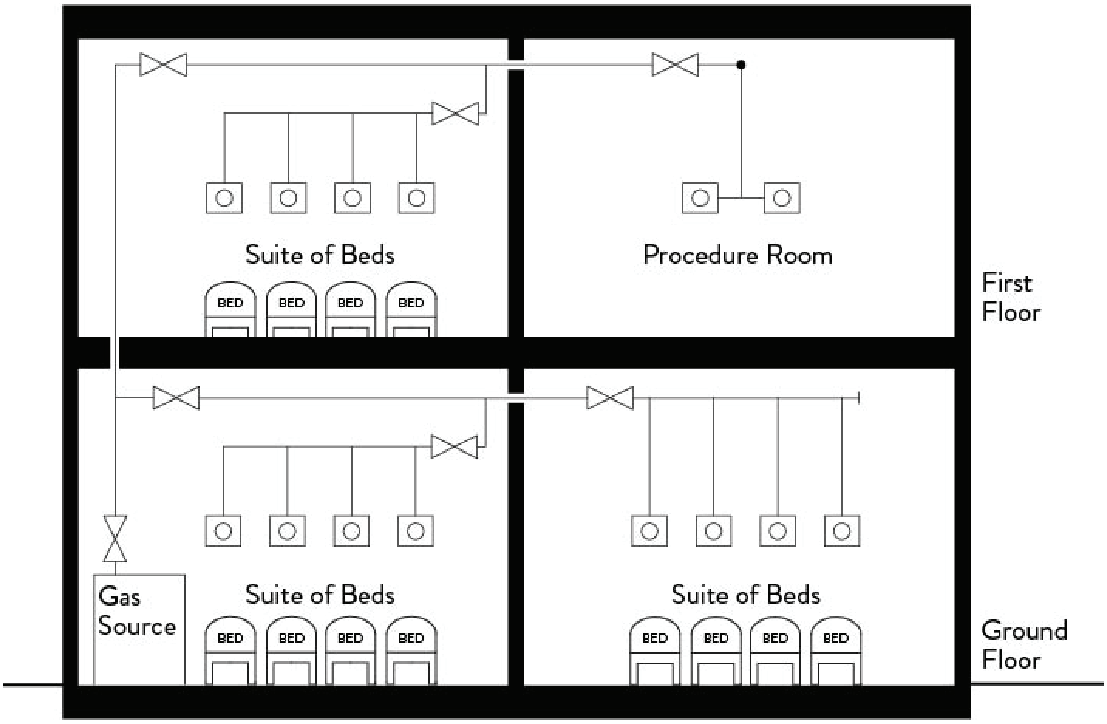
iii. Piping must be installed to allow at least 12in (30.5cm) of clearance around fittings for repair and maintenance access.

iv. Medical gas piping to outlets at patient beds must be run in stud walls or protected in surface-mounted metal conduit and terminated at manufactured outlet assemblies where possible. For surface mounting of piping in concrete block construction, piping to outlets must be provided with a minimum 18 gauge metal cover to protect the piping and for mounting of the outlet. Outlets at patient beds must be mounted at 5ft (1.5m) above finished floor.

31.3.F. Where central medical gas systems are used, shutoff valves must be provided in gas piping networks to allow isolation of each suite of rooms, each riser serving multiple floors, and each branch serving an entire floor to allow maintenance to isolated areas without interrupting service to other areas.

i. Consult the National Fire Protection Association, Chapter 99, 2005 Edition for all medical gas distribution systems design if possible.

Figure 31.c. Medical Gas Isolation Valve Scheme



31.3.G. An initial pressure test of the medical oxygen distribution system must be carried out to ensure system will not leak.

i. If possible, test with medical oxygen or nitrogen at 1.5 times normal system operating pressure. Pressure must be maintained until all piping joints have been tested for leaks with soapy water for a minimum of 2 hours.

ii. Tests must be performed prior to installation of any components such as manufactured medical gas outlets that may be damaged at high pressure.

31.4 Medical Gas Alarms

Medical gas alarms provide audible indication to facility staff that the line pressure in the distribution piping has deviated from an acceptable range, and/or that the source equipment has switched from primary source to reserve source equipment. No such alarms are required for facilities only utilizing small portable cylinders.

31.4.A. Central oxygen-only gas systems must have an audible alarm on the central source manifold control panel indicating low line pressure and switch over to reserve.

i. Consult manufacture information. Any reputable manifold control panel manufacturer will include these alarms or lest an option for these alarms as part of the packaged product.

ii. Consult the National Fire Protection Association, Chapter 99, 2005 Edition for all medical gas alarm systems if possible.

31.4.B. Central medical oxygen, medical air, and medical vacuum systems must have an audible alarm on the central source equipment and a master alarm panel indicating low line pressure, switch over to reserve, and gas quality monitoring.

i. Facilities at this acuity level require alarm systems based on The National Fire Protection Association, Chapter 99, 2005 Edition.

SITE WORK

CONTENTS

IMPACT

Site design and preparation has a significant impact on both wastewater management and the continued structural integrity of building foundations. These chapters outlines proper techniques for site drainage, clearing prior to construction, and soil compaction requirements for foundations.

PRIMARY USERS

Infrastructure Unit

Architects & Designers

Structural & Civil Engineers

Contractors

GUIDELINES FOR USE

Design decisions made using the Standards outlined in Chapter 10: Landscaping & Outdoor Space and Chapter 11: Stormwater Management & Erosion Control will be executed during site preparation. These chapters serve as a step-by-step process of implementation for previously made design decisions.

32 Site Preparation

Proper site preparation provides a safe and efficient construction site and avoids potential conflicts with existing improvements and utilities. Site preparation work includes clearing, debris management, grading, and erosion control activities.

Definitions

- **Bituminous:** Containing a black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation.
- **Clearing and Grubbing**: Removal of objectionable natural materials (e.g. trees, shrubs) and artificial materials (e.g. rubbish) from the project site or from areas of construction specified within the site.
- **Compaction**: The process by which sediment progressively loses its porosity due to the effects of loading.
- **Erosion Control:** The practice of preventing or controlling wind or water erosion in agriculture, land development, and construction. Effective erosion controls are important techniques in preventing water pollution and soil loss.
- **Erosion**: Detachment and movement of soil or rock fragment by water, wind, ice, and/or gravity.
- **Grading**: Work done to ensure a level ground, or ground with a specified slope.
- **Sedimentation**: The settling or deposition of eroded particles.
- **Subsoil**: The soil lying immediately under the surface soil.

32.1 Planning and Site Analysis

The site improvement plan should outline the scope of work that will be required to construct the project, including clearing and grubbing, erosion control, debris management, and soil preparation.

32.1.A. Provisions must be provided in the design plans and specifications for site preparation work.

i. This must include specifications for all labor, materials, equipment, and services required for clearing and grubbing, demolition, and removal and disposal of items as specified herein.

32.1.B. The assigned Infrastructure Unit (IU) representative or project surveyor must be contacted prior to commencement of site preparation so that areas of clearing, grubbing, and prep are laid out efficiently.

32.1.C. Before any site work is done, a site analysis must be carried out and shared with the site designer, so that existing site vegetation to be preserved can be identified and properly protected.

i. Selected existing vegetation/landscape features to remain must be identified, marked, and protected.

32.2 Clearing and Grubbing

Clearing and grubbing consists of removing all natural and artificial objectionable materials from the project site or from limited areas of construction specified within the site.

32.2.A. All clearing and grubbing must be undertaken according to the site plan provided by the facility designer. No work may be undertaken without the site plan and approval of the staked out area of proposed construction.

i. Clearing and grubbing must be performed in advance of grading and earthwork operations and must be performed over the entire area of earthwork operations.

ii. All trees and shrubs of 3in (75mm) caliper or less (caliper is the diameter as measured 12in (30cm) above the ground) and all scrub growth, such as cactus, yucca, vines, and shrub thickets, must be cleared. All dead trees, logs, stumps, rubbish of any nature, and other surface debris must also be cleared.

32.2.B. Buried material such as logs, stumps, roots of downed trees that are greater than $1^1/_2$in (38mm) in diameter, matted roots, rubbish, and foreign debris must be grubbed and removed to a minimum depth of 24in (60cm) below proposed finished grades.

32.2.C. Ground cover consisting of weeds, grass, and other herbaceous vegetation must be removed prior to stripping and stockpiling topsoil from areas of earthwork operations. This must be accomplished by removing the uppermost layers of sod or root-matted soil.

32.3 Pavement/Utility Removal and Backfilling

Existing pavement and utilities that are within the project area and will impact the new construction planned for the site should be removed or relocated to avoid potential conflicts during construction.

32.3.A. The specifications and plans must include provisions for the removal of pavement, concrete, and removal or relocation of utilities that may be in conflict with the proposed improvements.

32.3.B. Bituminous and concrete pavements must be removed safely, to preserve any adjacent construction or landscape assets that should be protected for future use.

i. Concrete curb and gutter must be removed safely, to preserve any adjacent construction or vegetal assets that should be protected for future use.

32.3.C. Utilities that will not be used and/or are in direct conflict with the proposed site improvements must be removed and/or relocated as specified in the site improvement plans.

32.3.D. The relocation or removal of other utilities owned by utility companies or other parties must be coordinated and approved by the owner of the utilities prior to their removal and/or relocation.

i. If temporary service is required this must be determined and setup before the existing utilities are removed and/or relocated.

32.3.E. There may be certain items on the site such as old building foundations, fences, and other undetermined structures and improvements that must be removed before construction can commence. Unless otherwise specified, such items become the property of the Contractor for subsequent disposal.

32.3.F. All holes, cavities, and depressions in the ground caused by site preparation operations must be backfilled and tamped to normal compaction and shall be graded to prevent ponding of water and to promote drainage.

32.3.G. Should any excavated hole or cavity be required to be left open overnight, the Contractor must be responsible to provide barriers and / or coverings to provide on-site accident prevention measures.

32.4 Waste Disposal

The proper management and disposal of construction related debris is important to maintain a safe work area and to avoid potential environmental problems or issues with neighbors.

32.4.A Provisions must be included for the proper and safe disposal of all waste materials generated by clearing, grubbing, removal, and demolition from the site and comply with any applicable local, regional, and national codes.

32.5 Grading

Grading activities on site may be minor or extensive depending on the topography and planned site improvements. Accurate staking and control is important to assure that the grading plans are followed and excavation is maintained within the limits of the project. The contractor should follow the following standards and guidelines:

Site Examination

32.5.A. The contractor must verify site conditions prior to execution of the grading activity to identify any potential conflicts. If any conflicts are identified than the Project Engineer or Architect must be notified to resolve the conflict prior to initiating the grading.

32.5.B. The contractor must verify that survey benchmark(s) and intended elevations for the work are as indicated.

Preparation

32.5.C. The contractor musts take out all required lines, levels, contours, and datums for inspection by the assigned IU representative.

32.5.D. The contractor must coordinate utility relocation or removal with the Project Engineer or Architect and the utility owner/company.

32.5.E. The contractor must identify and protect above and below grade utilities, which are to remain and provide temporary support of exposed utilities, as needed.

32.5.F. The contractor must protect benchmarks and site features, including existing structures, fences, sidewalks/paths, paving, trees, and other improvements that are indicated to remain.

Subsoil Excavation

32.5.G. Excavate subsoil from areas indicated to be excavated, graded, or landscaped.

32.5.H. Stockpile subsoil that be reused on the site and excess material that will not be reused must be removed from the site and taken to an approved disposal location.

Cutting and Filling

32.5.I. Cut and fill areas to contours and elevations indicated in the plans.

32.5.J. Place and compact structural fill materials in continuous layers not exceeding 6in (15cm) compacted depth, compacted to 95% of maximum density at optimum water content beneath paved areas, buildings and other improvements, and 90% of maximum density at optimum water content elsewhere.

32.5.K. Place and compact topsoil fill material in continuous layers not exceeding 6in (15 cm) compacted to depth.

32.5.L. Slope grade away from buildings minimum 2in in 10ft (50mm in 3m), unless noted otherwise.

32.5.M. Make grade changes gradual and smooth and blend slope into level areas.

Tolerances

32.5.N. The top surface of the subgrade must be within plus or minus 1in in 100ft (25mm in 3m).

Field Quality Control

32.5.O. Field inspection and testing must be performed under the direction of the assigned IU representative.

32.5.P. Tests and analysis of fill material must be performed in accordance with testing procedures adopted by the MOHSW in use at the time of the project.

32.5.Q. Compaction testing must be performed in accordance with testing procedures adopted by the MOHSW and in force at the time of the project.

32.5.R. If tests indicate works does not meet specified requirements, remove work, replace and retest at no cost to the MOHSW.

32.5.S. Testing must be done at a frequency of one per 1,000 cubic yards (767 m^3) but not less than one per layer of fill and not less than one per day.

32.6 Erosion Control

Erosion and sedimentation can cause severe impacts to a project site and downstream properties and water courses. It is the responsibility of those involved in the design and construction of any project to utilize a variety of strategies to minimize erosion and the transport of sediment to the greatest extent possible. The following sections present the standards and guidelines for erosion control measures that should be applied to all construction projects.

General Requirements

32.6.A. The contractor must protect adjacent properties and water resources from erosion and sediment damage throughout the life of the contract in accordance with the Erosion and Sediment Control Plan prepared for the project.

32.6.B. The contractor must conduct work in accordance with specific restriction on seasonal work limits, the amount of area that can be exposed at a given time, the general sequence of construction, and contractor monitoring.

32.6.C. The contractor must assign an experienced job foreman as the designated erosion control specialist for implementation of all erosion control measures for the project. Specific responsibilities include:

i. Assuring all erosion control measures are installed properly and effectively.
ii. Inspection of the project work site at least once a week and prior to any forecasted storm to determine the condition of erosion control measures in place and to install additional erosion control measures in areas that appear vulnerable.
iii. Inspection of all erosion control measures and drainage inlets after any significant rainfall. Accumulated silt/sediment should be removed when the depth of sediment reaches 50% of the barrier height. Accumulated silt/sediment should be removed from behind the silt/sediment barrier when the depth reaches 6in (150mm). A significant rainfall shall be defined as over ½in (12mm) of precipitation in any 24 hour period.

Preparation

32.6.D. The contractor must review the erosion control plan and identify any potential conflicts or deficiencies and bring these issues up to the project engineer or architect prior to initiating the work. Any conflicts and deficiencies must be resolved before the erosion control plan is executed.

32.6.E. The contractor must have all erosion control materials on site prior to initiating any site disturbance activities.

Erosion Control and Slope Protection Implementation

32.6.F. Install erosion control measures in accordance with the erosion control plan and in accordance with approved installation procedures.

32.6.G. The contractor must replace or repair any erosion control measures that are failing or not controlling erosion or siltation within 48 hours of notification from the project engineer, project architect, or IU.

32.6.H. Any additional material work required beyond the extent of the erosion control plan must be paid for by the owner, except where such measures are required to correct deficiencies caused by the failure of the contractor to construct work in accordance with the erosion control plan.

32.6.I. Slopes that erode easily must be temporary seeded and covered with mulch or an erosion control blanket to stabilize the soils.

32.6.J. The contractor must install final erosion control measures at the earliest available time to minimize the need for temporary controls.

33 Soil Preparation

Appropriate excavation methods and respective foundations can be implemented once soil properties and site conditions have been determined. The following section provides criteria for the classification of soil types as well as standards and methods for excavation.

Definitions

- **Boulder:** Particles larger than 12in (300mm)
- **Cobble**: Particles ranging in size from 3-12 in (80-300mm)
- **Cohesionless Soils**: Soil particles that do not stick together and include: gravel (>2mm), sand (0.1 mm to 2 mm), and silt.
- **Cohesive Soils**: Soil particles that are very small and tend to stick together. Cohesive Soils are considered sticky and plastic and include clay.
- **Dry Sieve Analysis**: Soil is oven dried and mechanically agitated over a set of sieves to determine size and percentage of soil particles that make up a given sample.
- **Excavation**: The action of making a hole or channel by digging.
- **Footings**: Concrete structures that are under foundation walls to distribute the weight of the structure over a greater area and thus prevent settling.
- **Gravel:** Particles ranging in size from 0.18- 3in (4.75-80mm)
- **Liquid Limit**: Moisture content of a soil at which the soil starts to flow and act as a liquid.
- **Modified Proctor Test**: Determines maximum dry density and moisture content of soil.
- **Organic Soils**: Soil that is spongy, crumbly, and compressible. Organic soils are undesirable for supporting structures.
- **Specific Gravity**: Measure of how much heavier or lighter a material is than water.
- **Plastic Limit**: Moisture content at which it is possible to make a wire of approximately ¼ in diameter by rolling the soil between two hands. (Moisture control at the boundary between a soil in plastic and semi-solid states)
- **Sand**: Particles ranging in size from $3.0\text{x}10^{-4}$ -0.18in (0.075 -4.75mm)
- **Slope:** The face of an embankment or cut section. Any ground whose surface makes an angle with the horizontal plane.
- **Specific Gravity**: Measure of how much heavier/lighter a material is than water.
- **Water Table**: The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere.
- **Wet Sieve Analysis:** Soil is washed with water over a sieve (#270) to facilitate the removal of silt and clay from the larger particles.

33.1 Soil Classification

Different soil types exhibit different properties and inherent characteristics that need to be understood before the type of foundation system can be selected, designed and constructed. To acquire this information soil at sites must be classified and tested, as outlined in this section.

33.1.A. **The following site information must be determined prior to classifying appropriate foundation type and excavation methods:**

- Site Grade
- Soil Classification
- Water Table Depth

Grade, Soil Classification, and Water Tables

The slope of the site must be known prior to excavation and construction. For buildings with a large footprint, it can be more economical to step footings to achieve a level ground plane slab than to excavate to one level.

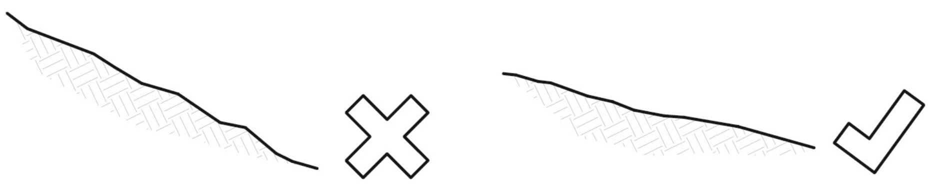
The soil type supporting any structure must be determined prior to excavation and construction. For example, moist or saturated soils (soils with a high water content) require larger and deeper foundations to adequately spread the load.

The depth of the water table with annual variances must be known. Foundations of each structure must be embedded below the water table to achieve adequate bearing.

33.1.B. **The building(s) must be located on sites with slope less than 25% as per Table 8.a and Figure 33.a.**

i. For a sloped site, a geotechnical engineer must determine depth of foundation required for stability.

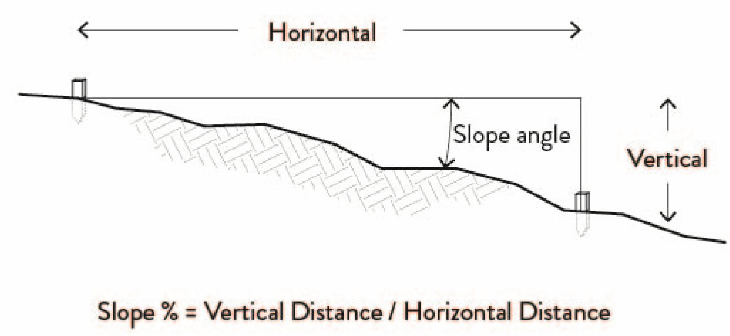
Figure 33.a. Appropriate Slopes



Slope greaterthan 25%

Slope less than 25%

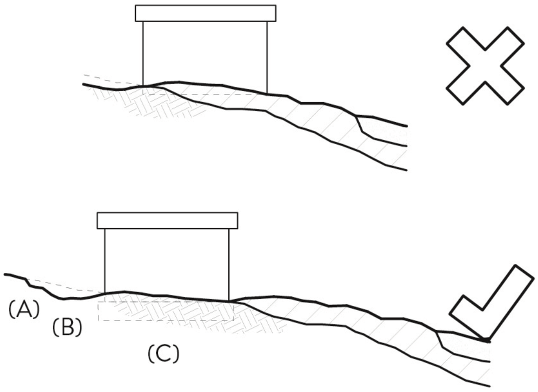
Figure33.b. Slope Definition



33.1.C. **Footings on or adjacent to slopes shall have adequate set back to protect against slope drainage, erosion and shallow failures.**

i. Adhere to the erosion control criteria in Figure 33.c.

Figure33.c. Construction Conditions for Varied Slopes



A. Erosion control measures of adjacent slopes must be taken (see 33.C)

B. All soil adjacent to building must be sloped away from structure (see 335.L)

C. Foundation must be placed entirely in compacted soil

33.1.D. **Soil classification must be determined through geotechnical testing.**

i. Geotechnical Reports must include the following test results:
- Site conditions and observations
- Chemicals in soil/ if any
- Wet sieve analysis
- Modified proctor test
- Moisture content
- Specific Gravity
- Plastic Limit
- Liquid Limit

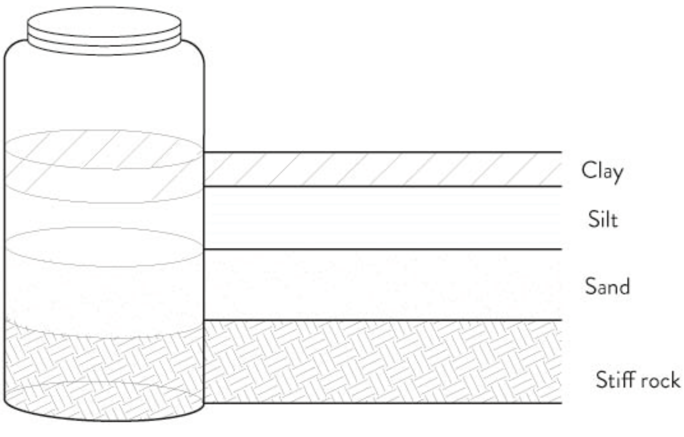
Soil Classification

Cohesionless Soils: Gravel (>2mm), Sand (0.1mm to 2mm), Silt are cohesionless soils. Soil Particles do not stick together

Cohesive Soil: Clay is a cohesive soil. Soil Particles are very small and tend to stick together. Cohesive soils are considered sticky and plastic.

Organic Soil: Soil is Spongy, Crumbly and Compressible. Organic Soils are undesirable for supporting structure.

Figure 33.d. Soil Chart



33.1.E. **Geotechnical Reports must interpret test results and include the following information for foundation design:**

- Recommendations of foundation given soil tests
- Soil bearing capacity
- Active and passive soil pressure
- Coefficient of friction
- Expected soil settlement

33.1.F. **Water table must be greater than 3ft (90cm) below ground surface per site selection requirements listed in Standard 8.4.C.**

i. Prevent groundwater from entering excavation by using berms and drainage channels or ditches.
ii. Groundwater can cause problems both during construction and in a completed building.

33.1.F. **The soils around the building must be sloped at least 3% away from the building foundation to direct runoff away from the building so that water will not collect under the foundation.**

33.1.G. **Sub-drainage systems must be included on all buildings.**

i. Pipe drain or sand drains are acceptable drainage methods. See Appendix S for installation procedures for both methods.

33.2 Excavation Methods

Excavation of the building footprint is the preliminary activity for the construction of the structure itself. Collecting trial pits to see the extent of soil and rock strata, is used to determine depth of soil removal.

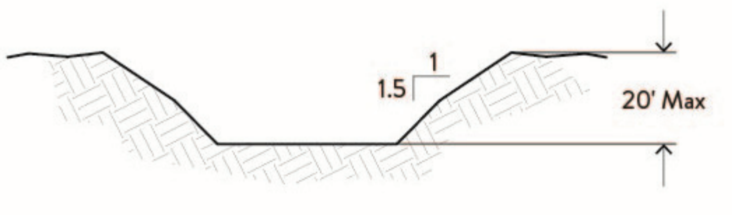
Quality Control Notes

- Record initial ground level
- Dispose of unsuitable material for filling
- Stacking suitable material for backfilling to avoid over handling
- Dressing bottom and sides of pits
- Sample for backfilling is approved
- Required watering and compaction is completed and required density is achieved

33.2.A. **Strip topsoil to its full depth over entire area of building footprint. Footings and foundations must be built on undisturbed soil or compacted fill.**

33.2.B. **In order to protect from cave in of excavation, sides must be sloped to the maximum angle of 1.5:1**

Figure33.e. Excavation



BUILDING STRUCTURE

CONTENTS

IMPACT

Proper structural design and implementation is not only key to building longevity, it is also a primary life safety issue. In addition to being the most basic expectation of building, structural integrity is a key to building longevity, which ultimately reduces upkeep needs and financial burdens of rebuilding.

PRIMARY USERS

Infrastructure Unit

Architects & Designers

Structural Engineers

Contractors

GUIDELINES FOR USE

These criteria are intended to be used by a qualified design professional with an understanding of structural engineering and should be applied following the load requirements of current design codes. These standards represent best practices and minimum sizes where indicated. The engineer must take care to provide a structure with continuous load paths for all applicable dead loads, live loads, and environmental loads using the materials selected from the specification in the material sections of this standard.

34 Foundations

A properly designed and constructed substructure, or foundation, is necessary for the delivery of durable, effective and cost efficient buildings. Foundation construction types should be determined by site conditions and building performance requirements during the development of and in conjunction with construction documents. Refer to Chapter 33 for additional information regarding soil preparation and excavation. Material baseline specifications such as concrete mix designs shall be in accordance with Chapter 39.

34.1 Foundation Selection

Prior to construction of all foundations, soil should be prepared according to specific site conditions in accordance with chapters 32 (Site Preparation) and 33 (Soil Preparation). Based on respective site conditions; appropriate foundation types should be utilized. Special care must be taken when footings and foundations are built close to the water table.

34.1.A. Foundation types must be appropriate to soil conditions.

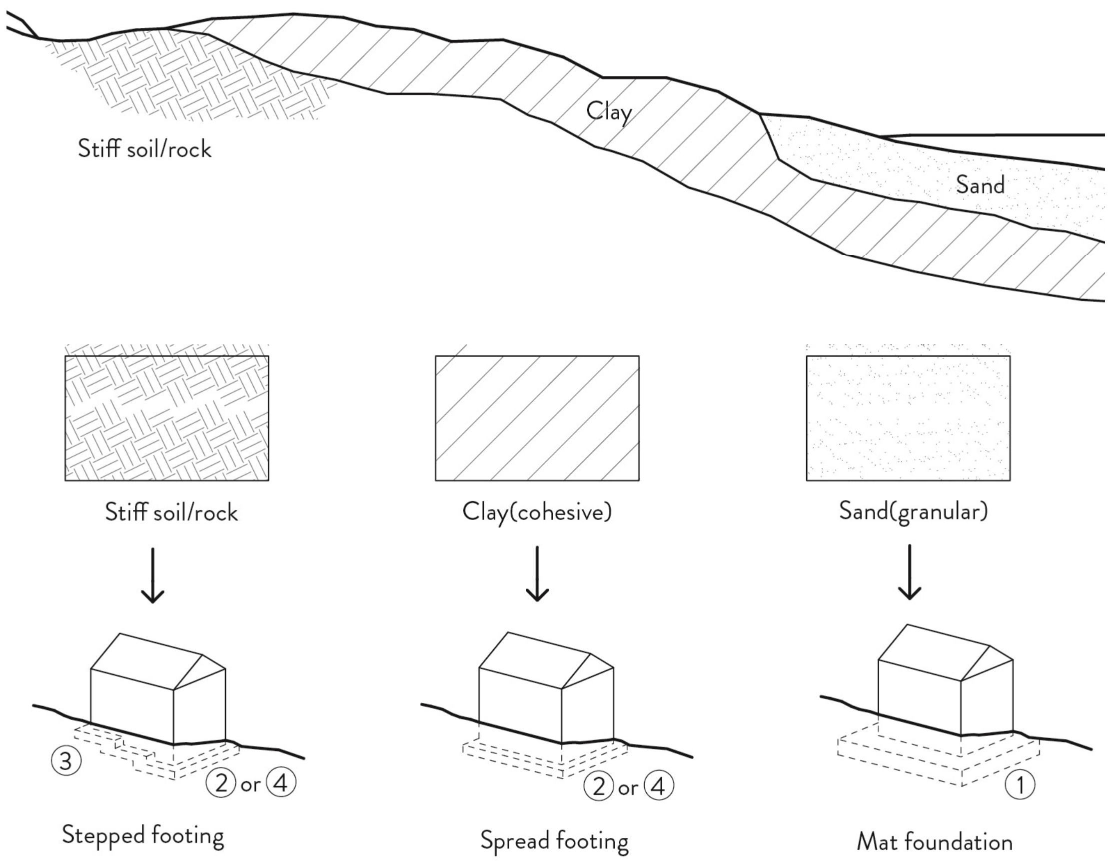
i. Continuous spread footings are recommended to distribute loads to cohesive and stiff soils; spread footings are appropriate for most typical conditions.

ii. Continuous stepped footings are recommended on sloped sites to eliminate the need for deep excavation in stiff soil.

iii. Mat foundations are recommended in sandy soils and other soils with low bearing capacity. The large mat area will help to spread the building weight over a large footprint, avoiding the need for a pile foundation, and prevent against building settlement.

iv. Deep foundations are recommended in sandy soils where the ground water table is close to the ground surface or where the soil cannot support the building loads. For these conditions deep foundation systems can be utilized to transfer the building loads through upper weak soil layers to deeper soil layers that have capacities suitable for supporting the building loads.

Figure 34.a. Recommended Foundation Types



34.1.B. **The top layer of organic soil must be removed prior to construction per excavation requirements in Chapter 33.**

34.1.C. **Footings and foundations must be built on undisturbed soil or compacted fill. Fill deeper than 24 inches must be engineered to prevent settlement.**

i. Soil must be compacted to 90%-95% density prior to construction.
ii. The minimum depth of the top of the footing below undisturbed ground soil must be at least 12 inches for stiff, clayey or sandy soils. Footings on rock sites need only penetrate the rock equal to the depth of the footing.
iii. Soil must be compacted prior to placing water proofing layer, concrete, rebar, or rubble.

Undisturbed Soil

Undisturbed soil refers to soil that is in its natural state and has not been moved. Once soil is moved on site, it must be re-compacted. If substructure is not founded a minimum depth into soil that is not compacted or undisturbed, settling will occur.

The soil compaction process is typically the most cost effective way to produce positive changes in the physical properties of natural soil. Principal soil properties affected by compaction include: settlement, shearing resistance, movement of water, volume change.

34.2 Concrete Foundations

For durability, concrete foundations are to be used as the primary option for health facilities. Where concrete has limited availability, rubble may be used as a partial supplement. Refer to Section 34.3 for specific requirements and allowable uses of rubble foundations.

Both spread footings and mat foundation systems distribute the load of the building directly to the bearing area of soil. For the stability of the building, it is very important that the footing is large enough to spread the bearing load without causing settlement. When the building location is near the coast, or in an area with water table near the ground surface, deep foundations should be used. A deep foundation system acts to distribute the building loads to deeper layers of soil below the weak upper layers that cannot adequately support the building.

General Performance Requirements

34.2.A. **Concrete must be properly cured prior to develop the strength of the concrete before construction continues and adds load to the foundation.**

i. Refer to standard 39.3.G for required cure times.

34.2.B. **For all concrete foundation types, minimum reinforcement quantities must be met in accordance to Table 34.b.**

i. Reinforcement quantity and spacing may be either option 1 or 2 as referenced in Table 34.b., or may be adjusted from the table values provided the same area of steel is provided.

Table34.b. Minimum Reinforcement in Shallow Foundations – Spread Footings and Mat Foundations

Foundation Thickness	Minimum Reinforcement[a] (Option 1)			Minimum Reinforcement[a] (Option 2)		
Depth (in)	Bar[b] (#)	Spacing[c] (in)	Location[d]	Bar[b] (#)	Spacing[c] (in)	Location[d]
10	3	6	Bottom	4	10	Bottom
12	3	8	Top &bottom	4	8	Bottom
16	4	12	Top &bottom	5	10	Bottom
18	4	12	Top &bottom	5	8	Bottom
24	4	8	Top &bottom	5	12	Top &bottom
30	4	8	Top &bottom	5	10	Top &bottom

[a] *Reinforcing bars are assumed to have a yield stress capacity of 60ksi (412 MPa). See 39.2.R. for additional reinforcing bar information.*

[b] *Bar # represents a diameter and area for a specified bar size. Refer to Table 39.i. for Reinforcement Bar Dimensions of respective bar #.*

[c] *Spacing indicates distance required a bar must be placed. Bar distance to edge of concrete is specified in Figure 34.c. and e.*

[d] *Reinforcement bars are to be located top and/or bottom in both directions. See Figures 34.c., 34.d., and 34.e. for placement notes.*

34.2.C. When reinforcement bars are too short, they must be overlapped to provide adequate length.

i. Refer to Standard39.2.U. for required overlap.

34.2.D. For all concrete foundation types, a minimum concrete cover must be provided. Refer to Table 39.h for cover requirements

34.2.E. For all concrete foundation types, the concrete mix and materials selected for use must be in accordance with concrete material parameters specified in Section 44.2.

34.2.F. For all concrete foundation types, the soil must be consolidated and prepped in accordance with site work requirements and recommendations before rebar or concrete is placed.

i. Refer to Chapter 33 for further details.

34.2.G. Foundations must be constructed to remain within a tolerance of 1.5in (3.8cm) from level.

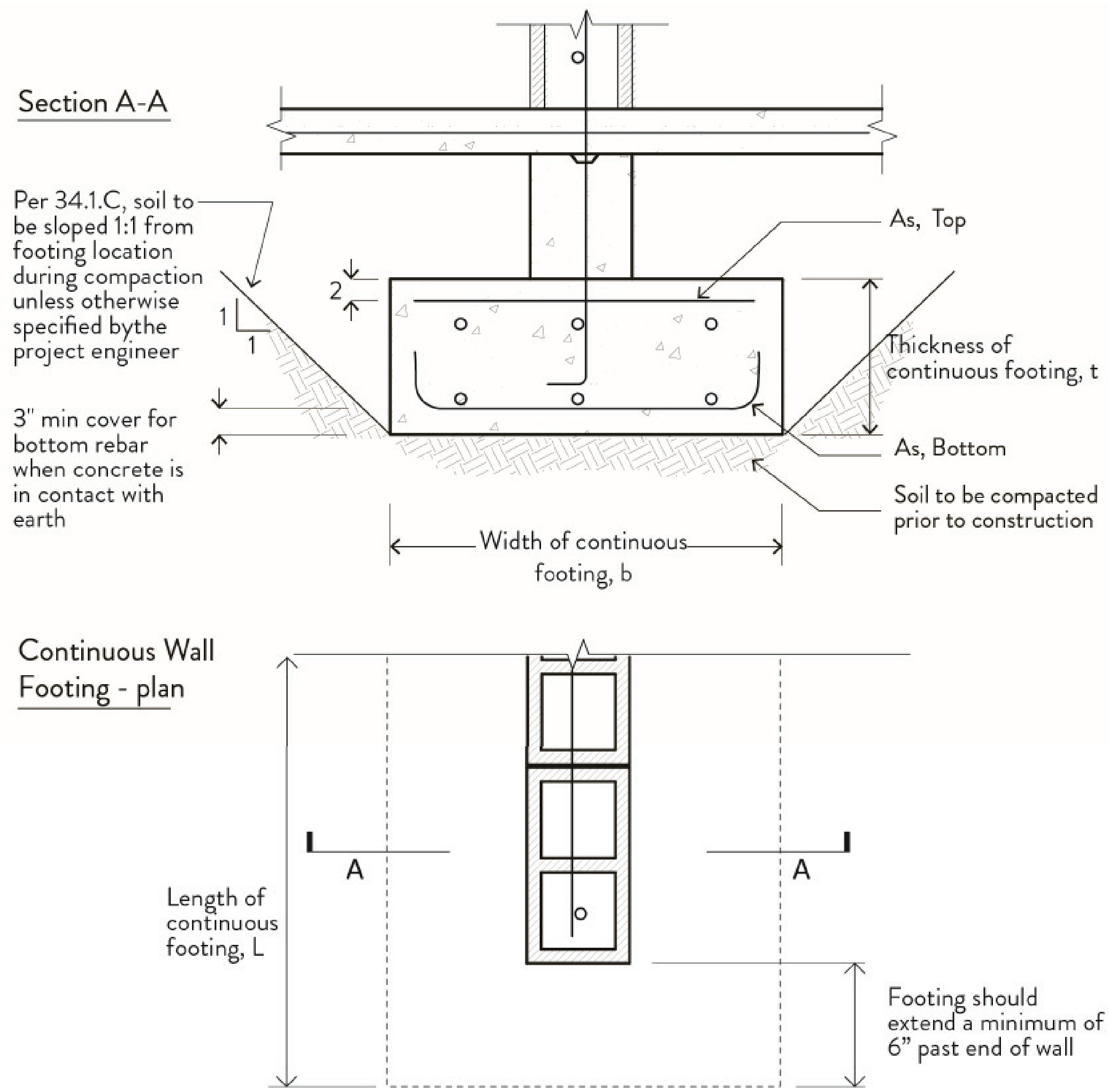
i. If the foundation is not level, $1^1/_2$ in (38mm) mortar beds are permitted below the wall to make up the difference from level.

Type 1) Spread Concrete Footings

34.2.H. Isolated spread footings and continuous wall footings must be tied together by grade beams to avoid foundation settlement. For buildings that are constructed entirely on rock, grade beams are not required.

34.2.I. The thickness, t, of a spread concrete footing must be 10in (250mm) minimum.

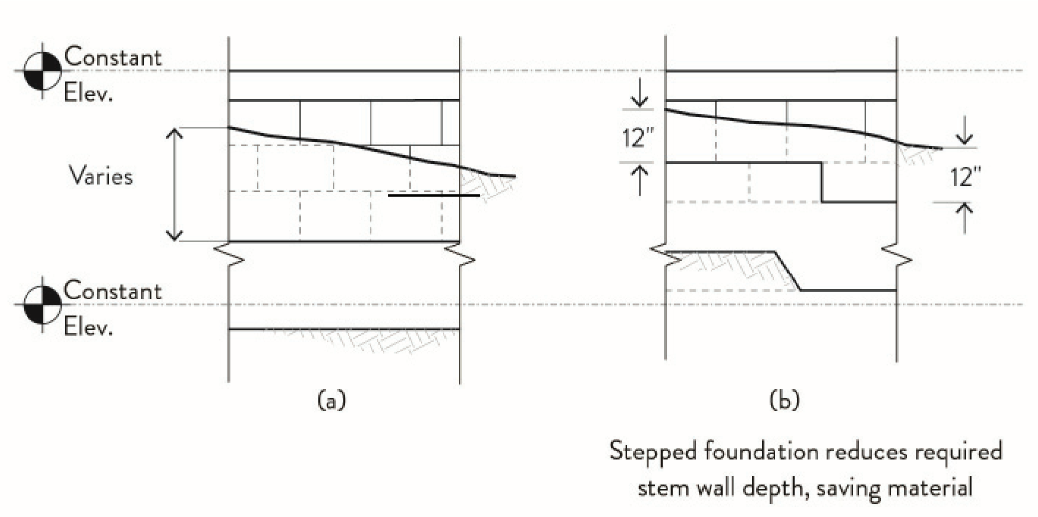
Figure 34.c. Continuous Foundation Detail Example - Type 1



Type 2) Stepped Spread and Continuous Concrete Footings

For a sloped site, cost should be considered before a system is selected. For example, if the slope of the finished grade is less than 2 feet. for a 30 foot long wall, a lower but constant bottom bearing footing with varied stem wall height may be more economical than a stepped footing. (a) For a very long wall, with only 1 ft., variation in site elevation will be more economical for stepped footing (b).

Figure 34.d. Stepped Foundation Applications



34.2.I. **Where continuous or spread concrete footings are required by construction documents, but are located on a sloped site, the footing must be stepped to a max 1:3 ratio.**

i. Refer to Figure 34.d. for a continuous concrete footing with a stepped condition.

34.2.J. **Footings must be stepped where the ground surface slopes more than 1 unit vertical to 10 units horizontal (10%). The bottom surface of footings is permitted to have a slope not exceeding 1 unit vertical to 10 units horizontal. The top surface of footings must be level.**

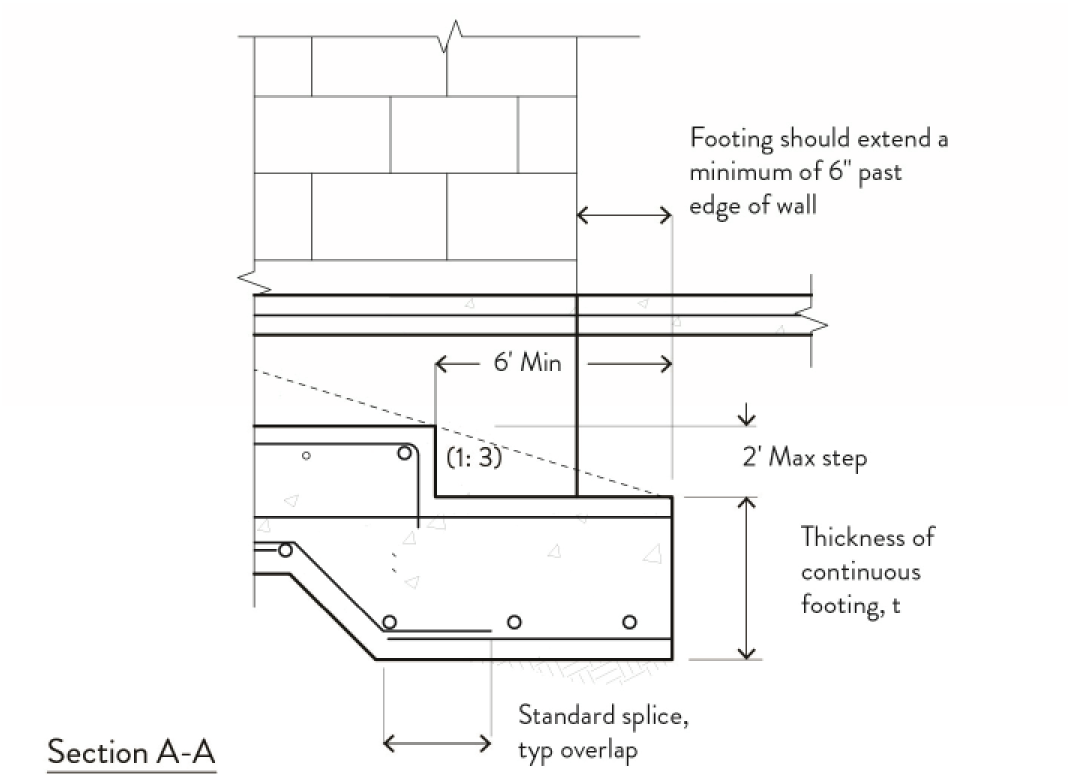
i. In a stepped footing, the vertical portion of the step must be of the same thickness and width as the horizontal footing and must be placed at the same time. If more than one step is necessary, the vertical step must not exceed 24in (60cm).

ii. The detail, (Figure 34.d.) may be used in conjunction with construction drawings as a guideline for the construction of a typical continuous footing with stem wall when a sloped site exists.

34.2.K. **Stepped footings shall follow the same general requirements of isolated concrete foundations.**

i. Refer to standards 34.2.A. - 34.2.G. for general requirements.

Figure 34.e. Continuous Stepped Foundation Detail - Type 2

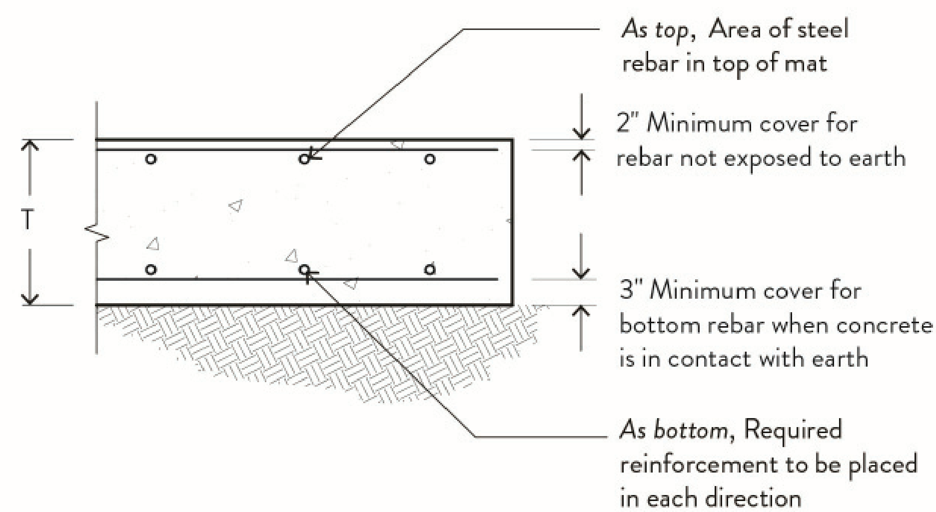


Type 3) Reinforced Concrete Mat

34.2.L. Reinforced concrete mat foundations must use minimum reinforcement in both top and bottom locations.

i. Refer to standard 34.2.B. for minimum reinforcement requirements.

Figure 34.f. Reinforced Concrete Mat Foundation – Type 3



34.3 Rubble Foundations

Rubble foundations with reinforced concrete cap beams may be used in the place of concrete where spread footings are required if crushed rock, crushed concrete or other rubble is present on site and soil bearing capacity permits. The width of rubble footings will need to be 16 in (400mm) if soil has a low bearing capacity.

If soil bearing capacity is strong enough to support rubble without increasing size greatly, this type of footing is a good low cost alternative. Rubble footings are cost effective if rubble, or crushed concrete, is available on or near the site due to reducing the amount of concrete required to build the footing. Rubble foundations also provide excellent drainage.

General Performance Requirements

34.3.A. Where a consolidated rubble foundation is required by construction documents, rubble must be compacted at 12in (30cm) lifts (vertical).

34.3.B. For a rubble foundation, the soil must be consolidated and prepped in accordance with site work requirements and recommendations before rebar or concrete is placed.

i. Refer to Chapter 33 for site work requirements.

34.3.C. Where a consolidated rubble foundation is used, special care must be taken to prevent erosion of adjacent grade. Erosion control and grading requirements must be followed.

i. Refer to Sections 32.5 and 32.6 for erosion control and grading requirements.

Type 4) Consolidated Rubble Continuous Footing

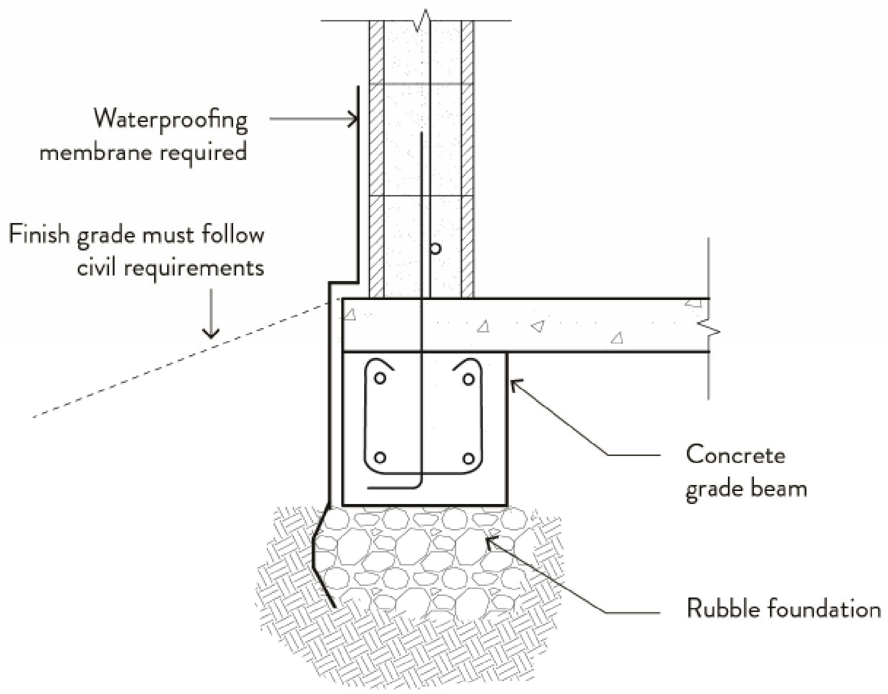
34.3.D. A continuous reinforced concrete grade beam must be constructed above all rubble foundations.

i. The reinforced concrete grade beam must be at least 10in (25cm) in depth and width.
ii. Reinforcing must be included per construction details. A minimum of (2) #4 bars, top and bottom must be used.
iii. All concrete cover for reinforcement requirements specified in 34.2.D. must be met.

34.3.E. Adequate waterproofing must be provided to protect against moisture damage of structure above grade.

i. A waterproofing membrane should be provided around rubble, and continue for 12in (30cm) above grade, to protect the structure from moisture damage.
ii. A filter fabric between the rubble and soil will help prevent silt from settling into voids between rubble and gravel. Silt will block the drainage of water over time.

Figure 34.g. Consolidated Rubble Foundation with Concrete Grade Beam Detail – Type 4



34.4 Foundation Finish Grade

34.4.A. All finish grade adjacent to new and existing facilities must be protected in accordance with Section32.6.

35 Walls and Columns

New healthcare facilities must be constructed to meet minimum standards in order for the building to remain structurally sound over its entire life span, thereby reducing the need for retrofit. Material baseline standards and specifications for construction including concrete masonry block mix design, and concrete mix design are established in respective Building Materials sections. Construction guidelines are further established for wall and column construction of various types herein.

35.1 Walls

Load bearing walls must have appropriate thickness to carry their material weight in addition to the weight of the building above them. The thickness and reinforcement required will depend on the type of building and number of stories supported by the walls.

Walls must be designed to prevent instability. There is a potential for collapse of the structure if load exceeds the strength of the material used, or if the wall is not adequately braced. Additionally, if walls are too tall, buckling may occur due to the slender geometry.

General Performance Requirements

35.1.A. Equipment, fixtures and other additional loading may only be attached to structural walls that are designed to accept the added load.

i. Major installations must be approved by the assigned IU representative.

35.1.B. If structural walls are not in the vicinity where equipment and fixtures are to be installed, the non-structural partition wall must be reinforced to accommodate the added load.

35.1.C. Structural wall surfaces must be free from open joints, cracks or crevices.

35.1.D. Wall penetrations and openings, such as windows and doors, must be properly sealed to protect against water, pests, and for reasons of infection control.

i. Refer to Standards 40.3.V. - 40.3.AA.for allowable lintel details.

35.1.E. Construction tolerances concerning maximum out of plumb dimensions must be met for all wall types to avoid instability.

i. Verify the vertical level of wall after each layer. Do not build more than 4ft (1.2m) height of masonry block wall per day.

ii. Refer to standards 35.2.F. and 35.2.J. for tolerances.

35.1.F. Wall slenderness, or height to thickness, ratios must be metered for all wall types according to Table 35.a.

Figure 35.a. Example Height to Thickness Ratios and Effects of Wall Slenderness

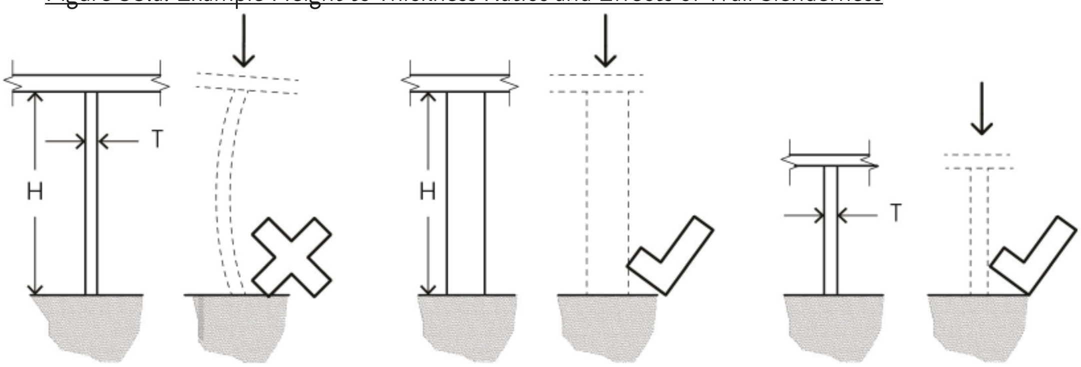


Table35.a. Minimum wall thickness requirements for common wall types

Wall Height[e]	Required Wall Thickness		
(ft)	Reinforced Concrete Wall[a,d] (in)	Reinforced Masonry Wall[b] (in)	Unreinforced Masonry and Confined Masonry Wall[c] (in)
8	6	6	6
10	6	6	8
12	6	8	10
14	8	10	12

[a] *Wall thickness assumes a concrete slenderness ratio of H/T, height of wall / thickness of wall = 25.*
[b] *Wall thickness assumes a slenderness ratio of H/T = 20 for reinforced masonry walls.*
[c] *Wall thickness assumes a slenderness ratio of H/T = 15 for unreinforced masonry and confined masonry walls.*
[d] *For Concrete Walls greater than 14ft (4.2m) in height and with more than one building level, wall reinforcement and thickness must be designed by an engineer.*
[e] *Wall height is measured for one story only*

Type 1) Masonry Walls

35.1.G. Mortar joints should be a minimum of ¼in (6.5mm) and maximum of ¾in (19mm) thick.

i. Where mortar joints exceed ¾in thick, high strength mortar should be selected, or
ii. Prism testing should be conducted to ensure wall meets expected design strength.

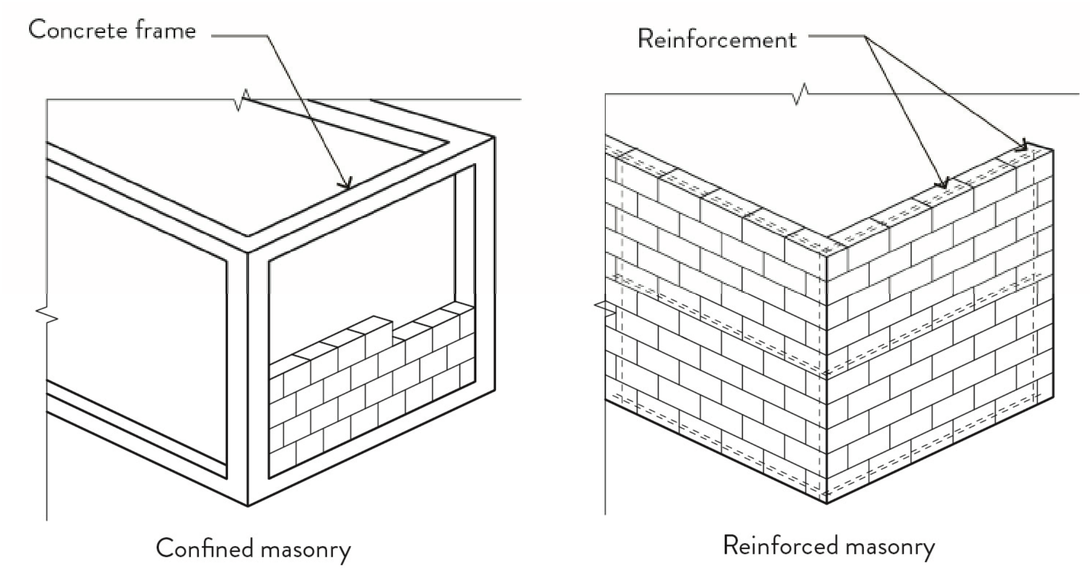
35.1.H. Mortar bed joints are permitted to vary by ±½in (13mm) maximum from level provided the joint does not slope more than ±¼in (6.5mm) over 10ft (300cm).

35.1.I. The dead weight of a masonry wall must be supported over an opening by a lintel.

i. Masonry lintels must be grouted and reinforced with a minimum of (2) #4 over the opening and extending a minimum of 24in(60cm) past the opening. Typical wall reinforcement should be used in the lintel above the (2)#4 bars. Typical for 3.5ft (1m) openings or smaller.
ii. Concrete lintels must be reinforced. Use a minimum of (2) #4 top and bottom in the lintel with #3 ties or vertical reinforcement with 12in(30cm) on center spacing. Typical for 3.5ft (1m) openings or smaller.
iii. Structural steel lintels must be galvanized, or have other protection, to reduce the possibility of rusting. Refer to Chapter 41 for structural steel specifications.

35.1.J. Masonry walls must be reinforced with vertical and horizontal reinforcement with fully grouted cells where reinforcement is located; or, walls must be confined using reinforced bond beams and columns.

Figure 35.b. Confined Masonry vs. Reinforced Masonry



Type 2) Confined Masonry Walls

35.1.K. Where bond beams and tie columns are used, maximum distance between reinforced confining columns is 12ft (3.65m). Tie columns should be placed at every wall intersection and adjacent to wall and door openings greater than 12in (30cm) square.

35.1.L. At a minimum, tie columns must be reinforced with (4)#3 bars over the entire column height with #3 ties spaced at 12in (30cm) on center when the tie column is at a wall intersection. Exception, vertical reinforcement in tie columns not at wall intersections and adjacent to windows or doors can be reduced to (2)#4 bars.

35.1.M. Reinforcement of confining column must be continued and doweled into foundation below and bond beam above the infill wall.

35.1.N. A bond beam must be placed at every floor level and roof, or a maximum vertical spacing of 12ft (3.65m).

35.1.O. At a minimum, bond beams must be reinforced with (4) # 3 bars over the entire beam length with #3 ties spaced at every 12in (30cm).

Type 3) Reinforced Masonry Walls

35.1.P. Where hollow masonry walls are required by construction documents for structural load bearing walls, the walls must be grouted in all reinforced cells.

i. Where possible, all cells, in addition to cells with reinforcement, must be grouted to provide maximum durability.

35.1.Q. Where grout fill is required in a hollow masonry wall, the masonry units with solid bottom face must be chipped to achieve a continuous grout fill.

35.1.R. The following minimum reinforcement requirements must be met:

i. Horizontal reinforcement, of at least 0.0007 x b x d, must be provided at the bottom and top of wall openings and shall extend 24in (60cm) past the opening. See figure 35.c. for "b" and "d" dimensions and example calculation.
ii. Vertical reinforcement of $0.2in^2$ ($1.2cm^2$) should be provided within 24in (60cm) of wall openings and wall edges. See Figure 35.e. for specified location.
iii. For walls greater than 14 ft. (4.2m) in height and with more than one building level, wall reinforcement and thickness must be designed by an engineer.
iv. For walls adjacent to window and door openings 3.5ft(1m) or less in width, or at free wall ends use a minimum of (2)#4 vertical reinforcement for the full wall height of the wall. Wall openings larger than 3.5ft(1m), should be designed by an engineer.

Figure 35.c. Rebar Placement in Masonry Unit

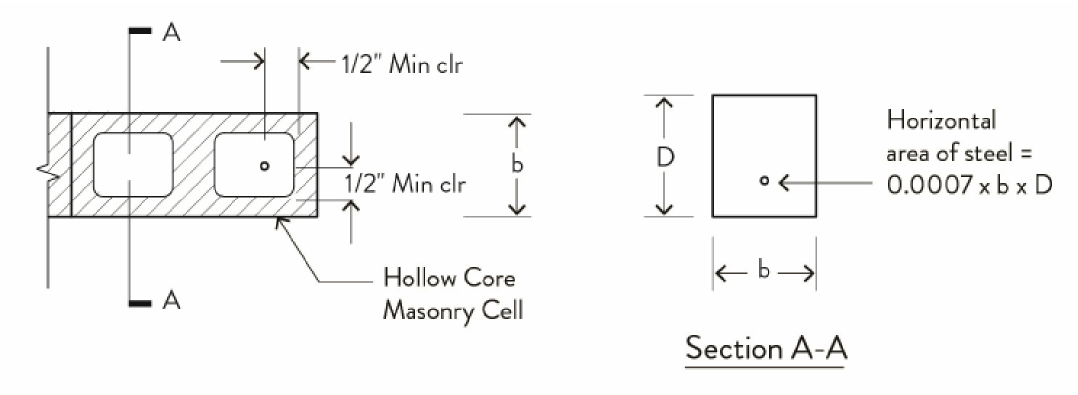


Figure 35.d. Reinforced Masonry Wall Detail

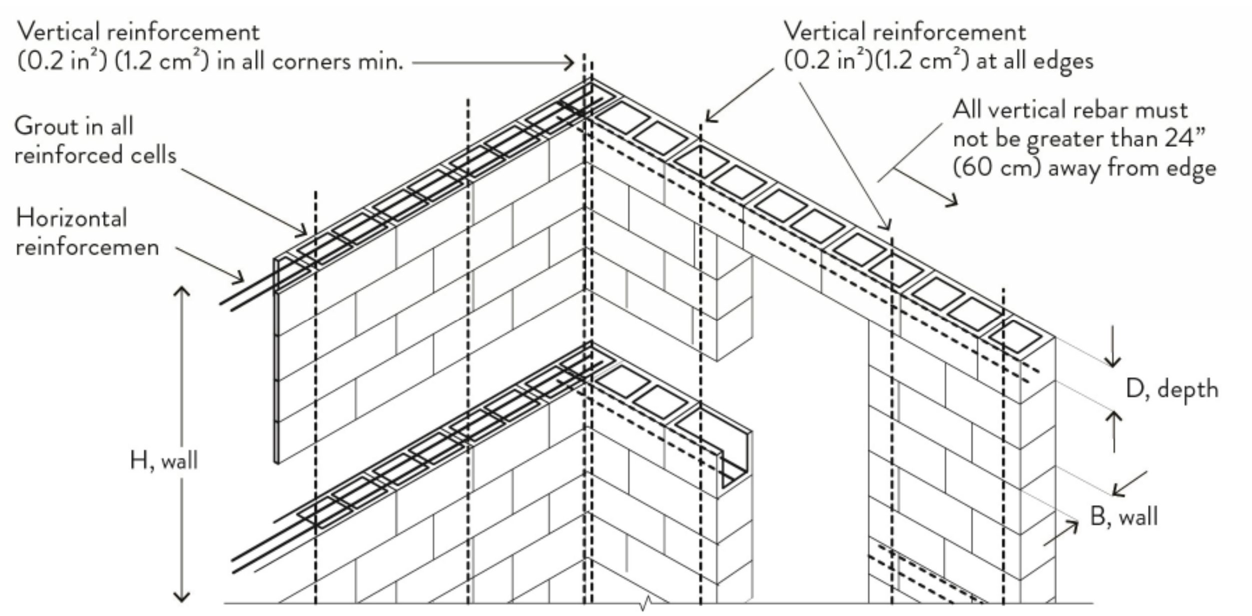


Figure 35.e. Masonry Tolerance

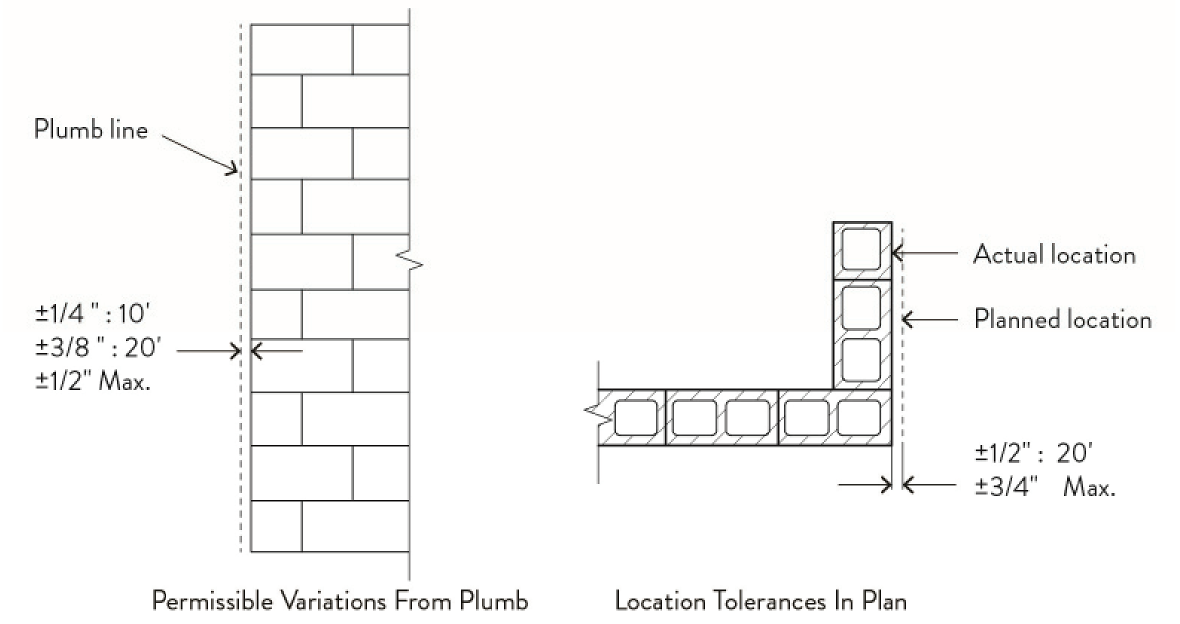
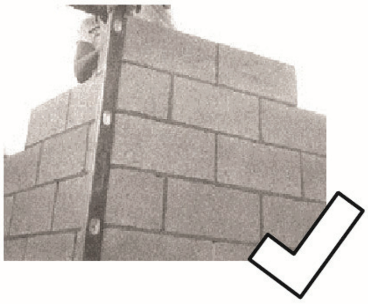
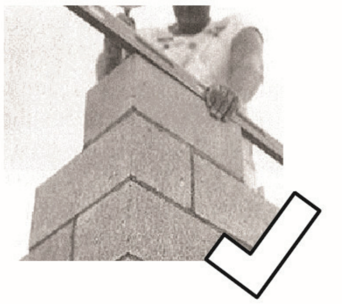


Figure 35.f. Methods for Maintaining Construction Tolerances





Reinforced Concrete Walls

35.1.S. Where reinforced concrete walls are required by construction documents, minimum slenderness requirements must be met. See Table 35.b. for minimum wall thickness.

35.1.T. Concrete walls must be reinforced to accommodate minimum temperature and shrinkage. See Table 35.b. for minimum reinforcement required for a given wall thickness.

35.1.U. Reinforcement must have a minimum concrete covering of 3/4in (20mm) for wall construction.

35.1.V. In any 10ft length of wall, lines and surfaces should remain within a±¼in (6.4mm) variation from plumb.

35.1.W. For standard splicing of reinforcement, refer to Standard 39.2.U. for requirements.

Figure 35.g. Reinforced Concrete Wall Detail

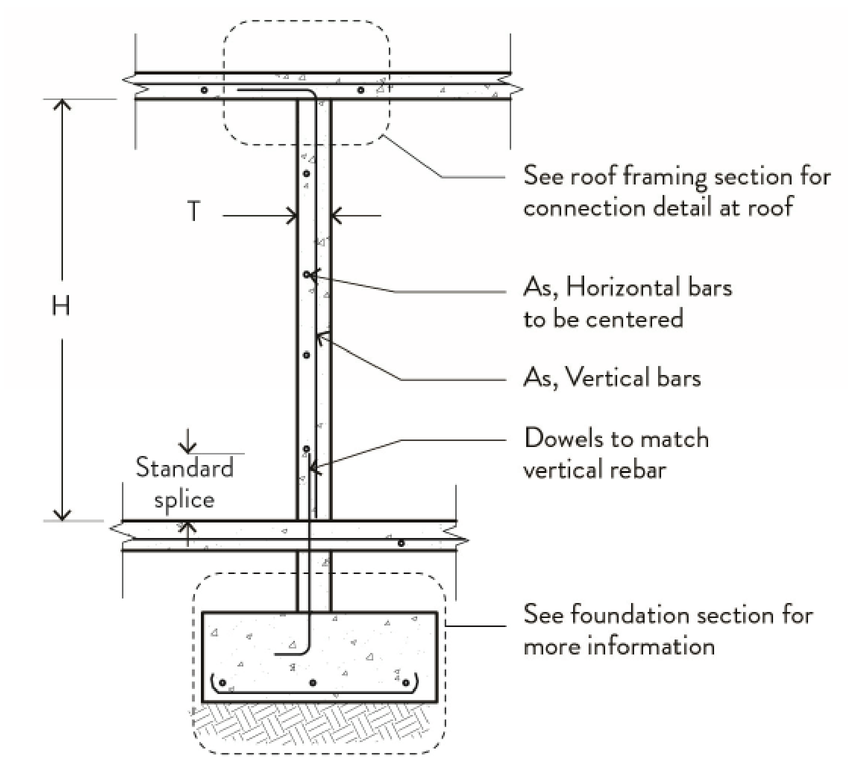


Table 35.b. Minimum Concrete Wall Thickness and Reinforcement

Wall Height (ft) [a]	Wall Thickness (in)	Minimum Reinforcement
8	4	#3 @ 12" spacing, vertical and horizontal
10	4	#3 @ 12" spacing, vertical and horizontal
12	5	#4 @ 16" spacing, vertical and horizontal -OR- #3 @ 10" spacing, vertical and horizontal
14	6	#4 @ 12" spacing, vertical and horizontal

[a] *For Concrete Walls greater than 14ft (4.2m) in height and with more than one building level, wall reinforcement and thickness must be designed by an engineer.*

35.2 Columns

Columns are commonly embedded within walls to transfer vertical loads. Also, column and beam construction may be used to transfer roof loads to the foundation where the building layout and program do not permit walls to be located. Similar to wall construction, columns are susceptible to instability based on height to thickness or slenderness ratios.

General Performance Requirements

35.2.A. Construction tolerances concerning maximum out of plumb dimensions must be met for all column types to avoid instability.

i. Refer to Standards 35.2.F. and 35.2.J. for tolerance details.

35.2.B. For all column construction, columns greater than 12ft (3.65m) and supporting more than one floor or roof level, columns must be designed by an engineer.

Concrete Columns

35.2.C. Where concrete columns are required by construction documents, minimum slenderness ratios must be met. See Table 35.c. for minimum column cross sectional area required to accommodate slenderness.

35.2.D. Concrete columns must be reinforced to accommodate temperature and shrinkage as a minimum. Refer to Table 35.c. for minimum steel requirements.

35.2.E. Reinforcement must have a minimum concrete covering of 1 ½in (40mm) for column construction.

35.2.F. The following plumb and cross-section tolerances must be met:

- Exposed corner columns for any 20 ft. (6m) of length: ±¼in (0.64cm)
- Exposed corner columns over entire length:±½in (1.3 cm)
- Variation in cross-section of columns and beams: ± ½in (1.3cm); - ¼in (0.64cm)

35.2.G. For standard splicing of reinforcement, refer to Standard 39.2.U. for requirements.

Figure 35.h. Reinforced Concrete Column Detail

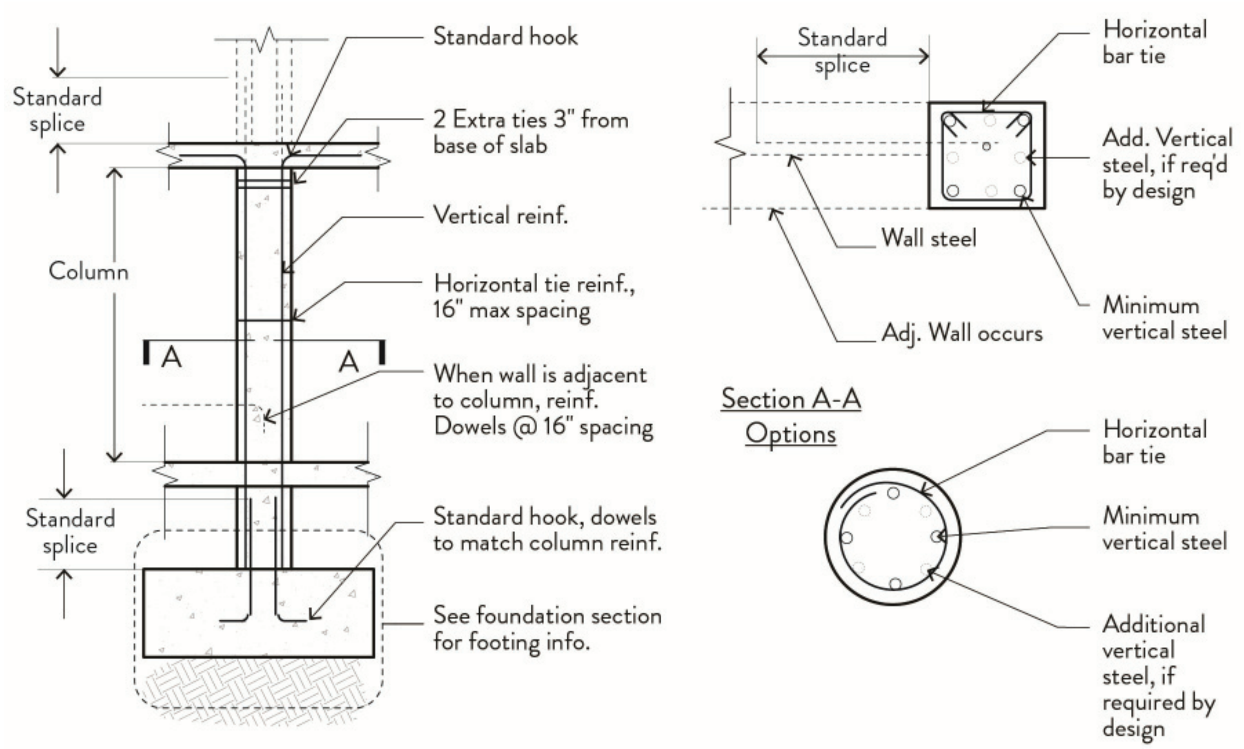


Table 35.c. Minimum Column Area and Reinforcement

Column Height[c,d] (ft)	Minimum Column Cross Sectional Area[a,e] (sq in)	Minimum Vertical ReinforcementArea[b] (sq in)
8	144	4.3
10	225	6.75
12	324	9.75

[1] *Cross sectional area is derived to accommodate the slenderness ratio kL/r < 22 for un-braced conditions, where effective length factor k =0.85.*

[2] *Minimum reinforcement for steel based on ratio 0.03*

[3] *For columns supporting more than one level, reinforcement and column area must be designed by an engineer*

[4] *For columns greater than 12 ft (3.65m), reinforcement and column area must be designed by an engineer.*

[5] *For all rectangular columns, where A=bxh, h must not be larger than 1.5x b*

[6] *Column cross sectional area and reinforcement may be decreased where specific condition is designed by an engineer.*

Steel Columns

35.2.H. **Where steel columns are required by construction documents, measures must be taken to protect steel sections from weather**

i. Refer to Standard 41.2.G. for finishing requirements

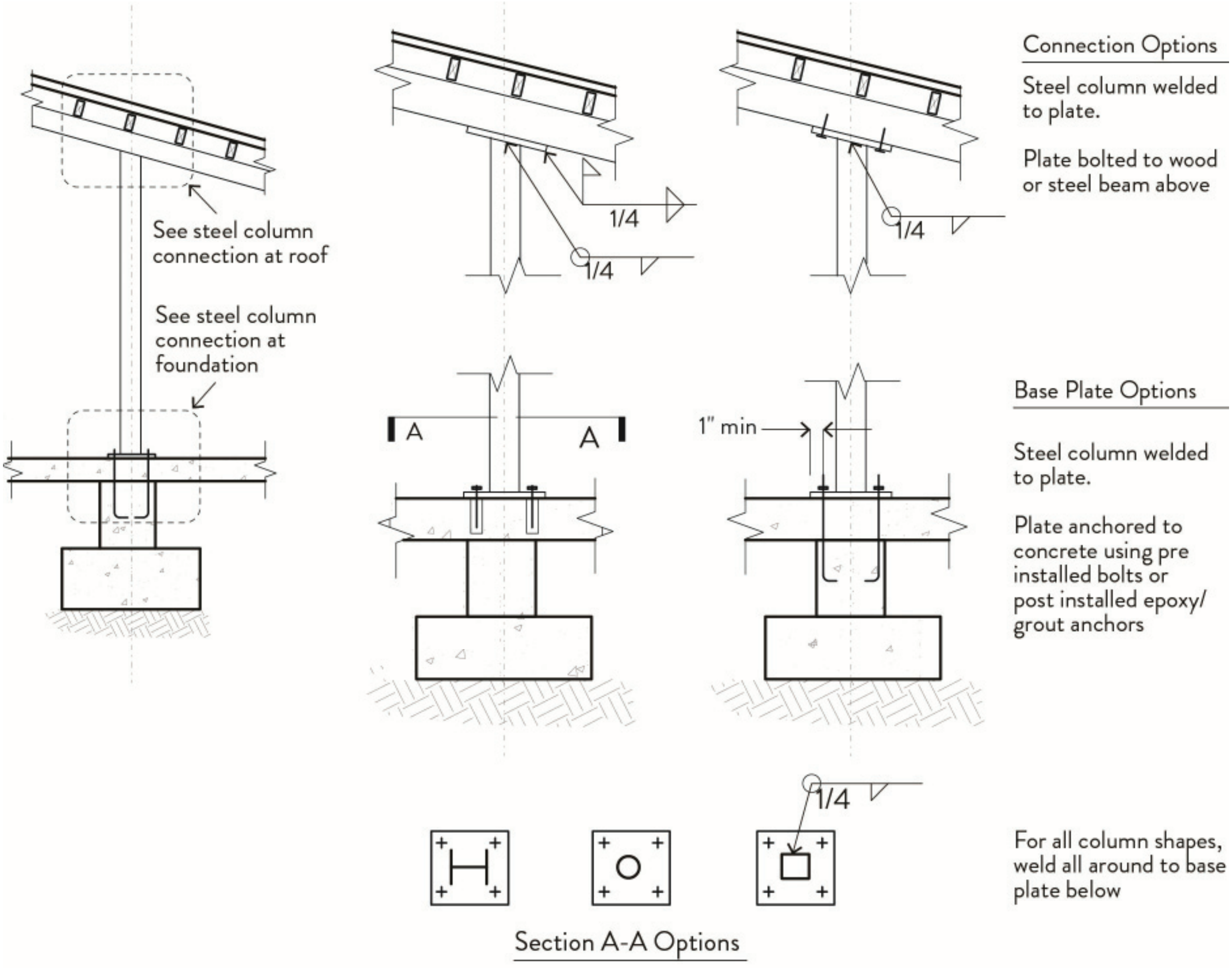
35.2.I. **Columns must be fastened to beam above and foundation below using welds or bolts.**

i. Refer to Figure 35.i. for details.

35.2.J. **The following steel construction tolerances must be met:**

- Perpendicular to building line: 1in (2.5cm) toward and 2in (5cm) away from the building with Max Height 200 ft. (61m).
- Parallel to building line: 2in (5cm) or less from the established column line with Max Height 200 ft. (61m).

Figure 35.i. Steel Column Connection Detail



36 Roof and Floor Framing

Roof systems with appropriate waterproofing and structural integrity are integrally related to the effectiveness of the facility. Due to the heavy rains and moisture in Liberia, material durability must be carefully considered for roof construction. Roof system failures lead to damage to structure, equipment, and ineffective ability to deliver services. Floor and roof systems also serve to tie the building together for lateral loads and should be designed for the forces specified. Attention should be paid to the interconnection of the floors and roof with the walls for lateral stability.

Material specifications and minimum performance criteria are stated herein, and shall be in accordance with Chapters 39 – 43 for the respective roof building components.

36.1 Roofing

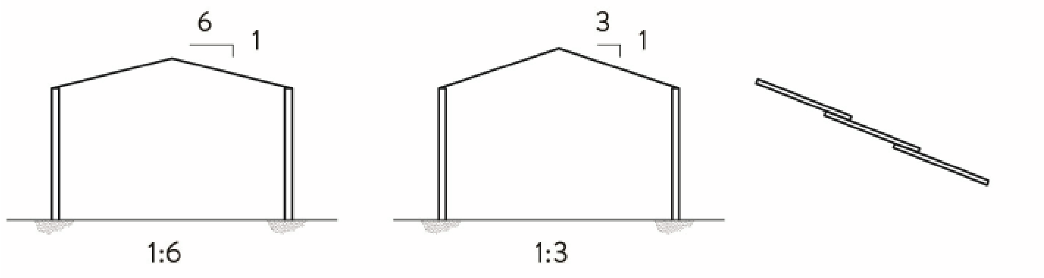
Because roof leakage is a major cause of damage to equipment and interiors, all roof types must be sealed.

General Performance Requirements

36.1.A. The minimum required slope for adequate drainage of various roofing types is indicated as follows:

- Corrugated, Overlapping Sheets 1:6
- Concrete and Clay Tile 1:3

Figure 36.a. Roof Slope



36.1.B. Any location where screws, nails, or various fasteners puncture the roof, water proofing sealant must be applied directly over the fastener. The Contractor must receive approval from assigned IU representative to use waterproofing methods not mentioned below.

i. Foil coated tape may be used to cover each screw or nail head location.
ii. Roofing cement may be used to cover each screw or nail head location.

Corrugated Metal Roofing

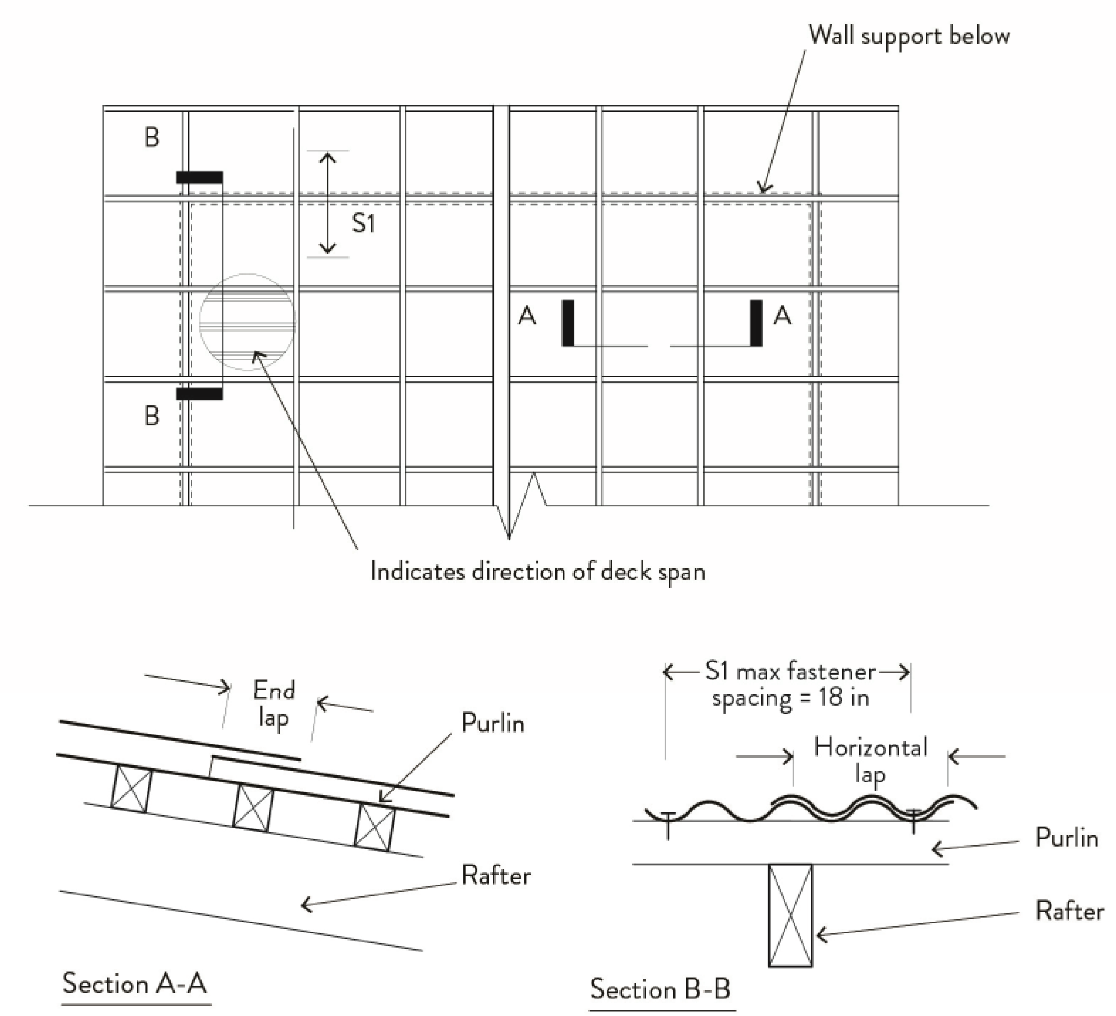
36.1.C. **Where corrugated metal deck / sheets are selected or required by construction documents, the roofing must be fastened at each purlin support.**

i. Metal deck panels must be fastened to supporting structure at regular intervals per manufacture and design specifications and within minimum guidelines. Refer to Figure 36.b.

ii. Metal deck panels from top slope must be overlapped and fastened above panel on lower slope.

iii. Pure aluminum panels (0.7mm thick) are recommended for use within 2 miles of the coastline to avoid weather damage.

Figure 36.b. Roof Deck Attachment Detail (Wood Framing)



36.1.D. **Corrugated metal sheet end laps must overlap a minimum of 12in (30cm). Sheets must be overlapped a minimum of two full corrugations.**

36.1.E. **Deck must be fastened along purlins (S1) a minimum spacing of 18in (45cm) on center.**

Miscellaneous Roof Panels

36.1.F. Where miscellaneous roof panels are required or an allowable substitution on construction documents, the panel must be waterproofed at each attachment to roof framing support.

i. Product specifications must be approved by the assigned IU representative.
ii. Roof panel span and joist spacing must be determined by product requirements.

36.1.G. Roof panel end lap must overlap a minimum 12in (30cm). Sheets must be overlapped a minimum of two full corrugations.

Clay or Concrete Tile Roofing

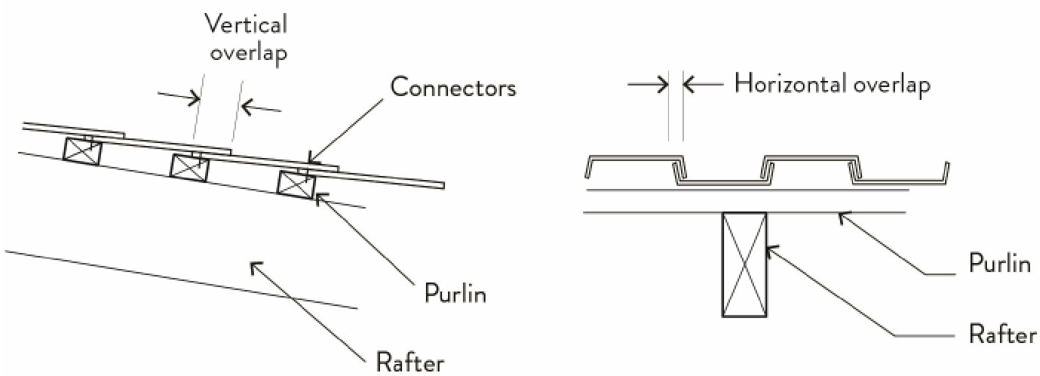
36.1.H. Roof pitch must be adjusted to accommodate tile construction and still provide adequate drainage.

i. Refer to Standard 36.1.A. for minimum roof pitch requirements.

36.1.I. Roof framing, beam and joist size and spacing, must be checked for adequacy by the assigned IU representative to accommodate heavy tile material.

36.1.J. Adjacent tiles must overlap a minimum 2in (5cm).

Figure 36.c. Roof Tile Attachment Detail



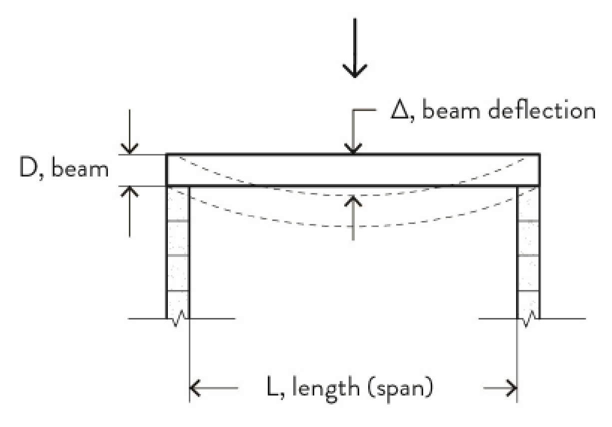
36.2 Floor and Roof Framing

Roof framing must be appropriately sized to prevent sagging, and appropriately spaced to receive roof fastening.

General Performance Requirements

36.2.A. Roof girders and rafters must remain within deflection limits. For simple span beam elements, deflection limit should be less than L/240.

Figure 36.d. Deflection Limit Ratios



Deflection:

The excessive deflection of wood beams and purlins over time will result in cracking of applied finishes and can damage structural connections, leading to failure of waterproofing seals, structural failure or collapse.

36.2.B. All roof framing must be attached to support walls, trusses, or beams.

i. For load to transfer, framing must be fastened with nails or screws.

ii. Regular fastening of structure must be used as it will prevent movement and instability under vertical and lateral loading such as high wind.

Wood Framing

36.2.C. Wood purlins and rafters supporting the roof deck must be fastened to supporting structure.

36.2.D. Wood purlins and rafters must not be used as framing if damaged or bowed prior to installation.

i. Refer to Chapter 43 for further material information and specifications.

36.2.E. Wood purlins must be protected against termite and moisture damage.

i. See Standard 43.3.I. for termite protection details.

36.2.F. In order to create a continuous load path; the wood roof framing must be connected to supporting walls or beam structure.

i. For span distances exceeding single lengths of wood, refer to standard 43.3.C. for splicing requirements.

Figure 36.e. Wood Roof Framing Connection Detail

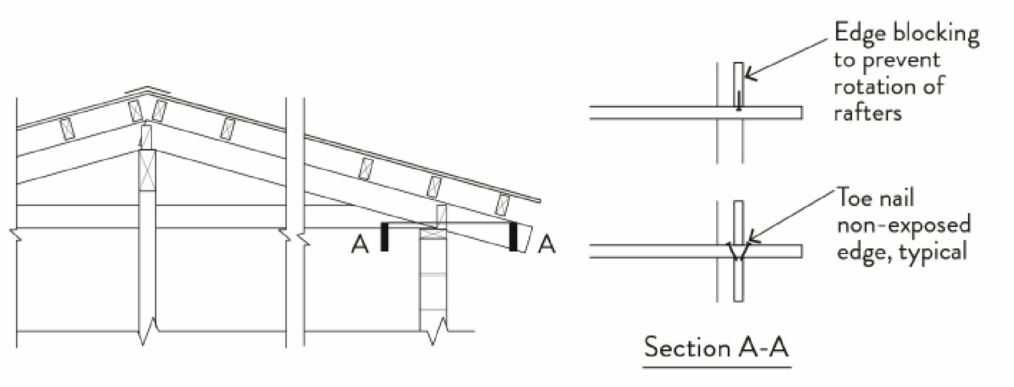


Table 36.a. Allowable Roof Beam Spans[3]

Beam Span (ft)	Minimum Depth[1,2] (in)
6	7.5
8	10
10	12.5
12	15

[1] *Minimum depth assumes a 2in (50mm)wide beam.*
[2] *Minimum depth required for given span assumes* kusia *wood type.*
[3] *Maximum beam spacing assumes 6ft (1.8m).*

Steel Framing

36.2.G. Steel purlins or other steel roof framing required by construction drawings must be fastened to supporting structure.

36.2.H. Steel framing must be adequately protected against damage due to weather.

i. See Chapter41 for further material information and specifications on steel.

Figure 36.f. Steel Roof Framing Connection Detail

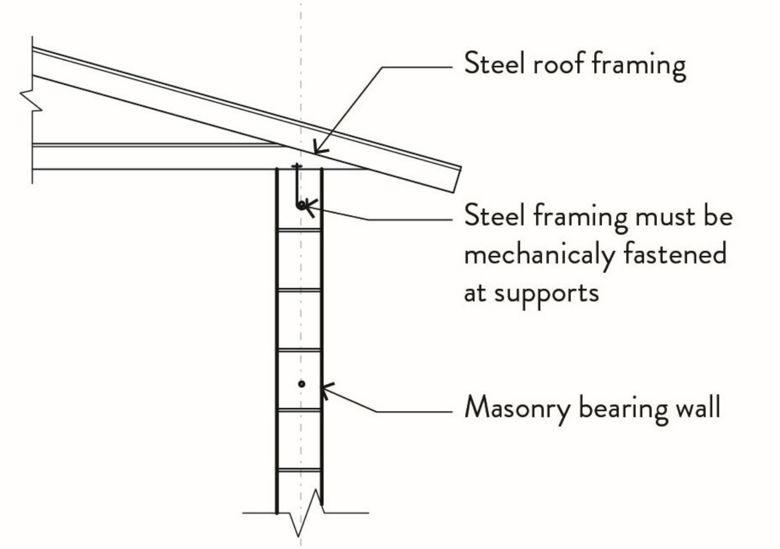
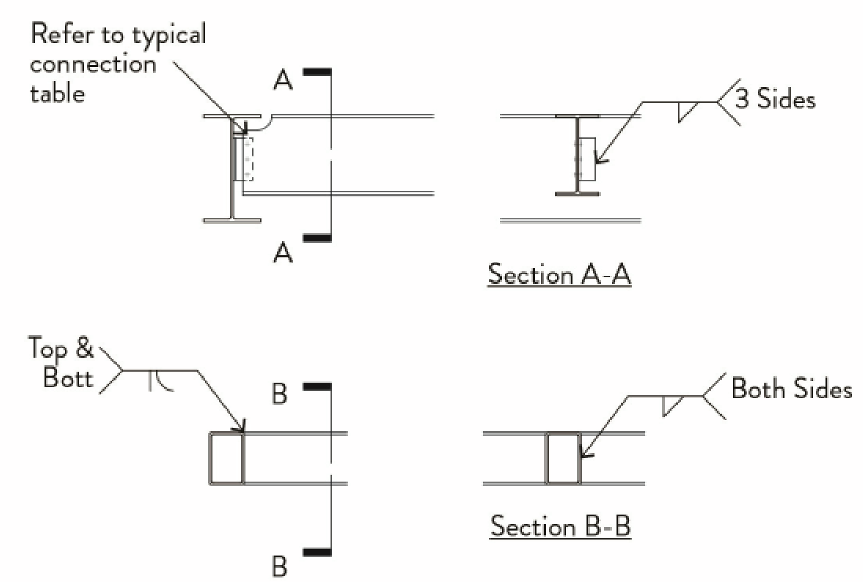


Figure 36.g. Typical Steel Beam Connection Details



Concrete Framing

36.2.I. Where concrete slab and beam framing are required on construction documents, minimum reinforcement ratios must be met.

Table36.j. Minimum Reinforcement for Concrete Beam or Slab

Beam or Slab Depth (in)	Minimum Reinforcement Area per foot of width[b] (in^2)
5	0.11
6	0.13
8	0.17
12	0.26

[a] *If slab depth is not directly listed on table, minimum reinforcement quantities may be interpolated.*
[b] *Minimum reinforcement quantity is based on the following ratio:*
Area of steel: Area of concrete > 0.0018.

36.2.J. Where bars are not long enough for framing geometry and must be spliced, the minimum bar splice length respective to bar diameter must be met.

36.2.K. Minimum concrete cover of reinforcement bars for beams, slabs and columns must be verified prior to placing concrete.

i. Slabs (not exposed to weather): Minimum distance from edge of rebar to edge of concrete = ¾in (2cm)
ii. Slabs (exposed to weather, such as roof slab): Minimum distance from edge of rebar to edge of concrete = 1 ½in (4cm)
iii. Beams: Minimum distance from edge of rebar to edge of beam = 1 ½in (4cm)

36.2.L. Concrete mix design for various framing elements must be in accordance with Chapter 39 requirements.

36.2.M. Bar placement and splice length must follow Figures 36.h. and 36.i.

Figure 36.h. Concrete Beam Elevation

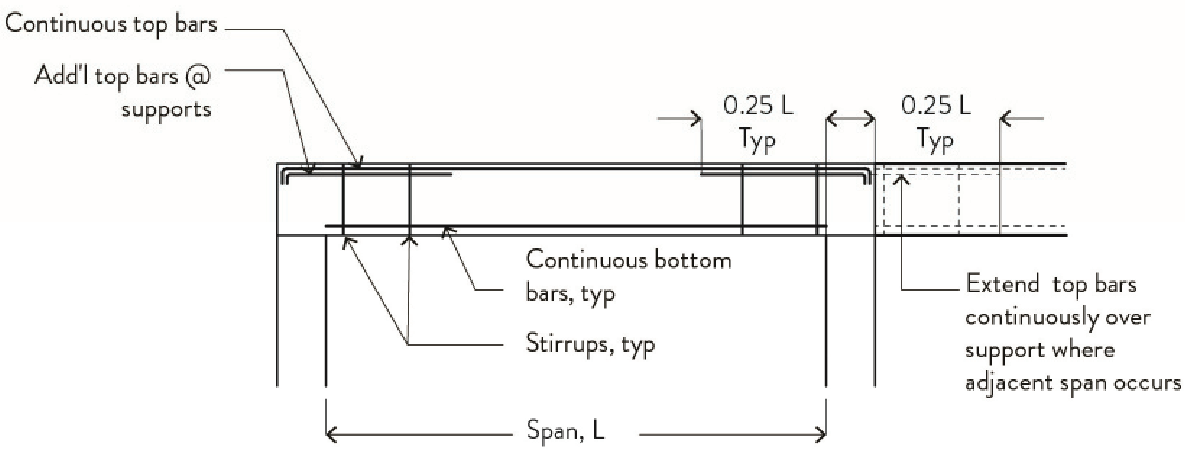
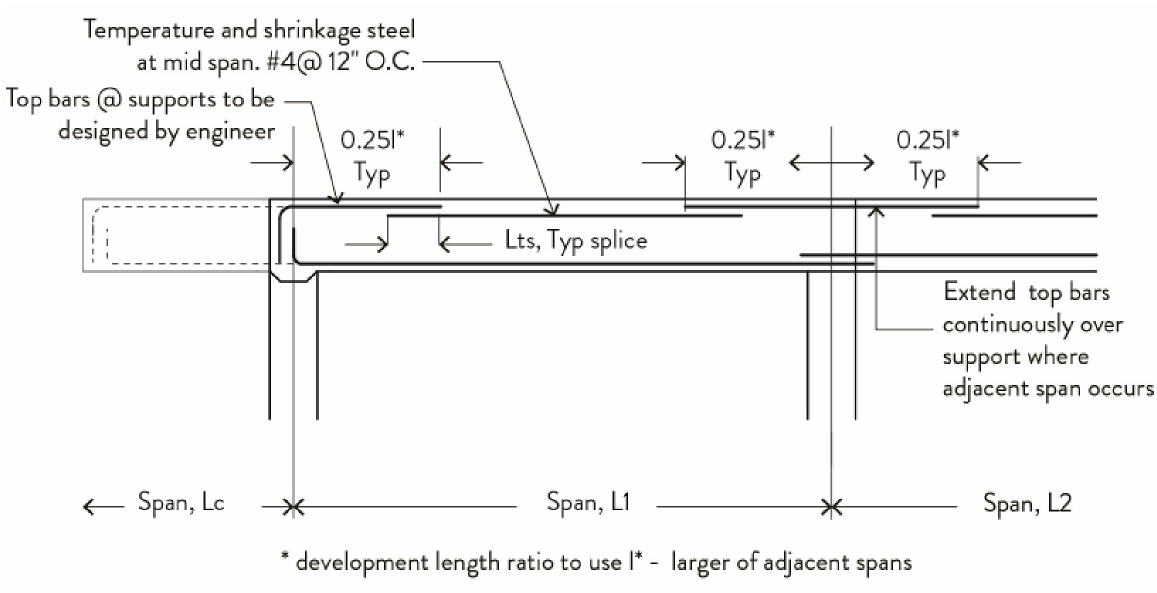


Figure 36.i. Typical Elevated Slab Section

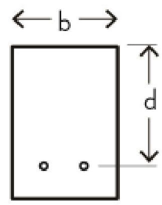


36.2.N. Concrete beam or slab thickness must meet minimum span to depth requirements as specified in Table 36.m.

i. Refer to Figure 36.j. for span to depth locations.

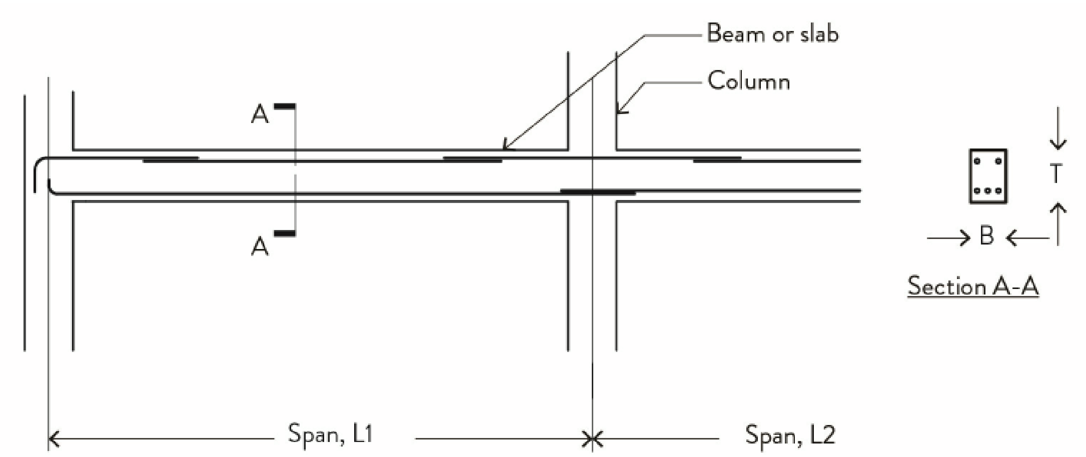
Table 36.m. Required Slab and Beam Thickness (*t*) Ratios

	Minimum thickness, t		
	Cantilever	Exterior Span	Interior Span
Member	Members not supported or attached to partitions or other construction are likely to be damaged by large deflections		
Solid 1-way Slabs	L/10	L/20	L/24
Beams	L/8	L/16	L/18.5



[a] *The width, b, of a rectangular beam should be between 1/3 and 2/3 of the effective depth, d. Effective depth, d is equal to the distance from centroid of steel group to the outermost compression fiber.*

Figure 36.j. Concrete Beam and Slab Span



37 Renovation & Expansion

Even though the retrofit and renovation of existing structures is generally not recommended due to cost ineffectiveness over time as well as limitation on achieving performance standards, this practice is common due to funding limitations. For effective facility performance and maintenance, building and facility assessments should take place on a regular basis. Refer to Chapter 7 Project Planning for established performance requirements. Once a facility has been assessed and renovation or expansion is required, the following standards and practices should be followed.

37.1 General Renovation Practices

The following general best practice guidelines and standards are provided to ensure appropriateness and longevity of renovations to existing facilities.

Floors

37.1.A. In facilities with damaged or non-structural floors, a new structural concrete slab must be installed over properly compacted blinding in order to meet the requirements of 36.2.I.

i. Elevated structural slabs must be of minimum 12 in (30cm) thick or as sized by a structural engineer. Structural slab on grade must be a minimum of 6 in (15cm) thick or sized by a structural engineer.
ii. Structural floors must meet all requirements listed in Standard 36.2.I.
iii. Floors may be considered damaged if large cracks, sinkholes, or fissures are visible.
iv. Care must be taken to plan for the floor finishes according to Section 44.2.
v. When adding new floors, care must be taken to maintain handicap access when transitioning between different elevations of surfaces.

37.1.B. In facilities with substandard floor finishes but intact structure (as verified by the assigned IU representative), a new concrete screed of minimum 3in (75mm) thick may be poured over existing subfloors.

i. Floor finishes must meet all requirements listed in Section 44.2 and have sufficient load capacity to support added fill.

Walls

37.1.C. Upon renovation, significantly damaged walls must be dismantled to below the height of the damaged area and rebuilt only after inspection of the remaining wall and approval by the assigned IU representative.

i. Significant damage may be interpreted as: any cracks larger than 1" (25mm) in width; cracks larger than 1/4" (6mm) in width and 24" (60cm) in length; exposed eroded depressions more than 3" (75mm) deep relative to the finished wall surface; visible water damage from the interior, or other noticeable material decay.
ii. Any supporting structure or framing must also be inspected by the assigned IU representative and assessed for structural integrity.

37.1.D. If re-plastering of walls is in order, it must only be done after removal of all paints or applied finishes and preparation of a textured surface for plaster to adhere to.

i. Removing existing plastering to reach the base material beneath before re-plastering is recommended.
ii. Wall finishes must meet all requirements in Section 44.3.

37.2 Structural Renovation

Some facilities that have experienced damage or severe weathering may require structural strengthening. During the renovation process, care must be taken not to damage existing structure that is to remain. The following standards are intended to ensure structurally sound connections between the new and existing structure occur.

37.2.A. Non-structural walls may be removed to accommodate new layout.

i. Walls must be verified as non-structural by the assigned IU representative, provided they are not continuous to underside of roof framing beams or trusses- walls continuous only to ceiling are not typically load bearing.

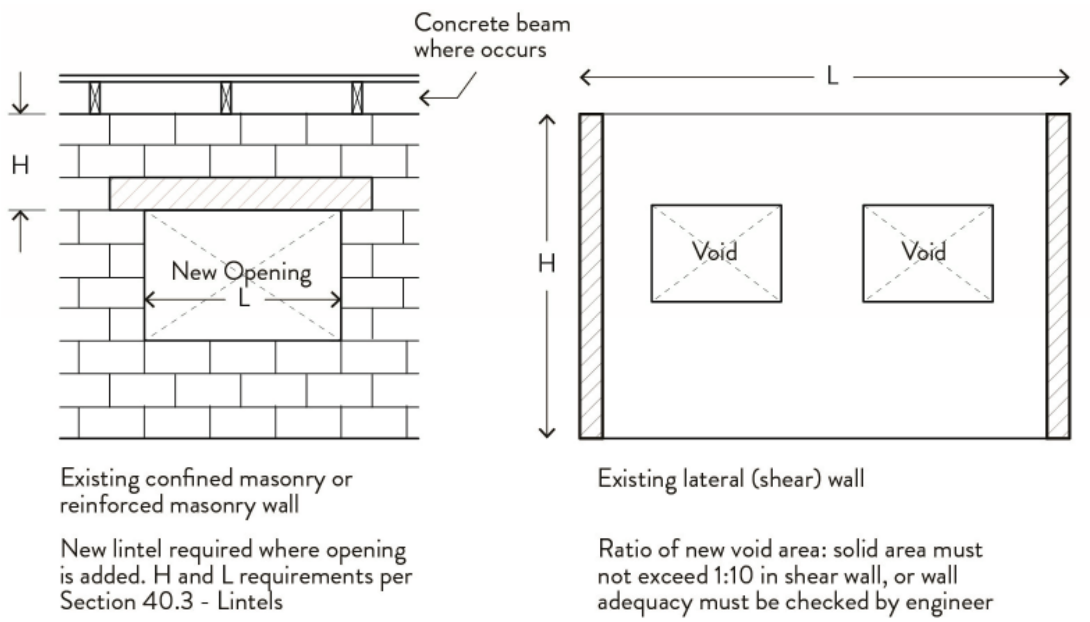
ii. The assigned IU representative must verify if wall is acceptable to remove prior to construction.

37.2.B. New openings added to non-structural or structural walls must be approved by the assigned IU representative prior to construction.

iii. Openings must not be placed near edges, or top of walls to avoid disrupting wall confinement.

iv. Acceptable opening placements, pending engineer approval for project specific requirements, are demonstrated in diagram below.

Figure 37.a. New Opening Placement in Existing Structure Example



37.2.C. Exterior structural walls must not be removed without approval of the assigned IU representative.

i. If load-bearing walls are removed, the wall(s) must be replaced with a beam that has been designed by an engineer to distribute loads to new structure. A continuous load path must exist from new beam down to foundation.

ii. If lateral (shear) walls are removed, the wall(s) must be replaced with a frame that has been designed or approved by an engineer to distribute lateral loads to the structure. The assigned IU representative must verify the change in lateral load path does by not decrease the overall strength or stiffness of the building.

37.3 Structural Expansion

Some facilities may require the expansion or addition to an existing structure. During expansion, care must be taken not to damage existing structures. The following standards are intended to ensure structurally sound connections between the new and existing structure occur.

37.3.A. **Additional levels must not be built above an existing building level unless new loads on existing wall and foundation construction is verified by a structural engineer and approved by the assigned IU representative.**

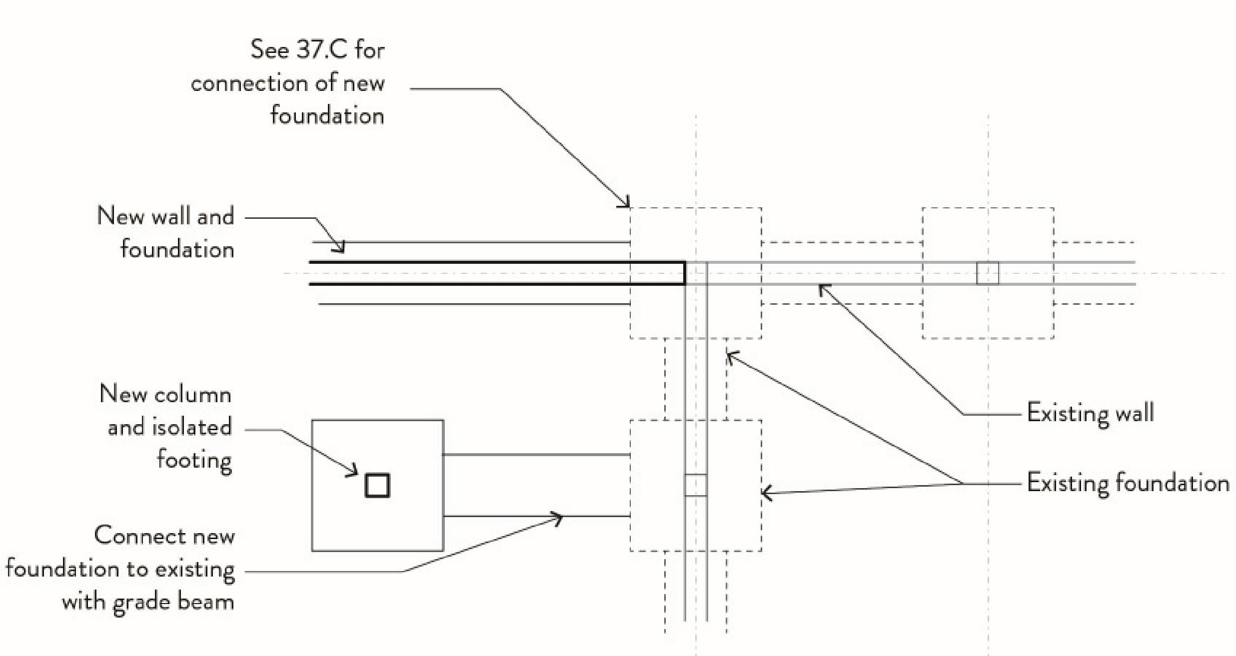
37.3.B. **All new structure must have adequate foundations that are tied back the existing structure.**

i. New construction must follow guidelines as referenced in Chapter 34.
ii. In order to prevent uneven building settlement, new foundations must be of equal or greater depth than existing foundation.
iii. Minimum reinforcement must tie new and old foundation together. Refer to Figure 37.b.

Construction Note:

When new footings are placed parallel and adjacent to existing footings, the footings should be of equal depth to prevent the new footing construction from undermining the existing footing. If the new footing is required to be deeper than the existing footing, the existing footing should be properly underpinned and stabilized by shoring during construction by the contractor to prevent settlement of the existing structure.

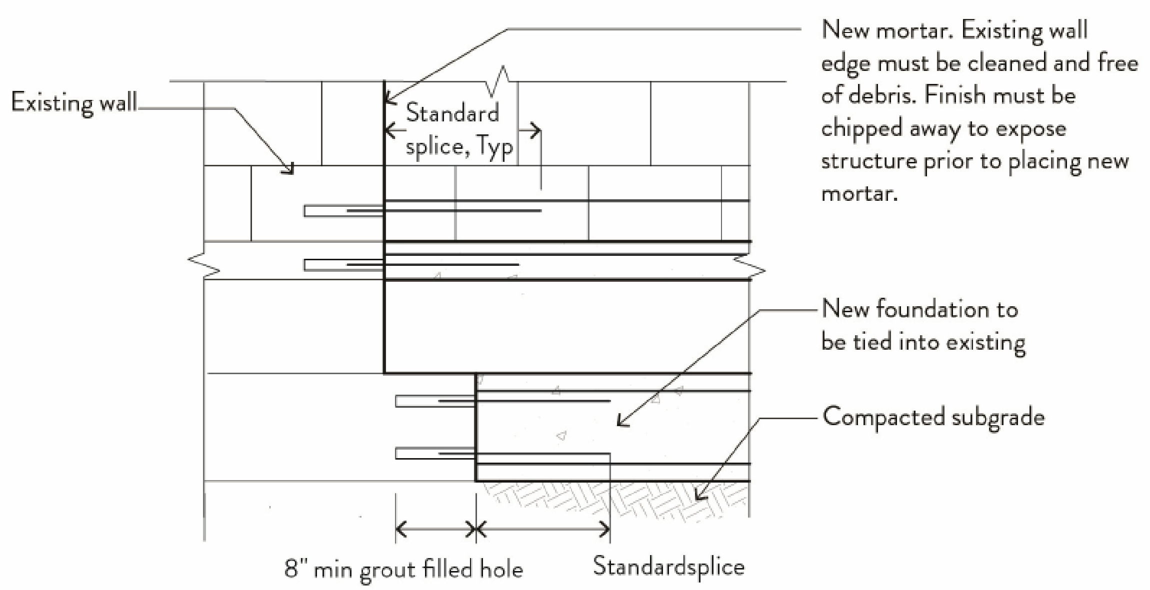
Figure 37.b. New Foundation Placement Example



37.3.C. Additional walls and their foundations must be tied into existing structure.

i. New construction must follow guidelines and standards as referenced in Chapter 35.
ii. Any re-working of walls must comply with Standards 37.1.C. and 37.1.C.
iii. New reinforcement dowels must be embedded in grouted hole of existing structure and lapped with reinforcement of new structure. Refer to Figure 37.c.

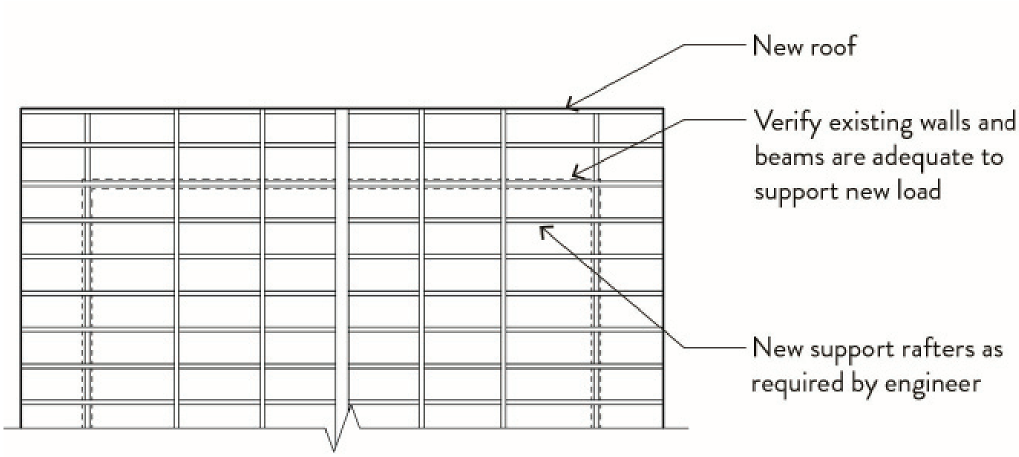
Figure 37.c. New Construction Connection to Existing Structure



37.3.D. Any additional roofing added to a building must be supported on new beams.

i. New construction must follow guidelines and standards as referenced in Chapter 36.
ii. Where new roofing material is added on an existing roof, the assigned IU representative must verify existing structure is adequate to support the new load; otherwise, new beams must be used to support the additional load.

Figure 37.d. New Framing Load Path

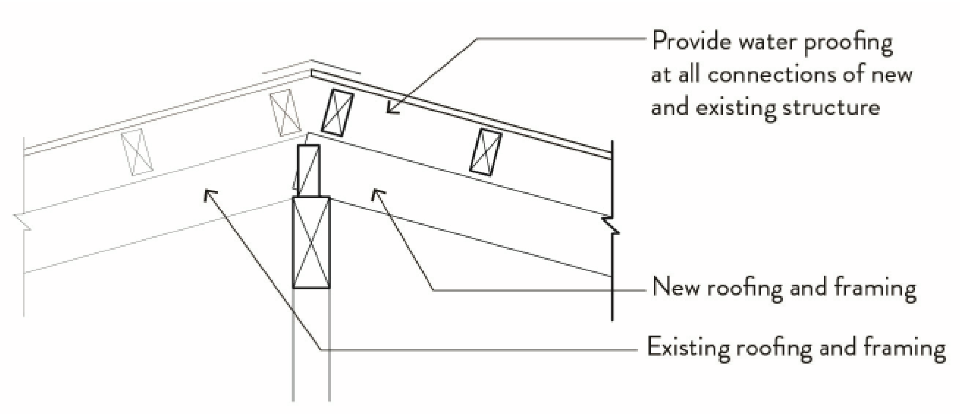


37.3.E. Waterproofing must be made continuous across new and existing building joints.

i. New construction must follow the standards referenced in Chapter 36 for roof water proofing examples and guidelines.

ii. All locations where new construction interfaces with existing building conditions, a continuous water proofing seal must be provided.

Figure 37.e: New Roof Construction Connection to Existing Building



37.3.F. New equipment must not be mounted on an existing wall or roof without the approval of the assigned IU representative.

37.3.G. Because existing wall construction might not be adequate to accept a new lateral (side) load, the new equipment must be either mounted to new grouted and reinforced wall, or the existing wall must be strengthened with pilaster supports. Pilasters must be continuous over entire length of wall and fastened to structure above and below.

37.3.H. New equipment must be placed only on new framing that has been designed to support the operating load.

i. In order to mount equipment on an existing roof, new roof beams and purlins must be added directly below attachment points. Appropriate beam and purlin size is dependent upon equipment weight and roof span. The assigned IU representative must approve equipment placement and purlin and rafter design.

ii. After structural support has been approved care must be taken not to compromise the existing weatherproofing during mounting of additional equipment on the roof or structure. New weatherproofing must be added at all attachment points.

MATERIALS & WORKMANSHIP

CONTENTS

IMPACT

The implementation of designs requires skilled labor inputs and rigorous standards of both materials to be used and workmanship of those materials. Building longevity, maintenance minimization, and even clinical hygiene are affected by the materials used and their construction or installation. These chapters presents standards to help ensure quality construction across common materials in Liberia.

An often overlooked impact of design is the environmental and economic impacts of material selection, material sourcing and labor which can infuse capital into local economies. Thus, these Chapters assist in making determinations to maximize local impact as well as ensure building quality

PRIMARY USERS

Infrastructure Unit

Architects & Designers

Structural Engineers

Contractors

GUIDELINES FOR USE

The data charts presented in Material Selection show performance areas of a variety of acceptable building material. They read from left to right, with the left-most indicators being the most desirable within that indicator. These are by no means the only materials available for construction but should be taken as suggested building materials, unless other materials are agreed to in a particular case as discussed and approved by the Infrastructure Unit. The designer of health facilities should, however, use similar criteria for selecting alternative materials.

Once materials are chosen, the following Chapters should be taken as minimum specifications for use. These Chapters are divided into Sections of General Requirements, Products, and Execution, which may be used for spec writing and construction procedures.

38 Material Selection

Allowable materials have been carefully chosen in developing these standards to balance a wide variety of factors, including durability, ease of construction, potential for local sourcing and economic impact, ecological sustainability, and performance for health-based outcomes. Various performance indictors across ecological, environmental, economic and social impacts have been analyzed and compared when choosing the materials. No particular material performs best in all the indicators, but the listed materials are acceptable provided all other material and construction standards are met. Ultimately, a balance must be struck - using the conditions and particularities of the project as a guide - between the performances of building materials across all factors.

The data charts presented here show the performance of a variety of acceptable building materials, and read from left to right, with the leftmost indicators being the most desirable within that indicator. These are by no means the only materials available for construction but should be taken as strongly suggested building materials, unless other materials are agreed to in a particular case as discussed and approved by the Infrastructure Unit. The designer of health facilities should, however, use similar criteria for selecting alternative materials.

Definitions

- **Carbon footprint:** A measure of the total amount of carbon dioxide (CO_2) emissions per unit of material production/use.
- **Longevity:** Expected useful/performance life
- **Renewable materials:** Raw materials can be regenerated through natural processes (such as wood).
- **Thermal resistance (R-value):** A measure of a material's ability to prevent heat gain or loss and preserve constant temperatures.

38.1 Performance & Maintenance

One of the chief factors in material selection is its ability to perform for predictable conditions in Liberia. Major factors include durability, resistance to water damage, and thermal properties to ensure a healthy and comfortable building environment.

Performance Factors

38.1.A. **Materials with high thermal resistances for walls and roofs must be prioritized to maintain thermal comfort, especially in areas directly exposed to the sun.**

i. Refer to Table 38.a. as a reference for R-values of common materials.[1] Resistance will vary with thickness, and in this chart the following typical thicknesses have been inferred and are represented by the data:

- Concrete, masonry and stone walls are listed assuming an 8in (20.3cm) thickness.
- Cement plaster is listed assuming a 1in (2.5cm) parge.
- Cementitious fiberboard and plywood are listed assuming a 3/4in (1.9cm) thickness.
- Gypsum board is listed assuming a ½in (1.3cm) thickness.
- Wood is listed assuming a 1in (2.5cm) clapboard.
- Bamboo is listed assuming a ¾in (1.9cm) thick lapped paneling.
- Metals are listed assuming 26 gauge sheeting.
- Glass is listed assuming a 4mm pane.

Table 38.a. R-values for Common Building Materials at common thicknesses

	VERY HIGH (R >5.0)	HIGH (R = 1.0-5.0)	MODERATE (R = 0.5-1.0)	LOW (R = 0.1-0.5)	MINIMAL (R< 0.1)
Reinforced Concrete				X	
Concrete Masonry		<----X---->			
Stone			X		
Baked Clay Masonry		<----X---->			
CSEB	X				
Cement Plaster				X	
Cementitious Fiberboard		X			
Gypsum Board		<----X---->			
Plywood			X		
Wood		<----X---->			
Bamboo			X		
Structural Steel					X
Aluminum					X
Hard Plastics					X
Glass			<----X---->		

Thermal Resistance (R-values)

Thermal resistance (R) measures a material's ability to prevent heat gain or loss and preserve constant temperatures. A higher R-value indicates a greater performance in this regard. R is measured through testing as: $(^{\circ}F)(ft^2)(h)/(Btu)(in)$ where $(^{\circ}F)$ is the temperature change in Fahrenheit, ft^2 is the surface area of the material, h is the time in hours, (Btu) is the energy applied, and (in) is the thickness of the material.

R-value ranges depend on material qualities such as density, hollowness, and coatings. Effectiveness as a measurement of thermal resistance also depends on exposure to wind, moisture saturation, and precision of installation. Soft materials are generally more susceptible to fluctuations in thermal resistance than solid materials.

38.1.B. Materials resistant to water damage must be used in all exterior areas and in sterile and/or sanitary spaces.

i. Refer to Table 38.b.as a reference for resistivity to water damage. However, there is no precise measurement for this property, and performance will depend greatly on finishes, exposure, and maintenance. Therefore, this should be used as a guide but not a definitive measurement.

Table 38.b. Resistance to Water Damage of Common Materials

	VERY HIGH	HIGH	MODERATE	LOW	VERY LOW
Reinforced Concrete		X			
Concrete Masonry		X			
Stone	X				
Baked Clay Masonry			X		
CSEB				<----X---->	
Cement Plaster		X			
Cementitious Fiberboard		<----X---->			
Gypsum Board				X	
Plywood				X	
Wood				X	
Bamboo					X
Structural Steel		X			
Aluminum	X				
Hard Plastics	X				
Glass	X				

Durability

38.1.C. Materials with a long expected useful/performance life must be prioritized.

i. Refer to Table 38.c.as a reference for expected longevity of materials. This should be used as a guide but not a definitive measurement.

Table 38.c.Expected Longevity of Common Materials

	VERY HIGH (entire building life)	HIGH (50+ years)	MODERATE (25-50 years)	LOW (10-25 years)	MINIMAL (less than 10 years)
Reinforced Concrete	X				
Concrete Masonry	X				
Stone	X				
Baked Clay Masonry	X				
CSEB		<----X---->			
Cement Plaster		X			
Cementitious Fiberboard	X				
Gypsum Board		<----X---->			
Plywood		X			
Wood		X			
Bamboo			<----X---->		
Structural Steel	X				
Aluminum	X				
Hard Plastics			<----X---->		
Glass		<--------X-------->			

Material Longevity

There is no precise measurement for this property, and performance will depend greatly on finishes, exposure, and maintenance.

Wood (and bamboo) if well-protected, can be highly durable, but properly cured and treated wood is essential to resist damage from moisture and termites.

Plastic and glass material themselves are long-lasting, but they may be prone to breakage, which reduces their expected longevity.

38.1.D. Materials with low maintenance requirements must be prioritized, especially in facilities with minimal staff, minimal resources, or availability of replacement materials or finishes.

i. Refer to Table 38.d.as a reference for expected maintenance requirements of materials. This should be used as a guide but not a definitive measurement.

Table 38.d.Maintenance Requirements of Common Materials

	MINIMAL (almost no maintenance during building life)	LOW (20+ year maintenance schedule)	MODERATE (5-20 year maintenance schedule)	HIGH (1-5 year maintenance or reapplication)	VERY HIGH (annual or more frequent maintenance or re-application)
Reinforced Concrete	X				
Concrete Masonry		X			
Stone	X				
Baked Clay Masonry		X			
CSEB				X	
Cement Plaster			X		
Cementitious Fiberboard			X		
Gypsum Board			X		
Plywood			X		
Wood				X	
Bamboo				X	
Structural Steel			X		
Aluminum		X			
Hard Plastics		X			
Glass		X			

Material Maintenance

Maintenance requirements will vary based on building use, construction quality, exposure, finishes, and other unpredictable factors. As defined here, maintenance does not include regular cleaning and inspection, which should be performed on all materials consistently and continuously.

Masonry materials may require long-term maintenance of joints and mortar bonding. Occasionally individual units will need to be replaced, but with proper construction this is rare.

Cement plaster needs to be periodically checked for cracks, chips, and if found, these should be repaired. High use areas and areas exposed to the elements are particularly susceptible to repairable damage.

CSEBs require protection against water infiltration; plastering must and coatings must be checked regularly and re-applied when needed.

Building boards such as fiberboard, gypsum, triplex, and plywood need occasional re-treating with paint or other proper finishes if exposed to use and/or the elements.

Vegetative materials (wood, bamboo) and structural steel require regular re-finishing with a protective coating (paint, varnish, or other appropriate finish) in order to ward off moisture damage and/or termite infestation. This is particularly important for steel in coastal areas due to the high moisture and salt content of the air.

Aluminum materials, plastics and glass require long-term maintenance of joints and fastenings.

38.2 Ecological Considerations

In order to promote sustainable development and promote a healthy environmental system, the ecological impact of the chosen material life-cycle must be considered. In the absence of sound ecological practices, the performance of the construction industry, and ultimately human health, is compromised.

Environmental Sensitivity

38.2.A. The carbon footprint of all building materials must be considered and evaluated with an effort to minimize the carbon emissions in material production and use as much as possible.

i. Refer to Table 38.e.as a guide for selection but it must be understood that actual values will vary based on production methods and transportation distances.[2] Data is for reference only and should not be taken to be definitive values.

Table 38.e. Estimated Carbon Footprint of Common Materials

	MINIMAL (less than 0.05 tCO$_2$e/t material)	LOW (0.05 - 0.1 tCO$_2$e/t material)	MODERATE (< 0.1 - 1.0 tCO$_2$e/t material)	HIGH (1.0 - 2.0 tCO$_2$e/t material)	VERY HIGH (>2.0 tCO$_2$e/t material)
Reinforced Concrete			X		
Concrete Masonry		X			
Stone	<----X---->				
Baked Clay Masonry			X		
CSEB	<----X---->				
Cement Plaster		X			
Cementitious Fiberboard				X	
Gypsum Board			X		
Plywood			X		
Wood		X			
Bamboo	X				
Structural Steel			<----X---->		
Aluminum					X
Hard Plastics					X
Glass			X		

Carbon Footprints

A carbon footprint is a measure of the total amount of carbon dioxide (CO_2) emissions per unit of material production/use. Major contributing factors usually include: the amount of energy used in material extraction, production, and/or manufacture; distance of transportation (although this is not considered in the chart above); loss of carbon-neutralizing matter (i.e. loss of plant species) in harvesting or extraction; and any other activities that contribute to the production of CO_2. It is often measured as the number of tons of carbon dioxide (CO_2) emitted per ton of material produced/used, resulting in the unit notation: tCO_2e/t material) of material.

Products using vegetative material either directly (wood, bamboo) or indirectly (baked bricks through the burning of biofuels in the kilning process) may be mitigated by replanting said materials. Refer to Standard38.2.D. for re-planting guidelines and requirements. Note that composite wood products (triplex and plywood) do not qualify as the primary carbon-producing products as they contain glues which cannot be remediated through replanting.

Recyclable materials such as metals, plastics, and glass have lower carbon footprints if recycled material is used, since the energy inputs into material extraction and production are not required after the first use.

Total carbon footprints can be reduced by using locally sourced materials to reduce transportation distances, and by controlling or specifying the production process to include low-energy production. The designer of the health facility should consider including this information in material specifications.

38.2.B **All materials must be free of lead (Pb) and asbestos.**

i. Lead (and lead-copper) used for radiation and/or MRI shielding are exempt from this requirement.

Lead and Asbestos

Lead poisoning has been proven to cause serious brain damage, particularly in children. Asbestos is a known carcinogen

Historically, lead has been found in paints, plumbing piping, and metal sheeting though these have largely been removed from the building industry. However, the absence of lead should be verified before material purchase.

Trace amounts of lead sometimes occur in harmless levels. Standards of the US EPA Safe Drinking Water Act[3] should be followed. It defines "lead-free" as: solders and flux containing 0.2% lead or less; pipes, pipe fittings and well pumps containing 8% lead or less.

When asbestos material disintegrates with age or is damaged, microscopic fibers may be disbursed into the air and inhaled, lodging in the lungs and leading to serious disorders or eventual death.[4] It has been widely used as a roofing and insulating material in the past due to its formability, high thermal resistance, and rigidity.

Life Cycle Considerations

38.2.C. **Wherever possible, renewable and/or recyclable materials must be prioritized.**

i. Refer to Table 38.f.as a guide for selection. This is for reference only and should not be taken to be definitive. Also shown is whether materials are recyclable, so that they may be reconstituted at the end of the material or building life.

Table 38.f. Renewability of Common Materials

	VERY HIGH (fully renewable in less than 10 years)	HIGH (fully renewable in more than 10 years)	MODERATE (made up of some renewable components)	LOW (made of re-creatable naturally sourced materials but not renewable)	NON-RENEWABLE (not made of creatable naturally sourced materials)	RECYCLABLE
Reinforced Concrete					X	
Concrete Masonry					X	
Stone					X	
Baked Clay Masonry				X		
CSEB				X		
Cement Plaster					X	
Cementitious Fiberboard					X	
Gypsum Board					X	
Plywood			X			
Wood		X				
Bamboo	X					
Structural Steel					X	X
Aluminum					X	X
Hard Plastics					X	X
Glass				X		X

Renewability

Renewable materials consist of those for which raw materials can be regenerated through natural processes. For building materials, these are commonly made up of vegetative materials (wood, bamboo). Some materials made from earthen materials (glass, ceramics) are semi-renewable in that the source material itself cannot be directly regenerated but is created found naturally.

A distinction is made between rapidly renewable resources, which can be regenerated within up to 5 years, and other fully renewable resources, which can also be regenerated but over a longer time span.

Higher quantities of materials that are not rapidly renewable are needed to be regenerated in order for supply to meet or exceed demand over time. Mature materials taking more than 5 years may not be harvestable until long after other building projects consume additional resources.

38.2.D. **When renewable resources are used, new material supplies must be generated at the quantity of 1x the amount of material of mature rapidly renewable sources and 2x the amount of material for other fully renewable sources.**

i. The amount of material may be calculated by length or weight. For example, if the length of the rapidly renewable material of bamboo used is equivalent to 20 mature bamboo shoots, then 1 x20 = 20 new shoots of bamboo must be planted. If the weight of the fully renewable of mahogany wood used is equivalent to wood used is equivalent to 5 mature mahogany trees, then 2 x 5 = 10 new trees should be planted.

ii. Regeneration of resources may happen at the project site where possible. This allows for greater control over the resource management and potentially provides a replacement material should the original one be subject to decay.

38.3 Economic Considerations

Materials vary widely in cost, and sometimes low-cost materials impede building performance, while sometimes they have little influence on performance. Thus, material cost should be considered as one, but not the only, factor in material selection. Ultimately, the goal is to achieve a high-performance design and construction with the minimum realistic cost.

Project economic decisions are also a factor in the national development of Liberia. Sourcing materials and labor locally has the added benefit of developing Liberia's construction industry and refueling local economies with capital.

Material Costs

38.3.A. Without compromising building performance, cost-effective materials must be prioritized.

38.3.B. Materials with a high cost/durability ratio must be prioritized.

Local Development

38.3.C. Materials produced and/or available within Liberia must be prioritized in order to fuel local economies, ensure availability of replacements, and invest in the development of Liberia's construction industry.

i. Refer to Table 38.g. as a reference for availability and production of materials in Liberia as of 2013. This may change over time and it is up to the user to verify the sourcing.

Table 38.g. Common Material Availability in Liberia

	VERY HIGH (able to be produced locally and readily available)	HIGH (partially produced in-country and available)	MODERATE (available in-country but produced externally)	LOW (limited availability and produced externally)	MINIMAL (by special order only)
Reinforced Concrete		X			
Concrete Masonry	X				
Stone	X				
Baked Clay Masonry	X				
CSEB	X				
Cement Plaster	X				
Cementitious Fiberboard				X	
Gypsum Board				X	
Plywood				X	
Wood	X				
Bamboo	X				
Structural Steel			X		
Aluminum			X		
Hard Plastics					X
Glass			X		

38.3.D. Materials with which local laborers have the skills to build or can be trained to build must be prioritized.

i. Refer to Table 38.h.as a reference for local availability of skilled labor for each of the materials presented as of 2013. This may change over time and it is up to the user to verify the local labor potential. Also shown are materials for which training of laborers is relatively straightforward for a modest increase in building construction cost.

Table 38.h. Availability of Local Craftspeople for Common Materials

	VERY HIGH (skilled laborers can be sourced anywhere)	HIGH (skilled laborers can be found nationwide)	MODERATE (skilled laborers can be found in some locations)	LOW (highly specialized)	MINIMAL (no in-country skilled labor available)	TRAINING CAPCITY (capacity to train laborers with marginal cost increase)
Reinforced Concrete			X			X
Concrete Masonry		X				X
Stone		X				X
Baked Clay Masonry		X				X
CSEB	<----X---->					
Cement Plaster			X			X
Cementitious Fiberboard				X		X
Gypsum Board				X		X
Plywood		X				X
Wood		X				X
Bamboo		X				X
Structural Steel			X			
Aluminum			X			X
Hard Plastics					X	
Glass		X				X

Local Resources

Materials produced in Liberia are preferred over materials available in Liberia but produced elsewhere. The goal is to keep the maximum amount of capital within Liberia as a way of fueling additional development.

Building with local labor achieves 2 goals of construction projects: it provides a source of revenue for local laborers and craftsmen, thereby infusing capital into local economies; and it helps ensure the familiarity of the worker with the construction techniques. However, skill levels are variable and this should not be taken as a guarantee of high-quality construction.

For some materials, on-site training may be provided to help increase the skill of the labor force in Liberia but the quality of the construction must not be compromised.

38.4 Material Selection Summary

The table below summarizes the information from the preceding Standards into a single reference. This table is not meant to be a shortcut or definitive material selection tool, only a reference guide to make quick comparisons of many considerations. Users should still refer to the individual Standards relating to each condition described in order to make informed decisions.

Within each performance criterion, materials are listed from XXXXX(5 Xs) for those with the most desirable performance for that criterion to X (1 X) for those with the least desirable performance for that criterion. For materials with a large range of performance values, the lower number of Xs is used but is followed by a + to indicate it may exceed that level of performance.

Table 38.i. Summary of Material Performance Criteria

	Thermal Resistance	Resistance to Water Damage	Longevity	Maintenance Requirements	Carbon Footprint	Renewability	Availability in Liberia	Availability of Local Craftspeople
Reinforced Concrete	XX	XXXX	XXXXX	XXXXX	XXX	X	XXXX	XXX
Concrete Masonry	XXX+	XXXX	XXXXX	XXXX	XXXX	X	XXXXX	XXXX
Stone	XXX	XXXXX	XXXXX	XXXXX	XXXX+	X	XXXXX	XXXX
Baked Clay Masonry	XXX+	XXX	XXXXX	XXXX	XXX	XX	XXXXX	XXXX
CSEB	XXXXX	X+	XXX+	XX	XXXX+	XX	XXXXX	XXXX+
Cement Plaster	XX	XXXX	XXXX	XXX	XXXX	X	XXXXX	XXX
Cementitious Fiberboard	XXXX	XXX+	XXXXX	XXX	XX	X	XX	XX
Gypsum Board	XXX+	XX	XXX+	XXX	XXX	X	XX	XX
Plywood	XXX	XX	XXXX	XXX	XXX	XXX	XX	XXXX
Wood	XXX+	XX	XXXX	XX	XXXX	XXXX	XXXXX	XXXX
Bamboo	XXX	X	XX+	XX	XXXXX	XXXXX	XXXXX	XXXX
Structural Steel	X	XXXX	XXXXX	XXX	XX+	X	XXX	XXX
Aluminum	X	XXXXX	XXXXX	XXXX	X	X	XXX	XXX
Hard Plastics	X	XXXXX	XX+	XXXX	X	X	X	X
Glass	XX+	XXXXX	XXX+	XXXX	XXX	XX	XXX	XXXX

39 Structural Concrete

The mixing and placing of concrete can have a wide range of results. Standardized procedures must be followed in order to ensure concrete strength and safety over the lifespan of healthcare facilities. Where concrete construction is required, for large and small projects, careful attention should be paid to mix parameters and material quality.

39.1 General Requirements

The following general requirements must be met for concrete in order to ensure proper mixing, casting, and ultimately structural strength.

Construction Testing

39.1.A. A slump test must be performed on a representative mix at each stage of construction to monitor consistency of unhardened concrete batches. Additional tests must be performed if the source of materials changes over the duration of the project.

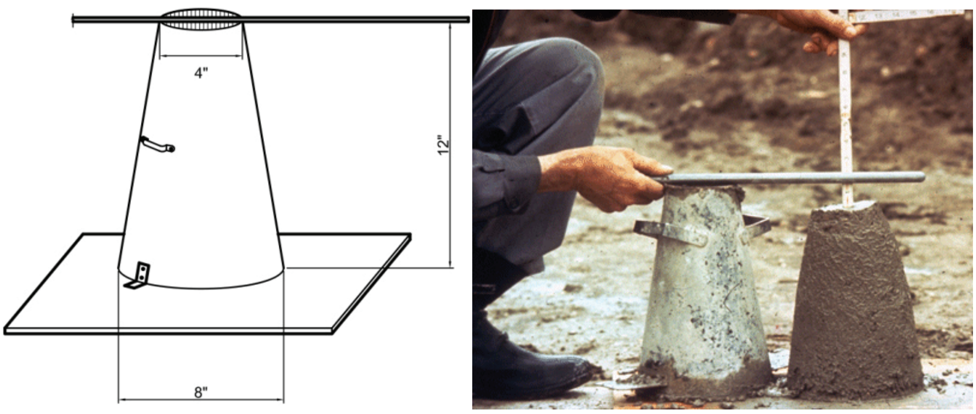
i. The apparatus required for the procedure include: a truncated metal cone (of dimensions below), #5 rebar (5/8in diameter, or 16mm diameter rod), and a metal pan.
ii. Concrete must be placed in the metal cone in three equal layers. At each layer, the concrete must be tamped 25 times with specified rod.
iii. The metal cone should be lifted vertically, leaving the concrete sample behind. The slump is then measured from the top of the cone. Refer to Table 39.a.

Table 39.a.Slump Range

Construction Type	Slump Range	Notes
Roads	0-1in (0-25mm)	Dry Mix
Foundations	1/3 –1 7/8in (10-40mm)	Low Workability
Normal Reinforced Concrete	2 – 3 ½in (50-90mm)	Medium Workability, Normal Reinforced Concrete placed with Vibration
	>4in >(100mm)	High Workability

Workability
Workability is the ease and homogeneity with which the concrete can be mixed, transported, poured, consolidated and finished. Concrete used for foundations typically requires less workability due to less rebar congestion associated with foundations. Concrete used for normal structural conditions, such as columns, walls, beams and elevated slabs, require a more workable mix due to the larger quantity of rebar present in which the mix must be placed around.

Figure 39.a.Slump "Cone" Parameters (left); Slump Test Example (right)



39.1.B. **For projects greater than one level or over 30ft (9.1m) in height and requiring concrete construction, cylinders for a compression test must be made from a representative mix at each stage of construction over the life of the project. Additional cylinders for compression testing are required for mixes where any materials change over the life of the project.**

i. Cylinder length must be two times the diameter. Cylinder diameter must be 3 times the maximum aggregate size. The ends of each cylinder shall be capped or made flush to provide a smooth testing surface.
ii. Apply a compressive axial load to a cylindrical specimen at a prescribed rate until failure occurs. Calculate and report the compressive strength.
iii. Cylinders must be kept in similar conditions to concrete placed on site.
iv. Move cylinder molds containing fresh concrete very carefully by supporting the body.
v. Additional recommendations: refer to ASTM C31 for further information regarding compression testing.

Compressive Strength
Compressive strength = Maximum load/ cross- sectional area of cylinder.

Quality Assurance

39.1.C. **Materials must be purchased from a supplier who is experienced in manufacturing ready-mixed concrete products and has production facility guidelines in place and available for review.**

i. If facility guidelines are unavailable from manufacturers, the Contractor must receive approval from the assigned IU representative for use of products obtained..
ii. Additional recommendations: refer to ASTM C94 for an example of ready mix concrete standards.

39.1.D. **Cementitious material types must be consistent for a single project except where directly specified by construction documents.**

i. Each type or class of cementitious material must be of the same brand from the same manufacturer's plant.
ii. When cementitious material from a single source is not available, three cylinder compression tests must be performed of both mixes to verify equal strength. Refer to Standard 39.1.B. for cylinder testing information.

39.1.E. **Aggregate and admixtures must be of the same type and quality for a single project, and be sourced from a single source.**

i. Where not possible to obtain same type and quality, the Contractor must receive approval from assigned IU representative for use of varied products.

Material Sources:
When material is obtained from a single source, mechanical properties will be consistent. Consistent material properties for a given mix design will result in a uniform strength of concrete.

39.1.F. **Structural concrete must always be mixed with, at minimum, a stationary, mechanical mixer.**

i. For a stationary mixer, concrete must be mixed no less than two minutes and ensure that mix achieves a visible blending of all materials.

ii. The maximum concrete mixing time must not exceed the minimum by more than 60 seconds-mixing time starts after all solid materials are in the mixer.

iii. Water used to clean mixing equipment and accessories must not be added into the mix.

iv. If site conditions do not allow a mechanical mixer to be delivered to site, concrete may be mixed on a mixing pad if approved by the assigned IU representative. Mixing pads must be made of a concrete base, be kept clean, and be free of foreign substances.

v. If a mixing pad is used, concrete must be completely turned over a minimum of 20 times while mixing.

39.1.G. The placement and finishing contractor qualifications must be reviewed and approved by the assigned IU representative.

Delivery, Storage and Handling

39.1.H. Cement must be stored off the floor in a dry room, well protected from rain.

i. When cement material is stored on elevated floors the stacks must not exceed 8 bags height and must be distributed over the floor to prevent concentrated loading on the existing floors that could potentially exceed the floor's capacity.

39.1.I. In the event that a crust develops on the surface of the material in the bag, this crust must be discarded as it will lower the strength of the mix if used.

ii. Any cement stored for more than 2 months from the date of receipt from the factory must either be avoided or used only if the test results are found to be satisfactory.

iii. Cement bags must be stacked such that the older bags will be used first.

Cement Notes:
When water is added to cement, it begins a chemical reaction called hydration, which is an irreversible curing process. As a result, cement is very sensitive to moisture and humidity, as water in any form will begin the reaction. Ensure that the cement purchased is powdery and has not begun to set-this is indicated by hard blocks or crust.

39.1.J. Steel reinforcement must be delivered, stored, and handled in a way to prevent bending and damage. Contact with grease, oil, dirt and other objectionable materials must be avoided.

i. Refer to Standards 39.2.Q. – 39.2.U. for further information including acceptable reinforcement grades and sizes.

Submittals

39.1.K. Contractor means and methods must be approved by the assigned IU representative prior to start of construction.

i. For the construction of projects greater than one level, the assigned IU representative must approve construction details or shop drawings.

39.1.L. Contractors must receive approval from the assigned IU representative for material substitutions or other proposed changes from construction drawings.

39.2 Products

The following product requirements must be met for concrete in order to ensure proper construction quality.

Manufacturers

39.2.A. Manufactured products such as bonding agents, mortar, joint filler, crack injection adhesives must be purchased from a supplier who is experienced in manufacturing and has production facility guidelines in place for review. Contractor must receive approval from the assigned IU representative for use of products obtained from manufacturers where facility guidelines are not available.

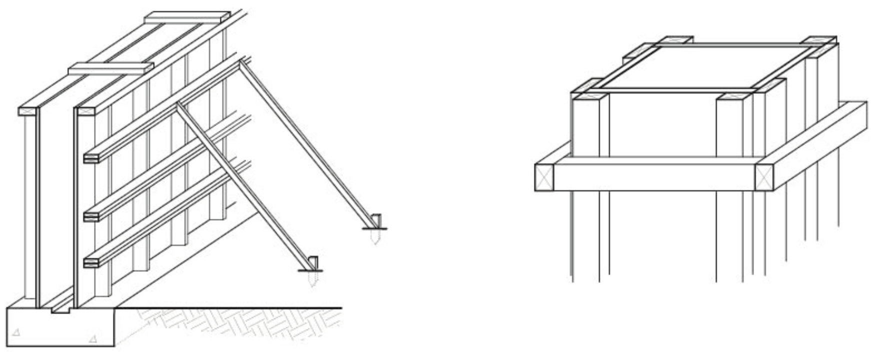
Formwork

39.2.B. For panel formwork, forms of the largest size possible must be used to minimize joints. Sheets must not be damaged and must have clean, straight edges.

i. The face of forms directly in contact with the concrete must be high-grade lumber or plastic overlaid plywood. Refer to Standard39.2.E. for acceptable wood types.

39.2.C. Acceptable formwork construction alternatives include board-formed concrete, or metal or plastic pans. Other formwork techniques must be approved by the assigned IU representative.

Figure 39.b.Formwork Layout



39.2.D. Bracing to ensure stability of all formwork must be provided. Shore or strengthen formwork subject to overstressing by construction loads.

i. Forms for walls must be supported by studs, tied together by continuous wales, and diagonally braced to the ground.
ii. Forms for columns require liners, diagonal bracing to the ground and straps or clamps to hold the formwork together.

39.2.E. The wood for formwork must conform to the following requirements. The types listed in Table 39.b.are acceptable for formwork.

i. Timber used for forms must be durable and treatable.
ii. Timber must have sufficient strength characteristics.
iii. Timber forms must be light weight and well-seasoned without warping
iv. Timber for formwork must hold nails well.
v. Where plywood is used, it must be built up of an odd number of layers with the grain of adjacent layers perpendicular to one another. Refer to Section 43.2 for additional wood information.

Table 39.b.Acceptable Wood Types – Formwork

Genus &Species	Local Name	English Name
Ceibapentandra	Fromager	Silk Cotton
Uapacaguineensis	Rikio	-
Erythrophleum ivorensis	Pali	Sasswood
Pycnanthusafricanus	Ilomba	-
Triplochitonscledroxylon	Wawa	-
Piptadeniastrum africanum	Dahoma	African Greenheart
Nauclea diderrichii[a]	Kusia[a]	African Peach[a]

[a] *Kusia* (Nauclea diderrichii) *is listed as a vulnerable species by the International Union for the Conservation of Nature and should be avoided where possible unless verifiable, sustainable harvesting practices are used. Refer to Section 43.2 on wood products.*

39.2.F. Where steel formwork is used, the steel must have a minimum yield stress of 36 ksi (250MPa).

39.2.G. Forms or bracing must not be removed until concrete has gained sufficient strength to carry its own weight and imposed loads.

Table 39.c. Shoring Removal Schedule

Structure	Removal Time
Bottom Forms: Slab, Beams, Girders	21days
Side Forms: Beams and Girders	7days
Columns and Walls	7days
Footings, Pile caps, Grade Beams	7days

Concrete Mixtures

39.2.H. The minimum allowable compressive strength must be 3,000psi (20.5MPa) for elevated slabs, columns, and walls and 2,000psi (13.8MPa) for foundations. Refer to Standard 39.1.B. for compressive test process.

39.2.I. Particles in concrete mixtures must be well graded or similar in size because strength is reduced when particle sizes vary.

39.2.J. Select the appropriate concrete mix by volume according to location of concrete placement in structure. Refer to Table 39.d.for mix appropriateness.

i. A concrete mix must be selected based on the intended application and is mixed by a ratio of Cement: Sand: Gravel: Water. The ratios are expressed by volume for ease of field measuring.
ii. Mix calculations may be performed per unit volume as an alternate process according to the following equations.

Mix Calculations

Volume of concrete = $1m^3$ (EQ. a)

Volume of cement = $\frac{\text{Mass of Cement}}{\text{Specific Gravity [SG]of Cement}} \times \frac{1}{1000}$ (EQ. b)

Volume of water = $\frac{\text{Mass of Water}}{\text{[SG]of Water}} \times \frac{1}{1000}$ (EQ. c)

Volume of chemical admixture (SG 2%by mass of cement) (EQ. d)

Volume of all aggregates = $(\text{EQ. a}) - (\text{EQ. b} + \text{EQ. c} + \text{EQ. d})$ (EQ. e)

Volume of course aggregates [CA] = $(\text{EQ. e}) \times \text{Volume of CA} \times \text{[SG]of CA}$ (EQ. f)

Volume of fine aggregates [FA] = $(\text{EQ. e}) \times \text{Volume of FA} \times \text{[SG]of FA}$ (EQ. g)

Table 39.d. Concrete Mixes by Volume and Use

Mix Ratio (Cement : sand : gravel : water)	Use	Aggregate Volume, per 50kg bag of cement	Approx. Yield
1 : 3 : 6 : 1.6	Mass foundations, foundations on stiff soils, kick block anchors	Sand 130 liters (4.6 ft^3) Gravel 180 liters (6.4 ft^3) Water 70 liters (2.4 ft^3)	$0.24m^3$ ($10ft^3$)
1 : 2.5 : 5 : 1.6	Foundations on soft soil	Sand 110 liters (3.9 ft^3) Gravel 160 liters (5.7 ft^3) Water 70 liters (2.4 ft^3)	$0.21m^3$ ($9.5ft^3$)
1 : 2 : 4 : 1.6	Floors, nonstructural walls	Sand 80 liters (2.8 ft^3) Gravel 130 liters (4.6 ft^3) Water 70 liters (2.4 ft^3)	$0.17m^3$ ($8.0ft^3$)
1 : 2.5 : 3.5 : 1.6	Beams, structural walls	Sand 110 liters (3.9 ft^3) Gravel 115 liters (4.0 ft^3) Water 70 liters (2.4 ft^3)	$0.17m^3$ ($8.0ft^3$)

**References for additional background information: ACI 211.1; Compressive Strength, when tested in accordance with ASTM C 39/C 39M at 28 days.*

39.2.K. If admixtures are used, they must be compatible with all other components in the mix and be approved by the assigned IU representative.

Aggregate

39.2.L. Course aggregates (gravel) must be rough and clean.

i. Rounded particles must be avoided because they will not adhere well in the mixture. River (smooth) gravel must be broken to form rough surfaces.
ii. Dirt and Organics in the mixture will decrease mix strength and must be removed.
iii. Stones that are brittle (easily breakable) are not good for construction and must be avoided.

39.2.M. Course aggregate sizes must be limited according to the location where mix will be placed. Refer to Table 39.e. for aggregate sizes.

i. Prioritize course aggregate that is crushed or angular (sharp). Stones must be hard and compact.
ii. Gravel must not be larger than 0.75 times the distance between rebar or between rebar and edge of concrete.
iii. Aggregate must be 3in (7.6cm) at a maximum for use in foundations. (Aggregates larger than 2in (5cm) will usually reduce concrete strength).

Table 39.e. Course Aggregate Maximum Diameter

Location	Maximum Gravel Size
Walls and Beams	0.20 x the smallest dimension between wall or beam forms, not to exceed ¾ in (2cm)
Slabs	0.33 x depth of slab, not to exceed 3/4in (2cm)
Foundations	0.33 x depth of slab, not to exceed 3in (7.5cm)

39.2.N. Sand must not contain earth (soil), mica, salt, organic filth, odor, iron compounds, or tar. Sand must not be moistened before use.

i. The particle size for sand, also called fine aggregate, can be as small as 0.005in (0.12mm), but not larger than ¼in (6mm).

39.2.O. Beach sand from the ocean is not acceptable and must not be used.

i. Any sand obtained in the coastal plain must be washed to ensure it contains no salt, sodium or chloride.

ii. Sources in the coastal plain should be verified to be salt free by the assigned IU representative.

39.2.P. Water for cleaning sand must be potable when possible. Dirty or salty water must not be used.

Sand Quality Test

To test if sand is of good quality, combine it with water. If too much soil or dust is present, it will separate from the mix and float to the surface. When collecting sand, dig approximately 2in (5cm) from the surface only to avoid gathering soil or dust.

Non-potable water can contain oils grease, dissolved salts, and organic materials that can negatively affect the chemical hydration and curing of concrete. In order to ensure concrete reaches its desired strength, only clean water should be used.

Steel Reinforcement in Concrete

39.2.Q. Reinforcing bars must have a grade or yield stress capacity 60ksi (412 MPa). Notify the assigned IU representative to verify rebar quantity is still adequate with building design given a lower stress.

39.2.R. Reinforcing steel must have specified concrete cover over reinforcement. Rebar must be inspected prior to being concealing with formwork to ensure proper cover, rebar type spacing, splices and quantity is installed correctly as shown.

Table 39.f. Minimum Concrete Cover over reinforcing steel

Location	Use	Minimum Cover
Concrete cast against and permanently exposed to earth	All	3in(75mm)
Concrete exposed to earth or weather	All	2in (50mm)
Concrete NOT exposed to weather or in contact with ground	Slabs, walls, joists	¾in (20mm)
	Beams, columns	1½in (40mm)

39.2.S. Vapor barriers and water proofing membranes, if present, must not be damaged or displaced by rebar.

39.2.T. Steel reinforcing bars must be measured to be actual diameter as specified by construction documents. Notify the assigned IU representative when bar diameters are not consistent to assess if actual steel quantity is adequate or needs to be increased.

Table 39.g.Rebar Dimensions

Bar Size	Nominal Dimensions (For Design)				Approximate Diameter to Outside Deformations	
	Diameter		Area			
	(in)	(mm)	(in^2)	(cm^2)	(in)	(mm)
#3	.375	9.5	.11	.71	7/16	11
#4	.500	12.5	.20	1.29	9/16	14.25
#5	.625	16	.31	2	11/16	17.5
#6	.750	19	.44	2.84	7/8	22
#7	.875	22	.60	3.87	1	25
#8	1.000	25	.79	5.10	1 1/8	28.5
#9	1.128	28.5	1.00	6.45	1 1/4	31.75
#10	1.270	32	1.27	8.19	1 7/16	36.5
#11	1.410	35.5	1.56	10	1 5/8	41.25

39.2.U. Where steel bars must be overlapped to provide continuous length, standard splice requirements must be followed per Table 39.h.

Table 39.h.Standard Splice Length

Bar Size	Standard Lap Splice Length[a]			
	Top Bars[b]		Other Bars[b]	
	(in)	(cm)	(in)	(cm)
#3	16	42	12	32
#4	22	56	18	44
#5	28	70	20	54
#6	32	84	24	64
#7	48	122	36	94
#8	54	140	42	108
#9	62	156	48	120
#10	68	174	52	134
#11	78	196	60	150

[a] *Standard tension lap splice length assumes f'c = 3000psi (C20) concrete.*

[b] *Lap splice length assumes conditions of clear bar spacing*

[c] *The smaller lap length may be used when splicing bars of different sizes*

[d] *Where specific conditions of clear bar spacing and confinement are met, a lesser standard splice length may be used if specified on drawings*

Reinforcement Accessories

39.2.V. For dowel bars, steel that has a yield stress of 60ksi (412MPa) must be used. Where yield stress is less than 60ksi (412MPa), notify assigned IU Representative to verify rebar quantity and sizes still are adequate with building design given a lower stress.

i. Steps must be taken to ensure that the yield stress of purchased items matches the advertised yield stress. Substitution of lower grade steel is commonplace in Liberia and must be avoided.

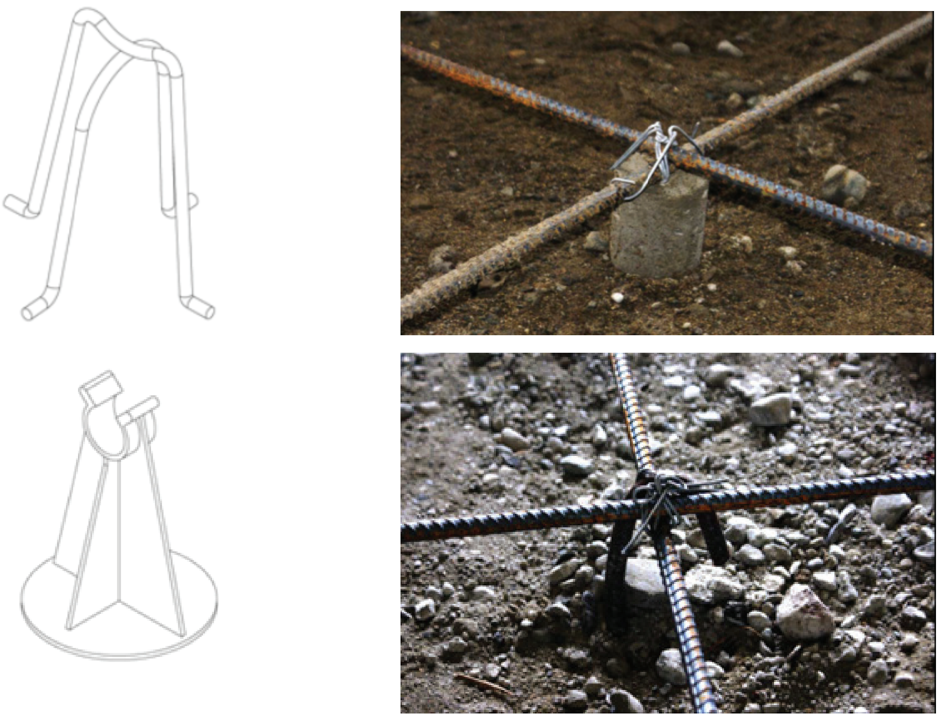
39.2.W. Plain-steel bars must be cut true to length with ends square and free of burrs. Ensure that ends are clean and raised edges from cutting have been removed.

39.2.X. Where wire is used to tie bars, annealed wire at a minimum of 16 gauge should be used.

i. Annealed, or heat treated wire, must always be used as the treatment process reduces brittleness.

39.2.Y. Use bar supports such as: bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars in place in order to achieve proper spacing and cover requirements.

Figure 39.c.Various Bar Supports



Waterproofing

39.2.Z. Below grade, plastic sheeting or a cementitious system must be provided between concrete and soil to prevent staining and mold.

39.3 Execution

The placement and construction quality of concrete will directly affect the strength and durability of the structure. Proper execution of the construction drawings is extremely important.

Examination

39.3.A. Dimensions of construction must match construction documents. Verify that lines, levels, and dimensions on project site are within acceptable tolerance limits prior to proceeding with concrete construction.

Installation

39.3.B. Concrete must not be placed until the assigned IU representative has approved reinforcing placement as consistent with construction drawings.

39.3.C. Where cement trucks are available for large projects, water may only be added once to each truckload in the field provided the specified water-cement ratio is maintained- water must not be added more than once.

39.3.D. Records of concrete placement must be maintained. Record date, location, quantity, air temperature, and test samples taken.

39.3.E. To avoid cold joints, placing concrete must be continuous and resumed before the surface hardens. For unusually long delays, the concrete should be kept active by periodically re-vibrating at 15 minute intervals. However, concrete cannot be over vibrated to the point of causing the mix to separate.

i. When concrete is placed, it must be placed against the preceding batch and not dumped in an individual pile.

39.3.F. Tolerances for concrete structural elements must be in accordance with recommendations provided in respective construction method sections.

Curing

39.3.G. Slabs on flat concrete elements must be kept continuously wet for7- 10 days to control moisture loss during the cement hydration process.

i. Water that is more than 5 degrees F (2.8 degrees C) cooler than the concrete must not be used as it will cause thermal shock and cause cracking.

Control and Expansion Joints

39.3.H. Any required control or expansions joints, as specified by construction drawings, must be installed so that the strength of the concrete is not impaired.

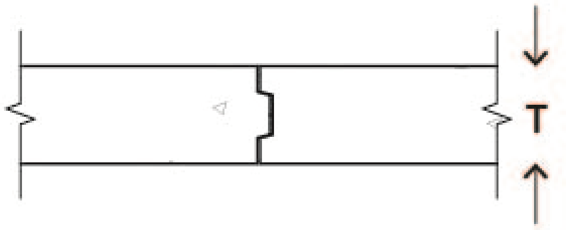
i. Where joint locations are not specified, proposed locations must be approved by the assigned IU representative.

39.3.I. All joints must be true to line with faces perpendicular to the main reinforcement.

i. Continue reinforcement across construction joint, in order to properly transfer load across a cold joint, unless specifically indicated otherwise on construction drawings.

39.3.J. Keyed joints must be formed as indicated on drawings. Embed keys at least 1½in (38mm) into concrete. Locate joints for beams, slabs, joists and girders in the middle third of spans.

Figure39.d. Concrete Key



De-Shoring

39.3.K. e

39.3.L. In multistory construction, shoring or re-shoring must be extended over a minimum of two consecutive stories to distribute loads in such a manner that no floor or member will be excessively loaded or will induce tensile stress in concrete members without sufficient steel reinforcement.

39.3.M. Contractor must plan the sequence of removal of shores and reshore to avoid damage to concrete. Locate and provide adequate reshoring to support construction without excessive stress or deflection. Complete reshoring in less than 24 hours.

Finishes

39.3.N. Where float finishes are applied to surfaces, the concrete must be covered with fluid applied or sheet waterproofing.

Repair

39.3.O. Repair and patch defective concrete areas where approved by engineer. Remove and replace concrete that cannot be repaired to meet approval.

39.3.P. For patching mortar, mix dry-pack patching mortar, consisting of 1part Portland cement to 21/2 parts fine aggregate, and using only enough water for handling and placing.

39.3.Q. To repair formed surfaces, immediately after form removal, cut out honeycombs, rock pockets, and voids more than ½in (13mm) in any dimension to solid concrete. Observe the following procedures:

i. Limit cut depth to 3/4in (1.9cm).
ii. Make edges of cuts perpendicular to concrete surface.
iii. Clean, dampen with water, and brush-coat holes and voids with bonding agent.
iv. Fill and compact with patching mortar before bonding agent has dried.
v. Fill form-tie voids with patching mortar or cone plugs secured in place with bonding agent.

40 Masonry

Stone, clay masonry units, and concrete masonry units are used extensively in the construction of walls to most efficiently take advantage of their compressive strength, durability, and fireproof characteristics. Care must be taken in the construction of masonry assemblies, from the mix process to the installation of protective finish, to ensure these characteristics are achieved.

40.1 General Requirements

Irrespective of specific block or material type, general requirements and guidelines for quality as described below should be met.

Construction Testing

40.1.A. The contact or must engage a qualified independent testing agency to perform construction testing indicated below.

40.1.B. For multi-story buildings (2 or more stories), a minimum of three grout prism tests prior to construction must be performed and achieve a compressive strength of f'm = 1500 psi (10.34MPa).

i. For all other projects, three grout prism tests must be performed when possible.
ii. Apply a compressive axial load, up to half of the expected to prism at a prescribed rate until failure occurs. Calculate and report the compressive strength to the assigned IU representative.

Prism Test

The rate of loading of a prism test should be applied at a continuous rate until half of the expected maximum load is applied. Next, the rate may be adjusted so that the remaining load is applied at a uniform rate in not less than 1nor more than 2 min. Refer to ASTM C1314 for additional testing procedure information.

40.1.C. For all buildings, mortar aggregate tests must be conducted if mortar material sources are changed and at all new stages in construction

i. Use the mortar aggregate test to verify quality of mix on site matches mix ratio specified in Standard 40.1.C.

Mortar Aggregate Test

The mortar aggregate ratio compares the volume of aggregate (sand) to that of the cementitious materials (cement and lime) in fresh mortar. The following procedure should be observed:

- Use a 500 gram sample size of mortar not more than four hours old.
- Determine aggregate volume by wet-sieving a split of the fresh mortar sample over a no. 100 sieve.
- Oven dry retained material and find dry weight.
- Flash off the alcohol from the sample that was at jobsite to retard hydration – mortar sample and alcohol should be fully agitated.
- Oven dry sample to find weight of cementitious ingredients.
- Using both results, determine volume ratio of the two portions.

For additional test background, Refer to ASTM C780, A4.

Quality Assurance

40.1.D. Contractor must purchase prefabricated units or cementitious materials from a single manufacturer. Where it is not possible to obtain material from one source, cementitious material must have uniform quality and be approved by assigned IU representative.

Material Sources:
When material is obtained from a single source, mechanical properties will be consistent. Consistent material properties for a given mix design, will result in a more uniform strength of cement. When poor quality cement is used, the entire strength of mix is compromised.

40.1.E. The qualifications of the contractor responsible for installation must be approved by the assigned IU representative prior to the start of construction.

40.1.F. When third party field or laboratory testing personnel participate on a project, the qualifications must be approved by the assigned IU representative.

Delivery, Storage and Handling

40.1.G. Five percent or less of a shipment containing chips, not larger than 1in (25mm) in any dimension, and not longer than 25% of the nominal height of unit is acceptable. Material must be discarded if chips larger than acceptable dimensions.

40.1.H. All units must be sound and free of cracks or other defects that interfere with the proper placement of the unit or significantly impair the strength or permanence of the construction.

i. Minor cracks, incidental to the usual method of manufacturer minor chipping resulting from customary methods of handling in shipment and delivery, are not grounds for rejection.

40.1.I. Masonry must be stored off the ground, under cover, and in a dry location to prevent deterioration or damage due to moisture, temperature changes, contaminate, corrosion, and other causes.

40.1.J. Cementitious materials must be stored off the ground, under cover, and in a dry location.

i. When cementitious material is stored on elevated floors the stacks must not exceed 8 bags in height and must be distributed over the floor to prevent concentrated loading on the existing floors that could potentially exceed the floor's capacity.

40.1.K. Aggregates must be stored where grading and other required characteristics can be maintained and contamination avoided.

40.1.L. All masonry accessories, including metal items, must be stored to prevent corrosion and accumulation of dirt and oil.

40.1.M. During construction, tops of walls, projections and sills with waterproof sheeting must be covered at the end of each day's work. Partially completed masonry must also be covered when construction is not in progress.

Concrete Mixing:

When water is added to cement, it begins a chemical reaction called hydration, which is an irreversible curing process. As a result, cement is very sensitive to moisture and humidity, as water in any form will begin the reaction. Ensure that the cement purchased is powdery and has not begun to set-this indicated by hard blocks or crust.

Once masonry units are fabricated, care should be taken while stored to ensure units reach desired strength. While masonry units are drying, they should be protected against external damage. During construction process and prior to final weatherproofing, exposed masonry construction should be protected to ensure materials are not compromised and desired strength is reached.

Submittals

40.1.N. **Contractor means and methods must be approved by the assigned IU representative prior to start of construction.**

i. For construction projects greater than one level, the assigned IU representative must approve construction details or shop drawings.

40.1.O. **Contractor must receive approval from assigned IU representative for material substitution or other proposed changes from construction drawings.**

40.2 Products

According to the specific brick or block product that is to be used on a project, respective material and construction guidelines are provided.

Concrete Masonry Units (CMUs)

40.2.A. The mix design for blocks has many variables that are project specific. The aggregate: cement ratio can be 6:1, 8:1, or10:1 depending on aggregate type available.

i. Determine optimum mix by the following procedure:

- First try course sand only. Then replace some course sand with some fine sand and some stone.
- For each combination, make a batch of concrete using a water content of approximately 5.5% of total batch weight. (For example 4,500 lbs of aggregate + 450 lbs of cement = 4,950 total lbs requires 272 lbs of water).
- Because block density is a good indicator of strength, blocks can be assessed by weighing them as they are demolded. Adjust the mix until the heaviest block is achieved.
- For buildings larger than one level, three compression tests of units must be performed.

40.2.B. Compression testing must be performed and must conform to the following criteria:

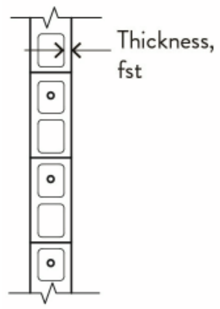
i. A minimum of 3 full-size units must be tested.
ii. Specimens must be tested with the centroid of their bearing surfaces aligned vertically with the center of load application from the testing machine.
iii. The units must be free of visible moisture or dampness.
iv. The rate of loading of a prism test must be applied at a continuous rate until half of the expected maximum load is applied. The rate may then be adjusted so that the remaining load is applied at a uniform rate in not less than 1 nor more than 2 min.
v. Refer to ASTM C140 for additional testing procedure information.

40.2.C. For hollow concrete masonry units, blocks must have minimum wall thickness according to Figure 40.a.

40.2.D. For units having end flanges, the thickness of each flange shall not be less than the minimum face shell thickness.

<u>Figure 40.a.WallThickness Parameters</u>

Minimum Thickness of Face Shells and Web	
Nominal width (w)	Minimum face shell thickness (fst)
4in (100mm)	$^{3}/_{4}$in (20mm)
6in (150mm)	1in (25mm)
8in (200mm)	$1^{1}/_{4}$in (32mm)
10in (250mm)	$1^{3}/_{8}$in (35mm)
12in (300mcm)	$1^{1}/_{2}$in (40mm)



40.2.E. For standard units, overall dimension (width, height, and length) must not differ by more than $\pm^{1}/_{8}$in (3mm) from specified dimensions.

40.2.F. Face shell thickness (t_{fs}) and web thickness (t_w) shall conform to the requirements prescribed in Figure 40.a.

40.2.G. **The net cross-sectional area of solid units in every plane parallel to the bearing surface shall be not less than 75% of the gross cross-sectional area measured in the same plane.**

40.2.H. **CMUs must be kiln or air cured under cover until the age of the blocks is at least 10 days.**

40.2.I. **For clinical areas and exposed exterior areas, concrete block walls must be rendered with plaster a minimum of ½in (12mm) thick.**

i. Plaster quality must conform to the standards in Section 44.3.
ii. Plastering must be in the range of ½in (13mm) to 1in (25mm) to minimize costs but ensure performance and quality.

CMU Waterproofing:

Concrete blocks are not waterproof and require an added layer of protection. A well-adhered plaster layer the abovementioned thickness adds the necessary protection and durability.[5]

Waterproofing at the lower wall is most *important* as it is most exposed to wind-driven rain, exposed to rain splashing, and bears the heaviest load. A consistent coat of bituminous paint or other acceptable waterproofing aids in wall protection

40.2.J. **Where bituminous paint waterproofing is used, it must be painted up to 16in (40cm) above the ground to ensure protection from rain and splashing.**[6]

Baked Clay Brick

40.2.K. **Bricks must contain a maximum of 20% sand content and be free of organic matter before kilning.**

i. High sand and/or organic content weakens the structural strength of the brick and must be avoided in favor of clay. This soil type and mixture is often found approximately 20" (50cm) below surface soil in valleys and plains.[7]

40.2.L. **For clinical areas, brick walls with less than $^1/_{16}$in (1.5mm) variance from plane may be finished with a brushed wash of minimum 20% cement and 80% sand to reach conformance of the standards in Section 44.3.**

i. Smooth-laid bricks, with flush mortar, need only to have small cavities filled in order to achieve performance requirements. This can be done with a paste mix of cement and sand brushed on to fill the cavities, in place of plastering, in order to save cost.[8]

Compressed Stabilized Earth Block (CSEBs)

CSEBs are an appropriate masonry option for facilities in rural or hard to reach areas, where material access is limited and transport costs high. CSEBs are also a useful material when sufficient access to appropriate soil is located on or near the construction site. CSEBs present a valuable opportunity to engage local communities in the construction process, both creating jobs and developing skills in manufacturing and installation. Engaging local labor also builds community ownership of facility after it is completed. However, strict quality control measures must be followed to ensure longevity. Refer to particular execution requirements of CSEBs in Section 40.3.[9]

Advantages and limitations of CSEBs

Advantages:

- A locally-made product, consisting primarily of natural materials.
- Can reduce dependency on foreign imports and strengthen local markets.
- Cost-effective when made from locally sourced materials.
- Durable and long-lasting, requiring minimal maintenance when protected from the elements.
- Training for CSEB production is fast, requiring only several weeks.
- Production creates jobs and requires only semi-skilled labor.
- A more sustainable material than typical CMU with a lower carbon footprint.

Limitations:

- Not all soil is appropriate for CSEBs. Correct soil composition must always be used.
- A stabilizing element must be added to the soil mix.
- Blocks must be carefully produced and handled to prevent damage.
- Workers must perform as a team and remain alert to ensure a quality end product.
- Machinery must be maintained and calibrated to achieve required tolerances.
- Blocks must be correctly cured and dried before installation.
- Blocks must be protected from the elements throughout the curing process and after construction of the building.

40.2.M. Use of CSEBs must be approved by the assigned IU representative.

40.2.N. CSEBs must not be used in a structural capacity. CSEBs may be used for infill masonry only.

40.2.O. CSEBs may only be used for single-story PHC 1, PHC 2 or Health Center Facilities. CSEBs must not be used for Hospital construction.

40.2.P. Soil used for CSEB production must have the proper composition.

i. An evaluation of local soil must be performed to assess composition and characteristics prior to engineering the CSEB mix. Only soil mixes with ideal compositions may be used when producing CSEBs. Topsoil or any other soil containing organic matter must not be used.

ii. The ideal soil composition is dependent upon the choice of stabilizer.

iii. Soil mix ratios and stabilizers must be approved by the assigned IU representative prior to any construction.

Soil characteristics

Optimal soil for CSEBs is determined by compressibility. Compressibility of a soil depends on the ratio of inert particles of gravel and sand to binders like silt and clay. Clay, silt, sand, and gravel, are defined by the following particle sizes:

Clay: 0.001-0.002mm, Silt: 0.002-0.06mm, Sand: 0.06-2mm, Gravel: 2-10mm

Liberia has predominantly lateritic soil, which is generally an appropriate soil type for use in CSEBs due to its clay ad silt content. Liberia also has available sand to supplement the soil mix when needed. Sand for use in CSEBs should not be harvested from the ocean floors or beaches, as the salt content in the sand can degrade the overall quality of the blocks.

40.2.Q. CSEBs must have a stabilizing element added to the soil mix.

i. Whenever possible, cement should be used as the added stabilizing element. While cement is the recommended stabilizer, in cases of soils with high clay content, industrial grade lime can be used.
ii. The amount of cement required to achieve CSEBs of acceptable compressive strength varies with soil composition. An optimal soil composition for cement stabilization is 20% Clay, 15% Silt, 50% Sand, 15% Gravel.
iii. The optimal soil composition for lime stabilization is as follows: 35% Clay, 20% Silt, 30% Sand, 15% Gravel.

Cement stabilization

The addition of cement to the soil mix as a stabilizer is necessary when producing CSEBs. However, CSEBs generally require less cement per block than typical CMU, and can therefore be a cost effective alternative.

Often soils do not meet the optimal distribution described above. When this is the case, soil can be improved by adding sand or gravel, or by mixing different soil types together to achieve a desirable composition.

When a desirable soil composition is achieved, between 6-10% by weight of cement is typically added. The ideal percentage of cement added can be determined through compression testing.

Lime stabilization

While cement is a more effective stabilizer for gravel, sand, and silt, lime is an effective stabilizer for clay. Lime may be used as stabilizer for soils with high clay contents. Lime may also be added to cement as a supplementary stabilizer.

40.2.R. Soil must be prepared by sieving to ensure proper granular size of particles.

i. Soil must be sieved for use in CSEBs. Sieving is required to remove particles above 10mm and all lumps. The sieve must have a mesh no larger than 10mm.
ii. Some soils, especially those with high clay content, should be crushed before sieving.

Sieving Soil

The sieve should be angled approximately 45° from the ground to achieve proper gradation of soil passing through. However, this angle can be adjusted to allow more or less course particles pass through. A vertically oriented sieve will remove course particles, while a flat sieve will allow them.

40.2.S. **The soil, sand, and stabilizer mix must be completely and evenly mixed.**

i. The soil mixture must be prepared by making a pile of soil on a level, clean cement pad and adding sand if necessary. Cement stabilizer must be spread on top of the pile, followed by water sprinkled evenly over the pile.
ii. The soil, sand, and stabilizer must be completely and evenly mixed by moving the pile a minimum of two times. The pile will be visually homogeneous, both consistent in color and texture, when adequately mixed.
iii. Any lumps that form in the mix must be crushed.

40.2.T. **The moisture content of a CSEB mix must be tested at least once for every mix batch.**

i. Moisture content tests must be approved by the assigned IU representative before being used for production of CSEB blocks.

Testing Moisture Content

To ensure the moisture content is correct, compress a soil ball into the hand and drop it on a hard surface from a height of one meter. The ball should break into 3-4 pieces. A ball which completely breaks apart like powder has too little water, while a ball that doesn't break is too wet.

40.2.U. **Soil must be properly pressed to achieve adequate compression and avoid damage.**

i. When fully mixed, the press mold must be filled with soil and leveled. The same amount of soil must be used for the each block.
ii. Close the lid and fully press the block to ensure adequate compression.
iii. Open the lid and carefully but firmly remove the block.
iv. After removal, all blocks must be homogeneous in color and texture and must not have damaged edges. Any material loss from the block must be minimal and pits must not exceed 1/8" (3mm).
v. Clean any remaining soil from inside the mold, such as the corners, top plate, or bottom plate, before refilling the mold and pressing the next block.
vi. Next, the block must be checked with a height gauge. No block should be 1mm more or less than the intended nominal block size. If the block size is incorrect, calibrate the press to achieve correct block dimensions. If block size continues to be incorrect after calibration of the press, adjust the moisture content of the mix. Blocks that are too thin are too wet, while blocks that are too wide are too dry.

40.2.V. **Blocks must be inspected after each new mixture of soil to ensure proper quality.**

i. The first block pressed from a new soil mix must be examined immediately after ejection from the mold.
ii. The block must be checked with a pocket penetrometer to test compressive strength and with a height gauge to ensure the block size is within acceptable tolerance. Block quality must be approved by the assigned IU representative before proceeding with full production of blocks.

Testing with penetrometer and height gauge

A pocket penetrometer is used to test the compressive strength of CSEBs by pressing the penetrometer into the top of the block. If the penetrometer reaches its preset mark without penetrating more than 6mm into the CSEB, the block passes the test, resisting more than 5kg/m2.

A height gauge is used to check the dimensions of the block. No block should be 1mm more or less than the intended nominal block size. If the block size is incorrect, the press should be calibrated to achieve correct block dimensions. If block size continues to be incorrect after calibration of the press, adjust the moisture content of the mix. Blocks that are too thin are too wet, while blocks that are too wide are too dry.

40.2.W. **Blocks must be properly cured for 28 days.**

i. Immediately after removal from the press, blocks must be stacked in piles nearby for 3 days. These piles must remain covered with a plastic tarp and never be allowed to dry so that the cement can begin to set properly.
ii. Blocks maybe piled 7-8 high, leaving approximately 2 inches between piles.
iii. On the third day after production, block should be moved with a flat wheelbarrow to a final stacking and curing location.
iv. Final stacking must occur in compact and organized piles of approximately 500 blocks, consisting typically of 6 layers of 85 blocks.
v. When complete, a pile must be immediately covered with jute cloth or plastic tarps.
vi. Blocks must cure for a minimum 28 days, with water being added as needed to prevent full drying.

40.2.X. **Blocks must be protected throughout curing to preserve structural integrity.**

i. After curing, blocks must be free from cracks and broken edges, or any other defects that could block strength or performance during construction.
ii. Blocks must not crumble or be easily broken at the edges when handled.
iii. Erosion of the blocks due to curing or weathering must not exceed 10% of total block area and individual pits must not be larger than 3mm.

40.2.Y. **After curing, blocks must be tested to meet minimum strength requirements.**

i. Dry compressive strength must achieve a minimum of 3 MPa (435psi)
ii. Wet compressive strength must achieve a minimum of 1.5 MPa (218psi)
iii. Dry bending strength must achieve a minimum of 0.3 MPa (44psi)
iv. Water absorption by weight must achieve a minimum of 0.2 MPa (29psi)
v. Block volumic mass must be a maximum of 15%. Volumic mass is calculated by dividing the air-dry mass of a block (in kg) by the volume of the material (in m^3).
vi. All wet tests must be performed after a block has been submerged in water for 24 hours at a temperature near 27˚C (80˚F).

Strength Requirements

Test results will show the strength of CSEBs produced. Blocks are divided into three classes: A, B, and C. Class A is of the highest quality; Class B is good quality; Class C is of moderate quality and should be carefully reinforced to ensure adequate performance. The performance class of a block is determined by its wet compressive strength.

Characteristics	Class A	Class B	Class C
Dry Compressive Strength	5 to 7 MPa	4 to 5 MPa	3 to 4 MPa
Wet Compressive Strength*	3 to 4 MPa	2 to 3 MPa	1.5 to 2 MPa
Dry Bending strength	0.5 to 1 MPa	0.4 to 0.8 MPa	0.3 to 0.6 MPa
Water absorption by weight	0.4 to 0.6 MPa	0.3 to 0.5 MPa	0.2 to 0.3 MPa
Block volumic mass	8 to 10%	10 to 12%	12 to 15%

40.2.Z. **Blocks must be safely stored and transported.**

i. Upon completion of curing, blocks must be stored in a safe location to prevent weathering or damage. Blocks must remain covered and be protected from the elements, such rain and wind.
ii. If transported, blocks should be moved flat and laid on a bed of sand for protection.
iii. Blocks must not be cracked or broken during storage or transportation. If damaged, blocks must not be used for construction.

Mortar and Grout Materials

40.2.AA. Calcium chloride must not be used in any mortar or grout.

<u>Calcium Chloride in Concrete:</u>
Concrete mixes containing calcium chloride have a faster cure rate than plain concrete, but may also produce side effects such as corrosion of steel. To avoid corrosion, calcium chloride should not be used in mortar or concrete.

40.2.BB. Portland cement-lime mortar must be used unless specifically stated otherwise by engineer or building inspector.

40.2.CC. Cement-sand mixes of 1:4 or 1:6 must be used for brick walls.

i. Adding lime to the cement in a ratio of ¼ to ½ of the cement will greatly increase the plasticity of the mix without reducing the strength.
ii. Do not add lime to masonry cement – lime is already included.
iii. Mortar shall be used within one hour of preparation.

40.2.DD. Admixtures must not be used unless specifically stated otherwise by engineer, construction drawings, or building inspector.

40.2.EE. Dirty or salty water must not be used as the water is likely to contain oils, grease, and organic matter than can affect the curing time and end strength of the mix.

Steel Reinforcement in Masonry

40.2.FF. Reinforcing bars for walls must be deformed, uncoated steel.

40.2.GG. Reinforcing bars must be deformed bars, 60ksi (412 MPa) yield tension stress. Notify assigned IU representative to verify rebar quantity is still adequate with building design given a lower stress.

40.2.HH. Bars must have only minimal surface corrosion to ensure adequate bonding to concrete occurs. Oil or other lubricants must never contaminate bar surfaces before pouring. Bars must be cleaned with a wire brush to remove corrosion and/ or lubricants prior to construction.

40.3 Execution

Not only are the material properties and block, mortar, grout strengths important on an individual level, the strength of the building system relies heavily on quality of construction. Construction guidelines and requirements are further described herein.

Examination

40.3.A. Items such as pipes built-in or passing through masonry structure must be located in appropriate areas so as to not compromise masonry.

i. Openings must be filled in solidly with masonry around built-in items. Fill space between any hollow metal frames and masonry solidly with mortar.

Installation

40.3.B. Location of elements in plans must not vary from what is indicated on construction documents by more than ½in (12mm).

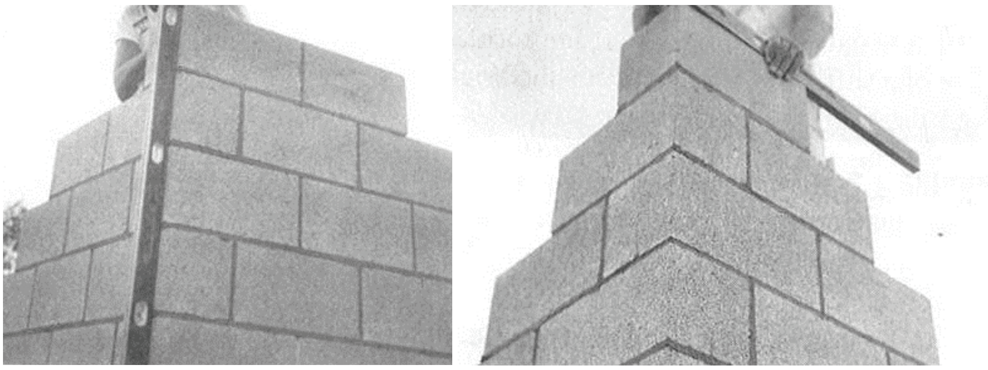
40.3.C. The location of elements in elevation must not vary from what is indicated on construction documents by more than ¼ in (6mm). Lines, levels, coursing and dimensions on project site must be within acceptable tolerance limits prior to proceeding with construction.

40.3.D. Masonry must not vary from lines and levels indicated on drawings by more than ½ in (12mm). Lay from exposed side, plumb (exactly vertical), level and true (accurately placed) to modular dimensions.

i. The assigned IU engineer must be notified during masonry construction to conduct regular inspection of tolerance limits.

40.3.E. Maximum variation from masonry unit to adjacent masonry units must be limited to ¼in (6mm).

Figure 40.b.Typical Corner Construction

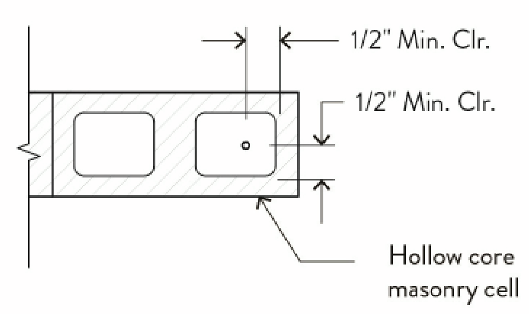


40.3.F. External and internal corners must be fully bonded for masonry walls that are not confined with a concrete frame.

40.3.G. Joint reinforcing, anchors and ties must be installed in full mortar surround and voids in blocks filled where necessary to completely embed items.

40.3.H. All cells with reinforcement must be fully grouted.

Figure 40.c.Reinforcement Placement Requirements

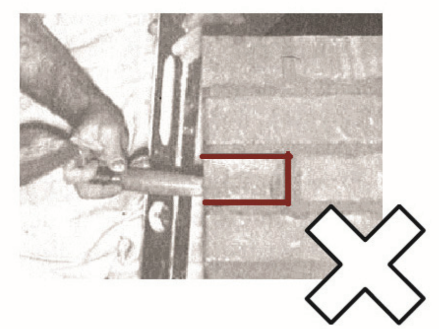


40.3.I. Concrete blocks and bricks must be kept dry, under cover and clean. Only clean, undamaged units should be laid. Units with moisture content over 40% must not be laid.

40.3.J. Concrete blocks and bricks must not be wetted before being laid; Burnt clay bricks should be wetted before being laid.

40.3.K. Masonry must not be shifted or tapped after mortar has taken initial set. Where adjustments need to be made, mortar must be removed and replaced.

Figure 40.d.Masonry Unit Placement Requirements



40.3.L. Masonry courses must be of uniform height. Vertical and horizontal joints must be of equal and of uniform thickness in full bed of mortar unless otherwise specified in construction drawings, and must be properly jointed with other work.

40.3.M. Temporary bracing during erection of concrete block work must be provided for confined and reinforced walls.

i. Temporary bracing must be in place until building structure is built and can provide permanent bracing.
ii. Do not apply uniform floor or roof loads for at least 2daysand concentrated loads for at least 5days after building masonry walls and columns.

Mortar Jointing& Reinforcement

40.3.N. Mortar bedding thickness must meet the following requirements:

i. Clay, concrete, and other solid bricks may have a mortar bed varying from ¼in (6mm) to ½in (12mm) thick.
ii. Hollow concrete masonry units must have a mortar bed 3/8in (10mm) thick.

40.3.O. Solid masonry units must be laid with completely filled bed and head joints; ends must be buttered with sufficient mortar to fill head joints and shove into place. Do not deeply furrow bed joints (created depressions in masonry bed)as it can create voids in mortar.

40.3.P. Masonry wall joints must be cut flush to receive plaster or other direct- applied finishes.

40.3.Q. Corners and intersections must be fully reinforced per Standard 35.1.R. and as shown in Figure 35.d.Refer to Standards40.3.CC. and 40.3.GG.for confined masonry wall corner and intersection requirements.

40.3.R. Masonry reinforcing splices must be lapped a minimum of 24in (60cm).

40.3.S. Walls must be reinforced, except masonry veneer or infill for confined frame, with continuous horizontal joint reinforcing and masonry ties. Refer to Standards40.3.CC. – 40.3.HH. for confined masonry conditions.

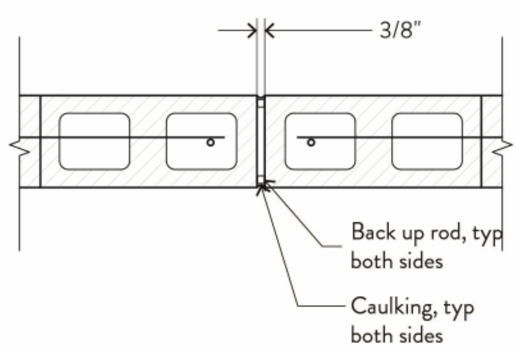
40.3.T. Longitudinal side rods must be fully embedded in mortar for the entire length with a minimum cover of $^{5}/_{8}$in (16mm) on exterior side of walls and $^{1}/_{2}$in (12mm) at other locations.

Control and Expansion Joints

40.3.U. Control joints in block work must be provided as indicated on drawings. If not shown, locate at 40ft (12m) for horizontal run of wall.

40.3.V. Horizontal masonry reinforcing must not be continued across control or expansion joints. Reinforcing must end approximately one inch either side of joints.

Figure 40.e.Standard Control Joint



Lintels

40.3.W. Prefabricated or built in place masonry lintels, must be made from bond beam CMUs, or other masonry units, with reinforcing bars placed and filled with course grout.

i. Precast lintels must be cured before handling and installing.
ii. Built in place lintels must be temporarily supported until cured.

40.3.X. Steel lintels may be used above wall openings up to 8ft (2.4m)

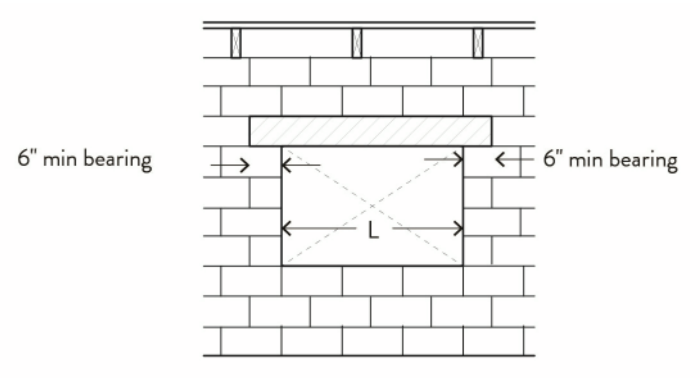
40.3.Y. Where steel lintels are used, the lintel must be shored until the masonry has attained sufficient strength to carry its own weight.

i. Shoring period must not be less than 24 hours.

40.3.Z. Where concrete lintels are used, the net-area compressive strength must not be less than the surrounding masonry units. Continuous reinforcing bars must be provided.

40.3.AA. A minimum 6in (15.3cm) bearing on each side of openings must be maintained. Masonry must be erected on full even beds of mortar within 3 courses of solid brick or one course filled-core hollow units under lintels and beam.

Figure 40.f.Lintel Construction



40.3.BB. Concrete or masonry lintels must reach 90% of design strength or 28 days after curing before removing temporary supports. Units that show evidence of cracking must be removed.

Confined Masonry

40.3.CC. Concrete confining columns must be placed at all wall intersections.

i. The spacing and reinforcement of the confining column must be in accordance with Standards 35.1.K. and 35.1.L. respectively.

40.3.DD. Ensure concrete confining columns have been doweled into foundation per Standard 35.1.M.

40.3.EE. Masonry infill must be placed between vertical confining element rebar in accordance with masonry installation requirements.

40.3.FF. Formwork for concrete elements must be constructed and braced in accordance with Standard 39.2.D.

40.3.GG. Mixture requirements for all concrete elements must conform to Standards 39.2.H.–39.2.K.

40.3.HH. The concrete bond beam reinforcement, per Standard 35.1.0., must be doweled into the confining concrete column at every joint or intersection.

Execution Requirements for CSEBs

40.3.II. **Contractor means and methods of production for CSEBs must be approved by the assigned IU representative before production may begin.**

40.3.JJ. **During construction, CSEBs must be protected from rain at all times.**

i. A roof or shelter must be provided while CSEB masonry work is going on, until the finished coat of plaster is applied.
ii. The top course of CSEBs must be finished with mortar at the end of each day to prevent water penetration during night rains.
iii. CSEBs must be protected with an impervious tarp during rain and when work is not in progress.

40.3.KK. **CSEBs must be protected from water to prevent long-term damage.**

i. Buildings with CSEB walls must have overhangs of a minimum depth of 20in (50cm) to prevent direct contact with rain.
ii. Walls must be plastered and sealed with a cement stucco to prevent water absorption.
iii. The building plinth must be made of stone or concrete and must be a minimum 20in (50cm) above ground level to prevent flooding and termite penetration.
iv. Water must never pool or accumulate at the building perimeter. Water should be directed away from the CSEB walls via sloped earth or gutter system.
v. A damp proof course must be laid at the base of each wall to prevent capillary absorption of water into the wall. This damp proof course is typically a concrete beam.

40.3.LL. **Blocks must be properly laid to ensure overall wall integrity.**

i. All blocks must be submerged in water just before laying. Briefly soaking the block strengthens the mortar bond.
ii. After laying a block, its position must be quickly set and it should remain undisturbed to ensure a high strength bond.
iii. If a block is improperly laid, it must be removed and the mortar must be discarded, before it can be properly laid again.

40.3.MM. **Joints between even and odd courses must be staggered to prevent weakness in walls.**

40.3.NN. **Walls must be properly reinforced in accordance with design specifications.**

40.3.OO. **CSEBs may be laid using stabilized earth mortar.**

i. Stabilized earth mortar for use in wall construction should have the following mix ratio:

1 cement + 4 soil + 8 sand

ii. Mortar must not be more than 1cm (2.5cm) to prevent shrinkage and cracking during drying.
iii. When laying a CSEB, mortar must be applied to the horizontal surface below and to the adjacent vertical surface before the block is laid in place.

41 Steel

Steel framing is typically used in longer span applications where wood or light framing may not be efficient. Provided steel is properly manufactured and installed, a steel system is structurally efficient and durable. Although initial material and transportation costs may be more expensive, these long-term benefits of strength and durability should be considered. The long-term maintenance of steel should also be considered –where steel is used, continuous protection from the environment must be provided to prevent deterioration.

41.1 General Requirements

The following general requirements must be met for steel in order to ensure proper quality construction.

Quality Assurance

41.1.A. The qualifications of the companies of individuals specializing in performing the work of this section must be reviewed and approved by the assigned IU representative.

i. This standard includes the qualifications of: companies or individuals performing fabrication; companies or individuals performing the erection of structural and other major building members.

41.1.B. For multi-story structures, testing and inspection by the assigned IU representative must be sought, and third party testing agency and special inspectors must aid the IU in evaluating the Contractor's performance.

i. This standard is not a substitute of the testing and inspection which is required as part of the contractor's quality control system.

41.1.C. Prior to fabrication of multi-story structures, fabrication and erection methods, submittals, and sequencing must be approved by the assigned IU representative.

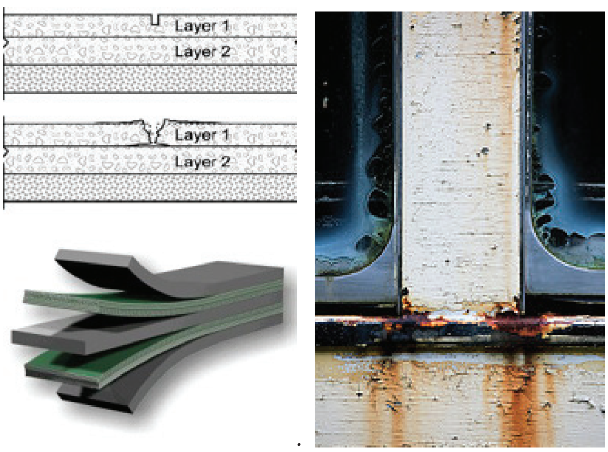
Delivery, Storage and Handling

41.1.D. Steel materials must be stored supported off the ground. Shoring and protection to prevent distortion and other damage must be provided.

41.1.E. Steel materials must be protected from rust and corrosion, kept free of dirt, grease and other foreign matter.

41.1.F. Structural steel that has begun to delaminate must not be used.

Figure 41.a.Steel Delamination



41.1.G. **Welding materials must be kept in moisture resistant packaging. Packages must be kept sealed until electrodes sticks are required for use.**

i. Electrode sticks used for welding must be kept dry. Moisture in electrodes leads to cracking and porosity. Low hydrogen electrodes are especially susceptible to moisture damage.

Submittals

41.1.H. **Contractor means and methods must be approved by assigned IU representative prior to start of construction.**

i. For large construction, IU representative must review and approve construction details and shop drawings where available.
ii. Steel drawings and details must include grade of steel, profiles, sizes, spacing, lengths and locations of structural members and connection types.

41.1.I. **If materials vary from construction documents or from suggested material specifications herein, material substitution must be approved by the assigned IU representative.**

41.2 Products

Limitations on steel products will help to eliminate substandard material and thereby increase construction quality and material strength.

Structural Framing and Shapes

41.2.A. In general, steel shapes must meet the following yield stress criteria as much as possible. Where criteria cannot be achieved, material specifications must be approved by the assigned IU representative.

Table 41.a.Material Specifications - Structural Shapes

Section Type	F_y ksi (MPa)	Reference Material Specification
Wide Flange	50 *(355)*	ASTM A992, Grade 345 EN 10025 S355
Channels	35, 36 *(235)*	ASTM A53 GR. B, ASTM A36, EN 10025 S235
Angles	35, 36 *(235)*	ASTM A53 GR. B, ASTM A36, EN 10025 S235
Plates	35, 36 *(235)*	ASTM A53 GR. B, ASTM A36, EN 10025 S235
HSS Rectangular or Square	46 35, 36 *(235)*	ASTM A500, Grade B ASTM A53 GR. B, ASTM A36, EN 10025 S235

Miscellaneous Materials &Fasteners

41.2.B. For welding material, use low hydrogen electrode types as much as possible

41.2.C. Immediately after surface preparation, apply primer according to manufacturer's written instructions to provide a minimum dry film thickness of 1.5mils (0.038 mm).

i. Use priming methods that result in full coverage of joints, corners, edges, and exposed surfaces.

41.2.D. Miscellaneous fasteners must meet the following yield stress criteria as much as possible. Where criteria cannot be achieved, material specifications must be approved by the assigned IU representative.

Table 41.b.Material Specifications- Fasteners

Type of Fastener	F_y ksi (MPa)	Reference Material Specification
Steel Bolts and Nuts	36 *(248)*	ASTM A307 EN ISO 898-1
Headed & Unheaded Anchor Rods	36 (248)	ASTM F 1554, Grade 36 ASTM A307 EN ISO 898-1

Fabrication

41.2.E. **Where prefabricated structural steel is used, the fabrication of structural steel in one location, by one fabricator, must be prioritized to help provide additional consistency to structural strength.**

Finishes

41.2.F. **Structural steel members must be shop primed in accordance with manufacturer's instructions. Surfaces that will be fireproofed, field welded, in contact with concrete, or in high strength bolt must not be primed.**

i. Structural steel that is permanently exposed to weather, and not shop primed, it must be galvanized or have another finish protection pre-approved by the assigned IU representative.

41.2.G. **Exposed steel must be coated with a protective oil-based paint, other impervious coating, or hot galvanized.**

i. Protective layers must be applied before corrosion sets in. Steel that is already rusted must either be ground until all rust is removed (but note that this weakens the steel), or discarded.
ii. Steel must be coated with their final protection as soon as possible in the construction process.
iii. Stainless steel must be of V4A (molybdenum alloy) or V3 (chrome-nickel) quality, especially in coastal areas.[10] These qualities offer greater resistance to rust.

Corrosion Protection:
Steel is highly susceptible to corrosion in Liberia's climate, especially in coastal areas. Protection and regular re-application of the protecting layer is essential for longevity.

41.3 Execution

Proper techniques in construction and fabrication of steel will extend the material and building life.

Examination

41.3.A. Prior to erecting or placing steel, the structure supporting steel elements must be prepared to support framing. Steel framing must not be adjusted (cut to fit, or altered in any way) on site unless approved by the assigned IU representative.

Steel Construction:
It is important not to deviate from structural documents during erection as structural instabilities are likely to occur, both instantaneously and over time, due to inadequate support.

41.3.B. Project site conditions must be cleared and structure cleaned and prepared for erection of structural steel for work to proceed.

Erection

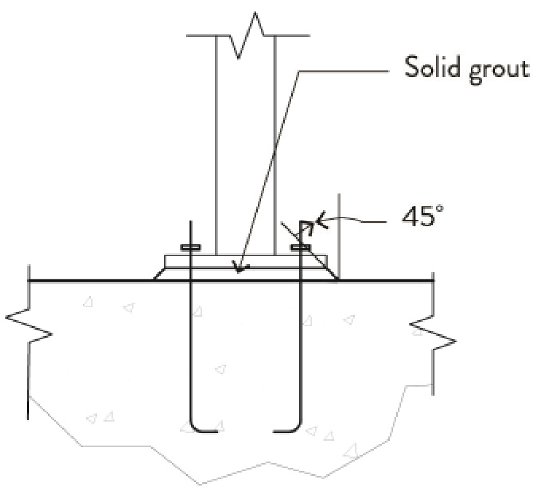
41.3.C. Allow for erection loads and provide sufficient temporary bracing to maintain structure in safe condition, plumb, and in true alignment until completion of erection and installation of permanent bracing.

41.3.D. Paint must not be applied to surfaces within 2in (5cm) of joints to be welded in the field.

i. Welded joints must be re-primed, painted, or otherwise protected from rust as soon as possible after welding is complete.

41.3.E. Grouting must be solid, using non-shrink grout, between column plates and bearing surfaces. Grouted surfaces must be troweled smooth, splaying nearly to 45 degrees.

Figure 41.b.Bearing Plate Detail



41 / Steel

Welding

41.3.F. Surfaces on which weld metal is to be deposited must be smooth, uniform, and free from fins, tears, cracks and other discontinuities that would adversely affect the quality or strength for the weld.

41.3.G. Surfaces to be welded, and surfaces adjacent to a weld, must be free from loose or thick scale, slag, rust, moisture, grease and other foreign material.

41.3.H. Welding Electrodes thickness and current must be appropriate for base metal thickness, Refer to Table 41.c.

Table 41.c.Welding Electrodes

Electrode Table				
Electrode Diameter or Thickness		Amp Range	Plate	
in	mm		in	mm
1/16	1.5	20-40	Up to 3/16	Up to 5
1/8	3	75-185	Over 1/8	Over 3
3/16	5	140-305	Over 3/8	Over 10
1/4	6	210-430	Over 3/8	Over 10
5/16	8	275-450	Over 1/2	Over 12

41.3.I. For structural welding, contractor must use E70xx low hydrogen electrodes. Where low hydrogen electrodes are not available, contractor must receive approval from assigned IU representative for a substitute product.

41.3.J. Minimum fillet weld size must be in accordance with Table 41.d.

Figure 41.c.Fillet Weld Guide

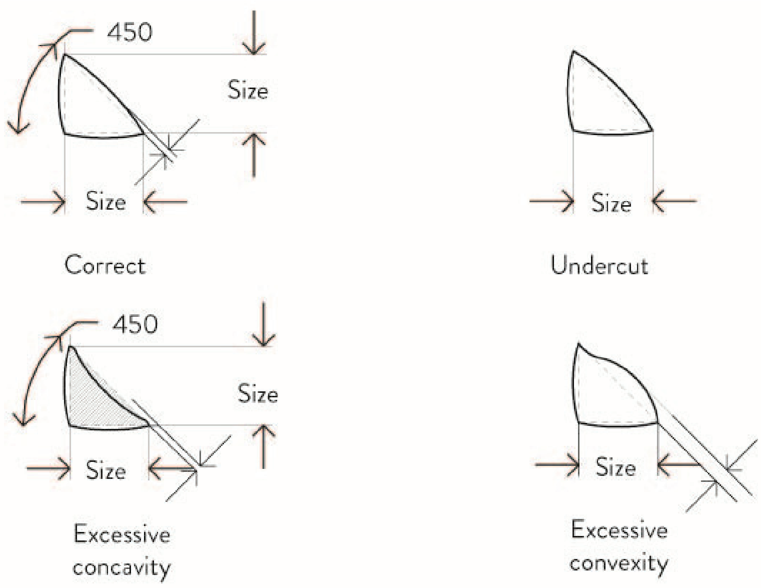


Table 41.d.Minimum Fillet Weld Thickness

Base Metal Thickness, T		Minimum Weld Size	
in	mm	in	mm
T< ¼	(6)	1/8	3
¼<T<½	(6<T<12)	3/16	5
½<T< ¾	(12<T<20)	1/4	6
¾ < T	(20<T)	5/16	8

41.3.K. Any welding imperfections listed in Table 41.emust be corrected.

Table 41.e. Weld Imperfections and Corrections

Imperfection	Cause	Solution
Misalignment	Joining plates of different thickness. Set-up, fit up problems	Careful set-up
Overlap	Protrusion of weld metal beyond toe or root of weld. Poor welding techniques	Grind off excess weld metal and grind surface smooth to base metal
Undercutting	Incorrect electrode angle, excessive current and travel speed	Repair by welding resultant groove with smaller electrode
Concave and Convex Welds	Incorrect electrode current and speed	Either fill or grind back to base metal
Cracking	Due to brittleness in heat zone	Preheat weld surface and filler material
Lamellar Tearing	Occurs below welded joints at points of high stress concentration resulting from non-metallic inclusions in base metal	Use material of adequate quality
Inclusions	Foreign material becoming part of weld, due to insufficient cleaning	Grind down and re-weld
Porosity	Contamination, inadequate shielding	Use of proper electrodes and filler material
Hammer Marks, Arc Strikes	Localized spots of remelted metal, small nicks caused by careless handling of welding electrode holder	Grind down and re-weld
Craters	Visual Depressions indicating improper weld terminations	Avoid by careful use of correct techniques
Spatter	Metal drops expelled from weld stick to surrounding surface	Grind Clean
Incomplete Fusion/Penetration	Weld material did not form bond with base metal	Difficult to detect. Avoid by careful use of correct techniques.

41.3.L. On large projects, contractors must receive approval of welding sequence from the assigned IU representative prior to beginning work. The sequence in welding and assembling of steel framing must minimize distortion and shrinkage.

42 Miscellaneous Metals

A variety of metals, in addition to steel, are utilized in a number of construction applications. Alloys resistant to weathering are highly efficient to use as metal roof deck. For metals not naturally resistant to weather, care must be taken to ensure material is protected adequately from moisture and weather.

42.1 General Requirements

The following quality assurance, storage and submittal guidelines are intended to provide guidelines to ensure the performance of the structure meets the intended use requirements over the life of the building.

Quality Assurance

42.1.A. Work that does not comply with specified requirements must be removed and replaced.

42.1.B. Additional inspecting should be performed by the assigned IU representative to determine compliance of any corrected work required by the building inspector or engineer.

42.1.C. All field welds must be subject to inspection by an assigned IU representative.

Delivery, Storage and Handling

42.1.D. Miscellaneous metal must be protected from corrosion, deformation, and other damage during delivery, storage and handling.

42.1.E. Plastic wrap must be cut to encourage ventilation and avoid the buildup of moisture resulting in corrosion.

42.1.F. Metal decking must be stacked on platforms or pallets and sloped to provide drainage. A waterproof covering must be provided and the space ventilated to avoid condensation.

Submittals

42.1.G. Contractor means and methods must be approved by assigned IU representative prior to start of construction.

i. For structures with more than one level, the assigned IU representative must review and approve construction details and shop drawings where available.

ii. Steel drawings and details must include layout and types of deck panels, anchorage details, and reinforcing techniques.

42.1.H. If materials vary from construction documents or from suggested material specifications herein, material substitution must be approved by the assigned IU representative.

42.2 Products

All miscellaneous metals used for construction should follow standards and guidelines provided. Miscellaneous materials, not specifically addressed herein, should be approved by a building official prior to use.

42.2.A. Roof decking must meet general quality standards per Table 42.a.

42.2.B. All fasteners must be corrosion resistant.

Table 42.a.Roof Decking Requirements

Type	Material grade and specification	Notes
Prime Painted Steel Sheet	Grade 33 – 33 ksi (230MPa)	Shop primed with manufacturer's standard baked-on, rust inhibitive primer
Galvanized Steel Sheet	Grade 33 – 33 ksi (230MPa)	
Galvanized and Shop-Primed	Grade 33 – 33 ksi (230MPa)	Zinc coating, cleaned, pretreated, and primed with manufacturer's standard baked-on, rust inhibitive primer.
Zinc Alloy or Aluminum Alloy	Grade 33 – 33 ksi (230MPa)	Aluminum, Zinc-Alloy coating

42.3 Execution

Proper installation and fabrication of metals will help ensure longevity and construction quality.

42.3.A. **Supporting framed and field conditions must be examined by the assigned IU representative for compliance with requirements, installation tolerances and other conditions affecting performance prior to installation.**

42.3.B. **Installation of metal decking must meet general installation requirements:**

i. Temporary shoring must be installed before placing deck panels if required to meet deflection.
ii. Place deck panels on supporting frame (beginning at low point on roof) and adjust to final position with ends accurately aligned and bearing on supporting frame before being permanently fastened.
iii. Provide additional reinforcement and closure pieces at openings as required for strength, continuity of deck, and support of another.
iv. Deck ends must be installed over a supporting frame with a minimum end bearing of 1½in (3.8cm).

42.2.C. **For each manufactured product, manufacturer's instructions must be followed.**

i. Where product instructions are not available, contractor means and methods of installation must be approved by the assigned IU engineer.

42.3.D. **Protection against corrosion must be prioritized for all metals.**

i. Aluminum may be protected from corrosion by the addition of magnesium alloy or anodizing.
i. Added protection must be used coastal areas as the air often contains a high salt content. This is especially important for buildings directly exposed to the sea breeze. A rubber membrane or barrier should be placed between concrete or other masonry blocks, or treated wood to protect aluminum roofing from corroding.

42.3.E. **Rust spots, welds and abraded areas of metal decking must be wire brushed and cleaned, with repair paint applied.**

43 Wood and Bamboo

Wood and bamboo are renewable resources that can be worked with easily. Additionally, they are high in various strength properties compared to its weight making it suitable for use in structural, non-structural applications. If care is taken to dry and protect it appropriately, local wood or bamboo can be a cost effective, sustainable resource for the construction of health facilities.

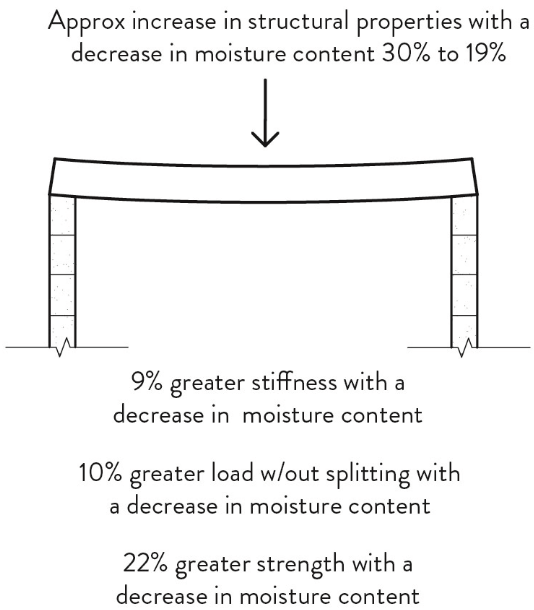
43.1 General Requirements

Wood and bamboo are easily workable and often readily available materials; however, quality can only be assured if certain conditions are met.

Minimum Performance Requirements

43.1.A. **Moisture content must be below 19% for all wood to reduce shrinkage effects and ensure adequate strength.**

Figure 43.a. Moisture Content Effects



Moisture Levels and Shrinkage

Notable shrinkage begins in most species at moisture content of 30%. Shrinkage at this stage is proportional to moisture loss. Various strength properties will increase when moisture content decreases from 30% to 19%.

In general, hardwoods shrink more than softwoods, and heavier species more than lighter ones. Decay will not occur in wood if moisture content is maintained below 20%.

Delivery, Storage and Handling

43.1.B. **Wood products must be covered during storage to protect against moisture. Stacked products must be supported to prevent deformation and allow air circulation.**

43.1.C. **Seasoned materials must not be stored in wet or damp portions of the building.**

43.1.D. **Boards and braces must be dry and protected from water to prevent moisture build up and swelling of wood.**

i. If wood is used as a form, apply a cover of oil on the surface before placing concrete.

43.2 Products

Wood or bamboo products must be reviewed for quality before being used in construction.

Rough Carpentry

43.2.A. For structural framing, refer to Table 43.a.to determine acceptable species. Refer to Standard 43.3.B. for visual grading guidelines.

43.2.B. Sawn, dimensioned lumber of acceptable species must be used for all structural framing.

43.2.C. Wood products supplied for rough carpentry must be of an acceptable species as listed in Table 43.a.

Table 43.a.Rough Carpentry

Type	Acceptable Species			Notes
	Local Name	English Name	*Species*	
Wood Framing	Dahoma Faro Kusia Tali Fromager Ilomba	African Greenheart Shedua African Peach Sasswood Silk Cotton -	*Africanum* *Thurifera* *Diderrichii* *Ivorensis* *Pentandra* *Africanus*	All wood for framing must be visually inspected per 43.3.B.
Furring	Dahoma Faro Kusia	African Greenheart Shedua African Peach	*Africanum* *Thurifera* *Diderrichii*	
Nailers and Blocking	Dahoma Faro Kusia	African Greenheart, Shedua African Peach	*Africanum* *Thurifera* *diderrichii*	
Sill Plates	Kusia	African Peach	*diderrichii*	All sill plates must be resistant to termite damage and seasoned or finished to protect against weather.

[a] *Kusia (Nauclea diderrichii) is listed as a vulnerable species by the International Union for the Conservation of Nature and should be avoided where possible unless verifiable, sustainable harvesting practices are used.*

Vulnerable and Threatened Wood Species

Numerous wood types common in Liberia have been intentionally left off the list of acceptable wood types due to their classification as threatened species by the International Union for the Conservation of Nature (IUCN) in its annual Red List publication. The IUCN Red List is considered the world's most comprehensive compilation of conservation status.[11]

The IUCN Red Lists ranks species ranging from Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, to Extinct. Any wood type known to be listed in a state of Vulnerable or worse has been left off the list of acceptable wood types, with the exception of *Nauclea diderrichii* (local name: kusia; English name: African Peach) due to its commonality. Nonetheless, kusia wood should also be avoided.

A list of commonly available woods in Liberia that are listed as Vulnerable or worse on the IUCN's Red List is given below.

Table 43.b. Known Vulnerable or Endangered Wood Species in Liberia.

Genus & Species	Local Name	English Name	IUCN Red List Status
Teminicia ivorensis	Framire	Black Afara	Vulnerable
Heritiera utilis	Niangon	Whismore	Vulnerable
Tieghemella heckelii	Makore	Cherry Mahagony	Endangered
Nauclea diderrichii	Kusia	African Peach	Vulnerable
Hallea ciliata	Abura	(none known)	Vulnerable
Fleroya ledermannii			

Sheathing

43.2.D. Repairs to plywood must be neatly made of wood and parallel to grain. The total repair of one sheet must be limited to six in number and be well matched for color and grain.

43.2.E. Concrete form panels must have a release agent applied. Wood species must not contain wood sugars that prohibit proper curing of concrete.

43.2.F. Structural plywood sheathing must not contain splits in faces over ¼in (6mm) and splits in back over ½in (12mm) and contain no knothole in veneer greater than 2 ½in (63.5mm).

Table 43.c.Sheathing- Design Base Values

Type	Acceptable Species			Notes
	Local Name	English Name	*Species*	
Plywood	Ilomba (Gboyei), Wawa	- -	*Africanus* *Scledroxylon*	

Finish Carpentry

43.2.G. Exterior finish carpentry (exposed and nonstructural) must be cleaned on exposed and semi-exposed surfaces. Touch up finishes to restore damaged or soiled areas.

Table 43.d.Exterior Finish Carpentry

Type	Acceptable Species			Notes
	Local Name	English Name	*Species*	
Planking, Paneling, Roof Shingles	Kusia	African Peach	*Diderrichii*	More numerous "pin" knots and other small blemishes.

43.2.H. Interior finish carpentry (exposed and nonstructural) must be cleaned on exposed and semi-exposed surfaces. Touch up finishes to restore damaged or soiled areas.

Table 43.e.Interior Finish Carpentry

Type	Acceptable Species			Grading Notes
	Local Name	English Name	*Species*	
Cabinet, Veneer, Flooring, Planking, Paneling	Kusia Ilomba (Gboyei)	African Peach -	*Diderrichii* *Africanus*	Small tight knots. May be nearly perfect on one side.

Plywood, Fiberboard, & Particle Board

43.2.I. Any non-structural plywood, MDF, HDF or particle board must be a minimum of $^3/_8$in (9mm) thick. Structural plywood must comply with engineer specifications and must be approved by the assigned IU representative.

43.2.J. MDF and HDF must not be used as structural elements, cladding, or secure enclosure and must not be used in any area in which there is a risk of consistent exposure to water.

43.2.K. If used, plywood, MDF, HDF, and particle board must be finished completely with an impervious waterproofing conforming with Standard 44.3.B.

MDF and HDF

MDF and HDF (medium and high density fiberboard) are made of compressed sawdust with a glue-based binding agent. Because they have no continuous fibers, they are structurally weak in tension and disintegrate quickly when exposed to water. They must be avoided in areas in which exposure to water is a risk, including as ceiling materials in case roof leaks develop.

43.3 Execution

Execution standards and guidelines are provided to give baseline criteria of acceptable construction and ensure the quality of building.

Framing and Installation

43.3.A. Proceed with installation only when existing and forecast weather conditions permit work to be performed and at least one coat of finish can be applied without exposure to rain or moisture.

43.3.B. Structural members must be level, plumb, and true to line. Pieces with defects that would lower required strength or result in unacceptable appearance of exposed members must be discarded.

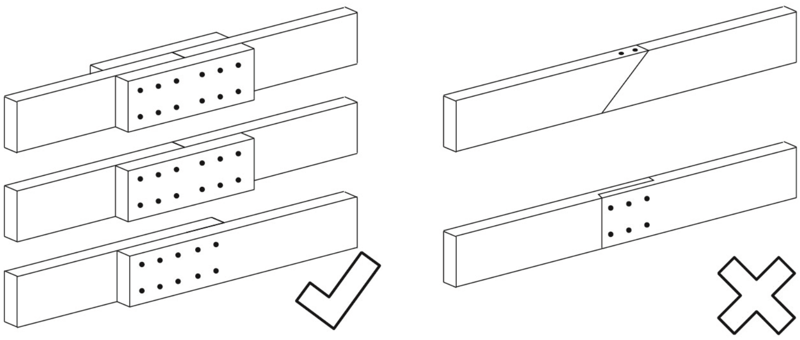
Visual Inspection Notes

It is assumed that as the defects become larger and more frequent, strength properties drop. Defects to look for include: number, size and position of knots and holes, decay, checks and splits, twisting, bowing and warp

43.3.C. Where structural members need to be spliced, the following requirements must be followed:

i. Members must be spliced must be of same wood type, quality, and size.
ii. Splice length overlap must be 1/3 of total combined length unless otherwise designed by an engineer.
iii. Splices must not occur in center third of spanning member.
iv. Splices must be connected @ 12in (30.5cm) on center with thru bolts or, nailed @ 6in (15.3cm) on center from both sides, staggered. Nails must penetrate through at least half of the adjoining member.
v. Simple angled, butt-end joints must not be used.

Figure 43.b.Acceptable Splicing Techniques



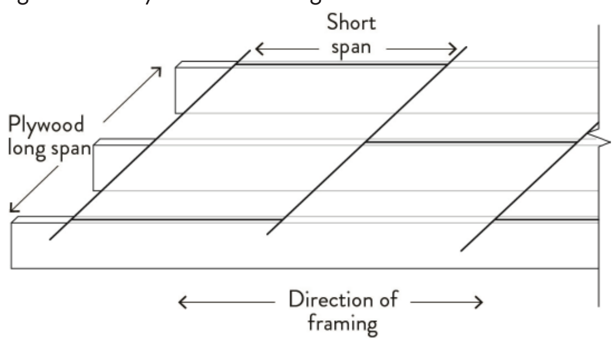
43.3.D. Provisions for temporary construction loads and temporary bracing sufficient to maintain structure in true alignment and safe condition until completion of erection and installation of permanent bracing must be provided.

43.3.E. Wood or bamboo members must not be cut, drilled, or notched unless shown in the structural drawings.

43.3.F. Horizontal spanning members must be installed with a minimum of 1½in (3.8cm) bearing at each end.

43.3.G. Plywood sheathing must be installed with long sides perpendicular to framing.

Figure 43.c.Plywood Sheathing Installation



Protection

43.3.H. Lumber must be kiln or air-dried to a maximum moisture content of 19%.

Moisture Content

Moisture content can be determined through oven drying or electric moisture meters.

Oven Dry Moisture Measurement: Wood is dried to a relatively constant weight in a ventilated oven at 218 F (102 C). Moisture content is the percentage difference of the green weight of wood to the oven-dried weight of wood. $MC = (W_g - W_o)/W_o \times 100\%$

Electric Moisture Meter: Where quick, reliable, non-destructive methods are needed, a portable electric moisture meter can be used which measures moisture content indirectly from electric properties of wood that change relative to the moisture of the wood.

43.3.I. Lumber in contact with roofing, flashing, waterproofing, masonry or concrete must be treated with acceptable waterproofing and anti-termite treatment. Two coats must be applied to all surfaces.

i. It is recommended to use "carboline" or similar anti-termite treatment to all structural wood.

FINISHES & FIXTURES

CONTENTS

IMPACT

From floors to walls to ceilings, building finishes are some of the most visible materials used in construction, the most important surfaces for adequate performance as contributors to infection control, and the primary wear surfaces. Base material protection, maintenance minimization, and sanitation are all affected by the choice and proper installation or application of finishes.

PRIMARY USERS

Infrastructure Unit

County Health and Social Welfare Teams

Facility Staff

Architects & Designers

Contractors

GUIDELINES FOR USE

The data charts presented in Section 44.1: Finish Selection Criteria show performance areas of a variety of acceptable building finishes. They read from left to right, with the left-most indicators being the most desirable within that indicator. While the comparisons are not comprehensive, the performance criteria may be used to asses any finishes to be used.

Once finishes are selected, specific Standards relevant to categories of spaces are outlined, thus giving the user flexibility in choice while maintaining rigorous requirements.

44 Building Finishes

Building finishes influence the maintenance of a strong infection control regimen, and are both the most visibly apparent building components, as well as the ones most in contact with users. Their quality may have a large impact not only on actual building longevity, but also on the perception of the standard of care.

Certain applied finishes have environmental impacts - both on a macro scale as ecological impacts, and on a micro scale as impact on indoor air quality. Indoor air quality is extraordinarily important in health facilities, where people come with the intention of being healed; clinic and hospital spaces must not contribute to a decline in a patient's health due to poor air quality resulting from the properties of chosen finishes.

Definitions

- **Toxicity:** The extent to which a substance can damage living organisms.
- **Volatile organic compounds (VOCs):** Organic chemical compounds whose composition makes it possible for them to be released as gasses from solid or liquid substances under normal building conditions.
- **Off-gassing:** The process of a material releasing evaporated substances into the air from a solid to a gaseous state.

44.1 Finish Selection Criteria

A wide array of performance criteria have been considered when selecting acceptable finishes. What is outlined in this section are some primary considerations and are not fully comprehensive. Nevertheless, the user may use these inputs to as basic performance criteria for health care outcomes given as a priority.

The data tables presented here are organized with most desirable properties on the left, less desirable on the right. Where possible, the data has been quantified, but there is not always a simple measurement for environmental properties.

Performance Factors

44.1.A. **Finishes that are impervious to water penetration must be prioritized in exterior areas, sterile areas, and sanitary spaces, and should be considered for other clinical spaces as well.**

i. Table 44.a may be used as a reference for imperviousness to water penetration. However, this depends on finish application and maintenance as well as the properties of the finish itself. Therefore, this should be used as a guide but not a definitive measurement.

ii. Terrazzo and smooth cement are screed materials but are not necessarily finishes themselves. Performance can be improved with an additional finish material added atop the screed.

Table 44.a: Imperviousness to Water Penetration of Common Finishes

	VERY HIGH	HIGH	MODERATE	LOW	MINIMAL
Latex Paint (water-based)			<----X---->		
Solvent Paint (oil-based)		X			
Polyurethane		X			
Synthetic Wax		X			
Natural Wax		X			
Epoxy resin	X				
Linoleum		<----X---->			
Vinyl Flooring		<----X---->			
Terrazzo			X		
Smooth Cement Screed			X		
Ceramic Tile		X			
Terra Cotta Tile			X		
Stone Tile		X			
Glass Tile		X			
Stainless Steel	X				

44.1.B. **Finishes with a long expected useful/performance life and low maintenance requirements must be prioritized, especially in facilities with minimal staff or available replacement finishes.**

i. Table 44.b may be used as a reference for expected maintenance or replacement requirements of common finishes. However, this will vary based on building use, installation quality, exposure, and other unpredictable factors. Therefore, this should be used as a guide but not a definitive measurement. Maintenance, as defined here, does not include regular cleaning and inspection, which should be performed on all finishes consistently and continuously.

Table 44.b. Maintenance or Replacement Requirements of Common Finishes

	MINIMAL (almost no maintenance during building life)	LOW (20+ year maintenance schedule)	MODERATE (5-20 year maintenance schedule)	HIGH (1-5 year maintenance or reapplication)	VERY HIGH (annual or more frequent maintenance or re-application)
Latex Paint (water-based)				X	
Solvent Paint (oil-based)			X		
Polyurethane			X		
Synthetic Wax					X
Natural Wax					X
Epoxy resin		X			
Linoleum			X		
Vinyl Flooring		<----X---->			
Terrazzo		X			
Smooth Cement Screed		X			
Ceramic Tile	X				
Terra Cotta Tile		X			
Stone Tile	X				
Glass Tile			<----X---->		
Stainless Steel	X				

Finish Longevity and Maintenance

Applied finishes such as paints, solvents and waxes may diminish over time and will require regular re-application, especially if exposed to the elements. This should be done in accordance with product recommendations, or as soon as deterioration is observed.

Certain floor materials such as epoxy resin, terrazzo, and concrete screed have particular maintenance requirements that must be followed in order to ensure material performance and longevity. This should be done in accordance with product recommendations or as part of a comprehensive maintenance plan tailored to the material itself. Epoxy resin may have a longer useful life if properly poured and maintained. However, this material is difficult to install, requires skilled labor, and is difficult to repair. Thus its useful life may be realistically expected to be within a big range of time.

The lifespan of sheet materials such as vinyl and linoleum depends largely on the quality of installation. Linoleum is more susceptible to wear and thus often has a shorter lifespan.
Cast cementitious materials (terrazzo, cement screed), have long life spans with proper construction and maintenance. However, they normally require additional applied finishes and thus are dependent on the performance of the added finish.
Tile material longevity depends as much on the quality of grouting, and the placement and quality of the setting bed, as the quality of the tile. Care must be taken to install them properly.
Stainless steel is highly durable but also highly expensive and is not practical for most applications.
Glass tile is more susceptible to breakage than other tiles; thus the maintenance involved may be higher. This should not be used in areas where heavy traffic or heavy loads are expected.

44.1.C. **Finishes, sealants, and topcoats must be made of non-flammable materials wherever possible.**

i. Product information must be referenced to determine flammability.

Ecological and Indoor Air Quality Considerations

44.1.D. Prioritize materials that have minimal toxicity levels and potential for off-gassing of volatile organic compounds (VOCs).

i. Table 44.c may be used as a guide for selection but it must be understood that precise toxicity levels will vary depending on the ingredients of the particular finish. This is for reference only and should not be taken to be definitive. The user should investigate specific properties of each finish under consideration.

Table 44.c: Toxicity Levels of Common Finishes

	NON-TOXIC (fully non-toxic)	LOW (contains nominal toxins)	MODERATE (contains moderate levels of toxins)	HIGH (contains harmful toxins)	VERY HIGH (contains dangerous toxins)
Latex Paint (water-based)				X	
Solvent Paint (oil-based)				<----X---->	
Polyurethane				<----X---->	
Synthetic Wax			<----X---->		
Natural Wax	X				
Epoxy resin					X
Linoleum		X			
Vinyl Flooring				X	
Terrazzo	X				
Smooth Cement Screed	X				
Ceramic Tile	X				
Terra Cotta Tile	X				
Stone Tile	X				
Glass Tile	X				
Stainless Steel		X			

Toxicity and Volatile Organic Compounds (VOCs)

Toxicity is the extent to which a substance can damage living organisms. In material finishes, this is often found in the form of *Volatile Organic Compounds (VOCs)*, which are organic chemical compounds whose composition makes it possible for them to be released as gasses from solid or liquid substances under normal building conditions. Many VOCs are extremely harmful to human health, and reducing their quantity is an important goal of indoor air quality and environmental health. VOCs are released through an off-gassing process that may last the entire life of the material, with newly produced or cured materials usually releasing them in greater quantities. The presence of non-natural, chemical compounds often contribute to the hazardousness of material finishes.

Many paints, polyurethanes, and resins contain high concentrations of VOCs that get released into the indoor environment. Release of VOCs is highest upon finish application before curing), and decreases exponentially over the life of the material. It is important to note that off-gassing does not stop with the curing of the finish. Thus, these products should be avoided where possible, and/or appropriate non-toxic alternatives found.

Many synthetic waxes are petroleum or polyethylene based. These materials potentially off-gas heavily. However, various types of synthetic waxes exist, and less toxic types do exist. The user should verify the contents of any specified synthetic waxes.

Vinyl continues to off-gas through the life of the material, which may have harmful effects on indoor air quality. Less toxic substitutes should be found where possible.

Cast cementitious materials (terrazzo, concrete screeding) are non-toxic themselves, but often require additional finishing agents which may contain toxins. The finishing agents should be researched and evaluated accordingly.

44.1.E. All finishes must be free of formaldehyde.

i. Formaldehyde is known to be a carcinogen. In building materials and finishes, it is most often found in binding agents of plywood, fiberboard, and particleboard, as well as components of some solvent-based finishes.[1]

Environmental and Life Cycle Considerations

44.1.F. Wherever possible, finishes made from renewable ingredients must be prioritized.

i. Table 44.d may be used as a guide for selection. This is for reference only and should not be taken to be definitive. Also shown is whether materials are recyclable, so that they may be reconstituted at the end of the material or building life.

Table 44.d Renewability of Common Finishes

	VERY HIGH (fully renewable in less than 10 years)	HIGH (fully renewable in more than 10 years)	MODERATE (made up of some renewable components)	LOW (made of re-creatable naturally sourced materials but not renewable)	NON-RENEWABLE (not made of creatable naturally sourced materials)	RECYCLABLE
Latex Paint (water-based)					X	
Solvent Paint (oil-based)					X	
Polyurethane					X	
Synthetic Wax					X	
Natural Wax	X					
Epoxy resin					X	
Linoleum			X			
Vinyl Flooring					X	
Terrazzo					X	
Smooth Cement Screed						
Ceramic Tile				X		
Terra Cotta Tile				X		
Stone Tile					X	
Glass Tile				X		X
Stainless Steel					X	X

Renewability

Renewable ingredients consist of those for which raw materials can be regenerated through natural processes. For material finishes, these are fairly rare, though there are an increasing number of products becoming available.

Natural waxes may be made from vegetable matter or beeswax, both of which are naturally occurring and can be regenerated.

Linoleum is made from hardened linseed oil, natural rosins, wood and/or cork dust, and natural fillers. Most of its ingredients are vegetative and all can be sourced naturally.

Most tile materials are made from materials that can be generated by nature over long timelines, but cannot be directly regenerated at will. This includes sand as an ingredient of glass, stone, and ceramic clay inputs.

Glass and metals are fully recyclable and can be reconstituted; however whether this is actually done might be beyond the control of the health care management system.

Economic and Development Considerations

44.1.G. **Without compromising building performance, cost-effective finishes and finishes with a high cost/durability ratio must be prioritized.**

44.2.H. **Finishes produced and/or available within Liberia must be prioritized in order to fuel local economies, ensure availability of replacements, and invest in the development of Liberia's construction industry.**

i. Table 44.e may be used as a reference for availability and production of materials in Liberia as of 2013. This may change over time and it is up to the user to verify the sourcing.

Table 44.e: Availability of Common Finishes in Liberia

	VERY HIGH (able to be produced locally and readily available)	HIGH (partially produced in-country and available)	MODERATE (available in-country but produced externally)	LOW (limited availability and produced externally)	MINIMAL (by special order only)
Latex Paint (water-based)	<----X---->				
Solvent Paint (oil-based)	<----X---->				
Polyurethane	<----X---->				
Synthetic Wax					X
Natural Wax					X
Epoxy resin					X
Linoleum					X
Vinyl Flooring				X	
Terrazzo	<----X---->				
Smooth Cement Screed	<----X---->				
Ceramic Tile			<----X---->		
Terra Cotta Tile	X				
Stone Tile			X		
Glass Tile					X
Stainless Steel					X

44.1.I. Prioritize finishes which local laborers have the skills to install or can be trained to install.

i. Table 44.f may be used as a reference for local availability of skilled labor for each of the finishes presented as of 2013. This may change over time and it is up to the user to verify the local labor potential. Also shown are materials for which training of laborers is relatively straightforward for a modest increase in building construction cost.

Table 44.f. Workability of Common Finishes by Local Laborers

	VERY HIGH (skilled laborers can be sourced anywhere)	HIGH (skilled laborers can be found nationwide)	MODERATE (skilled laborers can be found in some locations)	LOW (highly specialized)	MINIMAL (no in-country skilled labor available)	TRAINING CAPCITY (capacity to train laborers with marginal cost increase)
Latex Paint (water-based)	X					X
Solvent Paint (oil-based)	X					X
Polyurethane	X					X
Synthetic Wax			<----X---->			X
Natural Wax			<----X---->			X
Epoxy resin				<----X---->		
Linoleum			X			X
Vinyl Flooring			X			X
Terrazzo			<----X---->			
Smooth Cement Screed		<----X---->				
Ceramic Tile		X				X
Terra Cotta Tile		X				X
Stone Tile		X				X
Glass Tile		X				X
Stainless Steel					X	

Local Resources

Finishes produced in Liberia are preferred over materials available in Liberia but produced elsewhere. The goal is to keep the maximum amount of capital within Liberia as a way of fueling additional development.

Using local labor achieves two goals of construction projects: it provides a source of revenue for local laborers, thereby infusing capital into local economies; and it helps ensure the familiarity of the worker with the construction techniques. However, skill levels are variable and this should not be taken as a guarantee of high-quality construction.

For some finishes installation, on-site training may be provided to help increase the skill of the labor force in Liberia. Some other finishes do not require any particular skills.

44.2 Floor Finishes

As the primary wear surface of buildings, floor finishes play an important role in building longevity as well as building hygiene. Even durable floors may fail in a physical or performance sense in the absence of proper finishing.

General Requirements for All Floors

44.2.A. Floors of occupiable spaces must be flat, with variations from plane being less than 1:500 slopes.

i. Occupiable spaces are any areas intended to be used by staff or patients for non-circulation purposes. For circulation space requirements, refer to Section 16.2.

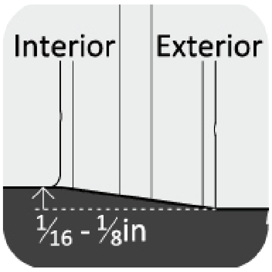
ii. Slope requirements do not apply to showers or sanitary spaces in which a slope towards a drain is intentional. For these areas, slopes must not exceed 1:40.

44.2.B. Flooring materials and/or finishes must be impermeable to water and other liquids to prevent infiltration.

i. Floor surfaces must be able to prevent moisture from penetrating the building fabric.[2] This can best be ensured by creating an impervious floor with appropriate safeguards from water penetration to walls, including skirtings per standard 44.2.L.

44.2.C. A sloped height difference of between $^1/_{16}$ in (1.5mm) and $^1/_8$ in (3mm) must be used between interior and exterior floors to prevent minor flooding from entering interior spaces. These height differences must be sloped, not stepped.

Figure 44.g: Threshold Slope Diagram



44.2.D. Ramps, stairs and level changes must be slip-resistant and visible to the visual impaired.

i. Ramps and stairs must be made of a slightly textured material finish, or with textured stair nosing, in order to provide slip resistance.

ii. Level changes greater than 2in (5cm) must have a contrasting color to indicate the beginning and end of the level change.

44.2.E. Applied floor finishes must be fully adhered to the subfloor in all places.

i. Tiles must be grouted to the structural slab and sheet-flooring such as vinyl or linoleum must use appropriate quality adhesives.

44.2.F. Floor finishes must be of a material that is not physically affected or degraded by detergents, disinfectants, or cleaning solvents likely to be used.

i. Information to this end must be obtained from the material supplier or manufacturer.

44.2.G. Finished floor materials must be of appropriate thicknesses and appropriate installation.

i. Epoxy resin floors must have a primed screed underlay in accordance with manufacturer's specifications and must be a minimum of $^{3}/_{32}$in (2mm).

ii. Linoleum sheet floors must be a minimum of $^{1}/_{8}$in (3mm) thick and be adhered to the subfloor using appropriate binding agents.

iii. Vinyl sheet floors must be a minimum of $^{3}/_{32}$in (2mm) thick and must be adhered to the subfloor with appropriate binding agents. Vinyl tiles must be a minimum of $^{1}/_{8}$in (3mm) thick and grouted or adhered to the subfloor with appropriate high quality binding agents.

iv. Smooth cement screeds and poured terrazzo floors must be a minimum of $1^{1}/_{4}$in (31mm) thick and be fully bonded to a concrete subfloor or structural slab.

v. Terrazzo tile and terra cotta tile must be grouted to the subfloor and at tile joints and must be a minimum of $^{1}/_{2}$in (12mm) thick.

vi. Stone tile and ceramic tile must be grouted to the subfloor and at tile joints and must be a minimum of $^{1}/_{4}$in (6mm) thick.

44.2.H. Glass tile must not be used as a floor surface.

44.2.I. Carpets must not be used in health facilities.

i. Carpets are havens for moisture, dirt, and particulates, thus acting as prime breeding grounds for pathogens. Liberia's humid climate makes carpet especially problematic.

ii. This standard does not include entry matting, which is defined in standard 44.2.T.

Floors in Clinical Areas

44.2.J. Terra cotta tiles must not be used as a finished floor surface in clinical areas.

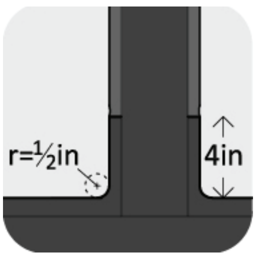
44.2.K. Floors must be smooth and non-porous, with no bumps or protuberances greater than $^{1}/_{16}$in (1.5mm) in height and no voids or air pockets.

44.2.L. In clinical spaces and corridors, a floor skirting of minimum 4in (10cm) height must be installed with a continuous, seamless return to the floor surface.[3]

i. It is recommended that the floor return have a radius of at least $^{1}/_{2}$in (12mm) in order to avoid the potential for water pooling or dirt collection at the joint.

ii. Skirting with the same properties is also recommended for non-clinical spaces.

Figure 44.h: Skirting Diagram



44.2.M. Seams and joints must be minimized or eliminated.

i. For floor types in which joints are unavoidable, joints must be properly grouted and smoothed, with grout or filler height not less than $^{1}/_{16}$in (1.5mm) below the surface of the flooring material.
ii. Joints designed for structural movement must be accommodated and must be filled with a compressible fill flush with the floor surface.
iii. Threshold strips must be avoided. They provide places for water and dirt to be harbored, thus contributing to microbial and/or potential pathogen growth. In Liberia's tropical climate, threshold sealing is unnecessary.

44.2.N. In sterile areas, special precautions must be taken:

i. If vinyl flooring is used it must be heat welded at joints in order to prevent penetration of substances into joints.
ii. If tiles of any sort are used, grouting must be flush with the face of the tile, smooth, and the entire floor surface treated with an impervious finish.
iii. Linoleum floors must not be used in sterile areas.

Floors in Sanitary Areas

44.2.O. Floors in sanitary areas (bathrooms, WCs, showers, and sluice rooms) must either meet all requirements for floors in clinical areas per standards 44.2.J - 44.2.M, or be of ceramic or stone tile.

i. Individual tile size must be minimized in order to provide traction at joints.
ii. Grouted tile joints must be straight, with a maximum width of $^{1}/_{16}$in (1.5mm), with grout or filler height not less than $^{1}/_{16}$in (1.5mm) below the surface of the flooring material.
iii. Skirting tile must be included at the joint between the floor and wall at least 4in (10cm) in height.

44.3.P. In shower areas, slip-resistant floor materials must be prioritized.

44.3.Q. Floor drains must be of aluminum or other non-corrosive metal, be located at the lowest point, and be either flush or recessed up to $^{1}/_{16}$in (1.5mm) from the finished floor level.

i. Floor drains must not protrude above adjacent finished floor level.
ii. Floor drains must have a drain trap to prevent odors from

Exterior Floors

49.2.R. Floors must be non-porous, with no bumps or protuberances greater than $^{1}/_{8}$in (3mm) in height and no voids or air pockets.

i. Textured surfaces may be permissible in areas exposed to rain, but care must be taken to ensure this does not impede cleaning or regular maintenance.

49.2.S. Any seams or joints must be made flush and sealed against water penetration or sloped towards a runoff area.

49.2.T. Matting suitable for pedestrian and gurney/wheelchair users must be provided at entrances where possible to reduce dirt being tracked into the building.

i. Matting must be made of a suitable, washable material and be part of a regular maintenance plan.
ii. Matting must be placed at the exterior of the door in areas that are sheltered from the elements.
iii. Recessed matting to ensure a co-planar surface with finished floor levels must be prioritized.

44.3 Wall Finishes

Wall surfaces, particularly to the height reachable by most people, are subject to frequent exposure of various elements. Thus, their finishes require careful consideration in order to maintain infection control standards. For more information on which spaces must follow General, Clinical, Sterile and Sanitary wall finishes requirements, refer to Standard 46.3.B. For additional specific requirements, refer to Chapters 47-50.

General Requirements for All Walls

44.3.A. **Wall surfaces must be non-absorptive and made of durable materials capable of withstanding the conditions it will be exposed to.**

i. Interior walls must be finished in a way so as to receive mountings, fittings and fixtures without causing substantial damage.
ii. Exterior walls must provide protection from the elements.

Requirements for Walls in Clinical Spaces

44.3.B. **Walls of clinical spaces must be finished with smooth, non-porous materials, with no bumps or protuberances greater than $^{1}/_{16}$in (1.5mm) unless designed as part of a wall accessory (e.g. switches, handrails, etc.).**

i. Accessories may include cabinetry, shelving, or other utility items.

44.3.B. **Wall finishes in clinical areas must be impermeable to water and other liquids to prevent infiltration.**

44.3.C. **Seams and joints must be eliminated or otherwise addressed, and walls must be free from fissures or cracks.[4]**

i. For wall types in which joints are unavoidable, joints must be properly grouted and smoothed, with grout or filler height not less than $^{3}/_{32}$in (2mm) below the surface of the flooring material.
ii. Care must be taken during installation of uniform finishes that proper curing and adherence techniques are followed in order to prevent the formation of cracks.
iii. Finish materials must be able to withstand expected expansion and contraction due to temperature and moisture changes or building movement.

44.3.D. **Non-brittle finish materials must be prioritized in high-traffic areas.**

i. For more requirements on impact protection, refer to Standard 45.2.C.

44.3.E. **If cavity walls are used, cavities must be completely sealed from clinical spaces.**

i. Penetration of pipes, conduit, or other building services must be tightly sealed to avoid the incursion of pests, maintain acoustic integrity, and increase fire resistance.[5]
ii. This requirement may be waived if the cavity is part of a natural ventilation system with an appropriately sized outlet from the cavity.

Requirements for Walls in Sterile Areas

44.3.F. **Walls of sterile spaces must be finished with smooth, non-porous materials, with no bumps or protuberances greater than $^{1}/_{16}$in (1.5mm).**

i. Punctures, apertures, or openings in walls of sanitary spaces (such as at pipe supply routes), must be sealed with a silicon or other water-resistant seal at the completion of fixture installation.

44.3.G. **Walls of sterile spaces must be finished with oil-based paint or other durable, waterproof materials.**

i. Wall surfaces must be able to withstand frequent cleaning and sterilization in these spaces.

Requirements for Walls in Sanitary Areas

44.3.H. **Walls of sanitary spaces (bathrooms, WCs, showers, and sluice rooms) must be finished with ceramic tile, glass tile, or other material impervious to water up to a height of at least 4ft (120cm), or to 7ft (210cm) for showers.**

i. Grouted tile joints must be straight, with a maximum width of $^{1}/_{16}$in (1.5mm), and must not be more than $^{1}/_{8}$in (3mm) recessed from the face of the tile.

ii. Walls above the tiled area must be finished with an oil-based paint or other water resistant finish.

44.3.I. **Punctures, apertures, or openings in walls of sanitary spaces (such as at pipe supply routes), must be sealed with a silicon or other water-resistant seal at the completion of fixture installation.**

44.3.J. **Insanitary areas, any electrical fixtures (such as electrical outlets, light switches, fuse boxes, or other fixtures wired with live electricity) must be at least 1ft (30cm) away from the edge of any sanitary fixture using water, and must not be anywhere along the perimeter of bathtubs or shower enclosures.**

44.4 Countertop Finishes

As a primary surface for work involving samples, countertops must be resistant to spills and able to withstand frequent cleaning.

General Requirements

44.4.A. Countertop surfaces must be flat and level, with a tolerance slope of not more than 1:500.

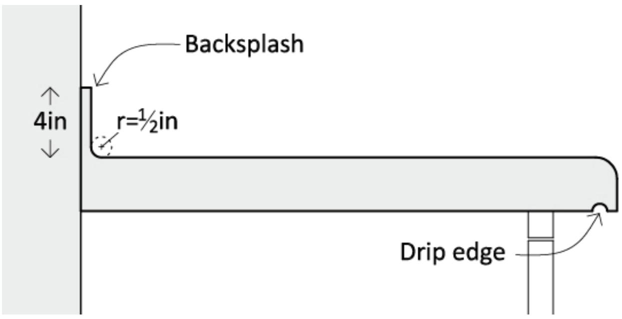
44.4.B. In clinical areas, countertop surfaces must be smooth and non-porous, with no bumps or protuberances greater than $^{1}/_{16}$in (1.5mm) above plane, and be made of durable, stain-resistant materials with minimal joints.

i. Acceptable materials include:
- Poured terrazzo or smooth cast concrete with impervious, protective finishing.
- Large polished stone tile with flush grouting and impervious, protective finishing at the joints.
- Epoxy- or hard cast plastic-based impervious composite surfaces (i.e. Formica or similar).
- Stainless steel.

44.4.C. Countertops in clinical spaces must have a backsplash of at least 4in (10cm) high, with a seamless return to the horizontal surface at a radius at least $^{1}/_{2}$in (12mm) greater, and a drip edge at the front overhanging edge.

i. A backsplash with these properties is also recommended for non-clinical spaces.

Figure 44.i. Countertop Profile Diagram



Laboratory Countertops

44.4.D. In laboratories, seams and joints in countertops must be eliminated or otherwise addressed, and be made of durable, stain-resistant and chemical resistant materials with minimal joints.

i. Acceptable materials include:
- Poured terrazzo or smooth cast concrete with impervious, protective finishing.
- Large polished stone tile with flush grouting and impervious, protective finishing at the joints.
- Stainless steel.

44.5 Ceiling Finishes

Ceilings are less likely to come up against solid or liquid contaminants from interior building use, but they form an important thermal and acoustical barrier between roof and spaces. Proper construction can also contribute to an improved infection control regimen. For more information on which spaces must follow General or Sterile and ceiling finish requirements, refer to Standard 46.3.C. For additional specific requirements, refer to Chapters 47-50.

General Requirements

44.5.A. Ceiling surfaces in clinical spaces must be smooth, with water-resistant finishes, and made of durable materials.

i. Acceptable materials include:
- Concrete slab finishes with cement plaster.
- Gypsum board at minimum $^{3}/_{8}$in (10mm) thickness.
- Timber of any type at a minimum $^{3}/_{8}$in (10mm) thickness.

44.5.B. Ceiling cavities must be sealed off from clinical spaces to avoid transfer of heat, dust, and/or moisture.

i. This requirement may be waived if the ceiling cavity is part of a natural ventilation strategy with appropriately sized exhaust openings in the cavity.

Ceilings in Sterile Areas

44.5.C. Ceiling surfaces in sterile areas must have suspended structural elements (if needed) behind (above) the ceiling surface so that the front (bottom) surface is uniform and planar.

44.5.D. Ceiling surfaces in sterile areas must be finished with oil-based paint or other water-resistant finish.

44.5.E. In sterile areas, ceiling fixtures (such as lights) must be recessed and have no horizontal surfaces beneath the ceiling upon which dust can collect.

i. The ceiling bottom surface must be smooth.

ii. Required and necessary equipment such as surgical lights, oxygen supply columns, or other medical devices are exempt from this standard.

45 Doors, Windows, & Fixtures

Windows and doors are among the most widely operated fittings within any building. Proper construction is essential to reduce long-term operating costs.

45.1 Frame Construction

Window and door frames are an often overlooked maintenance item, but proper construction can reduce the need for maintenance and extend the life of the window or door.

45.1.A Construction of window frames must be of durable materials, protected from corrosion or rot, and securely fixed to walls.

i. Window frames must be made of steel, extruded aluminum or other materials of high durability.
ii. Steel frames must be protected against rust and conform with the requirements in the steel materials section.
iii. In areas in which skilled labor for the installation of metal window frames is unavailable, well-treated, durable wood may be substituted. Refer to Chapter 43 for wood requirements.
iv. Window and door frames must be securely fixed to walls.

45.2 Doors

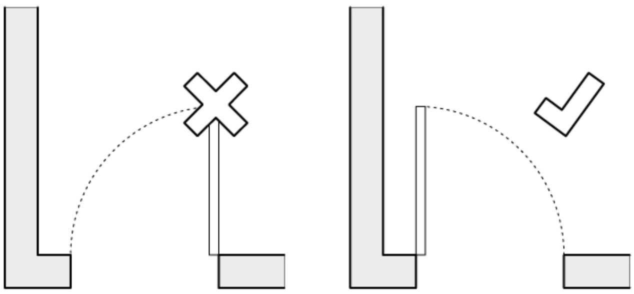
Access, privacy, and separation of function are dependent upon the functionality, and therefore craftsmanship and quality, of doors.

Door Construction

45.2.A. All swing doors must be on side-mounted hinges, with the leading edge of door towards the middle of the room and not into direct circulation areas.

i. Doors placed in corners should swing towards the wall to maximize the amount of usable space.
ii. Doors swinging out should be recessed from major circulation areas to prevent possible collisions of an opening door with passers-by.
iii. Refer to Figure 45.a for clarification.

Figure 45.a. Door Swing Diagram



45.2.B. Doors swinging in two directions must be fitted with viewing panels with transparent glass at a height of between 3ft 6in and 6ft (105cm and 180cm) or longer height.

i. Viewing panels larger than 6ft^2 (0.55m^2) in area must be of a transparent plexiglass a minimum of $^3/_{32}$in (2mm) thick, reinforced safety glass, or laminated glass a minimum of $^3/_{16}$in (4.5mm) thick to prevent excessive fragility.
ii. Placement of viewing panels must consider patient privacy. Do not use clear vision panels in areas in which patient privacy is a direct concern or in areas in which sanitary facilities are directly visible.

45.2.C. **Door construction must be of durable materials to withstand frequent impact of gurneys and carts, and must be easily cleaned.**[6]

i. Doors with exterior paneling of non-corrosive metal are ideal in places which frequent impact of carts and gurneys is expected. Panels of such metal, such as aluminum, may be placed at heights at which impact is most frequent, i.e. kickplates from the bottom of the door up to 8in (20cm) and pushplates between 32in (80cm) and 40in (100cm) in height on the outward side of the door swing (or both sides if a two-way swing).
ii. In cases where metal paneling is infeasible, braced, paneled doors may suffice. For areas in which frequent impact, thin-veneered hollow core doors must be avoided.
iii. For ordinary rooms in which frequent impact is not expected, thin-veneered hollow core doors may be used with appropriate bracing. Interior bracing must be spaced at not more than 3ft (90cm) in any direction.
iv. Easily cleanable materials include: non-corrosive metals; hard plastics; painted or finished surfaces.

Hardware

45.2.D. **All doors must be able to be opened from the interior without a key, even when locked.**

i. All interior room doors must be able to be opened without a key either to an adjacent space with access to an exit, a circulation space, or the exterior. This is to ensure that spaces may be rapidly evacuated in case of fire or other emergencies.
ii. Lockset hardware must include bolt locks or button locks with controls on the interior of the door. Double-sided keyed locksets must be avoided wherever possible. If other types of locksets are not available, a receptacle must be installed to hold the key within 24" (60cm) of the locket of the door, with the key permanently stationed in it.
iii. Private patient rooms must be lockable from the interior but have key access from the exterior for staff in case urgent medical attention or other emergency action is needed.

45.2.E. **Door mechanisms must be of high quality, with a handle lever rather than a twist knob.**

i. Locksets and hinges must be made of stainless steel or solid (not veneer) aluminum where possible to ensure strength and durability.
ii. Door handles must have a lever to release door latches so that doors can be opened without touching the handle with one's hands.
iii. Hydraulic door closers must be installed on spaces accessing sterile areas and common sanitary facilities. Spring hinges may also be acceptable if they can accommodate the weight of the door.
iv. If door closers are unavailable, doors to such facilities should be kept closed when not in use to preserve privacy, prevent the incursion of pests, and maintain sterility where needed.

45.3 Windows

Windows and apertures require the consideration of many factors: placement for ventilation, placement for privacy, operability, patient control, strategic daylighting, and durability.

Window Placement & Access

45.3.A. All windows must be accessible for cleaning.

i. Staff access must be balanced with privacy concerns, particularly on windows with access from the exterior.

ii. For buildings of more than one floor, exterior window cleaning is recommendable by being accessible from the interior.

45.3.B. In facilities unprotected with a security wall or controlled access, ground floor windows must be secure from intruders.

i. Ground floor mullions or burglar bars must be spaced at not more than 8" (20cm) in one direction for security measure and ease of replacement. This dimension is too small for people to pass through. Smaller panes of glass also allow for easier and inexpensive replacement if broken. Individual panes kept to a minimum sizes can be replaced with smaller sizes of glass, but this must be balanced with the cost and aesthetic of the window mullions.

ii. Laminated safety glass of $^{3}/_{8}$in (10mm) thick or greater, or wire mesh-reinforced security glass may also satisfy security requirements but the potential cost of replacement (if needed) must be considered.

Window Construction

45.3.C. Operable windows, when closed, must be constructed in a way as to prevent water from entering during heavy rains.

i. It is preferable for windows to open to the exterior, as it allows a fixed frame behind it to help ensure water does not penetrate the space between operable panel and fixed frame. This, however, may make installation of screens difficult. Other measures of water penetration prevention may need to be employed to ensure effectiveness.

ii. Operable panels must protect against insects as defined in Standard 45.3.D.

45.3.D. Operable windows and apertures must be screened with vinyl screen mesh with openings smaller than $^{1}/_{16}$ (1.6mm) or equivalently performing material for protection against insects. Screens must be properly affixed to the window frame with no gaps in excess of $^{1}/_{8}$ (3mm) at any point around the perimeter.

i. Malaria is a leading cause of preventable death; protection from mosquitoes is paramount in its prevention. To be effective, this strategy must be combined with safeguards against insects on exterior doors and other apertures.

45.4 General Fixtures and Fittings

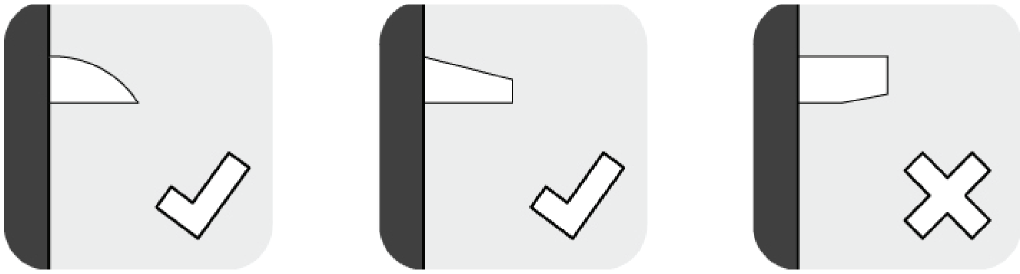
Fixtures and fittings intended to be for the benefit of building function and building users must not impede infection control measures, and must be accessible to all users.

Properties

45.4.A. **Horizontal surfaces, basins, and other places in which dust or particulates may collect must be minimized in all fixtures, and fixtures must be made of easy-to-clean materials.**

i. Horizontal elements must have rounded or tapered tops where possible to avoid flat surfaces in which dust/particulates may collect.
ii. Easy to clean materials include any durable material with a smooth finish that does not break down, disintegrate, or peel off with frequent application of solvent cleaners.

Figure 45.b: Fixture Diagram



45.4.B. **Protection fittings such as door stops, chair rails on walls at gurney-height, and corner guards must be installed in areas with expected gurney traffic.**

i. Protection fittings must be of durable, easy-to-clean materials such as non-corrosive metals, hard plastics, hardwoods, or materials with similar performance.

45.4.C. **Visual contrast of fixtures and fittings with the surface on which they are installed must be prioritized.**

Accessibility Requirements

45.4.D. **All wall-mounted fixtures and fittings (excluding lights and fire safety installations) must be accessible to individuals in wheelchairs by being placed between 10in (25cm) and 5ft 3in (160cm) above the finished floor. Fixtures and fittings intended to be used from a particular position should not be more than 2ft (60cm) away from the center of that position.**

i. Wall-mounted fixtures exclude impact protection fittings as outlined in Standard 45.1.B.

ROOM PLANNING

CONTENTS

IMPACT

Efficient and effective design requires a detailed knowledge of the requirements of individual program elements. These requirements have influences on building usability, staff comfort, infection control, efficiency of finances, and a host of other factors that affect the daily operation of the facility.

PRIMARY USERS

Infrastructure Unit

Facility Staff

Architects & Designers

Electrical, Mechanical & Plumbing Engineers

GUIDELINES FOR USE

All spaces are governed by all other general requirements presented throughout these standards, and elaborated on in these chapters; what is presented in these Chapters elaborates on them for each specific area. During the schematic and detailing phases of design, users may research the needs of each program element on a room-by-room basis, or as large classifications of spaces.

46 General Room Planning Requirements

This chapter outlines requirements consistent across all program elements as well as by categories of program elements. For additional requirements unique to specific spaces, refer to Chapters 47-50.

46.1 Spatial Requirements

Spatial Requirements common to groups of rooms or types of spaces are indicated in this section.

46.1.A. Ceiling heights in all occupiable spaces must be a minimum of 8ft 6in (260cm).

i. Ceiling heights in any space with an expected occupancy of 50 as defined by Standard 18.2.A. must be at least 10ft (300cm).

46.1.B. Door heights in all spaces must be of a minimum 80in (200cm).

46.2 Installations

Installation requirements are grouped by room types referenced below. For specific room-by-room installation requirements, refer to further spatial requirements listed in Chapters 47-50.

Electrical & Communication Installations

46.2.A. All spaces must meet the requirements for functional electrical outlets in Table 46.a.

i. For definitions and requirements of Class 1 -5, see Standard 23.6.A; for requirements of Class 6 (special), see the corresponding program requirements in Chapters 47-50.

ii. This standard applies to new construction and major renovations only.

Table 46.a. Electrical Requirements per Space by Classification

Class	Description	Spaces
Class 1	Public Areas & Stockrooms	Waiting Areas, Corridors in Clinical and Non-Clinical Areas, Dispensary & Pharmacy Stock
Class 2	General Clinical	Triage& Vital Signs, Examination Rooms, Immunization (EPI), Dressing Rooms, Family Planning and Antenatal Care, Specialist Consultation Rooms, Radiology, Advanced Diagnostics
Class 3	Nursing Stations	Nursing Stations
Class 4	Intensive Clinical	Post Anesthesia Care Unit, Post Operative Ward, Labor Ward, Delivery Room, Short Stay, Inpatient Wards, Pediatric Wards, Isolation Rooms,
Class 5	Administrative	Registration, Staff Rooms, Medical Records, Staff Offices, Meeting / Education Rooms
Class 6	Special Circumstances	Emergency Room, Operating Rooms, Intensive Care Unit, Neonatal Intensive Care Unit, General Laboratory, Biosafety Laboratory, Sterilization, Bathrooms, Laundry, Kitchen, Equipment Rooms, Morgue.
No requirement		Storage

46.2.B. At minimum, data outlets, or provisions for data cable access, coupled with an electrical socket, must be installed in the following spaces in Hospitals:

- Registration& Medical Records
- Triage& Vital Signs
- Examination Rooms
- Pharmacy Stock& Dispensary
- Staff Offices

- Nursing Stations
- General Laboratory
- Radiology

i. Refer to Chapter 26 for requirements on communication systems.

Plumbing Installations

46.2.C. At least one hand-washing station must be installed in the following spaces:

- Waiting Areas
- Triage& Vital Signs
- Examination Rooms
- Immunization (EPI)
- Dressing Rooms
- Family Planning and Antenatal Care
- Specialist Consultation Rooms
- Post Operative Ward
- Short Stay
- Nursing Stations
- Morgue

i. For other sink requirements refer to the room-by-room requirements in Chapters 47-50.
ii. Refer to Chapter 30 for plumbing requirements.

Other Installations

46.2.D. All doors must meet the requirements of Standard 16.2.L. and Section 45.2, as well as the width, swing, and protection requirements listed in Table 46.b.

i. All doors 46in (115cm) or wider, and all doors entering or exiting ward spaces, must be fitted with aluminum, stainless steel, or painted steel kickplates from the bottom of the door up to 8in (20cm) and pushplates between 30in (76cm) and 40in (100cm) in height on the contact side of the door (or both sides if a two-way swing).
ii. Two-way door swings may fulfill requirements for one-way door swings, and automatic side-sliding doors may fulfill requirements for both one-way and two-way door swings.
iii. Refer to Section 42.5 for additional door requirements.

Table 46.b. Minimum Door Width and Swing Requirements by Space

Minimum Width	Door Swing	Spaces
36in (90cm)	One-way	Registration, Triage& Vital Signs (if doors are present), Examination Rooms, Immunization (EPI), Dressing Rooms, Family Planning & Antenatal, Pharmacy & Drug Storage, Staff Rooms, Medical Records, Staff Offices, Meeting / Education Rooms, Bathrooms, Kitchen (if doors are present), Storage, Neonatal Intensive Care Unit, Isolation Rooms, General Laboratory, Biosafety Laboratory, Equipment Rooms
	Two-way	Nursing Stations (if doors are present)
46in (115cm)	One-way	Short Stay, Inpatient Wards, Pediatric Wards, Sterilization
	Two-way	Radiology, Advanced Diagnostics, Laundry, Morgue
60in (150cm)	One-way	Operating Rooms, Post Anesthesia Care Unit, Post Operative Ward, Labor Ward, Delivery Room
	Two-way	Waiting Areas (if doors are present), Emergency Room, Intensive Care Unit

46.3 Environmental & Technical Requirements

Environmental and technical Requirements common to groups of rooms or types of spaces are indicated in this section. For specific room-by-room requirements, refer to further spatial requirements listed in Chapters 47-50.

Environmental Requirements by Program Element

46.3.A. **Air conditioning climate control is required for the following spaces:**

- Operating Rooms
- Pharmacy Stock Room

i. Air conditioning is also recommended for the following spaces:

- Delivery Rooms
- Isolation Rooms
- ICU Rooms
- General and Biosafety Laboratories
- Morgue

ii. For further requirements on climate control refer to Chapters 21 and 22.

46.3.B. **High Levels of daylighting are required for all spaces except for those indicated in Table 46.c.**

i. For requirements of high, moderate, and low daylighting levels, refer to Standard 24.1.D.

Table 46.c.Daylighting Level Requirements for Exceptions to 46.3.B.

Space	Daylighting Level Requirement
Registration	Moderate
Corridors in Clinical Areas	Moderate
Operating Rooms	Recommended
Post Anesthesia Care Unit	Moderate
Intensive Care Unit	Moderate
Delivery Room	Moderate
Neonatal Intensive Care Unit	Moderate
Pharmacy & Drug Storage	Low
Biosafety Laboratory	Moderate
Radiology	Not required
Advanced Imaging Diagnostics	Not required
Sterilization	Moderate
Staff Rooms	Moderate
Staff Offices	Moderate
Meeting / Education Rooms	Moderate
Bathrooms	Recommended
Laundry	Moderate
Storage	Not required
Equipment Rooms	Recommended
Morgue	Recommended

46.3.C. Class 3 levels of artificial lighting are required for all spaces except for those indicated in Table 46.d.

i. For requirements of class levels of artificial lighting, refer to Standard 25.1.B.

Table 46.d. Artificial Lighting Level Requirements for Exceptions to 46.3.C.

Space	Artificial Lighting Requirement
Waiting Areas	Class 2
Registration	Class 2
Corridors in Clinical Areas	Class 2
Emergency Rooms	Class 4
Operating Rooms	Class 5
Intensive Care Unit	Class 4
Delivery Rooms	Class 5
Neonatal Intensive Care Unit	Class 4
Dispensary	Class 4
Pharmacy Stock	Class 2
General Laboratory	Class 4
Biosafety Laboratory	Class 4
Radiology	Class 2
Advanced Diagnostics	Class 2
Sterilization	Class 4
Staff Rooms	Class 2
Medical Records	Class 2
Bathrooms	Class 2
Laundry	Class 2
Kitchen	Class 4
Storage	Class 1
Equipment Rooms	Class 1
Morgue[a]	Class 1

[a] *If autopsies are performed in the Morgue, the autopsy area must be Class 4 lighting*

46.3.D. Ventilation levels must be appropriate for the risk level of the space per the requirements listed in Section 19.1. Table 46.e indicates appropriate risk levels.

Table 46.e. Required Ventilation Levels for Specific Program Areas.

Ventilation Level	Spaces
High Clinical Risk	Waiting Areas, Registration, Triage& Vital Signs, Corridors in Clinical Areas, Operating Rooms, Post Anesthesia Care Unit, Post Operative Ward, Intensive Care Unit, Delivery Room, Neonatal Intensive Care Unit, Isolation Rooms, Biosafety Laboratory
Medium Clinical Risk	Emergency Room, Labor Ward, Short Stay, Inpatient Wards, Pediatric Wards, Radiology, Nursing Stations, Sterilization
Low Clinical Risk	Examination Rooms, Immunization (EPI), Dressing Rooms, Family Planning & Antenatal, Specialist Consultation Rooms, General Laboratory, Advanced Diagnostics, Bathrooms (serving patients)
Non-Clinical	Pharmacy & Drug Storage, Staff Rooms, Medical Records, Staff Offices, Meeting / Education Rooms, Bathrooms (serving staff only or in administrative areas), Laundry, Kitchen, Storage, Equipment Rooms, Morgue

Technical Requirements by Program Element

46.3.E. **Floors in all spaces must meet both General floor requirements and Clinical floor requirements as specified in Section 44.2, except as indicated in Table 46.f.**

i. For requirements of General floor requirements only, refer to Standards 44.2.A - 44.2.I.
ii. For requirements of floors in Clinical spaces, refer to General requirements plus Standards 44.2.J - 44.2.N.
iii. For requirements of floors in Sanitary spaces, refer to Standards 44.2.O. - 44.2.Q.
iv. For requirements of Exterior floors, refer to Standards 44.2.R. - 44.2.T.

Table 46.f. Floor Requirements in Exception to Standard 46.3.E.

Space	Floor Requirement
Waiting Areas	Exterior
Registration	General only
Triage& Vital Signs	General only
Family Planning & Antenatal	General only
Dispensary	General only
Pharmacy Stock	General only
Staff Rooms	General only
Medical Records	General only
Staff Offices	General only
Bathrooms	Sanitary
Laundry	Sanitary
Kitchen	General only
Storage	General only
Equipment Rooms	General only
Morgue	Sanitary

46.3.F. **Walls in all spaces must meet both General wall requirements and Clinical wall requirements as specified in Standards 44.3.A - 44.3.E, except as indicated in Table 46.g.**

i. For requirements of General wall requirements only, refer to Standard 44.3.A.
ii. For requirements of walls in Clinical spaces, refer to General requirements plus Standards 44.3.B.- 44.3.E.
iii. For requirements of walls in Sterile spaces, refer to Standards 44.3.F. - 44.3.G.
iv. For requirements of walls in Sanitary spaces, refer to Standards 44.3.H. - 44.3.J.

Table 46.g. Wall Requirements in Exception to Standard 46.3.F.

Space	Wall Requirement
Waiting Area	General only
Registration	General only
Triage& Vital Signs	General only
Family Planning and Antenatal	General only
Scrub Rooms	Sterile
Operating Rooms	Sterile
Intensive Care Unit	Sterile
Neonatal Intensive Care Unit	Sterile
Isolation Rooms	Sterile
Dispensary	General only
Pharmacy Stock	General only
Sterilization	Sterile
Bathrooms	Sanitary
Laundry	Sanitary
Morgue	Sanitary

46.3.G. Ceilings in all spaces must meet General ceiling requirements as specified in Standards 44.5.A - 44.5.B, except as indicated in Table 46.h.

i. For requirements of General ceiling requirements only, refer to Standards 44.5.A - 44.5.B.
ii. For requirements of ceilings in Sterile spaces, refer to General requirements plus Standards 44.5.C - 44.5.E.

Table 46.h. Ceiling Requirements in Exception to Standard 46.3.G.

Space	Ceiling Requirement
Waiting Areas	No ceiling requirement[a]
Triage& Vital Signs	No ceiling requirement[a]
Corridors in Clinical Areas	No ceiling requirement[a]
Scrub Rooms	Sterile
Operating Rooms	Sterile
Intensive Care Unit	Sterile
Neonatal Intensive Care Unit	Sterile
Isolation Rooms	Sterile
Biosafety Laboratory	Sterile
Sterilization	Sterile
Laundry	No ceiling requirement[a]
Kitchen	No ceiling requirement[a]
Storage	No ceiling requirement[a]
Equipment Rooms	No ceiling requirement[a]

[a] *Note: this Standard refers only to ceilings and does not supersede any roofing requirements.*

47 Entry and Reception

In addition to the General Programmatic Requirements in Chapter 46, refer to additional room-specific Entry and Reception space requirements below. These should be taken as specific design and installation requirements and must be accommodated during facility design, construction, and/or renovation.

47.1 Waiting Areas

As the primary interaction point of patients and family members, appropriate provisions for Waiting Areas are important both in the utility of the facility and for infection control.

Spatial Requirements

47.1.A. Waiting Areas must contain built-in or fixed-in-place seating, with seat or bench heights between 16in (40cm) and 20in (50cm) above the floor surface.

i. Benches or seating must contain enough seats to accommodate the expected patient load calculated in Section 14.1, plus an additional 50% to account for family members and attendants.
ii. One seat must be considered to be 20in (50cm) of the length of a bench.
iii. Seating must be configured to avoid congested areas with numerous people in close proximity to one other, and must be spread out as much as possible without compromising designated circulation areas.
iv. If seating is organized in rows, a minimum of 4ft (120cm) must be left between rows.
v. Moveable furniture may be substituted for built-in benches only if all of the following are met:
- There is a complete, adequate furnishing plan for the entire facility and pre-allocated budget for furnishings at the time of design approval.
- The waiting area is enclosed within a lockable door, gate, or other security fence or wall. The furnishing is clearly and indelibly labeled with the facility name and location or relevant infrastructure record number.

47.1.B. Exterior Waiting Areas must be configured or designed so as to be completely sheltered from rain.

47.1.C. A separately designated, spatially distinct, well-ventilated Waiting Area must be included to which patients suspected of having tuberculosis or other highly infectious diseases can be separated from other users in the Waiting Area. This separate Waiting Area must be at least 5% the size of the total floor area of the Waiting Area or at least 80ft^2 (7.5m^2), whichever is greater.

Installations

47.1.D. One hand-washing sink must be provided near the exterior entrance of the Waiting Area for patients and visitors to be used upon arrival.

47.1.E. In Health Centers and Hospitals, waiting areas must include an electrical outlet and cable jack between 6ft and 8ft (1.8m and 2.4m) above the floor in one wall near the Registration for the provision of a television.

47.1.F. Waiting areas must include wall -hung pin-boards for public health announcements and health campaign literature totaling an area at least 5% of the total floor area, positioned near the Registration.

Technical and Environmental Environments

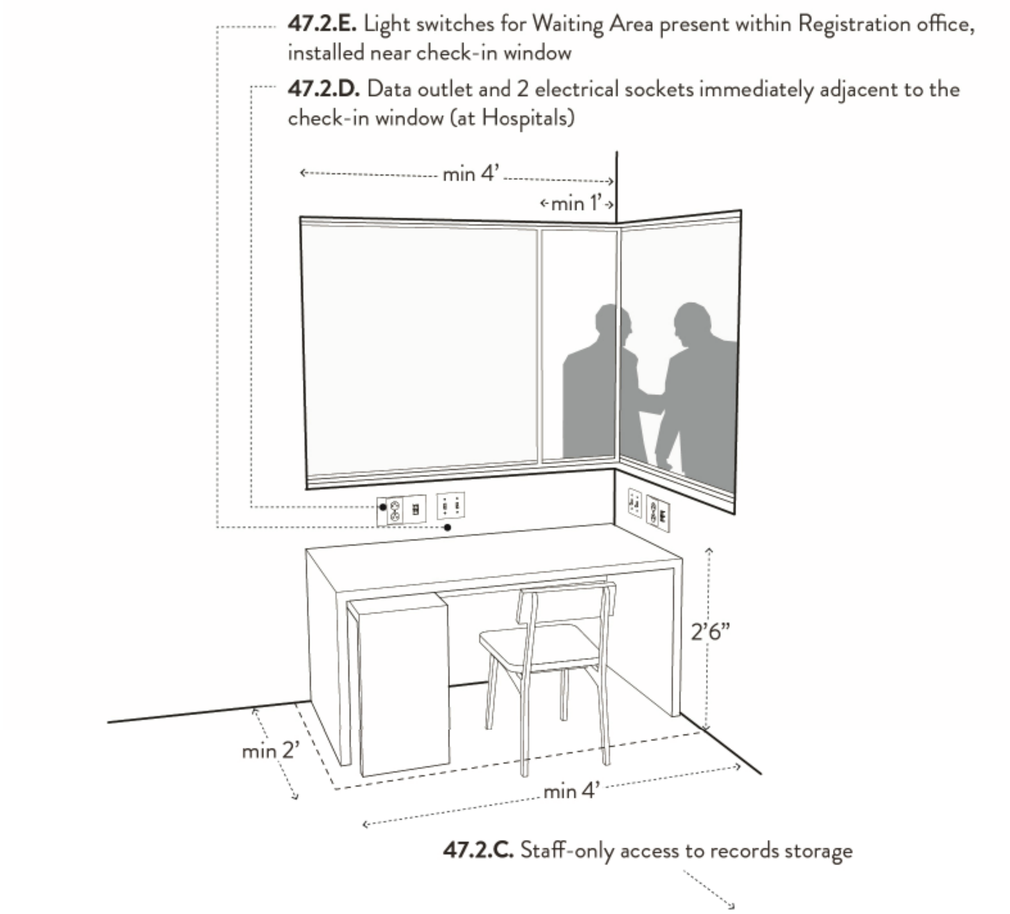
47.1.G. General Waiting Areas must either be sheltered exterior or semi-exterior (enclosed on less than 3 sides) spaces. In Hospitals, additional waiting areas beyond the General Waiting Area at reception must be sheltered exterior or semi-exterior spaces, or have operable windows or louvers with at least 20% of the total wall area being operable.

i. Waiting Areas must be designed for either cross ventilation, stack ventilation, or other natural means unless a mechanical system meets the requirements outlines in Chapter 20. For natural ventilation standards refer to Chapter 19.

47.2 Registration

Registration must be able to act as the first control point for patient flow, with direct access from the Waiting Area and direct access to Triage& Vital Signs.

Quick Design Guide



Spatial Requirements

48.11.A. If enclosed, Registration must include an operable check-in window (dimensions above)

Environmental & Technical Requirements

47.2.F. Countertops must meet the requirements for countertops in clinical areas

Spatial Requirements

47.2.A. If enclosed, Registration must include an operable check-in window, at least 4ft (90cm) width of vision glass and at least 1ft (30cm) of operable pane, with sill height at least 2ft 6in (80cm) above the floor, positioned to overlook the Waiting Area and control access to Clinical Areas.

47.2.B. A space of at least 4ft by 2ft (120cm by 60cm) must be provided at the check-in window for the registrar's desk. This area must be free of other obstructions.

47.2.C. Registration must have direct, staff-only access to the Records Storage.

i. This standard does not apply to PHC 1, in which Records Storage is assumed to be within the Registration room.

Installations

47.2.D. At Hospitals, the Registration Office must have a data outlet and two electrical sockets mounted at a height of 2ft 6in (80cm) above the floor immediately adjacent to the check-in window, on the interior of the room.

47.2.E. Light switches for the Waiting Area must be present within the Registration Office, installed near the check-in window.

i. This standard does not prohibit lights in the Waiting Area from being wired to two switches, one in Registration and one in the Waiting Area near the entrance.

Technical and Environmental Requirements

47.2.F. Countertops at the Registration Area must also meet the requirements for countertops in clinical areas as defined in Section 44.4.

47.3 Triage& Vital Signs

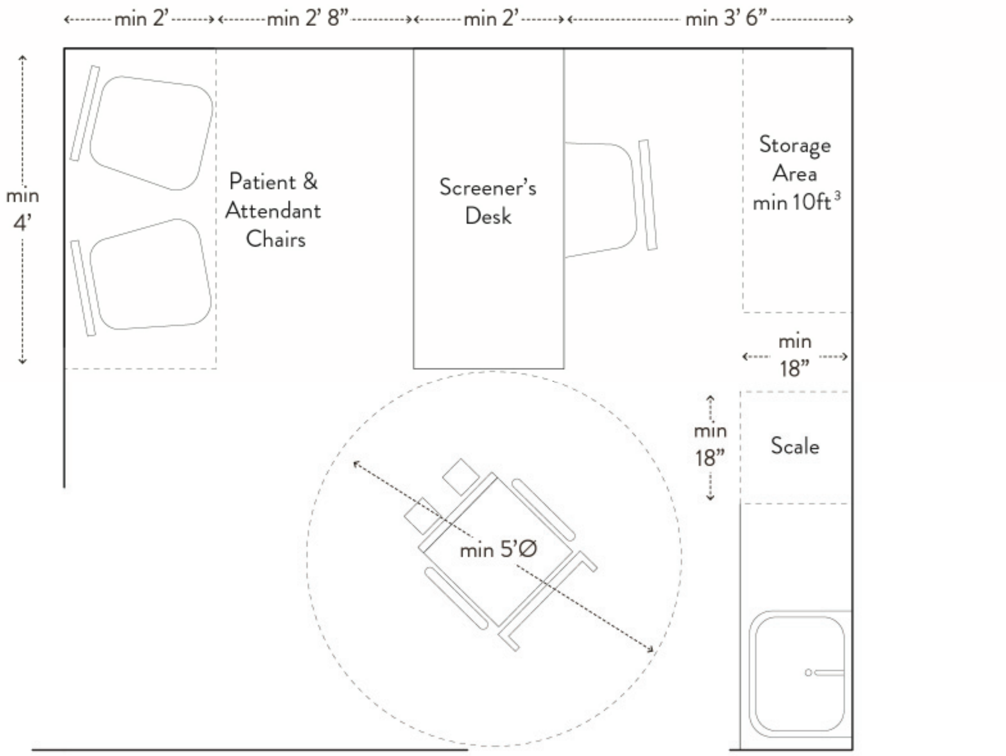
Spatial Requirements

47.3.A. Triage & Vital Signs Areas do not need to be fully enclosed, but visual and acoustical privacy must be maintained from any public areas.

47.3.B. Triage & Vital Signs Areas must be adequately sized to accommodate patient interviews and taking of vital signs.

i. An unobstructed area of at least 2ft by 4ft (60cm by 120cm) for a screener's desk and chair must be provided, with a minimum of 3ft 6in (105cm) of clear space behind it for access and storage space.
ii. In front of the desk, a clear space of minimum 2ft 8in (80cm) must be provided to allow nurses to approach patients for vital signs.
iii. A minimum of 2ft by 4ft (60cm by 120cm) must be provided adjacent to this clear space for the positioning of two chairs (for patient and patient attendant).
iv. A minimum clear diameter of 5ft (150cm) must be kept within the Triage Area for the turning of a wheelchair.
v. A clear space of 18 in by 18in (45cm by 45cm) must be kept free outside of other clear spaces for the positioning of a medical scale.
vi. At least 10ft^3 (0.3m^3) of drawer and cabinet storage must be provided.

Figure 47.a. Possible Triage & Vital Signs Plan Diagram



Installations

47.3.C. A hand washing sink must be provided.

47.4 Corridors in Clinical Areas

Often overlooked, corridors can be one of the most dangerous culprits in the transmission of nosocomial infection if not properly designed and ventilated. Proper attentiveness to these issues is essential.

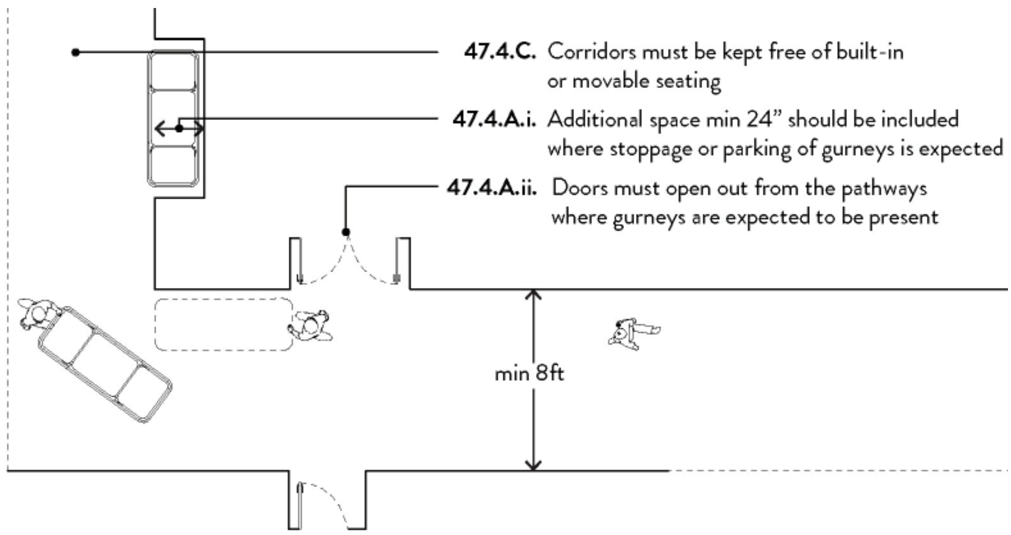
Spatial Requirements

47.4.A. Corridors in clinical areas must be at least 8ft (182cm) wide to allow passage of people, trolleys, gurneys, and equipment during peak operational hours.

i. In areas in which stoppage or parking of gurneys or trolleys is expected, an additional space of at least 24in (60cm) must be included at the side of the corridor.
ii. Doors to corridors must open outwards towards the corridor without interfering with the egress path used by gurneys.

47.4.B. Corridors must be kept free of built-in or movable seating to limit crowding and reduce infection risks.

Figure 47.b. Corridor Width Requirements

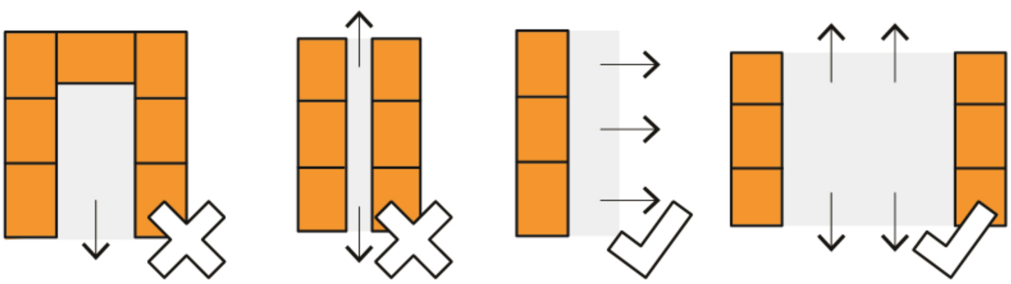


Technical and Environmental Environments

47.4.C. Corridors must be naturally ventilated in accordance with the requirements of Chapter 19where possible, or mechanically ventilated in accordance with the requirements of Chapter 20.

i. Open-air corridors must be prioritized.
ii. Corridors must also conform to the standard outlined in Standard 46.3.G.
iii. Corridors in PHC facilities and Health Centers must be predominantly sheltered exterior walkways, with at least 50% of the perimeter height open to the exterior.
iv. Single-loaded corridors must be prioritized for naturally ventilated facilities.
v. Corridors serving high clinical risk areas must have either 50% of the perimeter height open to the exterior for natural ventilation, or be mechanically ventilated to meet the standards outlined in Standard 19.1.C.
vi. A through-path for cross ventilation through all corridors must be prioritized.
vii. Corridors enclosed on three sides must be avoided where possible.

Figure 47.c. Advisable and Unadvisable Corridor Layouts for Natural Ventilation



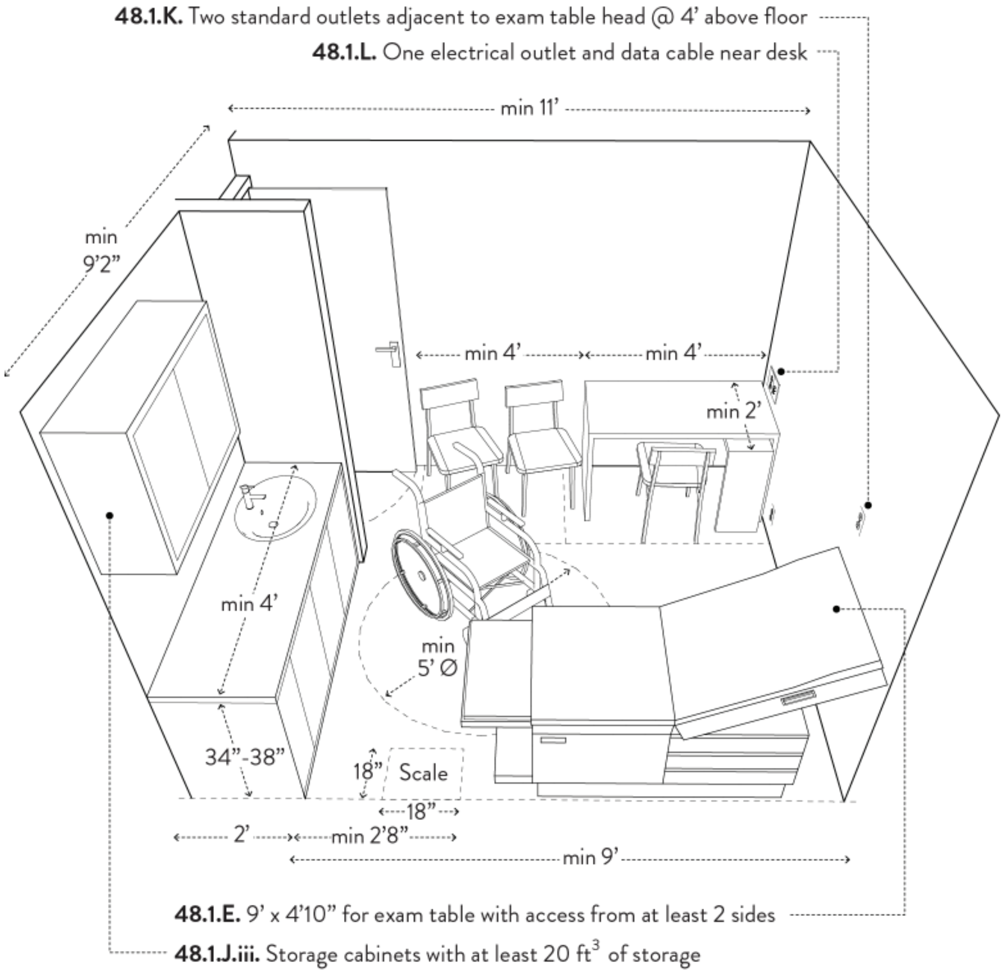
48 Clinical Areas

General Programmatic Requirements apply to all spaces as indicated in Chapter 46. Any listed requirement is in addition to, and not a substitute for, general requirements.

48.1 Consultation and Dressing Rooms

Doctors and nurses are expected to consult many patients in a day and have a quick turnover time. To maximize performance, an efficient design is necessary.

Quick Design Guide



Spatial Requirements

48.1.E. Exam table assumed to be 2'2" wide by 6'4" long

48.1.F. Clear space of 5' between exam table and semi-permanent furnishings

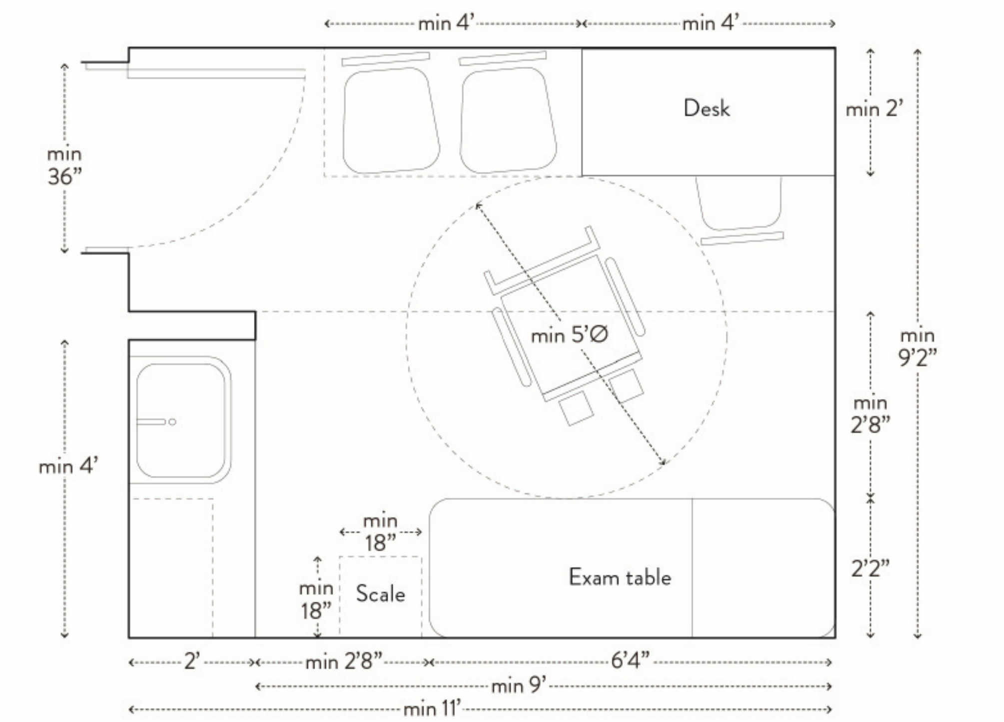
Spatial Requirements

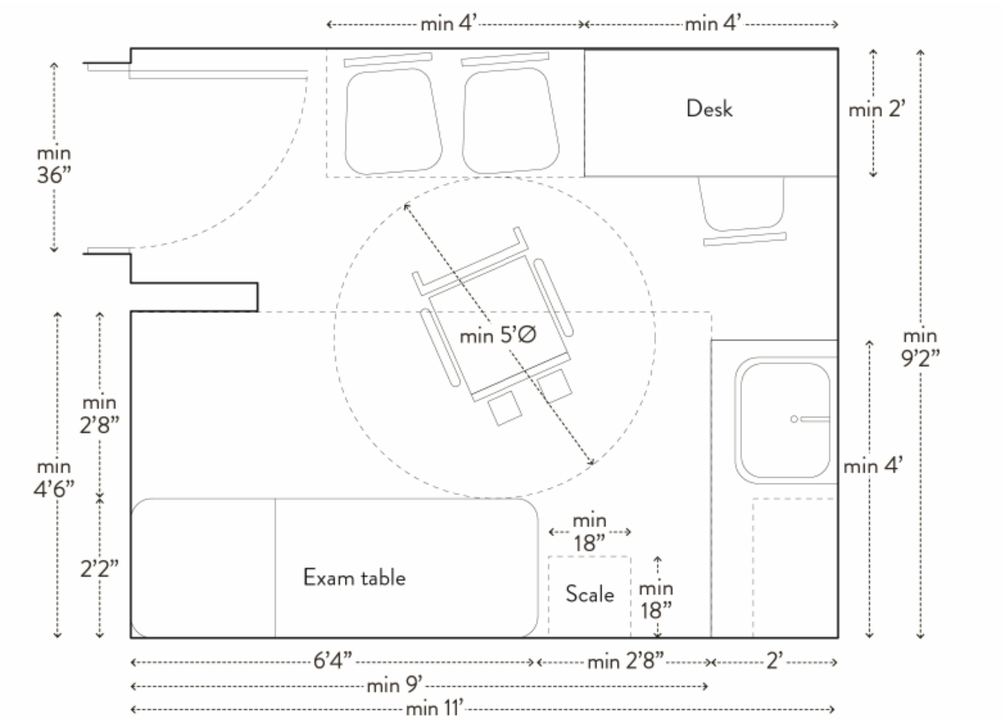
48.1.A. Minimum room dimensions for general and specialist consultation rooms are 9ft 2in by 11ft (280cm by 335cm)

i. This requirement is only a minimum. All Consultation Room designs must be supported in design plans with a proposed furniture and equipment layout to be approved by the assigned IU representative before facility design can be accepted.

ii. In all design plans a 5ft (150cm) wheelchair turning diameter must be incorporated into all spaces; these areas must be free of installations or furnishings.

<u>Figure 48.a. Possible Consultation Room Layouts.</u>





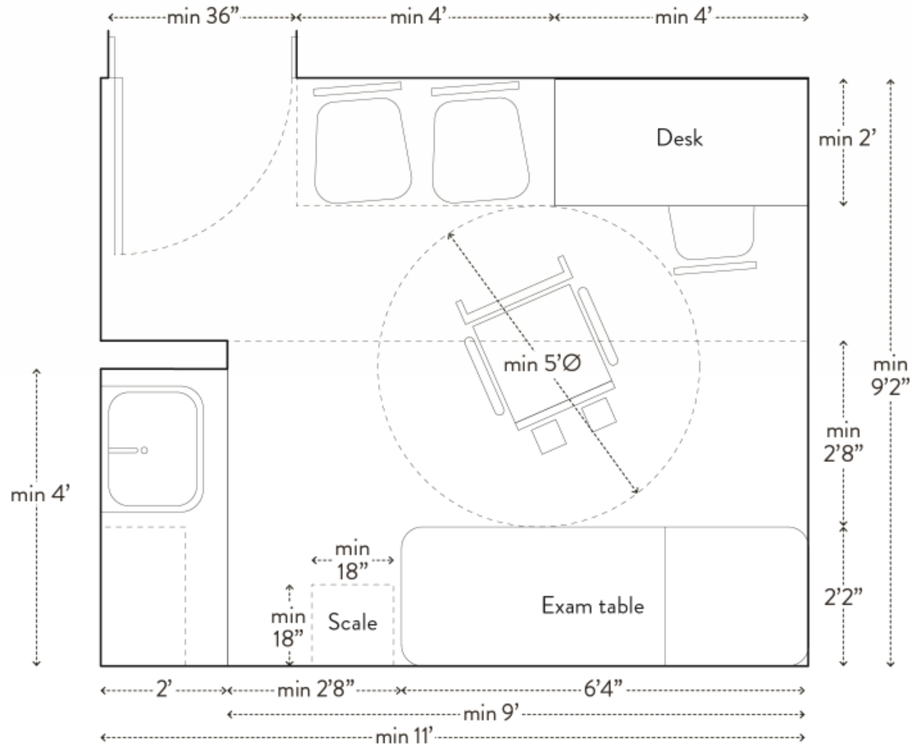
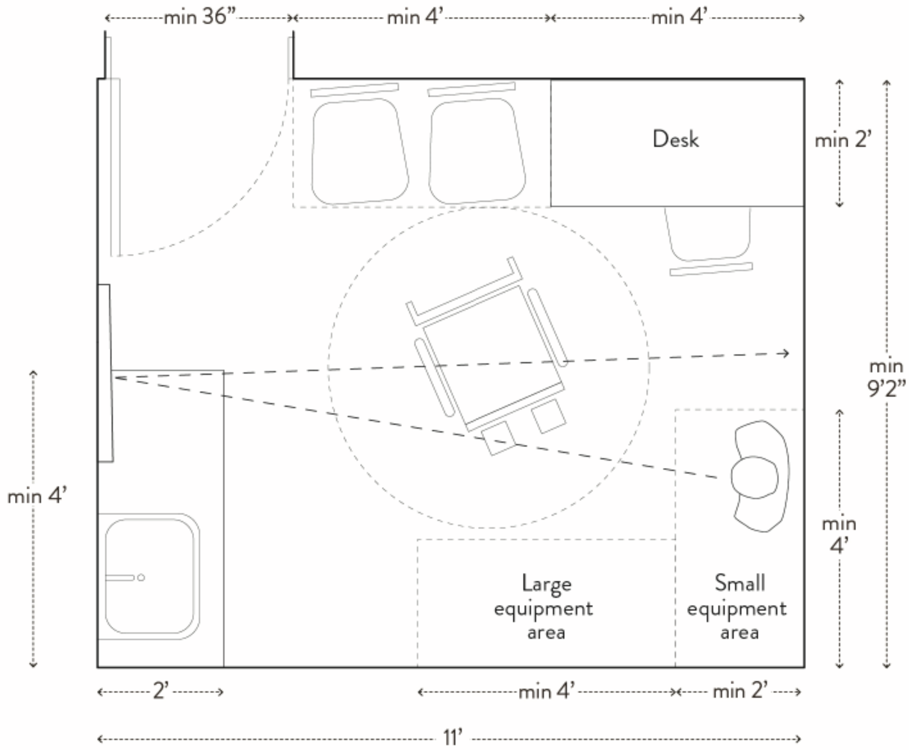


Figure 48.b. Possible Plan Layout for Optometry or Ophthalmology Consultation Rooms



48.1.B. **For Optometry and Ophthalmology Consultation Rooms, the room length must either be 21 ft (610cm) or be exactly 11ft (335cm) with a mirror of minimum area $5ft^2$ ($0.5m^2$) mounted on one wall to allow for the reading of an eye chart from 20ft away.**

i. Optometry and Ophthalmology Rooms must meet all other requirements of other General Consultation Rooms except as indicated below.

ii. Exam tables and associated spaces are not required, nor is space for a medical scale.

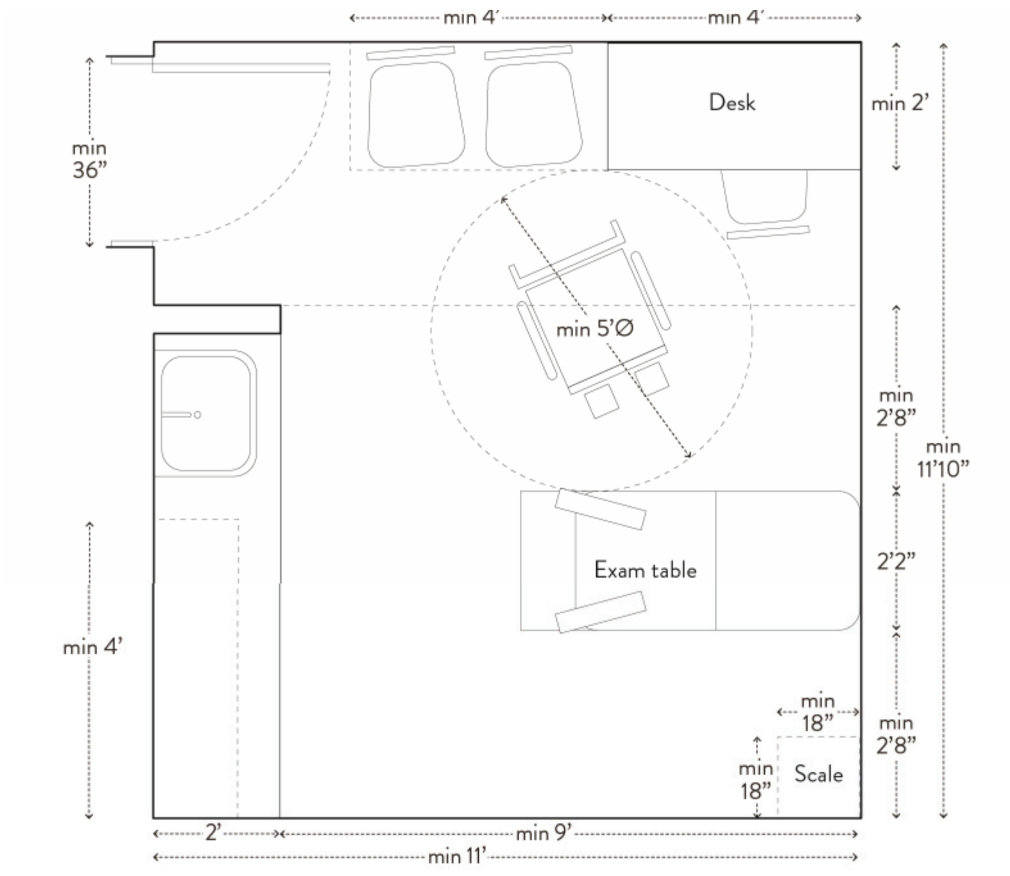
iii. An area of 2ft by 4ft (60cm by 120cm) must be allocated in one corner for the positioning of a patient chair and small equipment. This area must be accessible from the front along the long dimension.

iv. An area in front of the patient chair area of 4ft by 2ft (120cm by 60cm) must be allocated for large equipment such as a slit-lamp biomicroscope and a phoropter.

48.1.C. **For gynecology or OB/GYN rooms, the minimum dimensions are 11ft by 11ft 10in(335cm by 360cm).**

i. The additional width of 2ft 8in (80cm) is needed to provide access to the exam table on 3 sides.

Figure 48.c. Possible Plan Layout for Gynecology or OB/GYN Consultation Rooms



48.1.D. **Consultation Rooms specifically designated for airborne disease (e.g. Tuberculosis) consultation that use natural ventilation must be located separately, at least 65ft (20m) from other non-airborne disease spaces, with separate entrances.**

i. If mechanical ventilation is used, these rooms must be kept at negative pressure relative to surrounding spaces, with air exhaust directed away from public areas.

48.1.E. **A minimum area of 9ft by 4ft 10in (240cm by 140cm) of space must be kept clear for the positioning of an exam table with access from at least one side and one end in one corner of the room.**

i. The exam table itself may be assumed to be 2ft 2in wide by 6ft 4in long (66cm wide by 193cm long). 2ft 8in (80cm) of clear space must be kept on one side and at the foot of the table for circulation.
ii. The length of this space must be oriented so that when a patient is lying in the bed the nurse or doctor can approach from the patient's right.
iii. For OB/GYN rooms this exam table must be positioned in the middle along one wall with 2ft 8in (80cm) of clear space on three sides.

48.1.F. **A clear space of 5ft (150cm) must be kept between the side of the exam table and other semi-permanent furnishings such as desks.**

i. Movable chairs are not considered to be semi-permanent furnishings for this standard.

48.1.G. **An area of 18inby 18in (45cm by 45cm) must be allocated along one wall or in one corner for the positioning of a medical scale.**

i. This area must be accessible from one side.
ii. If along a wall, this area may be part of the 2ft 8in (80cm) clear space at the foot of the exam table.

48.1.H. **An area of 4ft wide by 2ft deep (180cm wide by 60cm deep) must be kept clear along one wall or in one corner for the positioning of a desk.**

i. This is only a minimum area. The design must allow for one person seated at it to be facing or perpendicular to the patient when seated in an adjacent chair or on the exam table.

48.1.I. **An area of 4ft wide by 2ft deep (90cm wide by 60cm deep) must be kept clear along one wall or in one corner for the positioning of two chairs for a patient and one attendant.**

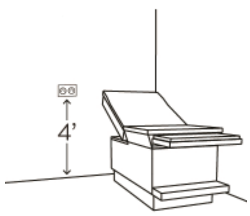
i. This area must be accessed from the front along the long dimension.

Installations

48.1.J. **A countertop, hand-washing station (sink) and storage must be provided in all consultation rooms.**

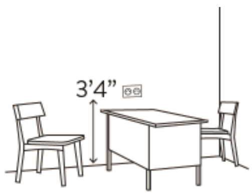
i. Countertop dimensions, including washbasin area, must be at least 2ft deep by 4ft wide (60cm deep by 120cm wide), and should be at a height of between 34in and 38in (86cm and 96cm).
ii. The area over the countertop must be clear of any obstructions for at least 2ft 6in (76cm) in height, and must not have any obstructions protruding more than 12in (30cm) from the wall above that.
iii. Storage with cabinets and drawers must be of at least 20ft^3 (0.5m^3).

48.1.K. **Two standard electrical outlets must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended exam table head position.**



48.1.L. **One standard electrical outlet must be provided at a height of 3ft 4in (100cm) at the intended position of the desk.**

i. In Hospitals, this electrical outlet must also be accompanied by a data outlet or provisions for a data cable.



48.2 Immunization (EPI)

Immunization (EPI) area must be close to Waiting Areas and have access to MCH program since many immunizations in infants are performed during post-partum. They must remain flexible in spatial configuration to accommodate both individual visits and large vaccination campaigns.

Spatial Requirements

48.2.A. Immunization (EPI) Areas must be designed flexibly so they can be used as Triage& Vital Signs Areas if necessary. EPI Areas must meet the requirements of Section 47.3.

EPI Areas must contain an unobstructed area of at least 3ft by 4ft (90cm by 120cm) for a vaccinator's desk and chair, adjacent to an unobstructed area of at least 3ft by 3ft (90cm by 90cm) for two patient/attendants' chairs.

48.2.B. EPI Areas must be adjacent or in close proximity to the General Waiting Area and the MCH Waiting Area.

Technical and Environmental Environments

48.2.C. EPI Areas must be adjacent to, with direct access to, a storage room or area with a refrigerator for vaccines. At least one standard electrical outlet and one 3-phase outlet must be provided for the refrigerator.

48.1.M. High levels of natural daylight must be present in the EPI injection area.

i. EPI storage rooms do not require natural daylight unless storage is included in an EPI injection room.

48.3 Family Planning and Antenatal Care

These areas are some of the most critical and most used, particularly at the primary care level. Care needs to be taken to optimize the flow through these spaces to reduce unnecessary overlap with other unrelated clinical zones.

Spatial Requirements

48.3.A. Family Planning and Antenatal Care must be adjacent to its own separate Waiting Area.

48.3.B. The Family Planning and Antenatal Care Rooms must consist of an Antenatal Counseling Room of minimum 100ft^2 (0.93m^2) connected to an Antenatal Examination Room. The Antenatal Examination Room must meet Standards 48.1.A and Standards 48.1.C.

Technical and Environmental Environments

48.3.C. The Antenatal Counseling Room must meet the requirements indicated in Table 48.3.d.

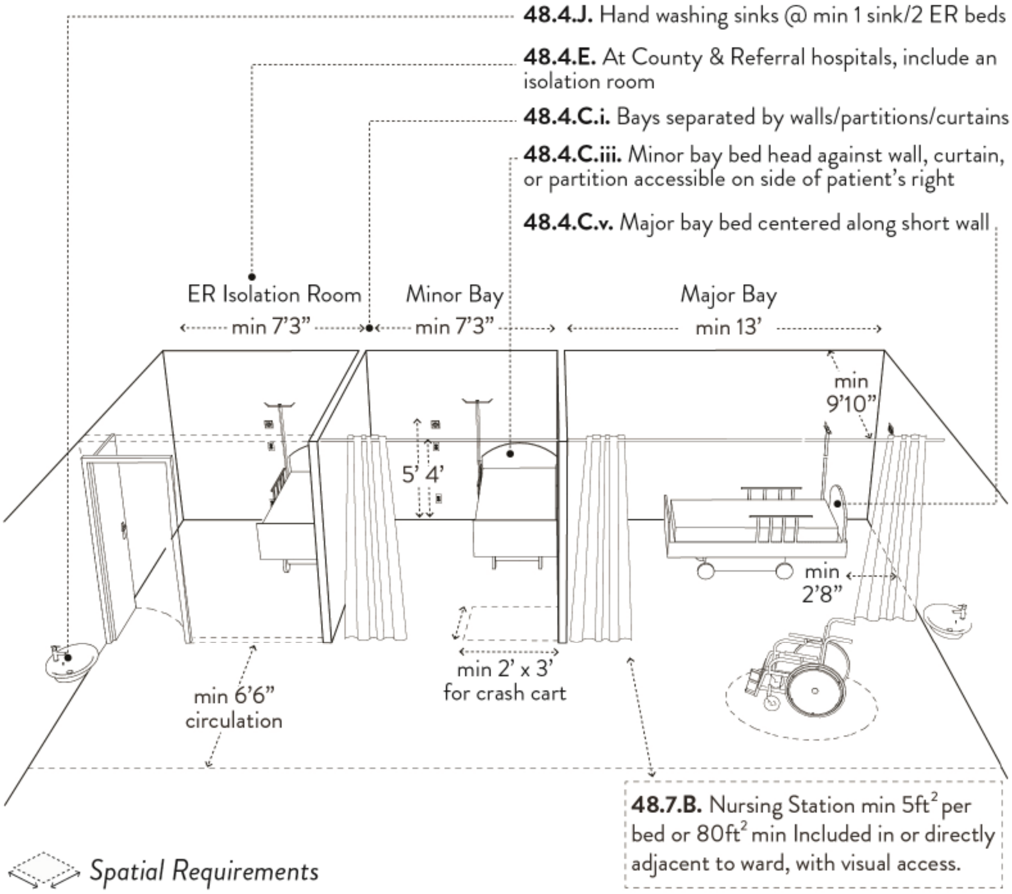
Table 48.a. Antenatal Counseling Room Requirements.

Category	Requirement	Reference Standard
Electrical	Class 5	23.6.A.
Doors	36in (80cm) One-way	46.2.D.
Floors	Clinical	44.2.A. - 44.2.N.
Walls	Clinical	44.3..- 44.3.E.
Ceilings	General	44.5.A. - 44.5.C.
Daylighting	Moderate	24.1.D.
Artificial Lighting	Moderate	24.1.B.
Ventilation	Low Clinical Risk	19.1.C.

48.4 Emergency Room

Emergency medicine has unique requirements that need to be accommodated physically in design and construction.

Quick Design Guide



Spatial Requirements

48.4.A. Entrance directly from the exterior

48.4.B. Min 1 major (4-side access to bed) & 1 minor bay (2-side access to bed)

Spatial Requirements

48.4.A. **The Emergency Room must have an entrance directly from the exterior**

48.4.B. **Each Emergency Room must have at least 1 major and 1 minor bay.**

Major and Minor Bays

Emergency Rooms often contain **major** and **minor** bays.
A **major** bay is larger, with access on all 4 sides of the beds. It is usually used for heavy trauma patients where procedures requiring multiple staff are needed.
A **minor** bay can be smaller, and requires access on only 2 sides of the bed (at the foot and at the patient's right).

48.4.C. **Each major bay must be at least 9ft 10in by 13ft (300cm by 400cm) with access on at least one side enclosed only with a curtain, accessing the major circulation. Each minor bay must be at least 7ft 3in by 9ft 10in (220cm by 320cm) with similar access.**

i. Bays may be separated by walls, partitions or curtains.
ii. The end at the head of the bed must be a permanent wall structure.
iii. In minor bays in which the bed is up against a wall, partition, or curtain, the bed must be positioned so that the accessible side of the bed is on the patient's right when lying in the bed.
iv. A minimum clear space of 2ft by 3ft (30cm by 60cm) must be accommodated at the foot of the bed in minor bays for the parking of an emergency crash cart.
v. In major bays; the bed must be positioned in the center of the short dimension of the bay, 2ft 8in (80cm) from the head wall to allow access from the head side of the bed.

48.4.D. **Circulation between opposite bays or bays and any wall and partition must be a minimum of 6ft 6in (2m) wide.**

48.4.E. **At County Hospitals and Regional/National Referral Hospitals, each ER must contain at least 1isolation room meeting High Risk ventilation requirements for suspected highly infectious patients to be temporarily housed and diagnosed.**

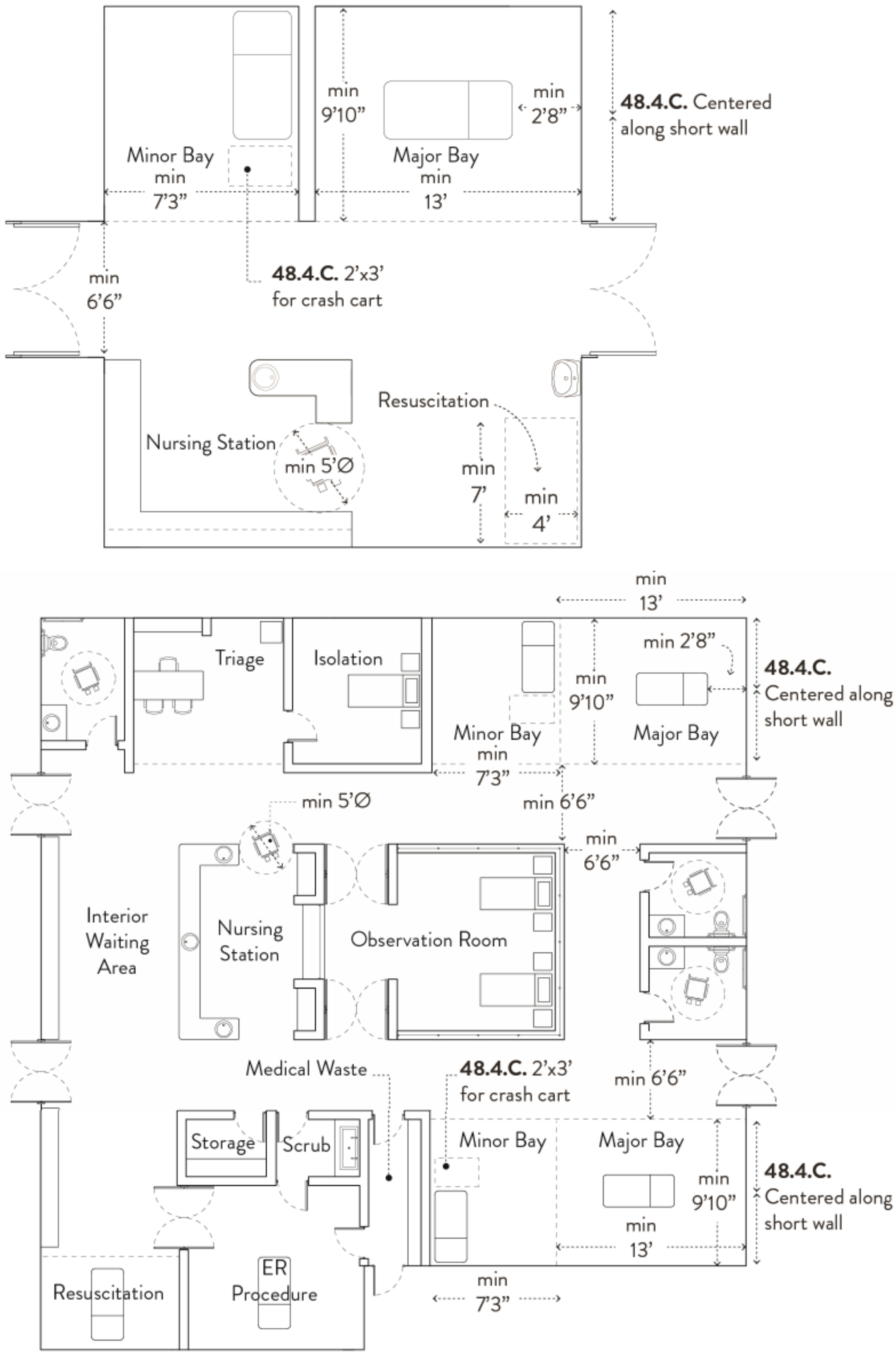
i. Access to the room must be separate from or before access to the other ER bays so infectious patients are not passed through the ER.
ii. ER Isolation Rooms must meet all requirements of Isolation Rooms as outlined in Section 48.9, with the following exception: En suite bathrooms are not required for ER Isolation Rooms.

48.4.F. **A central Nursing Station must be positioned to have direct visual access and control access to the ER bays.**

i. Nursing Stations must include easily accessible storage for planned portable ER equipment, including rolling equipment and carts.
ii. Cabinets must be provided for required drugs.

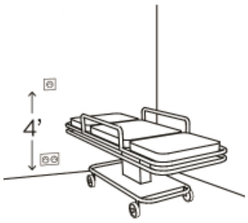
48.4.G. **Enclosed, lockable storage must be provided at a rate of $6ft^2$ ($0.5m^2$) per ER bay.**

Figure 48.d. Possible Large and Small ER Layouts.



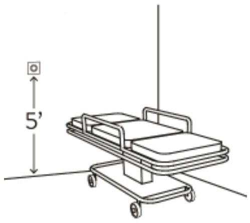
Installations

48.4.H. On one narrow end wall of each bay (a permanent wall construction, not a curtain) 1 electrical outlet must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended bed head position, and 2 electrical outlets at the normal height on the wall next to but not behind the bed.



48.4.I. For tertiary hospitals, a piped oxygen outlet must be mounted at 5ft (150cm) above the floor immediately adjacent to the bed.

i. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.

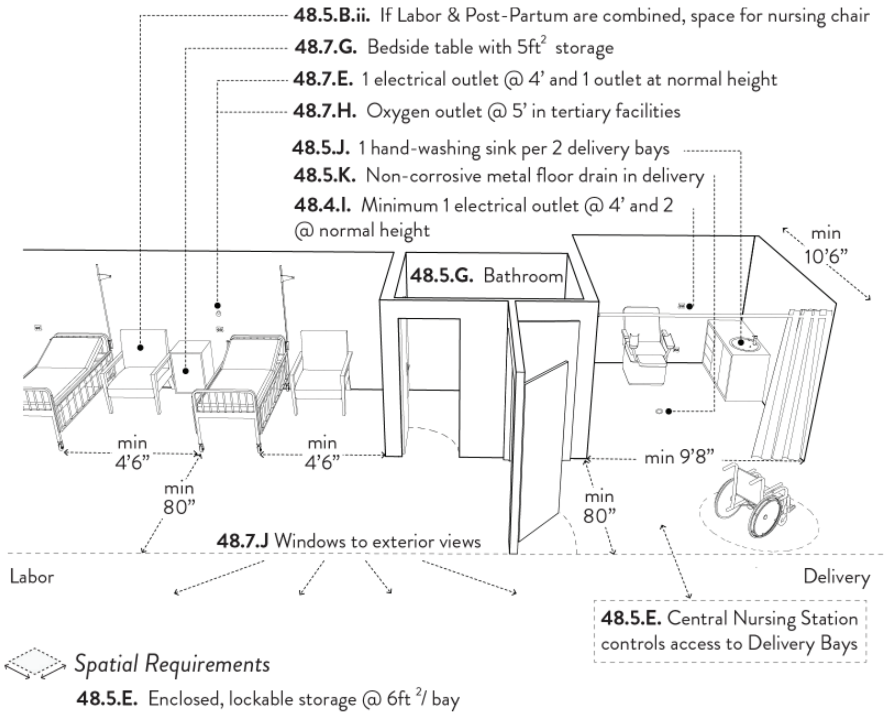


48.4.J. Hand washing sinks must be provided at a minimum rate of 1 sink per 2 ER beds.

48.5 Labor and Delivery

Improving child and maternal health depends on the strengthening of facilities to accommodate maternity and deliveries. Certain basic requirements, listed here, can have a major impact on the quality of care.

Quick Design Guide



Spatial Requirements

48.5.A. **Labor and Delivery Rooms must be immediately adjacent to each other.**

i. Initial access must be through the Labor Ward, which accesses Delivery, which then accesses Post-Partum if part of the facility program.

48.5.B. **Labor Rooms must meet all ward standards in Section 48.7 with the following additions:**

i. Toilets for Labor Wards must be accessed directly from either a private, enclosed exterior area or from the Labor Ward itself.

ii. If Labor Wards are combined with Post Partum (applicable only in PHC 1 and PHC 2 facilities, the clear space between beds must expanded to at least 4ft 6in (180cm) to accommodate a nursing chair.

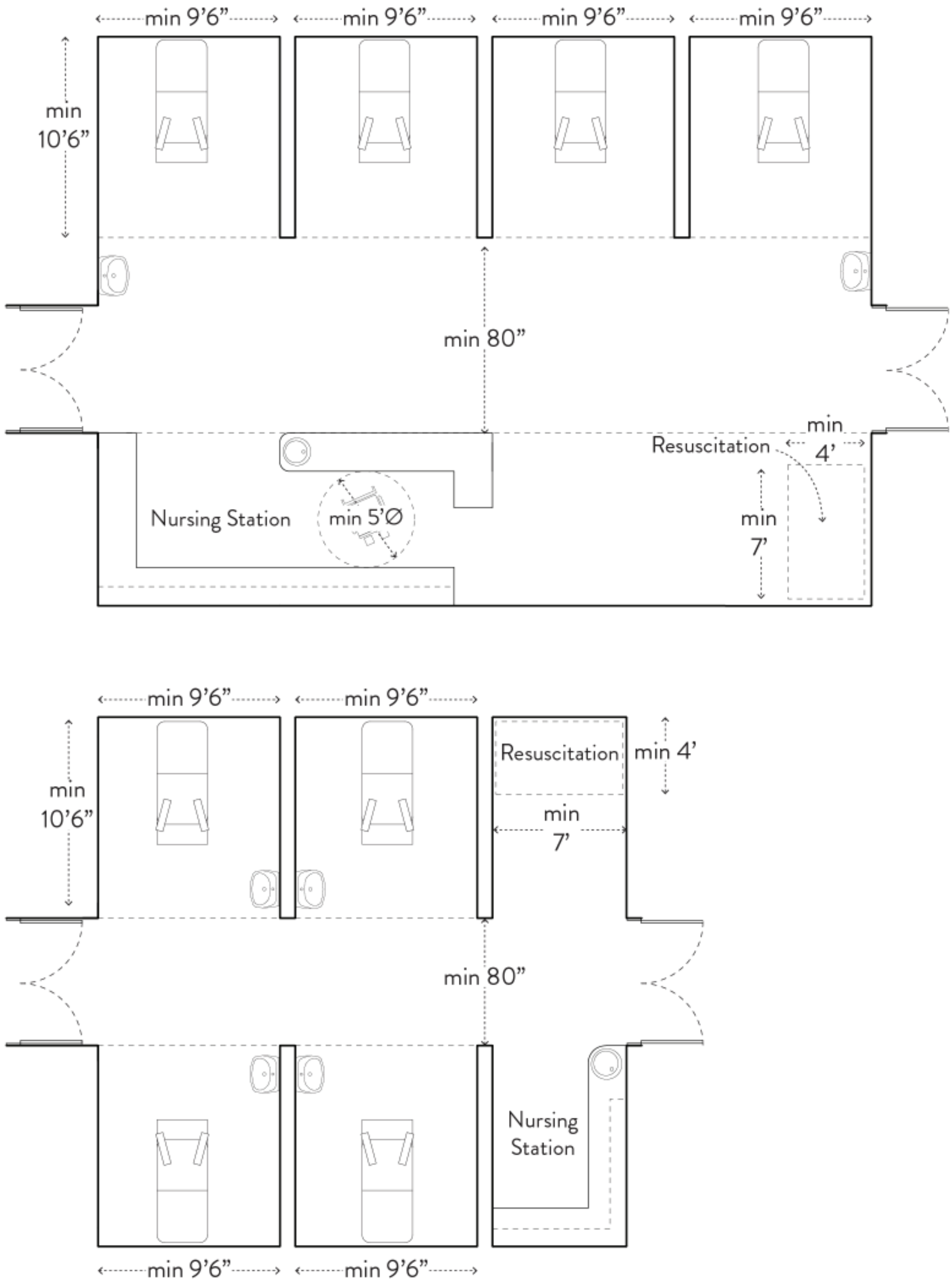
48.5.C. **Delivery Rooms must have individual bays separated by walls, partitions, or curtains. Each bay must be at least 9ft 6in by 10ft 6in (290cm by 320cm) with access to circulation from one end.**

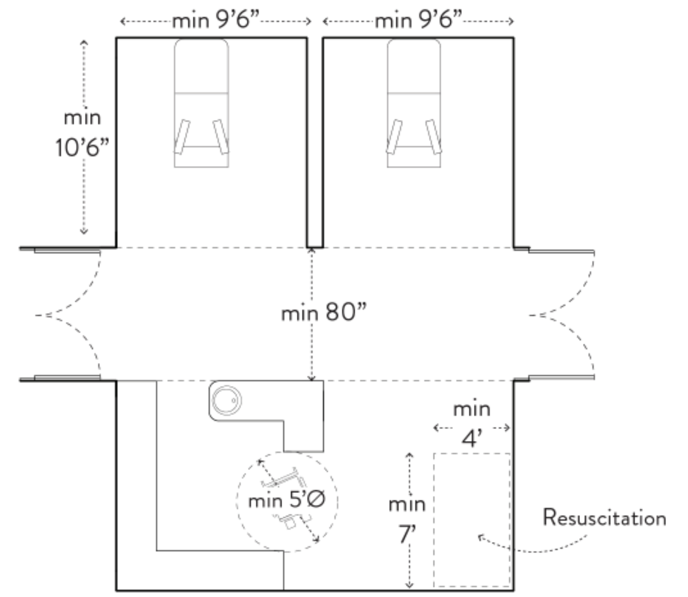
i. Individual rooms may also be used meeting the same dimensional requirements. The swing of a 36in door must not intrude into the dimensions stated above.

ii. In PCH 1 facilities, bays may be reduced to 7ft 10in by 10ft (240cm by 305cm) .

48.5.D. A clear space for circulation of at least 80in (203cm) must be maintained at the end of each delivery bay.

Figure 48.e. Possible Delivery Room Plan Layouts (Large and Small)





48.5.E. A central Nursing Station must be positioned to control access to the Delivery bays and provide immediate physical and visual access to it.

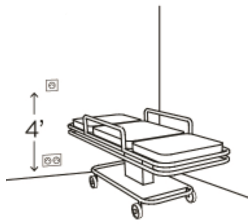
48.5.F. Enclosed, lockable storage must be provided at a rate of $6ft^2$ ($0.5m^2$) per Delivery bay.

48.5.G. A bathroom with at least 1 toilet must be located adjacent to, or in close proximity with private access to, the Labor Rooms.

48.5.H. A resuscitation area of minimum 4ft by 7ft (120cm by 210cm) is recommended for Delivery Rooms with more than one delivery bay.

Installations

48.5.I. On one narrow end wall of each bay (a permanent wall construction, not a curtain) 1 electrical outlet must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended bed head position, and 2 electrical outlets at the normal height on the wall next to but not behind the bed.



48.5.J. A minimum of 1 hand-washing sink must be present in the Delivery Room for every 2 delivery bays.

i. It is advisable for each delivery bay to have it's own hand-washing sink.
ii. Private delivery rooms must have their own hand-washing sink.

48.5.K. Anon-corrosive metal floor drain, with trap clean out, must be installed within each Delivery bay or private room near the foot of the bed.

48.6 Short Stay

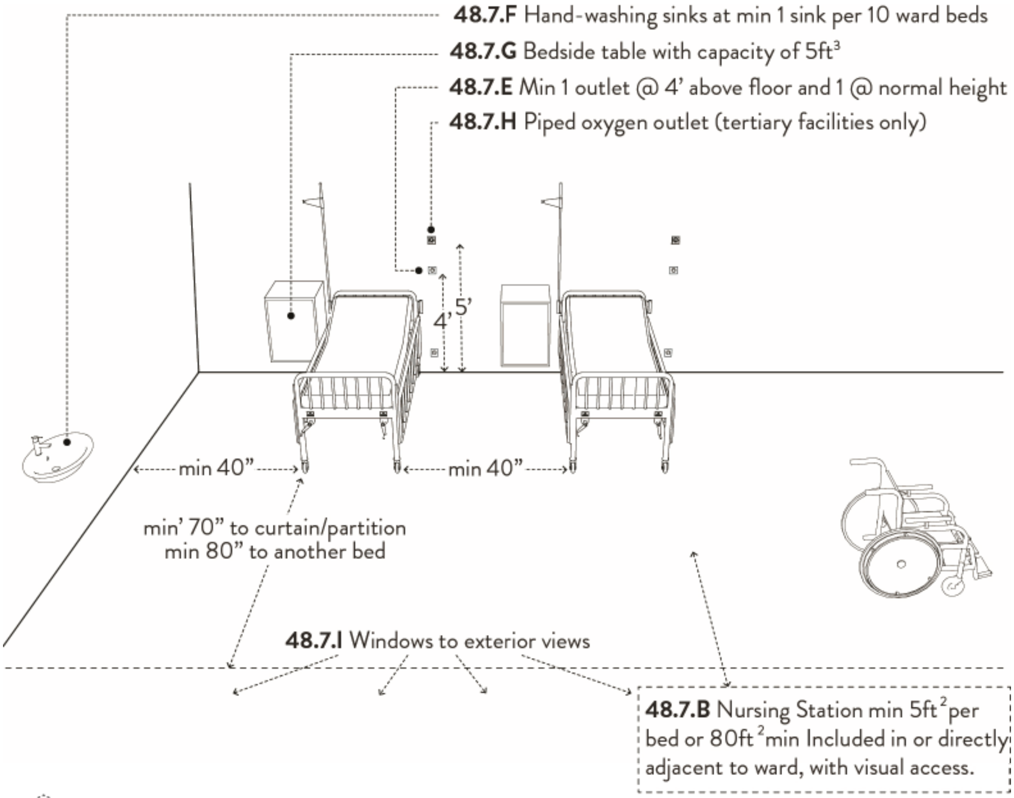
48.6.A. Short Stay rooms must meet all requirements of Section 48.7, with the following exceptions:

- Direct access to a toilet is not required, though a toilet must be accessible in the vicinity.
- Direct access to a Nursing Station is not required, though a Nursing Station or OPD office must be within close proximity.
- A bedside table is not required. This space may be used for a chair for a patient attendant.

48.7 Men's and Women's Inpatient Wards

Inpatient wards should be thought of as hybrid between clinical spaces and domestic spaces in which patients spend a lot of time. Keeping patient needs in mind will provide for a higher quality, more effective environment for healing.

Quick Design Guide



Spatial Requirements

48.7.C Enclosed, lockable storage at a rate of 1 ft^2 per ward bed.

48.7.D. Bathrooms containing min 2 toilets, 1.5 sinks, and 1 shower for every 10 ward beds

Installations

48.7.G. Durable, cleanable bedside tables

Environmental & Technical Requirements

48.7.J.i. Privacy to be addressed for ground floor wards.

48.7.J.ii. Prioritized views of landscaped areas must be prioritized

Spatial Requirements

48.7.A. Minimum dimensions surrounding ward beds must be:

- Clear space of 40in (100cm) between beds and between beds and walls.
- Clear space of 70in (180cm) between the foot of the bed and any walls or partitions for circulation
- Clear space of 80in (200cm) between the foot of any bed and any other bed

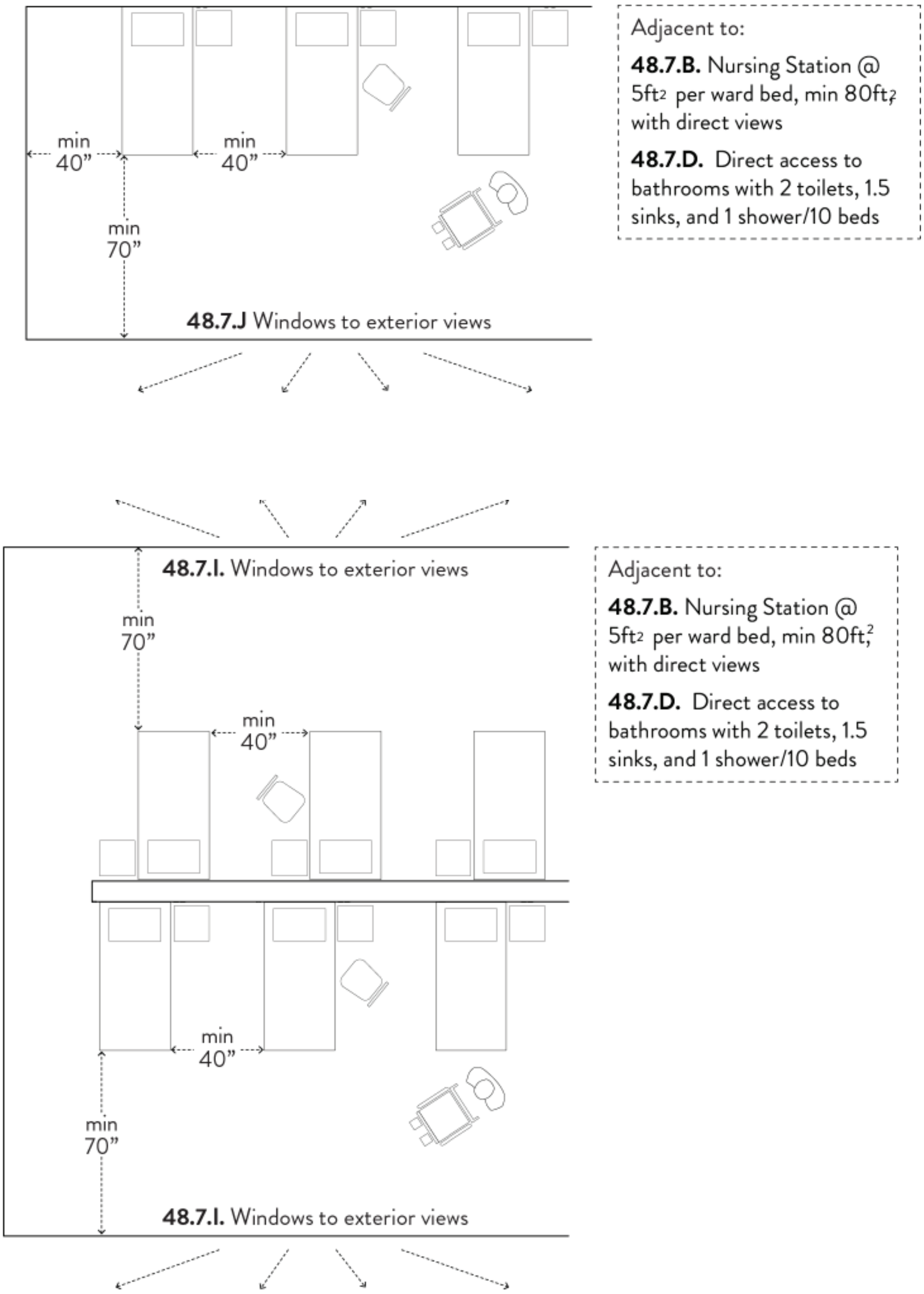
i. Recommendable bed layouts are shown in Figure 48.f.

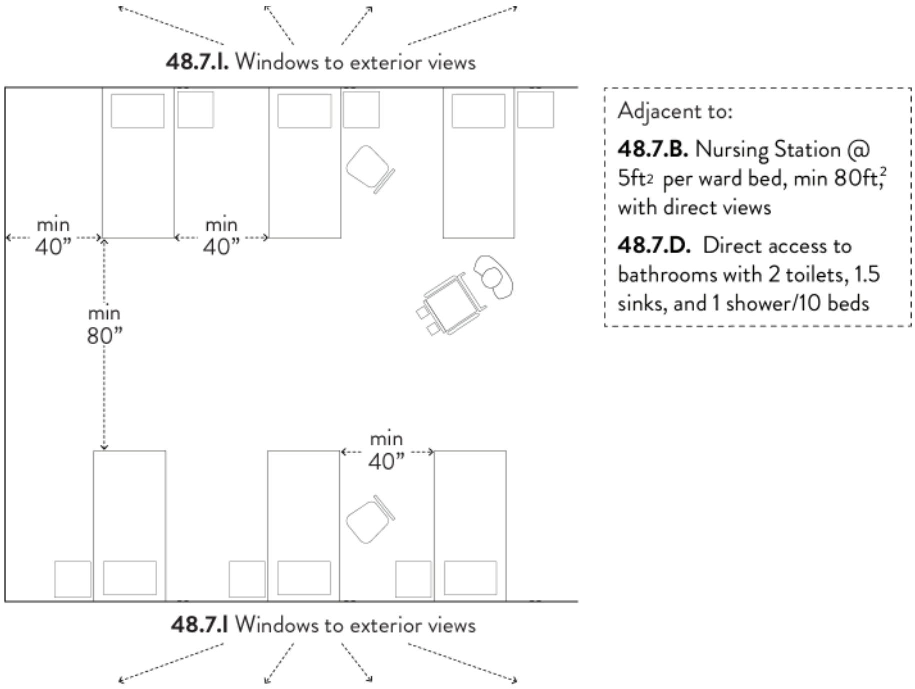
Bed Spacing and Infection Control

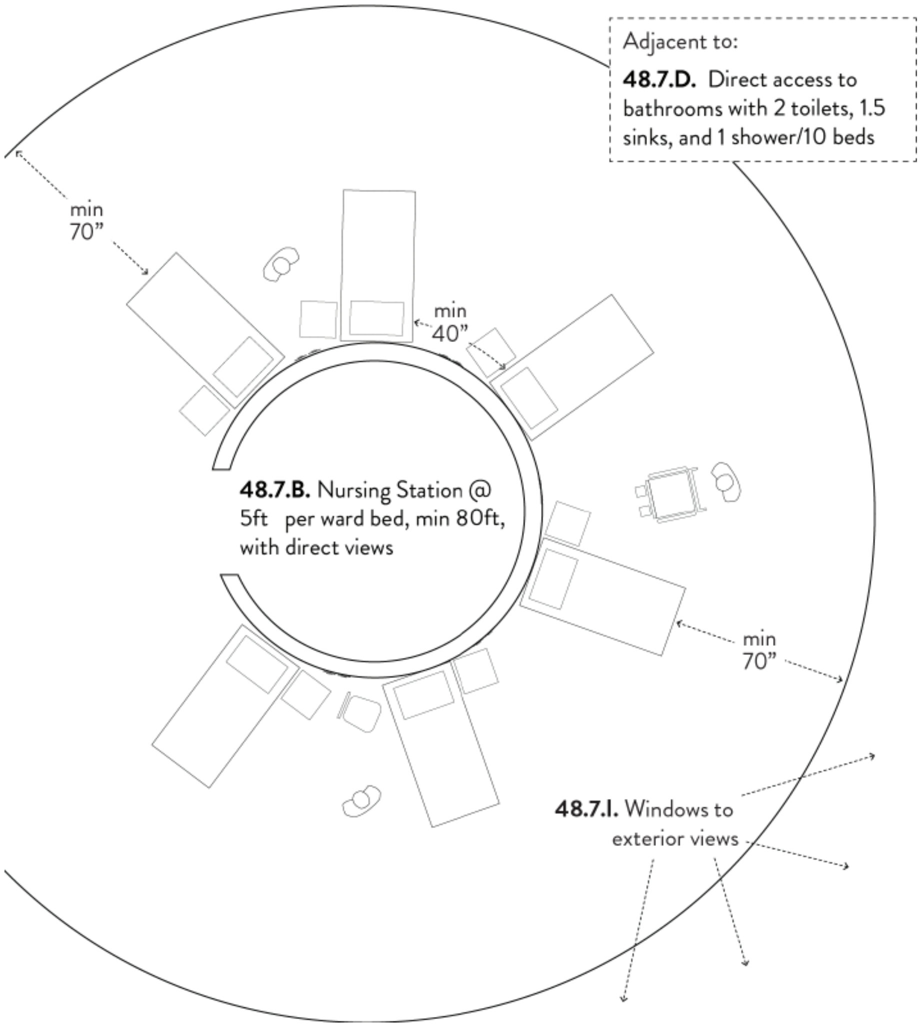
Bed spacing must be large enough to avoid droplet-spread infections, either by adequate bed spacing or by inserting partitions between beds.

When a patient sneezes, airborne droplets, potentially containing disease-spreading agents, ordinarily travel a maximum of about 40in (100cm). Thus, the minimum acceptable bed spacing is 40in (100cm).

Figure 48.f. Possible Ward Bed Layouts




48.7.I. Windows to exterior views
Adjacent to:
48.7.B. Nursing Station @ 5ft2 per ward bed, min 80ft2, with direct views
48.7.D. Direct access to bathrooms with 2 toilets, 1.5 sinks, and 1 shower/10 beds
min 40"
min 40"
min 80"
min 40"
48.7.I Windows to exterior views


Adjacent to:
48.7.D. Direct access to bathrooms with 2 toilets, 1.5 sinks, and 1 shower/10 beds
min 70"
min 40"
48.7.B. Nursing Station @ 5ft per ward bed, min 80ft, with direct views
min 70"
48.7.I. Windows to exterior views

48.7.B. **Wards must include or be directly adjacent to, with direct access to and from, a Nursing Station sized at 5 ft^2 ($0.5m^2$) per ward bed, but not less than 80 ft^2($7.5m^s$), and be positioned to control access to the Ward. The Nursing Station must have direct views into the ward from its entire floor area.**

i. Nursing stations must be placed to provide easy monitoring of all patients in the ward. It is recommendable for all beds to be visible from the nursing station.
ii. There must be at least one door from the Nursing Station directly into the ward.

48.7.C. **Enclosed, lockable storage must be provided at a rate of $1ft^2$ ($0.1m^2$) per Ward bed.**

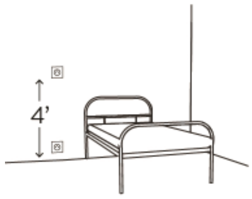
i. Storage space must be inaccessible to patients and accessed only by staff.

48.7.D. **Wards must have direct access to bathrooms containing at minimum 2 toilets, 1.5 sinks, and 1 shower for every 10 Ward beds.**

i. Bathrooms should be placed for easy access of patients.

Installations

48.7.E. **A minimum of 1 electrical outlet must be provided at a height of 4ft (120cm) above the floor immediately adjacent to all bed head positions, and 1 electrical outlet at normal height on the wall next to but not behind each bed.**



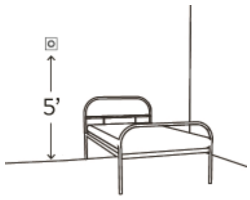
48.7.F. **Hand-washing sinks must be installed in easily accessible places at a minimum rate of 1 sink per 10 Ward beds, but not less than 1.**

48.7.G. **A bedside table with storage capacity of minimum 5 ft^3 must be provided at each bed.**

i. Tables must be mounted with their tops at bed height or slightly above.
ii. Tables should be made of durable, cleanable material in line with reference material & finishes standards.

48.7.H. **For tertiary hospitals, a piped oxygen outlet must be mounted at 5ft (150cm) above the floor immediately adjacent to the bed.**

i. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.



Environmental & Technical Requirements

48.7.I. **Wards must contain windows to exterior views.**

i. Privacy must also be addressed if windows face a ground-level public area. However, curtains must not be used as they block access to airflow from operable windows and collect and harbor dust and microorganisms. Other means of achieving privacy must be developed, such as translucent glass, visual shielding devices, or clerestory windows.
ii. Views of landscaped areas must be prioritized. Refer to Section 15.2 for details.

48.8 Pediatric Inpatient Wards

Treating children has unique requirements; a healthy environment for children must be fostered in the ward.

48.8.A. **Pediatrics Wards must meet all requirements of Section 48.7, with the following additions:**

- **In Hospitals, ward space for boys and girls must be physically separated or separately spatially organized.**
- **Required number of toilets, sinks and showers must be calculated separately for boys and girls, with separate boys and girls bathrooms.**
- **At least one toilet dimensioned for small children must be prioritized in each bathroom.**
- **At least one hand-washing sink must be mounted at between 24in and 30in (60cm and 76cm) above the floor for easy access by children.**

Environmental & Technical Requirements

48.8.B. **Windowsills in Pediatrics Wards must not be higher than 32in (80cm) so that small children are able to have a view to the exterior.**

48.8.C. **Pediatric Wards must have direct access to contained exterior play spaces.**

i. Play spaces must be protected from outside access.
ii. Play spaces must be at minimum 150ft2 (14m2) in area and have a soft ground surface such as grass or sand.
iii. Refer to Standards 10.1.C. and 10.1.D. for play space requirements.

48.9 Isolation Rooms

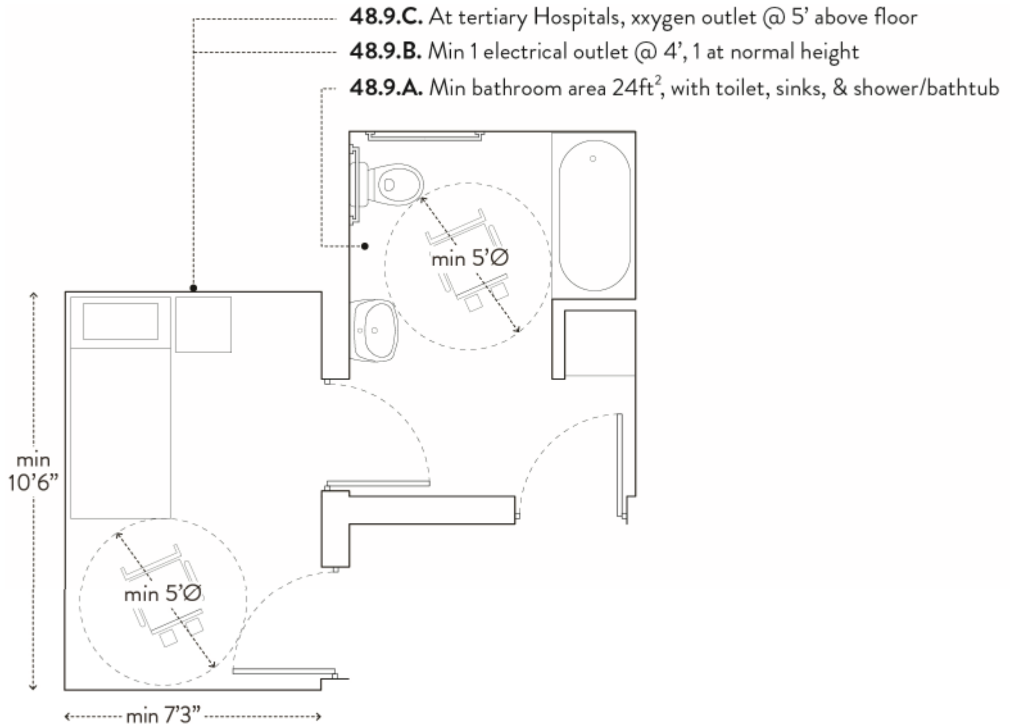
Isolation Rooms may be included to house highly infectious patients whose presence on the wards would put patients, staff, and visitors at risk. These are particularly important for areas with a high prevalence of tuberculosis (TB) or other airborne diseases.

Spatial Requirements

48.9.A. **Isolation Rooms must be of minimum dimensions 7ft 3in by 10ft 6in (220cm by 320cm) for the bed area, and a minimum of 50ft^2(4.6m^2) area for an en-suite bathroom.**

i. Bathrooms require privacy but do not need to be completely enclosed from the isolation room; walls up to 6ft 6in (200cm) may suffice as division between bathroom and patient room area.
ii. Bathrooms must include toilets, sinks and showers or bathtubs.

Figure 48.g. Possible Isolation Room Plan Layout



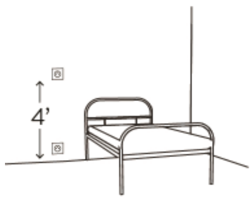
Environmental & Technical Requirements

48.9.D. Windows with exterior views, but room privacy must be addressed

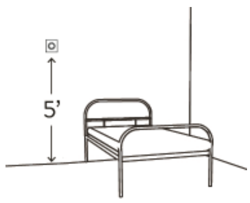
48.9.E. Rooms kept at negative air pressure

Installations

48.9.B. A minimum of 1 electrical outlet must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended bed head position, and 1 electrical outlet at the normal height on the wall next to but not behind the bed.



48.9.C. For tertiary hospitals, a piped oxygen outlet must be mounted at 5ft (150cm) above the floor immediately adjacent to the bed.



i. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.

Environmental & Technical Requirements

48.9.D. Rooms must contain windows with access to exterior views.

i. Privacy must also be addressed if windows face a ground-level public area. However, curtains must not be used as they block access to airflow from operable windows and collect and harbor dust and microorganisms. Other means of achieving privacy must be developed.

ii. Views of landscaped areas must be prioritized. Refer to Section 15.2 for details

48.9.E. Isolation Rooms must be kept at negative air pressure per Standard 20.3.A, or be substantially naturally ventilated using cross or stack ventilation as outlined in Chapter 19. Exhaust air must be directed away from all occupiable spaces, including corridors, waiting areas, and public spaces.

i. If natural ventilation is used, Isolation Rooms must have at least 2 exterior walls, and corridors accessing the rooms must be sheltered exterior spaces.

ii. If ventilation is done by cross ventilation by natural means only, openings must be at least 10% of total perimeter wall area, with at least must be permanently fixed in an open position. Additional operable window area may be added in excess of this.

48.10 Intensive Care Units (ICU)

Intensive Care Units (ICUs) require continuous, direct observation of patients by clinical staff.

48.10.A. ICUs must meet the requirements of Standards 48.9.A. - 48.9.E. with the following exceptions:

- En-suite bathrooms are recommended but not required for ICU rooms. Bathrooms outside the rooms must not be more than 80ft (24m) from any room, and must be segregated between men's and women's.
- A clear space of at least 2ft by 2 ft (60cm by 60cm) must be provided on each side of the ICU bed for equipment.

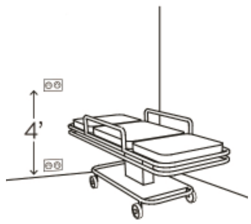
Spatial Requirements

48.10.B. Partitions between individual ICU rooms and the ICU Nursing Station must be made of vision glass, with a direct line of site from the Nursing Station to the room, and no curtains, shades, or other visual obstructions at the glass walls.

Installations

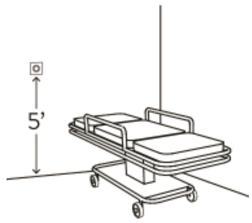
48.10.C. Two electrical outlets must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended bed head position, and 2 electrical outlets at the normal height on the wall next to but not behind the bed.

i. On walls without the bed head, a minimum of 1 electrical outlet every 15ft (4.5m) must be provided.



48.10.D. A Piped oxygen outlet must be mounted at 5ft (150cm) above the floor immediately adjacent to the bed.

i. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.



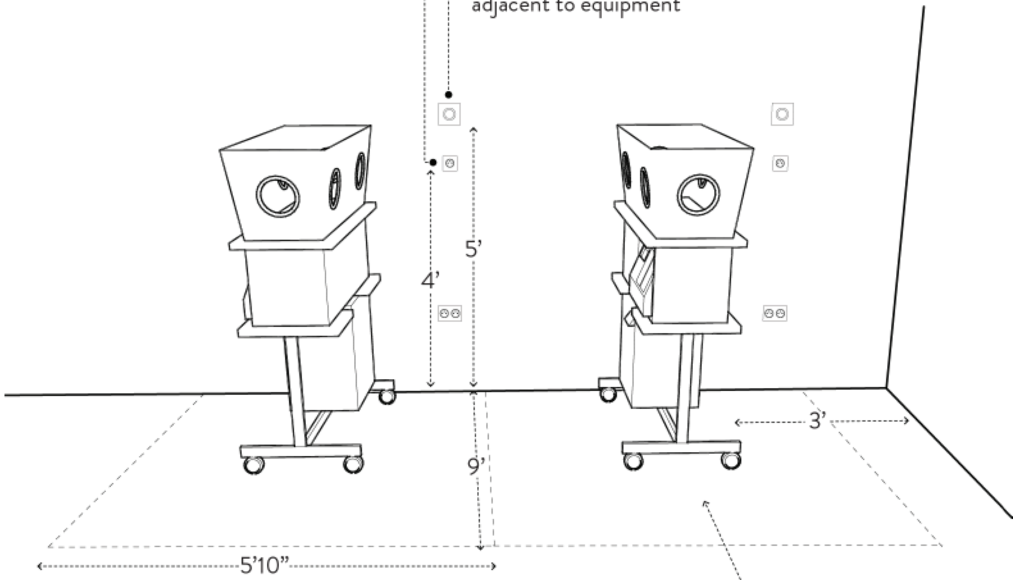
48.11 Neonatal Intensive Care Units (NICU)

Neonatal intensive Care Units (NICUs) require continuous, direct observation of infants, specialized equipment, and a secure dirty-to-clean entry sequence. They must be in close proximity to the Maternity spaces.

Quick Design Guide

48.11.F. 1 electrical outlet adjacent to equipment station provided @ 4' above the floor; 2 @ normal height, next to and not behind the station

48.11.G. Piped oxygen outlet mounted @ 5' adjacent to equipment



48.7.B. Nursing Station min 5ft² per bed or 80ft² min included in or directly adjacent to ward, with visual access.

Spatial Requirements

48.11.A. Access through NICU through anteroom

Installations

48.11.C. Anterooms with hand-washing station and shelving for gowns, clothing, and other clean storage

48.11.D. Includes or is directly adjacent to Nursing Station at 5ft² per ward bed, but not less than 80ft²

48.11.G. If piped oxygen cannot be accomodated, adequate storage for portable cyclinders must be included in areas protected but accessible for maintenance and refilling

Environmental & Technical Requirements

48.11.E. Enclosed storage at a rate of 2ft² per equipment station

Spatial Requirements

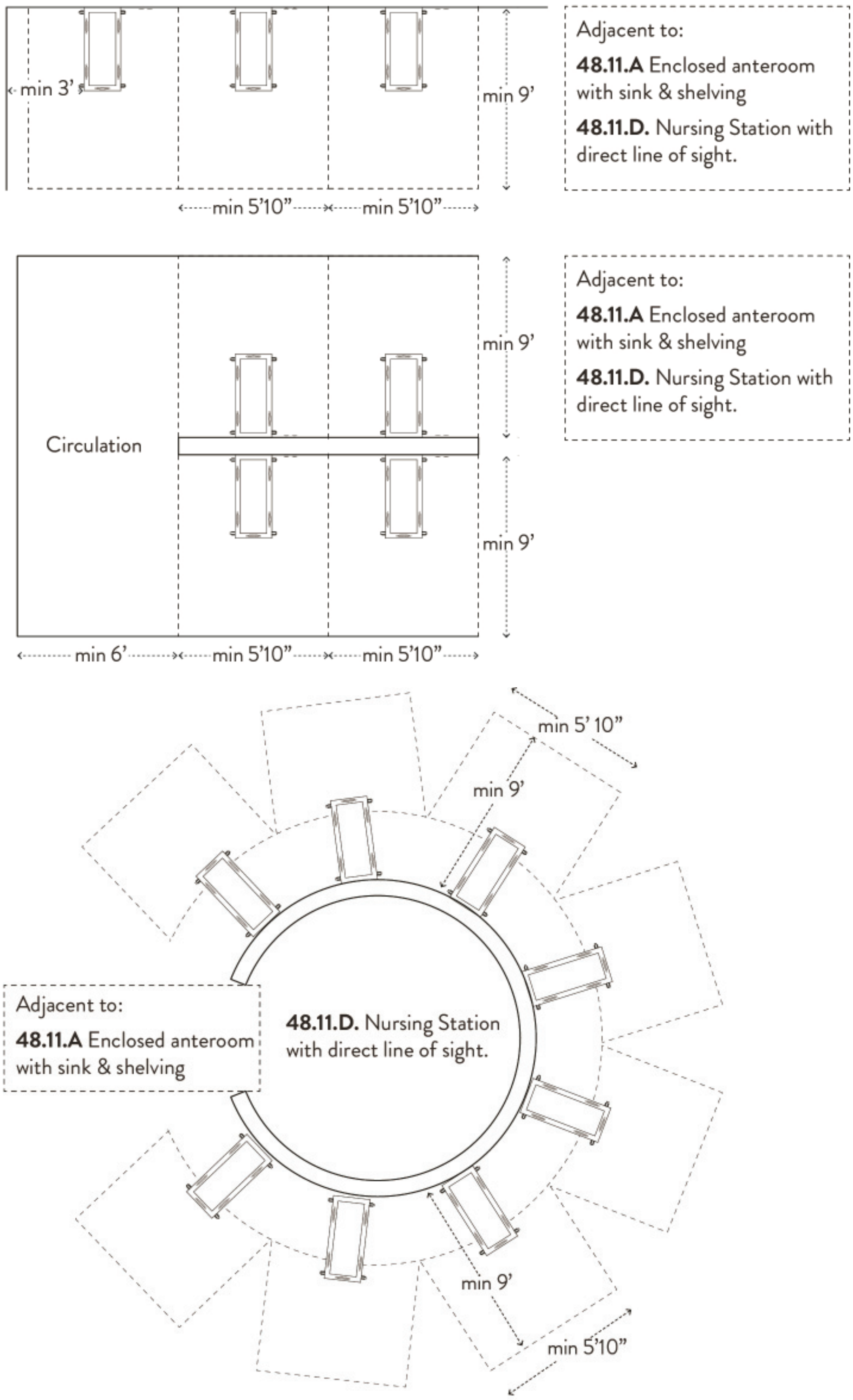
48.11.A. Access to the NICU must be through an enclosed anteroom, with doors on both the entry from the exterior/corridor and the entrance to the NICU to create an airlock.

48.11.B. NICUs must have designated equipment stations for incubators and/or warming tables. Minimum dimensions around these equipment stations must be of the following:

– 5ft 10in (180cm) width for each station (this includes the incubator, space for a monitor, and access to the incubator from one side)
– 9ft (275cm) depth for each station (this includes the incubator against a wall and circulation access at the foot of the incubator).
– Minimum side clear space of 3ft (90cm) between any incubator or warming table and any wall or partition.

i. Equipment sizes may vary and must be considered during design.

Figure 48.h. Possible NICU Plan Layouts



48.11.C. Enclosed storage must be provided at a rate of 2ft2 (0.2m2) per equipment station.

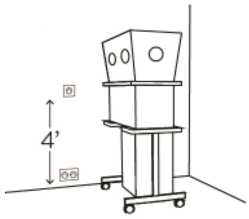
Installations

48.11.D. NICU anterooms must contain a hand washing station and shelving for gowns / clothing and other clean storage.

48.11.E. NICUs must either include or be directly adjacent to, with direct access to and from, a Nursing Station sized at 5 ft^2 (0.5m^2) per ward bed, but not less than 80 ft^2 (7.5m^s), positioned to control access to the NICU.

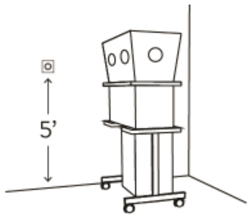
i. Nursing stations must have a direct line of sight to all equipment stations.

48.11.F. One electrical outlet must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended equipment stations, and 2 electrical outlets at the normal height on the wall next to but not behind the station.



i. On walls with no equipment stations, a minimum of 1 electrical outlet every 15ft (4.5m) must be provided.

48.11.G. Piped oxygen and outlets must be mounted at 5ft (150cm) above the floor immediately adjacent to each equipment station.



i. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.

49 Surgery, Diagnostics & Clinical Support

General Programmatic Requirements apply to all spaces as indicated in Chapter 46.These services require additional specialize systems; any listed requirement is in addition to, and not a substitute for, general requirements.

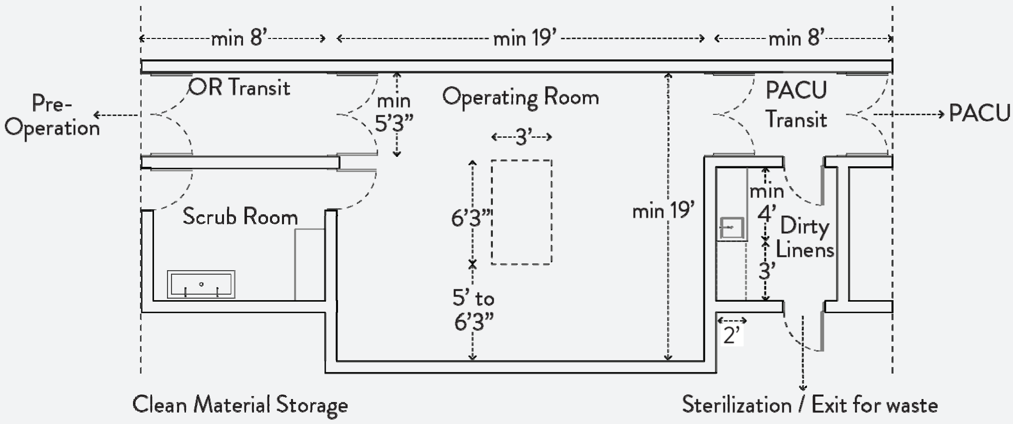
49.1 Pre-Operation and Scrub Rooms

Pre-Operation(Pre-Op) and Scrub rooms begin the sterile entry sequence into the Operating Rooms that play an active role in ensuring the performance of the Operating Rooms.

Surgical Sequence

The sequence of access to and exit from Operating Rooms (ORs) is very particular and is intended to ensure the sterility of the ORs. Pre-Op spaces may, if required, also be used as Post-Anesthesia Care Units (PACUs), but this is not recommended if space permits the two to be separated

Figure 49.a. Operating Room Sequence and Possible Layout.



Spatial Requirements

49.1.A. Pre-Op spaces must be designed to accommodate two times the number of gurneys as the number of Operating Rooms.

i. For each gurney, a clear space 'parking' area must be allocated with minimum dimensions of 7ft 6in by 3ft 4in (230cm by 100cm).

ii. Aside the parking space, a clear width of 5ft 10in (180cm) must be maintained for circulation and movement of gurneys and people.

49.1.B. A small Nursing Station within Pre-Op must be provided, with a minimum area of $60ft^2$ ($5.5m^2$) and a minimum countertop work space of 3ft 4in (1m) in length and 1ft 8in (50cm) in depth.

i. A minimum of $10ft^3$ ($0.3m^3$) of drawer and cabinet storage must be provided at the Nursing Station.

49.1.C. Pre-Op must be configured so that the Nursing Station has access to a Clean Material Storage Room that supplies the Operating Rooms.

i. This access must be controlled by, at minimum, a lockable door and accessed only by staff.

ii. If direct access to the Clean Material Storage Room is not possible, entrance may be provided through a controlled, sterile corridor.

49.1.D. Pre-Op must have direct access to the Scrub Rooms and to a Pre-Op Transit Room leading to the Operating Theaters.

i. Both Scrub Rooms and Pre-Op Transit must have automatically closing doors on both ends of the room to control airflow out of the Operating Rooms and prevent unsterilized air from entering the Operating Rooms.

ii. Doors to each of these rooms must swing in the direction of travel towards the Operating Rooms. Double-swing doors must not be used except in Health Centers in there is no Pre-Op space and traffic moves in and out from the same entrance.

iii. A minimum of 10ft^3 (0.3m^3) of drawer and cabinet storage must be provided at the Nursing Station.

49.1.E. Patient Transit Rooms must be a minimum of 5ft 3in (160cm) wide by 8ft (243cm) long in the direction of travel in order to allow gurneys to pass through and doors to create an airlock.

49.1.F. Scrub Rooms must include a scrubbing area recessed in an alcove so as not to interfere with the main circulation path.

Installations

49.1.G. Pre-Op must contain a small shoe-shelf unit for storage of shoes and surgical slippers.

49.1.H. Scrub Rooms must contain a scrub sink with at least two water faucets.

i. The scrub sink must be a minimum of 3ft (90cm) wide if both faucets flow into a single basin.

ii. Water taps must be able to be operated without using one's hands. Hands-free sensor faucets, foot pedals, may accomplish this or by faucets with long lever arms that can be manipulated with one's elbows. Non-automatic systems (i.e. foot pedals or long lever arm faucets) are preferable from a maintenance perspective.

iii. Scrub sinks basin must be made of easy-to-clean, non-corrosive, durable materials. Acceptable materials include: stainless steel, aluminum, and sealed and waterproofed concrete.

49.1.I. Scrub Rooms must contain wall-mounted shelving for the storage of surgical gowns, gloves, and masks.

49.2 Operating Rooms

Proper spatial and technical configuration of Operating Rooms is essential to achieve the maximum potential for surgical care. Requirements unique to Operating Rooms are outlined below.

Spatial Requirements

49.2.A. Operating Rooms must be accessed directly from a Pre-Op Transit Room and exited through a Post-Anesthesia Care Unit (PACU) Transit Room.

49.2.B. Dimensions of Operating Rooms must be at least 19ft by 19ft (580cm by 580cm) in dimension.

49.2.C. A space of 6ft 6in by 3ft (200cm by 90cm) must be designated for the operating table at the center of the room, with the head position between 5ft and 6ft 3in (1.5m and 1.9m) of the center of one wall.

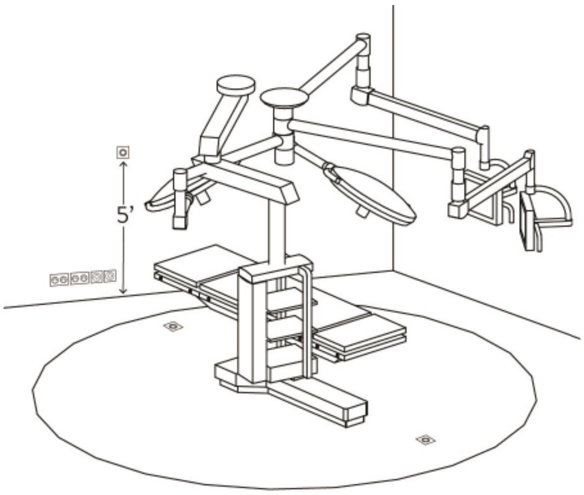
49.2.D. Ceiling heights in Operating Rooms must be a minimum of 9ft 6in (290cm) and a maximum of 14ft (425cm), with structure at the center of the room to support specialized lights and equipment above operating table.

Installations

49.2.E. A minimum of two floor drains must be provided between 24in and 48in (60cm and 122cm) of each end of the operating table.

49.2.F. A minimum of four standard electrical outlets and two 3-phase outlets must be provided at the center of the wall perpendicular to the operating table head position. A minimum of two standard electrical outlets must be provided each of the other walls.

Figure 49.b. OR Installations.



49.2.G. At Hospitals, ceiling-mounted surgical lights must be provided over the center of the operating table.

i. At Health Centers, floor-stand surgical lights may be used.

49.2.H. If split-unit wall-mounted air conditioners are used, the unit must be mounted at least 7ft (213cm) above the floor on the head wall, aligned with the operating table.

49.2.I. Continuous supply of oxygen, anesthetic gas (nitrous oxide), suction, and medical gas must be accommodated in Operating Rooms.

i. Piped oxygen, nitrous oxide, suction and medical gas are recommended, especially for tertiary hospitals. Wall outlets for these services must be mounted at 5ft (150cm) above the floor within 1ft (30cm) of the center of the head wall, or supplied via a ceiling column stopping 6ft (180cm) above the floor.

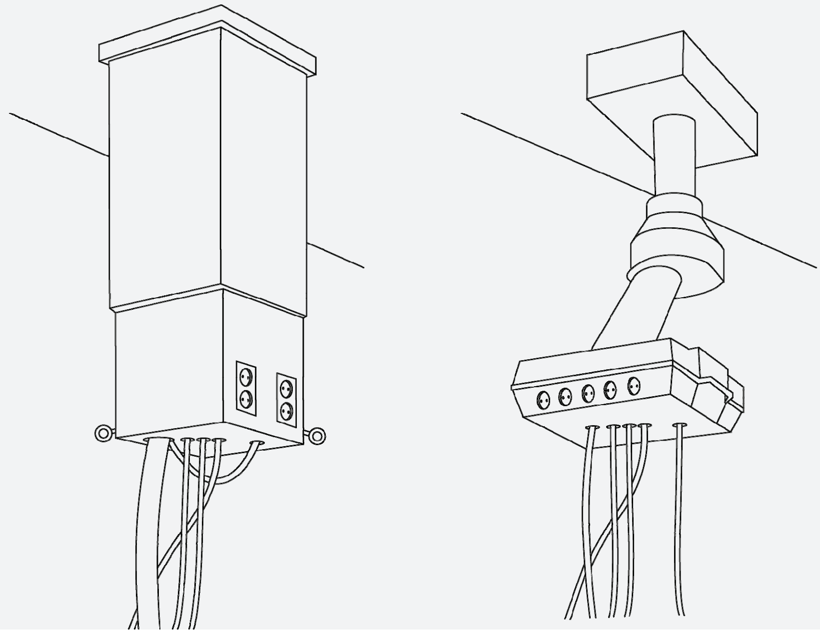
ii. If a ceiling column is used, it must be positioned with its innermost corner 18in (45cm) from one corner of the head of the operating table, measured on a 45-degree angle relative to the table.

iii. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.

Ceiling Columns

In an operating room context, a ceiling column is a suspended shaft providing services such as oxygen, medical gas, suction, and electricity to the operating table. It is normally suspended behind and to one side of the operating table head position.

Figure 49.c. Types of ceiling columns



Environmental & Technical Requirements

49.2.J. **Operating Rooms must have climate control provided either by central air conditioning or wall-mounted air conditioning units.**

49.2.K. **Operating Rooms must be kept at positive air pressure relative to surrounding spaces per requirements in Chapter 20. Air supply must be filtered with a minimum filter grade of MERV 11.**

i. Positive air pressure is important to ensure air from other rooms does not enter to contaminate the OR.

ii. A suggested ventilation maintenance plan for OR spaces must be developed and approved by the assigned IU representative before construction begins.

49.2.L. **Air exhaust from Operating Rooms must be fitted with backdraft dampers to prevent airflow from reversing.**

i. Refer to Standard 20.2.A. for mechanical ventilation requirements.

49.2.M. **Natural light in Operating Rooms must be prioritized, but no view whatsoever should be allowed from exterior to interior in order to preserve privacy.**

i. Privacy must be addressed if windows face a ground-level public area. However, curtains must not be used as they block access to airflow from operable windows and collect and harbor dust and microorganisms. Other means of achieving privacy must be developed, such as translucent glass, visual shielding devices, or clerestory windows with sill heights greater than 7ft (2.1m).

49.3 Post Anesthesia Care Unit (PACU)

The PACU is a critical post-operation service area in which patients are brought out of anesthesia and begin the recovery process.

Spatial Requirements

49.3.A. **Minimum clear spaces surrounding PACU bed stations must be a minimum of:**

- 4ft (120cm) from any PACU bed to any wall or partition
- 5ft (150cm) between the sides of any 2 PACU beds
- 6ft (180cm) between the foot of any PACU bed and any wall, partition, bed, or other obstruction.

49.3.B. **Storage for clean linens and equipment must be provided at a minimum rate of of5ft^2(0.5m^2) per bed.**

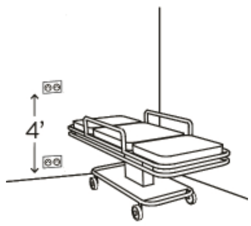
i. Storage sizing must be checked against planned equipment needs.

49.3.C. **A nursing station with direct visual and physical access to the PACU beds must be provided at a size of not less than 60 ft^2 (5.5m^s).**

Installations

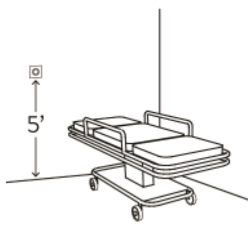
49.3.D. **At least one hand-washing sink must be provided.**

49.3.E. **Two electrical outlets must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended bed head position, and 2 electrical outlets at the normal height on the wall next to but not behind the bed.**



i. On walls without the bed head, a minimum of 1 electrical outlet every 15ft (4.5m) must be provided.

49.3.F. **A piped oxygen outlet must be mounted at 5ft (150cm) above the floor immediately adjacent to the bed.**



i. If piped oxygen cannot be accommodated, adequate storage for portable cylinders must be included in areas protected but accessible for maintenance and refilling.

49.4 Post-Operation Wards

Post-Operation Wards have more stringent requirements than ordinary wards because the patients remain immuno-compromised during recovery.

49.4.A. **Post-Operation Wards must meet all requirements of Section 48.7, with the following additions:**

- Access to the Post-Operation Ward must be controlled via private entrances accessed by staff only.
- A staff WC must be provided in close proximity to the Post-Operation Ward.

49.5 Clean Material Storage

The Clean Material Storage houses sterile surgical materials needed to supply the ORs during procedures. Staff accessibility without compromising cleanliness is paramount.

Spatial Requirements

49.5.A. Shelves a minimum of 16in (40cm) deep must be provided for the storage of clean and sterile supply materials.

49.5.B. A work counter a minimum of 4ft (120cm) long must be provided.

49.5.C. A door or closable window from Clean Material Storage to the Operating Rooms must be included for the passage of supplies and materials.

Installations

49.5.D. At least one hand-washing sink must be provided.

49.6 Dirty Linens

After surgeries, materials are passed through a Dirty Linens room for sorting, movement to Sterilization, and disposal if necessary. Space for instruments and soiled linens must be provided.

Spatial Requirements

49.6.A. A work counter of a minimum of 4ft (120cm) long must be provided.

49.6.B. A clear space of minimum 3ft by 2ft (90cm by 60cm) must be provided for the parking of a soiled linens trolley.

Installations

49.6.C. At least one hand-washing sink must be provided.

49.7 Dispensary and Pharmacy Stock Rooms

Adequate design of the storage and dispensary facilities is required to ensure the safekeeping of drugs. These requirements apply to configurations in which Dispensaries and Pharmacy Stock Rooms are separated; in many PHC facilities they may be combined and may be included with the Registration area.

Spatial Requirements

49.7.A. Pharmacy Stock Rooms must be organized to allow for shelving 1ft 4in (40cm) in depth or greater as accessed from one side, with minimum aisle space between shelves of 3ft (90cm).

49.7.B. Pharmacy Stock must allow for one receiving entry with a minimum door width of 60in (150cm) for the delivery of drugs.

i. This entrance must have direct access to a non-clinical corridor or direct access to the exterior for deliveries to be made.
ii. The entrance must be securable and accessible only to designated staff.

49.7.C. Pharmacy Stock must have a secure, direct entrance to/from the Dispensary.

49.7.D. Dispensary rooms must be enclosed and must include an operable dispensary window with at least 3ft (90cm) width of vision glass and at least 1ft (30cm) of operable pane, with sill height at least 2ft 6in (80cm) above the floor, positioned to overlook the Waiting Area.

49.7.E. A space of at least 4ft by 2ft (120cm by 60cm) must be provided at the dispensary window for the registrar's desk. This area must be free of other obstructions.

Installations

49.7.F. Pharmacy Stock Rooms must have shelving at 1ft 4in (40cm) in depth or greater as accessed from one side provided.

49.7.G. If wall-mounted air conditioning units are used, the units must be mounted at least 7ft (213cm) above the floor.

49.7.H. Pharmacy Stock Rooms must have ceiling fans installed at a rate of 1 fan per 250ft^{2} (25m^{2}).

49.7.I. Each Pharmacy Stock Room must have at least one 3-phase outlet next to at least 2 standard electrical outlets in a designated cold storage area.

49.7.J. A lockable room or cage for expired drugs of minimum area 8ft^{t} (0.75m^{2}) must be provided.

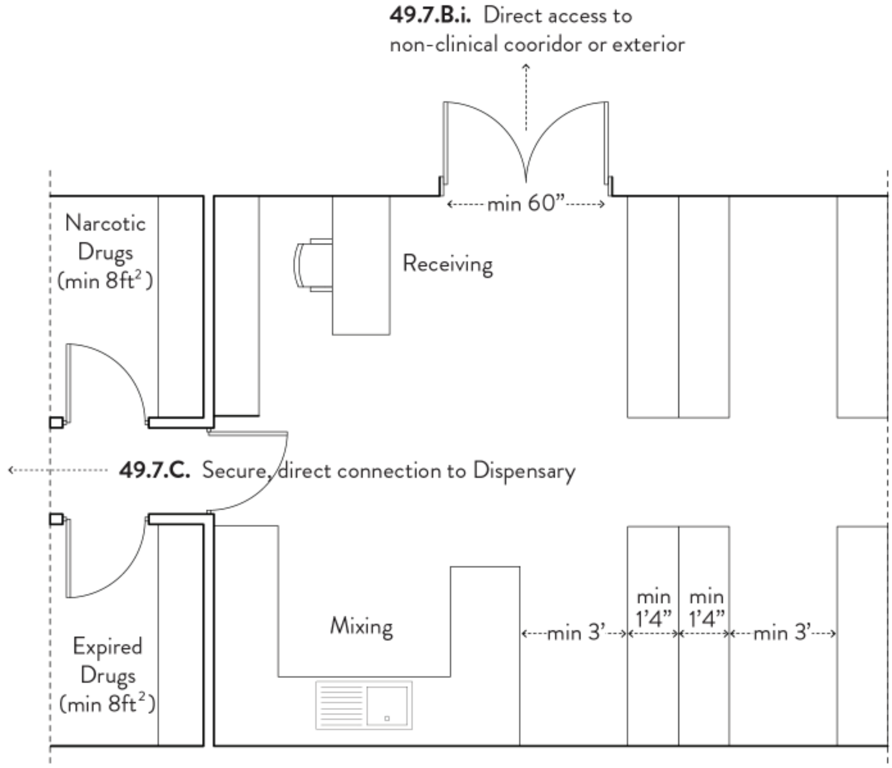
49.7.K. A lockable room or cage for expensive, narcotic, or difficult to procure drugs of minimum area 8ft^{t} (0.75m^{2}) must be provided.

Environmental & Technical Requirements

49.7.L. In Health Centers and Hospitals, the Pharmacy Stock Room must be climate controlled, either through a centralized air conditioning system or with wall-mounted AC units.

i. Ceiling fans must be kept running continuously for air circulation.

Figure 49.d. Pharmacy Stock Requirements and Possible Layout



Spatial Requirements

49.7.B.ii. Secure entrance to Pharmacy Stock

49.7.D. Enclosed dispensary room with operable dispensary window (3’ wide with 1’ of operable pane) @ 2’6” above the floor

49.7.E. 4’ x 2’ space at dispensary window for registrar’s desk

Installations

49.7.G. Wall-mounted A/C @ 7’ (if used)

49.7.H. Ceiling fans @ 1 fan / 250ft^2

49.7.I. At least one 3-phase outlet and 2 standard outlets in designated cold storage area

49.7.K. Lockable room or cage for expensive, narcotic, or difficult to procure drugs (min 8ft^2)

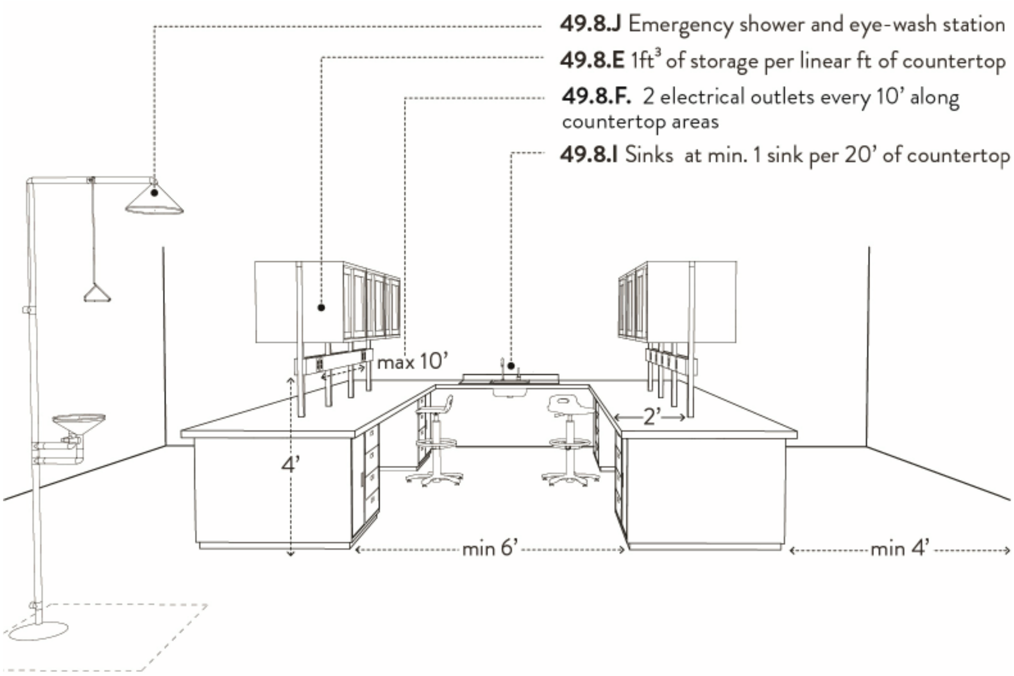
Environmental & Technical Requirements

49.7.L. Climate controlled room

49.8 Laboratory

Laboratory work requires a specific set-up, which must be accommodated during the design.

Quick Design Guide



Spatial Requirements

49.8.B. If hazardous samples are to be handled, a separate Biosafety Laboratory room must be provided -- accessible through two sets of doors, creating an airlock. Entry at least 10ft in area

49.8.D. A Specimen Collection Room with minimum one collection station must be provided in close proximity to the General Lab

Installations

49.8.G. At least one 3-phase outlet, coupled with 2 standard electric outlets, must be provided in a designated cold storage area

Environmental & Technical Requirements

49.8.M. If a Biosafety Lab is required, it must be kept at negative air pressure relative to surrounding occupiable spaces

Spatial Requirements

49.8.A. Countertop space, a minimum of 2ft (60cm) in depth must be provided.

i. At least half of the countertop space must be free of cabinetry beneath so a technician can sit at the workspace.

ii. Space between the work side of the countertop and any wall must be at least 4ft (120cm).

i. Space between two work sides of countertops parallel to each other must be at least 6ft (180cm).

49.8.B. If hazardous samples, including cultures of infectious organisms, are to be handled, a separate Biosafety Laboratory room must be provided.

i. The Biosafety Lab must be accessed through two sets of doors, creating an airlock. The vestibule entry between General Lab and Biosafety Lab must be at least 10ft^2 (0.9m^2) in area.

ii. Doors must close automatically.

ii. The Biosafety Lab must be at least 35ft^2 (3.25m^2) in area and include a designated area for a biosafety cabinet.

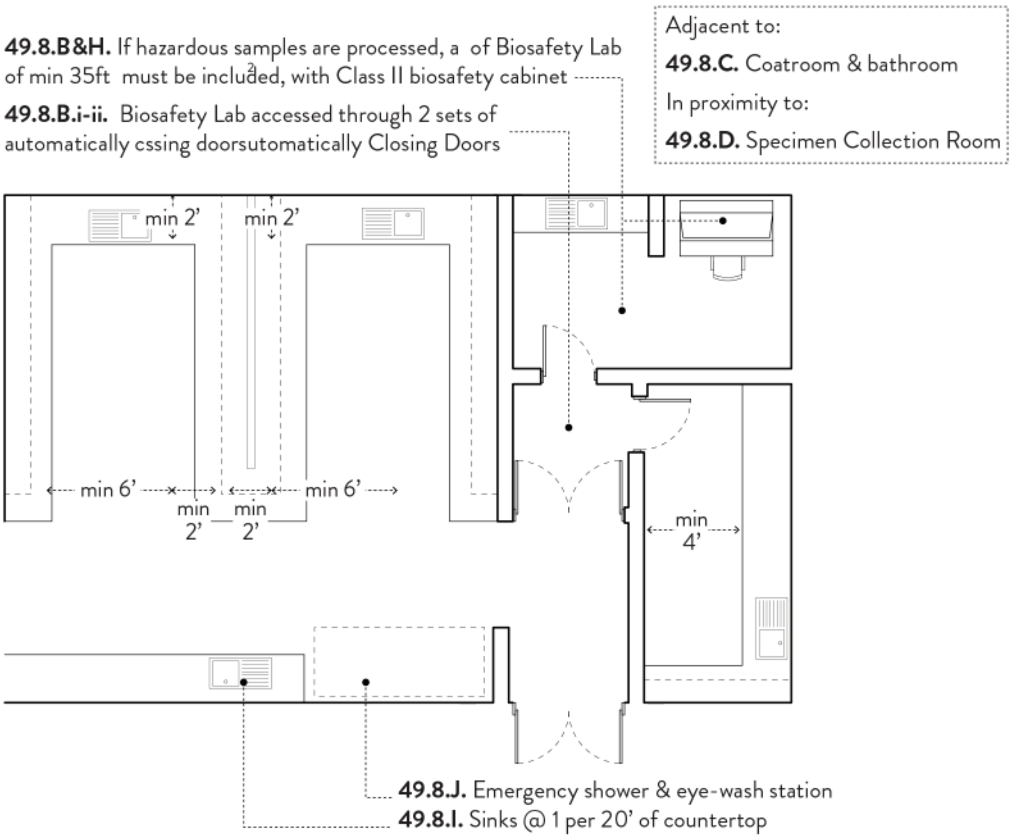
49.8.C. In Hospitals, a coatroom for storage of lab coats / clothing, with access to at least one unisex bathroom, must be immediately adjacent and connected to the lab.

49.8.D. A Specimen Collection Room with minimum one collection station must be provided in close proximity to the General Lab.

i. It is recommended that a compartment with doors on both sides be included between Specimen Collection and Lab for the passing of specimens. Privacy considerations must be maintained when considering its placement.

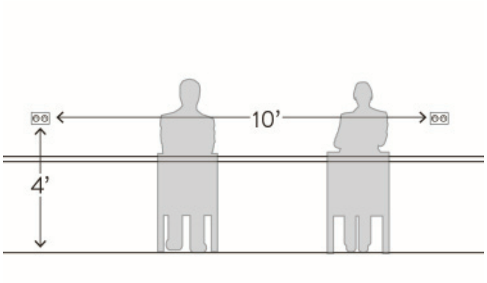
ii. It is recommended for patient bathrooms adjacent to the Lab include a compartment with doors on both sides for the passing of specimens to the Lab. Privacy considerations must be maintained when considering its placement.

Figure 49.e. Possible Lab Layout



49.8.E. Enclosed storage must be provided at a rate of 1ft^3 per linear ft of countertop space (1m^3 per linear m).

Installations



49.8.F. A group of 2 standard electrical outlets must be provided at a height of 4ft (120cm) above the floor every 10ft (3m) along countertop areas.

i. On walls without countertops, one electrical outlet must be provided every 10ft (3m).

49.8.G. At least one 3-phase outlet, coupled with two standard electrical outlets, must be provided in a designated cold storage area.

49.8.H. If a Biosafety Lab is included, a class I or II biosafety cabinet must be provided, and the appropriate electrical outlets provided for in the area.

49.8.I. Sinks must be provided at a minimum rate of 1 sink per 20ft (6m) of countertop length.

i. Lab sinks must be made from materials not easily stained by reagents or affected by heat. Acceptable materials include stainless steel and porcelain.

49.8.J. All Labs must be equipped with an emergency shower and emergency eyewash station.

49.8.K. In Specimen Collection Rooms, one standard electrical outlet must be provided at a height of 4ft (120cm) above the floor immediately adjacent to the intended collection chair position.

49.8.L. In Specimen Collection Rooms, one standard electrical outlet must be provided at a height of 3ft 4in (100cm) at the intended position of the desk.

Environmental and Technical Requirements

49.8.M. If a Biosafety Lab is required, it must be kept at negative air pressure relative to surrounding occupiable spaces.

i. Negative pressure helps ensure that contaminants within the Biosafety Lab do not escape to other areas of the building.

49.9 Radiology and Advanced Imaging Diagnostics

Special equipment requirements need to be catered for in Radiology and Advanced Imaging Diagnostics.

Spatial Requirements

49.9.A. Medical professionals and facility staff must be consulted when designing the patient sequence for Radiology and Advanced Imaging. For Radiology and Special Diagnostics, patients must enter first into an Office/Consultation Room.

i. Sequencing may differ depending on the size of the facility, the available equipment, and the patient load.

ii. It is recommended that an Office/Consultation Room be included prior to entering the exposure room. This Office/Consultation Room must have direct access to the equipment room (i.e. the Xray Room for Radiology, or the room with CT scanner, MRI machine, or similar advanced diagnostic equipment).

iii. A changing room must be included. It is recommended that this be accessed from the Office/Consultation Room.

49.9.B. For Radiology, a small darkroom must be provided. This space must have all natural light blocked and contain a red light for film development.

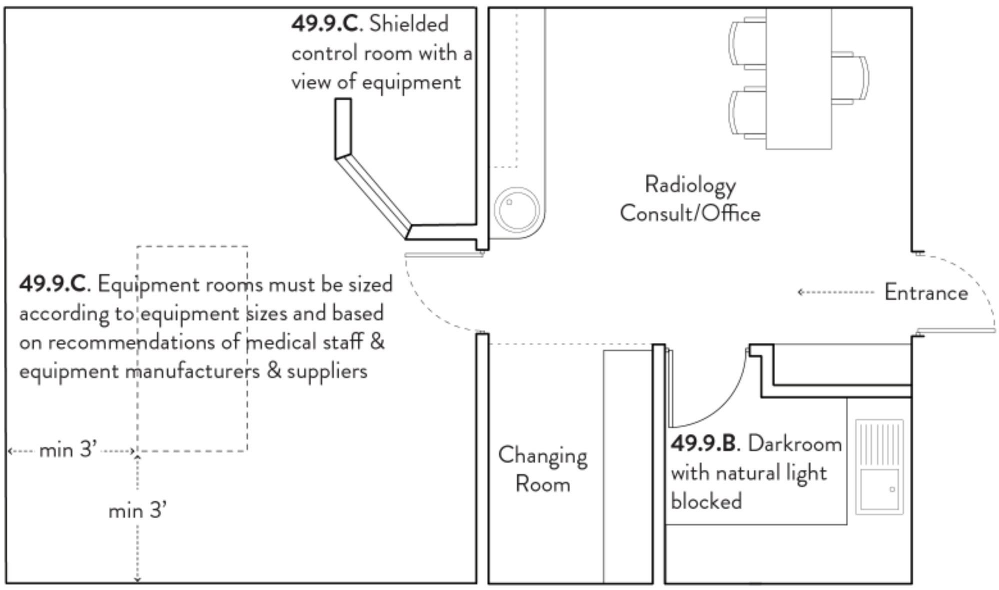
49.9.C. Equipment rooms must be sized according to equipment sizes and based on recommendations of medical staff and equipment manufacturers and suppliers.

i. A clear space of at least 3ft (90cm) must be kept on at least 3 sides of the machinery unless otherwise specified by equipment specifications.

ii. Door swings must be taken into account so as not to interfere with this clear space.

49.9.D. X-Ray Exposure Rooms must contain a shielded control room with a view of the equipment.

Figure 49.f. Radiology Requirements and Possible Layout



Spatial Requirements

49.9.A. Medical professionals and facility staff must be consulted when designing the patient sequence for Radiology and Advanced Imaging

Installations

49.9.E. Electrical outlets must be provided as needed according to equipment specifications

49.9.F. Warning light or adjustable sign outside the equipment room to warn of equipment use

49.9.G. Equipment installation must be done according to manufacturer's instructions

Environmental & Technical Requirements

49.9.H. Design details and specifications must be made to prevent staff from potentially harmful exposure of radiation from Xray machines and the magnetic field of MRI machines

Installations

49.9.E. **Electrical outlets must be provided as needed according to equipment specifications.**

i. If no specifications are given, one wall of the equipment room must contain at least 3 standard electrical outlets and at least one 3-phse outlet. On other walls, one electrical outlet must be provided every 10ft (3m).

49.9.F. **A warning light or adjustable sign must be installed outside the equipment room to warn anyone in the Office/Consult room that the equipment is in use.**

i. It is recommended that this light be wired to illuminate when equipment is in use rather than being manually controlled.

49.9.G. **Equipment installation must be done according to manufacturer's instructions.**

Environmental and Technical Requirements

49.9.H. **Design details and specifications must be made to prevent staff from potentially harmful exposure of radiation from Xray machines and the magnetic field of MRI machines.**

i. Consultation with medical professionals, equipment manufacturers, and relevant experts is recommended in determining technical and finishing requirements.

49.10 Sterilization

Sterilization rooms contain special equipment that must be designed for overall infection control practices require the space to remain sterile.

49.10.A. **Sterilization must meet the requirements of Standards 49.5.C., 49.5.D., 49.5.F., and 49.5.I.**

Spatial Requirements

49.10.B. **A minimum countertop length of 2in (5cm) per bed in the hospital or 6ft (180cm) per Operating Room in the facility, whichever is larger, must be provided for.**

49.10.C. **A minimum of 3ft (90cm) of continuous countertop space must be provided next to each sink for the laying out of instruments.**

49.10.D. **A designated floor space of 3ft 4in by 3ft 4in (1m by 1m) must be allocated for a floor-stand autoclave at the rate of one autoclave per Operating Room or one autoclave per 150 beds in the hospital, whichever is greater.**

i. Autoclaves are likely to produce steam, so materials that are not water and heat resistant must not be used in their vicinity.

Installations

49.10.E. **A floor drain, minimum 4in (10cm) in diameter or as indicated by autoclave manufacturer's specifications, must be installed at the back of the designated autoclave space.**

i. These drains must be capable of withstanding high temperatures. The following drain and piping materials are acceptable: copper, galvanized steel, ductile iron, or PCV.

49.10.F. A Clean water supply must be provided for the autoclave areas per manufacturer's specifications.

49.10.G. A minimum of 1 standard electrical outlet and one 3-phase outlet must be present for each space designated for a floor-stand autoclave, and a minimum of 1 standard outlet above the countertop per 6ft (180cm) of countertop length.

Environmental and Technical Requirements

49.10.H. A hot air exhaust from Sterilization must be provided.

i. Autoclaves and sterilization equipment may produce steam. A ceiling or upper wall-fed vent routed directly to the exterior must be incorporated to avoid moisture build-up and exhaust excessive heat.

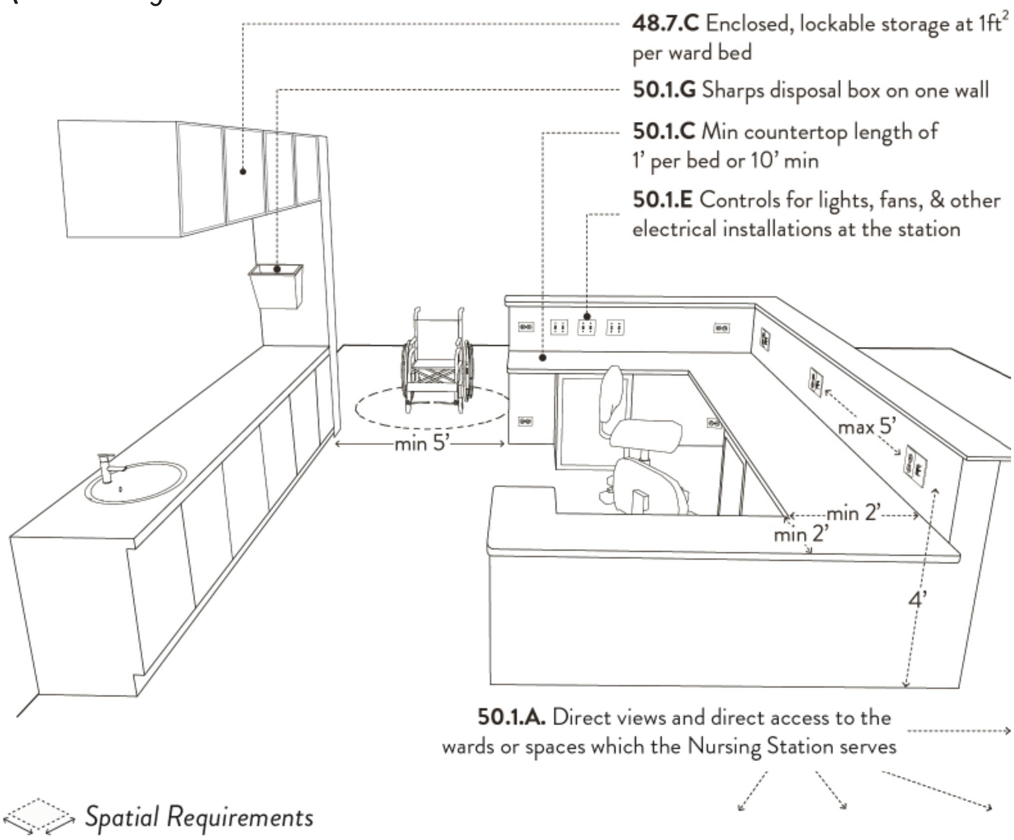
50 Staff Areas & Non-Clinical Support

Staff Areas bridge between clinical and non-clinical areas. Some of them require attention to particular clinical issues, while other can follow more general practices.

50.1 Nursing Stations

Nursing Stations need to be treated both as clinical spaces with infection control measures, and as efficient office work areas. They are heavily used and form the command center for inpatient wards.

Quick Design Guide



Spatial Requirements

50.1.B. Physically separated from infectious diease wards

Installations

50.1.D. A group of 2 standard electrical outlets @ height of 4' every 5' along countertop

50.1.F. Nursing Stations outfitted with their own artificial lighting separate from wards

Environmental & Technical Requirements

50.1.H. Positive air pressure or natural ventilation for Nursing Stations near infectious disease wards.

Spatial Requirements

50.1.A. **Nursing Stations must be configured to provide direct views and direct access to the wards or spaces that they serve.**

i. This may be accomplished by placing the Nursing Station within the ward or as an adjacent room with vision glass allowing views into the ward(s).

ii. If Nursing Stations are placed inside wards, they must meet all ventilation requirements of the wards. Refer to Standard 46.3.G. for ventilation requirements of wards.

iii. Central positioning provides views into wards.

50.1.B. **Nursing Stations for designated infectious disease wards must be physically separated from the ward.**

i. An airlock with two sets of closable doors must be present at the entrance to any infectious disease wards, such as TB wards.

ii. Nursing stations must open to corridors or the exterior before entering a ward through the airlock entrance.

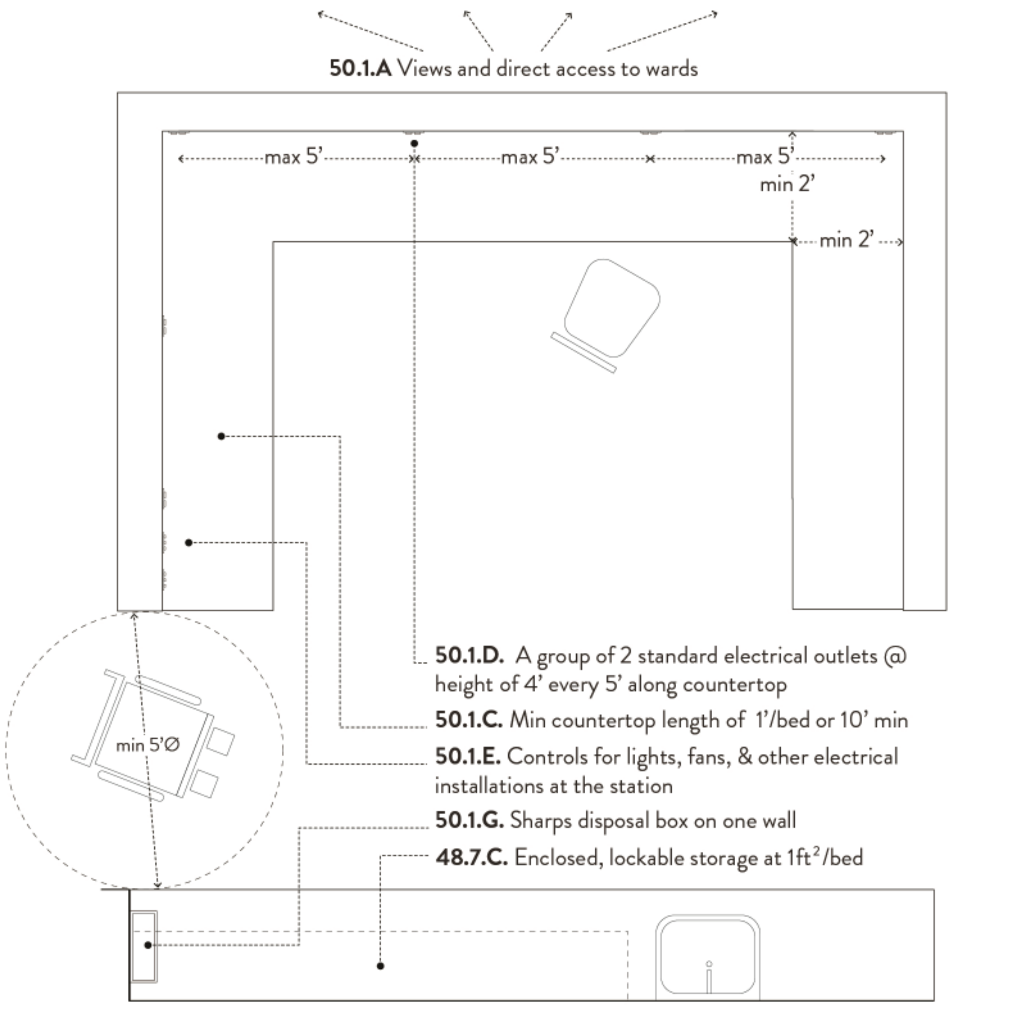
50.1.C. **A minimum countertop workspace length of 1ft (30cm) per bed in the ward or a total length of 10ft (300cm), whichever is greater, must be included in a Nursing Station.**

i. Minimum countertop depth must be at least 2ft (60cm)

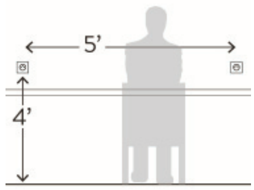
ii. This standard does not apply to Pre-Op and NICU, which have their own Nursing Station requirements.

iii. Storage required as defined in Standard48.7.C.may be included in the Nursing Station.

Figure 50.a. Possible Nursing Station Plan Layout



Installations



50.1.D. A group of 2 standard electrical outlets must be provided at a height of 4ft (120cm) above the floor every 5ft (1.5m) along countertop workspace areas.

50.1.E. Controls for lights, ceiling fans, and other electrical installations must be placed at the Nursing Station.

i. This standard does not prevent controls from also being placed within the wards.

50.1.F. Nursing Stations must be outfitted with their own artificial lighting separate from wards so nurses can control task lighting even if ward lights are off.

50.1.G. A sharps disposal box must be mounted to one wall of every nursing station.

Environmental and Technical Requirements

50.1.H. For Nursing Stations of infectious disease wards, Stations must be kept at a positive air pressure relative to the ward or located in a position so that natural ventilation is not exchanged between the Nursing Station and ward.

i. Nursing Stations for infectious disease wards must be environmentally separated from the ward area, with no opportunity for air exchange between the two.

50.2 Medical Records

Medical Records are currently mostly paper-based, but as the health delivery system develops these are likely to move towards digital storage. Both hard copies of medical files and provisions for future computerized medical records must be accounted for.

Spatial Requirements

50.2.A. Medical Records must be organized to allow for shelving 1ft 4in (40cm) in depth or greater as accessed from one side, with minimum aisle space between shelves of 2ft 8in (80cm), for the storage of files and binders.

Installations

50.2.B. One area of Medical Records must contain a series of 4 electrical outlets and at least 1 data outlet for the future provision of a computer server room.

50.3 Staff Offices

Staff Offices must be designed to provide efficient and comfortable workspaces.

Spatial Requirements

50.3.A. Staff Offices may be organized as group offices or individual. Individual offices must be a minimum of 100ft^2 (9.3m^2). Group offices must be organized so that every assumed desk at a size of 5ft by 2ft 6in (150cm by 75cm) has at least 3ft (90cm) of clear space between it and any other wall or desk on at least one side of it

50.3.B. Each office must have an additional designation of 4ft^2 (0.37m^2) or greater area for filing cabinets.

50.3.C. Each office must have an additional designation of at least 4ft by 2ft (120cm by 60cm) of space for shelving.

50.4 Meeting, Training and Education Rooms

Meeting and Training Rooms must be designed to facilitate the process of learning, exchange of knowledge, and information sharing.

Spatial Requirements

50.4.A. Meeting ,Training and Education Rooms must be organized so that one wall, painted white, is present with a predominance of seating either facing or perpendicular to the wall for presentation projections.

Installations

50.4.B. Training Rooms must be organized so that primary entrances are at the back, away from the stage, podium, or place of presentation.

50.4.C. Floor supplied electrical outlets must be included in the vicinity of 20ft to 30ft (6m to 9.1m) from the projection wall, at the center of the wall.

50.5 Sanitary Spaces

Sanitary spaces receive heavy use, especially by inpatients, and must be conveniently designed to accommodate many users.

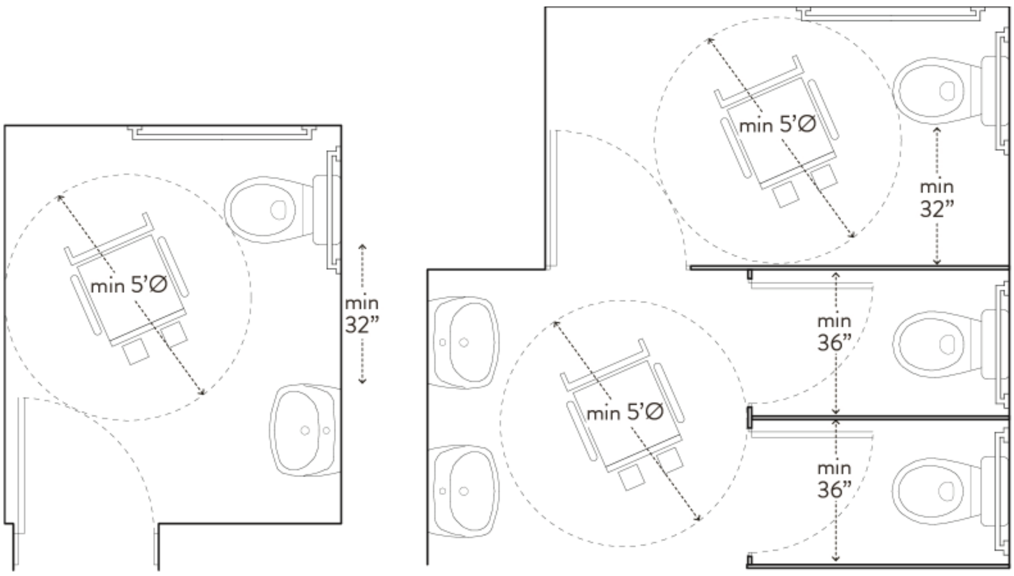
Spatial Requirements

50.5.A. All bathrooms must include at least one toilet and at least one sink.

50.5.B. For multi-stall bathrooms, at least one sink must be provided per 1.5 toilets or urinals. Toilets must be separated into stalls, one of which must be handicapped accessible as defined in Section 16.2; others must have minimum dimensions of 2ft 6in by 5ft (75cm by 150cm).

i. For men's bathrooms, each bathroom must contain at least one toilet. The proportion of urinals to toilets must not exceed 2:1.
ii. Toilets must be installed in the center of the stall with the back within 3in (7cm) of the wall.
iii. Stall doors must open inwards towards the toilet unless necessary to open outwards for handicapped accessibility.
iv. At least 5ft (150cm) of clear space must be maintained between sinks and entrances to toilet stalls.

Figure 50.b. Accessible Bathroom Plan Requirements (Excluding Shower)



Installations

50.5.C. In Hospitals, at least one electrical outlet must be provided at a height of 4ft (120cm) above the floor for every 2 sinks present in the bathroom.

i. Placement must be at least 1ft (30cm) away from any faucet, shower, or other water source.
ii. This requirement may be waived if hand dryers are hard wired to the electrical supply.

50.5.D. Sinks must be mounted between 34inand 38in (86cm and 96cm) above the floor.

50.5.E. If urinals are used, they must be mounted with the bottom of the urinal not more than 24in(60cm) above the floor, with at least one mounted not more than 17in (43cm) above floor.

50.5.F. Each toilet stall must include a toilet paper holder and coat hook.

50.5.G. One paper towel dispenser or automatic hand dryer must be provided for every 3 sinks. A minimum of one must be present in every bathroom.

50.5.H. In Pediatrics Wards, fixtures must be mounted at appropriate heights for children.

i. Sinks must be mounted between 25in and 30in above the floor.
ii. Where possible, at least one child-sized toilet must be installed.

Environmental and Technical Requirements

50.5.I. Bathrooms must be exhausted through either natural or mechanical ventilation to achieve Low Clinical Risk ventilation requirements per Standard 20.2.A.

50.6 Laundry

Laundry facilities must take into account laundry being done both by hand and by machine.

Spatial Requirements

50.6.A. For Primary Health Clinics, at least one large laundry sink of minimum size 3ft wide by 2ft deep by 2ft tall(90cm wide by 60cm deep by 60cm tall) must be provided at the exterior of the building. For Health Centers at least two must be provided.

50.6.B. For Hospitals, space must be designated for washing machines and dryers, with each machine given at least 3ft by 3ft (90cm by 90cm) of space. Driers must be located along an exterior wall to allow for venting through the exterior wall or roof. Laundry sinks must be provided in the case of electrical or mechanical failure.

Installations

50.6.C. For Hospitals, hot and cold water must be provided to each machine location.

50.6.D. Exterior clotheslines must be provided with a minimum length of 20ft (8.2m) for Clinics, 40ft (16.4m) for Health Centers, and 80ft (24m) for Hospitals. Multiple lines may be used to accommodate the required length.

50.7 Kitchens

Kitchens must be in a protected area not exposed to patients or potential air- or water-borne diseases.

Spatial Requirements

50.7.A. Kitchens must be located at least 65ft (20m) from any interior or exterior space in which infectious disease is likely to be treated. This includes wards and consultation rooms.

50.7.B. A designated waste area must be defined and kept separate from cooking areas.

Installations

50.7.C. A countertop with minimum length and minimum number of stainless steel dish sinks by facility type per Table 50.a. must be included.

Table 50.a. Minimum Countertop Length and Number of Sinks by Facility Type.

Facility type	Min. countertop length	Min. number of sinks
Health Center	6ft (1.8m)	1
District Hospital	10ft (3.0m)	2
County Hospital	20ft (6.1m)	2
Regional/National Referral Hospital	30ft (9.1m)	3

50.7.D. A fire extinguisher must be mounted within 20ft of the cooking area.

Environmental and Technical Requirements

50.7.E. Kitchen spaces must be well ventilated.

i. If naturally ventilated, Kitchens must have at least 30% of the perimeter wall area (if walls are present) operable or in a permanently fixed open position.

ii. If mechanically ventilated, Kitchens must meet Non-Clinical ventilation requirements as defined in Section 19.1.

50.8 Equipment and Communication Rooms

Equipment and Communication Rooms are highly dependent on the type and quantity of equipment being used.

Spatial Requirements

50.8.A. **Generator shelters must be located in a way to prevent the generator noise from disturbing patients.**

Installations

50.8.B. **Equipment and Communications Rooms must be designed by consulting manufacturer's specifications for appropriate spatial requirements, electrical loads, and other provisions needed to run and manage the equipment.**

Environmental and Technical Requirements

50.8.C. **Communication equipment must be placed in a way to allow for adequate ventilation to prevent overheating.**

50.9 Morgue

Morgues must provide space to cleans bodies, perform autopsies, and temporarily store bodies.

Spatial Requirements

56.9.A. **At Hospitals, morgues must contain one room for the performing of an autopsy, with an autopsy table at 3ft by 6ft 6in (90cm by 200cm) at the center and clear space of at least 3ft (90cm on all sides).**

i. Autopsy tables must meet the requirements of sanitary wall surfaces per Standards44.3.H. - 44.3.J.

56.9.B. **At Hospitals, morgues must contain one room with a designated space 6ft 6in (200cm) deep for the installation of refrigerators.**

i. The width of the designated space must be determined based on the number of refrigerators.
ii. On the front side of the designated area there must be a clear space at least 6ft (180cm) wide for the passage of gurneys.

Installations

56.9.C. **Electrical outlets must be provided according to the number and requirements of refrigerators according to manufacturer's specifications in the refrigerator area.**

56.9.D. **A floor drain must be installed in the autopsy area.**

51 Supporting Facilities

Staff retention is a critical factor of health delivery that is often dependent on the capacity for staff to be well-accommodated at the clinic or health center site. Furthermore, increasing the number of births which occur in a health facility may be dependent on the comfort of the mother and ability to access the facility.

This chapter covers supplemental facilities such as staff housing and maternal waiting homes to help strengthen health delivery.

51.1 Maternal Waiting Homes

For Maternal Waiting Homes to be successful, each woman must have proper sleeping accommodations and a sense of dignity as she waits to deliver her baby. Addressing the needs of the women and making their stay a positive experience will encourage other expecting mothers to come to maternal waiting homes for the much needed access to maternal care.

Spatial Requirements

51.1.A. Maternal waiting homes must be located on or near the facility site, and must be within a safe walking distance to the facility.

51.1.B. Maternal waiting homes must be fully functioning and have spaces and amenities for sleeping, cooking, bathing, and laundry.

51.1.C. Covered outdoor gathering space must be provided, and protected from the elements.

51.1.D. Sleeping quarters must be designed to accommodate pregnant mothers comfortably.

i. Sleeping quarters must have no more than 8 beds per room. Smaller sleeping rooms provide more privacy and prevent the spread of infection by allowing for the sick and healthy patients to be separated.
ii. Beds must be spaced apart at least 3ft (90cm).

51.1.E. Spatial accommodations must be made for attendants accompanying mothers.

i. If possible, provide beds for attendants in the sleeping rooms. Otherwise, provide covered, protected sleeping spaces for attendants.

51.1.F. Separate storage areas must be provided for belongings and food.

i. Provide individual, lockable bedside storage for personal items within sleeping spaces.
ii. Provide secure storage for food and cooking implements in proximity to the outdoor cooking area.

51.1.G. A designated space for outdoor cooking must be provided.

i. Where possible , the cooking space must be located downwind of sleeping quarters.
ii. Potable water must be provided near the cooking area.

51.1.H. A designated space for clothes washing must be provided.

i. A washbasin of minimum 2ft by 2ft wide and 16in deep (60cm by 60cm wide and 40cm deep) must be provided.
ii. Clotheslines for drying must be provided.

51.1.I. Bathrooms must be provided within close proximity to the bedrooms. If in a separate structure, an accessible, covered walkway must be included from bedroom areas to the bathrooms.

Installations

51.1.J. A minimum of 1 toilet, and 1 shower, and 1 sink for every 10 women to be housed must be provided.

Technical and Environmental Environments

51.1.K. Maternal waiting homes must be naturally ventilated and naturally day-lit.

51.1.L. A reliable supply of potable water must be provided.

51.2 Staff Housing

Especially in rural or remote areas where quality housing stock may not be available, the provision of staff housing can successfully improve staff retention rates at healthcare facilities. Spatial accommodations may vary according to the facility type, location, and staff circumstances (i.e. single or family arrangements); however all staff housing must meet the following requirements.

Spatial Requirements

51.1.M. Staff housing must be located on or near the facility site, and must be within a short walking distance to the facility.

51.1.N. To maintain staff satisfaction, staff housing must adequately meet the level of quality and living standards expected by healthcare workers.

51.1.O. The following spaces must be accommodated in staff housing:

- One bedroom per staff member to be housed.
- At least one common living room.
- At least one bathroom with toilet, shower and sink for every 3 bedrooms.
- A kitchen with countertop space and access to water.

SUPERVISION & MAINTENANCE

CONTENTS

IMPACT

Frequent check-ins and sign-offs ensure that projects adhere to the intended design and that construction work meets the performance and quality requirements laid out in Chapters 32-45. The participation of all stakeholders is important in order to combine the expertise of the IU and hired consultants/contractors with the administrative capabilities of the CHSWTs, who are the end custodians of the building.

Once buildings are completed, ongoing upkeep is necessary to ensure that facilities perform effectively and that buildings and equipment last for their intended lifespan. Having knowledgeable staff and clear processes in place to oversee preventative and reparative processes reduces the risk of debilitating infrastructure challenges.

PRIMARY USERS

Infrastructure Unit

County Health & Social Welfare Teams

Architects & Designers

Structure, Electrical, Mechanical and Civil Engineers

Contractors

GUIDELINES FOR USE

The Construction Supervision Chapter presents important points of inspection by the IU and participation by CHSWTs in order to make sure construction is proceeding smoothly. A chart indicating these points during common phases of construction illustrates specific needs for technical expertise to be present on site during construction. A similar chart is presented for construction hold-points - milestones in construction that must be approved by the IU before construction can proceed.

51 Construction Supervision

Coordinated oversight during all construction phases is important to prevent delays, increases in cost, or other roadblocks. Communication between the IU and CHSWT is particularly valuable during the construction process, especially when challenges do arise.

51.1 Coordination

Construction of public health facilities has various stakeholders: the MOHSW Infrastructure Unit is responsible for the construction processes; the County Health Teams are the ultimate caretakers; and the communities they serve as the ultimate beneficiaries. Thus, all parties have a role in the construction process, and proper coordination between these entities is crucial for successful completion.

51.1.A. The contractor for the project must be selected according to standard procedures as stated in the Liberia public procurement law. The contractor must visit the site and meet with the CHSWT to confirm project feasibility prior to signing a contract.

51.1.B. Before any construction work begins, a construction permit must be obtained from the Ministry of Public Works (MPW).

51.1.C. Throughout construction, the assigned IU representative must visit the site regularly to supervise quality control and conformance with the Standards.

i. See Table 51.a for required project inspection points. Notes on technical compliance checks have been included in the rightmost column.

51.1.D. Throughout construction, the CHSWT must have one dedicated team member assigned to periodically check in on work and address any problems that may arise.

i. See Table 51.a for project participation requirements. The CHSWT representative is not responsible for overseeing quality control and technical conformance to the standards; however he/she must be present on site at the indicated points to liaise with the IU representative supervising the project.

51.1.E. Both the CHSWT and IU project representatives must be informed of any major project developments and must collaborate to see the project through to completion.

X = IU inspection

√ = CHT participation

Table 51.a. Construction Participation and Inspection

Inspection		IU	CHT	Notes
1	**Site Selection**			
	Site location	X	√	
	Site investigation		√	
	Final site selection	X	√	Inspect site for compliance with standards and legal issues
	Construction permitting		√	MPW to approve building permit
2	**Pre-construction**			
	Site is secured		√	Check for safety of materials stored on site
	Demarcation of building	X	√	Check for compliance with the building size in plans
3	**Site work/Substructure**			
	Site clearing	X	√	Check for removal soil containing organic components
	Excavation	X	√	Check width and depth of excavations
	Approval of materials for foundation	X		Test materials for compliance with the standards
	Approval of completed foundations	X	√	Inspect load bearing capacity of the foundation
	Backfill and sand fill	X		Check compliance with standards and specs
4	**Structural Framing**			
	Reinforcements	X		Check size, layout, and splicing
	Checking Formwork			
	Material Tests	X		
	Pouring concrete	X		Check that concrete is properly mixed and vibrated
	Approval of completed framing	X	√	Inspect concrete for defects
5	**Masonry/Infill**			
	Approval of Masonry materials	X	√	Check materials quality
	Block laying	X		Check level courses, patterns
	Lintel and tie beam	X		Check for appropriate reinforcement
	Final Approval of the walls	X	√	Check verticality, etc.
6	**Roof**			
	Materials inspection	X		Check type, sections, quantity for compliance with standards
	Structural assembly	X		Check assembly for flaws in structure
	Final inspection	X	√	Check roof for leakages
7	**Interior Finishes**			
	Materials approval for walls and floors	X	√	Check type, quantity and sizes for compliance with standards
	Plaster application thickness	X		Check compliance with standards, uniformity in application
	Inspection of walls, subsurface, finishes	X		Check for cracks, levelness
	Floor and ceiling finishes	X		Check for compliance with standards
	Finishes final inspection	X	√	Check assembly, level, compliance with standards
8	**Fixtures and Installations**			
	Approval of MEP materials and supplies	X	√	Check quality and compliance with standards and specs
	Installation of electrical wiring	X	√	Check for safety and compliance with standards and specs
	Installation of piping for plumbing	X	√	Check for functionality &compliance with standards &specs
	Installation of mechanical systems	X	√	Check for compliance with standards and specs
	Installation of windows and doors	X		Check for compliance with standards and specs
	Installation of MEP fixtures	X		Check functionality, heights, distances, positions, safety
	Fixtures and installations final Inspection	X	√	Check functionality, heights, distances, positions
9	**Landscape work**			
	Approval of landscape materials	X	√	Check quality & approve compliance with standard & specs
	Topography, soil and vegetation	X		Check quality & approve compliance with standard & specs
	Site work final inspection	X	√	Check quality & approve compliance with standard & specs
9	**Occupancy**			
	Occupancy permit	X	√	MPW to issue occupancy permit

51.2 Approvals

Each stage of the construction process must be completed properly and appropriately in order to achieve the overall project goals. To ensure the highest quality, contractors must only proceed if important points of construction are approved by the relevant stakeholders, including the assigned IU representative and CHSWT representative.

51.2.A. **The contractor must receive sign-off from the IU once the demarcation of the building has been made, prior to any excavation work.**

i. The assigned IU representative must approve the proper sizing of the building demarcation. The position of the building on the site must also be verified before excavation begins.

51.2.B. **The contractor must receive sign-off from the assigned IU representative after the site work and foundation have been completed, before further work can proceed, to confirm that construction to that point has adhered to the Standards.**

i. Excavations must be checked for conformance with the Infrastructure Standards. Proper sizing, levelness, and depth must be confirmed.
ii. Sign-off must include a record of any rebar placement and quality control during the construction of the foundation.
iii. Mortar mix ratios and quality of stone and aggregate (if used) must be approved before foundations are built.

51.2.C. **The contractor must receive sign-off from the assigned IU representative after the framing of the structure has been completed, before further work can proceed, to confirm that construction to that point has adhered to the Standards.**

i. Steel reinforcements, if used, must be checked for compliance with the standards and structural specifications.
ii. Formwork must be checked for proper sizing, verticality and compliance to the standards and guidelines as well as structure specifications.
iii. The quality of aggregates, cement and mix ratios must be approved before concrete is used.

51.2.D. **The contractor must receive sign-off from the assigned IU representative after the concrete pouring has been completed before further work can proceed, to confirm that construction to that point has adhered to the Standards.**

i. The cured and dried concrete structures must be checked for quality and compliance to the design standards and guidelines.
ii. Sign-off must include a record of rebar and formwork inspection.

51.2.E. **The contractor must receive sign-off from the assigned IU representative after masonry infill has been completed before further work can proceed, to confirm that construction to that point has adhered to the Standards.**

51.2.F. **The contractor must receive sign-off from the assigned IU representative after the roof has been completed before further work can proceed, to confirm that construction to that point has adhered to the Standards.**

51.2.G. **The contractor must receive sign-off from the assigned IU representative after the interior finishes and fixtures have been completed in order to request a full facility construction quality assessment from the MOHSW.**

51.2.H. **Hold points in construction must be maintained until the approvals in Table 51.b are granted.**

52.2.I. **Building certification and commissioning must be performed per MOHSW requirements.**

X = IU inspection

√ = CHT participation

Table 51.b. Construction Approvals

Sign Off		IU	CHT	Notes
1	**Site Selection**			
	Site location			
	Site investigation			
	Final site selection	X	√	Approve site, issue deep plan, obtain construction permit
	Construction permitting	X	√	MPW to issue building permit
2	**Pre-construction**			
	Site is secured			
	Demarcation of building	X	√	Approve measurements before excavation begins
2	**Site work/Sub structure**			
	Site clearing			
	Excavation	X		Approve level, size and depth of the excavations
	Approval of materials for foundation	X		Approve mix ratios, type of stone, type of aggregates
	Approval of completed foundations	X	√	Approve foundation quality; give go ahead for next step
	Backfill and sand fill			
3	**Structural Framing**			
	Reinforcements	X		Confirm that reinforcements conform to structural specs
	Checking Formwork	X		Confirm that formwork meets specifications
	Material Tests	X		Approve the quality of aggregates, cement, mix ratios
	Pouring concrete			
	Approval of completed framing	X	√	Approve quality of structural framing; give go ahead
4	**Masonry/Infill**			
	Approval of Masonry materials	X		Approve the quality of bricks, aggregates, cement, mix ratios
	Type of walls			
	Bloc laying			
	Lintel and tie beam			
	Final approval of walls	X	√	Approve quality of masonry/infill; give go ahead for next step
5	**Roof**			
	Materials inspection	X		Approve quality of materials
	Structural assembly			
	Final inspection	X	√	Approve quality of the roof and give a go ahead for the next step
6	**Interior Finishes**			
	Materials approval for walls and floors	X		Approve quality of aggregates, tiles, cement, mix ratios etc.
	Plaster application thickness			
	Inspection of walls, subsurface, finishes			
	Floor and ceiling finishes			
	Finishes Final Inspection	X	√	Approve quality of finishes and give a go ahead for the next step
7	**Fixtures/Installations**			
	Approval of MEP materials and supplies	X	√	Approve quality and specification of MEP materials and supplies
	Installation of electrical wiring			
	Installation of piping for plumbing			
	Installation of mechanical systems			
	Installation of windows and doors			
	Installation of MEP fixtures	X		Approve quality of installation of electrical and plumbing fixtures
	Fixtures/installations final Inspection	X	√	Approve quality of fixtures/installations
8	**Landscape work**			
	Approval of landscape materials	X		Approve quality of materials
	Topography, soil, and vegetation			
	Site work final inspection	X	√	Approve quality of site work; give go ahead for the next step
9	**Occupancy**			
	Occupancy permit	X	√	MPW to issue occupancy permit

52 Maintenance and Repair

It is said that eighty percent of a building's costs occur after it is constructed. These expenses must be considered when deciding on the form of services to be included in the construction of a new building. Keeping buildings and the systems within them operational is critical to the overall functioning of a clinic, health center, or hospital. Without maintaining the right conditions for infection control and patient safety, a facility may end up doing more harm than good as a resource to the community it is intended to serve.

52.1 Cleaning

While it may seem acceptable to clean some parts of the facility on an as-needed basis, adhering to a strict schedule of regular cleaning has many benefits: it ensures that sanitation and safety standards are consistently met, it serves as preventative care to keep systems in good working order, and it allows staff to identify potential problems before they become debilitating.

52.1.A. Facility staff must maintain a strict cleaning schedule that includes clear delineation of responsibilities and accountability for tasks.

i. Cleaning schedules must specify what tasks must happen immediately after procedures, daily, weekly, monthly, or otherwise in order to maintain appropriate levels of sterility and general cleanliness around facilities.

ii. Staff members must be assigned specific tasks according to skills, level of training, and familiarity with equipment and systems requiring cleaning.

iii. Documentation outlining who is responsible for what cleaning and requiring acknowledgement of each task's completion must be used to hold individuals accountable for each task.

52.1.B. Cleaning supplies must be stored near where they are to be used, but kept secure and out of reach of patients, particularly children.

i. Supplies must be nearby in the case that rooms need to be cleaned following procedures, spills, or other events affecting facility cleanliness.

ii. Supply closets where hazardous cleaning supplies are kept must be locked. Only mild cleaning products, if any, should be in visible locations.

52.2 Servicing

Routine servicing helps equipment and building systems to consistently operate at full capacity. Preventative maintenance saves time and money over the long run because well-kept equipment and systems require fewer repairs and replacements.

52.2.A. Facility staff must establish and maintain schedules for routine servicing of building systems and equipment and include clear delineation of responsibilities and accountability for necessary tasks.

i. One knowledgeable staff member should be designated to oversee maintenance of facility systems and equipment and to allocate more routine tasks to staff members with less technical expertise.

ii. In facilities that have predictable trends of patient activity, routine servicing should be scheduled for off-peak periods to be minimally disruptive.

52.3 Spare Parts

Quickly repairing equipment and building systems is only possible if spare parts are kept on-site. Small budgets and limited access to facilities may mean that facilities must identify and prioritize the most critical elements to have available at all times.

52.3.A. County Health Teams must stock spare parts for equipment and systems that are necessary for emergency care, surgery, delivery, and intensive care.

i. Parts for lighting, ventilation, heating, and other systems that are necessary for key procedures must be kept in stock at the county level and distributed as needed.

ii. Critical parts (e.g., light bulbs for operating theaters) that are less expensive and require minimal storage space must be kept on-site at facilities.

iii. Less critical but more expensive components should be ordered as needed.[1]

52.3.B. Spare parts must be used and stored under specified conditions.

i. Substitutes for parts must only be used where they are known to work. Some parts are designed for use under particular conditions (e.g., indoor-only light bulbs); inappropriately use of these may shorten their lifespan or may damage equipment.

ii. Spare parts must be stored in specified conditions. Some parts may not tolerate heat; these must be kept in well-ventilated areas that do not exceed manufacturers' noted temperatures.

52.4 Repair and Replacement

All facilities occasionally require large-scale maintenance processes, including repair or full replacement of systems and equipment. Planning ahead and developing interim work-around during maintenance periods reduce the level of inconvenience that projects cause for clinical staff and patients.

52.4.A. Facilities must plan ahead for how to repair or replace systems and equipment quickly and how to continue to provide care while systems and equipment are in disrepair.

i. Systems must be designed so that they can be repaired effectively with locally available materials and local manpower.

ii. Alternatives for critical systems and equipment must be available on-site. Backup electrical and mechanical devices to keep facilities in operation in the case of primary system failure should be part of initial building design.

iii. An on-site maintenance and repair station must be designated to keep processes orderly and to separate potentially hazardous construction and mechanical work from public and patient-oriented areas.[2]

52.5 Training

Healthcare facilities may include designs, equipment, and operational practices that are unfamiliar to staff. Even simple and operational and infection-control elements are of little use if their intent is subverted by actual practices and use. Any aspect of the facility design that requires staff input, participation, or awareness for its use needs to be communicated to the staff before they occupy facility. Effective training is the lynchpin to ensuring that facilities are used to their greatest potential.[3]

52.5.A. All facility staff members must be trained prior to using equipment and systems that are under their purview to operate.

i. Clinical staff must be provided with basic information about operating building systems and equipment, including natural ventilation design and mechanical systems, lighting fixtures, and other relevant systems.
ii. Maintenance and cleaning staff must be trained in both preventative maintenance measures and basic repair and replacement procedures.
iii. At least one facility employee or community member must be trained by contractors or engineers to understand the workings of more complex systems such as solar panels, mechanical systems, and waste treatment infrastructure.

52.5.B. All facilities must have a user manual for equipment and systems that outlines proper cleaning, preventative maintenance, and repair procedures.

i. The building design team must develop instructions that can be used in up-front training and as an ongoing reference.
ii. Instructions for maintenance and cleaning must be visually oriented and simple to follow through the use of diagrams and images.

References

Introduction (Chapters 1-5)

[1] MOHSW National Health and Social Welfare Policy, pg. 12
[2] Ibid.
[3] MOHSW National Health and Social Welfare Policy, pg. 14
[4] Ibid.
[5] MOHSW National Health and Social Welfare Policy, pg. 17
[6] MOHSW National Health and Social Welfare Plan, pg 83-84.
[7] MOHSW National Health and Social Welfare Policy
[8] http://web.undp.org/annualreport2011/poverty_reduction_and_achieving_the_mdgs.html, http://www.who.int/bulletin/volumes/88/7/09-071068/en/
[9] Liberia Poverty Reduction Strategy, Chapter 9, 2008
[10] National Health and Social Welfare Policy, pg 7
[11] National Health Infrastructure Situational Analysis, 2010
[12] National Health and Social Welfare Policy, pg 7.
[13] National Health Infrastructure Policy, pg 5

Site Planning and Masterplanning (Chapters 8-10)

[1] ARUP, Facility Design Guidelines for Aboriginal Islander Health, 2009, p. 15
[2] From August 2014 onwards, the MOHSW's Infrastructure Unit will have 5 qualified installation technicians in-house, following the setup of a 'Solar Maintenance Unit' under the solar energy project as implemented by Merlin.
[3] WHO, District health facilities – Guidelines for development and operation, 1998, p. 25
[4] Republic of Liberia. 2009. *Safe Management of Health Care Waste in Liberia*. Health System Reconstruction Project
[5] Casebook; WHO, District health facilities – Guidelines for development and operation, 1998, p. 48
[6] WHO, District health facilities – Guidelines for development and operation, 1998, p. 40
[7] Ibid.
[8] WHO, District health facilities – Guidelines for development and operation, 1998, p. 36-37
[9] WHO, District health facilities – Guidelines for development and operation, 1998, p. 46
[10] ARUP, Facility Design Guidelines for Aboriginal Islander Health, 2009, p. 20

Building Layout (Chapters 12-14)

[1] USAID-BU, Primary Health Care Centers, 1982, p. 47
[2] England Department of Health, Diagnostic Imaging: PACS and Specialist Imaging, p.14.
[3] England Department of Health, Diagnostic Imaging: PACS and Specialist Imaging, p.22.
[4] WHO, District Health Facilities – Guidelines for development and operation, 1998, p. 58

Patient Centricity (Chapters 15-18)

[1] International Building Code

Ventilation & Thermal Comfort (Chapters 19-22)

[1] WHO, District health facilities – Guidelines for development and operation, 1998, p. 119.
[1] Gustafson et al., 1982; Bloch et al., 1985; Hutton et al. 1990; Calder et al. 1991.
[1] WHO, District health facilities – Guidelines for development and operation, 1998, p. 44-45, WHO, Natural Ventilation for Infection Control in Health-Care Settings, 2009.
[1] (WHO, 2007).

Water (Chapters 27-28)

[1] Water Supply Committee of the Great Lakes. 2012. *Recommended Standards for Water Works (Ten State Standards)*. Published by Health Research, Inc. Albany, New York
[2] Guidelines for Water and Sanitation Services in Liberia. 2010. Ministry of Public Works, WASH.

Sanitation (Chapter 29)

[1] WHO, Safe management of wastes from healthcare activities, 2013, p. 3

[2] Ibid.

[3] WHO, Safe management of wastes from healthcare activities, 2013, p. 3, 4, 9.

[4] WHO Safe management of wastes from healthcare activities, 2013 pgs. 4, 9

[5] WHO Safe management of wastes from healthcare activities, 2013, pgs. 12, 13

[6] Republic of Liberia, Guidelines for the safe management of healthcare waste in Liberia. IDA/HSRP, 2009 p. 21

[7] Ibid p. 22

[8] Medecins Sans Frontieres, 2010

Plumbing & Medical Gas (Chapters 30-31)

[1] Laestadius JG, Dimberg L. Hot water for handwashing-Where is the proof? [Letter]. *Journal of Occupational & Environmental Medicine.* 2005; 47(4):434-435.

Materials & Workmanship (Chapters 38-43)

[1] Data derived from: ASHRAE, AHRAE Handbook, 1993 Fundamentals, Appendix B, pp. B7-B10.

[2] Data derived from: England Environment Agency, Carbon Footprint Calculator, 2007, available at: http://www.environment-agency.gov.uk/business/sectors/136252.aspx (accessed July 2013).

[3] United States Environmental Protection Agency, Safe Drinking Water Act, 1996, available at: http://www.epa.gov/safewater/sdwa/index.html (accessed July 2013).

[4] United States Environmental Protection Agency, Indoor Air Pollution: An Introduction for Health Professionals, available at: http://www.epa.gov/iaq/pubs/hpguide.html#VOCs, (accessed July 2013).

[5] World Health Organization, Health care Facility Projects in Developing Areas: Planning, Implementation, and Operation, 1984, p. 42.

[6] World Health Organization, Health care Facility Projects in Developing Areas: Planning, Implementation, and Operation, 1984, p. 42.

[7] World Health Organization, Health care Facility Projects in Developing Areas: Planning, Implementation, and Operation, 1984, p. 42.

[8] University of Nairobi Housing & Research Development Unit, Design for Medical Buildings, 1975, p. 88.

[9] CSEB standards were adapted from the Auroville Earth Institute Code of Practice, Auroville Earth Insititute: http://www.earth-auroville.com/

[10] Wolfgang Lauber, Tropical Architecture, 2005, p. 121.

[11] IUCN, http://www.iucnredlist.org, accessed November 2013.

Building Finishes (Chapters 44-45)

[1] United States Environmental Protection Agency, Indoor Air Pollution: An Introduction for Health Professionals, available at: http://www.epa.gov/iaq/pubs/hpguide.html#VOCs, (accessed July 2013).

[2] England Department of Health, Health Building Note 00-10 Part A: Flooring, 2013, p.6.

[3] England Department of Health, Health Building Note 00-10 Part A: Flooring, 2013, p.5.

[4] England Department of Health, Health Building Note 00-10 Part B: Walls & Ceilings, 2013, p.5.

[5] England Department of Health, Health Building Note 00-10 Part B: Walls & Ceilings, 2013, p.5.

[6] England Department of Health, Health Building Note 00-01: General Design Principles, 2013

Supervision & Maintenance (Chapters 51-52)

[1] USAID-BU, Primary Health Care Centers, 1982, p. 67

[2] WHO, District health facilities – Guidelines for development and operation, 1998, p. 79

3 Primer, WHO, Essential environmental health standards in health care, 2008, 22

Glossary

Adjacency: Placement next to or with direct access to another program element.
Aerobic: Using molecular oxygen. Growing or occurring only in the presence of molecular oxygen, such as aerobic organisms.
Aggregate: A group of soil particles cohering so as to behave mechanically as a unit.
Air changes per hour (ACH): The metric for air change rate, or the amount of air that must be circulated in the room in one hour.
Air distribution pattern: The manner in which air is supplied and exhausted from a space.
Air gap: The distance between a water outlet and a sink, tub, or other sanitary drain receptor's maximum water level.
Air Relief Valve: A brass or plastic, manually operated valve located at the top of a filter tank for relieving the pressure inside the filter and for removing the air inside the filter.
Airborne precaution room: A room with >12 air changes per hour (ACH).
Airflow direction: The general direction air flows through building spaces.
American National Standards Institute/National Science Foundation (ANSI/NSF): Organization that oversees the development standards for products, services, processes, systems, and personnel in the US.
American Society for Testing and Materials (ASTM): International standards organization that develops and publishes technical standards for a wide range of materials, products, systems, and services.
American Water Works Association (AWWA): Association founded to improve water quality and supply.
Ampere(AMP): Unit of electric current, or electric charge passing a point in an electric circuit.
Anaerobic Baffled Reactor (ABR): An improved septic tank in which the configuration of the tank inlet and outlet baffling or piping forces the wastewater to flow vertically upwards through the sludge.
Anaerobic filter (AF): A fixed-bed filter.
Annulus: The void space between well rings.
ASTM: American Society for Testing and Materials
ASTM/AASHTO: A private non-profit organization that oversees the development of standards for products, services, processes, systems, and personnel in the United States.
Automatic transfer switch (ATS): A device that switches electrical load from one power source to another.

Backflow: The undesirable reverse flow of a liquid, gas or solid into potable water supply.
Back-siphonage: Occurs when higher pressure fluids move to an area of lower pressure.
Bacteria: Unicellular microorganisms which feed upon and degrade organic matter.
Baffle: A deflector at the inlet (top) of a typical water softener which disperses the water over the top of the resin bed.
Battery: Stores energy for supplying to electrical appliances when there is a demand.
Berm: A mound or wall of earth or sand.
Best Management Practices (BMP): A method, activity, maintenance procedure, or other management practice for reducing the amount of pollution entering a water body.
Blackwater: Liquid and solid human waste and the waters generated through toilet usage.
Biochemical Oxygen Demand (BOD): Measure of the concentration of organic impurities in wastewater. The amount of oxygen required by bacteria while decomposing organic matter under aerobic conditions, expressed in mg/L.
Bioretention: A technique that uses parking lot islands, planting strips, or swales to collect and filter storm water.
Bituminous: Containing a black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation.
Boulder: Particles larger than 12in (300mm).

Carbon footprint: A measure of the total amount of carbon dioxide (CO_2) emissions per unit of material production/use.
Catch Basin: A receptacle with a sediment bowl or sump, diverting surface water to a subsurface pipe.
CCT: Correlated color temperature measured in degrees Kelvin. The higher the number the more cool or blue the light appears. The lower the number the more warm or amber the light appears.
Centralized Packaged Air Conditioner: An air conditioning system in which a single housing contains the condensing unit, compressor and evaporator, ducting conditioned air to the serviced spaces.
CFL: Compact fluorescent lamp.
CFM: Cubic feet per minute, used as a unit of medical gas volume.
Charge controller: Regulates the voltage and current coming from the PV panels going to the battery, prevents battery overcharging, and prolongs battery life.
Chemical-Feed Pump: A mechanical device that introduces chemicals into a water system at a rate proportional to the water flow. Also called a chemical feeder.
Chlorination: The use of chlorine gas or solutions to disinfect water or as an oxidizing agent.
Chlorine Demand: A measure of the amount of chlorine which can be consumed by organic matter.
Chemical-Feed Pump: A mechanical device designed to introduce chemicals into a water system at a rate proportional to the water flow. Also called a chemical feeder.
Chlorination: The use of chlorine gas or solutions of its compounds to disinfect water or as an oxidizing agent.
Chlorine Demand: A measure of the amount of chlorine which can be consumed by organic matter and other oxidizable substances in water without chlorine residual.
Chemical Hazardous Waste: Solid, liquid, and gaseous waste/chemicals from diagnostic and laboratory work, housekeeping and cleaning, disinfecting procedures, car/truck fleet management, and building operations.
Cistern: Waterproof receptacle for holding potable water.
Clarifiers: Settling tanks that remove settleable solids by gravity, colloidal solids by coagulation following chemical flocculation, or floating oil and scum through skimming.
Clearing and Grubbing: Removal of objectionable natural materials (e.g. trees, shrubs) and artificial materials (e.g. rubbish) from the project site or from areas of construction specified within the site.
Clerestory: Any high windows or openings above eye level.
Cobble: Particles ranging in size from 3-12 in (80-300mm)
Cohesionless Soils: Soil particles that do not stick together and include: gravel (>2mm), sand (0.1 mm to 2 mm), and silt.
Cohesive Soils: Soil particles that are very small and tend to stick together. Cohesive Soils are considered sticky and plastic and include clay.
Combustible: A substance that is able to catch fire and burn easily.
Compaction: The process by which sediment progressively loses its porosity due to the effects of loading.
Compost: To make vegetable matter or manure into compost.
Condensing Unit: Part of an air conditioning unit that cools and condenses incoming refrigerant vapor into liquid.
Conveyance: The process of transporting water from one place to another.
CPVC: Chlorinated polyvinyl chloride.
CRI: Color rendering index is given in a range from 0 to 100. The closer the number is to 100 the better the lamp's ability is to render true color in comparison to incandescent or daylight.
Critical loads: Loads associated with building occupant safety and patient life support systems
Culvert: Any structure not a bridge that provides a waterway or opening under a road.
CWMA: Central Waste Management Area.
Cylinder bank or Cylinder manifold: A group of pressurized gas containers connected to a common pipe.

Detention Pond: An impoundment, normally dry, for temporarily storing storm runoff from a drainage area to reduce the peak rate of flow.
Digestion: The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization.
Discharge: Flow rate in a culvert, pipe, or channel.
Disinfection: Killing pathogenic microbes in or on a material without necessarily sterilizing it.
Dispersion: The process of distributing water over a wide area.
Dissolved solids (TDS): Solids present in solution.
Dissolved solids: Theoretically, the anhydrous residues of the dissolved constituents in water. Actually, the term is defined by the method used in determination.
Distribution: Entire set-up consisting of procedures, methods, equipment, and facilities, designed and interconnected to facilitate and monitor the flow of water from the source to the end user.
Diurnal swing: the variation in temperature that occurs during the high daytime temperature and the low night temperature.
Downspout: A pipe to carry rainwater from a roof to a drain or to ground level.
Drainage: Interception and removal of ground or surface water by artificial or natural means.
Drainage Area: The area drained by a channel or sub-surface drain.
Drilled Well: A well constructed by either cable-tool or rotary methods usually to depths exceeding a 50 ft with capacities to provide for industry, irrigation, or municipalities.
Dry Sieve Analysis: Soil is oven dried and mechanically agitated over a set of sieves to determine size and percentage of soil particles that make up a given sample.
Drywell: An underground structure that disposes of unwanted water, most commonly stormwater runoff, by dissipating it into the ground.
Ducted fans: Fans that are connected to air ducts for supplying and exhausting air to and from spaces.
Ductless Split Air Conditioner: An air conditioner with an exterior condensing unit and an interior fan unit, connected by refrigerant and electrical lines.
Dug Well: A shallow, large-diameter well constructed by excavating with hand tools or power machinery instead of drilling or driving, typically for individual domestic water supplies and yielding considerably less than 100 gal/min (380 L/min).

Earth berming: Using a mound or bank of earth as a barrier or to provide insulation.
Earth coupling: The practice of building into the ground to take advantage of the vast thermal mass of the earth, which typically remains a constant temperature at a certain depth below grade.
Earthing/grounding: Low resistance path to earth which allows electrical faults to flow safely to earth without harming users or equipment.
ECPs: Erosion control plans.
Effluent: Sewage, water, or other liquid, partially or completely treated or in its natural state, flowing out of a reservoir, basin, or treatment plant.
Encapsulate: To enclose something in a sealed container.
Equipotential: The same voltage or no voltage between 2 points. A good grounding system eliminates voltage differences between 2 objects that may be simultaneously touched by a person, causing shock.
Erosion: Detachment and movement of soil or rock fragment by water, wind, ice, and gravity.
Erosion Control: The practice of preventing or controlling wind or water erosion in agriculture, land development, and construction. Effective erosion controls are important techniques in preventing water pollution and soil loss.
ESC: Erosion and sediment control.
Excavation: The action of making a hole or channel by digging.

Fault current: A fault on the electrical system is any abnormal electrical current. A fault typically occurs as a “short circuit” where phase-to-phase or phase-to-ground current bypasses the load and an enormous amount of current is released.
Fenestration: The arrangement of windows and doors on the elevations of a building.
Fill: Dirt, rock or other material added to level or raise the elevation of a land feature.
Filter Fabric: Textile of relatively small mesh or pore size used to (a) allow water to pass through while keeping sediment out (permeable), or (b) prevent both runoff and sediment from passing through (impermeable).
Filtration: The processing of passing water through a filter in order to remove solid particles.
Fixture unit (FU): Equal to one cubic foot of water drained in a 1 1/4in pipe over one minute. A Fixture Unit is not a flow rate unit but a design factor. It is a value is assigned to each fixture based on its rate of water use, its likely use duration, and the average use frequency.
Flush Valve Toilet (also referred to as flushometer, or blowout toilets): A tankless toilet with a water-diverter that uses an inline handle to flush toilets or urinals. It uses water pressure from the water supply system.
Flush Tank Toilet: A toilet with a water tank mounted on or near it. It uses water pressure from the weight of water in the raised tank to flush toilets or urinals.
Footings: Concrete structures that are under foundation walls to distribute the weight of the structure over a greater area and thus prevent settling.
Franklin Lightning Protection System: A lightning rod designed by Benjamin Franklin in 1749 and still used today around the world to protect buildings from lightning strikes.
Full Load Amps (FLA). The current drawn by equipment after startup when running at full capacity.

Generator: Diesel or gasoline-fired engine that produces energy by the turning of a piston.
Geosynthetics: Degradable and nondegradable products used for a variety of purposes, including soil and slope stabilization, erosion and sediment control, soil reinforcement, and subsurface drainage.
Glare: A very harsh, bright light causing discomfort.
Glazing: Panes or sheets of glass set or made to be set in frames for windows, doors or skylights.
GPM: Gallon/s per minute as a measure of flow rate.
Grading: Work done to ensure a level ground, or ground with a specified slope.
Gravel: Particles ranging in size from 0.18- 3in (4.75-80mm)
Graywater: Wastewater generated by water-using fixtures and appliances, excluding the toilet and possibly the garbage disposal.
Ground Fault Circuit Interrupter: An electrical wiring device that disconnects a circuit whenever it detects that the current is not balanced between the energized conductor and the neutral conductor.
Groundwater: Water found in pore spaces in the subsurface below the water table.
Grouting: A cementitious fluid poured or injected into a borehole during well drilling to seal crevices and prevent contamination , to provide a protective wall , or to improve the strength and elastic properties of the rock.

Hand Pump: A pump worked by hand that can serve a structure with water.
Hardscape: Paved exterior areas.
Hazardous Waste: Waste that poses substantial or potential threats to public health or the environment and includes pressurized containers and mercury-containing waste.
Headwall: A vertical wall at the end of a culvert to support the pipe and prevent earth from spilling into the channel.

Heat island: A surface which is significantly warmer than its surrounding areas, typically due to absorption of solar radiation.
Heat sink: A device or substance for absorbing excessive or unwanted heat.
HEPA filter: A high efficiency particulate air filter that is effective at removing a high percentage of airborne contaminants.
High-Density Polyethylene (HDPE): Polyethylene thermoplastic made from petroleum that is commonly used for corrosion-resistant piping and geomembranes.
Horsepower (HP): A unit of power approximately equal to 746 watts.
HRT: Hydraulic residence time.
HVAC: Heating, ventilation, and air conditioning.

Illuminance: The amount of luminous flux per unit area measured in lumens per square feet or footcandles [lm/ft^2 or fc].
Immunosuppressed patient: Patients lacking a natural immune response.
Impervious: Resistant to penetration by fluids or by roots.
Incinerate: To destroy waste material by burning.
Infectious Non-Sharp Waste: Waste that includes soiled surgical dressings, cotton wool, gloves, swaps and all other contaminated waste from treatment areas. Also includes disposable plasters, bandaging, items significantly contaminated with blood, and materials from cases of infectious diseases (human biopsy materials, blood, urine, stools).
Infiltration: The downward entry of water into the surface of a soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.
Influent: Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant.
Instantaneous Water Heater: An electric water heater that has little or no storage.
Interim Waste Storage Vaults: Temporary storage for sharps waste prior to incineration on-site and/or taken to a higher-level facility for incineration.
Inverter: converts DC output of PV panels into a clean AC current.
IPC: International Plumbing Code.
ISO: International Standards Organization

Landscape Irrigation: Water used for watering plants or landscaped areas.
Leach Field: Area where septic-tank effluent is distributed for natural leaching.
LEC: Liberia Electricity Corporation.
LED: Light emitting diode.
Light Trespass: Light falling where it is not needed or wanted.
Lighting Power Density (LPD): The amount of power produced by the lighting per the unit area measured in watts per square feet (W/ft^2).
Liquid Limit: Moisture content of a soil at which the soil starts to flow and act as a liquid.
Load shedding: Manual or automatically turning off noncritical circuits to enable a standby system to cover all critical loads. Also used to prolong the runtime of critical loads for a given amount of backup power fuel.
Loading Rate: The amount of effluent that is applied to the soil, usually in liters/square meter or gallons/square feet.
Longevity: Expected useful/performance life.
LPW: Lumens per watt.
LPM: Liters per minute, used as a unit of medical gas volume.

Manifold Control Panel: An assembly of devices intended to provide automatic switchover from a depleted cylinder bank to a full cylinder bank.
Maximum overcurrent protection (MOCP): The largest circuit breaker or fuse recommended by the manufacturer to protect a piece of equipment.
Minimum circuit amps (MCA): The min. size conductor suggested by the manufacturer to feed equipment.
Modified Proctor Test: Determines maximum dry density and moisture content of soil.
Mulch: Materials such as leaves, bark, or compost, spread around a plant to enrich or insulate the soil.
Municipal Water: Water that is treated by a municipality to an established quality level and distributed by the municipality through a piping network to users.

National Electric Code (NEC): An international document with instructions for safely installing electrical systems.
NFPA: National Fire Protection Association, a US trade association that creates and maintains private, copyrighted, standards and codes for usage and adoption by local governments.
Night flushing: Drawing cooler outside air into a space during the night for cooling. This strategy is typically coupled with high thermal mass materials such that they can provide cooling during the day from the night flushing.
Noncritical loads: Loads associated with normal facility operation where power loss does not affect patient care.
Nosocomial infection: A new infection that develops in a patient during hospitalization.

Off-gassing: The process of a material releasing evaporated substances into the air from a solid to a gaseous state.
One-line diagram: A representation of an electrical system by means of single lines and graphic symbols showing the major components of the electrical system.
Organic Soils: Soil that is spongy, crumbly, and compressible. Organic soils are undesirable for supporting structures.
Organic Waste: Type of waste that can be broken down, in a reasonable amount of time, into its base components by micro-organisms and other living things. Examples include kitchen waste and yard waste.
Oxidation: Deposition that forms on the surface of a metal as a result of contact with oxygen.

Particle Size: The effective diameter of a particle usually measured by sedimentation or sieving.
Passive cooling: Technologies or design features used to cool buildings without power consumption.
Pathological Waste: Waste materials consisting of human or animal remains, anatomical parts, and/or tissue, the bags/containers used to collect and transport the waste materials, and animal bedding. Also includes lab waste or any other waste contaminated with blood and bodily fluids.
Peak Flow: The maximum instantaneous discharge rate resulting from a given storm condition at a specific location.
Peat: Compressed dead vegetation that has been preserved from decay by acidic groundwater in low-lying areas.
Penetrometer: A device to test the strength of a material such as soil.
Percolation: The flow or trickling of a liquid downward through a contact or filtering medium, as in movement of soil water toward the water table.
Permeability: The ease with which gases, liquids, or plant roots penetrate or pass through soil.

Pharmaceutical Waste: Waste that includes expired drugs and vaccines, drugs returned from wards, spilled or contaminated drugs, and cytotoxic wastes or other chemotherapy drug waste.
Pharmaceuticals: Compounds manufactured for use as a medicinal drug.
Plastic Limit: Moisture content at which it is possible to make a wire of approximately ¼ in diameter by rolling the soil between two hands. (Moisture control at the boundary between a soil in plastic and semi-solid states)
Potable: Water suitable for human consumption.
Potable Water: Water suitable for human consumption.
Pour Flush (PF) dual pit latrines: Simple, low cost, easy to construct and maintain sanitation system.
Power (Watt): The rate energy is transferred in an electric circuit. Power (Watt) = Volts * Amps.
Pressure Balancing Mixing Valve: A device used to mix hot and cold water to a desired temperature such as a shower valve.
Priming: The process of introducing fluid into a pump to improve the sealing of the pump.
Program: A list of the constituent elements (functions, rooms, or spaces) that compose a building.
Program element: The individual functions, rooms, or spaces in a building.
Proximity: Close placement in terms of space, time, or relationship.
PSI: Pounds per square inch.
PV module: Photovoltaic module, converts sunlight into DC electricity.
PV panel: Photovoltaic panel.
PVC: Polyvinyl chloride is used extensively in sewage pipe due to its low cost, chemical resistance, and ease of jointing.

Radioactive Waste: Solid, liquid, or gaseous waste contaminated with radionuclides generated from "in vitro" analysis of body tissues, organ imaging and tumor localization, and therapeutic procedures.
Rain Garden: A planted depression that allows rainwater runoff from impervious areas the opportunity to be absorbed.
Rainwater Harvesting: The method of collecting runoff from rainwater for use as water for human consumption.
Recycle: To convert waste into reusable material and is applicable to materials such as metals, bottles, clothes, etc.
Redundant Fans: Secondary duplicate fans that are sized for 100% airflow that are normally off when the primary fan is being used, but are capable of being used in the event of failure of the primary fan.
Refrigerant Line: Tubing which connects the interior and exterior units of a ductless split air conditioner.
Relative Compaction: The degree of compaction achieved, as a percentage of the laboratory compaction.
Renewable materials: Raw materials can be regenerated through natural processes (such as wood).
Runoff: Precipitation or surface discharge carried off from the area on which it falls.
Sand: Particles ranging in size from $3.0x10^{-4}$ -0.18in (0.075 -4.75mm)
Saturated zone: The area below the water table where the soil pores are fully saturated with water.
Sedimentation: The act or process of depositing sediment.
Septic Tanks: Typically two or three chambered concrete tanks that are constructed just below ground level and receive excreta and all other wastewater from the facility.
Service panel: Electrical panelboard where the building's point of service is established. Panelboards have earthing connections to an earth rod, steel structure, cold water pipe, etc. The neutral bus is bonded to ground bus to establish a zero potential for neutral wire.
Settleable Solids: That matter in wastewater which will not stay in suspension during a preselected settling period, but either settles to the bottom or floats to the top.
Sharps Waste: Medical waste composed of discarded syringes, needles, cartridges, scalpel blades, and saws.
Sheet Flow: Flow over plane, sloped surfaces in a thin layer.

Short-circuiting: Situation in which exhaust air is brought back in through intake.
Silt Fence: A temporary sediment control device used on construction sites to protect water quality in nearby streams, rivers, lakes and seas from sediment in stormwater runoff.
Slope: The face of an embankment or cut section. Any ground whose surface makes an angle with the horizontal plane.
Soakaway Tanks: Rectangular two compartment tanks constructed just below ground level that receive both excreta and flush water from flush toilets and other waste flows.
Solar gain (solar load): The amount of thermal heat energy (temperature) on a surface or in a space caused by solar radiation from the sun.
Solar heat gain coefficient (SHGC): The amount of solar thermal energy passing through glass.
Solid Waste: Refuse or rubbish consisting of everyday items that are discarded by the public, including paper, packing materials, cardboard containers, plastic bags, food wrappings/containers, metal cans, floor sweepings, non-infectious patient related waste, and bulky waste (debris).
Softscape: The elements of a landscape that comprise live, horticultural elements.
Specific Gravity: Measure of how much heavier or lighter a material is than water.
Spillage Containment Equipment: Equipment that aids in the containment of spills.
Splash block: A masonry block with its top close to the ground surface, which receives roof drainage and prevents erosion below the spout.
Spring: A place where groundwater flows naturally from a rock or the soil onto the land or a water body.
Stack effect: the movement of air into and out of buildings driven by buoyancy which occurs due to a difference in indoor-to-outdoor air density resulting from temperature and moisture differences.
Submersible Pump: A pump designed to fit into a well and operate below the water level.
Subsoil: The soil lying immediately under the surface soil.
Subsurface wastewater infiltration systems (SWIS): Common systems for the treatment and dispersal of onsite wastewater.
Surface Water: Water on the surface of the planet, such as in a stream, river, lake, wetland, or ocean.
Surge Protection Device (SPD): Equipment designed to capture power surges, thereby protecting electrical distribution systems and equipment.
Suspended Solids: Solids physically suspended in water, sewage, or other liquids.
Swale: A constructed or natural grassed or vegetated waterway.

Thermal bridging: Heat transfer that occurs when materials that are poor thermal insulators come into contact, allowing heat to flow through the path of least thermal resistance (R-value).
Thermal mass: The ability of a solid to absorb heat which typically occurs during the day and can be released at night.
Thermal resistance (R-value): A measure of a material's ability to prevent heat gain or loss and preserve constant temperatures.
Total Suspended Solids (TSS): The solids remaining as residue after water has been evaporated from a sample.
Toxicity: The extent to which a substance can damage living organisms.

Ultraviolet Germicidal Irradiation (UVGI): A sterilization method that uses ultraviolet (UV) light at a sufficiently short wavelength to break down microorganisms.
Underwriters laboratory (UL): International company testing electrical equipment for safe operation.

Vacuum Breaker: A device used on a water outlet.
Ventilated Improved Pit (VIP): A type of latrine that reduces odors and flies.
Ventilation rate: The amount of outside air that enters a space within a given period of time.
Visual Light Transmittance (VLT): The proportion of visible light that passes through a glazing system relative to the incident light on that glazing system, expressed as a percent.
Volatile organic compounds (VOCs):Organic chemical compounds whose composition makes it possible for them to be released as gasses from solid or liquid substances under normal building conditions.
Volatile Solids: The quantity of solids in water, sewage, or other liquid lost on ignition of total solids.
Volt: Electric potential between two points.
Voltage Drop: The difference in voltage between two points in a circuit. Too much voltage drop leads to dim lights, poorly operating equipment, and early failure.

Waste Activated Sludge (WAS): Excess sludge removed from the treatment process.
Waste Generation Study: Determines waste types and generation amounts to size waste management infrastructure/operations accordingly.
Waste Management: The handling, storage, treatment and disposal of wastes and their residuals.
Waste Stabilization Ponds (WSPs): Large, shallow ponds that use a combination of natural processes involving bacteria and algae to treat the wastewater.
Water Table: The surface of a body of unconfined ground water.
Watershed: A drainage basin, or area contributing to the supply of a stream or lake.
Weatherhead: An electrical device that keeps water from entering a conduit.
Wet Sieve Analysis: Soil is washed with water over a sieve (#270) to facilitate the removal of silt and clay from the larger particles.
Window Air Conditioner: A single-unit air conditioning system which fits into a window.
Window Fans and Panel Fans: Propeller fans installed in either windows or walls for exhausting air from spaces for ventilation and supplemental cooling.
WMA: Waste Management Area.

APPENDICES

Appendix A Construction Costs Based on Grading Site Work
Appendix B Water Quality Standards for Drinking Water Sources
Appendix C Natural Ventilation Principles
Appendix D Typical R-values for Building Materials
Appendix E Electrical Load Analysis
Appendix F 30.3 NFPA 70, NEC TABLES
Appendix G Fault Current Calculations
Appendix H Voltage Drop Chart
Appendix I Feeder Sizing
Appendix J Minimum Circuit Ampacity
Appendix K Earthing Electrode Conductor
Appendix L Generator Sizing
Appendix M PV Sizing
Appendix N Junction Box Fill
Appendix O Basic Power Equations
Appendix P Percolation Test Procedures
Appendix Q Guidelines to Estimate Wastewater Flows
Appendix R Waste Generation Rates
Appendix S Pipe Drainage Installation Procedure:
Appendix T Facility Sizing Information
Appendix U Sample Schematic Facility Plans

Appendix A

Range of Construction Costs Based on Grading and Other Site Development Work

Site Improvements	Units	Quantity	Unit Costs	Total Costs ($LRD)
1.Grading				
1.1 Onsite Disposal	CY	1000	$8	$8,000
	CY	2000	$8	$16,000
	CY	5000	$8	$40,000
	CY	10000	$8	$80,000
1.2 Offsite Disposal	CY	1000	$16	$16,000
	CY	2000	$16	$32,000
	CY	5000	$16	$80,000
	CY	1000	$16	$160,000
2. Retaining Walls				
2.1 Walls under 5 feet tall	SF	100	$15	$1,500
Dry Stacked Stone Walls	SF	100	$30	$3,000
Concrete Block Wall	SF	100	$50	$5,000
Cast-in-Place Concrete	SF	100	$25	$2,500
Treated Wood Walls	SF	100	$25	$2,500
2.2 Walls >5 feet and under 10 feet				
Dry Stacked Stone Walls	SF	100	$35	$3,500
Concrete Block Wall	SF	100	$60	$6,000
Cast-in-Place Concrete	SF	100	$100	$10,000
Treated Wood Walls	SF	100	$55	$5,500

Appendix B

<u>Water Quality Standards for Drinking Water Sources</u>

**Source: Ministry of Health and Social Welfare Water Quality Standards, 1987*

Parameter	Unit	WHO	Class 1 – Drinking Water Standards
pH	-log H	--	6.5 – 8.0
Chloride	mg/L	350	≤250
Sulphate	mg/L	250	≤150
Hardness		100 – 500	≤190
Iron Total	mg/L	0.1	≤0.1
Manganese	mg/L	0.1	≤0.1
Zinc Total	mg/L	5	≤1
Coliform Bacteria	n/ml	0	0
Bacteria Total	n/ml	0	0
Dissolved Substances	mg/L	500	≤500
Suspended Solids	mg/L	--	≤10
Ammonia	mg/L	0.5	≤1.0
Nitrate	mg/L	50	≤40
Nitrite	mg/L	--	≤0.1
Phosphate (PO_4)	mg/L	--	≤0.01
Phenols	mg/L	0.001	≤0.001
Detergents	mg/L	--	≤1
Fluoride	mg/L	1.5	≤1.5
Cyanide	mg/L	0.05	Non-Detectable
Lead	mg/L	0.1	≤0.1
Mercury	mg/L	0.01	Non-Detectable
Copper	mg/L	0.05	≤0.01
Cadmium	mg/L	0.01	Non-Detectable
Chromium Trivalent	mg/L	--	≤0.5
Chromium Hexavalent	mg/L	0.05	≤0.05
Nickel	mg/L	--	≤1
Silver	mg/L	0.05	≤0.1
Vanadium	mg/L	--	≤1
Boron	mg/L	--	≤1
Arsenic	mg/L	0.05	≤0.05

Appendix C

Natural Ventilation Principles

**Adapted from WHO, Natural Ventilation for Infection Control in Health-Care Settings, 2009*

Natural forces (winds and thermal buoyancy forces due to indoor and outdoor air density differences) can be used to drive outdoor air through building openings such as windows, doors, solar chimneys, and wind towers. This type of ventilation of buildings depends on climate, building design and human behavior.

If properly installed and maintained, there are several advantages of a natural ventilation system, compared with mechanical ventilation systems.

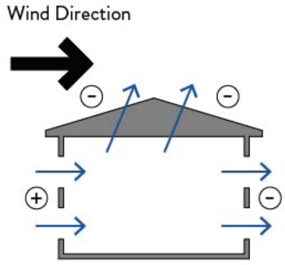
- Natural ventilation can generally provide a high ventilation rate more cost effectively, due to the use of natural forces and large openings.
- Natural ventilation can be more energy efficient, particularly if heating is not required.
- Well-designed natural ventilation system can be coupled with daylighting strategies.

If properly designed, natural ventilation can be reliable, particularly when combined with a mechanical system using the hybrid (mixed-mode) ventilation principle, although some of these systems may be more expensive to construct and design than mechanical only systems. Hybrid systems may also include a combination of natural ventilation and UVGI.

In general, the primary advantage of natural ventilation is its ability to provide high air exchange rates economically with a relatively simple system. Although ventilation rates can vary significantly, buildings with natural ventilation system can achieve very high air exchange rates by natural forces (if designed properly), which can greatly exceed minimum ventilation requirements.

Driving Forces of Natural Ventilation

The two primary naturally driven forces of ventilation are wind pressure and stack pressure. Without either of these, mechanical forces are required to provide ventilation. When considering a design for a natural ventilation system, designers need to understand the main driving forces; wind pressure and stack (or buoyancy) pressure as these forces control how air moves within and through a building.

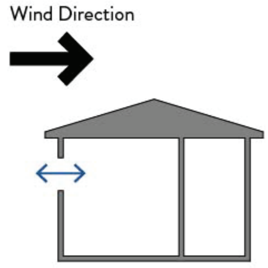


Wind-Induced Flow Direction in a Building

Wind pressure

Wind striking a building creates a positive pressure on the windward face (the side of the building directly facing the wind and a negative pressure on the leeward face (the side of the building facing away from the direction the wind coming from). This causes air to flow through the building from windward openings to leeward faces.

For building configurations with windows on only one side, the contribution from average wind pressures is very small and will primarily depend on the fluctuating components of the wind. Simply because a window is open, sufficient air changes per hour (ACH) are not guaranteed.



Fluctuating Components Contributing to Single-Sided Airflow

Wind-driven natural ventilation rate through a room with two opposite openings (e.g. a window and a door) can be calculated as follows using this general guideline:

$$\text{ACH} = \frac{0.65 \times \text{wind speed (m/s)} \times \text{smallest opening area (m}^2\text{)} \times 3600\text{ s/h}}{\text{room volume (m}^3\text{)}}$$

$$\text{Ventilation rate (l/s)} = 0.65 \times \text{wind speed (m/s)} \times \text{smallest opening area (m}^2\text{)} \times 1000\text{ l/m}^3$$

The wind speed refers to the value at the building height at a site sufficiently away from the building without any obstructions

The table below provides estimates of the air exchange and ventilations rate due to wind alone, at a wind speed of 2.24 miles/hour, assuming a ward of size 23' (length) × 20' (width) × 10' (height), with a window of 5' × 6.5' and a door of 3' × 6.5' (smallest opening).

Openings	ACH	Ventilation Rate (CFM)
Open window (100%) + open door	37	2750
Open window (50%) + open door	28	2065
Open window (100%) + closed door	4.2	315

Estimated air changes per hour and ventilation rate for a 23' x 20' x 10' ward

Stack (buoyancy) effect

Stack (or buoyancy) effect is generated from the air temperature or humidity difference (sometimes defined as density difference) between indoor and outdoor air. This difference generates an imbalance in the pressure gradients of the interior and exterior air columns, causing a vertical pressure difference. When the room air is warmer than the outside air, the room air is less dense and rises. Air that enters the building through lower openings escapes through upper openings. Stack effect causes the indoor pressure to be lower than outdoors at the low inlet and higher than outdoor at the outlet. The indoor pressure is equal to the outdoor pressure (neutral zone) halfway between the inlet and the outlet. For multi-story buildings, care must be taken to understand how the pressures affect flow. Because room air must be warmer (or more humid) than outdoor air, stack pressure is less effective and less desirable in hot and humid climates.

The flow direction is reversed when the room air is colder than the outside air; the room air is denser than the outside air. Air enters the building through the upper openings and escapes through the lower openings. Stack effect flows in a building are driven by indoor and outdoor temperatures. The ventilation rate through a stack is a function of the pressure differential between the two openings of that stack.

For stack effect driven natural ventilation, the ACH for a single story room can be calculated as:

$$\text{Air changes per hour (ACH)} = \frac{0.15 \times \text{smallest opening area (m}^2\text{)} \times 3600\text{ s/h} \times \sqrt{(\text{indoor} - \text{outdoor air temperature (°K))} \times \text{stack height (m)}}}{\text{room volume (m}^3\text{)}}$$

$$\text{Ventilation rate (l/s)} = 0.15 \times 1000\text{ l/m}^3 \times \text{smallest opening area (m}^2\text{)} \times \sqrt{(\text{indoor} - \text{outdoor air temperature (°K))} \times \text{stack height (m)}}$$

Natural Ventilation Systems

There are four design methods available for natural ventilation systems:

- Cross flow (no corridor) – the simplest natural ventilation system with no obstacles on either side of the prevailing wind (i.e. windows of similar size and geometry open on opposite sides of the building);
- Wind tower (wind catcher/wind extractor) – the positive-pressure side of the wind tower acts as a wind catcher and the negative-pressure side of the wind tower acts as a wind extractor;
- Stack (or buoyancy), simple flue – a vertical stack from each room, without any interconnections goes through the roof; this allows for air movement based on density gradients; and
- Stack (or buoyancy), solar atrium – a large stack that heats due to solar radiant loading, which induces air movement due to density (temperature) differentials. For multi-story buildings, care must be exercised to understand the neutral zone and pressures within the atrium.

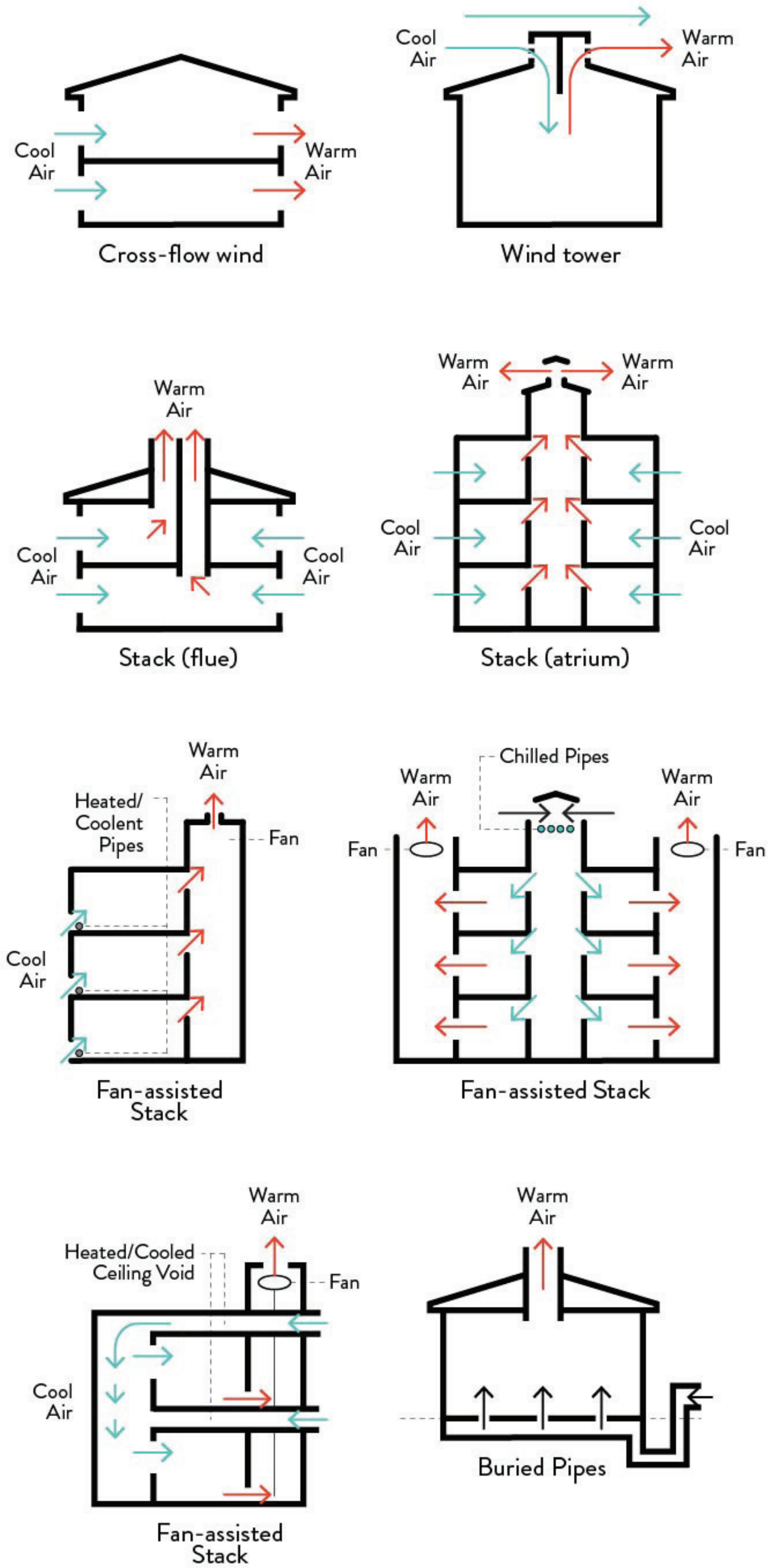
Hybrid (mixed-mode) Ventilation Systems

Hybrid (mixed-mode) ventilation relies on natural driving forces to provide the desired (design) flow rate. It uses mechanical ventilation when the flow rate is less than that required to produce natural ventilation. UVGI may also be considered as part of a hybrid systems to assist with air disinfection for hybrid systems.

Three design methods are available for hybrid ventilation systems.

- Fan-assisted stack – when there is insufficient solar radiant loading on the stack (i.e. evenings and inclement days) the ventilation rate is supplemented by extraction fans. Inlet air is heated and cooled to maintain comfort for building occupants.
- Top-down ventilation (fan-assisted stack plus a wind tower) – when there is insufficient solar radiant loading on the stack (i.e. evenings and inclement days) the exhaust ventilation rate is supplemented by extraction fans while the supply ventilation rate is supplemented by the wind tower (wind scoop). Inlet air is heated and cooled to maintain comfort for building occupants.
- Buried pipes– when land is available, ventilation pipes (ducts) can be buried. If air remains underground for long enough, the air will approach the steady-state underground temperature (i.e. warming or cooling the outside air). This system is not ideal for high ventilation rates. Also, care must be taken to prevent the intrusion of insects and animals. The ducts must be water tight to mitigate the breeding of mold.

The below figure illustrates the different systems of natural and hybrid ventilation.



Adapted from VEETECH, Coventry, UK

Design Considerations

When developing the design concept for a naturally ventilated building for infection control, three basic steps are involved.

1. Specify the desired airflow pattern from the inlet openings, through the wards and other hospital spaces such as corridors, to the outlet openings. This is associated with the form (single corridor, central corridor, courtyard, etc.) and organization (relative location of the nursing station, offices, storage, etc.) of the building, which in turn depends on its intended use and site conditions, such as prevailing winds.
2. Identify the main available driving forces that enable the desired airflow pattern to be achieved. The effective strategies for infection control tend to be mostly wind driven, although the stack-driven strategy may also work if designed properly. A combined wind-driven and stack-driven flow needs to be considered where necessary and feasible. In some cases, hybrid (mixed-mode) ventilation may be used and these natural forces can be supplemented by fans. In a good design, the available dominating driving forces are in synergy with the intended flow pattern.
3. Size and locate the openings so that the required ventilation rates can be delivered under all operating regimes. This is, in itself, a three-step process. First, the ventilation rates need to be determined based on the infection control requirements as specified in Part 1 of this document. Second, the openings need to be sized and located to deliver these airflow rates under design conditions. Third, a control system needs to be designed to maintain the required flow rates under varying weather and occupancy conditions.

A general procedure for natural ventilation design includes several components.

- Architectural design — architects and engineers must initially set the global geometric configuration of the system (e.g. siting of the building and landscape configuration, overall building form, and approximate positions of fresh air inlets and air exhausts), considering both dominant and prevailing wind conditions, as well as unusual conditions by time of day and season.
- System layout and component selection — the designer will then lay out the airflow paths from inlet to outlet that will achieve the desired airflow objective (e.g. for the purpose of infection control and thermal comfort) and then select the types of airflow components (e.g. windows, doors, vents, solar chimneys) that will provide the desired control of airflow.
- Opening (door, window, vent etc.) size — the designer will then size the components selected considering the ventilation requirements and relevant climatic conditions. Both the indoor and outdoor design conditions (or design criteria) need to be considered.
- Design control strategy — the designer must then develop a strategy for controlling ventilation flow to the design objectives when the operating conditions vary. At this stage, both hardware and software for control may need to be chosen to implement the control strategy if a high-tech natural ventilation strategy is used.
- Detailed design drawing — finally, the designer must develop detailed drawings so that the systems can be built.

Building Design

Internal space distribution is important for ensuring clean to dirty airflow distribution. Relatively “dirty” spaces should be located on the leeward side to avoid reverse flow of polluted air and odors into other spaces. Large windows for other living spaces in the windward side, such as the wards, can create a funnel effect to induce more incoming air. Interior partitions and furniture should not block the airflow.

For infection control, a single-row ward layout has potential advantages over a double-row layout with a central corridor in terms of natural ventilation and daylight. Large, open spaces should always have large windows in opposite walls. With the central corridor layout, natural ventilation may be improved by combining cross-ventilation with stack (or buoyancy) ventilation through corridor vents or through shafts in multistory buildings. For multistory hospitals, stairwells and other shafts can work as exhaust ventilation systems to avoid warm air entering the upper-level apartments or offices. The outlet openings of the shafts should be located on the leeward side of the building, above the top floor level, with the inlet openings on the windward side of the building.

As the penetration depth of wind-driven natural ventilation is limited, the width of the building is limited (CIBSE, 2005). However, the use of wind towers may permit deeper buildings.

Vent Opening Design

In any design, the smallest opening area (the bottleneck) controls natural ventilation flow rate. Inlet and outlet openings should have as near equal dimensions as possible to maximize the airflow rate.

The position of openings needs to be considered with care, because of the possible conflict between cross and stack (or buoyancy) ventilation, human cooling or thermal mass cooling, etc.

Proper selection and design of openings such as windows, screens, louvers, solar chimneys, passive stacks, is also important. Proper sizing may be done using the vent sizing methods discussed earlier.

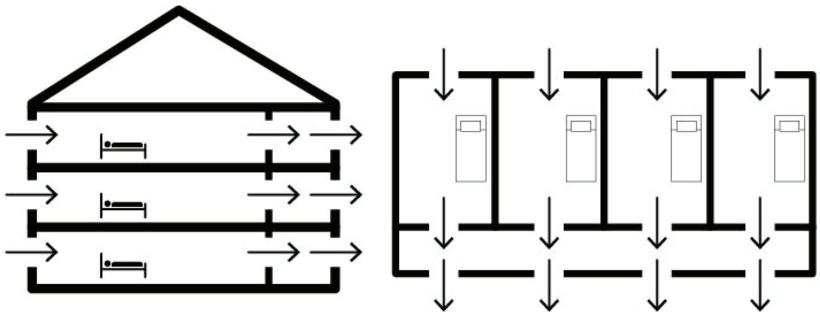
There are some other aspects to consider.

- Furniture and internal portioning — ventilation openings should not be blocked, and furniture layout and internal partitioning must not restrict the intended flow path and opening access.
- Ward depth — unlike mechanical ventilation, naturally ventilated buildings need to be relatively narrow to encourage cross ventilation. The natural air currents may penetrate deeply into a building.
- Shading — blinds, overhangs and projections may be used. Self-shading by the building itself and remote shading (e.g. by another building or trees) may also work if properly considered. Retractable blinds can also be helpful.
- Daylight and glare control — windows may be provided with a screen to avoid the direct sunlight. The shape and the position of the window openings are also important. The color and the finishes of the surfaces must also be chosen properly for a comfortable level of lighting and glare control.
- Cooling — during hot and humid weather, local spot cooling or personalized cooling systems may be used (e.g. by using ceiling fans or desk fans).
- Noise and acoustics — external noise may be avoided by locating the windows and other ventilation openings away from the primary noise courses. Absorbent partitioning, ceiling banners, etc., may also be used to absorb noise.
- Fire safety — designing a building with openings that connect rooms may conflict with fire-safety and smoke-control requirements. Ventilation openings may need to be closed during a fire. Fortunately, naturally ventilated buildings can be designed to be in line with the compartmentalization requirements for smoke control. The fire escape route needs special attention, because natural ventilation design also has an impact on smoke flow pattern.
- Security — security risks may be created with opening windows, particularly on ground floors.

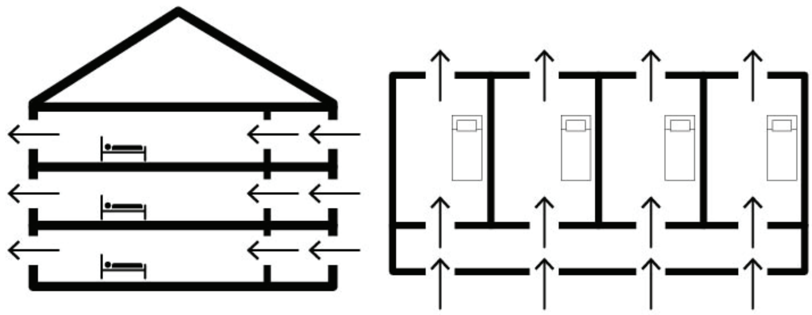
Single Sided Corridor Natural Ventilation

In the single-side corridor type of natural ventilation system, the corridor is on one side of the ward (see Figures 5.4 and 5.5). The airflow is a single directional flow either from the ward to the corridor or from the corridor to the ward, depending on the wind incident direction. This single directional flow can help to prevent cross-infection. The design of the windows is crucial for this type of design: it is better to position the windows in line with the ward door to create the path for cross-ventilation (Allard, 1998).

F. Beer is credited with designing the first corridor hospital, where all the rooms were arranged alongside internal walkways. His hospital in Bern, built between 1718 and 1724, was the first of this type.



Conceptual diagram for wind-driven natural ventilation in the single-sided corridor hospital with wind entering the ward



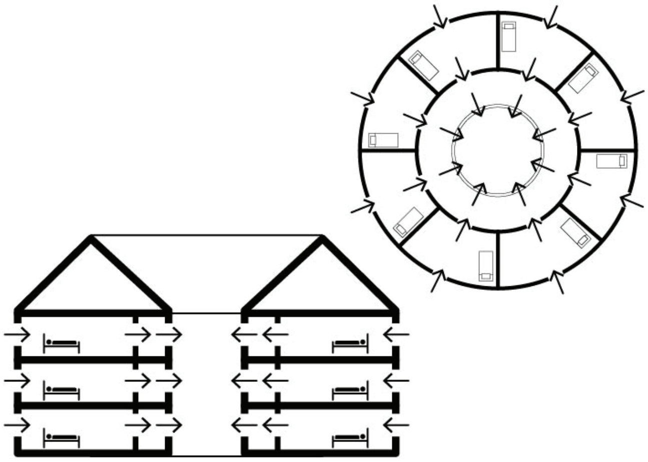
Conceptual diagram for wind-driven natural ventilation in the single-sided corridor hospital with wind entering the corridor

Central Corridor Type

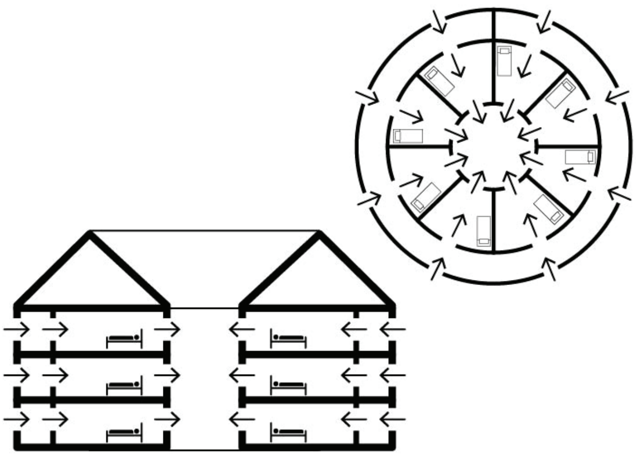
The central corridor type of natural ventilation system is derived from the single-side corridor type by adding another series of wards on the other side of the corridor. The possible airflow path would be from one ward to the corridor, and then to the ward on the other side. When the wind is parallel to the windows, adding a wing wall helps to drive the outdoor air to enter the wards first, and exit from the central corridor. A central corridor type of floor layout would result in possibly contaminated air moving from the upstream ward to the downstream ward. At present, this guideline does not recommend this type of design.

Courtyard Type

Courtyards are traditionally enclosed zones that can help to channel and direct the overall airflow and thus modify the microclimate around the buildings. Based on the relative position of wards and corridor to the courtyard, this type of natural ventilation system can be divided into the inner corridor and outer corridor subtypes (see Figures below). This system can supply more ventilation than the others, as long as the courtyard is sufficiently large. The outer corridor type has an advantage over the inner type, because it can avoid cross-infection via connected corridors by delivering clean outdoor air into the corridor first.



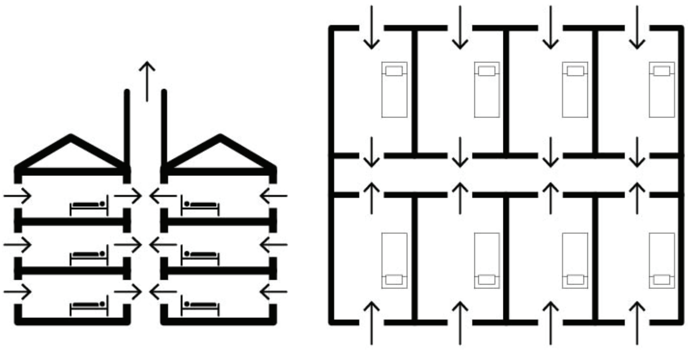
Inner corridor courtyard configuration



Outer corridor courtyard configuration

Atrium and Chimney Type

An atrium or chimney can help to increase the natural ventilation potential. An atrium or chimney type of natural ventilation system can be a side-atrium or chimney type, or a central atrium or chimney type, depending on the relative position of the wards, and the atrium or chimney (see Figure 5.10). Outdoor air is sucked into the wards through the windows by the stack (or buoyancy) effect. After diluting the contaminated air in the ward, the hot and polluted air converges in the atrium or chimney and discharges through the top openings. The applicability of this type of design will mainly rely on the height of the chimney, the indoor–outdoor temperature difference and its interaction with the background wind. This approach may be combined with motor-driven dampers and pressure sensors to control airflows and overcome some of the limitations of natural ventilation.



Buoyancy-driven natural ventilation solar chimney

Hybrid (mixed-mode) Ventilation Type

A limitation of natural ventilation is that it can sometimes depend too much on the outdoor climate. For example, if the outdoor wind speed is too small or the outdoor temperature is too high, the availability of natural ventilation will be reduced. To overcome this, hybrid (mixed-mode) ventilation can be used. In a simple hybrid (mixed-mode) ventilation system, mechanical and natural forces are combined in a two-mode system where the operating mode varies according to the season, and within individual days, reflecting the external environment and taking advantage of ambient conditions at any point of time.

The main hybrid (mixed-mode) ventilation principles are:

- Switching between natural and mechanical ventilation
- Fan-assisted natural ventilation
- Concurrent use of natural and mechanical ventilation.

Each of the natural ventilation solutions discussed above (single-corridor, central corridor, courtyard, wind tower, and atrium and chimney) may be combined with mechanical fans to create a hybrid (mixed-mode) system. Of course, like all the systems that use natural or mechanical ventilation, design and control are critical.

Appendix D

Typical R-values for Building Materials

Wall Assembly R value example

Components	R-value (h·ft2·°F/Btu)
Wall - Outside Air Film	0.17
Sliding - Wood Bevel	0.80
Plywood Sheathing - 1/2"	0.63
3 1/2" Fiberglass Batt	11.00
½" Drywall	0.45
Inside Air Film	0.68
Total Wall Assembly R-Value	**13.73**

R value Table

Material	R/Inch	R/Thickness
Insulation Materials		
Fiberglass Batt	3.14	
Fiberglass Blown (attic)	2.20	
Fiberglass Blown (wall)	3.20	
Rock Wool Batt	3.14	
Rock Wool Blown (attic)	3.10	
Rock Wool Blown (wall)	3.03	
Cellulose Blown (attic)	3.13	
Cellulose Blown (wall)	3.70	
Vermiculite	2.13	
Air-entrained Concrete	3.90	
Urea terpolymer foam	4.48	
Rigid Fiberglass (> 4lb/ft3)	4.00	
Expanded Polystyrene (beadboard)	4.00	
Extruded Polystyrene	5.00	
Polyurethane (foamed-in-place)	6.25	
Polyisocyanurate (foil-faced)	7.20	
Construction Materials		
Concrete Block 4"		0.80
Concrete Block 8"		1.11
Concrete Block 12"		1.28
Brick 4" common		0.80
Brick 4" face		0.44
Poured Concrete	0.08	
Soft Wood Lumber	1.25	

2” nominal (1 1/2”)		1.88
2x4 (3 1/2")		4.38
2x6 (5 1/2")		6.88
Cedar Logs and Lumber	1.33	
Sheathing Materials		
Plywood	1.25	
1/4"		0.31
3/8"		0.47
1/2"		0.63
5/8”		0.77
3/4"		0.94
Fiberboard	2.64	
1/2"		1.32
25/32”		2.06
Fiberglass (3/4”)		3.00
(1”)		4.00
(1 1/2")		6.00
Extruded Polystyrene (3/4”)		3.75
(1”)		5.00
(1 1/2")		7.50
Foil-faced Polyisocyanurate (3/4”)		5.40
(1”)		7.20
(1 1/2")		10.80
Sliding Materials		
Hardboard (1/2”)		0.34
Plywood (5/8”)		0.77
(3/4”)		0.93
Wood Bevel Lapped		0.80
Aluminum, Steel, Vinyl (hollow backed)		0.61
(w/ 1/2” Insulating board)		1.80
Brick 4”		
Interior Finish Materials		
Gypsum Board (drywall 1/2")		0.45
(5/8”)		0.56
Paneling (3/8”)		0.47
Flooring Materials		
Plywood	1.25	
(3/4”)		0.93
Particle Board (underlayment)	1.31	
(5/8”)		0.82
Hardwood Flooring	0.91	
(3/4”)		0.68
Tile, Linoleum		0.05
Carpet (fibrous pad)		2.08
(rubber pad)		1.23

Roofing Materials		
Asphalt Shingles		0.44
Wood Shingles		0.97
Windows		
Single Glass		0.91
w/storm		2.00
Double insulating glass (3/16") air space		1.61
(1/4" air space)		1.69
(1/2" air space)		2.04
(3/4" air space)		2.38
(1/2" w Low-E 0.20)		3.13
(w/ suspended film)		2.77
(w/ 2 suspended films)		3.85
(w/ suspended film and low-E)		4.05
Triple insulating glass (1/4" air spaces)		2.56
(1/2" air spaces)		3.23
Additional for tight fitting drapes or shades, or closed blinds		0.29
Doors		
Wood Hollow Core Flush (1 3/4")		2.17
Solid Core Flush (1 3/4")		3.03
Solid Core Flush (2 1/4")		3.70
Panel Door w/ 7/16" Panels (1 3/4")		1.85
Storm Door (wood 50% glass)		1.25
(metal)		1.00
Metal Insulating (2" w/ urethane)		15.00
Air Films		
Interior Ceiling		0.61
Interior Wall		0.68
Exterior		0.17
Air Spaces		
1/2" to 4" approximately		1.00

Appendix E

Electrical Load Analysis

Typical Loads:

GENERAL LOADS	
DESCRIPTION	LOAD
Lighting	1.0 W/ft^2
Receptacles	0.5 W/ft^2

TYPICAL CONNECTED LOADS		
DESCRIPTION	LOAD	NOTES
Kitchen Appliances	1,000W	
Laundry	1,000W	
Elevator	50HP	up to 5 stories
Water Booster Pump	10,000W	up to 12 stories
Electric Hot Water Heating	2,000W/bed	
VAC pump	180W/bed	
Compressor	100W/bed	
HVAC	Nameplate Rating	
Medical Equipment	Nameplate Rating	
X-Rays	Nameplate Rating	

Example Load Analysis – Given Information:

- 5,000 ft^2 Healthcare Facility
- (2) dedicated kitchen appliance circuits
- (1) dedicated laundry circuit
- HVAC Nameplate = 5,000W
- X-Ray Nameplate = 2,000W

Step 1 – Total General Loads:
Lighting = (1.0W/ft^2) x (5,000ft^2) = 5,000W
Receptacles = (0.5W/ft^2) x (5,000ft^2) = 2,500W
Total General Loads = 7,500W

Step 2 – Total Connected Loads:
(2) Kitchen Appliances = (2) x (1,000W) = 2,000W
(1) Laundry = 1,000W
HVAC Nameplate = 5,000W
X-Ray Nameplate = 2,000W
Total Connected Loads = 10,000W

Step 3 - TOTAL Load:
TOTAL Load (W) = Total General Loads (W) + [0.5 x Total Connected Loads (W)]
TOTAL Load (W) = 7,500W + [0.5 x 10,000W] = 12,500W or 12.5kW

Step 4 – Service Panel Sizing:
Size service panel based on the TOTAL Load (W)

- Clinic Power Distribution – 120/240V, 1ϕ
  - Service Panel Size = TOTAL Load (W)/240V
  - Service Panel Size = 12,500W/240V = 52 Amps

- Hospital or Health Center Power Distribution – 240/400V, 3ϕ
  - Service Panel Size = TOTAL Load (W)/[1.73x400V)
  - Service Panel Size = 12,500W/[1.73 x 400V] = 18 Amps

Step 5 - Generator Size:
Generator Size = Total Load (W) x 1.25
Generator Size = 12,500W x 1.25 = 15,625W or 15.6kW
Refer to Appendix L: Generator Sizing
Generator Capacity = 17,500W or 17.5kW

Appendix F

30.3 NFPA 70, NEC TABLES

Copper

Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C, Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth, Based on Ambient Temperature of 30°C.			
Size kcmil (AWG)	60°C	75°C	90°C
	TW, UF	THHW, THWN, XHHW	THHW, XHHW, RHW-2
4 kcmil (#14)	15	20	25
7 kcmil (#12)	20	25	30
10 kcmil (#10)	30	35	40
17 kcmil (#8)	40	50	55
26 kcmil (#6)	55	65	75
42 kcmil (#4)	70	85	95
53 kcmil (#3)	85	100	115
66 kcmil (#2)	95	115	130
84 kcmil (#1)	110	130	145
106 kcmil (#1/0)	125	150	170
133 kcmil (#2/0)	145	175	195
168 kcmil (#3/0)	165	200	225
212 kcmil (#4/0)	195	230	260
250 kcmil	215	255	290
300 kcmil	240	285	320
350 kcmil	260	310	350
400 kcmil	280	335	380
500 kcmil	320	380	430
600 kcmil	350	420	475

NEC 2011 HANDBOOK, Table 310.15(B)(16), pg. 336

Aluminum or Copper-Clad Aluminum

Allowable Ampacities of Insulated Conductors Rated Up to and Including 2000 Volts, 60°C Through 90°C, Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth, Based on Ambient Temperature of 30°C.			
Size kcmil (AWG)	60°C	75°C	90°C
	TW, UF	THHW, THWN, XHHW	THHW, XHHW, RHW-2
4 kcmil (#14)	-	-	-
7 kcmil (#12)	15	20	25
10 kcmil (#10)	25	30	35
17 kcmil (#8)	35	40	45
26 kcmil (#6)	40	50	55
42 kcmil (#4)	55	65	75
53 kcmil (#3)	65	75	85
66 kcmil (#2)	75	90	100
84 kcmil (#1)	85	100	115
106 kcmil (#1/0)	100	120	135
133 kcmil (#2/0)	115	135	150
168 kcmil (#3/0)	130	155	175
212 kcmil (#4/0)	150	180	205
250 kcmil	170	205	230
300 kcmil	195	230	260
350 kcmil	210	250	280
400 kcmil	225	270	305
500 kcmil	260	310	350
600 kcmil	285	340	385

NEC 2011 HANDBOOK, Table 310.15(B)(16) pg. 336

Maximum Number of Conductors or Fixture Wires in Flexible Metal Conduit (FMC)

CONDUCTORS											
		Metric Designator									
	Conductor Size	16	21	27	35	41	53	63	78	91	103
Type	kcmil (AWG)	½"	¾"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"
THHN,	4 kcmil (#14)	13	22	33	52	76	134	202	291	396	518
THWN,	7 kcmil (#12)	9	16	24	38	56	98	147	212	289	378
THWN-2	10 kcmil (#10)	6	10	15	24	35	62	93	134	182	238
	17 kcmil (#8)	3	6	9	14	20	35	53	77	105	137
	26 kcmil (#6)	2	4	6	10	14	25	38	55	76	99
	42 kcmil (#4)	1	2	4	6	9	16	24	34	46	61
	53 kcmil (#3)	1	1	3	5	7	13	20	29	39	51
	66 kcmil (#2)	1	1	3	4	6	11	17	24	33	43
	84 kcmil (#1)	1	1	1	3	4	8	12	18	24	32
	106 kcmil (#1/0)	1	1	1	2	4	7	10	15	20	27
	133 kcmil (#2/0)	0	1	1	1	3	6	9	12	17	22
	168 kcmil (#3/0)	0	1	1	1	2	5	7	10	14	18
	212 kcmil (#4/0)	0	1	1	1	1	4	6	8	12	15
	250 kcmil	0	0	1	1	1	3	5	7	9	12
	300 kcmil	0	0	1	1	1	3	4	6	8	11
	350 kcmil	0	0	1	1	1	2	3	5	7	9
	400 kcmil	0	0	0	1	1	1	3	5	6	8
	500 kcmil	0	0	0	1	1	1	2	4	5	7
	600 kcmil	0	0	0	0	1	1	1	3	4	5

NEC 2011 HANDBOOK, Table C.3, pg. 1364

Appendix G

Fault Current Calculations

*Note: Fault current calculations are based on Bussman point to point method.

Three (3) phase line to line fault current calculations:

I_{sc} = ($I_{available}$)*M

M = 1/(1+F)

F = (1.73 x L x $I_{available}$)/(C x n x E_{L-L})

C = values found in Bussmann SPD Handbook for conductors and busway

E_{L-L} = line to line voltage

L = length of run in feet (1m = 3.281ft OR 1ft = 0.3048m)

n = number of conductors per phase

The same calculations for single (1) phase line to line, F value changes:

F = (2 x L x $I_{available}$)/(C x n x E_{L-L})

The same calculations for the fault current at the secondary side of the transformer, F value changes:

F = ($I_{sc,primary}$ x $V_{primary}$ x 1.73 x %Z)/(100,000 x kVA_{xfmr})

"C" VALUES FOR BUSWAY					
Ampacity	Busway				
	Plug In	Feeder		High Impedance	
	Copper	Aluminum	Copper	Aluminum	Copper
225	28700	23000	18700	12000	----
400	38900	34700	23900	21300	----
600	41000	38300	36500	31300	----
800	46100	57500	49300	44100	----
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	----	----	277800	256400	----

"C" VALUES FOR CONDUCTORS								
Copper					Aluminum			
	Three Single Conductors Conduit		Three-Conductor Cable Conduit		Three Single Conductors Conduit		Three-Conductor Cable Conduit	
Kcmil (AWG)	Steel	Nonmagnetic	Steel	Nonmagnetic	Steel	Nonmagnetic	Steel	Nonmagnetic
	600V	600V	600V	600V	600V	600V	600V	600V
4 kcmil (#14)	389	389	389	389	236	236	236	236
7 kcmil (#12)	617	617	617	617	375	375	375	375
10 kcmil (#10)	981	981	981	981	598	598	598	598
17 kcmil (#8)	1557	1558	1559	1559	951	951	951	951
26 kcmil (#6)	2425	2430	2431	2433	1480	1481	1481	1482
42 kcmil (#4)	3806	3825	3830	3837	2345	2350	2351	2353
53 kcmil (#3)	4760	4802	4760	4802	2948	2958	2948	2958
66 kcmil (#2)	5906	6044	5989	6087	3713	3729	3733	3739
84 kcmil (#1)	7292	7493	7454	7579	4645	4678	4686	4699
106 kcmil (#1/0)	8924	9317	9209	9472	5777	5838	5852	5875
133 kcmil (#2/0)	10755	11423	11244	11703	7186	7301	7327	7372
168 kcmil (#3/0)	12843	13923	13656	14410	8826	9110	9077	9242
212 kcmil (#4/0)	15082	16673	16391	17482	10740	11174	11184	11408
250 kcmil	16483	18593	18310	19779	12122	12862	12796	13236
300 kcmil	18176	20867	20617	22524	13909	14922	14916	15494
350 kcmil	19703	22736	22646	24904	15484	16812	15413	17635
400 kcmil	20565	24296	24253	26915	16670	18505	18461	19587
500 kcmil	22185	26706	26980	30028	18755	21390	21394	22987
600 kcmil	22965	28033	28752	32236	20093	23451	23633	25750
750 kcmil	24136	28303	31050	32404	21766	25976	26431	29036
1000 kcmil	25278	31490	33864	37197	23477	28778	29864	32938

TRANSFORMERS				
Table 1. Short-Circuit Currents Available from Various Size Transformers				
Voltage & Phase	kVA	FLA	%Z	I_{SC}
120/240 1ph	25	104	1.50	12175
	37.5	156	1.50	18018
	50	208	1.50	23706
	75	313	1.50	34639
	100	417	1.60	42472
	167	696	1.60	66644
120/208 3ph	45	125	1.00	13879
	75	208	1.00	23132
	1125.5	312	1.11	31259
	150	416	1.07	43237
	225	625	1.12	61960
	300	833	1.11	83357
	500	1388	1.24	124364
	750	2082	3.50	66091
	1000	2776	3.50	88121
	1500	4164	3.50	132181
	2000	5552	4.00	154211
	2500	6940	4.00	192764
277/480 3ph	75	90	1.00	10035
	112.5	135	1.00	15053
	150	181	1.20	16726
	225	271	1.20	25088
	300	361	1.20	33451
	500	602	1.30	51463
	750	903	3.50	28672
	1000	1204	3.50	38230
	1500	1806	3.50	57345
	2000	2408	4.00	66902
	2500	3011	4.00	83628

Appendix H

Voltage Drop Chart

230 VOLT, SINGLE PHASE LOADS										
WATTS	DISTANCE (ft.)									
	50	100	150	200	250	300	350	400	450	500
500	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)
1000	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	10 kcmil (#10)	10 kcmil (#10)	10 kcmil (#10)
1500	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	10 kcmil (#10)	10 kcmil (#10)	10 kcmil (#10)	17 kcmil (#8)	17 kcmil (#8)	17 kcmil (#8)
2000	7 kcmil (#12)	7 kcmil (#12)	7 kcmil (#12)	10 kcmil (#10)	10 kcmil (#10)	17 kcmil (#8)	17 kcmil (#8)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)
2500	7 kcmil (#12)	7 kcmil (#12)	10 kcmil (#10)	10 kcmil (#10)	17 kcmil (#8)	17 kcmil (#8)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	26 kcmil (#6)
3000	7 kcmil (#12)	7 kcmil (#12)	10 kcmil (#10)	17 kcmil (#8)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	26 kcmil (#6)	26 kcmil (#6)	42 kcmil (#4)
3500	7 kcmil (#12)	7 kcmil (#12)	10 kcmil (#10)	17 kcmil (#8)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	26 kcmil (#6)	42 kcmil (#4)	42 kcmil (#4)
4000	7 kcmil (#12)	10 kcmil (#10)	17 kcmil (#8)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	26 kcmil (#6)	42 kcmil (#4)	42 kcmil (#4)	42 kcmil (#4)
4500	10 kcmil (#10)	10 kcmil (#10)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	26 kcmil (#6)	42 kcmil (#4)	42 kcmil (#4)	42 kcmil (#4)	66 kcmil (#2)
5000	10 kcmil (#10)	10 kcmil (#10)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	42 kcmil (#4)	42 kcmil (#4)	42 kcmil (#4)	66 kcmil (#2)	66 kcmil (#2)
5500	10 kcmil (#10)	10 kcmil (#10)	17 kcmil (#8)	26 kcmil (#6)	26 kcmil (#6)	42 kcmil (#4)	42 kcmil (#4)	42 kcmil (#4)	66 kcmil (#2)	66 kcmil (#2)

Calculations:

-For service panel conductors VD% < 2%

-For branch conductors VD% < 3%

Three (3) phase voltage drop calculation:

VD = (1.73*L*R*I)/1000

VD% = (VD/V)*100

VD = voltage drop

L = length of run in feet

R = conductor resistance (Ω/1000 ft)

I = current (amps)

Single (1) phase voltage drop calculation:

VD = (2*L*R*I)/1000

VD% = (VD/V)*100

COPPER CONDUCTOR PROPERTIES	
WIRE SIZE	AC RESISTANCE [Ω/1000 ft]
4 kcmil (#14)	3.1
7 kcmil (#12)	2
10 kcmil (#10)	1.2
17 kcmil (#8)	0.78
26 kcmil (#6)	0.49
42 kcmil (#4)	0.31
53 kcmil (#3)	0.25
66 kcmil (#2)	0.2
84 kcmil (#1)	0.16
106 kcmil (#1/0)	0.13
133 kcmil (#2/0)	0.11
168 kcmil (#3/0)	0.094
212 kcmil (#4/0)	0.08
250 kcmil	0.073
300 kcmil	0.065
350 kcmil	0.06
400 kcmil	0.056
500 kcmil	0.05
600 kcmil	0.047

NEC 2011 HANDBOOK, Table 9, pg. 1321

ALUMINUM CONDUCTOR PROPERTIES	
WIRE SIZE	AC RESISTANCE [Ω/1000 ft]
4 kcmil (#14)	0
7 kcmil (#12)	3.2
10 kcmil (#10)	2
17 kcmil (#8)	1.3
26 kcmil (#6)	0.81
42 kcmil (#4)	0.51
53 kcmil (#3)	0.4
66 kcmil (#2)	0.32
84 kcmil (#1)	0.25
106 kcmil (#1/0)	0.2
133 kcmil (#2/0)	0.16
168 kcmil (#3/0)	0.14
212 kcmil (#4/0)	0.11
250 kcmil	0.1
300 kcmil	0.088
350 kcmil	0.08
400 kcmil	0.073
500 kcmil	0.064
600 kcmil	0.058

NEC 2011 HANDBOOK, Table 9, pg. 1321

COPPER CONDUCTOR PROPERTIES	
WIRE SIZE	DC RESISTANCE [Ω/1000 ft]
4 kcmil (#14)	3.26
7 kcmil (#12)	2.05
10 kcmil (#10)	1.29
17 kcmil (#8)	0.809
26 kcmil (#6)	0.51
42 kcmil (#4)	0.321
53 kcmil (#3)	0.254
66 kcmil (#2)	0.201
84 kcmil (#1)	0.16
106 kcmil (#1/0)	0.127
133 kcmil (#2/0)	0.101
168 kcmil (#3/0)	0.0797
212 kcmil (#4/0)	0.0626
250 kcmil	0.0535
300 kcmil	0.0446
350 kcmil	0.0382
400 kcmil	0.0331
500 kcmil	0.0265
600 kcmil	0.0223

NEC 2011 HANDBOOK, Table 8, pg. 1320

ALUMINUM CONDUCTOR PROPERTIES	
WIRE SIZE	DC RESISTANCE [Ω/1000 ft]
4 kcmil (#14)	5.17
7 kcmil (#12)	3.25
10 kcmil (#10)	2.04
17 kcmil (#8)	1.28
26 kcmil (#6)	0.808
42 kcmil (#4)	0.508
53 kcmil (#3)	0.403
66 kcmil (#2)	0.319
84 kcmil (#1)	0.253
106 kcmil (#1/0)	0.201
133 kcmil (#2/0)	0.159
168 kcmil (#3/0)	0.126
212 kcmil (#4/0)	0.1
250 kcmil	0.0847
300 kcmil	0.0707
350 kcmil	0.0605
400 kcmil	0.0529
500 kcmil	0.0424
600 kcmil	0.0353

NEC 2011 HANDBOOK, Table 8, pg. 1320

Appendix I

Feeder Sizing

FEEDER SCHEDULE (COPPER)						
AMPACITY	Qty	Conductor Size (Provide For 3ϕ Conductors)	NEUTRAL SIZE	EARTH SIZE	CONDUIT (3C+E)	CONDUIT (3C+N+E)
20	1	7 kcmil	7 kcmil	7 kcmil	16	16
30	1	10 kcmil	10 kcmil	10 kcmil	21	21
40	1	17 kcmil	17 kcmil	10 kcmil	21	27
50	1	26 kcmil	26 kcmil	10 kcmil	27	27
60	1	42 kcmil	42 kcmil	17 kcmil	35	35
70	1	42 kcmil	42 kcmil	17 kcmil	35	35
80	1	53 kcmil	53 kcmil	17 kcmil	35	41
90	1	66 kcmil	66 kcmil	17 kcmil	35	41
100	1	84 kcmil	84 kcmil	17 kcmil	41	53
125	1	106 kcmil	106 kcmil	26 kcmil	41	53
150	1	106 kcmil	106 kcmil	26 kcmil	41	53
175	1	133 kcmil	133 kcmil	26 kcmil	53	53
200	1	168 kcmil	168 kcmil	26 kcmil	53	63
225	1	212 kcmil	212 kcmil	42 kcmil	63	63
250	1	250 kcmil	250 kcmil	42 kcmil	63	78
275	1	300 kcmil	300 kcmil	42 kcmil	63	78
300	1	350 kcmil	350 kcmil	42 kcmil	78	78
350	1	500 kcmil	500 kcmil	53 kcmil	78	91
400	2	168 kcmil	168 kcmil	53 kcmil	91	103
500	2	250 kcmil	250 kcmil	66 kcmil	63	78
600	2	350 kcmil	350 kcmil	84 kcmil	78	78
800	3	300 kcmil	300 kcmil	106 kcmil	63	78
1000	3	400 kcmil	400 kcmil	133 kcmil	78	91
1200	4	350 kcmil	350 kcmil	168 kcmil	78	78
1400	4	500 kcmil	500 kcmil	212 kcmil	91	103
1600	5	400 kcmil	400 kcmil	212 kcmil	91	103
2000	6	400 kcmil	400 kcmil	250 kcmil	78	103
3000	8	500 kcmil	500 kcmil	400 kcmil	103	103
4000	12	400 kcmil	400 kcmil	500 kcmil	91	103
NOTES: C = CONDUIT E = EARTH N = NEUTRAL						

FEEDER SCHEDULE (COPPER)						
AMPACITY	QTY	CONDUCTOR SIZE (PROVIDE FOR 3ϕ CONDUCTORS)	NEUTRAL SIZE	EARTH SIZE	CONDUIT (3C+E)	CONDUIT (3C+N+E)
20	1	#12	#12	#12	1/2"	1/2"
30	1	#10	#10	#10	3/4"	3/4"
40	1	#8	#8	#10	3/4"	1"
50	1	#6	#6	#10	1"	1"
60	1	#4	#4	#8	1-1/4"	1-1/4"
70	1	#4	#4	#8	1-1/4"	1-1/4"
80	1	#3	#3	#8	1-1/4"	1-1/2"
90	1	#2	#2	#8	1-1/4"	1-1/2"
100	1	#1	#1	#8	1-1/2"	2"
125	1	#1/0	#1/0	#6	1-1/2"	2"
150	1	#1/0	#1/0	#6	1-1/2"	2"
175	1	#2/0	#2/0	#6	2"	2"
200	1	#3/0	#3/0	#6	2"	2-1/2"
225	1	#4/0	#4/0	#4	2-1/2"	2-1/2"
250	1	250 kcmil	250 kcmil	#4	2-1/2"	3"
275	1	300 kcmil	300 kcmil	#4	2-1/2"	3"
300	1	350 kcmil	350 kcmil	#4	3"	3"
350	1	500 kcmil	500 kcmil	#3	3"	3-1/2"
400	2	#3/0	#3/0	#3	3-1/2"	4"
500	2	250 kcmil	250 kcmil	#2	2-1/2"	3"
600	2	350 kcmil	350 kcmil	#1	3"	3"
800	3	300 kcmil	300 kcmil	#1/0	2-1/2"	3"
1000	3	400 kcmil	400 kcmil	#2/0	3"	3-1/2"
1200	4	350 kcmil	350 kcmil	#3/0	3"	3"
1400	4	500 kcmil	500 kcmil	#4/0	3-1/2"	4"
1600	5	400 kcmil	400 kcmil	#4/0	3-1/2"	4"
2000	6	400 kcmil	400 kcmil	250 kcmil	3"	4"
3000	8	500 kcmil	500 kcmil	400 kcmil	4"	4"
4000	12	400 kcmil	400 kcmil	500 kcmil	3-1/2"	4"

NOTES:
C = CONDUIT
E = EARTH
N = NEUTRAL

FEEDER SCHEDULE (ALUMINUM)						
AMPACITY	QTY	CONDUCTOR SIZE (PROVIDE FOR 3ϕ CONDUCTORS)	NEUTRAL SIZE	EARTH SIZE	CONDUIT (3C & E)	CONDUIT (3C+N+E)
20	1	10 kcmil	10 kcmil	10 kcmil	16	16
30	1	17 kcmil	17 kcmil	17 kcmil	21	21
40	1	26 kcmil	26 kcmil	17 kcmil	27	27
50	1	42 kcmil	42 kcmil	17 kcmil	35	35
60	1	53 kcmil	53 kcmil	17 kcmil	35	41
70	1	66 kcmil	66 kcmil	26 kcmil	41	41
80	1	84 kcmil	84 kcmil	26 kcmil	41	53
90	1	106 kcmil	106 kcmil	26 kcmil	53	53
100	1	106 kcmil	106 kcmil	26 kcmil	53	53
125	1	133 kcmil	133 kcmil	42 kcmil	53	53
150	1	168 kcmil	168 kcmil	42 kcmil	53	63
175	1	212 kcmil	212 kcmil	42 kcmil	63	63
200	1	250 kcmil	250 kcmil	42 kcmil	63	78
225	1	300 kcmil	300 kcmil	66 kcmil	78	78
250	1	350 kcmil	350 kcmil	66 kcmil	78	78
275	1	500 kcmil	500 kcmil	66 kcmil	78	91
300	1	500 kcmil	500 kcmil	66 kcmil	78	91
350	2	212 kcmil	212 kcmil	84 kcmil	63	63
400	2	250 kcmil	250 kcmil	84 kcmil	63	78
500	2	350 kcmil	350 kcmil	106 kcmil	78	78
600	2	500 kcmil	500 kcmil	133 kcmil	78	91
800	3	400 kcmil	400 kcmil	168 kcmil	78	91
1000	4	350 kcmil	350 kcmil	212 kcmil	78	78
1200	4	500 kcmil	500 kcmil	250 kcmil	78	91
1400	5	500 kcmil	500 kcmil	350 kcmil	78	91
1600	6	400 kcmil	400 kcmil	350 kcmil	78	91
2000	7	500 kcmil	500 kcmil	400 kcmil	91	91
3000	10	500 kcmil	500 kcmil	600 kcmil	103	103
4000	13	500 kcmil	500 kcmil	750 kcmil	103	103

NOTES:
C = CONDUIT
E = EARTH
N = NEUTRAL

FEEDER SCHEDULE (ALUMINUM)						
AMPACITY	QTY	CONDUCTOR SIZE (PROVIDE FOR 3ϕ CONDUCTORS)	NEUTRAL SIZE	EARTH SIZE	CONDUIT (3C & E)	CONDUIT (3C+N+E)
20	1	#12 Cu	#12 Cu	#12 Cu	1/2"	1/2"
30	1	#8	#8	#8	3/4"	3/4"
40	1	#6	#6	#8	1"	1"
50	1	#4	#4	#8	1-1/4"	1-1/4"
60	1	#3	#3	#8	1-1/4"	1-1/2"
70	1	#2	#2	#6	1-1/2"	1-1/2"
80	1	#1	#1	#6	1-1/2"	2"
90	1	#1/0	#1/0	#6	2"	2"
100	1	#1/0	#1/0	#6	2"	2"
125	1	#2/0	#2/0	#4	2"	2"
150	1	#3/0	#3/0	#4	2"	2-1/2"
175	1	#4/0	#4/0	#4	2-1/2"	2-1/2"
200	1	250 kcmil	250 kcmil	#4	2-1/2"	3"
225	1	300 kcmil	300 kcmil	#2	3"	3"
250	1	350 kcmil	350 kcmil	#2	3"	3"
275	1	500 kcmil	500 kcmil	#2	3"	3-1/2"
300	1	500 kcmil	500 kcmil	#2	3"	3-1/2"
350	2	#4/0	#4/0	#1	2-1/2"	2-1/2"
400	2	250 kcmil	250 kcmil	#1	2-1/2"	3"
500	2	350 kcmil	350 kcmil	#1/0	3"	3"
600	2	500 kcmil	500 kcmil	#2/0	3"	3-1/2"
800	3	400 kcmil	400 kcmil	#3/0	3"	3-1/2"
1000	4	350 kcmil	350 kcmil	#4/0	3"	3"
1200	4	500 kcmil	500 kcmil	250 kcmil	3"	3-1/2"
1400	5	500 kcmil	500 kcmil	350 kcmil	3"	3-1/2"
1600	6	400 kcmil	400 kcmil	350 kcmil	3"	3-1/2"
2000	7	500 kcmil	500 kcmil	400 kcmil	3-1/2"	3-1/2"
3000	10	500 kcmil	500 kcmil	600 kcmil	4"	4"
4000	13	500 kcmil	500 kcmil	750 kcmil	4"	4"

NOTES:
C = CONDUIT
E = EARTH
N = NEUTRAL

Appendix J

Minimum Circuit Ampacity

$$FLA = \frac{(HP)\left(\frac{W}{HP}\right)}{(VOLTS)\sqrt{PHASE}}$$

$$MCA = 1.25 \times FLA$$

Example for clinic:

$$FLA = \frac{(10HP)(746\frac{W}{HP})}{(230V)\sqrt{1}} = 32.4\ amps$$

$$MCA = 1.25 \times FLA = 40.5\ amps$$

Example for hospital or health center:

$$FLA = \frac{(10HP)(746\frac{W}{HP})}{(400V)\sqrt{3}} = 10.8\ amps$$

$$MCA = 1.25 \times FLA = 13.5\ amps$$

Appendix K

Earthing Electrode Conductor

Earthing Electrode Conductor for Alternating-Current Systems			
Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Are for Parallel Conductors kcmil (AWG)		Size of Grounding Electrode Conductor kcmil (AWG)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
66 (#2) or smaller	106 (#1/0) or smaller	17 (#8)	26 (#6)
84 (#1) or 106 (#1/0)	133 (#2/0) or 168 (#3/0)	26 (#6)	42 (#4)
133 (#2/0) or 168 (#3/0)	212 (#4/0) or 250	42 (#4)	66 (#2)
over 168 (#3/0) thru 350	over 250 thru 500	66 (#2)	106 (#1/0)
over 350 thru 600	over 500 thru 900	106 (#1/0)	168 (#3/0)
over 600 thru 1100	over 900 thru 1750	133 (#2/0)	212 (#4/0)
over 1100	over 1750	168 (#3/0)	250

NEC 2011 HANDBOOK, Table 250.66, pg. 246

Earthing Conductor

Min. Size Equipment Earthing Conductors for Earthing Raceway and Equipment		
Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amps)	Size kcmil (AWG)	
	Copper	Aluminum or Copper-Clad Aluminum
15	4 (#14)	7 (#12)
20	7 (#12)	10 (#10)
60	10 (#10)	17 (#8)
100	17 (#8)	26 (#6)
200	26 (#6)	42 (#4)
300	42 (#4)	66 (#2)
400	53 (#3)	84 (#1)
500	66 (#2)	106 (#1/0)
600	84 (#1)	133 (#2/0)
800	106 (#1/0)	168 (#3/0)
1000	133 (#2/0)	212 (#4/0)
1200	168 (#3/0)	250
1600	212 (#4/0)	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

NEC 2011 HANDBOOK, Table 250.122, pg. 268

Appendix L

Generator Sizing

GENERATOR SIZING							
Generator Capacity (Watts)	Generator Weight, Wet (kg)	Generator Dimensions (mm)			Minimum Room Dimensions (Meters)		
		Length	Width	Height	Length	Width	Height
5000	181	876	581	514	3.0	2.4	2.5
6000	190	923	615	565	3.1	2.4	2.5
6500	190	923	615	565	3.1	2.4	2.5
7000	272	911	566	593	3.0	2.4	2.5
7500	223	972	535	607	3.1	2.4	2.5
8000	191	923	615	565	3.1	2.4	2.5
9500	315	1033	566	593	3.2	2.4	2.5
10,000	348	1054	621	658	3.2	2.4	2.5
11,000	315	1033	566	593	3.2	2.4	2.5
12,000	359	1053	621	685	3.2	2.4	2.5
13,500	404	1127	602	698	3.3	2.4	2.5
17,500	422	1127	602	698	3.3	2.4	2.5
19,000	422	1127	602	698	3.3	2.4	2.5

Appendix M

PV Sizing

1. Determine what type of PV system to install
    a. Off-grid
    b. Grid-tied with batteries
    c. Grid-tied without batteries
2. Determine power consumption demands
    a. Calculate total watt-hours per day for each appliance used.
    b. Calculate total watt-hours per day needed from the PV modules.
3. Size the PV modules
    a. Calculate the total watt-peak rating needed for pv modules
    b. Calculate the number of PV panels for the system
4. Inverter sizing
5. Battery sizing (desired autonomy = 3-4 days)
6. Charge controller sizing

Resources:
http://www.leonics.com/support/article2_12j/articles2_12j_en.php
http://www.energytorus.com/resources-solar-pv-design.html

Appendix N

Junction Box Fill

JUNCTION BOXES							
Box Trade Size		Minimum Volume	Maximum Number of Conductors arranged by kcmil (AWG)				
mm (in.)	shape	cm^3 (in^3)	4 (#14)	7 (#12)	10 (#10)	17 (#8)	26 (#6)
100 x 32 (4 x 1-1/4)	square	295 (18.0)	9	8	7	6	3
100 x 38 (4 x 1-1/2)	square	344 (21.0)	10	9	8	7	4
100 x 54 (4 x 2-1/8)	square	497 (30.3)	15	13	12	10	6
120 x 32 (4-11/16 x 1-1/4)	square	418 (25.5)	12	11	10	8	5
120 x 38 (4-11/16 x 1-1/2)	square	484 (29.5)	14	13	11	9	5
120 x 54 (4-11/16 x 2-1/8)	square	689 (42.0)	21	18	16	14	8
75 x 50 x 38 (3 x 2 x 1-1/2)	device	123 (7.5)	3	3	3	2	1
75 x 50 x 50 (3 x 2 x 2)	device	164 (10.0)	5	4	4	3	2
75 x 50 x 57 (3 x 2 x 2-1/4)	device	172 (10.5)	5	4	4	3	2
75 x 50 x 65 (3 x 2 x 2-1/2)	device	205 (12.5)	6	5	5	4	2
75 x 50 x 70 (3 x 2 x 2-3/4)	device	230 (14.0)	7	6	5	4	2
75 x 50 x 90 (3 x 2 x 3-1/2)	device	295 (18.0)	9	8	7	6	3
100 x 54 x 38 (4 x 2-1/8 x 1-1/2)	device	169 (10.3)	5	4	4	3	2
100 x 54 x 48 (4 x 2-1/8 x 1-7/8)	device	213 (13.0)	6	5	5	4	2
100 x 54 x 54 (4 x 2-1/8 x 2-1/8)	device	238 (14.5)	7	6	5	4	2

NEC 2011 HANDBOOK, Table 314.16(A), pg. 367

Volume Allowance Required per Conductor	
Size of Conductor kcmil (AWG)	Free Space Within Box for Each Conductor
	cm^3 (in^3)
4 (#14)	32.8 (2.0)
7 (#12)	36.9 (2.25)
10 (#10)	41 (2.5)
17 (#8)	49.2 (3.0)
26 (#6)	81.9 (5.0)

NEC 2011 HANDBOOK, Table 314.16(B), pg. 368

For junction boxes containing conductors 42 kcmil (#4 AWG) or larger the minimum dimensions of junction boxes installed must meet the following criteria.
1) Straight Pulls: in straight pulls, the length of the box or conduit body shall not be less than eight times the metric designator (trade size) of the largest raceway.
2.) Angle or U Pulls, or Splices: for splices and u pulls the distance between each raceway entry inside the box and the opposite wall of the box shall not be less than six times the metric designator (trade size) of the largest raceway in a row. This distance shall be increased for additional entries by the amount of the sum of the diameters of all other raceway entries in the same row on the same wall of the box. Each row shall be calculated individually, and the single row that provides the maximum distance shall be used.

NEC 2011 HANDBOOK, Table 314.16(C), pg. 378

Appendix O

Basic Power Equations

Single Phase Power	Power = Volt * Amps	P=V*I
Three Phase Power	Power = √3* Volt * Amps	P = √3*V*I
Definitions:		
P = Power (Watts)	V = Volts	I = Amps

Example: Determine Power (Watts)	
Conditions	Calculation
Single Phase	P=V*I
Volts=230, 1 Phase	P=230*20
Amps=20	P=4,600 Watts

Example: Determine Power (Watts)	
Conditions	Calculation
Three Phase	P= √3*V*I
Volts=230, 1 Phase	P=√3*230*20
Amps=20	
	P=7,967 Watts

Appendix P

Percolation Test Procedures

A. Preparation of Test Holes

Dig or bore three holes 3, 5 and 7 feet deep. After holes are dug, remove all loose material possible after carefully scraping the bottom and sides to remove any smeared soil surfaces. Add clean pea-gravel (maximum of 1 inch) to stabilize the hole, insert a perforated pipe (3 inch diameter) and place pea-gravel around exterior of pipe at least 12 inches, or up to ground surface.

B. Presoaking of Test Holes

On the day prior to conducting the tests, fill the holes completely with clear water and refill at least four (4) times the day prior to the tests.

C. Percolation-Rate Measurements

Percolation-rate measurements must be made on the day following the presoaking of test holes.

1) When water remains from presoaking, record the inches of water remaining on the report form and adjust the water level to 12 inches over the gravel base. Measurements are then taken from a fixed point at the top of the pipe to the top of the water and like measurements taken each hour for six hours. Record measurements accurately, vertically, and to the nearest 1/8 inch.

2) When no water remains from presoaking, gently add clear water to the hole to a depth of 12 inches over the gravel base. Measure the drop in the water level from a fixed point at the top of the pipe to the top of the water each 30 minutes for four hours. Additional water may be added to 12 inches above the gravel when the hole is empty, or after any reading that indicates the water is less than 2 inches above the gravel. Record the new water elevation and continue measurements for duration of initial six-hour test. Record measurements to the nearest 1/4 inch.

3) When hole is dry before the first 60 minutes upon start of test measurements, add clear water to 12 inches over the gravel base and take measurements every ten minutes for two hours. The 12 inches of water is to be replaced at any time the hole is empty or the water depth is less than 2 inches as stated in B above.

D. Percolation Test Acceptance Criteria

For the soils where the subsurface disposal system is proposed, the minimum acceptable percolation rate is 60 minutes per inch (one inch per hour). The maximum acceptable percolation rate is 1 minute per inch (60 inches per hour). For soils beneath the leaching device the minimum acceptable percolation rate is 60 minutes per inch in the first 3 feet below the trench and 120 minutes/inch (1/2 inch per hour) from 3 to 10 feet below the trench.

E. Groundwater Observation

Observation for seasonal high water tables must take place during the rainy season and when six inches of rainfall has occurred within thirty (30) consecutive days.

Appendix Q

Guidelines to Estimate Wastewater Flows for Different Healthcare Facilities

These guidelines can be used to estimate the wastewater flow for different types of healthcare facilities based on the type of facility and the number of patients served. Table A below presents the per capita daily wastewater flow for each patient served. Because water use and corresponding wastewater flows will be variable at any site, Table A presents three different flow rates that guide the designing to make reasonable flow estimates for the particular facility.

The designer is recommended to use the higher flow values to size any wastewater treatment system, such as a soakaway tank, septic tank, or anaerobic baffled reactor. Using these values will assure that the system is sized to handle a wide range of flow conditions that may occur at the site. If a site has very limited water supply then the designer may opt to use the low flow values. The designer must take into consideration water supply availability and the expected use at the site, than select flow values that they believe are representative of the site.

To estimate wastewater flows at a site simply multiplying the number of patients served each day by the unit flow presented in Table A.

Table A. Wastewater Flow Per Patient Per Day for Different Facility Type

Facility Type	Per Capita Flow (Gallons Per Patient Per Day)		
	Low Flow	High Flow	Average Flow
Regional Hospital	15	30	22.5
Cholera Treatment Center	25	45	35
Regional Health Center	5	10	7.5
Outpatient Clinic	1	3	2

For example:
A regional health clinic is being planned to be installed in Bomi County and the County Health Director estimates that the facility will attend to 300 patients per day. Therefore, the wastewater flows for the facility can be calculated:

Type	Flows	Number of Patients	Daily Flow (Gallons)
Low	5	300	1500
High	10	300	3000
Average	7.5	300	2,250

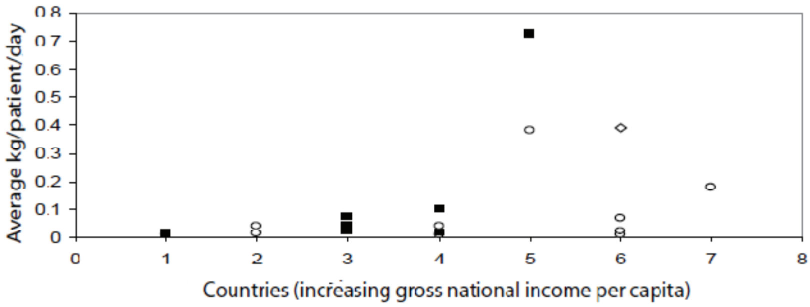
Appendix R

Waste Generation Rates

Average waste generation rates are calculated in kilograms (kg) per day or kg per year. Kilograms per occupied bed per day and kg per patient per day are used especially when comparing different healthcare facilities with different levels of activities. If inpatient occupancy rates and the daily number of outpatients are not available, the total number of beds is often used to estimate kg per bed per day.

Waste-generation data from other countries must be used with caution because of the wide variability even within a country and the many factors that influence the rates. The data in figure 36 b. and 36 c. are provided as indicative values and should be viewed only as examples. They may be useful for order-of–magnitude estimations, but should not be used for detailed planning, budgeting or procurement. Even a limited survey will probably provide more reliable data on local waste generation than any estimated based on data from other countries or types of establishment.

Figure A. Total and infectious waste generation in small clinics, health centers and dispensaries (in kg per patient per day)[1]



■ = total health-care waste; o = infectious waste
1-Tanzania, 2-Bangladesh, 3-Pakistan, 4-Mongolia, 5-Ecuador, 6-South Africa, 7-Mauritius
Source: Emmanuel (2007)

[1] WHO, Safe Management of wastes from healthcare activities, 2013, p. 16

Table A. Total and infectious waste generation by type of healthcare facility[2]

Type of healthcare facility	Total healthcare waste generation	Infectious waste generation
Pakistan		
Hospitals	2.07 kg/bed/day (range 1.28-3.47)	
Clinics and dispensaries	.075 kg/patient-day	.06 kg/patient-day
Basic health units	.04 kg/patient-day	.03 kg/patient-day
Consulting clinics	.025 kg/patient-day	.002 kg/patient-day
Nursing homes	.3 kg/patient-day	
Maternity homes	4.1 kg/patient-day	2.9 kg/patient-day
Tanzania		
Hospitals	.14 kg/patient-day	.08 kg/patient-day
Health centers (urban)	.01 kg/patient-day	.007 kg/patient-day
Rural dispensaries	.04 kg/patient-day	.02 kg/patient-day
Urban dispensaries	.02 kg/patient-day	.01 kg/patient-day
South Africa		
National central hospital		1.24 kg/patient-bed/day
Provincial tertiary hospital		1.53 kg/patient-bed/day
Regional hospital		1.05 kg/patient-bed/day
District hospital		.65 kg/patient-bed/day
Specialized hospital		.17 kg/patient-bed/day
Public clinic		.008 kg/patient-day
Public community health center		.024 kg/patient-day
Private day-surgery clinic		.39 kg/patient-day
Private community health center		.07 kg/patient-day

[2] WHO, Safe management of wastes from healthcare activities, 2013, p.17.

Appendix S

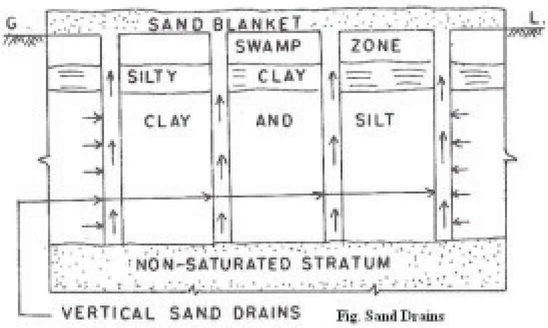
Pipe Drainage Installation Procedure:

Drainage pipes (perforated pipes are laid with perforations down per manufacturer's instructions) should be set in a compacted 4" thick bed of drainage fill material laid with its bottom on the undisturbed sub-grade at the bottom of the footing. The pipes should then be covered with drainage fill material that extends approx. 6 in on each side of the pipe up to about 12 in below the surface of the ground. (The drainage fill shall be placed in 3" lifts) The drainage layer is finally covered in a filter fabric to prevent fine materials from infiltrating drainage layer.

Sand Drains:

Sand drains prove very effective in marshy soils. Soil becomes marshy by as thick layers of clays and silts mixed with organic matter. When this type of soil is subjected to load, its wet soils contents are gradually pushed out on either side- resulting in a "sinking" effect. To avoid this, sand drains are made in the ground. The diameter of the sand drains varies between 12 to 18 inches, and is spaced between 9 and 18 feet. The drain holes are driven deeper than the marshy layer possibly up to an underlying rock or firm base - the hole for making the sand drain can be made by driving steel pipe casting into the ground. The marsh in the pipes is removed. Selected type of sand is then filled into the pipes and the pipes are withdrawn leaving vertical sand piles in the ground. A thick layer of sand (sand blanket) is spread over the entire area to be consolidated. When the sand layer is subjected to load, the water from the muck of the marshy soil gets squeezed into the vertical sand drains.

Figure A. Sand Drain



Appendix T: Facility Sizing Information

Calculating Adjusted Catchment Populations:
Facility sizes are based on catchment population, as well as a number of variables which determine the appropriate sizes of some program elements such as the number of examination rooms, size of wards, number of delivery bays, and number of operating theaters.

A facility is sized based on the expected needs within the next 10 years. Any less than this and facilities may require expansion after being opened for just a few years; any more than this and facilities may be oversized for their initial use, causing increased upfront costs which ought to be avoided.

Using UN data, the overall population growth rate of Liberia is 2.6%. This, however, is not evenly spread across the country; urban areas are growing faster (at 3.4%) than rural areas (at 1.9%). (For these calculations an urban area is considered one in which the population is at least 500,000). Thus, for optimal sizing it is important to distinguish between facilities in faster-growing urban areas and those in more slowly growing rural areas. This leads to the concept of an adjusted catchment population, which is the projected catchment population within 10 years time. For primary care facilities, this is referred to as the adjusted primary catchment population An increase of 3.4% per year in urban areas leads to an approximately 40% overall growth over 10 years; thus if the current population is multiplied by 1.4, an adjusted urban catchment population in 10 years time is achieved. Similarly, an increase of 1.9% per year in rural areas leads to an approximately 20% overall growth over 10 year; thus a multiplier of 1.2 may be used.

Adjusted primary catchment population.

Data		Value
A	Current primary catchment population	TBD
B	Growth rate factor	1.2 for rural areas; 1.4 for urban areas
C	Adjusted primary catchment population	A x B
Example for rural catchments		
A	Current primary catchment population	5,000
B	Growth rate factor	1.2
C	Adjusted Rural Catchment Population	5,000 x 1.2 = **6,000**
Example for urban catchments		
A	Current primary catchment population	5,000
B	Growth rate factor	1.4
C	Adjusted Rural Catchment Population	5,000 x 1.4 = **7,000**

A similar procedure is adopted for referral facilities. In this case, however, the growth of facilities in urban areas is not as rapid, as these facilities are likely to have cases referred from both urban and rural facilities, so the growth rate is somewhere between the two. In this condition, the national average growth rate of 2.6% is used as a balance between urban and rural growth rates. A population growing at 2.6% per year over 10 years leads to a total growth of approximately 30% over 10 years; thus a growth rate factor of 1.3 is used when determining the adjusted referral catchment population for urban facilities, as indicated in the table below.

Adjusted referral catchment population.

Data		Value
A	Current referral catchment population	TBD
B	Growth rate factor	1.2 for rural areas; 1.3 for urban areas
C	Adjusted referral catchment population	A x B
Example for rural catchments		
A	Current referral catchment population	50,000
B	Growth rate factor	1.2
C	Adjusted referral catchment population	50,000 x 1.2 = **60,000**
Example for urban catchments		
A	Current referral catchment population	50,000
B	Growth rate factor	1.3
C	Adjusted referral catchment population	50,000 x 1.3 = **65,000**

Calculating Expected Peak Outpatient Loads:

The peak patient load per day uses many of the same calculations used to find the quantity of examination rooms. Here, the adjusted primary catchment population is multiplied by the average number of first visits per year, and by average number of follow-up visits per year. These numbers are summed to find the total number of visits per year. When this is divided by the number of operating days, one is left with the average patient load per day. A 20% fluctuation in average numbers is assumed on any given day, meaning the average patient load per day must be multiplied by 1.2 to obtain the Peak primary care outpatient visits per year.

Peak primary care outpatient visits per day

Data		Value
A	Adjusted primary catchment population	From 14.1.B
B	Total number of first visits per year	1 x A
C	Total number of follow-up visits per year	1 x B
D	Total number of visits per year	B + C
E	Operating days per year	260
F	Total number of visitors per average day	D / E
G	Peak day fluctuation factor	1.2
H	Total peak visitors per day	F x G
Example		
A	Adjusted primary catchment population	7,000
B	Total number of first visits per year	1 x 7,000 = **7,000**
C	Total number of follow-up visits per year	1 x 7,000 = **7,000**
D	Total number of visits per year	7,000 x 7,000 = **14,000**
E	Operating days per year	260
F	Total number of visitors per average day	14,000 / 260 = **53.8**
G	Peak day fluctuation factor	1.2
H	Total peak visitors per day	53.8 x 1.2 = **65**

This number essentially give the number of patients that need to be accommodated in the waiting area per day. However, patients often come with attendants and/or family members. To account for this, the patient load is multiplied by 1.5 under the assumption that one out of every two patients will bring one guest. This results in the total peak users per day.

When all steps in the process above are combined, it results in the following formula:

$$V_t = 1.2[2(C_p)/260] = 0.0092 \times C_p = V_t$$

where: C_p *= adjusted primary catchment area from Standard 14.1.B.*
V_t *= total peak OPD visitors per day*

Calculating Waiting Room Size by Expected Patient Load.
The size of waiting areas will depend on how many people it needs to accommodate comfortably at one time. This requires two calculations; one is the peak patient load per day, the other the proportion of that patient load that will be present at one time.

Not all the users within a day will be present at the same time, however, so this number can be reduced in order to find the total peak users at a time. Here, it is assumed that only half the users will be present in the space all at once, so the peak users per day is multiplied by 0.5 to find the total peak users at a time. This is the number of users the space needs to accommodate.

From this, a safe area per person must be determined so that people may be comfortably seated in a fashion which is distributed enough to help prevent nosocomial infection. Approximately 1.5m^2 is needed to ensure this (including seating area and circulation), so the number is multiplied by 1.5 to determine the total waiting area size.

Required sizing of OPD Waiting Areas.

Data		Value
A	Total peak visitors per day	From 14.1.C
B	Assumed attendants/family members per patient	1.5
C	Total peak users per day	A x B
D	Assumed users per day present at one time	0.5
E	Total peak users at a time	C x D
F	Floor area per user	1.5m^2 (16ft^2)
G	Total waiting area size	E x F
Example		
A	Total peak visitors per day	65
B	Assumed attendants/family members per patient	1.5
C	Total peak users per day	65 x 1.5 = **97.5**
D	Assumed users per day present at one time	0.5
E	Total peak users at a time	97.5 x 0.5 = **48.75**
F	Floor area per user	1.5m^2 (16ft^2)
G	Total waiting area size	48.75 x 1.5 = **73m^2** 48.75 x 16 = **780ft^2**

When all steps in the process above are combined, it results in the following formulas:

$A_f\ (ft^2) = (1.5)(0.5)(16)V_t\ =\ 12x\ V_t$

$A_m\ (m^2) = (1.5)(0.5)(1.5)V_t\ =\ 1.125\ x\ V_t$

where: V_t = *total peak OPD visitors per day from Standard 14.1.D.*
A_f = *required floor area in* ft^2
A_m = *required floor area in* m^2

Calculating Quantity of Triage Areas by Expected Patient Load.
Triaging a patient typically takes around 4 minutes, meaning about 15 patients can be triaged in an hour. If one uses the total peak visitors per day from Standard 14.1.C and divides by the 8 hours per day that a clinic is open, the total peak triage needs per hour are found. This can then by divided by the 15 triages performed in an hour to determine the number of triage areas needed.

Total number of triage areas needed

Data		Value
A	Total peak visitors per day	From 14.1.C
B	Hours per day of facility operation	8
C	Total peak triage needs per hour	A / B
D	Number of triages per hour	15
E	Total number of triage areas needed	C / D
Example		
A	Total peak visitors per day	65
B	Hours per day of facility operation	8
C	Total peak triage needs per hour	65 / 8 = 8.13
D	Number of triages per hour	15
E	Total number of triage areas needed	10.8 / 15 = 0.54

Figures should be rounded up. In this example, 1 triage area would be needed. From these figures, the quantity of triage areas by expected patient load, with some rounding to align with expected catchments of each facility types, can be determined to be as follows:

Minimum Quantity of Designated Triage Areas by Expected Patient Load

Expected Patient load (from 14.1.d)	Number of triage areas
<130	1
130-240	2
>240	3

Calculating Examination Room Quantity Requirements by Adjusted Catchment Population:
Once the adjusted catchment populations are determined, the results can be used to determine several sizing requirements.

The number of examination rooms based on the maximum visits of a primary catchment population. This is based on a series of inputs outlined below.

On average, each person pays approximately 1 new visit to a health facility per year in Liberia. Also on average, each new visit will result in 1 follow up visit. The length of these consultations depends on the visit, but as an average, first visits will last approximately 15 minutes (or 0.25 hours) and follow-up visits will last about 7.5 minutes (or 0.125 hours). Furthermore, most outpatient facilities are open only on weekdays, meaning there are 260days of the year in which they are open. Thus all of this consultation time divided up amongst 260 days of the year. From this, the total number of hours per day examination rooms are needed can be found.

Total room time needed per day.

Data		Value
A	Adjusted catchment population	calculated above
B	Total number of first visits	1 x A
C	Average hours of first visits	0.25
D	Total hours of first visits	B x C
E	Total number of follow-up visits	1 x B
F	Average hours of follow-up visits	0.125
G	Total hours of follow-up visits	E x F
H	Total hours of consultation visits (total room time)	D + G
I	Operating days per year	260
J	Total room time needed per day	H / I
Example		
A	Adjusted catchment population	7,000
B	Total number of first visits	1 x 7,000 = **7,000**
C	Average hours of first visits	0.25
D	Total hours of first visits	7,000 x 0.25 = **1,750**
E	Total number of follow-up visits	1 x 7,000 = **7,000**
F	Average hours of follow-up visits	0.125
G	Total hours of follow-up visits	7,000 x 0.125 = **875**
H	Total hours of consultation visits (total room time)	1,750 + 875 = **2,625**
I	Operating days per year	260
J	Total room time needed per day	2,625 /260 = **10.1**

Average numbers do not determine the mean, not the maximum realistic patient load per day. Because there are often peaks and valleys in the number of patients per day, these swings must be accommodated. It is wise to allow for a variation of at least 10% above the average number. This is accommodated with a peak day fluctuation factor of 1.1. Clinics are often open for approximately 8 hours per day (some only see patients in the morning if the patient load is low, while others see patients across an 8 hour day). Using the total room time per day, this can be divided across a 8 hour day to determine the number of rooms needed.

Calculation of number of examination rooms needed

Data		Value
A	Total room time needed per day	calculated above
C	Peak day fluctuation factor	1.1
D	Maximum room time needed per day	A x B
E	Operating hours per day	8
F	Number of rooms needed	D / E

Example		
A	Total room time needed per day	10.1
B	Peak day fluctuation factor	1.1
C	Maximum room time needed per day	10.1 x 1.1 = **11.11**
D	Operating hours per day	8
E	Number of rooms needed	11.11 / 8 = **1.39**

Decimals should always be rounded up. In this example, 2 examination rooms would be needed.

Using the formulas above, the examination room rate comes out to 1 examination room per 3,782 adjusted catchment population

Since the EPHS calls for PHC 1 facilities to serve a catchment population of 3.500, and PHC 1 facilities will always have one examination room, this standard has been tweaked to ensure that the minimum current catchment population requiring more than is greater than 3,500, resulting in an adjusted catchment population of 4,200. (Since PHC 1 facilities are only to be constructed in rural areas the growth factor for rural areas is used). Other requirements are based on the ratio of 1:3,780 as rounded from the ratio expressed above. Thus, the standards (with a small amount of rounding) are as indicated in the table below.

Number of Consultation Rooms per adjusted catchment population

Adjusted primary catchment population	Number of Consultation Rooms
<4,200	1
4,200 - 12,599	2
12,600 - 17,599	3
17,600 - 22,600	4
>22,600	5

Number of Delivery Bays

Deliveries normally happen in the primary catchment area, so this figure is used to run the calculation. Referral births do happen on rare occasions; this is not accounted for in the following methodology, however the methodology remains extremely conservative in it's inputs, thus allowing some room for expansion.

- A birth rate of 3.6% - this is the national average for Liberia according to MoHSW statistics.
- No fluctuation is accounted for, but the model assumes the goal of 70% of births happening at health facilities. Currently the figure is only 37%, according to MoHSW statistics. This high percentage helps account for fluctuations and referral births.
- The birth rate multiplied by the percentage of births happening at facilities; this is then multiplied by the catchment population to equal the arrival rate.
- An average delivery plus clean-up time within one bay of between 3 and 6 hours. This is the bay occupancy time.
- Facilities receive births at any time, 24 hours a day,365 days a year.
- The arrival time of mothers in labor is random.

The methodology uses a mathematics queue theory model to determine a percentage of patients served (i.e. the percentage for which there is enough space in the delivery bays at a time) based on the above assumptions.

The model uses the arrival rate to generate random arrival times across 1,000 permutations, and assigns a random bay occupancy time within the expressed interval to each. From this, it can be determined how many patients are in the system at any given time, and thus whether the patient is served (i.e. if a delivery bay is open upon arrival). Patients which can be served are assigned a value of 1 and patients which cannot be served are assigned a value of 0. Over the 1,000 permutations, these values are averaged to produce the percentage of patients served.

In determining the requirements, the model seeks to serve 95% of patients or greater for each catchment population.

The model is defined by a queue theory formula referred to as Erland's C formula:

$$P_W = \frac{\frac{A^N}{N!}\frac{N}{N-A}}{\sum_{i=0}^{N-1}\frac{A^i}{i!} + \frac{A^N}{N!}\frac{N}{N-A}}$$

where:

- *A* is the total traffic offered in units of erlangs
- *N* is the number of delivery bays
- P_W is the probability that a patient has to wait for service.

Results vary due to the randomness assigned to arrival times and bay occupancy times, but on average the following results were found:

- PHC 1 facilities (with maximum adjusted primary catchment population of 4,200) achieve approximately 95% patient service with only 1 delivery bay
- The largest (theoretical) adjusted primary catchment area (using the urban growth factor) of a PHC 2 (16,800) can achieve over 97% service with 2 delivery bays.
- At catchment area of approximately 20,000, 3 delivery bays are needed to achieve 95% service. This population is between the largest (theoretical) area of a PHC 2 and the smallest (theoretical) area of a Health Center.
- The smallest (theoretical) Health Center adjusted catchment population of 30,000 was able to achieve well over a 97% service rate with 3 delivery bays.
- At an adjusted catchment population of approximately 56,000 4 delivery bays are needed to achieve a 95% service rate.
- The smallest county adjusted catchment population of 65,760 (Grand Ku County)achieved a 99% service rate with 4 delivery bays.
- At approximately 110,000 adjusted catchment population, a 5th delivery bay is needed to achieve 95% service.

Since entire referral populations are unlikely to be served for deliveries by a single county hospital, the model was not continued beyond this stage. Some rounding was used to accommodate expected boundaries between facility types, but using the data above, the following distribution was developed:

Minimum number of delivery bays per adjusted catchment population

Adjusted primary catchment population	Facility Type	Number of Delivery Bays
<4,200	PHC 1	1
4,200 - 16,799	PHC 2	2
>16,800		3
Adjusted referral catchment population	Facility Type	Number of Delivery Bays
<56,000	Health Center	3
>56,000		4
<80,000	District Hospital	4
>80,000		5
<110,000	County Hospital	4
>110,000		5
all populations	Regional Referral Hospital	4-5

Minimum Number of Beds for Labor, Post-Partum and Post C-Section

To calculate beds in the maternity sequence, the following method was used:

Data		Value
A	Adjusted catchment population	to be inputted
B	Birth rate (from UN statistics)	0.036
C	Births per year	A x B
D	Target percentage of births in health facilities	0.70
E	Adjusted births per year	C x D
F	Days per year	365
G	Adjusted births per day	E / G
Example		
A	Adjusted catchment population	7,000
B	Birth rate (from UN statistics)	0.036
C	Births per year	7,000 x 0.036 = **252**
D	Target percentage of births in health facilities	0.70
E	Adjusted births per year	252 x 0.70 = **176.4**
F	Days per year	365
G	Adjusted births per day	176.4 / 365 = **0.48**

Labor Ward bed quantities are set equal to the number of delivery bays, calculated above.

For PHC 1 facilities, the adjusted births per day is multiplied by an assumed length of stay of 1 day in Post-Partum to determine the number of beds needed.

For Health Center facilities, which may include some C-Section patients who stay longer, the adjusted births per day is multiplied by an assumed length of stay of 1.5 days in Post-Partum to determine the number of beds needed.

For Hospitals, in which Post-Partum and Post C-Section are separated, an assumed C-section rate of 40% is used to determine the number of Post-Partum patients (adjusted births per day x 60%) and Post C-

Section patients (adjusted births per day x 40%). These are then multiplied by an assumed length of stay of 1.5 days in Post-Partum and 2.5 days for Post C-Section to achieve the number of beds in each.

With some rounding, the following results are recommended.

Minimum number of rooms and beds for Labor, Post-Partum, and Post C-Section Wards

Adjusted primary catchment population	Facility Type	Minimum Space Required
<4,200	PHC 1	One room with minimum 1 bed
4,200 - 16,799	PHC 2	One room with minimum 2 beds
>16,800		One Labor Ward with minimum 2 beds One Post Partum Ward with minimum 3 beds
Adjusted referral catchment population	Facility Type	Minimum Space Required
>38,000	Health Center	One Labor Ward with minimum 3 beds One Post Partum Ward with minimum 4 beds
38,000 - 48,000		One Labor Ward with minimum 3 beds One Post Partum Ward with minimum 5 beds
>48,000		One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 6 beds
<72,000	District Hospital	One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 5 beds
72,000 - 80,000		One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 6 beds
>80,000		One Labor Ward with minimum 5 beds One Post Partum Ward with minimum 6 beds One Post C-Section Ward with minimum 7 beds
<72,000	County Hospital	One Labor Ward with minimum 4 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 5 beds
72,000 - 79,999		One Labor Ward with minimum 5 beds One Post Partum Ward with minimum 5 beds One Post C-Section Ward with minimum 6 beds
80,000 - 110,000		One Labor Ward with minimum 5 beds One Post Partum Ward with minimum 6 beds One Post C-Section Ward with minimum 7 beds
110,000 - 149,999		One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 7beds One Post C-Section Ward with minimum 9beds
150,000 - 249,999		One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 8beds One Post C-Section Ward with minimum 10 beds
>250,000		One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 10 beds One Post C-Section Ward with minimum 12 beds

all populations	National Referral Hospital	One Labor Ward with minimum 6 beds One Post Partum Ward with minimum 10 beds One Post C-Section Ward with minimum 12 beds

Calculating the Minimum Number of ER Bays

To calculate bays in the ER, an identical model to the calculation of delivery bays was used, except an ER rate was substituted for the adjusted birth rate, and the amount of time spent in the ER bays was randomly distributed between 2 and 4 hours. . The ER rate is the percentage of people seeking ER treatment once in an average year. This number is modeled here as 3%.

The following data was found:

- At the smallest (theoretical) catchment population of a Health Center (30,000), a service rate of over 95% was achieved with only 2 ER bays
- Up to the maximum (theoretical) Health Center catchment of 56,000, a 95% service rate is achieved with 3 ER bays.
- At approximately 130,000 catchment population, a 5th ER bay is needed to achieve a 95% service rate.
- At approximately 200,000 catchment population, a 6th ER bay is needed to achieve a 95% service rate.
- At approximately 250,000 catchment population, a 7th ER bay is needed to achieve a 95% service rate.
- Over 550,000 catchment population, 8 ER bays are needed.

The results are interpreted into the following table:

<u>Emergency Room sizing</u>

Adjusted Referral Catchment Population	Facility Type	Minimum ER Bays Required
<30,000		2
30,000 - 56,000	Health Center	3
>56,000		4
all populations	District Hospital	4
>130,000		4
130,000 - 199,999		5
200,000 - 249,999	County Hospital	6
250,000 - 550,000		7
<550,000		8
all populations	National Referral Hospital	8

Calculating the Number of Ward Beds

Based on comparative statistics, the following ratios were assumed to determine ward bed quantities:

- For Men's Wards, a ratio of 0.00008 beds per person in the adjusted referral catchment area.
- For Women's Wards, a ratio of 0.000092beds per person in the adjusted referral catchment area.
- For Pediatrics Wards, a ratio of 0.000108beds per person in the adjusted referral catchment area.
- For Surgical Wards, a ratio of 0.00004beds per person in the adjusted referral catchment area.

These ratios result in the quantities in the table below.

Minimum Inpatient bed requirements by adjusted referral catchment population

Adjusted Referral Catchment Population	Facility Type	Minimum Space Required
>30,000	Health Center[a]	One Men's Ward with minimum 3 beds One Women's Ward with minimum 3 beds One Pediatrics Ward with minimum 4 beds
30,000 - 47,999		One Men's Ward with minimum 4 beds One Women's Ward with minimum 4 beds One Pediatrics Ward with minimum 5 beds
48,000 - 56,000		One Men's Ward with minimum 4 beds One Women's Ward with minimum 5 beds One Pediatrics Ward with minimum 6 beds
>56,000		One Men's Ward with minimum 5 beds One Women's Ward with minimum 5 beds One Pediatrics Ward with minimum 7 beds
all populations	District Hospital	One Men's Ward with minimum 5 beds One Women's Ward with minimum 6 beds One Pediatrics Ward with minimum 7 beds
<80,000	County Hospital	One Men's Ward with minimum 6 beds One Women's Ward with minimum 6 beds One Pediatrics Ward with minimum 8 beds One Surgical Ward with minimum 3 beds
80,000 - 110,000		One Men's Ward with minimum 7beds One Women's Ward with minimum 8 beds One Pediatrics Ward with minimum 9 beds One Surgical Ward with minimum 4 beds
110,000 - 149,999		One Men's Ward with minimum 9 beds One Women's Ward with minimum 10 beds One Pediatrics Ward with minimum 12 beds One Surgical Ward with minimum 5 beds
>150,000		One Men's Ward with minimum 12 beds One Women's Ward with minimum 14 beds One Pediatrics Ward with minimum 16 beds One Surgical Ward with minimum 6 beds
all populations	Regional/National Referral Hospital	One Men's Ward with minimum 20 beds One Women's Ward with minimum 23 beds One Pediatrics Ward with minimum 27 beds One Surgical Ward with minimum 10 beds

[a] *In Health Centers, inpatient wards may be separated by curtains or partitions and do not necessarily need to be independent rooms*

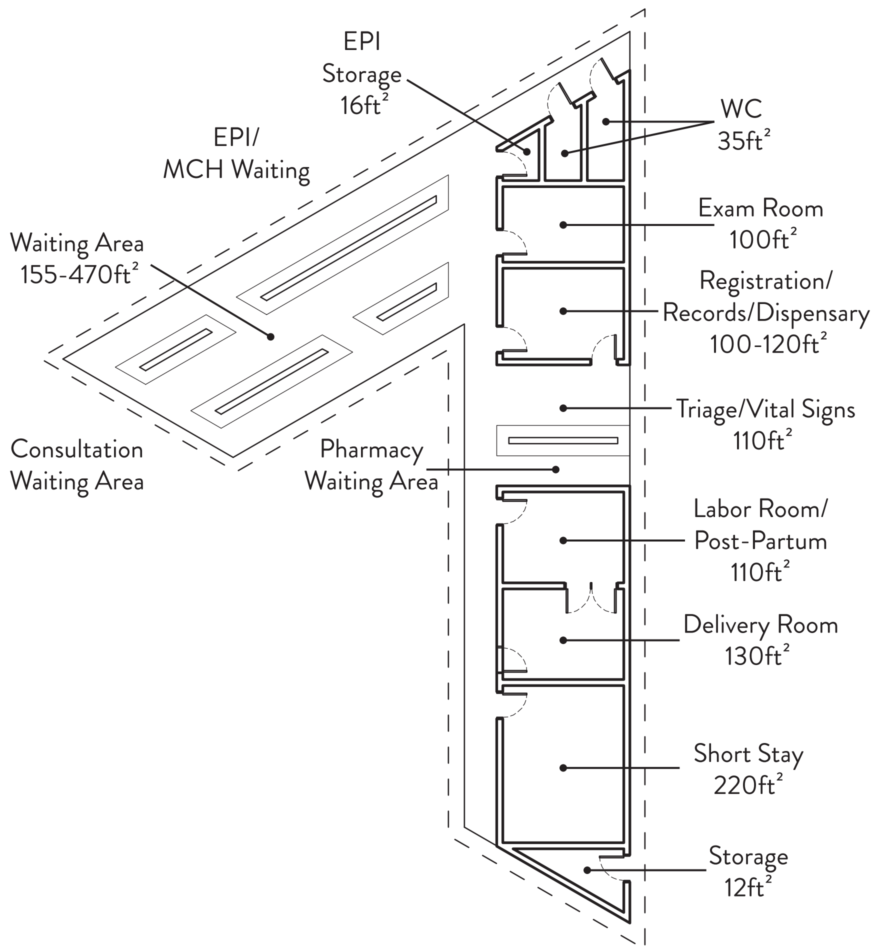
Appendix U: Sample Schematic Facility Plans

Sample facility plans are shown on the following pages.

All plans must comply with the entirety of these Standards and must not be used without appropriate adaptation for the site, the catchment size, environmental conditions, and other factors affecting facility design.

All final designs must be approved b y the assigned IU representative for each project.

Sample schematic plan: PHC 1 facility



Reference notes:

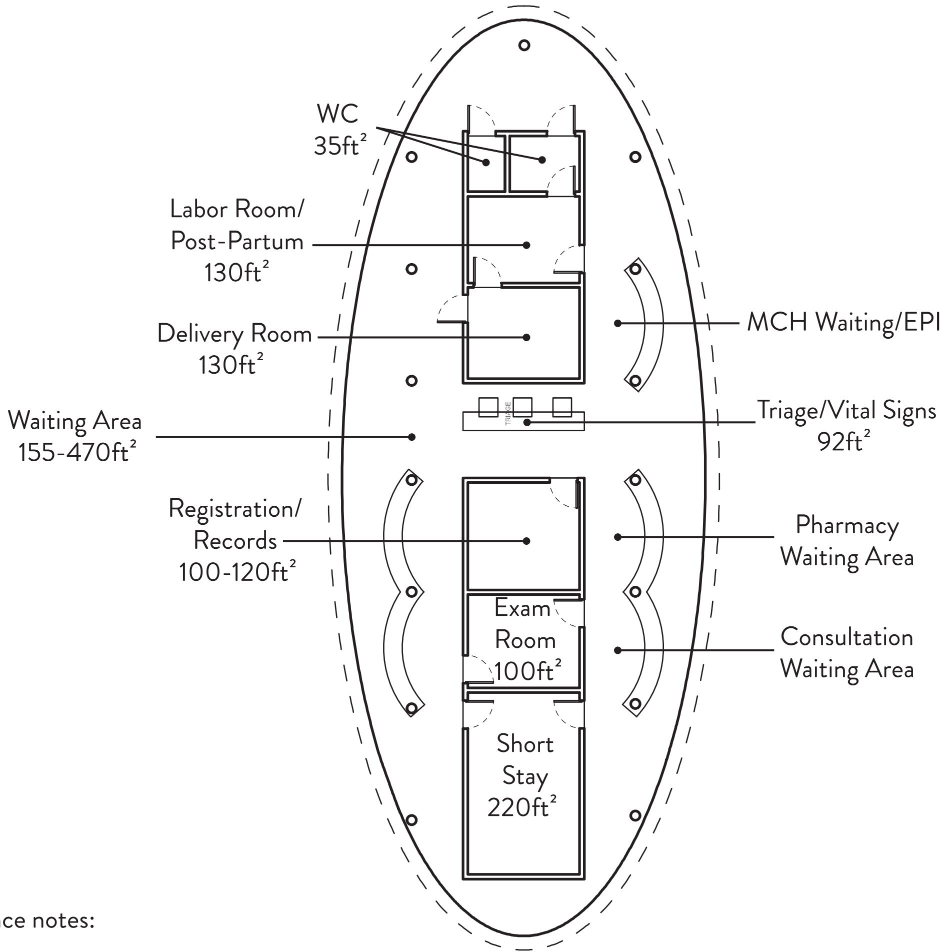
Not to be used for construction.

These plans are intended to show a possible layout for PHC 1 facilities and must not be used for construction without adaptation according to site conditions, catchment population, environmental factors, and project budget. Such adaptations should be done by a qualified architect or engineer and approved by the assigned IU representative.

Room sizes are listed as a minimum or possible range for PHC 1 facility; final sizing will be determined based on indicators in Chapter 14: Building Layout and must be approved by the assigned IU representative.

For detailed program requirements, refer to Chapters 46-51: Room Planning. Elaborated detail drawings should be done by a qualified architect or engineer and must be approved by the assigned IU representative.

Sample schematic plan: PHC 1 facility



Reference notes:

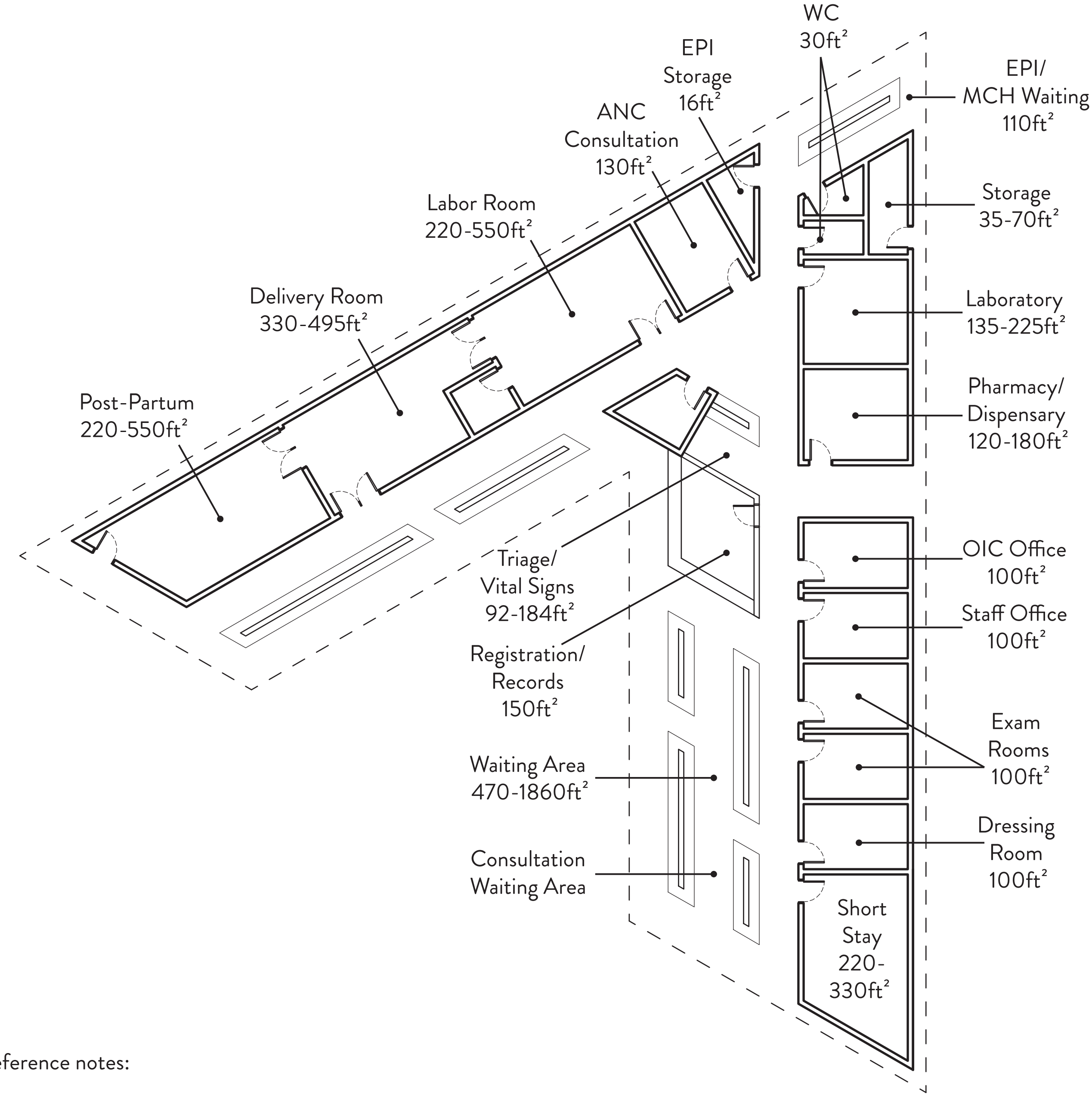
Not to be used for construction.

These plans are intended to show a possible layout for PHC 1 facilities and must not be used for construction without adaptation according to site conditions, catchment population, environmental factors, and project budget. Such adaptations should be done by a qualified architect or engineer and approved by the assigned IU representative.

Room sizes are listed as a minimum or possible range for PHC 1 facility; final sizing will be determined based on indicators in Chapter 14: Building Layout and must be approved by the assigned IU representative.

For detailed program requirements, refer to Chapters 46-51: Room Planning. Elaborated detail drawings should be done by a qualified architect or engineer and must be approved by the assigned IU representative.

Sample schematic plan: PHC 2 facility



Reference notes:

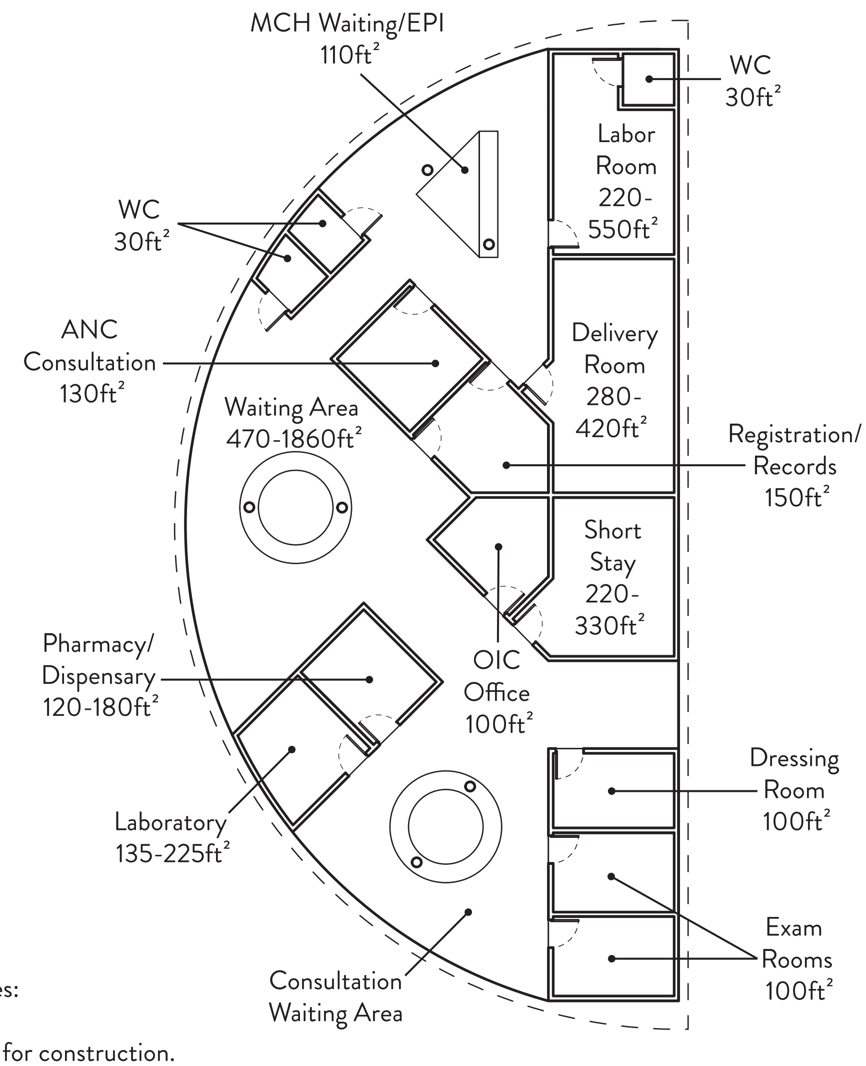
Not to be used for construction.

These plans are intended to show a possible layout for PHC 2 facilities and must not be used for construction without adaptation according to site conditions, catchment population, environmental factors, and project budget. Such adaptations should be done by a qualified architect or engineer and approved by the assigned IU representative.

Room sizes are listed as a minimum or possible range for PHC 2 facility; final sizing will be determined based on indicators in Chapter 14: Building Layout and must be approved by the assigned IU representative.

For detailed program requirements, refer to Chapters 46-51: Room Planning. Elaborated detail drawings should be done by a qualified architect or engineer and must be approved by the assigned IU representative.

Sample schematic plan: PHC 2 facility



Reference notes:

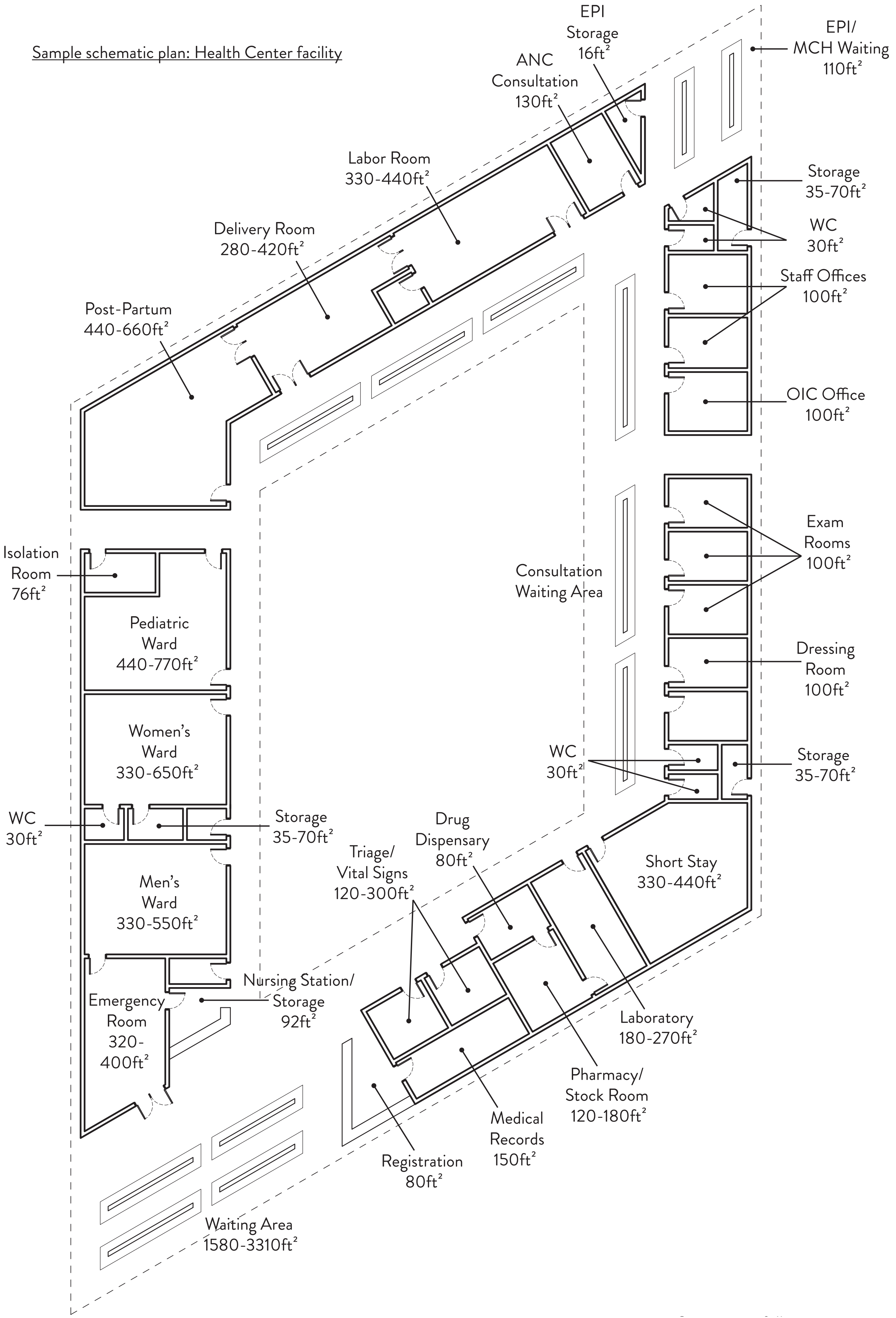
Not to be used for construction.

These plans are intended to show a possible layout for PHC 2 facilities and must not be used for construction without adaptation according to site conditions, catchment population, environmental factors, and project budget. Such adaptations should be done by a qualified architect or engineer and approved by the assigned IU representative.

Room sizes are listed as a minimum or possible range for PHC 2 facility; final sizing will be determined based on indicators in Chapter 14: Building Layout and must be approved by the assigned IU representative.

For detailed program requirements, refer to Chapters 46-51: Room Planning. Elaborated detail drawings should be done by a qualified architect or engineer and must be approved by the assigned IU representative.

Sample schematic plan: Health Center facility



Reference notes:

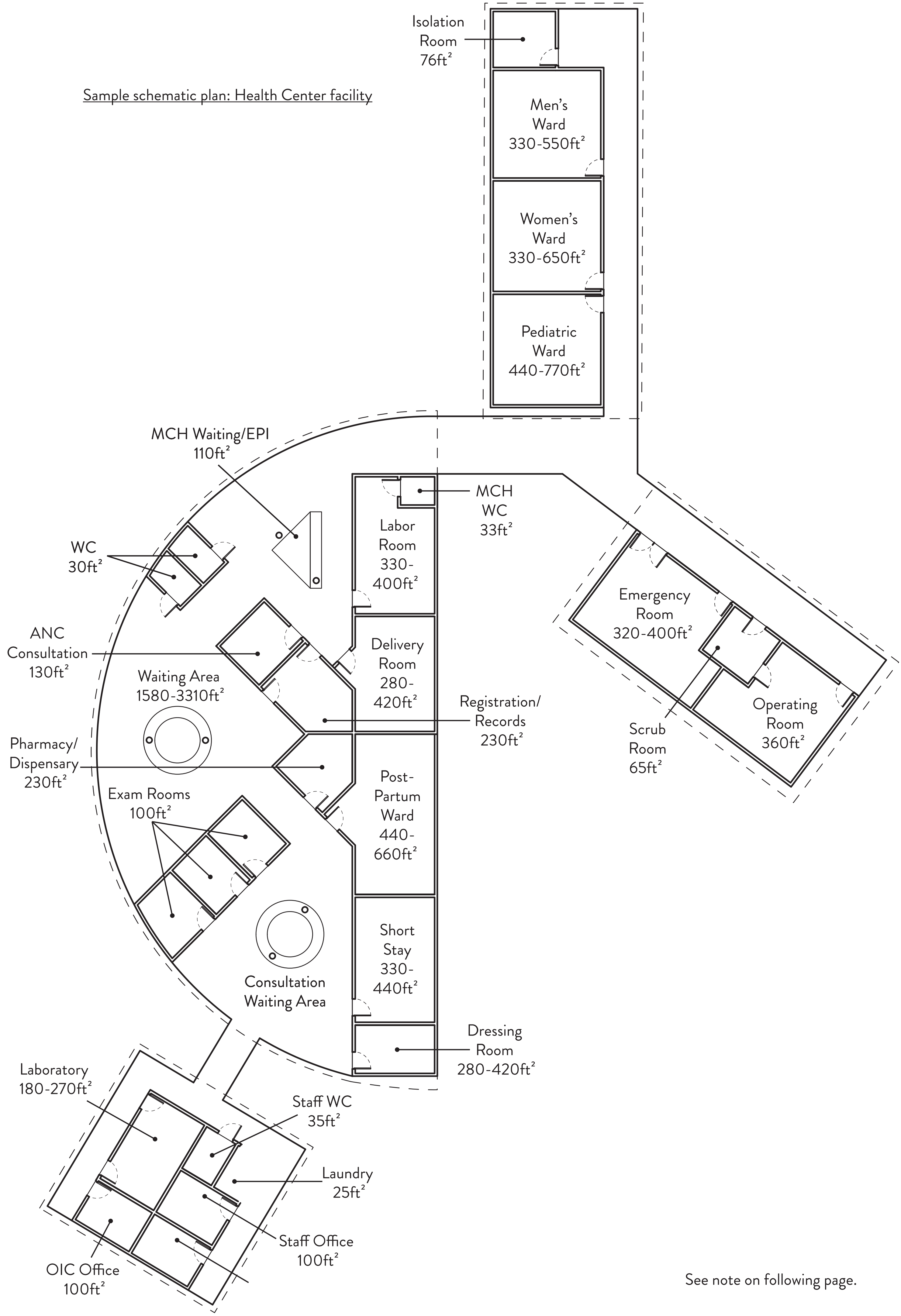
Not to be used for construction.

These plans are intended to show a possible layout for Health Center facilities and must not be used for construction without adaptation according to site conditions, catchment population, environmental factors, and project budget. Such adaptations should be done by a qualified architect or engineer and approved by the assigned IU representative.

Room sizes are listed as a minimum or possible range for Health Center facility; final sizing will be determined based on indicators in Chapter 14: Building Layout and must be approved by the assigned IU representative.

For detailed program requirements, refer to Chapters 46-51: Room Planning. Elaborated detail drawings should be done by a qualified architect or engineer and must be approved by the assigned IU representative.

<u>Sample schematic plan: Health Center facility</u>



See note on following page.

Reference notes:

Not to be used for construction.

These plans are intended to show a possible layout for Health Center facilities and must not be used for construction without adaptation according to site conditions, catchment population, environmental factors, and project budget. Such adaptations should be done by a qualified architect or engineer and approved by the assigned IU representative.

Room sizes are listed as a minimum or possible range for Health Center facility; final sizing will be determined based on indicators in Chapter 14: Building Layout and must be approved by the assigned IU representative.

For detailed program requirements, refer to Chapters 46-51: Room Planning. Elaborated detail drawings should be done by a qualified architect or engineer and must be approved by the assigned IU representative.

MASS Design Group
We're building a movement where architecture creates a better, more beautiful, more just world. MASS immerses itself in the challenges our partners and their constituents face. We develop solutions that are contextually optimized and seek to improve health, economic, and social outcomes using architecture to build a better, more equitable world.
www.massdesigngroup.org

Mazzetti
We make the world a better place by creating better environments. We drive the future of infrastructure through research and policy. We help clients plan forward-looking infrastructure investments and access creative ways to finance them. And we produce transformational engineering solutions through project and post-project delivery.
http://www.mazzetti.com/

Fall Creek Engineering (FCE)
We are an engineering firm providing pre-project planning, design, construction planning, supervision and coordination. FCE has been working on a wide breadth of projects including civil, environmental, water resource, restoration and ecological engineering design and planning studies. FCE employs state-of-the-art engineering methods and computer assisted drafting to provide accurate and clear design plans and technical studies.
http://www.fallcreekengineering.com/

Nous Engineering
With offices in London and Los Angeles, our Engineering team offers sophisticated bespoke engineering solutions to architects, artists and developers. Nous takes a tailored and collaborative approach to the design process – each project is different, each client unique. We seek out synergies between engineering and design, and are continually adapting to engage the latest modeling tools, advanced simulation software and cross-platform links between design, structure and fabrication.
http://www.nouscollaborative.com/

prepared by

MASS Design Group
Fall Creek Engineers
Mazzetti
Nous Engineers

in collaboration with

MOHSW Infrastructure Unit
Director David M. Jallah

with support from

Rebuilding Basic Health Services
John Snow, Inc.

USAID
FROM THE AMERICAN PEOPLE

Healthy Life

THE LOVE OF LIBERTY BROUGHT US HERE
REPUBLIC OF LIBERIA