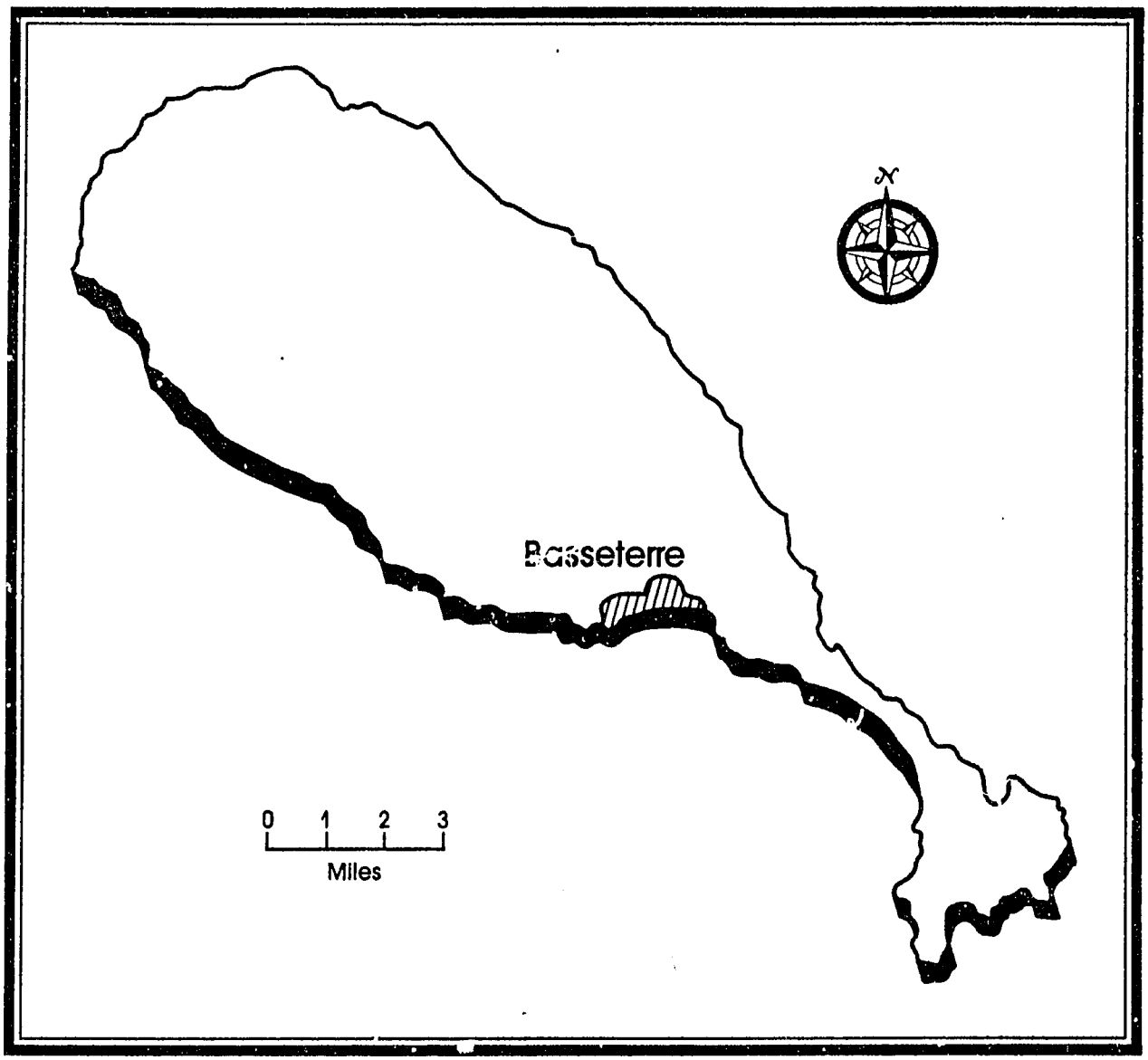
SOIL CONSERVATION PLANNING GUIDE AND HANDBOOK

ST. KITTS



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St. Kitts, West Indies

Prepared by:
Devres, Inc.
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Prepared for:

Ministry of Agriculture
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The Honorable Hugh Heyliger
Minister

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In addition to those named above, others who made valuable contributions to this Handbook were:

James Bailey	-	Superintendent, Public Works Dept.
Karlyn Fraser	-	Secretary, Resource Management Project
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Jayne Millar Wood
President, Devres
May, 1987

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1. INTRODUCTION

1.1 Overview--Importance of Soil Conservation to St. Kitts

St. Kitts presently faces important decisions concerning the future use of its soil resources. The island has a substantial amount of potentially productive soils. If they are properly used and protected, they can serve generations yet to come with the highest potential economic return.

Historically, the soil resources of St. Kitts have been partly protected by the production of sugar cane. Cane has provided an excellent cover for the soil, which is not completely exposed except during re-planting once every several years. Only the steeper slopes have suffered damaging soil loss. However, as St. Kitts now seeks to diversify its agriculture and plant new crops, soil conservation practices must be applied on nearly all lands to preserve the resource base. Decisions regarding the "mix" among sugar cane, other crops and alternative land uses must be made in the context of an overall resource management plan.

Choosing which, and how much, land will remain in sugar cane can be as important as assigning other land uses. Increased management efficiency, along with the proper choice of lands, is vitally needed to increase production and reduce cost if the sugar industry is to compete in the market place. Therefore, good soil and water resource information is needed by the sugar industry in St. Kitts as well as for the diversification of agriculture.

To complete a specific land use management plan is only a step beyond the generalized land use management plan included here. Decisions will have to be made as to which of the alternative uses will be selected for any given area on St. Kitts. Specific land use decisions must be made by first determining proper alternative uses in the context of a general land use plan. Circumventing this approach will certainly lead to some unwise decisions with potentially disastrous results. To attempt to reach any conclusions without the proper information concerning the available soil resources, and their varied potentials and characteristics, can only lead to a plan, and eventually to land use, that results in land degradation and reduced economic return.

Many areas in the world have already depleted their soil resources, and it is now too late to institute good land management programs. Their vital soil resource is gone, and there is nothing that can be done to replace it. St. Kitts is fortunate in this respect. There are areas where the productive capacity of the soil has been seriously depleted but, because of the protection of sugar cane over the cropping history, most of the land has retained reasonable productive capacity.

To ensure high productivity on St. Kitts in the future, land use decisions must be wisely made and acted upon acknowledging parameters other than just the soil resources. Population patterns, water, crops and markets, industrial potential, and transportation factors must be considered in the context of overall socio-economic and political realities. Land use planning must be based on the best and most complete soil resource and technical data available.

This Soil Conservation Planning Guide and Handbook, included as a part of the St. Kitts/Nevis Resource Management Project, is envisioned as a generalized land use management plan. The soils are classified according to their capability for long-term use and productivity. Necessary conservation treatments and management practices are described and designated for each soil type, capability classification, and alternative potential uses.

With the changes that are now taking place and with the desire to plan for the best possible land use, it is certainly the time to get all elements of the planning process in the proper sequence. This Soil Conservation Handbook will be an important tool for helping government officials of St. Kitts do this.

1.2 How to Interpret and Use the Handbook

1.2.1 Purpose and use

This Handbook is for the use of policy makers, soil conservationists and professional agriculturalists on St. Kitts. Since many of the conditions on St. Kitts are common to other islands in the region, it should be of interest to professional agriculturalists in the Eastern Caribbean and beyond. This Handbook provides "state-of-the-art" guidance on soil conservation for St. Kitts with a practical "how to do" handbook. As such, it will be subject to change for improvement as technology improves. This dictates publishing in a form that makes page removal and replacement easy.

1.2.2 Description of Handbook

The Handbook will help an agriculturalist better understand the causes of soil erosion. More importantly, it provides practical guidance to develop a resource management system for a given field. An agriculturalist can determine from the soils map and tables the land capability unit grouping for the soils. Guidance in the Handbook will help one determine needed treatment for soils in that group and identify specific conservation practices needed on the field. Another section provides guidance and specifications for applying and maintaining conservation practices. With this guidance, the extension agent as well as a trained soil conservationist can help the land user properly conserve and use his soil resources productively.

Section 1 explains causes of erosion, principles of soil conservation and future revisions and additions to the handbook. Section 2 provides information needed to evaluate the soil and water resources. It contains data for use in the planning process and criteria for selecting sites on which to work. Section 3 describes the government organizational needs for implementing a conservation program. Section 4 gives guidance and specifications for installing and managing soil and water conservation practices.

1.3 Causes of Soil Erosion and Principles of Soil Conservation

1.3.1 Causes of soil erosion

Where man does not interfere, natural vegetation conserves the soil. There may be droughty periods when fires denude forests or indigenous animals overgraze grasslands. At this time soil loss by erosion is more than that produced through soil building processes. Eventually the forest litter returns to cover the soil. Many animals die off from a scarcity of forage, the rains return and vegetation again covers the soil. The long term net effect is a soil-building process. Man's intervention has been the root cause of excessive erosion.

1.3.1.1 Erosion caused by water

The process of soil erosion by water consists of three principal steps:

- Loosening soil particles by the impact of raindrops or by the scouring action of runoff;
- Moving the detached particles by flowing water; and
- Depositing them at the new location.

These steps occur in sequence from ridge to ghauts in a watershed.

Raindrops break clumps of unprotected soil apart and separate the small particles from each other. They splash the bits of soil about and gradually move them downslope.

Whenever the rain falls faster than it can soak into the ground, a sheet of water collects on the surface and moves downhill. The rain continues to dislodge soil and keeps it suspended in the moving sheet, or feeds it into little streams of water flowing off the field along crop rows or rills. Mineral nutrients and organic matter are churned into the runoff and carried away, leaving the coarser, less fertile particles behind.

The combined actions of beating rain and flowing water remove layers of soil from the fields. This is called sheet erosion and takes

place wherever muddy water moves off a field. If the water in the little streams moves fast enough, it too, dislodges soil and carries it along with that splashed by the raindrops. This scouring action carves out channels that join farther down the slope. This is called rill erosion. Sheet and rill erosion can remove enormous amounts of soil from unprotected fields. Cultivation that follows the eroding storm may fill in the rills and hide the evidence of erosion. The damaging effects of sheet and rill erosion may go unnoticed until the subsoil begins to show and crop yields decline.

As rills join to make larger channels, the runoff becomes more and more concentrated as it moves downslope and its scouring action increases. A sudden drop, or overfall, in the channel multiplies the cutting power of the stream and enlarges the channel as the over-fall advances upstream. Channels so deep they cannot be smoothed by ordinary cultivation are called gullies.

Gullies often are a sign that sheet erosion and rill erosion have been going on a long time. They may divide fields into small areas impractical to cultivate. The banks of some large gullies slump and cave. In this way gullies can advance rapidly across areas, cutting roads and often making otherwise productive land impossible to farm.

The final step in the erosion process is the deposition of the soil particles that have been moved. This sediment deposit may occur in the lower part of the field where it can damage crops. Or the sediment may fill streams or be carried out to sea.

Erosion goes on all the time. Normal erosion occurs where water, wind, or other erosive agents remove soil or rock from slopes that have not been disturbed by man. This is called geologic erosion.

In arid and semiarid regions these processes are rapid and erratic. Infrequent but torrential rains carve the hills and scour the valleys. The sparse vegetation offers little protection. The result is a landscape of angular forms. Flat-topped mesas and concave slopes are characteristic.

In humid and sub-humid St. Kitts, the soil, where man has not disturbed it, is held in place by dense forests. Here normal erosion is less rapid than soil formation. Steep slopes have developed. Hilltops and mountains are rounded and slopes are curved. Sharp angles and straight lines in the landscape are unusual.

1.3.1.2 Erosion caused by wind

The wind as an erosive agent detaches and transports soil particles, sorts the finer from the coarser particles, and deposits them unevenly. Loss of the fertile topsoil in eroded areas reduces the rooting depth and, in many places, reduces crop yield. Abrasion by airborne soil particle damages plants and man-made

structures. Sand and dust in the air can harm animals, humans, and equipment.

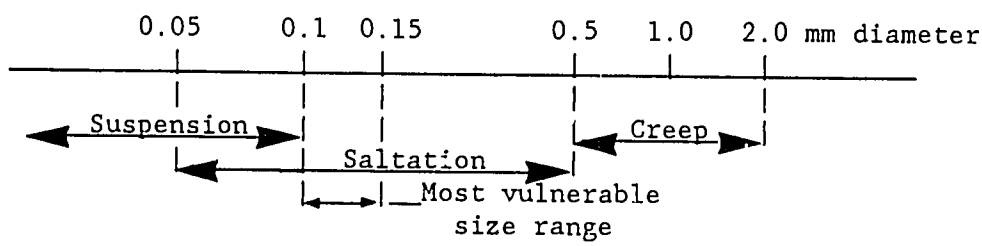
The wind erosion process is complex. It involves detachment, transport, sorting, abrasion, avalanching, and deposition of soil particles. Turbulent winds over erodible soils cause wind erosion. Field conditions conducive to erosion are:

- Loose, dry and finely granulated soil;
- Smooth soil surface with little or no vegetation present;
- Sufficiently large area susceptible to erosion; and
- Sufficient wind velocity to move soil. Winds are considered erosive when they reach 13 miles per hour at 1 foot above the ground or about 18 miles per hour at 30 feet.

The wind transports soil particles in three ways:

- Saltation;
- Suspension; and
- Surface creep.

The kind of movement of a soil particle is determined by its size, as shown in the diagram below. The dividing lines are naturally not very precise, with some overlap.



The form of movement by wind is a function of particle size[1]

<u>Saltation</u> is by far the most important of the three forms of movement. For one thing more soil is moved in this way than either of the other two, and also neither creep nor suspension occur without there being saltation. In saltation, individual particles lift off the surface at a 50 to 90 degree angle and follow distinct trajectories under the influence of air resistance and gravity. The movement is by a series of low bounces over the surface, and it occurs among the middle size of particles, light enough to be sometimes lifted off the

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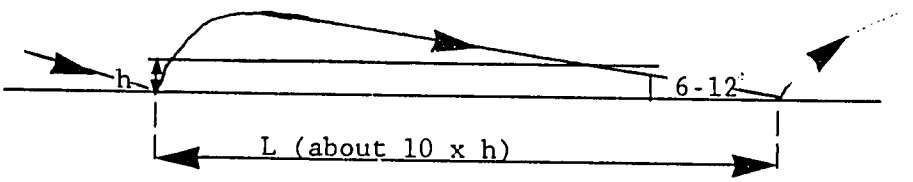
[1]<u>Soil Conservation</u> by Norman Hudson, Cornell University Press, Ithaca, New York

surface, but too large to go into suspension. Saltation particles are abrading "bullets" that wear away the protective soil crusts and clods. The size range of particles which may move in saltation is from 0.05 mm to 0.5 mm diameter, with most movement among particles 0.1 to 0.15 mm diameter.

The form of this bouncing movement is shown in the diagram below and starts with a particle rising into the airstream under the action of wind. The vertical speed falls off under the action of gravity, and at the same time the particle picks up lateral velocity from the wind. After rising to a peak which is only a few inches high it starts to fall, but continues to accelerate laterally under the force of the wind, and so returns to the soil in a long flat glide path, striking the soil with high ener .



The path of a particle moving in saltation [2]

Suspension occurs when the dust particles, (.02 to .1 mm in diameter), are dislodged from an eroding area by saltation and remain in the air mass for an extended period. Some suspension-sized particles are present in the soil, but many are created by abrasion during erosion. From 3 to more than 38 percent of an eroding soil may be carried in suspension, depending on soil texture. Generally, less than 10 percent of the eroding soil goes into suspension.

Surface creep occurs when sand-sized particles or aggregates are set in motion by the impact of saltating particles. In high winds, the whole soil surface appears to be creeping slowly forward as particles are pushed and rolled by the saltation flow. From 7 to 25 percent of total transport may be surface creep.

Saltation and creep particles are deposited when blown into vegetated strips, ditches, or other areas sheltered from the wind. Particles in suspension, however, may be carried a great distance. Saltation and creep particles are deposited as long as the vegetated strip or sheltered area has the capacity to hold the sediment. If the incoming soil covers the vegetation, fills the ditch or sheltered area, or if the wind direction changes, the erosion process will continue downwind.

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[2]Same reference.

Few regions are entirely safe from wind erosion. Wherever the soil surface is loose and dry, vegetation is sparse or absent, and the wind sufficiently strong, erosion will occur unless control measures are applied.

In St. Kitts the primary problem caused by wind erosion is crop damage, particularly during the dry summer months. Some crops are more vulnerable to wind erosion damage than others. Many of the vegetable crops are especially vulnerable. Some crops are tolerant enough that some changes can be made in tillage and other crop production techniques to increase their ability to withstand or recover from erosion damage. Even though wind erosion rates may be well below the soil loss tolerance, wind may cause far more loss where crops are susceptible to wind damage. Pasture grasses are also adversely affected by winds. In addition to soil loss, winds carry salt particles up from the sea and deposit them on grasses and crops, which reduces productivity.

Wind erosion in St. Kitts is a problem for growers of vegetables on sandy soils. The crops are damaged both by moving soil particles and wind. Methods of control include reduced cultivation, field wind breaks, wind strip cropping and management of crop residue for soil surface cover.

1.3.2 Principles of soil conservation

Nature's secret to soil conservation is vegetative cover. Human activity that copies this is the first principle of soil conservation. It is easy to do on forage lands and woodland. It is more difficult on cropland, but tools are available, for example, chisel plowing instead of moldboard plowing or disking. Another important tool is a form of conservation-tillage, normally called "no-till." This farming system is used by many farmers in North America. By leaving crop residue undisturbed, planting with a narrow opener that slices into the soil, depositing the seed, and controlling weeds with herbicides, the farmer leaves the soil completely protected. Other systems provide vegetative cover at least part of the year. These are mulching and various types of crop residue management.

If soil cover cannot be maintained, conservation practices that control water flow are useful. Some of these are contour farming, terraces, diversions, grassed or concrete waterways and water drop structures.

- Contour farming provides row-ridges that hold most or all of the water from light rains. They are ineffective during heavy rain storms or on very steep slopes.

- Terraces catch runoff and conduct it to a safe outlet or hold it until the ground absorbs it. In many semiarid lands, terraces are used more for water conservation than erosion.

On St. Kitts they serve both purposes. Diversions divert excess water before it reaches the cropland.

- Grass or concrete-lined waterways provide safe outlets for terraces. They also provide safe areas for concentrated flow through cropland. Waterways on problem soils and steep slopes may need support from water drop structures. These normally are concrete, mortared rock, or gabion structures. They are erosion resistant where water crosses the top and where it strikes the bottom. The drop structures permit establishing non-erosive grades in waterways or less steep grades that can be safely vegetated.

1.4 Revisions and Additions to the Handbook

This is a "how-to-do" handbook and will need periodic review and frequent revision. Section 1 contains basic information that will need very little modification. Section 2 provides guidance based primarily on the 1966 soil surveys by Lang and Carroll. New soil surveys would provide current data. Extensive revision of this section will be needed if new soil surveys are forthcoming. Section 4 has guidance and specifications for applying and managing conservation practices. New conservation engineering techniques, improved plant cultivars, better herbicides and other technology advances will make improvement possible in these conservation tasks.

1.4.1 Need for additional technical data

Good, up-to-date information such as soils and rainfall data are not presently available on St. Kitts.

Most of the data included on "R" factors for determining soil loss using the Universal Soil Loss Equation and the rainfall frequencies were extrapolated from information published for Puerto Rico and the U.S. Virgin Islands. Annual rainfall data included were taken from previously published documents, but it is known that it was also extrapolated from rainfall information collected from the lower elevations of the island.

There is some rainfall data available but, as stated, it is mostly taken from rainfall stations located at lower elevations. It can be used for annual determinations but would be directly applicable to lower elevations.

More long-term daily rainfall records are required to refine rainfall frequencies. Procedures to determine frequencies are included in SCS Hydrology, Section 4 National Engineering Handbook.

The data included for "C" values to be used in the Universal Soil Loss Equation are for broad general cropping systems and general

application. More specific "C" values could be developed with more specific information on rainfall distribution throughout the year.

Soil Erodibility Factor "K" used in the Universal Soil Loss Equation are based on present knowledge of soil as described in the Lang and Carroll's Soil and Land Use Survey 1966. When a new soil survey is completed appropriate "K" factors will be determined as a part of that survey report.

Specific information for refining "C", "K" and "R" values are included in USDA/SEA Predicting Rainfall Erosion Losses, Agricultural Handbook No. 57.

1.4.2 Responsibilities

The official responsibility for keeping this guide and handbook up-to-date should be vested in the Soil Conservation Unit. Unit personnel should always be seeking new information and data that would strengthen the handbook and the soil conservation effort on St. Kitts. Any information that comes to their attention which appears to be pertinent should be first reviewed with specialists having expertise in the field with which the information applies. If collectively they believe the information is suitable and important, a revision or addition should be issued.

It will also be the responsibility of the Soil Conservation Unit to keep a complete list of all persons holding copies so that each person can be informed of any changes and additions.

One official copy of the Soil Conservation Planning Guide and Handbook should be kept by the Soil Conservation Unit and kept up-to-date with all the official changes and additions.

Each person holding a copy man, in addition to official revisions, place information of personal interest and importance in his/her copy. Each holder should also pass on to the Soil Conservation Unit any information they believe important enough to be include as official revisions.

2. PLANNING THE RESOURCE MANAGEMENT SYSTEM TO IMPROVE SOIL CONSERVATION

2.1 Introduction

This section provides guidance for determining the needed land conservation treatment for a particular field or area. Follow this procedure:

- Determine the soil mapping unit and slope from the soil map, Annex 4, for the field or area in question. Determine slope gradient in percent by dividing the horizontal distance in feet as measured on the map into the vertical (or elevation) change in feet as shown by the contour lines. Move the decimal two places to the right for percent. Table 2.1, p. 14, provides the soil name of the mapping unit and other information about the soils.

- Determine the land capability unit classification of the soil and slope from Table 2.2, p. 16. For an explanation of the land capability classification system, see Section 2.2.2.

- Determine levels of soil loss and erosion, in order to identify appropriate conservation practices. Section 2.3 describes this in detail.

- Consider possible alternative uses of the soils after the land capability unit is determined and after taking mean annual rainfall into account (See Figure 2.1, p. 18). Section 2.4 provides guidance.

- Identify resource use, select appropriate management systems and select the conservation practices needed for that system. Figure 2.3, p. 43, indicates the suitable land use. See Section 2.4 for guidance.

2.2 Evaluating Available Resources

2.2.1 Soil characteristics of the mapping units

The soils of St. Kitts range in surface texture from loamy fine sand to clay. The majority of the cropland soils range from loamy to loamy sand. Generally, these soils are freely permeable, and have moderate available moisture and fertility holding capacities. Slope can greatly affect susceptibility to water erosion, and soils on St. Kitts generally range from moderately steep to steep. Drainage through the soils varies from slow to rapid, depending largely on soil texture. Generally, the sandier soils drain more rapidly than heavier soils. Although rapid drainage can make a soil less susceptible to erosion, it is also correlated with droughtiness, which can affect a soil's productivity. Soil limitations also result from other factors, e.g.,

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hard sub-surface layers or by water tables near the surface, which adversely affect root growth. Table 2.1, p. 14 summarizes these and other soil characteristics, including erosion hazards, general fertility, special management problems, and stony or rocky conditions.

2.2.2 Capability classes defined

The land capability classification provides three major categories of soil groupings:

- Land capability class;
- Land capability subclass; and
- Land capability unit.

The bases for differentiating capability classes are soil and climatic limitations in relation to the use, management, and productivity.

The first and broadest category in the land capability classification places all the soils in eight capability classes. The risks of soil damage or limitations in use become progressively greater from Class I to Class VIII. Soils in the first four classes under good management are capable of producing the common cultivated field crops as well as pasture grasses and forest trees. Soils in Classes V, VI, and VII are suited to the use of adapted native plants, but normally are not suited for cultivation. Some soils in Class VI are capable of producing specialized crops, such as certain fruits and ornamentals, even field and vegetable crops under highly intensive management involving elaborate practices for soil conservation. Soils in Class VIII do not return on-site benefits for inputs of management for crops, grasses, or trees without major reclamation.

The grouping of soils into capability classes, subclasses, and units is done primarily on the basis of their capability to produce common cultivated crops and pasture plants without deterioration of the soils over a long period of time. The eight classes are:

- **Class I**--Soils with few limitations that restrict their use;
- **Class II**--Soils with some limitations that reduce the choice of plants or require moderate conservation practices;
- **Class III**--Soils with moderately severe limitations that reduce the choice of plants or require special conservation practices or both;
- **Class IV**--Soils with severe limitations that restrict the choice of plants, require very careful management, or both;
- **Class V**--Soils with little or no erosion hazard but have other limitations impractical to remove that limit their use

largely to pasture, range, woodland, or wildlife food and cover;

- Class VI--Soils with severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover;

- Class VII--Soils with very severe limitation that make them unsuited to cultivation and that restrict their use largely to grazing, woodland, or wildlife; and

- Class VIII--Soils and landforms with limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife, or to aesthetic purposes.

The second category, the capability subclass, is a grouping of capability units having similar kinds of limitations and hazards. They are:

- Subclass erosion (e)--The susceptibility to erosion is the dominant problem or hazard;

- Subclass excess water (w)--Excess water is the dominant hazard or limitation. Poor soil drainage, wetness, high water table, and overflow are the criteria for determining which soils belong in this subclass;

- Subclass soil limitations (s)--Soils have such limitation as shallowness of rooting zones, stones, low moisture-holding capacity, low fertility difficult to correct, and salinity or sodium; and

- Subclass climatic limitation (c)--Climate (temperature or lack of moisture) is the only major hazard or limitation.

The third category, land capability unit, is a grouping of soils that have about the same responses to systems of management of common adapted cultivated crops and pasture plants. The unit designation, i.e. IIe1, IIe2, IIe3, etc., groups soils that have the same basic degree of limitation, but may differ in such characteristics as pH, crop adaptation and crop yield potential. The unit designation (1,2,3, etc.) has no relation to the severity of the limitation or hazard. Estimated long-term yields of adapted crops for individual soils within the unit under comparable management do not vary more than about 25 percent. This is the unit for which conservation treatment is designed, and includes land capability class, subclass, and unit designation.

Table 2.1: Some Important Characteristics of the Soil Mapping Units of St. Kitts[1]

Map Symbol	Soil	Dominant Slope Range, Percent	Drainage Through Soil	Any High Water Table	Moisture Supplying Capacity	Root Limiting Layer	Erosion Hazard	General Fertility	Any Special Management Problems	Stones—Boulders
1 2	Cockleshell Bay Loamy Sand Frigate Bay Loamy Sand	0–3.5	Very rapid	—	Very low	Nil	Danger of wind erosion if clean cultivated	Low	Low fertility. Wind-blast	Nil.
3	Bird Rock Loamy Sand	3.5–40	Rapid	—	Low	Nil	Gullying on steeper slopes	Moderate	Moisture conservation. Stoniness	Generally stony and bouldery.
4	Peninsula Loamy Sand	0–3.5	Rapid, but slight impedance below C.	—	Low	Cemented sub-surface horizon	Very low	Moderately low	Moisture conservation. Salinity	Few stones or boulders.
5	Shadwell Loamy Sand	0–40	Rapid	—	Low	Nil	Gullying on steeper slopes	Moderately high	Moisture conservation	Variable, not very stony.
6	Golden Rock Loamy Sand and Sandy Loam	0–17	Rapid, but often impeded in subsurface horizons	—	Low to moderate	Usually a compact subsurface horizon	Low	Moderately high	Moisture conservation. Prevention of "packing" in sub-surface horizons	Relatively few stones or boulders.
7	Ogee's Sandy Loam	12–40+	Rapid	—	Low	Nil	Liable to both sheetwash and gullying	Moderately high	Erosion	Some stones and boulders.
8	Sandy Bay Loamy Sand and Sandy Loam	0–40	Rapid	—	Low	Nil	Moderately low, tends to gully	Moderately high	Moisture conservation	Very variable, often very bouldery.
9	Harris Loamy Fine Sand	9–40	Rapid	—	Low	Nil	Much soil lost by creep	Moderately low	Erosion. Stoniness	Stony and bouldery.
10	Pump Loamy Fine Sand	9–40	Rapid	—	Low	Very fine sandy sub-surface horizons often "pack"	Easily eroded due to light texture	Moderately high	Moisture conservation. Erosion. Cultivation	Usually slightly stony and bouldery.
11	Brownson's Loamy Sand	5–40	Very rapid	—	Very low	Nil	Low	Moderate	"Dry" soil	Usually not very stony.
12	Lavington's Loamy Fine Sand and Fine Loam	9–25	Rapid	—	Low	Nil	Low, an accumulating soil	Moderate	Moisture conservation	Relatively few stones or boulders.
13	Vambelle Silt Loam and Silt	9–40	Moderately rapid, often limited by impervious layer towards base of soil	—	Low	Cemented subsurface horizons	Easily deflated. Often severely gulied	Moderately high	Erosion. Cemented subsurface horizons	Often stony.
14	Estridge's Loam and Sandy Loam	5–35	Moderately rapid	—	Moderate to low	Generally base of soil	Topsoil usually lost by sheet erosion	Moderate	Shallowness. Erosion	Usually few stones.
15	Mansion Loam	5–40	Moderately rapid	—	Moderate	Generally base of soil	Topsoil usually lost by sheet erosion	Moderate	Rehabilitation and conservation of topsoil	Usually few stones.
16	Duporte Loam	9–70	Moderately rapid	—	Moderate	Generally base of soil	Topsoil usually lost by sheet erosion	Moderately high	Rehabilitation and conservation of topsoil	Usually few stones.
17	Parson's Loam	20–40	Moderately rapid	—	Moderate	Generally base of soil	Topsoil usually lost by sheet erosion	Moderately high	Rehabilitation and conservation of topsoil	Usually some stones or boulders.
18	Otley's Level Loam	12–70	Moderately rapid	—	Moderate to low	Generally base [illegible]	Topsoil usually lost by sheet erosion	Moderately high	Rehabilitation and conservation of topsoil	Usually some stones or boulders.

Table 2.1: Some Important Characteristics of the Soil Mapping Units of St. Kitts (continued)

Map Symbol	Soil	Dominant Slope Range Percent	Drainage Through Soil	Any High Water Table	Moisture Supplying Capacity	Root Limiting Layer	Erosion Hazard	General Fertility	Any Special Management Problems	Stones—Boulders
19	Whites Clay Loam	20-50	Moderately rapid	—	Moderate	Increasing loss of structure in deeper subsoils	Topsoil usually lost by sheet erosion	Moderate	Rehabilitation and conservation of topsoil	Not appreciably stony or bouldery.
20	Wingfield Level Clay Loam	5-45	Moderately rapid	—	Moderate	Increasing loss of structure in deeper subsoils	Topsoil usually lost by sheet erosion	Moderate	Rehabilitation and conservation of topsoil	Not appreciably stony or bouldery.
21	Fahie's Clay Loam	17-40	Moderate	—	Moderate	Deeper subsoil is very compact	Topsoil usually lost by sheet erosion	Moderate	Rehabilitation and conservation of topsoil	Not appreciably stony or bouldery.
22	Phillips. Level Silt Loam	5-70	Moderately rapid	—	Moderate	Structure lost in deeper subsoil	Easily eroded if plant cover removed	Moderate	Conservation of topsoil. Fairly low nutrient content	Not appreciably stony or bouldery.
23	Mount Misery Silt Loam	30-100	Rapid	—	Moderate to low	Nil	Very liable to sheetwash erosion	Moderately low	Conservation of topsoil	Slightly stony.
24	Peak Silt Loam	40-100	Moderately rapid	—	Moderate	Generally base of soil	Only moderate danger under present vegetation	Moderate	Steepness of slopes. Difficulty of access	Some stones and boulders.
25	Jack in the Box Clay Loam	20-40	Moderately slow. Fairly impervious clay horizon	Imperfect. Surface puddling	Moderately high	Heavy clay subsoil	Topsoil easily lost when clean cultivated	Moderate	Cultivation. Preservation of subsurface structure	Few stones or boulders.
26	Bayford's Loam	9-40	Usually moderate, may be impeded	Imperfect. Surface puddling	Moderate	Often a subsurface cemented horizon	Some sheetwash on slopes over 5°	Moderately high	Prevention of subsoil "panning"	Not very stony.
27	Conaree Hills Loam	5-70	Moderate	—	Moderate	Solid parent material	Moderately low	Moderately low	Stoniness	Generally stony and bouldery.
28	Sir Timothy's Clay Loam	17-70	Moderate	—	Moderate to low	Solid parent material	Topsoil easily lost	Low	Shallow soil on steep slopes	Stony and bouldery with rock outcrops.
29	Monkey Hill	17-75	Moderate	—	Moderate	Usually base of soil	Very liable to sheetwash	Moderate	Erosion on steep slopes. Bouldery nature	Stony and bouldery.
30	Salt Pond Sand and Loamy Sand	0-3.5	Rapid	Usually below 2'-3'	Moderate, but water usually brackish	Nil	Very low	Low	Low fertility. Salinity	Nil.
31	Muddy Pond Silty Clay and Sandy Clay	0-3.5	Slow	At 12"-18"	Moderately high, but water usually brackish	Poorly drained soil below 6"	Very low	Very low	Drainage. Salinity	Almost stone free.
32	Friar's Bay Clay and Silty Clay	0-3.5	Very slow	Usually at 6" or less	High, brackish water	Wet, saline soil	Very low	Very low	Excessive salinity	Nil.

[1] Adapted from D.M. Lang and D.M. Carroll, "Soil and Land-Use Surveys," No. 16, August 1966, The Imperial College of Tropical Agriculture, Trinidad, West Indies.

Table 2.2: St. Kitts: Land Capability Classification of the Soil Groups and Slope Classes

Map Symbol	Soil	Land Capability Unit[1] with Subclasses and Slope Gradient, Percent								
		IIsl 0-3.5	IIIel 3.5-5	IIIe2 5-12	IVel 12-17	IVe2 17-25	Vwl 0-3.5	Vsl 0-3.5	VIel 25-35	VIIel >35
1	Cockleshell Bay Loamy Sand						X			
2	Frigate Bay Loamy Sand						X			
3	Bird Rock Loamy Sand		X	X	X				X	X
4	Peninsula Loamy Sand							X		
5	Shadwell Loamy Sand	X	X	X	X	X			X	X
6	Golden Rock Loamy Sand & Sandy Loam	X	X	X	X					
7	Ogee's Sandy Loam			X	X				X	X
8	Sandy Bay Loamy Sand & Sandy Loam	X	X	X	X	X			X	X
9	Harris Loamy Fine Sand			X	X	X			X	X
10	Pump Loamy Fine Sand			X	X	X			X	X
11	Brotherson's Loamy Sand			X	X	X			X	X
12	Lavington's Loamy Fine and Fine Loam			X	X	X			X	X
13	Vambelle Silt Loam and Silt			X	X	X			X	X
14	Estridge's Loam and Sandy Loam			X	X				X	X
15	Mansion Loam			X	X	X			X	X
16	Duporte Loam			X	X	X			X	X

[1] A land capability unit is a grouping of soils and slope ranges that require similar treatment. Basically a treatment unit designed to make it possible for selecting a suitable resource management system and the needed

Table 2.2: St. Kitts: Land Capability Classification of the Soil Groups and Slope Classes (continued)

Map Symbol	Soil	Land Capability Unit[1] with Subclasses and Slope Gradient, Percent								
		IIsl 0-3.5	IIIel 3.5-5	IIIe2 5-12	IVel 12-17	IVe2 17-25	Vwl 0-3.5	Vsl 0-3.5	VIel 25-35	VIIel >35
17	Parson's Loam					X			X	X
18	Ottley's Level Loam				X	X			X	X
19	Whites Clay Loam					X			X	X
20	Wingfield Level Clay Loam			X	X	X			X	X
21	Fahie's Clay Loam					X			X	X
22	Phillips' Level Silt Loam			X	X	X			X	X
23	Mount Misery Silt Loam								X	X
24	Peak Silt Loam									X
25	Jack in the Box Clay Loam					X			X	X
26	Bayford's Loam			X	X				X	X
27	Conaree Hills Loam			X	X	X			X	X
28	Sir Timothy's Clay Loam					X			X	X
29	Monkey Hill					X			X	X
30	Salt Pond Sand and Loamy Sand							X		
31	Muddy Pond Silty Clay and Sandy Clay							X		
32	Friar's Bay Clay and Silty Clay							X		

[1]The land capability unit is a grouping of soils and slope ranges that require similar treatment. Basically it is a treatment unit designed to make it possible for selecting a suitable resource management system and the needed conservation practices.

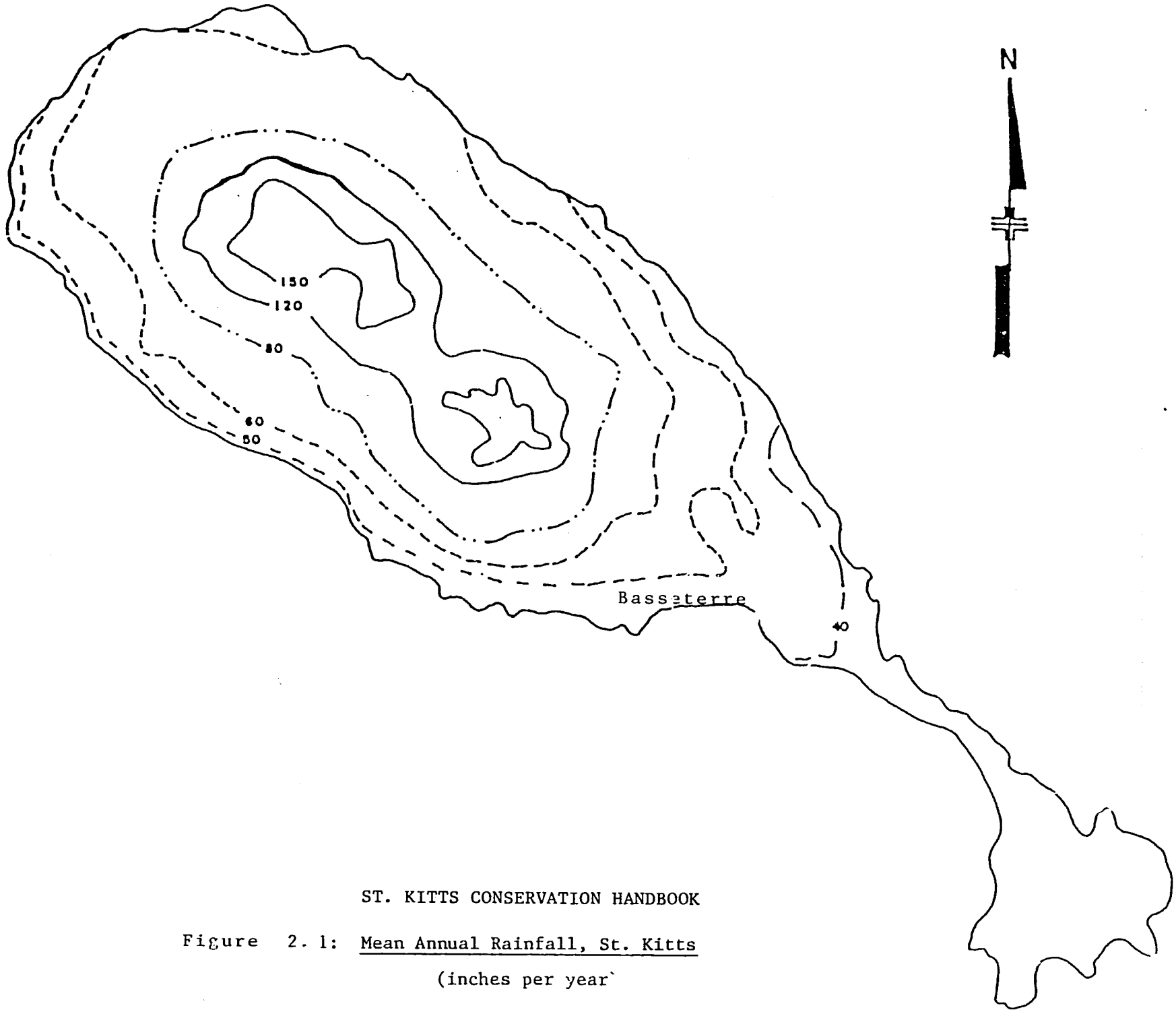

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Figure 2. 1: Mean Annual Rainfall, St. Kitts

(inches per year)

2.3 Determining Water Runoff, Soil Loss and Erosion, Field by Field

Erosion, or the loss of soil, can go unnoticed by farmers and other agricultural workers unless it is dramatic and sudden, such as the advance of a gully to a valuable building or bridge during one storm. However, there are ways to recognize and quantify different kinds of erosion early so that erosion can be slowed or stopped. The following sections describe some of these, including detailed explanations of two quantitative tools for estimating soil loss and storm runoff field by field.

2.3.1 Visual observation and measurement of soil erosion

The field in question should be carefully inspected for any evidence of erosion. A good time to do this is after a heavy rain and before any tillage operation. Very small rills downslope or small accumulations of sediment in any quantity indicate that soil loss is exceeding allowable rates. Look for accumulations of sediment in depressions or low places in rows. Erosion specialists generally agree that any visual signs of erosion indicate soil loss at rates of 18-20 tons per acre per year, which is about four times the allowable rates. This type of erosion is called sheet and rill erosion and can be the most critical since it can go unnoticed for long periods. Sheet and rill erosion can be estimated by use of the Universal Soil Loss Equation (see below), and the soil loss is expressed in tons per acre per year.

Check depressions beginning 200 to 500 feet down from the top of a slope. If concentrated flow erosion is present, there will be evidence of a scour channel. This type of erosion is not estimated by use of the Universal Soil Loss Equation. Any scour channel is considered to be concentrated flow or gully erosion. Concentrated flow erosion is measured by estimating the volume of the eroded channel and applying a unit weight of soil to determine loss. Values of in-place soil density usually range from 80 to 100 pounds per cubic foot. This erosion rate is expressed as tons per year.

Gully erosion is readily observed by head cuts moving up channel and unstable sides of the ghaut breaking off and collapsing into the draw. Subsequent storm flows move the loose soil downstream, leaving vertical banks to collapse again, thus repeating the process. It is estimated by physically measuring the void left by the erosion. The time factor can be estimated using photographs, maps, survey points, interviews with local residents or any other records available. For instance, if a gully head advanced 100 feet in 5 years (determined by scaling aerial photographs) the volume of the void would be measured, multiplied by the volume weight estimated for the soil, and divided by 5 to determine average annual erosion rates. Normally, gully erosion should be measured over several years to eliminate the extremes of rare storms. Gully erosion is expressed as tons per year.

Beach erosion is usually measured as a distance the beach moves inland perpendicular to the beach front. Similar data to that developed for gullies can be used for this estimate. Beach erosion rates are expressed as feet per year.

2.3.2 Using the Universal Soil Loss Equation (USLE)

2.3.2.1 Purpose of the USLE

The Universal Soil Loss Equation is designed to estimate long-term average annual soil losses from sheet and rill erosion. It can be used to estimate erosion on farm fields, construction sites and other areas.

The USLE is useful in evaluating the need for conservation measures. Soil losses from a field can be estimated for the present condition or for a future condition, for example, after erosion control measures are applied. Thus, conservation measures can be selected to reduce erosion to an acceptable level.

The soil loss equation is:

$$A = R \times K \times LS \times C \times P$$

where

A = the computed soil loss per unit area (tons per acre per year)

R = the rainfall factor

K = the soil erodibility factor

L = the slope-length factor[1]

S = the slope-gradient factor[1]

C = the cover and management factor

P = the erosion and control factor (contour, terrace and strip crop farming used on cropland; on non-agricultural land P has a value of 1 and is not considered)

Soil losses calculated with the USLE are the best available estimates for sheet and rill erosion. They should be regarded as estimates, not absolutes. These amounts are expressed as average

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[1]A combined "LS" factor is used in the equation

annual soil loss over a number of years. The amount of erosion occurring in any one year may be more or less than the average. The USLE does not apply to erosion caused by heavy concentration of run-off water, for example, gully and streambank erosion.

2.3.2.2 Applying the USLE

To calculate average annual soil loss A from a field, select R, K, LS, C and P values for the particular field from appropriate maps and tables. Use the following procedure:

- Determine the rainfall factor R from Figure 2.2, p. 33 in this section. Interpolate as necessary;

- Determine the soil erodibility factor K. First determine the soil from appropriate soil survey then obtain K for the soil using Table 2.3, p. 25;

- Determine the slope length and slope gradient factors LS;

  -- First, determine slope length (feet) and gradient (percent) at the site. Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins, or runoff water enters a well-defined channel that may be part of a drainage network or a constructed channel.

  -- Second, obtain LS value from Table 2.4, p. 26.

- Determine the cover and management factor C for the appropriate crop cover condition, as given in Tables 2.5, 2.6, 2.7, or 2.8, pp. 27 to 30;

- On cropland determine the erosion control practice factor P, as described in Section 2.3.2.3 which follows Table 2.10, p. 32. On other lands P has a value of 1 and does not affect the equation. Use Tables 2.9 and 2.10, pp. 31 to 32;

- Multiply together the values R, K, LS, C and P obtained in the previous steps. The product A is the average annual soil loss expressed in tons per acre per year; and

- If 90 percent or more of the site is made up of one soil, calculate soil loss for the area based on that soil. If no soil occupies 90 percent or more of the site, calculate soil loss for each soil that makes up at least 10 percent of the area. Obtain a weighted average annual soil loss for the area.

2.3.2.3 Erosion control practices and the P factor

Research and production experience have shown that cultivated sloping soil suffers less erosion damage if certain conservation practices such as contour farming, contour strip cropping, and terracing are used. This is especially important in St. Kitts where cropland slopes range from 5 to 25 percent and sometimes steeper. The factor P used in the USLE is expressed as the ratio of soil loss with the practice, such as contour farming, in place compared to farming up and down the hill.

The values for contour farming are contained in Table 2.9, p. 31. For this factor to apply, the tillage must be such that water will not run down rows until it reaches a low place and breaks through the tillage ridge. This requirement is met if the tillage operations are parallel to terraces. Normally a variation from level not exceeding a one (1.0) percent grade is considered as on the contour. If before-treatment condition is such that most of the tillage is generally across the slope, but does not meet the above criteria, a factor reflecting one-half the effect shown in Table 2.9 may be used to estimate present conditions; $\left(\frac{1.0 + \text{contour factor}}{2}\right) = P$.

Research and observation indicate that slopes can get so long that the water breaks through and contouring loses its effectiveness. These limits are shown in Table 2.9. For example, if sugarcane is planted on the contour as defined above, with substantial ridges to stay in place throughout the five-year growing cycle, it is permissible to increase the slope length limits to give credit for these ridges.

Contour strip cropping, where strips of sod forming grasses are alternated with equal width strips of row crops, is more effective than contouring alone. However, this practice is not expected to be used in St. Kitts, so the factors are not included.

The P factor values for terraces are based on the same logic as contour strip cropping, i.e., the eroded sediment moves a short distance and is trapped.

The P factor credit for terraces is the largest for closed terraces. They trap 90 to 95 percent of the sediment that enters them. For gradient terraces, the factor is higher for very low grades and decreases as the grade increases. The factor gets smaller as the horizontal interval between terraces gets larger because the area of the terrace is a smaller proportion of the interval. Table 2.10, p. 32 contains the P factors for terraces.

2.3.2.4 Practice problems--determining P factor values

Problem 1--Determine the P factor for the following conditions:

Land slope 15 percent
Contour Farming--Sugarcane
Level Terraces (closed outlet)
Horizontal Interval 120 feet

Then read from Table 2.9, p. 31 a P factor for contouring of 0.7. This is permissible since sugarcane on ridges and heavy residue can be contoured to 160 ft. (double 80). Then read from Table 2.10, p. 32 for closed outlet terraces less than 110-140 ft. spacing a terrace P factor of 0.6. The composite P factor is then calculated by multiplying the two factors, 0.7 x 0.6 = 0.42. This can be used in applying the USLE.

Problem 2--Determine the P factor for the following conditions:

Land Slope 20 percent
Length of slope 75 feet
Contour vegetables with mulch

Read P factor from Table 2.9 of 0.80. The slope limit of 60 feet can be increased by 25 percent because of the beneficial effects of the mulch, which gives 75 feet maximum.

2.3.2.5 Practice problems--using the USLE

Problem 1--Compute the average annual soil loss, A, from sheet and rill erosion, on an uncropped field of Ogee Sandy Loam with grass cover of 40% and no canopy. Determine the following:

R rainfall factor = 300

K soil erodibility factor = 0.17
(from Table 2.3, p. 25)

L length of slope = 200 ft.
(from field observation)

LS = 1.4

S gradient of slope = 8%
(from field observation)
(combine LS value from Table 2.4, p. 26)

C cover and management factor = 0.10
(from field observation and Table 2.6, p. 28)

P erosion control practice factor = 1.0

Calculate as follows:

$A = R \times K \times LS \times C \times P$

$A = 300 \times 0.17 \times 1.4 \times 0.10 \times 1.0$
$A = 7.1$ tons/acre/year average annual soil loss

Problem 2--Determine the cover and management (C) value needed to limit soil loss to 5 tons/acre/years, given the following:

R = 250
K = 0.10 LS = 1.4
L = 200 ft.

S = 8%
P = 1.0
A = 5 tons/acre/year

Calculate as follows:

$A = R \times K \times LS \times C \times P$

$$C = \frac{A}{R \times K \times LS \times C \times P}$$

$$C = \frac{5}{250 \times 0.10 \times 1.4 \times 1.0}$$

C = 0.14 This is the highest C value that will keep soil loss within 5 tons. See C value tables to determine the kind of cover or management needed to achieve this value

Problem 3--Determine slope length that will limit soil loss to 5 tons/acre/year, given the following:

R = 250
K = 0.10
S = 12%
C = 0.25
P = 0.36 (Contouring and terracing)

Calculate as follows:

$A = R \times K \times LS \times C \times P$

$$LS = \frac{A}{R \times K \times C \times P}$$

$$LS = \frac{5}{250 \times 0.10 \times 0.25 \times 0.36}$$

LS = 2.2

L = 150 feet (from Table 2.4, p. 26) For the given condition, slope length can be no greater than 150 feet.

Table 2.3: K Values and Soil Loss Tolerance by Soil Mapping Unit

Map Symbol	Soil	Erodibility Factor (K)	Tolerance[1] (tons/acres/yr.)
26	Bayford	.28	5
3	Bird Rock	.05	4
11	Brothersons	.05	5
1	Cockleshell Bay	.05	5
27	Conaree Hills	.17	4
16	Duporte	.28	4
14	Estridge's	.28	3
21	Fahie's	.17	5
32	Friar's Bay	.37	5
2	Frigate Bay	.05	5
6	Golden Rock	.10	5
9	Harris	.17	5
25	Jack-in-the-Box	.28	3
12	Lavington's	.05	5
15	Mansion	.28	4
29	Monkey Hill	.28	3
23	Mount Misery	.17	5
31	Muddy Pond	.28	5
7	Ogee's	.17	5
18	Ottley's	.10	4
17	Parson's	.28	4
24	Peak	.17	3
4	Peninsula	.10	3
22	Phillips' Level	.17	5
10	Pump	.17	5
30	Salt Pond	.05	5
8	Sandy Bay	.10	5
5	Shadwell	.10	5
28	Sir Timothy's	.28	3
13	Vambelle	.17	3
19	Whites	.28	5
20	Wingfield Level	.28	5

[1]Tolerance is the permissable average soil loss per year based on soil rebuilding characteristic and continued economic production.

Table 2.4: LS Values by Slope Gradient and Length

Percent Slope	Slope Length (feet) 25	50	75	100	150	200	300	400	500	600	800	1,000
0.5	0.065	0.080	0.091	0.099	0.112	0.122	0.138	0.150	0.160	0.169	0.185	0.197
1	.085	.105	.119	.129	.146	.159	.180	.196	.210	.222	.242	.258
2	.133	.163	.185	.201	.227	.248	.280	.305	.326	.344	.376	.402
3	.190	.233	.264	.287	.325	.354	.400	.437	.466	.492	.536	.573
4	.230	.303	.357	.400	.471	.528	.621	.697	.762	.820	.920	1.010
5	.268	.379	.464	.536	.656	.758	.928	1.070	1.200	1.310	1.520	1.690
6	.336	.476	.583	.673	.824	.952	1.170	1.350	1.500	1.650	1.900	2.130
8	.496	.701	.859	.992	1.210	1.400	1.720	1.980	2.220	2.430	2.810	3.140
10	.685	.968	1.190	1.370	1.680	1.940	2.370	2.740	3.060	3.360	3.870	4.330
12	.903	1.280	1.560	1.800	2.210	2.550	3.130	3.610	4.040	4.420	5.110	5.710
14	1.150	1.620	1.990	2.300	2.810	3.250	3.980	4.590	5.130	5.620	6.490	7.260
16	1.420	2.010	2.460	2.840	3.480	4.010	4.920	5.680	6.350	6.950	8.030	8.980
18	1.720	2.430	2.970	3.430	4.210	4.860	5.950	6.870	7.680	8.410	9.710	10.900
20	2.040	2.880	3.530	4.080	5.000	5.770	7.070	8.160	9.120	10.000	11.500	12.900
25	2.950	4.170	5.100	5.890	7.220	8.330	10.200	11.800	13.200	14.400	16.700	18.600
30	3.980	5.620	6.890	7.950	9.740	11.200	13.800	15.900	17.800	19.500	22.500	25.200
40	6.330	8.950	11.000	12.700	15.500	17.900	21.900	25.300	28.300	31.000	---	---
50	8.910	12.600	15.400	17.800	21.800	25.200	30.900	---	---	---	---	---
60	11.600	16.400	20.000	23.100	28.400	---	---	---	---	---	---	---

Table 2.5: Average Annual C Values by Cropping System

Crop Type	Examples	Treatment	C Value[1]
Cotton		(1) Clean tilled residue removed	0.45
		(2) Weedy, residue removed	0.30
		(3) Conservation tillage	0.15
Leafy Vegetables	Onion Tomato	(1) Clean tilled	0.36
		(2) Cover crop or weed cover	0.25
		(3) Conservation tillage	0.10
Head Vegetables	Cabbage	(1) Clean tilled	0.40
		(2) Cover crop or weed cover	0.30
		(3) Conservation tillage	0.10
Vine Crops	Yams Pumpkins Watermelon Sweet potatoes	(1) Vines on surface after harvest	0.17
		(2) Vines covered after harvest	0.22
		(3) Conservation tillage	0.10
Tannia and Dasheen		(1) Clean tilled	0.25
		(2) Weedy	0.20
		(3) Conservation tillage	0.10
Plantains and Bananas		(1) 50% ground cover	0.20
		(2) 80% ground cover	0.10
Peanuts		(1) Clean tilled residue removed	0.36
		(2) Clean tilled residue remain	0.25
		(3) Weedy, residue remain	0.17
		(4) Conservation tillage	0.15
Sugarcane		(1) 5-year rotation	0.11
		(2) 5-year rotation	0.14
		(3) 4-year rotation	0.15
		(4) Conservation tillage	0.06

[1]The listed C values assume that the vegetation and mulch are uniformly distributed over the entire area.

Table 2.6: Average C Values for Permanent Pasture, Natural Grazing Land, and Idle Land

Vegetative Canopy			Cover that Contacts the Surface (Percent Ground Cover)					
Type and Height[1]	Percent Cover	Type[2]	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	0.43	0.110
Tall weeds or short brush with average drop fall height of 20 in.	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.35	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.033
		W	.17	.12	.09	.068	.038	.011
Appreciable bush or brushes, with average drop fall height of 6-1/2 ft.	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft.	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1]Portion of total area surface that would be hidden from view by canopy in a vertical projection (bird's eye view). Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 feet.

[2]G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with 2 little lateral root network near the surface) or undecayed residue or both.

Table 2.7: Average C Values for Forest Land

Stand Condition	Tree Canopy[1] (Percent of Area)	Forest Litter[2]	Undergrowth[3]	C Factor
Well stocked	100-75	100-90	Managed[4]	.001
			Mismanaged[5]	.003-.011
Medium stocked	70-40	85-75	Managed	.002-.004
			Mismanaged	.01-.04
Poorly stocked	35-20	70-40	Managed	.003-.009
			Mismanaged	.02-.09

[1]When tree canopy is less than 20 percent, the area will be considered as grassland for estimating soil loss.

[2]Forest litter is assumed to be at least 2 inches deep over the percent ground surface area covered.

[3]Undergrowth (usually found under canopy opening) is defined as shrubs, weeds, grasses, vines, etc. on the surface area not protected by forest litter.

[4]Managed: grazing and fires are controlled.
Mismanaged: stands that are overgrazed or subjected to repeat burning.

[5]Mismanaged: stands that are overgrazed or subjected to repeat burning.

Table 2.8: Average C Values for Ground Cover

Kind of Ground Cover	Value
Grass Sod	.01
Seedlings (fully established stand): [Permanent grasses (rhizomatous or stoloniferous)]	.01
Mulches:	
Sugarcane residue from the field (2 tons/acre)	.03
Bagasse (2 tons/acre)	.02
Hay or cut grass(2 tons/acre)	.02
Woodchips (6 tons/acre)	.06
Wood cellulose fiber (1 3/4 tons/acre)	.10
Peanut shells (2 tons/acre)	.10
Bare soil	1.00

Table 2.9: P Values and Slope-Length Limits for Contoured Cultivation

Land Slope	P Value (Feet)	Maximum Length[1] (Feet)
1 to 2	0.60	400
3 to 5	0.50	300
6 to 8	0.50	200
9 to 12	0.60	120
13 to 16	0.70	80[2]
17 to 20	0.80	60[2]
21 to 25	0.90	50[2]
25 & up	1.00	NA

[1]Length limit may be increased 25 percent for mulching or residue that produces 50 percent cover.

[2]These limits may be doubled for sugarcane ridges with 50 percent residue cover.

Table 2.10: P Values for Terraced Cultivation

Horizontal Interval (ft)	Closed Outlets[1]	Open Outlets, (percent Grade)[2]		
		0.1-0.3	0.4-0.7	0.8
Less than 110	0..	0.6	0.7	1.0
110-140	0.6	0.7	0.8	1.0
140-180	0.7	0.8	0.9	1.0
180-225	0.8	0.8	0.9	1.0
225-300	0.9	0.9	1.0	1.0
More than 300	1.0	1.0	1.0	1.0

Note: If contouring P factors are appropriate, they can be multiplied by the terrace P factor for the composite P factor.

[1]P factors for closed outlet terraces also apply to terraces with underground outlets and to level terraces with open outlets

[2]The channel grade is measured on the 300 ft of terrace or the one-third of total terrace length closest to the outlet, whichever distance is less.

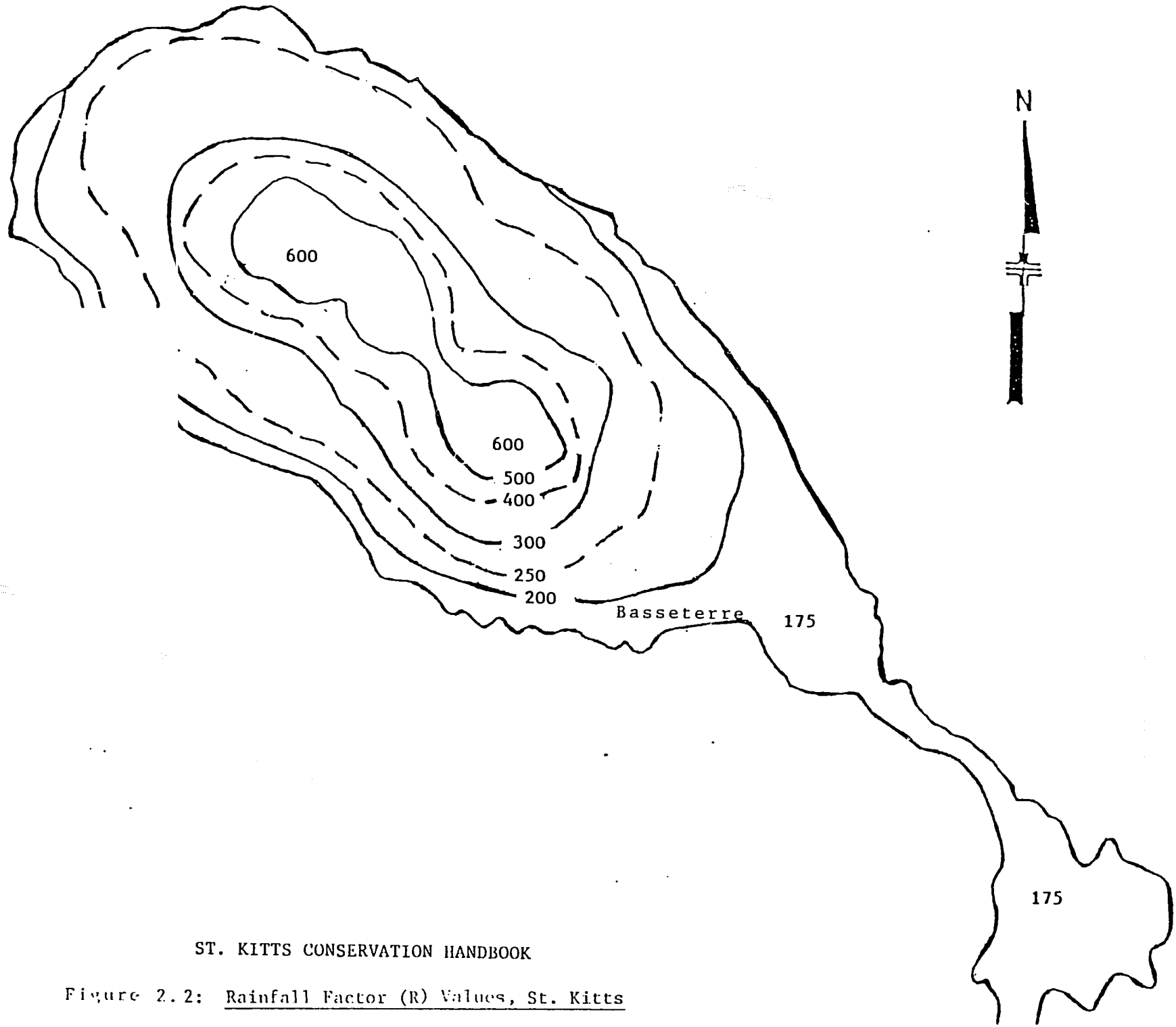

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Figure 2.2: Rainfall Factor (R) Values, St. Kitts

2.4 Identifying Appropriate Resource Use and Appropriate Management Systems--Conservation Practices

This section gives guidance on conservation treatment needs for seven land uses:

- Cropland;
- Pastureland;
- Natural grazingland;
- Forestland;
- Recreationland;
- Orchardland, including coconutland; and
- Beachland.

After the land capability unit has been determined for the soils as described in Section 2.2, use Figure 2.3, p. 43 as an aid in determining appropriate land use. This figure shows how intensely land in each land capability class can be used. For cropland use, Table 2.11, p. 39 indicates acceptable resource management systems, C-1 through C-10, which are explained in the footnote to that table. These ten systems state which conservation practices are essential.

2.4.1 Resource management systems for cropland and conservation practices

Crop Land systems reflect different levels of treatment for soil conservation. Table 2.11 specifies which of the systems generally can provide soil protection for each land capability unit. For these systems to accomplish their purpose they must include good farming practices. This includes pest control (insects, disease, weeds, etc.) and fertility management. Use of good farming practices denotes those that can be applied by the small farmer. For pest control this means use of common insecticides, adapted local varieties of crops resistant to known diseases, and crop rotation to reduce crop exposure to the same pest time after time. Good fertility management means use of all available manure, rotations that include legumes, leaving all crop residue on the fields, and applying commercial fertilizer judiciously. Some crop varieties, more than others, produce vegetation that remains as crop residue. Some provide good surface cover. These characteristics influence soil conservation and are classified in Table 2.12, p. 42.

Generally, one of the designated systems shown in Table 2.11 will control soil erosion on the soils within the group. However, the chosen system could be inadequate for steeper soils of the group. Where questions arise, the planned system should be evaluated with the Universal Soil Loss Equation, (See Section 2.3.2, above). Adjustments to the system should be made by changing the crop rotation, additional mulching, or switching to a more intense system.

An example for cropland service management follows:

System: C-4

The area to be planned has been identified as a Sandy Bay Loamy Sand on a 15% slope. (Both the soil and the slope should be verified in the field).

From Table 2.2, p. 16 - A Sandy Bay Loam Sand on 15% slope is identified as in Land capability classification IVel

From Table 2.11, p. 39 - The most intense Resource Management System that can be considered is C-4 which is cleaned tilled crop rotated so that one-half of the land will be in crop or crops that provide good to fair surface cover with crop rotation, contour farming, crop residue management and conservation tillage or mulching. These combinations could be vegetables such as tomatoes, cabbage, carrots, etc. and a good to fair cover producing crop such as sweet potatoes, water melons, cucumbers, blackeye peas (cowpeas), sugarcane, etc. (Table 2.12, p. 42)

Before recommending this cropping system, the soil loss should be checked using the Universal Soil Loss Equation.

For these conditions, the following criteria apply:

R - Rainfall Factor - Locate field on Figure 2.2, p. 33. For this example, assume that it is between 250 and 300, say 275;

K - Soil erodibility Factor - Sandy Bay Loamy Sand, Table 2.3, p. 25, K = 0.10;

L - Slope Length Factor - Table 2.9, p. 31 - Maximum slope length for contour for 15% slope is 80 ft;

S - Slope Gradient Factor = 15%

LS Factor - L = 80 ft., S = 15% by interpretation between L = 75 and 100 and S = 14% and 16%.

at 14% LD for 80' = $1.990 + \frac{2.300-1.990}{5} = 2.058$;

at 16% LS for 80' = $2.460 + \frac{2.840-2.460}{5} = 2.536$;

at 15% LS for 80' = $\frac{2.058 + 2.536}{2} = 2.297$

C - Crop and Management Factor - Conservation Tillage = 0.10

P - Control Factor - contouring 15% slope = 0.7

Applying the Universal Soil Loss Equation

$A = R \times K \times LS \times C \times P$
$A = (275)\ (0.10)\ (2.297)\ (.10)\ (.70)$
$A = 4.42$ - (within allowable)

Solve for L with an allowable soil loss of 5.0 tons per acre per year;

$$LS = \frac{A}{RKCP} = \frac{5}{(275)(0.20)(.10)(.7)} = \frac{5}{1.93} = 2.60$$

From Table 2.4, p. 26:

LS for L = 100 ft, S = 14% = 2.300
LS for L = 100 ft, S = 16% = 2.840
LS for L = 100 ft, S = 15% = $\frac{2.3 + 2.84}{2} = 2.57$

L for LS 2.60, S = 15% = 100 ft (within the degree of accuracy expected from these calculations).

Greater slope lengths would require terraces, C-7 or other cropping system.

Cost: Additional cost of controlling weeds and insects with pesticides or by hand:

- Special Equipment Cost;
- Increase in planting cost; and
- Increase in Management Cost.

Benefits:
- Reduced cost of tillage;
- Controlled erosion within the allowable;
- Maintenance of present crop yields (slight increase possible with time);
- Continued crop reduction without degradation as long as the system is maintained; and
- Conservation of moisture

2.4.2 Pastureland systems

Pasture land is defined as areas developed for forage production by planting adapted grasses and legumes. Generally, these species or cultivars are introduced. Examples are guinea grass, pangola grass, elephant grass, and siratro.[1] Fertilizing is essential for high production and may or may not be necessary to maintain the introduced plants. There is a direct correlation in the amount of the correct

[1]Scientific names of grass and legume species are given in Annex 2.

analysis fertilizer used and the amount of forage produced. There are pasture management techniques as important, or in many cases more important, than fertilizing. The appropriate conservation practice for establishing or managing pastureland are:

- Pasture planting;
- Proper pasture management;
- Brush control;
- Fencing; and
- Livestock water development.

2.4.3 Natural grazingland

Grazing lands are areas composed primarily of native herbaceous forages. They may be abandoned cropland, former pastureland, or cleared woodland. Introduced grasses such as guinea grass, devel grass (bermuda grass), and sour grass may be common in these fields. Production is low to moderately high, depending on soils and forage management. Appropriate conservation practice are:

- Proper grazing use;
- Brush control;
- Fencing; and
- Livestock water development.

2.4.4 Forestland

Forest is the natural coverage of most lands in St. Kitts. Presently, soil conservation would be improved if the cropland and abondoned cropland are returned to forestland. However, economic and social demands make usage in non-forest important and so it is important to manage properly the present forests and lands suitable for forests so as to minimize erosion, avoid conflicting uses and satify social and economic demands. Some appropriate practices are:

- Protection;
- Forest site preparation;
- Tree planting; and
- Forest improvement and forest improved harvesting.

2.4.5 Recreationland

The use of land for recreation is important. Developing it usually requires soil disturbance. Using it normally imposes heavy foot traffic. Both these conditions require soil conservation considerations. Appropriate practices are:

- Recreation area grading and shaping;
- Critical area treatment;
- Livestock exclusion; and
- Fencing.

2.4.6 Orchardland and coconutland

Lands on which these perennial crops grow may be treated as cropland or "forest land". As cropland, weeds may be controlled by cultivating. This leaves the soil susceptible to erosion. As "forest land", a continuous mulch of residue or growing vegetation may protect the soil. Because of these factors it is difficult in this handbook to provide guidance on conservation systems. Use the Universal Soil Loss Equation to design an adequate system for each condition.

2.4.7 Beachland

Major damage to beach land is caused by hauling of sand from the beach and erosion caused by large items on the beach such as shipwrecks. Remedying this may require legislation and effective enforcement.

Table 2.11: Primary Recommendations of Resource Management Systems for Soil Conservation on Cropland[1]

Land capability unit/percent slope	Soils	RESOURCE MANAGEMENT SYSTEM									
		C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
IIs1 0-3.5%	Golden Rock Sandy Bay Shadwell	X	X	X							
IIIe1 3.5-5%	Bird Rock Golden Rock Sandy Bay Shadwell		X	X	X		X				
IIIe2 5-12%	Bayford's Bird Rock Brotherson Conaree Hills Duporte Estridge Golden Rock Harris Lavington Mansion Ogee's Phillips Level Pump Sandy Bay Shadwell Vambelle Wingfield Level			X	X		X	X			
IVe1 12-17%	Bayford's Bird Rock Brotherson Conaree Hills Duporte Estridge Golden Rock Harris Lavington Mansion Ogee's Ottley's Level Phillips Level Pump Sandy Bay Shadwell Vambelle Wingfield Level				X	X	X	X	X		
IVe2 17-25%[2]	Brotherson Conaree Hills Duporte Estridge Fahies Harris Jack-in-the-Box Lavington Mansion Ottleys Parsons Phillips Level Pump Sandy Bay Shadwell Sir Timothy's Vambelle Whites Wingfield						X	X	X	X	X

[1] See systems matrix on next page

[2] Cropland on slopes greater than 25% requires specific analysis, treatment and management.

Table 2.11: Primary Recommendations of Resource Management Systems for Soil Conservation on Cropland (continued)

Resource Management Systems and Essential Conservation Practices for cropland are as follows:

System	Cropping and Conservation Practices
C - 1	Annual cash crops (vegetables, cotton, corn, etc.) Rotation, conservation crops Contour farming Crop residue management
C - 2	Annual cash crops rotated so that one-half of the land will be in a crop or crops that provide good or fair surface cover Rotation, conservation crops Contour farming Crop residue management
C - 3	Perennial cash crops, perennial grasses, or perennial legumes at least five years out of every six (sugarcane, pasture, orchards, etc.) Contour farming Crop residue management
C - 4	Annual cash crops rotated so that one-half of the land will be in a crop or crops that provide good or fair surface cover Rotation, conservation crops Contour farming Conservation Tillage or mulching
C - 5	Perennial cash crops, perennial grasses, or perennial legumes at least five years out of every six Contour farming Conservation tillage
C - 6	Annual cash crops Rotation, conservation crops Contour farming Crop residue management Terracing

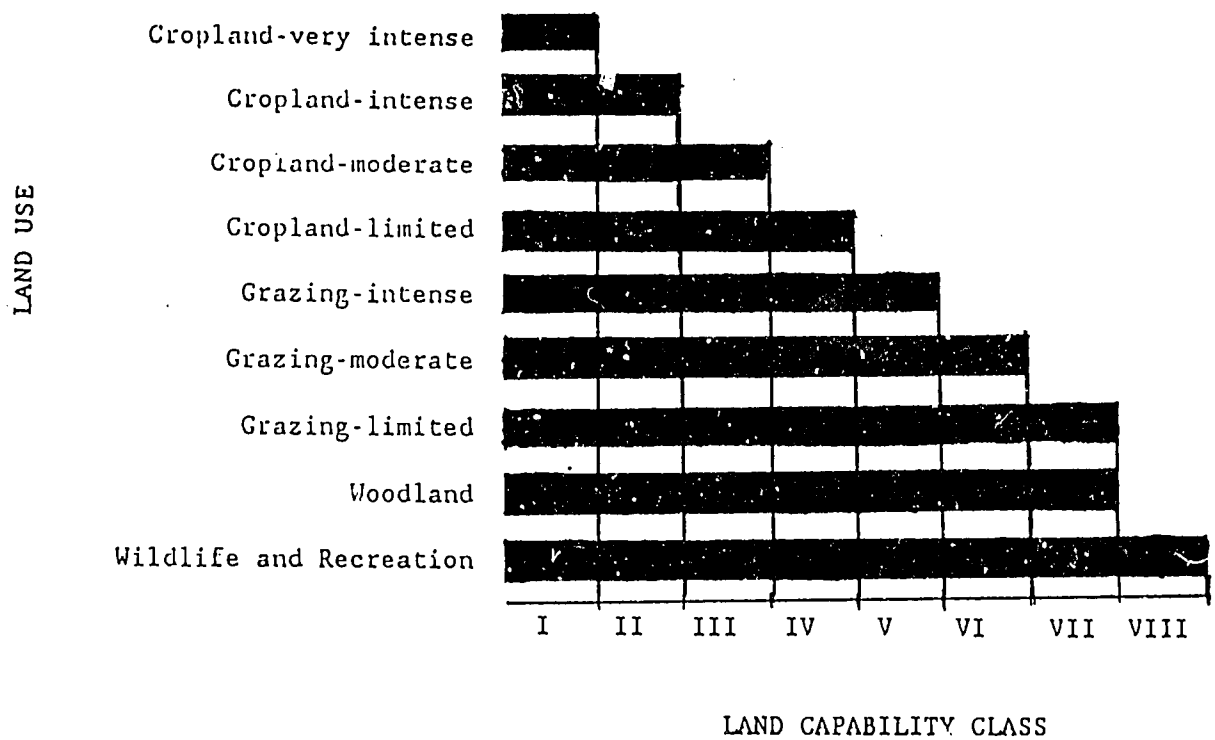
Table 2.11: Primary Recommendations of Resource Management Systems for Soil Conservation on Cropland (continued)

C - 7	Annual cash crops rotated so that one-half of the land will be in a crop or crops that provide good or fair surface cover Rotation, conservation crops Contour farming Crop residue management Terracing
C - 8	Perennial cash crops, perennial grasses, or perennial legumes at least five years out of every six Contour farming Crop residue management Terracing
C - 9	Annual cash crops rotated so that one-half of the land will be in a crop or crops that provide good or fair surface cover Rotation, conservation crops Contour farming Conservation tillage or mulching Terracing
C - 10	Perennial cash crops, perennial grasses, or perennial legumes at least five years out of every six Contour farming Conservation tillage Terracing

Table 2.12: Classification of Crops by Residue and Surface Cover for Determination of C Factors

Crop	Crop Residue Produced			Surface Cover		
	High	Medium	Low	Good	Fair	Poor
Sugarcane	X			X		
Corn (Maize)	X					X
Yam	X[1]		X	X[1]	X	
Sweet Potato		X		X		
Peanuts			X		X	
Pumpkin		X			X	
Tomato			X			X
Cabbage			X			X
Carrots			X			X
Watermelon			X		X	
Cucumber			X		X	
Pigeon Pea		X			X	
String beans			X		X	
Blackeye pea			X		X	
Tannia			X			X
Dasheen			X			X
Cassava			X			X
Onions			X			X
Cotton		X				X

[1]When mulched.



Note: As an example, Class I land can be used for any purpose and still be adequately protected for soil conservation; on the other hand, if the land has a capability class of III, it can be put to any use <u>except</u> for intense or very intense cropland assuming good farming practices are being used.

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Figure 2.3: <u>Land Capability and Intensity of Use</u>

2.5 Site Selection Criteria for Erosion Control

2.5.1 Cropland

Criteria for selecting the treatment area include the following:

2.5.1.1 Universal Soil Loss Equation (USLE)

Determine sheet and rill erosion rates using the USLE. Those areas showing annual erosion rates exceeding A (allowable soil loss--see Table 2.3, p. 25) should be considered for treatment. Areas with the highest erosion should be treated first.

2.5.1.2 Visual inspection and loss measurement

Inspect for concentrated flow erosion in depressions on crop fields. Any evidence of soil movement indicates excessive erosion and a need for treatment. Scour channels indicate serious erosion, probably requiring terraces or other mechanical treatment to control. The calculated rate in tons/year may be used for comparison of present condition with the treatment planned.

If land use is not to be changed, the calculated rate of erosion should be determined under existing conditions. If land use is to be changed, calculations should be made for future conditions. For concentrated flow erosion, similar conditions in fields already in the planned land use can be inspected to estimate future conditions.

2.5.2 Beachland

Beach land is a special case, and estimates of annual losses of beachfront should be made using photographs, structures that have failed, and interviews. The measurement should be made in feet lost per year, perpendicular to the beachfront. This will permit calculating the time to damage high value property. Mining of sand may aggravate beach erosion, or start accelerated erosion if little is present, and all such mining should be prohibited. Usually the decision to treat is based on the rate of loss, the value of land or property being threatened, and the estimated effective treatment costs. These problems are complex and costly, and each project requires a thorough engineering study.

2.5.3 Ghauts/gullies

Selection of sites for gully, ghaut or drainage control includes considering overfalls advancing up the bottom of the ghaut or drainage channel and instability of the sides and upper land use practices. The rate of advancement of the head or side cut can be related to damage areas or structures such as crop fields, roads, pipelines, buildings and other important features. Alternate treatments and their costs can be compared to the value of the potential loss to determine need and priorities for ghauts to be treated. Controlled mining of sand for construction can be one method of control.

2.6 Estimating Storm Runoff

Four critical elements affect storm runoff:

- The amount of rainfall is the potential source of water that may run off small watersheds;
- The kind of soil;
- The type of vegetation affects the amount of water that runs off; and
- The existence of terraces and diversions, along with steepness and shape of a watershed, affect the rate at which water runs off.

The tables and figures in this section may be used to estimate the effect of these elements on the two key factors of storm runoff--the volume and peak discharge rate--for any given watershed. They provide a quick and reliable estimate of runoff rates and associated volumes for a range of storm rainfall amounts, soil groups, land use, and cover conditions. The peak discharge rates in the charts were computed by automatic data processing equipment using procedures developed by the Soil Conservation Service, U.S. Department of Agriculture.

2.6.1 Rainfall amounts and expected frequency

It is impractical to design conservation practices to accommodate the peak rate of runoff from the most intense rainstorm ever known or anticipated. The spillway for an ordinary farm pond is usually designed to pass the runoff from a 25-year frequency storm (Figure 2.5, p. 53). This means a storm with only a 4-percent chance of occurring in any year or the size beyond which larger storms would not occur more often than an average of once in 25 years. Designing for a 50-year storm frequency is recommended for spillways for larger dams (Figure 2.6, p. 54). A 10-year storm frequency may be adequate for sizing the spillway in very small ponds, usually less than 20 acres drainage area and less than 15 feet in dam height (Figure 2.4, p. 52). Terraces, diversions and grassed waterways are usually designed for a 10-year frequency storm. Maps showing the amount of rainfall expected in a 24-hour period on St. Kitts have been reproduced in Figures 2.4, 2.5, and 2.6.

2.6.2 Hydrologic groupings of soils

The soils on St. Kitts have been classified in four hydrologic groups according to infiltration and transmission rates. They include:

- Group A--These soils have a high infiltration rate. They are chiefly deep, well-drained sands or gravels with low runoff potential.

- Group B--These soils have a moderate infiltration rate when thoroughly wet. They are usually moderately deep, well-drained soils of moderately fine to moderately coarse texture.

- Group C--These soils have a slow infiltration rate when wet. They are soils with a layer that impedes downward movement of water and soils of moderately fine to fine texture.

- Group D--These soils have a very slow infiltration rate. They are chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan at or near the surface, and shallow soils over nearly impervious material. They have high runoff potential.

The Hydrologic Soil Groups for soils found in St. Kitts are shown in Table 2.13, p. 49.

2.6.3 Runoff curve numbers

A numerical rating system has been developed through many years of research that permits direct calculation of runoff. This system uses curve numbers that represent the watershed condition. This system makes it easy and quick to determine the runoff for design of conservation practices such as terraces and ponds. The numerical runoff rating is shown in Table 2.14, p. 50 for a range of soil-use-cover complexes. These numbers relate to the runoff depth given in Table 2.15, p. 51. Figure 2.7, p. 55 shows the peak rates of discharge for these curve numbers.

The watershed often contains areas represented by different curve numbers. A weighted curve number can be obtained based on the percentage of area for each curve number. For example, assume that the watershed is mainly (three-fourths) in good pasture and a soil in hydrologic group B. The remainder is cultivated with conservation treatment on a soil in hydrologic group C. According to Table 2.14, three-fourths of the watershed has a 61 curve number, and the other one-fourth a 78 curve number.

A weighted curve number for the total watershed would be calculated as follows:

3/4 X 61 = 46 (approximately)

1/4 X 78 = 20 (approximately)

Weighted = 66 = 46 + 20

2.6.4 Volume of storm runoff

Often it is good to know how much water runs off from a big storm as well as the rate at which it flows. The volume is needed

to compute the peak discharge rate and may be used to calculate terrace and detention dam storage requirements.

The figures in Table 2.15, p. 51 are the depths (in inches) at which the storm runoff, if spread evenly, would cover the entire watershed. For example, the volume of runoff from a 3-inch rainfall on a 100-acre watershed with the weighted curve number (CN) of 66 would be:

Read 0.55 inch (interpolated between 0.51 for CN 65 and 0.72 for CN 70) from Table 2.15.

100 acres X 0.55 inch = 55 acre-inches

55 acre-inches X 27,154 gallons per acre-inch

= 1.5 million gallons (approximately)

2.6.5 Peak discharge rate

The peak discharge rate is the rate at which storm runoff passes a given point and is measured in cubic feet per second (cfs). (This can also be expressed as ft^3/sec.) Peak rates of runoff are used to design earth spillways for ponds, grade stabilization structure sizes, diversions, etc. This permits design of a safe reliable pond or structure. The vertical scale of the chart in Figure 2.7, p. 55 shows the cubic feet of water per inch of runoff. To determine this rate, follow the chart along the base at the size of the area of the watershed. Move vertically to the curve number. Read the peak discharge rate in cfs per inch of runoff along the vertical scale. The volume of runoff is obtained by entering Table 2.15 with the 24-hour rainfall from the applicable figure (2.4, 2.5 or 2.6, pp. 52 to 54) and the curve number. The peak discharge rate in cfs is the discharge rate from Figure 2.7 multiplied by the volume of runoff from Table 2.15. These discharge rates are for the intense rains that are common in St. Kitts.

The following example illustrates how to use Tables 2.13 through 2.15 and Figures 2.4 through 2.7 to obtain the peak discharge rate for estimating the capacity needed in the spillway of a pond.

- Given:
  - -- The area of the watershed is 30 acres;
  - -- The soil shown on the St. Kitts soil map is 13, Vambelle. Table 2.13 shows this to be in Hydrologic Group B; and
  - -- The land condition is vegetables with conservation treatment.
- Solution:

-- Table 2.14, p. 50 shows a curve number of 71 for hydrologic soil Group B;

-- The peak discharge for a pond with 30 acres drainage area should be a 25-year frequency;

-- Figure 2.4, p. 52 shows the 24-hour, 25-year frequency rainfall to be about 10.5 inches;

-- Table 2.15, p. 51 shows a runoff of 6.7 inches (by interpolation) for 10.5 inches of rain and a 71 curve;

-- Figure 2.7, p. 55 shows 35 cfs per inch of runoff for 30 acres drainage area and a 71 curve. Then, 35 cfs/inch X 6.7 inches = 235 cfs; and

-- The spillway should be designed to carry 235 cfs.

Table 2.13: St. Kitts: Hydrologic Soil Groups

Map Symbol	Soil	Hydrologic Group
1	Cockleshell Bay Loamy Sand	A
2	Frigate Bay Loamy Sand	A
3	Bird Rock Loamy Sand	A
4	Peninsula Loamy Sand	A
5	Shadwell Loamy Sand	A
6	Golden Rock Loamy Sand and Sandy Loam	B
7	Ogee's Sandy Loam	A
8	Sandy Bay Loamy Sand and Sandy Loam	A
9	Harris Loamy Fine Sand	A
10	Pump Loamy Fine Sand	A
11	Brotherson's Loamy Sand	A
12	Lavington's Loamy Fine Sand and Fine Sandy Loam	A
13	Vambelle Silt Loam and Silt	B
14	Estridge's Loam and Sandy Loam	B
15	Mansion Loam	B
16	Duporte Loam	B
17	Parson's Loam	B
18	Ottley's Level Loam	B
19	Whites Clay Loam	B
20	Wingfield Level Clay Loam	B
21	Fahie's Clay Loam	B
22	Phillips' Level Silt Loam	B
23	Mount Misery Silt Loam	A
24	Peak Silt Loam	B
25	Jack in the Box Clay Loam	C
26	Bayford's Loam	C
27	Conaree Hills Loam	B
28	Sir Timothy's Clay Loam	B
29	Monkey Hill	B
30	Salt Pond Sand and Loamy Sand	A
31	Muddy Pond Silty Clay and Sandy Clay	C
32	Friar's Bay Clay and Silty Clay	D

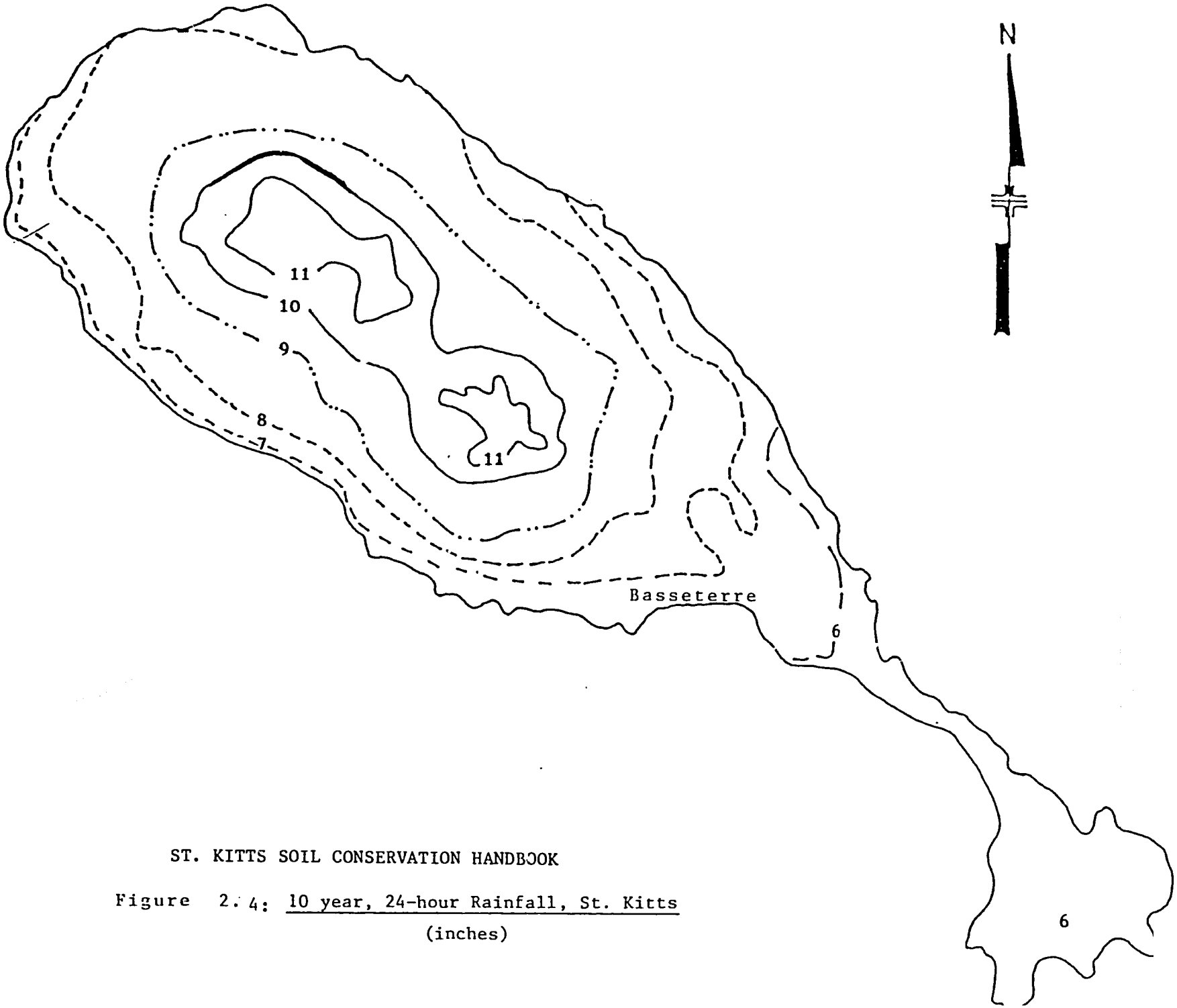
Table 2.14: Runoff Curve Numbers

	Hydrologic soil group			
	A	B	C	D
Cultivated:				
Without conservation treatment[1]	72	81	88	91
With all recommended conservation treatments	62	71	78	81
Sugarcane, ridged, good residue	55	68	79	83
Pasture range:				
Poor cover	68	79	86	89
Good cover	53	61	74	80
Meadow	55	58	71	78
Woods, shrubs, or forest:				
Thin stand, poor cover, no mulch	55	66	77	83
Good cover	55	55	70	77
Farmsteads	59	74	82	86
Roads	74	84	90	92

[1]Interpolation may be necessary to meet existing conditions.

Table 2.15: Runoff Depth
(inches)

Rainfall (inches)	Curve number 55	60	65	70	75	80	85	90
1.0	0	0	0	0	0.03	0.08	0.17	0.32
1.2	0	0	0	.03	.07	.15	.28	.46
1.4	0	0	.02	.06	.13	.24	.39	.61
1.6	0	.01	.05	.11	.20	.34	.52	.76
1.8	0	.03	.09	.17	.29	.44	.65	.93
2.0	0	.06	.14	.24	.38	.56	.80	1.09
2.5	.08	.17	.30	.46	.65	.89	1.18	1.53
3.0	.20	.33	.51	.72	.96	1.25	1.59	1.98
4.0	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92
5.0	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88
6.0	1.50	1.92	2.35	2.87	3.28	3.78	4.31	4.85
7.0	2.12	2.60	3.10	3.62	4.15	4.69	5.26	5.82
8.0	2.76	3.33	3.90	4.47	5.04	5.62	6.22	6.81
9.0	3.48	4.10	4.72	5.34	5.95	6.57	7.19	7.79
10.0	4.22	4.90	5.57	6.23	6.88	7.52	8.16	8.78
11.0	5.00	5.72	6.44	7.13	7.82	8.48	9.14	9.77
12.0	5.78	6.56	7.32	8.05	8.76	9.45	10.12	10.76



ST. KITTS SOIL CONSERVATION HANDBOOK

Figure 2.4: 10 year, 24-hour Rainfall, St. Kitts (inches)

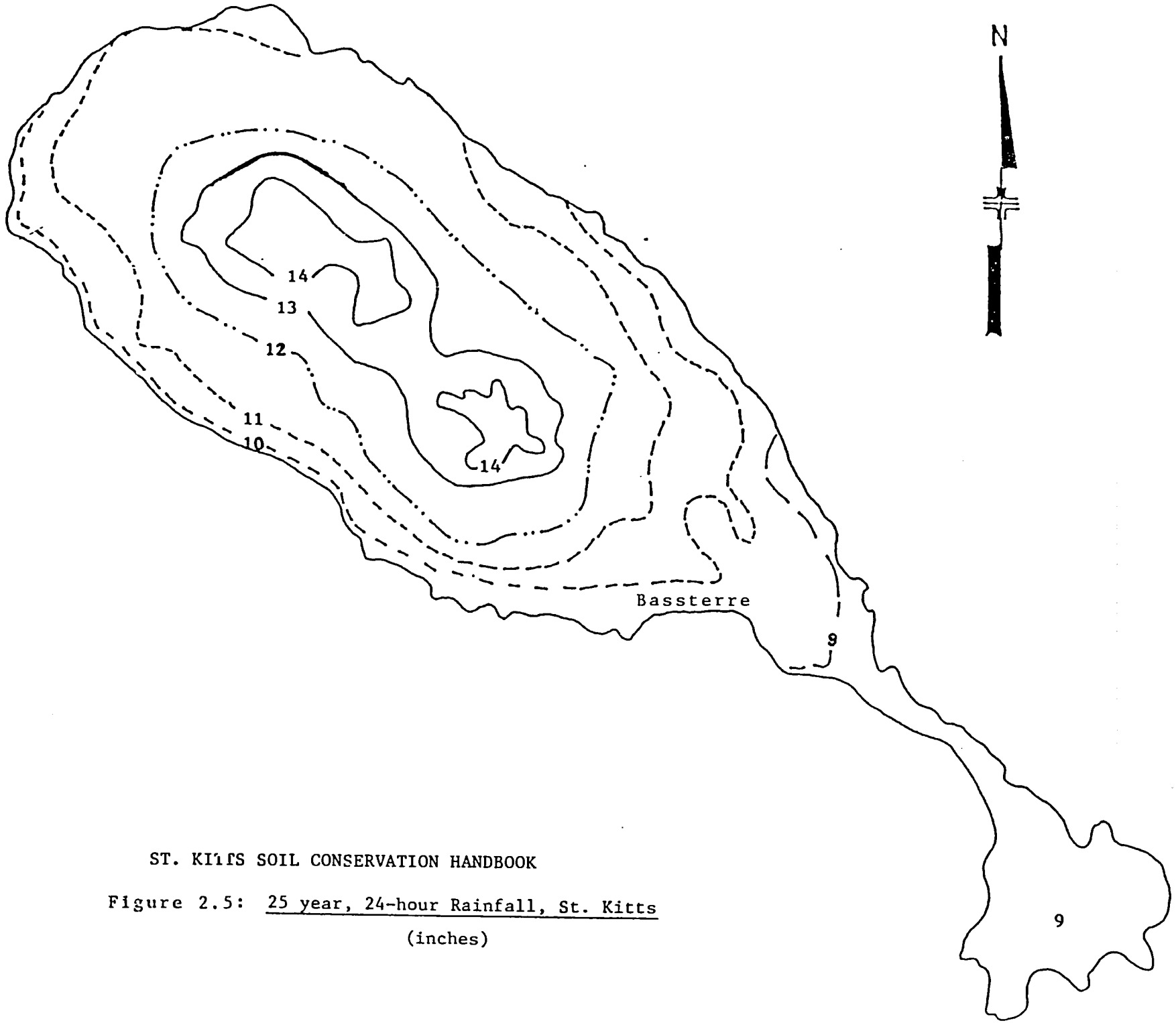


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Figure 2.5: 25 year, 24-hour Rainfall, St. Kitts (inches)

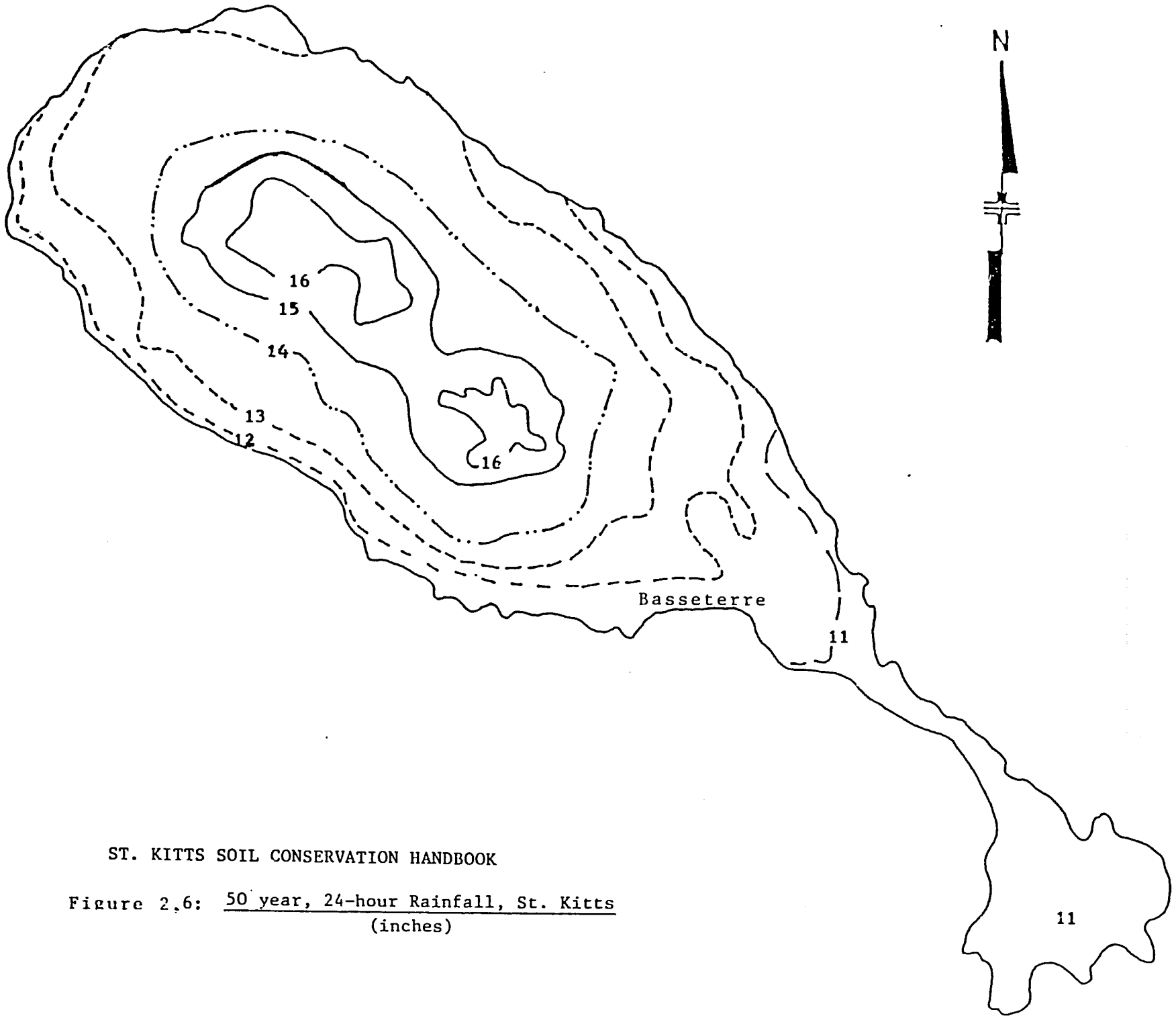

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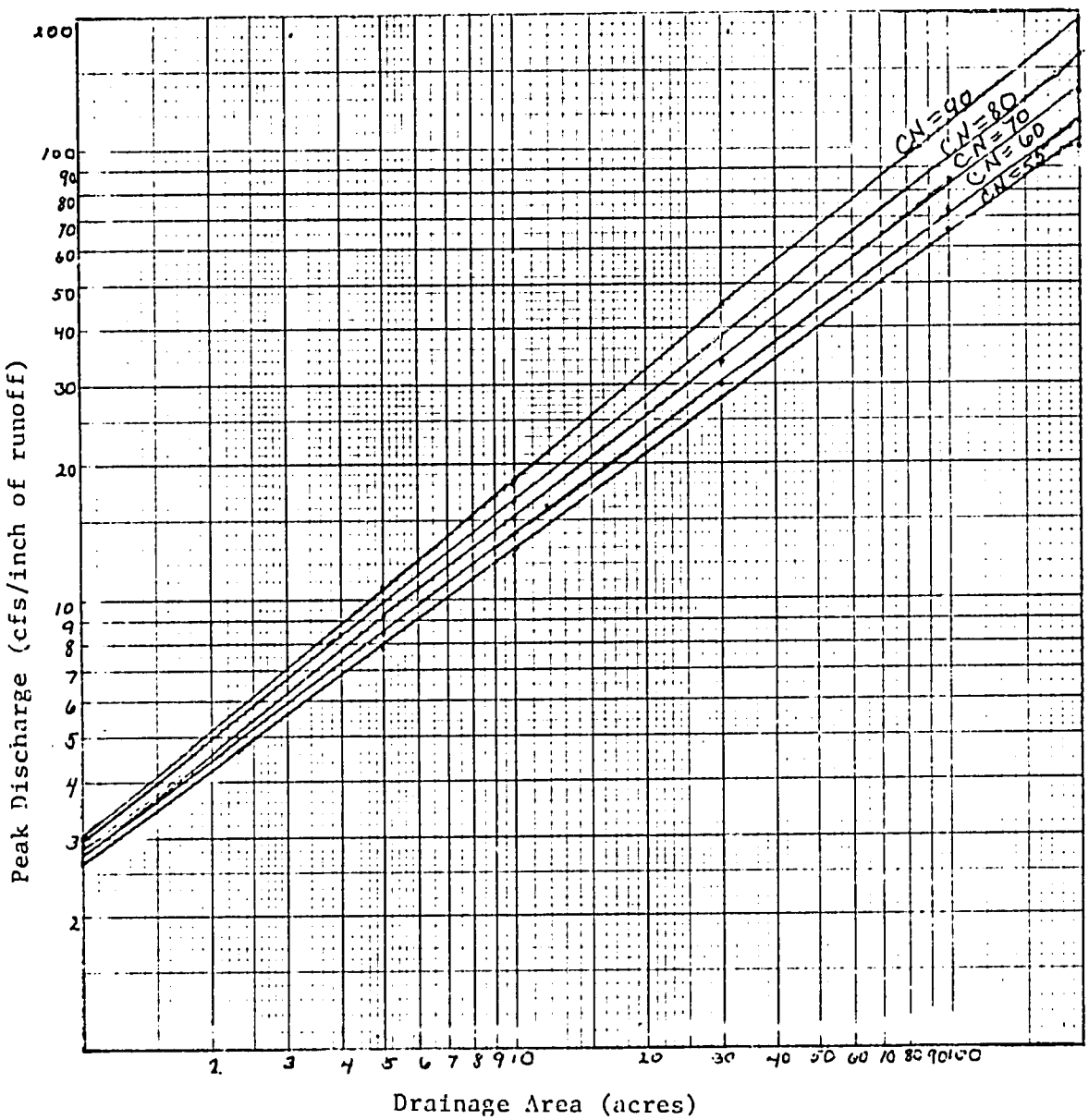
Figure 2.6: 50 year, 24-hour Rainfall, St. Kitts
(inches)



ST. KITTS SOIL CONSERVATION HANDBOOK

Figure 2.7: Peak Rates of Discharge for Small Watersheds on Steep Slopes (24-hour, intense storm)

3. IMPLEMENTING A CONSERVATION PROGRAM

3.1 Soil Conservation Planning

3.1.1 Generalized plan

A generalized soil conservation land treatment plan can be developed for St. Kitts utilizing the information included in this guide and handbook and considering alternative land uses as follows:

Note: A treatment plan is usually developed considering the most intensive use of the land. Less intensive use is always acceptable. More intensive land treatment is also acceptable. Either will result in less erosion and soil loss. Each area to be planned will require a specific plan compatible with its intended use in actual practice.

The Class IIs1 soils on 0-3.5% slope can be utilized for any purpose with reasonable care. Sugarcane and clean-tilled crops such as cotton, corn and vegetables can be safely produced using contour farming, crop rotation and crop residue management.

The Class IIIe1 soils on 3.5-5% slopes could be utilized for clean tilled crops if one half the area is maintained in crops that provide good or fair vegetative cover and crop rotation, contour farming and crop residue management are practiced. Sugarcane could safely be produced utilizing crop rotation, contour farming and crop residue management.

The Class IIIe2 soils on 5-12% slope can be utilized for clean tilled crops with one half the area in good or fair cover with the addition of conservation tillage, crop rotation, contour farming, crop residue management and mulching or terracing on the steeper slopes. Sugar cane can be safely produced using crop rotation contour farming and crops residue management.

The Class IVe1 soils on 12-17% slopes can be used for clean-tilled crops with one half the area under crops with good to fair cover using crop rotation, contour farming, crop residue management, conservation tillage, mulching, and terracing. Terracing or conservation tillage may be sufficient on the lesser slopes. Sugarcane can be safely produced using crop rotation, contour farming, crop residue management with either conservation tillage or terraces.

The Class IVe2 soils on slope 17-25% slopes will require the most intensive land treatment to be safely utilized for clean-tilled crops. Extreme care must be exercised to maintain soil loss within the allowable limits. Land treatment would include crop rotation, contour farming, crop residue management, conservation tillage and bench terracing. Sugarcane can be produced safely with crop rotation, contour farming, crop residue management and terracing. Conservation tillage may also be required on steeper slopes to control erosion

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within the allowable limits. Pasture and livestock production is also a good land use for Class IVe2.

The Class Vwl and Vsl soils should be limited to pasture, range, woodland and wildlife. No conservation treatment is required for these uses.

The Class VIel soils on 25-35% slopes should not be utilized for general crop production. Some small areas with slope lengths less than 100 feet may be utilized for sugarcane with intensive treatment. Production of clean-tilled crops should only be considered on very small areas with slope lengths of 50 feet or less.

Agroforestry, where crops are interplanted with trees or other high growing perennial plants, may be considered for Class VIel, but very careful management is needed to control erosion. Pasture and livestock production is also a good use.

The Class VIIel soil above 35% slope should only be considered for forestry with possibly some small areas of well-managed pasture for livestock.

3.1.2 Specific soil conservation plans

A Soil Conservation Plan for a specific area (including the island of St. Kitts) cannot be developed until the planned land use for the area is known. In addition, treatment alternatives have to be selected. For instance, there are cases where maintaining one half of the area in good or fair cover can be used in lieu of conservation tillage or terraces and other cases where there may be a choice between conservation tillage and terracing. Generally, a soil conservation plan is limited to an area under one management system.

3.1.3 Land capability map

A land capability map could be developed based on slope and soils. The accuracy of such a map with the information presently available on St. Kitts, would be of questionable value. In any case, general information, stated or shown on a map, should not be taken as sufficiently accurate to plan and install conservation land treatment and use. Each area to be planned must be specifically examined on the ground and plans developed compatible with observed characteristics.

3.2 Overall Responsibilities

3.2.1 Land owners and users

Land owners and users have the responsibility for protecting the soil and water resources they use. They need to recognize early signs of soil erosion, identify water conservation opportunities, and request technical assistance for planning and

implementing needed treatment. They should recognise their responsibility to conserve the soil resources for the common good and for future generations.

3.2.2 Government

Responsibilities for soil conservation are also shared by Government. The proper management of St. Kitts resources is vital to the continued welfare of the country's economic and social well-being. Major responsibilities include preparing and adopting standards for proper land use and conservation treatment, and providing extension advice to farmers and other land users on conservation-related matters. The Government should provide strong leadership in an information program, to promote problem recognition, and develop public awareness of the consequences of poor soil and water resource management. The availability of technical assistance to land users should be well-publicized.

The Government also has a major responsibility for basic and applied research related to soil and water management. Extension officers and others who work directly with farmers need to identify soil and water conservation problems, and, with the assistance of outside agencies such as CARDI, formulate research activities to find viable solutions.

Since most soil and water conservation measures have long-term benefits, the cost of implementation may not be returned quickly. In such cases, there is little incentive for land users to practice sound soil and water conservation or to apply needed treatment measures. The Government must therefore share in the cost of more expensive conservation practices and/or treatment so as to provide encouragement to land users to implement them.

Finally, Government should carry out a program of regular survey and of inspections of installed conservation measures to be sure they continue to protect the resources as planned.

3.3 Organization

3.3.1 Institutional structure and personnel

The Department of Agriculture (St. Kitts) is headed by a Chief Agricultural Officer. Currently, there are seven divisions under his leadership:

- Extension;
- Research;
- Veterinarian Services;
- Livestock;

- Cooperatives;
- Forestry; and
- Fisheries.

Due to the smallness of the island as well as the Department, there is considerable communication and interplay among these divisions.

The Extension Division is supervised by a Chief Extension Officer. The island has been divided into six sectors, each of which is provided direct technical assistance by an Extension Officer. It is recommended that the title of the Extension Division be changed to the Extension and Conservation Division, and the Soil Conservation Unit be placed in this Division. This is appropriate since true soil conservation includes not only the use of mechanical measures for erosion control, such as terraces, diversions, gully control structures, etc., but also such measures as mulching, contour farming, windbreaks, pasture management, proper grazing, conservation tillage, and other agronomic measures. An alternative to this would be to establish a Soil Conservation Division with a Soil Conservation Officer and place the Soil Conservation Unit under his/her supervision or Forestry and Soil Conservation could be combined into one unit.

With soil conservation and extension closely allied, conservation of soil and water on St. Kitts can be given the preeminence it needs and deserves. The Extension Officers can meet with and inform farmers about the need for soil erosion control and water conservation on a day-to-day basis, utilizing information from this Soil Conservation handbook to assist them. The Soil Conservation Unit would be responsible for providing technical assistance and guidance to land users for planning and applying needed soil and water conservation measures as identified by land users and extension personnel.

The Soil Conservation Unit should consist of not less than two full-time people, a professional and a technician. A crew of four or five should also be available to assist in construction of erosion control practice such as gabion structures for grade stabilization and the planting on ghaut banks. It should be headed by a technically competent individual who is experienced in designing, laying out and implementating soil and water conservation practices. This person should be educated and trained in at least one of the following disciplines: agronomy, engineering, forestry, soil conservation or soil scientist. He/she should have extensive appropriate field experience in soil and water conservation to supplement educational qualifications. He/she should have a general knowledge of several disciplines related to soil conservation such as agronomy, engineering, forestry, farm management, livestock production, and erosion control and have a working knowledge in as many of these disciplines as possible. (Field experience provides the understanding to make local

adoptions that might not be apparent to persons who have not had the opportunity to exercise their educational background).

As an alternative, if such person is not available, the Chief Extension and Conservation Officer should play a more active role in the direct management of the soil and water conservation program. He/she should, either personally or through direction of Extension Officers, provide the professional technical assistance required. In this case, however, the Soil Conservation Unit would still need a competent leader who could manage and schedule the daily, weekly and monthly activities required to carry out the program. It is important for the success of a program to protect the island's resources that it be kept active and that work continue to be performed regularly. The bulldozer should be kept active in constructing conservation measures or in providing soil management assistance to land users.

In addition, due to the complex nature of soil and water conservation work, additional short-term technical assistance will be needed periodically to handle more complex measures as they arise. Such assistance can be expected to be needed from time-to-time in the fields of engineering, agronomy, pasture management, forestry, and soil science. An experienced and competent manager of the Soil Conservation Unit should recognize when a proposed activity is beyond his/her capability and request appropriate assistance through the Chief Agricultural Officer.

A conservation technician should be assigned to work with the manager specifically in the soil and water conservation program. The technician would have the daily responsibility of field surveys and layout, and on-site direction of conservation construction activities.

3.3.2 Soil conservation responsibilities

General soil conservation responsibilities of the Soil Conservation Unit should include:

- Providing timely technical assistance to land users to encourage them to make and carry out decisions on land use and treatment;
- Assist in the design, layout and implementation of soil conservation practices;
- Assist in training of new personnel and farmers;
- Encouraging land users to consider alternative land uses and treatments, and short- and long-range effects;
- Setting priorities for work, based on the effective use of available resources, and close attention to critical resource problems such as erosion, water conservation, flooding, or deterioration of plant and animal resources;

- Developing a system to determine changes in land ownership so that new land users can be informed about and provided with timely technical assistance;

- Assisting with an information program which publicizes the benefits of sound soil and water conservation practices and the availability of technical assistance to land users;

- Assessing the impacts of land use changes and of conservation treatment planned and applied; and

- Making periodic inspections of installed conservation measures, and arranging for and carrying out maintenance work needed to keep practices functioning as intended by the design. (Ideally, maintenance should be done willingly by the land owner or user, but often the need and purpose of proper maintenance is not fully understood and accepted by the land user.) If practices are left unmaintained, they will certainly fail. This will impact adversely on future opportunities to apply needed measures.

3.3.3 Use of the Government bulldozer

The soil conservation bulldozer offers an opportunity for assisting to supply funds for the operation of the Soil Conservation Unit. Conservation practices needed for soil and water conservation on privately owned or operated lands will be identified. Many of these practices will require the use of heavy construction equipment and the bulldozer should be made available for this use. Such practices would include, but not necessarily be limited to, construction of small dams for water conservation, building terraces, land clearing, soil-ripping, etc. An indirect benefit of installing conservation measures with the Government-owned bulldozer is that there is better assurance that work will be accomplished correctly and in conformance with specifications.

When used on private lands, the bulldozer should be rented to the user. Since Government also has an obligation for soil conservation, it is recommended that the rental price be set as low as possible.

In this way, Government will in fact be subsidizing and encouraging soil and water conservation work to be done. Any extra funds over the cost of operation received for use of the bulldozer should be used to operate the Soil Conservation Unit, and not directed to other purposes. When the bulldozer is not in demand by other land users, it would be kept busy with implementation of conservation measures on Government agricultural lands so that these lands can be seen as models for good soil and water conservation management.

Since sugarcane occupies such a large part of the island, and application of soil conservation measures on these lands is going to continue to be a major portion of the work performed by the dozer, it

is recommended that the St. Kitts Sugar Manufacturing Corporation (SSMC) continue to provide overall operation and maintenance facilities for the dozer through a cooperative arrangement with the Department of Agriculture. Through this cooperative arrangement, SSMC could also provide a labor crew to install gabion structures for ghaut and erosion control.

3.3.4 Equipment and tools

3.3.4.1 Field equipment

Most agronomic type soil conservation practices can be applied with regular farming equipment such as tractors with disc, plows, mowers, planters, etc.

Heavy construction machinery is needed to construct some of the engineering type erosion control practices. Some of the major pieces of equipment include dozer, backhoe, front-end loader, motor grader, tractor and wagon.

3.3.4.2 Engineering equipment

Engineer's level, level rod and measuring tapes are the major pieces of equipment required to survey and layout practices in the field. Supplies of survey stakes and flags are also needed to identify survey points and relay proper information.

Office equipment needed include planimeter, light table, drafting equipment, calculator and drafting table. Associated equipment such as typewriter and copy machine add to the efficiency of the work.

Hand levels (with level rods) are also important and should be available to each person working with farmers to establish contour farming. Abney levels are useful in determining land slope and should be available for use as needed by field personnel.

4. TECHNICAL "HOW TO" GUIDE FOR APPLYING CONSERVATION PRACTICES NEEDED IN RESOURCE MANAGEMENT SYSTEMS

4.1 General Overview

Conservation practices are tools used in a resource management system. The system combines uses of soil, water, plants, capital, and management to produce a crop, hopefully at a profit. The conservation practices make it possible to do this and also protect the soil from accelerated erosion. Guidance and specifications for each practice explain the practice, its purpose, things to consider when planning it, and techniques of installing and maintaining it. This technical information provides guidance to professional agriculturalists who may lack specific soil conservation expertise. It will be useful to those who have conservation responsibilities in St. Kitts.

4.2 Conservation Practices

In general, each conservation practice has the same format. The practices are arranged alphabetically. Each practice is dated and the pages numbered internally, e.g., Brush Control 1. The pages of the following sections of Chapter 4 are not numbered consecutively. This permits adding new conservation practices or revising others without the need for reprinting unrelated ones.

Information included for Conservation Practices is that level of information generally needed by trained and experienced soil conservationists and technicians to plan and install these practices. There will be cases where a specific design is needed for situations not fitting the norm or where more information is desired. In these cases more detailed information can be found in the SCS Engineering Field Manual and other noted references. The conservationist and technical specialists must also recognize their personal limitations and seek the advice and assistance of specifically trained technicians as needed to solve problems beyond their capability.

CAUTION ON USE OF HERBICIDES (WEEDICIDES)

Certain of the following practices include as part of their requirements, the use of various herbicides (or weedicides) and/or other chemicals. If herbicides, insecticides/pesticides, or fungicides are handled or applied improperly, or if unused portions are not disposed of safely, they may injure humans, domestic animals, desirable plants and fish or other wildlife, and may contaminate nearby crops and other vegetation. Follow directions and precautions on the container label and/or recommendations of the manufacturer, and laws and regulations for kind of material, susceptible species, and precautions for use.

In general, herbicides and other chemicals should be selected which have low orders of dermal and oral toxicity, are non-mobile

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(i.e., will not leach into water sources), and are not persistent. The use of extremely toxic herbicides, e.g., paraquat, should not be promoted. Other less toxic herbicides, such as "Round-up," should be used instead.

A list of useful references is provided in Annex 1.

BRUSH CONTROL

Definition

Managing or controlling stands of brush such as acacia and/or cactus on grazing land and pastureland by mechanical, chemical, or biological means or by prescribed burning.

Purpose

To improve or restore a quality plant cover to:

- Reduce sediment and improve water quality;
- Increase quality and production of desirable plants for livestock and wildlife;
- Enhance aesthetic and recreation qualities;
- Maintain open land; and
- Protect life and property.

Planning Considerations

Brush management objectives and procedures may be different for different kinds of land and for different uses of land. For example, the objective on natural grazing land may be to maintain a plant community that is not native to the site but that provides soil protection and benefits the uses planned for the land. It is usually desirable to exclude all brush, such as acacia, and cactus on pastureland, except for odd areas left for shade, birds, or aesthetic value. Brush along ghauts, and borders around pasture boundaries, or strips of woody vegetation separating pastures may be left undisturbed for use by birds or other wildlife and as protective cover.

Conservation planners are to:

- Encourage land users to fully consider present and future land use opportunities in relation to brush management, including expected effects on forage production, potential recreation use, and attractiveness of the landscape;
- Determine that the land user understands the technical requirements, possible hazards, and costs of each practice and that the land user will apply the kind of grazing management and maintenance measures that will ensure success; and

- Help land users understand the environmental impacts of brush management, both positive and negative, on-site and off-site.

Manual, mechanical, chemical, and biological procedures and prescribed burning may be used singly or in combination, depending on such factors as:

- Kind of land (site);
- Topography;
- Species of woody plants or cactus--whether they are rootsprouters or non-sprouters;
- Size, abundance, and distribution of woody plants or cactus;
- Hazards of treatment, if any;
- Objectives of the land user; and
- Costs in relation to expected benefits.

Effective control and eradication may require only one method or a combination of methods. The best time to reduce brushy plant or cactus populations is at the beginning of an invasion. At this stage, effective control is less costly. Brush control is usually most effective when practiced towards the end of the rainy season as the re-growth potential is reduced during the subsequenty dry season.

Specifications

1. Manual control--brush chopping and girdling

Repeated brush chopping with a cutlass or similar equipment will control nonsprouting brush if carried out over a sufficient length of time. Large woody plants may be destroyed by girdling. Cut a band completely around the woody plant from one to six inches wide through the bark and cambium layer. Girdle as near to the soil surface as practical.

2. Mechanical control--rotary mowing

Repeated mowing of smaller brush improves the grass stands. In most cases, mowing is more efficient as a brush control measure than chopping. Repeated mowing of pastures containing palatable woody plants has the advantage of keeping the plants at a size most suitable for grazing purposes. Rotary mowing should leave brush stubble height not over 8 inches and should be less if damage to implement tires is not a factor.

3. Chemical control

Chemical brush control measures, are used on steep land that does not allow the use of mechanical equipment, on land infested with brush but with a good stand of grass, and on land recently planted to pasture. The use of mechanical control practices is needed, under certain conditions, as a supplement to chemical control measures. The successful use of herbicides is dependent upon correct interpretation of manufacturer's instructions as well as timely and accurate applications.

Follow recommendations of the manufacturer and laws and regulations for kind of materials, susceptible species, and precautions for use. Use pre-emergence, selective herbicide sprays immediately after pasture planting on broadleaf-infested areas. Use foliar sprays for widespread and indiscriminate control of broadleaf plants during growing season. Use basal sprays or other basal treatment for selective killings.

Exercise caution when using herbicides as described at beginning of Section 4.

4. Other management practices

The use of fire to control brush is described in the practice Prescribed Burning.

Disposal of debris shall be accomplished in a matter suitable to the land user and that will not interfere with the establishment, re-establishment, maintenance, or natural beauty of the area. Acceptable disposal methods include burning, which should be carried out in compliance with ordinances; shredding or mulching; and removal to other areas.

Brush control should leave the land in condition so that maintenance operations can be carried out without undue difficulty. Where treatment is applied to only part of a pasture, such areas should be fenced separately or entire pasture managed on basis of treated area.

CONSERVATION TILLAGE

Definition

Any tillage and planting system that maintains crop residue on at least 30 percent of the soil surface after planting.

Purpose

To reduce soil erosion and help maintain or develop good soil tilth, efficient moisture use, and water quality.

Planning Considerations

Successful conservation tillage depends on one's preparing the seedbed, planting and controlling weeds in ways that leave crop and weed residue on the soil surface. This can be done by a St. Kitts farmer using a hoe or cutlass (machette) or by the St. Kitts Sugar Manufacturing Corporation using modern machinery and chemical herbicides. The specifications here cannot describe all possible ways to practice conservation tillage. The agriculturalist should use ingenuity in helping farmers plant in heavy crop residue and leave that residue on the soil surface when he tills the weeds.

Specifications

1. Cotton

Conservation tillage for cotton should be carried out as follows:

- Seedbed preparation--After harvest, rake cotton residue and burn. Plant a cover crop as soon as soil moisture permits. Two or three weeks before planting cotton, kill the cover crop and all other vegetation with a contact herbicide;

- Planting--With an implement equipped with a coulter, (straight disc), open a narrow furrow to the desired depth and drop the seed into the slit. Pack row. Do not disturb more than 10 percent of the surface with these operations; and

- Weed control--Weeds may be controlled by hoeing and/or by herbicides. If herbicides are used, use approved pre-emergence, post-emergence herbicides, or both. In addition, use spot treatment of weeds that are difficult to control. If herbicides are not used, hoe in a manner that leaves the residue on the surface.

2. Sugarcane

Conservation tillage for sugarcane should be carried out as follows:

- Seedbed preparation--After harvest, spread crop residue evenly. Two or three weeks before planting, kill all vegetation with a contact herbicide;

- Planting--With an implement equipped with a coulter (straight disk), open a narrow furrow to the desired depth, drop the stalks in the furrow bottom and cover with hoe or row disks and pack row. Do not disturb more than 10 percent of the surface with these operations; and

- Weed control--Use approved pre-emergence, post-emergence herbicides, or both; use spot control of weeds such as guineagrass; or use hand hoeing in a manner that will leave the residue on the surface.

3. Vegetables, small farmer operations

- Initial seedbed preparation, planting and weed control--Prepare for conservation tillage by building beds, making furrows and planting as usual. Hoe weeds with a sharp hoe in a way that leaves them on the soil surface and disturbs the soil minimally;

- Harvesting root crops--Harvest root crops with as little soil disturbance as possible. Leave all crop residue in the field. Rebuild beds shortly after harvest in a manner that leaves the crop residue on the surface; and

- Second operations of seedbed preparation, planting and weed control--For the second and succeeding crops, control weeds by carefully undercutting with a sharp hoe. Grub any brush or shrub in a way that will cause minimal soil disturbance. Make narrow slits or holes with hoe, machete, or probe and place seed, plant or cutting into the soil at the desired depth. Be sure that the seed or cutting gets through the surface residue into the soil. Pack with heavy hand roller, walking on row, or pressing probed holes with the heel, or toe, or hoe.

4. Pesticide use

The term "pesticide" refers to a chemical that kills any pest--insects, plant disease organisms, weeds, etc.

Therefore a herbicide is a type of pesticide. Use all pesticides in accordance with label instructions, laws and legal regulations.

Exercise caution when using pesticides as described at beginning of Section 4.

CONTOUR FARMING

Definition

Farming sloping land in such a way that preparing land, planting, and cultivating are done on the contour. (This includes following established grades of terraces or diversions.)

Purpose

To reduce erosion and control water.

Planning Considerations

Sheet, rill and gully erosion is a problem on St. Kitts. Terraces are the mainstay of controlling these types of erosion, but contour farming reduces erosion rates between terraces, permits wider terrace spacing and helps more water seep into the soil, thus increasing crop production in dry times. Contour farming with mulch can be used without terracing to control erosion within tolerable levels on small (less than 100 feet up and down hill) vegetable fields with up to 25 percent slopes. Farming on the contour will reduce erosion rates significantly on sloping cropland. Normally, crops should be planted as close to the contour as possible, even though this requires some point rows. Proper maintenance of structures such as terraces or contour furrows is essential to their effectiveness.

Contour lines can be laid out with dumpy levels, hand levels, or homemade A-frames (see Figure 1).

Procedure for Use of the A-frame

Select a point near the top of the field to be contoured. Walk the A-frame on the contour, alternating legs, and staking each point as the level contour is determined working your way from one edge of the field to the other. Move down the field a few feet and repeat the process. The distance between marked contour lines will depend on the uniformity of the slope. On a uniform (unchanging without breaks) the marked lines may be 10 to 20-row spacings. On changing slopes with breaks the marked lines may have to be less than 5-row spacings. Keep repeating until you get near the bottom of the field. After preparing a furrow on a marked contour, prepare rows or furrows above and below each contour line to about halfway between the staked lines. Any odd areas can be filled in with point rows (See Figure 2).

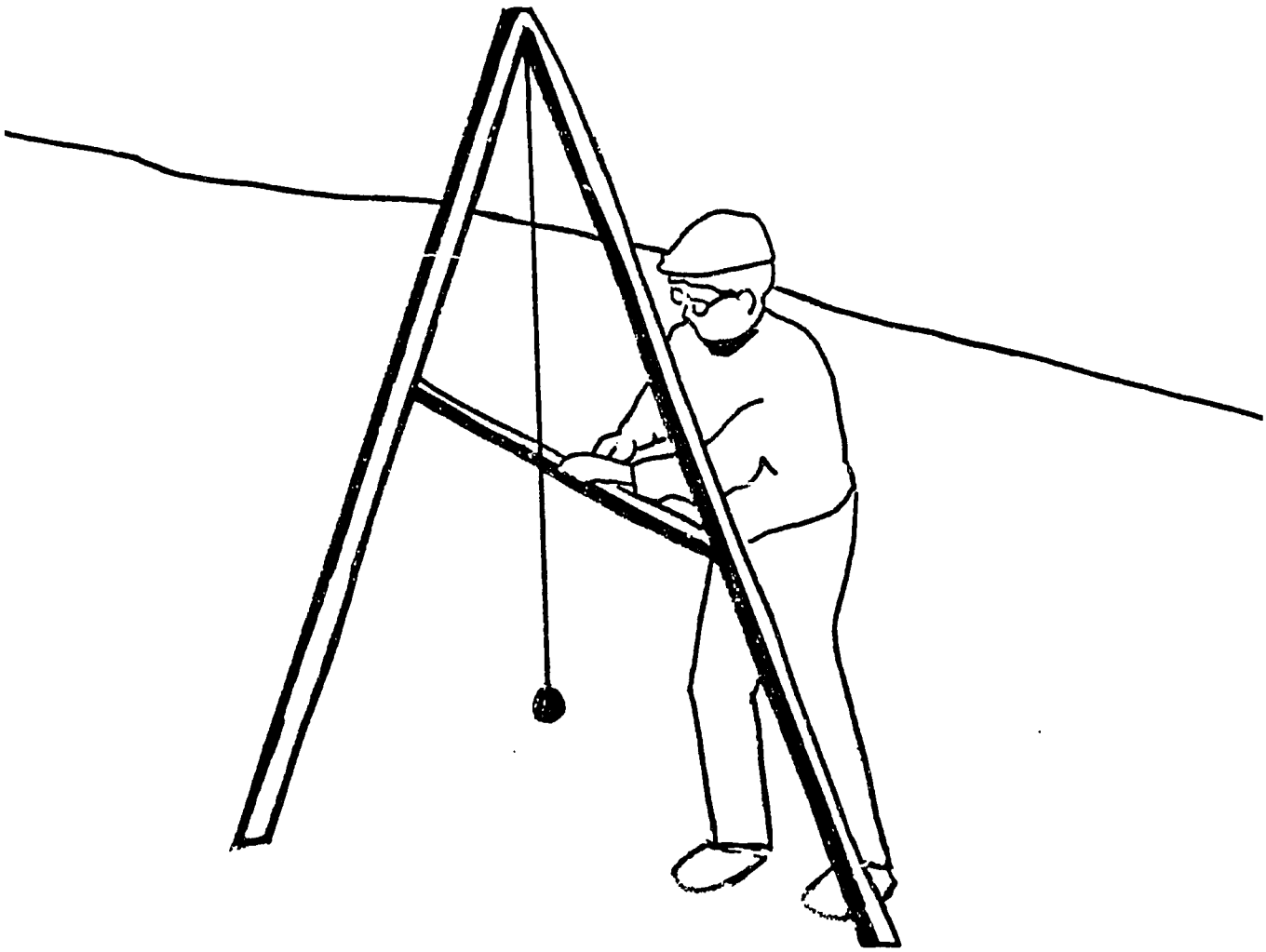
An alternative is to use a carpenter's level on the cross of the A, calibrating the A-frame as it is constructed on a level surface. The level should be tied to the A-frame to prevent dropping and breaking it as it is used.

Contour lines will need to be staked much closer together for hand-planted vegetable crops on small, steep slopes than for slopes prepared by multi-row tractor-pulled equipment.

Specifications

All planting and tillage operations shall be parallel to the terraces or contour lines as staked in the field. Contour lines shall not vary from horizontal grade more than one foot in one hundred feet except for correction point rows between terraces or contour lines. There shall be no reversals in grade that will concentrate runoff in unprotected areas.

Grassed waterways or other protection will be provided for any runoff from ditches or furrows.



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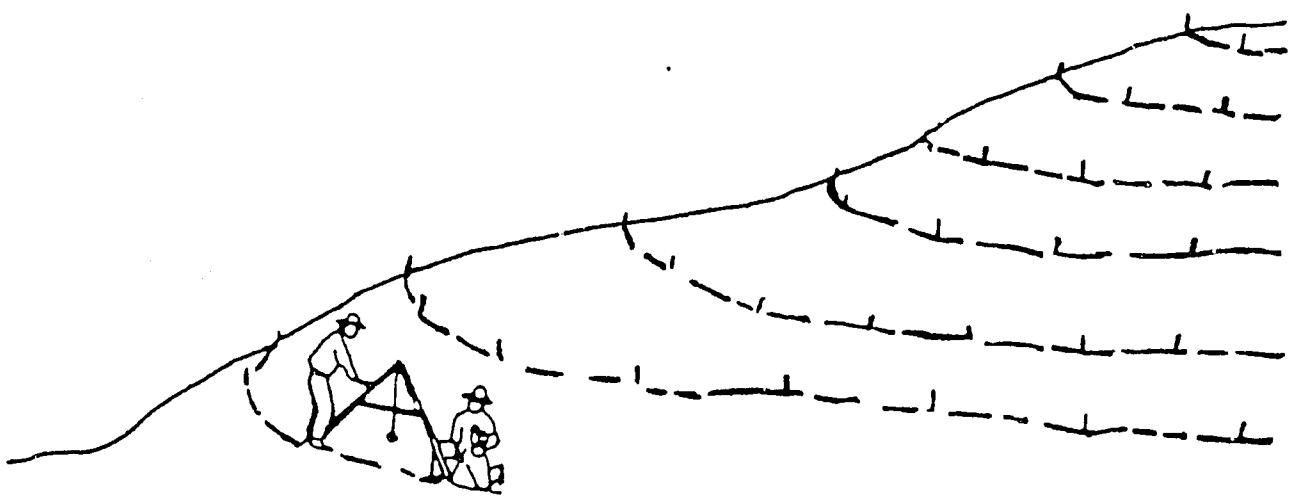
Contour Farming Figure 1: Homemade A-Frame

Calibrate the A-Frame by placing the legs on a nearly level surface. Mark the points where each leg rests on the ground. Fasten a string or wire securely at the top of the A-Frame and maintain vertical tension with a small rock, bolt, or other heavy object. When the plumb line comes to rest, mark the position of the string on the horizontal bar. Then turn the A-Frame around, placing each leg on the opposite mark and repeat the procedure. Finally, make a permanent mark halfway between the two temporary marks. When the plumb line (string) is over this permanent mark, the feet of the A-frame are exactly level.



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Contour Farming Figure 2: Marking Contour Lines With the A-Frame

May 1987

CRITICAL AREA TREATMENT

Definition

Stabilizing areas of accelerated erosion by planting adapted vegetation.

Purpose

To use for treatment of erosion of agricultural land and protect soils in areas of the island being developed for urban use by stabilizing the soil, reducing damage from sediment and runoff, and improving appearances.

Planning Considerations

Critical areas usually cannot be stabilized by ordinary conservation treatment and management and if left untreated can cause severe erosion or sediment damage. Examples of areas are dams, cuts, fills, and denuded or gullied areas where vegetation is difficult to establish by usual planting methods. Maintenance is the most important controllable factor in retaining effective vegetative cover. Other considerations are:

- Type of critical area, i.e., critically eroding area, earth fills or concentrated flow area;
- Special and secondary uses to be made of the area such as access or recreation;
- Measures to enhance appearance;
- Properties of the soils;
- Need for supporting erosion control practices such as grassed waterways, grade stabilization structures, and diversions;
- Need for structures such as debris basins and silt screens to prohibit movement of sediment offsite; and
- Need for diversions or barriers to provide protection in areas of concentrated runoff while the vegetative cover is becoming established.

If excessive erosion is a hazard only during the establishment period, erosion control blankets and temporary above-ground barriers (such as hay bales or erosion control fabrics buried level with the floor of the channel, and rock or gravel barriers) can effectively control water flow and excessive erosion. Overfalls and blowouts are

limitations for above-ground barriers. Above-ground barriers should be staked to the ground and removed as soon as adequate vegetative cover is established. An erosion control blanket downslope from the barrier will greatly reduce damages due to overfall.

Barriers should be located where erosion is expected to occur. They are especially beneficial below confluences of drains, below outlets of terraces or diversions, and at increases in grade.

Specifications

1. Site preparation

- Clear and disturb the minimum area necessary to construct the buildings or install other works of improvement;
- Grade and/or clear the site to leave the soil in the best possible condition for planting. Leave as much topsoil as possible or replace with three to four inches of topsoil or similar material where the soil texture is sandy clay, silty clay, clay, or infertile sand. If needed, rip prior to the addition of the new material to break up any compaction;
- If possible, grade the surface to fall at least one foot in 100 feet, but not more than five feet in 100 feet near buildings;
- Fill in rills and/or low areas in layers, with a maximum of six inches for each layer. Thoroughly compact, and water if necessary, to settle each layer. Fill areas should have a maximum slope of not more than 2:1 (50 foot drop in 100 feet);
- Divert concentrations of surface water where safe outlets can be provided;
- Locate roads and streets on the contour and provide adequate road or street ditch capacity for safe disposal of run-off where practical;
- Remove all loose rock, woody material and other obstructions from the surface that will interfere with the establishment and maintenance of vegetation; and
- Slope the areas to be planted to a 3:1 slope or flatter where conventional equipment is to be used for seeding and maintenance.

2. Seedbed preparation

- On all sites where conventional equipment is used (slopes 3:1 or flatter), prepare seedbeds to depth of 3 to 4 inches. The soil will be tilled to prepare a firm, smooth seedbed, free of clods and debris, to insure good seed-soil contact;

- On slopes too steep for conventional equipment (3:1 or steeper), scarify the surface with a grader blade, hand tools, or other equipment that will pit the soil or make small trenches across the slope in which seed can lodge and germinate; and

- When hydraulic seeding and fertilizing equipment is used on flat areas, the area should be scarified to insure sites for seed to lodge and germinate, and reduce competition from weeds.

3. Lime and fertilizer for establishment

Fertilize and lime according to soil test. In the absence of a soil test in grass stands, apply fertilizer at the rate of 80 to 100 pounds each of nitrogen, phosphate, and potash per acre or 2 pounds of each per 1,000 square feet. This can be supplied with 800 to 1,000 pounds of 10-10-10 per acre or 19 to 23 pounds of 10-10-10 per 1,000 square feet. In the absence of a soil test in grass-legume mixture, apply fertilizer at the rate of 800 to 1,000 pounds of 5-10-10 per acre. Uniformly spread fertilizer over the area.

Normally, an additional application of 30 to 60 pounds of nitrogen per acre or 1 to 2 pounds per 1,000 square feet is needed within three to twelve months after planting to establish grass plantings. Application of 200 to 400 pounds of 0-10-20 per acres is needed to establish grass-legume mixtures. Application should be timed to growing cycle of the species being established.

4. Choice of plants

Table 1 gives information on the grasses that are best suited for permanent cover. All of these grasses can also be planted vegetatively by sprigging or sodding.

5. Planting

If irrigation is possible, planting may be done anytime of the year. Otherwise, plant between August 15 and November 15. Plant vegetative material on the contour in furrows or holes 2 to 3 feet apart. (See Pasture Planting Table 1.) To avoid stimulating weeds, apply the ferlizer near the seedling but not in the row middles. After

planting pack the soil over or around the planted material by walking on it, pressing the holes with the heel of the foot, or rolling the row with a heavy wheel or cultipacker. On clay or clay loam soils, pack after the surface is dry enough not to crust or stick to packer or feet. The specified planting depths are those obtained after packing the soil. If mechanical equipment is to be used for maintenance (mowing, etc.), plant and cover in such a way that the land is smooth after planting.

6. Mulching

Mulching is of great value in conserving moisture and helping increase infiltration. A variety of materials can be used for mulching. Plant materials have some advantages over man-made materials, e.g., many are locally available, and they will decompose to improve the soil. Mulching materials for critical areas include the following:

- Dry straw--Uniformly spread mulch over the area at the rate of 1.5 to 2 tons per acre (75 to 90 pounds per 1,000 square feet) so that above 75 percent of the ground surface is covered;

- Wood cellulose fiber mulch--This is usually mixed with seed, fertilizer and water. The resulting slurry is sprayed on with hydraulic seeding equipment at the rate of 500 pounds per acre. Where straw or hay is applied, use at the rate of 1,000 to 1,500 pounds per acre without other mulching materials. Applied in a slurry, wood cellulose fiber mulch is self-anchoring;

- Jute matting--This coarse, open mesh material woven of heavy jute twine may be used instead of mulch or sod and has the strength to withstand water flow. It is an acceptable practice to sow half the seed before placing the matting. Sow the remaining half after the matting is laid. Unroll the mesh in direction of water flow. Anchor the up-slope end by burying in a narrow trench 4 or 6 inches deep. Staple the matting at 5 to 6 foot intervals on the edges, and down the center of each roll. If more than one strip is required, overlap at least 4 inches. Bury edges at least 4 inches around structures. On steeper slopes and for severe conditions, establish "check dams" every 25 to 100 feet by burying a fold of mesh. After the mesh is in place and seeding is complete, the application should be rolled to compact the seedbed and to insure that the mesh is in firm contact with the soil;

- Bonded fiber blanket--This material consists of approximately 1/4 x 1/4 inch plastic mesh netting laminated to one side of

a mulch blanket. It is designed for use in areas that are highly susceptible to wind and/or water erosion. It is unrolled and stapled over prepared and seeded surfaces;

- Petroleum-derived mulch--Petroleum derived mulch is a liquid spray-on mulch. It is applied as a thin, continuous film on the soil. It will generally remain intact for periods ranging from 4 to 10 weeks or longer;

- Emulsified asphalt--Apply uniformly 0.04 gallons per square yard or 200 gallons per acre of rapid curing (R.S.-1 or R.S.-2), medium curing (M.S.-2), slow setting (S.S.-1) depending on desired curing time. Rapid curing (R.S.) is formulated for curing in approximately 24 hours even during periods of high humidity. Slow setting (S.S.) is formulated for use during hot, dry weather with approximately 24 hours curing time. The higher the number appearing in the "formula", the heavier the resultant residue; and

- Liquid asphalt--Liquid asphalt may be applied at any time of the year since it is thinned with a kerosene-like product. It should not be applied if it is raining. Uniformly apply 0.10 gallons per square yard or 500 gallons per acre of rapid curing (R.D.-1, R.C.-2, R.C.-3) or medium curing (M.C.-2, M.C.-3) depending on desired curing time.

  Note: In areas of playing children or pedestrian traffic, petroleum-derived mulch could cause problems of "tracking in" floors, damaging shoes, clothing, etc.

Most mulch materials must be anchored immediately after placing to minimize loss by wind and water. Consider the size of area, type of site, and cost, and select one of the following mulch anchoring methods:

- Mulch anchoring tool--The mulch anchoring tool has a series of flat notched disks that punch and anchor material into the soil. A regular farm disk weighted and set nearly straight may be used instead of the mulch anchoring tool, but it does not do as good a job. The disk should not be sharp enough to cut up the mulch. The soil should be moist, free of stones, roots or debris and loose enough to permit penetration to a depth of three inches. Operate as near as practical on the contour;

- Mulch nettings--There are several different types and kinds of netting to anchor mulch material. They are made of light paper, jute, plastic or wire. The mesh size for jute is approximately 5/8 to 1 inch, paper netting 1/2 to 2 inches and 1/4 x 1/4 inch, plastic netting 3/4 to 1 inch. These

nettings are usually 3 to 4 feet wide and up to 300 feet long. They are usually stapled along the edges and along the lap joints at 5 to 6 feet intervals, and one staple in each edge and one in the center of the netting on top and bottom folds;

- Peg and twine--Drive 8 to 10 inch wooden pegs to within 2 to 3 inches of the soil surface every 4 feet in all directions. Stakes may be driven before or after applying mulch. Secure mulch to soil surface by stretching twine between pegs in a criss-cross within a square pattern. Secure twine around each peg with two or more round turns;

- Pick chain--The rolling spiked-chain implement can be operated on slopes of 3:1 or steeper. It is attached to a tractor or truck which operates along the top of the slope. The pick chain can also be used for seedbed preparation and mixing lime and fertilizer with the soil; and

- Slit--With a square pointed spade, cut mulch into the soil surface in contour rows about 18 inches apart.

7. Irrigation

If soil moisture is deficient, irrigation will aid in getting new plantings established. Apply sufficient amount of water immediately after mulching and mulch anchoring to raise the moisture in the top six inches of the soil to field capacity. The area should receive water every three to seven days when needed to maintain the moisture in the top twelve inches of soil above 60 percent field capacity. Irrigate until the root system exceeds 12 inches in depth.

8. Maintenance

Maintenance is the most important controllable factor in retaining an effective vegetative cover. The following controls are especially important:

- Control of competition--Competitive weed and nurse crop growth during the period of establishment should be controlled by cutting. Weeds can be controlled with the use of herbicides; when herbicides are used, follow current recommendations, adhere strictly to the instructions on the label, and note the precautions given for Conservation Tillage.

- Repairs--Inspect all areas for planting failures and make necessary repairs, replacements and reseeding within the planting season, if possible; and

- Grazing--Some sites may be grazed if planted to suitable species. Do not allow grazing for a minimum of 18 months after planting or until the planting is well-established. Do not graze as short as regular pastures. Graze bermuda grass type plants no shorter than six inches. Graze guinea grass types no shorter than 12 inches to avoid damaging the stand. Do not allow livestock to graze when soils are saturated.

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Critical Area Treatment Table 1: Grasses Suitable for Permanent Cover

Plant	Planting Rate (per acre)	
Carpet grass[1]	Vegetative material:	2 tons
	Seed:	80 lbs
Devil grass[2]	Vegetative material:	2 tons
	Hulled seed:	40 lbs.
	Unhulled seed:	80 lbs.
Guinea grass[3]	Vegetative material:	2 tons
	Seed	30 lbs.
Pangola grass	Vegetative material:	2 tons
St. Augustine grass	Vegetative material:	2 tons
Khus khus grass	Vegetative material:	2 tons

[1]Savannah grass

[2]Common bermuda grass

[3]Only in combination with carpet grass

CROP RESIDUE MANAGEMENT

Definition

Using plant residues to protect cultivated fields during critical erosion periods.

Purpose

To conserve moisture; increase infiltration; reduce soil loss; and improve soil tilth.

Planning considerations

One should encourage the leaving of all crop residue on the field. Although St. Kitts farmers are tempted to use it for livestock forage, research generally has shown that it has more cash value when left on the field to maintain or improve yields than it does for forage. Crop residues are more valuable for soil maintenance and soil building when left on the surface than when turned under.

Specifications

Leave all crop residue, except cotton residue, on the field. Rake and burn the cotton residue, but do not include weed residue with this. Leave soil undisturbed until seedbed preparation begins for the next crop, unless the field has to be hoed or cultivated for weed control during the fallow period. If the residue is disturbed, leave as much on the soil surface as possible. When economical, use herbicides to control weeds instead of cultivation. When using herbicides, follow label instructions and all laws and regulations.

Exercise caution when using pesticides as discussed at beginning of Section 4.

DIVERSIONS

Definition

A channel constructed across the slope with a supporting ridge on the lower side.

Purpose

To divert excess water from one area for use or safe disposal in other areas, to reduce erosion, and to control gullies.

Planning Considerations

There are a number of places on St. Kitts where runoff is causing severe erosion. There are pond sites that need more runoff to provide a dependable water supply. Diversions can help solve these problems by diverting water away from places where there is too much water and to places where more water is needed or can be handled safely.

Diversions should be located as close as practical to the areas to be protected, but must be stable after construction. Diversions used to divert water into a pond should be located so the outlet will be stable.

The diversion layout should start at the keypoint--either the outlet or above the area to be protected. If the diversion empties on grass, an allowance must be made for grade and depth of cut in the last 100 feet so the water will outlet at ground level.

Extra cut or fill may be used to secure the desired alignment. Usually a bulldozer will be used to construct the diversion, in much the same manner as a terrace.

Specifications

Diversions that protect agricultural land must have the capacity to carry the peak runoff from a 10-year frequency, 24-hour duration storm as a minimum. Higher value property or development will require greater protection and should be specifically designed on a site-by-site basis.

1. Cross section

The channel may be parabolic, V-shaped, or trapezoidal (See Figure 1). The diversion shall be designed to have stable side slopes. The ridge height shall include an adequate settlement factor, but not less than 5 percent. The ridge shall have a minimum top width of 4 ft. at the design elevation. The minimum cross section shall meet the

specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified overfill for settlement.

2. Grade and velocity

Channel grades may be uniform or variable. Channel velocity shall not exceed that considered nonerosive for the soil and planned vegetation or lining (See Diversion Table 1).

Channel velocity is determined by use of Manning's formula:

$$V = \frac{1.486}{n} r^{2/3} s^{1/2}.$$

where:

V = velocity (ft/s);
r = hydraulic radius - (channel area/wetted perimeter);
s = slope of channel (ft/ft); and
n = roughness coefficient.

The rate of discharge, Q, from a diversion is calculated as:

Q = A x V, where:

Q = capacity in ft^3/s;

A = area in ft^2; and

V = velocity in ft/s.

Diversion Tables 2 through 5 have been developed as parabolic designs for the range of channel grades appropriate for St. Kicts. Use the one with the grade that best fits site conditions. Additional tables for trapezoidal design are found in Annex 3. The flow rate is based on retardance factors. Retardance factors range from "A" for very tall dense grass, through "B", "C" and "D" down to "E" which is for very short grass or burned stubble.

Tables 2 through 5 were developed with D vegetative retardance for velocity control. D retardance is for a good stand of grass 3 to 5 inches in height. The depth in the tables is to provide B retardance for capacity. B retardance is for a good stand of grass 12 to 16 inches in height. This type design keeps the velocity low enough to be stable when the grass is short and prevents overtopping when the grass is tall. For situations beyond the data included here or if additional information is required, refer to SCS Engineering Field Manual.

3. Outlets

Each diversion must have a safe and stable outlet with adequate capacity. The outlet may be a grassed waterway, a vegetated or paved area, a grade stabilization structure, a pond, a stable watercourse, or a combination of these practices. The outlet must convey runoff to a point where outflow will not cause damage. Vegetative outlets shall be installed before diversion construction to ensure establishment of vegetative cover in the outlet channel.

The design elevation of the water surface in the diversion shall not be lower than the design elevation of the water surface in the outlet at their junction when both are operating at design flow.

4. Construction

Fill all ditches or gullies and remove undesirable trees and other obstructions before construction begins. The diversion shall be constructed to planned alignment, grade, and cross section.

Diversion ridges constructed across gullies or depressions shall be compacted sufficiently to keep settlement within tolerable limits. The surface of the finished diversion shall be reasonably smooth and present a workmanlike appearance. Topsoil should be stockpiled and spread over excavations and other areas to facilitate revegetation.

5. Vegetation

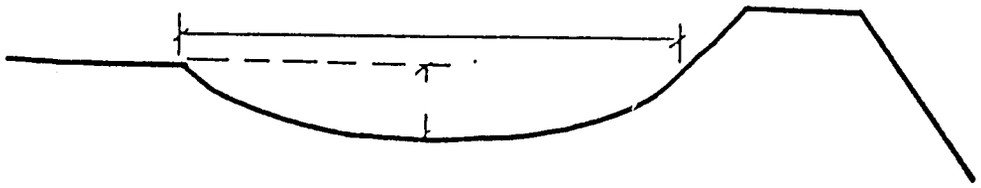
Disturbed areas that are not to be cultivated shall be established to grass as soon as practicable after construction. Seedbed preparation, seeding, fertilizing, and mulching shall comply with standards for grassed waterways. The vegetation shall be maintained and trees and shrubs controlled by hand, machine, or chemicals.

6. Operation and maintenance

A maintenance program shall be established to maintain diversion capacity, storage, ridge height, and the outlets. Maintenance needs are to be discussed with the landowner or operator who is responsible for maintaining diversion.

The diversion should be inspected after each major flow or at least annually to determine if erosion or sediment is becoming a problem. Any problems encountered should be treated promptly.

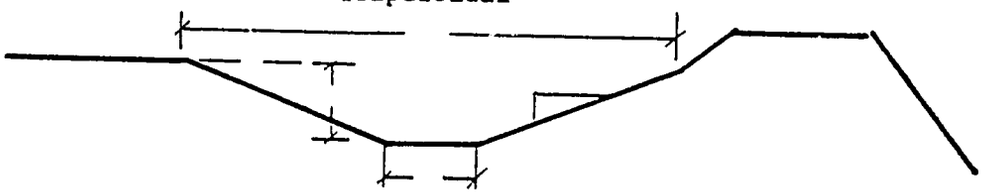
Parabolic



Cross-sectional area (A)=2/3 Td

Design top width $(T)=\frac{1.5A}{d}$

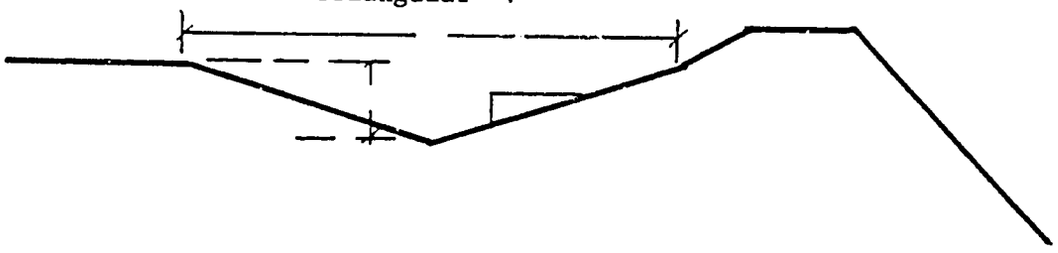
Trapezoidal



Cross-sectional area $(A)=bd + zd^2$

Design top width (T)=b + 2dz

Triangular "V"



Cross-sectional area $(A)=zd^2$

Design top width (T)=b + 2dz

d=design width
b=design bottom width
z=side slope ratio

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Diversion Figure 1: Typical Diversion Cross Sections

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Diversion Table 1: Maximum Permissible Channel Velocities for Various Covers and Soils

Cover	Slope Range %	Maximum Permissable Velocity (ft/s) Erosion-Resistant Soils	Maximum Permissable Velocity (ft/s) Easily Eroded Soils
Bermuda grass	0-5	8	6
	5-10	7	5
	>10	6	4
Carpet, Guinea, Pangola, St. Augustine Grasses	0-5	7	5
	5-10	6	4
	>10	5	3
Other grasses	0-5	5	4
	5-10	4	3

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Diversion Table 2: Top Widths for Parabolic Diversion Design for 0.5 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=2.0 ft	v=3 ft/sec d=2.5 ft
20		
30	21	
40	29	
50	36	
60	43	
70	50	23
80	57	27
90	64	30
100	71	34
120		40
140		47

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Diversion Table 3: Top Widths for Parabolic Diversion Design for 1 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=1.5 ft	v=3 ft/sec d=1.8 ft	v=4 ft/sec d=2.1 ft
20	20		
30	30		
40	40	20	
50	50	25	
60	60	30	
70	70	36	20
80		41	22
90		46	25
100		51	28
120		61	34
140			40

Note: Based on retardance D for velocity control and B for capacity.

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Diversion Table 4: Top Widths for Parabolic Diversion Design for 2 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=1.2 ft	v=3 ft/sec d=1.3 ft	v=4 ft/sec d=1.5 ft
20	29		
30	44	22	
40	59	30	
50	73	37	22
60		44	26
70		52	30
80		59	35
90		66	39
100		74	43
120			52
140			61

Note: Based on retardance D for velocity control and B for capacity.

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Diversion Table 5: Top Widths for Parabolic Diversion Design for 3 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=1.0 ft	v=3 ft/sec d=1.1 ft	v=4 ft/sec d=1.2 ft
20	36	18	
30	54	27	
40	72	36	22
50		45	27
60		55	33
70		64	38
80			44
90			49
100			55
120			65

Note: Based on retardance D for velocity control and B for capacity.

FOREST IMPROVEMENT

Definition

Improving forests by protection and/or removing unmerchantable or unwanted trees, shrubs or vines.

Purpose

To protect the genetic variety of forests and to fully use the potential of a site; to maintain plant cover for soil protection; to improve stand composition by leaving the best trees, spaced for best growth; to improve forage production on grazable woodland; or to improve the natural beauty, wildlife, or recreation values of the area.

Planning Considerations

Use this practice on forests where a stand of trees is overstocked; where desirable trees are overtopped by less desirable ones; or where removing part of a stand will improve stand quality, forage production, or the recreation, aesthetic, or hydrologic values of an area. Maintaining forests on the island in good condition is very important in order to recharge groundwater and springs.

Specifications

1. Removal of undesirable species

Undesirable species should be removed to improve the growth of desirable trees and reduce regeneration of such trees. Trees and shrubs should not necessarily be eliminated merely because they are not the most desirable for commercial wood production. Understory trees and shrubs should be controlled only where they are restricting regeneration or normal development of an adequate stand of desirable tree seedlings. Species to be released should be adapted to the site.

Some owners will decide to favor wildlife in their woodlands, residential areas, on farms and in forested areas. Valuable food trees or shrubs for the species of wildlife to be favored should be released by individual chemical treatment or by cutting, and possibly chemically treating the stump(s).

2. Pre-commercial thinning

Unmerchantable trees should be removed from an immature forest as needed to reduce stand density. Thinning is done where the number of trees are too great for the best growth of the planned crop. The selection of trees to leave in pre-commercial thinnings shall be based on management objectives, insect and disease hazards, and species

adaptability, as well as the form and vigor of individual trees. Always try to keep the best trees for future growth. Pre-commercial thinnings should try to provide the better trees in a stand with suitable growing space until the trees reach a commercial size.

Trees to be removed can be cut with a chain saw, axe, cutlass (machete), or similar tool. Trees should be completely cut down and cuts should be made close to the ground. Cut trees should be flat on the ground and not left hanging against trees to be left standing. Firebreaks should be constructed around treated area and extreme caution exercised to prevent fire following thinning.

FOREST, IMPROVED HARVESTING

Definition

Systematically removing some of the merchantable trees or products from a stand or all the trees from a designated part of a forest.

Purpose

To harvest some of the merchantable trees or products from an immature stand in order to improve the conditions for forest growth; and/or to remove or harvest trees in a manner that encourages the regeneration and normal development of a new stand.

Planning Considerations

Use where the site, size, species, and density of a forest stand make the planned and systematic harvesting of forest trees economically and/or silviculturally feasible for improving the growth of the remaining trees or to regenerate the stand. Proper harvesting must be done in a way to maintain heavy litter on the ground. This will help conserve water and maintain spring flow so important to the island's water supply.

Specifications

1. Forest intermediate cutting

Forest intermediate cutting refers to the practice of removing merchantable trees from a stand, i.e., commercial thinning. In intermediate cuttings with mixed species, always favor the species which are best adapted to the site. (If the better adapted species are not present in a forest, consideration might be given to interplanting or conversion of the area to a suitable species or stand.) Selection of trees to leave should be based on one or more of the following:

- Management objectives;
- Desirable characteristics of species;
- Insect, disease and wind hazards;
- Form, vigor, and size of individual trees; and
- Spacing of trees to be left.

Always leave some of the trees in a stand for future growth. Consideration should also be given to species which will provide choice wildlife food, cover and enhance the natural beauty of the woodland.

Intermediate cuttings should leave trees that will have suitable growing space for a planned number of years. Cuttings should be made in accordance with the landowner's objectives and Government policies. Spacing for special purposes or products should be allowed on the advice of a professional forester.

In large areas, divide the area into compartments if practical. Complete forests may be divided into as many compartments as there are years in the cutting cycle. This gives the owner an annual return from his woods. Compartments, however, should be large enough to justify a cutting operation.

Any trees which have been killed or seriously damaged by wind, fire, insects or disease should be cut to improve stand health and safety conditions and salvaged when possible to prevent economic loss.

2. Harvest cutting

Mature crop trees should be harvested in a manner that will encourage regeneration and normal development of a new stand. The term "crop trees" refers to merchantable trees. Any valuable species is considered potentially merchantable. Species to be favored, or ones considered for establishment of a new stand, should be adapted to the site. Crop trees are also trees considered for cutting for one or more of the following reasons:

- Condition--A tree with a wide spreading crown may be utilizing the space which could be growing several high quality trees; or a disease or insect attack may be threatening to kill the tree; or some other impairment may cause the tree to be in need of removal;

- Age--The tree may have reached a point where growth is slowing down or where it is a poor risk to leave it until the next scheduled cut;

- Species--A low value species occupying space which could more profitably be replaced by more valuable species; and

- Management objectives--The final crop will depend largely on the markets available in the locality. In any case, the trees harvested at rotation age, or rotation size, are "crop trees."

The area of harvest cut and size of final crop trees depends mainly on the management objectives. Items to be considered are:

- Desired frequency of income--The owner may want an annual income or a periodic return;

- Specific product--The final product may be Christmas trees harvested at 5 years of age, or high quality poles harvested at 60-80 years of age;

- Capability of site--Consider the soil-site potential. For example, don't try to grow a 90 foot pole on a 60 foot site;

- Reproduction potential--If the area is to be restocked naturally, harvest trees and leave trees must be of seed-bearing size and age. This point is not a consideration if artificial reforestation is planned; and

- Type of stand desired--Decision should be made whether an even-aged or all-aged stand will be grown. This will determine size and area of crop trees.

Selection of trees to harvest will depend on future plans for the area to be cut. Some of these considerations are:

- Starting a new crop of trees--In stands where management objectives have been reached, the standing crop should be cut and a new crop planted. This may be a clearcut of certain sized trees for pulpwood or some other product. Regeneration is usually by planting or direct seeding;

- Releasing a crop of existing reproduction--In areas where an adequate stand of desired seedlings has already been established naturally or artificially, the overstory stand of merchantable trees could be cut. This would allow an orderly development of new crop;

- Change of species--On certain sites the existing stand of trees might be removed in order to establish a species of trees which is better adapted to the soil; and

- Maximum utilization of site--Scattered merchantable trees in an understocked stand could be cut to allow a full stand of trees to be established and develop normally.

3. Methods of stand regeneration

Regeneration may be accomplished by natural seeding, direct seeding, or planting. Natural reseeding is practical only where sufficient seed trees of the desired species are present and predominant. In hardwood stands the dependability of natural regeneration makes planting generally unnecessary. Area to be regenerated must be protected from wildfire and harmful grazing. Livestock must be excluded from areas of hardwood regeneration. Competing vegetation should be controlled to allow natural development of the new stand.

FOREST SITE PREPARATION

Definition

Protecting and treating areas to encourage natural seeding of desirable trees or to permit forestation by planting or direct seeding.

Purpose

To protect or prepare land for establishing a forest to conserve soil and water, improve catchment areas, or to produce wood or other forest products.

Planning Considerations

Use this practice on fields with understocked areas, growing undesired vegetation (brush, etc.) on which forest reestablishment is desired. Improving or establishing forests will help increase spring flow and improve the island's available water supply.

Specifications

Most species of pines and pioneer hardwoods are relatively intolerant to shade. Therefore some provision must be made to ensure that a planted or direct-seeded seedling will obtain adequate light. This factor and moisture competition usually make site preparation a necessary consideration for all trees planted for forestry purposes. A number of other factors should be taken into consideration:

- Excessively well drained, coarse textured soils--Severe competition for available moisture makes reduction of competing vegetation necessary;

- Well drained, coarse to fine textured soils--Elimination of grass cover may be necessary;

- Special areas--Some areas need special attention due to existing vegetation, for example the following:

  -- Improved pastures--Pasture grasses tend to retard early growth of seedlings. Eliminate grass competition by scalping or furrowing where trees will be planted;

  -- Scattered residual trees--After a clearcut harvest cutting, there may be numerous small residual trees left; and

-- Larger hardwoods of less desirable species--Landowners may desire to leave these large hardwoods for other purposes such as beautification or for wildlife food and cover.

Several methods can be used for site preparation. Burning before planting or seeding reduces logging debris and some competing vegetation. On some sites it may be all that is needed to prepare the site for planting. Spraying of herbicides should be tried out before large scale operations are initiated. Chemicals may be injected into stems of trees by use of an injector or by frilling or notching. Treatment of areas with large numbers of stems per acre may prove too costly for this method.

Exercise caution when using herbicides as described at beginning of Section 4.

GRADE STABILIZATION STRUCTURE

Definition

A structure used to control the grade and head cutting in natural or artificial channels.

Purpose

To stabilize the grade and control erosion in natural or artificial channels and to prevent the formation or advance of ghauts.

Planning Considerations

Steep slopes and heavy rains often cause severe gullying. There are about 100 ghauts on St. Kitts, with 39 considered to be a problem. Two of the more notable are the Wash and the Hope Ghauts. Grade stabilization structures are a vital part of the solution to the ghaut problem on St. Kitts. Grade stabilization structures are usually complex and expensive. Therefore, all other methods of stabilization should be considered before or along with such structures. Furthermore, the upper watershed practices which may have contributed to such critical areas must also be planned for improvement.

Specifications

1. Ghaut treatment

Most importantly, keep the water from entering the ghaut. Vegetation can be used to increase infiltration of rainfall. Terraces can lead the water away from the ghaut or, if the soils are permeable, the terraces can be designed so the water will soak into the ground. This method works best on A or B Hydrologic Soil Groups.

In some cases terraces with underground outlets can be used. The procedures for design of the terraces and the underground outlets may be found in the US Soil Conservation Service (SCS) Engineering Field Manual.

In cases where there is little or no drainage outside the gully area, shaping, vegetation, and livestock exclusion may solve the problem.

2. Structures

If the above methods will not do the job, a structure that will mechanically control the grade and provide a method of taking the energy out of the water will be necessary. See Grade Stabilization Figures 1,2,3 and 4 for pictures of typical grade stabilization

structures. The most common solution for St. Kitts will be a drop spillway made with rock-filled wire gabions or reinforced concrete.

To be effective, the control for the upstream grade must be at an elevation and location that will stabilize the head cut or grade. The floor of the structure must be at an elevation that is stable against head cuts coming up from downstream and undermining the structure. If the drop is too great to control with one structure, more than one structure should be used. In all cases the structures must be located so that the grade is stable. Channels upstream and downstream should be shaped and protected with vegetation or rock as necessary to ensure stability.

In some cases, a sill can be installed across the channel to provide a grade control point. Walls or deflectors can be used where the stream curves. The footing should be extended below the deepest expected scour hole. The top of the wall should be extended above the design storm flow plus any velocity run-up anticipated because of the curve. Normally, footings of sills and walls would be extended about three feet below the channel grade line. The top of the wall or deflector would be placed at design high water plus two feet. The top of the sill would be at the desired grade control elevation.

When planned structural work is completed and the grading is done, all disturbed bare areas should be vegetated as necessary. Livestock should be excluded, if necessary, to maintain vegetation.

3. Capacity

The completed system of channel work, sills and grade stabilization structures must be stable for all flows up to and including the design capacity. Structures with 20 acres or less drainage area shall be designed to carry the peak flow expected from a 10-year frequency storm. Those with more than 20 acres drainage area shall carry the peak flow expected from the 25-year storm. Higher frequency storms should be used if the hazard from failure warrants.

4. Design criteria

Footings shall extend at least two feet below the channel grade. Wing walls of structures shall have at least 0.5 foot freeboard with water flowing at design depth. Capacity of gabion-type drop spillways (which can also be made of concrete) shall be calculated by the following formula:

$$Q = 3.3\ L\ (H+V^2/2g)^{3/2}$$

where:

Q = design discharge capacity in ft^3/s

L = the length of the weir opening in ft
H = the depth of water flowing over the weir crest in ft
V = the channel velocity in ft/s at design discharge immediately upstream from the structure
g = acceleration of gravity, usually taken as 32.2 ft/s/s.

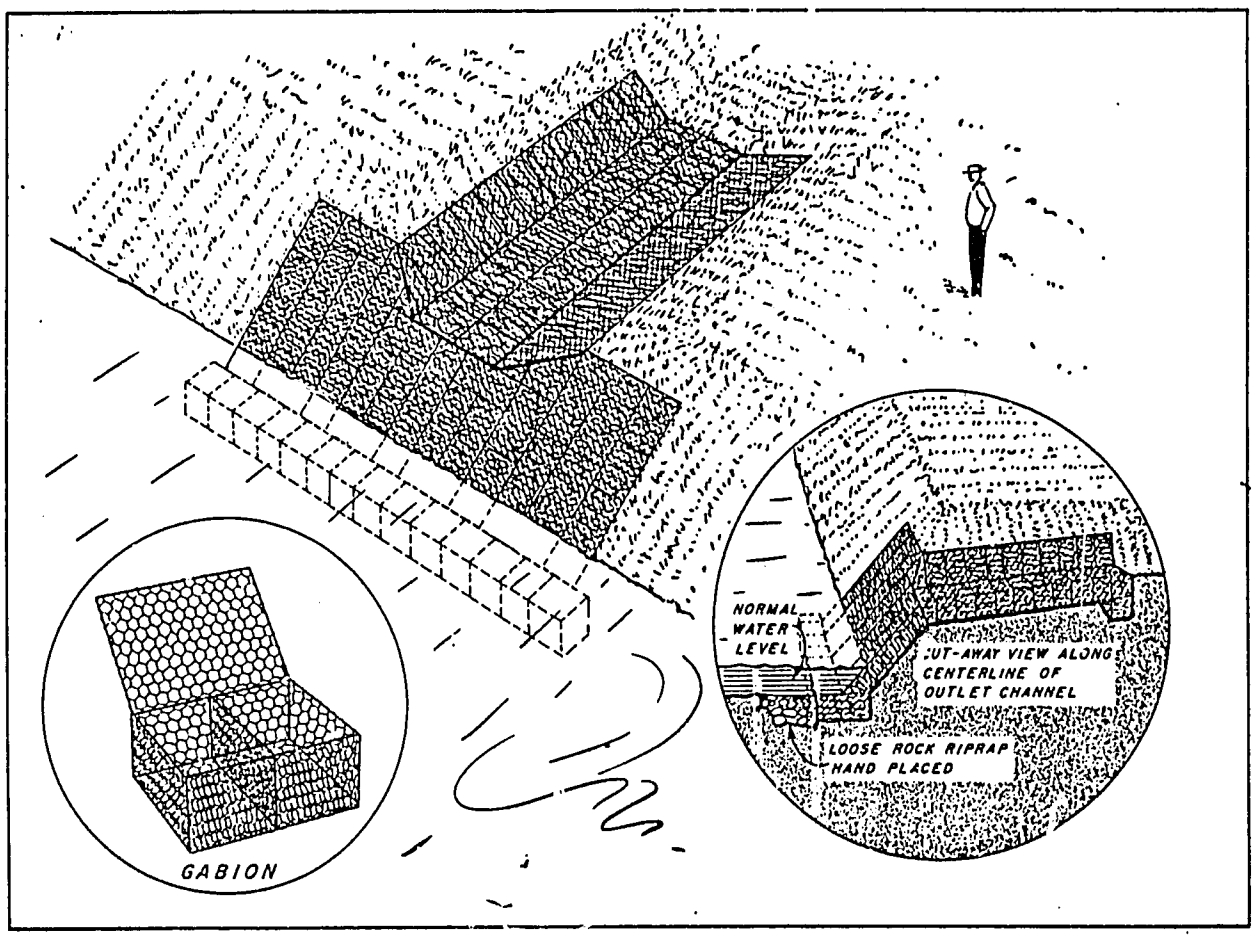
5. Materials

Gabion-type structures shall be of the manufacturers' recommended quality wire fabric, placed to line and grade and hand filled with quality stone before backfilling.

Concrete structures shall be installed according to plans and specifications for the job. Small jobs may be a 1:2:3 mix with 6 gallons of water to one cubic foot of cement. For larger jobs, concrete with a 28-day compressive strength of 3,000 psi shall be used.

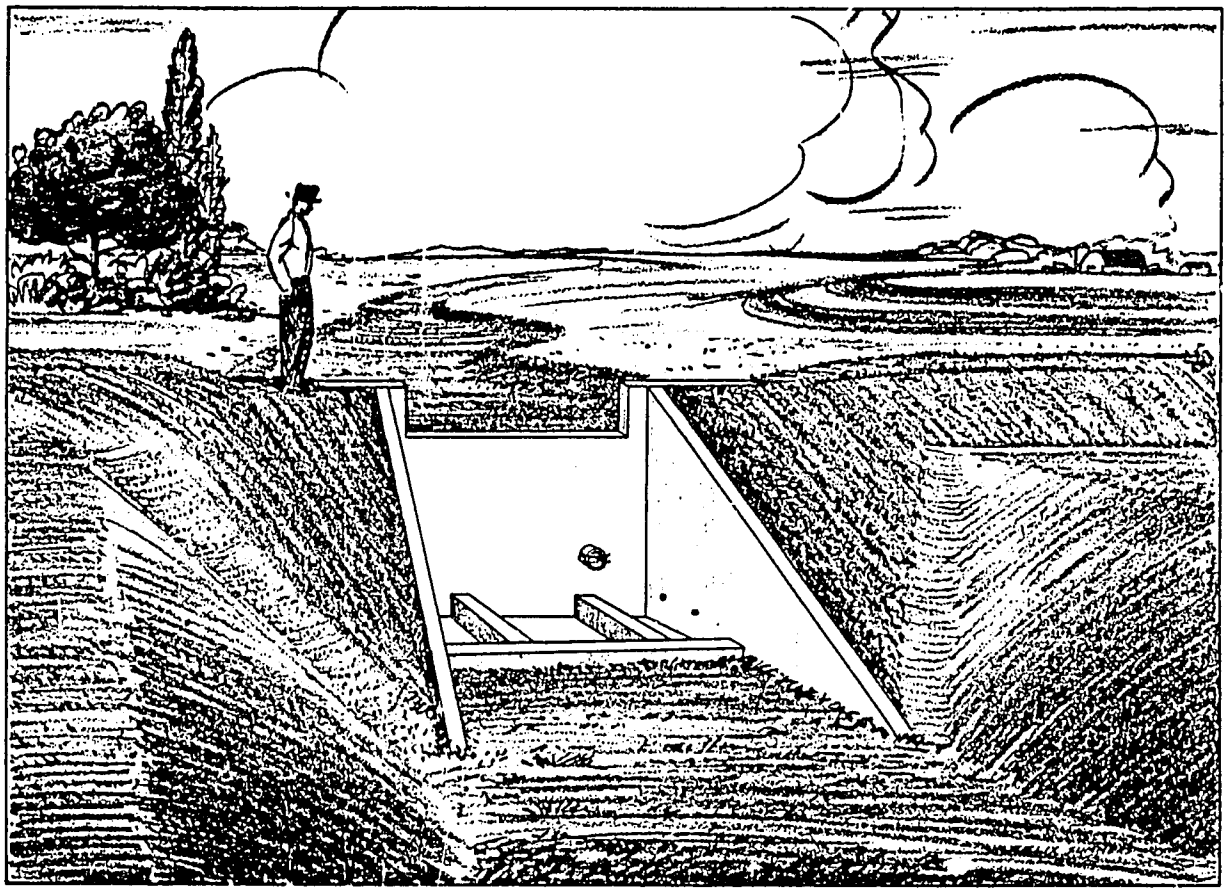
6. Installation

The structures and earthwork shall be installed to line and grade according to the plans or as staked in the field. Selected backfill shall be placed around structures and compacted in a manner to prevent damage from unequal loading. The fill shall be started at the lowest point and brought up in horizontal layers of a thickness such that adequate compaction can be obtained. If necessary for protection, fill areas shall be vegetated and fenced to prevent damage from livestock.

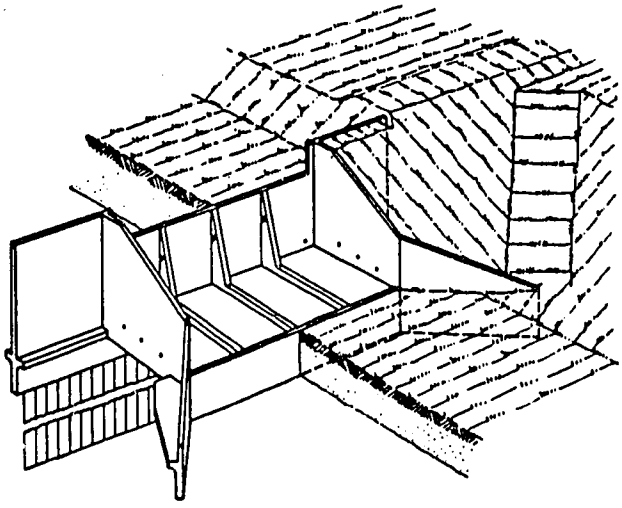


Gabion Chute

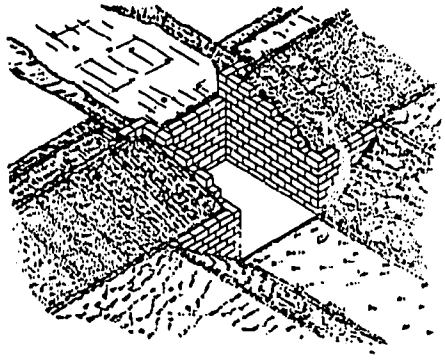
Grade Stabilization Structure Figure 1: Gabion Chute



Drop Spillway



Reinforced Concrete



Concrete Block

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Grade Stabilization Structure Figure 2: Drop Spillway

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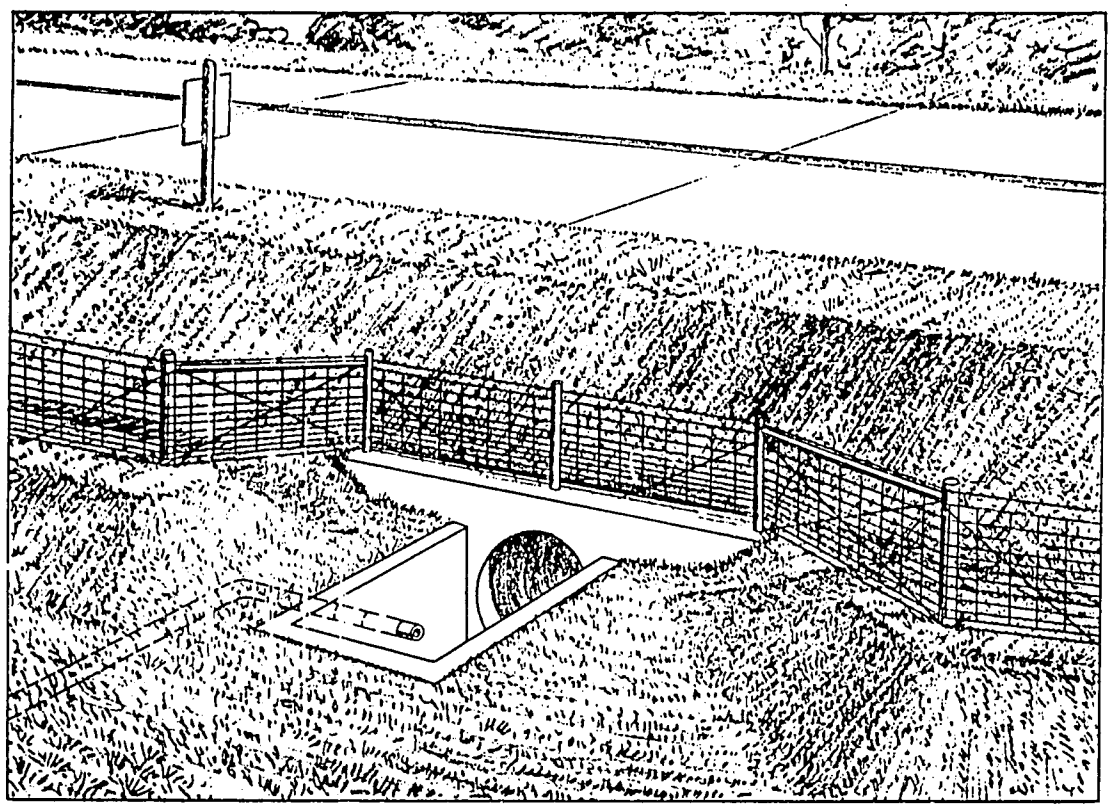
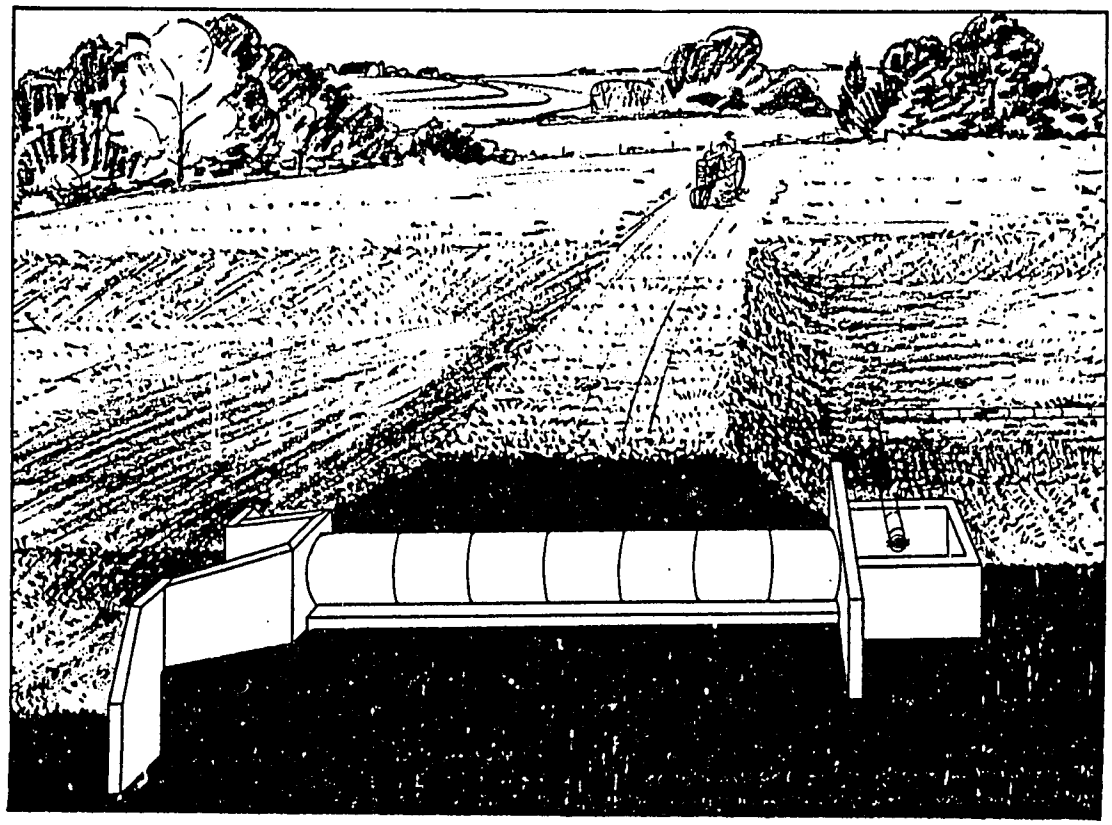


Culvert box-inlet.



Dry basin type earthfill dam with box-inlet culvert type spillway.

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Grade Stabilization Structure Figure 3: Culvert

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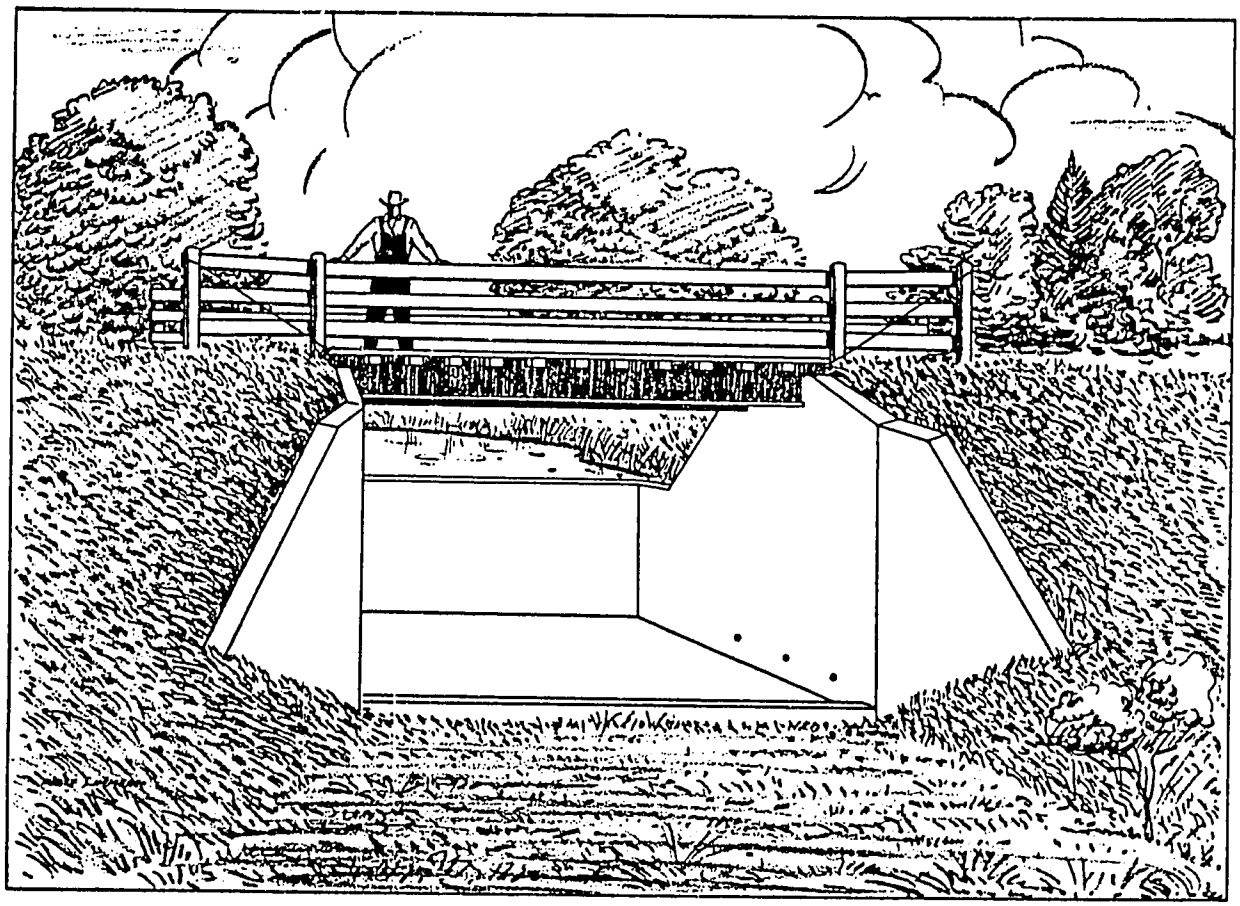
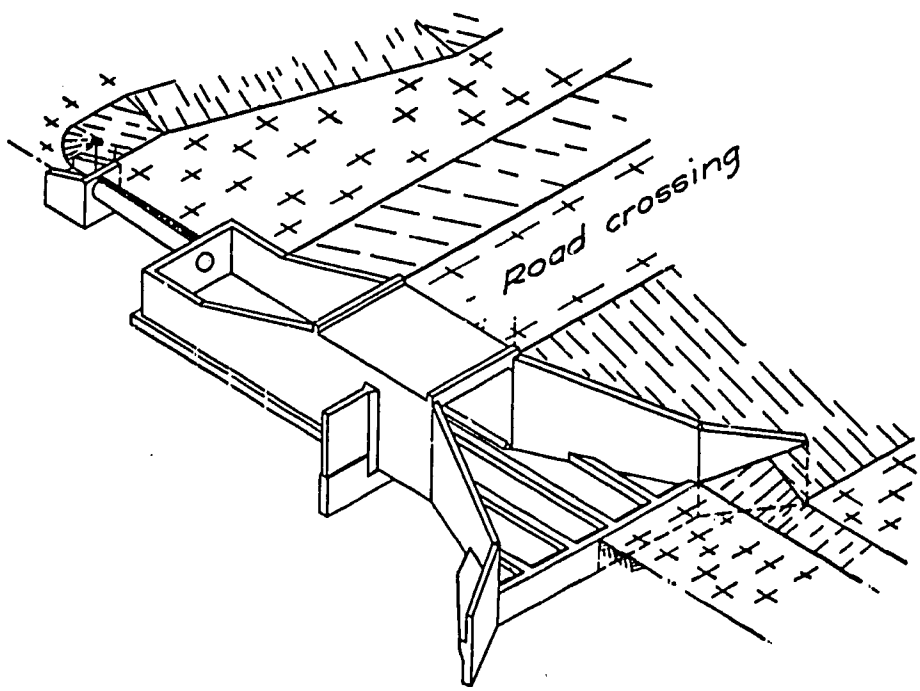


Box-inlet drop spillway with a bridge over the top.



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Grade Stabilization Structure Figure 4: Road Crossing

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GRASSED WATERWAY

Definition

A natural or constructed channel that is shaped or graded to required dimensions and has suitable vegetation established for the stable conveyance of runoff.

Purpose

To convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality.

Planning Considerations

St. Kitts has many steep hillsides that receive large amounts of rain. Part of this rain runs off. If not controlled, this runoff can cause gullying. Grassed waterways, in many cases, can be used to carry this water down the hillside without causing erosion. This section describes how to plan, design, install and maintain grassed waterways.

A preliminary site investigation should be made to pick the best location and outlet for the planned waterway. If possible, the natural drainage system should be used. Avoid abrupt changes in flow direction.

Surveys are necessary to determine grade and drainage area. Peak runoff rates can be determined using the section on estimating storm runoff (See section 2.6). These rates are used with Grassed Waterway Tables 1 through 6 to select an appropriate top-width and depth for a parabolic waterway. As for diversions, channels for grassed waterways may be parabolic, V-shaped, or trapezoidal (See Figure 1). Annex 3 includes tables for selecting an appropriate bottom-width and depth for a trapezoidal waterway.

The most critical time in successfully installing grassed waterways is when vegetation is being established. Special protection such as mulch anchoring, straw or hay bale dikes, or other diversion methods are warranted at this critical period. Divert all foreign water away from the waterway channel. Supplemental irrigation may also be warranted. The vegetation should be well established before large flows are permitted in the channel.

GRASSED WATERWAY 2

Specifications

1. Capacity

The minimum capacity shall be that required to convey the peak runoff expected from a 10-year frequency, 24-hour duration storm. When the slope is less than 1 percent, out-of-bank flow may be permitted if such flow will not cause excessive erosion. The minimum in such cases shall be the capacity required to remove the water before the crops are damaged. Out-of-bank flow should not be permitted on slopes greater than 1.5 percent because of the extreme hazard of erosion.

2. Velocity

Design velocities shall not exceed those shown in Tables 1 through 6 for a parabolic design, or those shown in Annex 3 for a trapezoidal design. The tables are based on grades of waterways appropriate for St. Kitts. [See Diversions section for discussion of Mannings formula and refer to Diversions Table 1 for permissable velocities].

Vegetative retardances refer to the effect of waterway vegetation on water velocity and are designated as A, for very tall dense grass; B, C, & D for shorter grass; and E for very short mowed or grazed grasses and burned crop stubble. The waterway tables are designed for B & D retardances, typical of St. Kitts' conditions.

The waterway tables are designed for velocity control with a good stand of grass generally 3 to 5 inches high. The waterway tables are designed for depth and capacity with a good stand of grass generally 12 to 16 inches tall. This type design keeps the velocity low enough to be stable when the grass is short (D retardance) and prevents overtopping when the grass is tall (B retardance).

3. Dimensions

The minimum depth of a waterway that receives water from terraces, diversions, or other tributary channels shall be that required to keep the design water surface elevation at, or below, the design water surface elevation in the terrace, diversion or other tributary channel at their junction when both are flowing at design depth. This flow depth is indicated on the tables.

Side slopes shall not be steeper than a ratio of two horizontal to one vertical. They should be designed to accommodate the land user's equipment.

The bottom width of trapezoidal waterways shall not exceed 100

feet unless multiple or divided waterways or other means are provided to control meandering of low flows.

4. Outlets

All grassed waterways shall have a stable outlet with adequate capacity to prevent ponding or flooding damage. The outlet can be another vegetated channel, an earth ditch, a grade stabilization structure, or other suitable outlet.

5. Construction

All trees, stumps, brush, and similar material are to be removed from the site and disposed of in a manner consistent with environmental concerns and proper functioning of the waterway.

The waterway shall be shaped to the grade and dimensions specified in the plans or as staked in the field. Topsoil shall be stockpiled and respread where necessary to provide a seedbed for the grass.

The constructed bottom of trapezoidal waterways shall not vary from side to side by more than 0.2 feet. The constructed bottom of parabolic waterways shall not vary from planned cross section by more than 0.2 feet. The quarter points of the bottom shall be no more than one-quarter the depth up from the maximum depth.

Any spoil shall be spread where it will not interfere with flow into the waterway. If necessary, excess water shall be diverted away until vegetation is established. After establishment, any protective works shall be removed, and the disturbed areas that are not to be farmed shall be seeded to permanent grass.

6. Vegetation

Seedbed preparation; time of seeding; planting mixture and rate; stabilizing crop, mulching, or mechanical means of stabilizing; and fertilizer and lime requirements shall be specified for each applicable area. In order to accomplish the purpose of this practice, intensive methods of establishment and management of vegetation are essential. Vegetative cover must be established as rapidly as possible to prevent erosion. Vegetation shall be well established before additional surface water from diversions or other conservation measures are let out into newly constructed waterways. Great care should be exercised to prevent destruction of established vegetation by grazing or other means. Following are further details on several key factors:

- Seedbed preparation--The waterway or outlet will be properly shaped before attempting to vegetate it. Plant on a well-prepared firm seedbed. If possible, the waterway should be smooth enough to allow farm equipment to travel over it.

- Choice of plants--Grassed Waterway Table 7 gives information on the grasses that are best suited for permanent cover. All of these grasses can also be planted vegetatively by sprigging or sodding.

- Planting--Plant between August 15 and November 15. Plant vegetative material on the contour in furrows or holes 2 to 3 feet apart. (See Pasture Planting Table 1.) To avoid stimulating weeds, apply the fertilizer near the seedling but not in the row middles. After planting pack the soil over or around the planted material by walking on it, pressing the holes with the heel of the foot, or rolling the row with a heavy wheel or cultipacker. On clay or clay loam soils, pack after the surface is dry enough not to crust or stick to packer or feet. The specified planting depths are those obtained after packing the soil. If mechanical equipment is to be used for maintenance (mowing, etc.), plant and cover in such a way that the land is smooth after planting.

- Mulching--Mulching with straw, native vegetation, bagasse, or similar materials will be necessary where there is a heavy concentration of water. When mulching with straw or hay, apply one or two inches of loose thickness uniformly over the area. Cut this into the soil, so as to produce a loose mulch thickness of no more than three to four inches. Be sure that the mulching materials are not cut too deeply into the soil. Course materials such as limbs should be staked or wired to prevent movement. In extreme cases it may be necessary to use netting, petroleum-derived mulch or wood-fiber cellulose materials.

- Fertilizer and lime requirements--At time of planting, base fertilizer and lime application on a soil analysis or apply 60 pounds each of N, P and K per acre. Apply a maintenance fertilizer each year at rates specified in soil analysis.

- Management--Additional measures may be necessary to completely grass the waterway and prevent erosion. Replant if a good stand of grass is not obtained after the initial planting. Small bare areas should be sodded or mulched and reseeded before they cause serious erosion. If grazed, livestock should be removed from the area until grass is well established. Grazing after establishment should not go beyond the point of good pasture management.

7. Maintenance

A maintenance program shall be established to maintain waterway capacity, vegetative cover, and the outlet. Vegetation damaged by livestock, machinery, herbicides, or erosion must be repaired promptly.

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Grassed Waterway Table 1: Top Widths for Parabolic Waterway Design for 1 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=1.5 ft	v=3 ft/sec d=1.8 ft	v=4 ft/sec d=2.1 ft
20	20		
30	30		
40	40	20	
50	50	25	
60	60	30	
70	70	36	20
80	80	41	22
90	90	46	25
100	100	51	28
120		61	34
140		71	40
175		89	50
200		101	56
250			71
300			86

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Grassed Waterway Table 2: Top Widths for Parabolic Waterway Design for 2 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=1.2 ft	v=3 ft/sec d=1.3 ft	v=4 ft/sec d=1.5 ft
20	29		
30	44	22	
40	59	30	
50	73	37	22
60	88	44	26
70		52	30
80		59	35
90		66	39
100		74	43
120		88	52
140		103	61
175			76
200			87
250			108
300			130

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Grassed Waterway Table 3: Top Widths for Parabolic Waterway Design for 3 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=1.0 ft	v=3 ft/sec d=1.1 ft	v=4 ft/sec d=1.2 ft
20	36		
30	54	27	
40	72	36	22
50	90	45	27
60	108	55	33
70		64	38
80		73	44
90		82	49
100		91	55
120		109	65
140			76
175			95
200			109
250			136
300			164

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Grassed Waterway Table 4: Top Widths for Parabolic Waterway Design for 5 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=2 ft/sec d=0.8 ft	v=3 ft/sec d=0.9 ft	v=4 ft/sec d=1.0 ft	v=5 ft/sec d=1.1 ft
20	45	23		
30	67	35	22	
40	90	46	29	
50	112	58	36	24
60		69	43	29
70		81	50	33
80		93	58	38
90		104	65	43
100		116	72	48
120			87	57
140			101	67
175				83
200				95
250				119
300				143

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Grassed Waterway Table 5: Top Widths for Parabolic Waterway Design for 8 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=3 ft/sec d=0.8 ft	v=4 ft/sec d=0.8 ft	v=5 ft/sec d=0.9 ft	v=6 ft/sec d=1.0 ft
20	30			
30	45	28		
40	60	37	25	
50	75	46	31	22
60	90	55	37	26
70	105	65	43	31
80	120	74	50	35
90		83	56	39
100		92	62	44
120		111	75	52
140			87	61
175			109	76
200				87
250				109

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Grassed Waterway Table 6: Top Widths for Parabolic Waterway Design for 10 Percent Grade

Q (ft^3/s)	Velocity (v) and Depth (d) v=3 ft/sec d=0.7 ft	v=4 ft/sec d=0.8 ft	v=5 ft/sec d=0.8 ft	v=6 ft/sec d=0.9 ft
20	33	20		
30	49	30	21	
40	66	40	28	20
50	82	50	35	25
60	99	60	42	30
70	115	70	49	35
80		80	56	40
90		90	63	45
100		100	70	50
120			84	60
140			98	70
175				87
200				99

Note: The calculations are based on retardance D for velocity control and B for capacity.

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Grassed Waterway Table 7: Grasses Suitable for Waterways

Plant	Planting Rate (per acre)
Carpet grass[1]	Vegetative material[2] 80 lbs. seed
Common bermuda grass (hulled) (unhulled)	Vegetative material[2] 40 lbs. per acre 80 lbs. per acre
Guinea grass[3]	Vegetative material[2] 30 lbs. per acre
Pangola grass	Vegetative material[2]
St. Augustine grass	Vegetative material[2]
Khus Khus (along sides)	Vegetative material

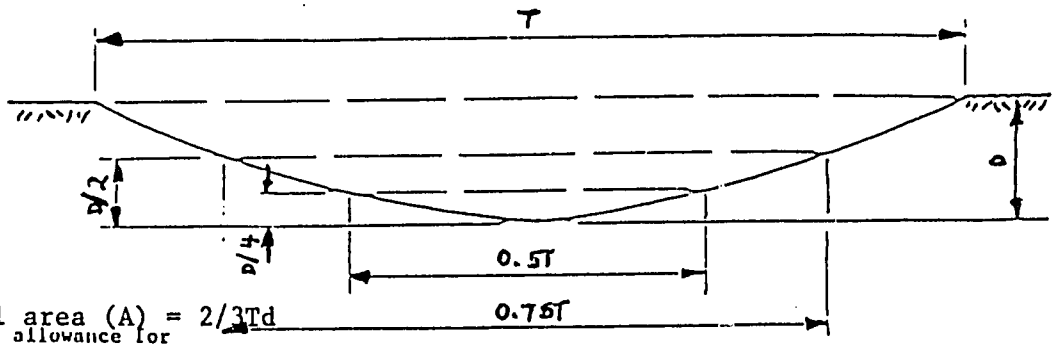
(Note: A more descriptive planting specification is included in Pasture Planting and should be considered here)

[1] Axonopus compressus

[2] Two (2) tons per acre.

[3] Only in combination with carpetgrass.

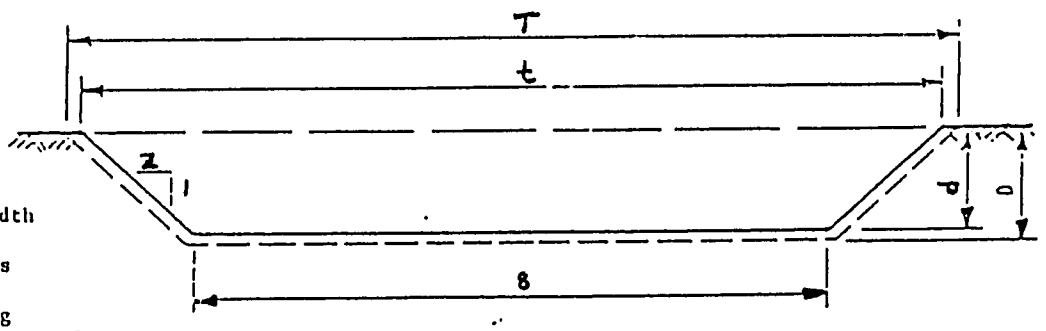
Parabolic Cross Section



T=design top width
D=design depth

Cross sectional area (A) = 2/3Td
Both values include allowance for the vegetative lining.

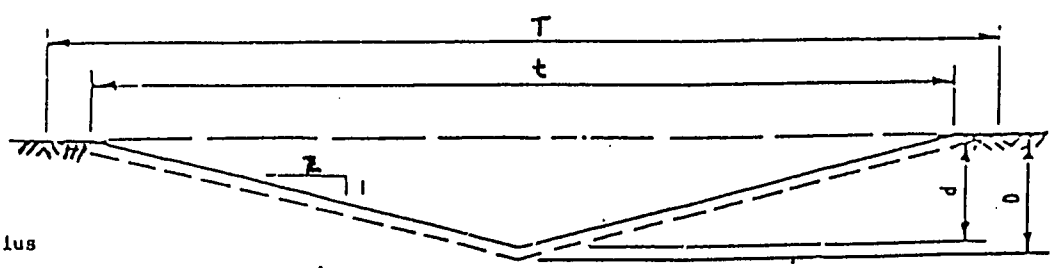
Trapezoidal Cross Section



B=design bottom width
d=design depth
D=design depth plus allowance for vegetative lining
t=design top width =B+2dz
T=design top width plus allowance for vegetative lining
z=side slope ratio

Cross Sectional Area (A)=Bd+zd^2

Triangular Cross Section



d=design depth
D=design depth plus allowance for vegetative lining
t=design top width
T=design top width plus allowance for vegetative lining
z=side slope ratio

Cross sectional Area(A) = xd^2

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Grassed Waterway Figure 1: Typical Waterway Cross Sections

GRAZING, DEFERRED

Definition

Postponing grazing or resting grazing land for a prescribed period.

Purpose

- To promote natural revegetation by increasing the vigor of the forage stand and permitting desirable plants to produce seed;
- To provide a feed reserve for dry-season grazing or emergency use; and
- To reduce soil loss and improve water quality.

Planning Considerations

Planned deferment periods should be based on the following:

- Physiological requirements and the vigor of the species in the plant community;
- The number of grazing units and number of animals maintained in the operating unit; and
- Weather and growing conditions.

The planned deferment must not result in overuse of, or have an adverse impact on, the rest of the operating unit. The area being deferred must be fenced so that none of the many sheep and goats on the island can get into the area. For quick results, the best pastures should be deferred first.

Specifications

All domestic livestock must be removed from the deferred area. When a unit of grazing land is deferred, other units must meet the requirements noted in the section on proper grazing use. Following deferment, the unit should be stocked to meet the requirements indicated under proper grazing use.

GRAZING, DEFERRED 2

Periods of deferment include the following:

- Three consecutive months--September through November;
- Six consecutive months--September through February; or
- Any twelve consecutive months.

Grazing lands in poor condition should be deferred for twelve consecutive months; those in fair condition should be deferred for six consecutive months. Deferment may be practiced on grazing lands in good or excellent condition as desired for a planned grazing system. Following brush control or on newly seeded areas, deferment should be practiced until grass has made full growth and produced one seed crop.

Where there are not desirable plants remaining or only traces of such plants are found, deferring alone can be expected to give little change in composition or would take too long to establish desirable plants. In such cases, deferment should be used following some other treatment that may be needed, such as seeding or brush control, to re-establish desirable forage.

GRAZING, PROPER USE

Definition

Grazing at an intensity that will maintain enough cover to protect the soil, maintain or improve the quantity and quality of desirable vegetation, and avoid soil compacting by the cattle.

Purpose

- To increase the vigor and reproduction of key plants;
- To accumulate litter and mulch necessary to reduce erosion;
- To improve or maintain the condition of the vegetation;
- To increase forage production; and
- To maintain natural beauty.

Planning Considerations

Proper grazing use is based on the principle that, if the grazing area is to provide forage throughout the year, it must be undergrazed during the favorable growing period. This is in order to allow the leaves of the plants to develop adequate surface area to photosynthesize and thus produce more forage. Animals and forage plants produce more efficiently and profitable on slightly understocked grazing areas than on overstocked lands. Although forage quality may decline somewhat when the plant is undergrazed, quality is adequate for adult animals. Proper grazing should be practiced on native grass pastures, abandoned cropland, and abandoned improved pastures where there are mixtures of native and introduced grasses and legumes.

Specifications

- Have water in each pasture available to the animals at all times;
- Graze the forage plants no closer to the ground than six (6) inches, except for taller growing grasses such as guineagrass. The taller plants should be grazed no shorter than eight (8) inches. Base proper grazing heights on the more productive species such as guineagrass; and
- Control brush by periodic hand clearing or with herbicides. Apply herbicides according to label instructions and all laws and regulations. Observe the precautions noted in the beginning of Section 4.

HILLSIDE DITCH

Definition

A channel that has a supporting ridge on the lower side, constructed across the slope at a definite vertical interval and gradient, with or without a vegetative barrier.

Purpose

To control the flow of water on steep sloping areas by diverting runoff to a protected outlet, thus minimizing erosion and runoff.

Planning Considerations

The small vegetable fields on the steeper slopes above sugarcane fields and ghaut banks can suffer very severe erosion. Contour farming and mulching help control the erosion. However, when field slopes approach 100 feet in length, these practices lose their effectiveness. If suitable outlets can be found or developed, hillside ditches can be used effectively on slopes up to 40 percent to control erosion. Regular maintenance and proper design is essential to prevent breakthroughs and ensure effectiveness.

Specifications

- Location--Hillside ditch systems shall be designed to fit land conditions. They shall drain from the ridge to a stable outlet;

- Outlets--Adequate outlets shall be provided before beginning construction of hillside ditch(es) to dispose of discharge without creating an erosion hazard. Such outlets may be a natural waterway or a constructed one, a stable watercourse, or stable disposal areas, such as well-established pasture;

- Length--Maximum length draining in one direction shall be 400 feet. This length may be extended to 500 feet. if necessary to reach a stable outlet beyond the cultivated field;

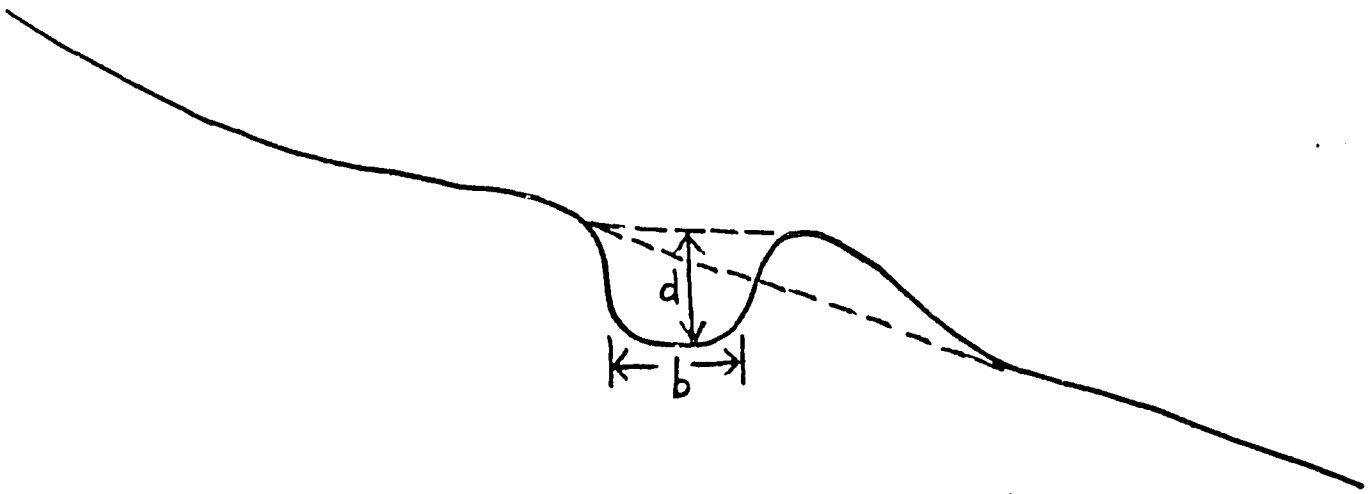
- Grade--The ditch grade may be either constant or variable but must not exceed 3 percent;

- Side slopes--Side slopes shall be stable for the soil in which the ditch is constructed;

- Horizontal spacing and cross-sectional area--The maximum horizontal spacing and minimum cross-sectional area per 100 feet of ditch shall be as shown on Hillside Ditch Table 1.

Spacing may also be determined using the USLE and specific design using conservation practice, area between ditches, storm runoff, and safe velocities (refer to diversions and estimating runoff).

- Construction--All dead furrows, ditches or gullies to be crossed by the hillside ditch should be filled before construction begins. The ditches shall be constructed to design grade and cross section. The outlet shall be prctected during construction. (See Hillside Ditch Figure 1).



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Hillside Ditch Figure 1: Cross Section of Typical Hillside Ditch

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Hillside Ditch Table 1: Spacing and Area of Hillside Ditches by Slope

Average Slope (Percent)	Maximum Spacing (Ft.)	Minimum Cross-Sectional Area Per 100-ft. Length (Ft2)
12 or less	40	0.35
12-25	35	.3
25-40	25	.2

LIVESTOCK EXCLUSION

Definition

Excluding livestock from an area not intended for grazing.

Purpose

To protect, maintain, or improve the quantity and quality of the plant and animal resources; maintain enough cover to protect the soil; maintain moisture resources; and increase natural beauty.

Planning Considerations

Arrangements must be made to exclude the many sheep and goats found on the island as well as cattle and donkeys. Experience elsewhere has shown that, for such arrangements to be successfully implemented, the support of local livestock owners is essential, and is best secured through their active participation in developing the livestock exclusion arrangements.

Specifications

All livestock should be excluded permanently from all woodland areas, steep land highly susceptible to erosion, and other critical areas which will release silt or sediment into ghauts and onto adjoining land if adequate litter and ground cover are not maintained.

All livestock should be excluded by adequate fencing or other appropriate measures from woodlands where reproduction is present or desired. Hogs, sheep, and goats should be excluded at all times from all areas managed for the production of forest products and water catchments. Cattle should be excluded from plantings until the seedlings will not be damaged by grazing.

MULCHING

Definition

Applying plant residues or other suitable materials not produced on the site to the soil surface.

Purpose

To conserve moisture; prevent surface compaction or crusting; reduce runoff and erosion; control weeds; and help establish plant cover.

Planning Considerations

There is some local knowledge of how valuable mulch is for controlling erosion and saving moisture through evaporation reduction and increased infiltration. For example, mulching of yams is a common practice on the island. This practice should be encouraged for all vegetable crops and fruit trees. The use of a particular mulch and mulching method is determined by availability, cost, intensity of needed treatment, and degree of slope.

Specifications

1. Agricultural land

Fruit trees and other cultivated crops should be mulched with dry grass, coconut fiber, or vegetation such as guinea grass or khus khus. One inch thickness or more of close fitting material should be used. This will require 1 1/2 to 2 tons of mulch per acre or 60 to 100 pounds per 1000 square feet.

Spread the mulch uniformly by hand or mechanically so that from 75 to 100 percent of the soil surface is covered. Mulching around fruit trees should leave at least 6 inches of exposed ground at the base of each tree. For uniform distribution of hand-spread mulch, divide area into approximately 1000 square-foot sections and place 100 pounds of mulch for distribution within each section.

2. Critical areas

Mulches for critical areas are described in more detail in the section on critical areas. Useful mulches include the following:

- Vegetative material--Mulch with dry grass, coconut fiber or vegetation such as guinea grass or khus khus. One inch or more will be used. On slopes the mulch should be staked and/or wired down;

- Man-made materials--If available, mulch as described in Annex O with other materials such as:

- Mesh netting--This is a mesh, web-like material woven of jute yarns or nylon. The mesh must be in firm and complete contact with the sod. Avoid stretching the material. Seed and mulch in a split application with half the seed sown before applying the mesh and the balance sown after;

- Wood-cellulose fiber mulch--This mulch is made of natural wood cellulose fiber. It can be mixed with fertilizer and grass seed in water. This forms a homogeneous slurry which can be sprayed onto the groud. Once on the ground, it forms a fibrous mat. A hydraulic seeder is required to apply this mulch; and

- Petroleum-derived mulch--This is a liquid, spray-on mulch derived from petroleum. It forms a uniform coating that clings ti, but does not deeply penetrate it generally remains intact for 4 weeks or longer. The for good adhesion of the mulch. Applicators are required to apply this mulch.

3. Urban areas

Special treatments may be called for in the case of in-town development. Vegetative material, anchored with special tools, or if available, asphalt or netting tie-down, is generally applicable where conventional equipment can be operated. Asphalt emulsion if available, is suited for a limited period of time where travel by people or vehicles is not a problem.

On slopes where conventional equipment cannot operate, the vegetative material is anchored with asphalt or netting tie down. Special equipment that blows or sprays the material on the surface is also applicable. This includes continuous filament fiberglass and wood-cellulose fiber mulches. Erosion control netting combined with a paper-type mulch is also commercially available.

4. Mulch--anchoring methods

Anchor the mulch immediately after placement to minimize loss by wind or water. This is accomplished by one or more of the following methods, depending upon the size of the area, steepness of slopes, and costs:

- Slit--With a square pointed spade, cut mulch into the soil surface in contour rows 18 inches apart.

- Disk or mulch anchoring tool--Disk the mulch into the soil with a weighted disk set nearly straight. A mulch-anchoring disk is also available. This is a special tool of a series of flat, notched disk that punch and anchor the mulch material into the soil. Tool penetration should be about 2 to 3 inches. Its use is limited ot those slopes upon which a tractor can operate safely;

- Mulch anchoring tool--A tractor-drawn implement, especially designed to punch and anchor mulch into the soil surface. Tool penetration should be about 2 to 3 inches. Its use is limited to those slopes upon which a tractor can operate safely;

- Pick chain--This rolling spiked-chain implement can be operated on slopes of 3:1 gradient or steeper. It is attached to a vehicle which operates along the top of the slope;

- Petroleum-derived mulches--This is usually emulsified asphalt which is blown from the applicator or as a separate operation.

PASTURE MANAGEMENT

Definition

Proper treatment and use of pastureland for grazing, haying, or cutting.

Purpose

To prolong life of desirable forage species; to maintain or improve the quality and quantity of forage; and to protect the soil and reduce water loss.

Planning Considerations

Profitability of "improved pastures" depends primarily on two things:

- The relationship of costs for fertilizer, fencing and water supply to the animal product price; and
- Proper grazing use of the forages.

Proper forage utilization permits the plants to make good growth and helps livestock perform well. The forage plant is a factory and the leaves are the producing part. Roots provide minerals, the sun furnishes energy, and the air contains carbon dioxide from which the plant can obtain food. The leaves put these together through photosynthesis. For the plant to produce forage efficiently, it must have an adequate leaf surface during the growing period. Excessive removal of the leaves by over grazing or cutting reduces the productive potential. Examples of heavily overgrazed areas indicate a lack of understanding of these principles. They need to be reviewed and stressed with livestock producers.

Specifications

Fertilizer should be applied according to soil analysis and the level of forage production desired. Rotation grazing is desirable. Provide two or more pastures to permit rotation grazing. Divide the fields into approximately equal forage producing areas or units. The length of cycle is determined by the season and the rate of growth of pasture plants. An example of average grazing and resting periods is given in Pasture Management Table 1.

Pastures should not be overstocked. Do not graze the pastures below the appropriate proper use heights during the period of grazing. When forage is grazed down to the minimum height indicated in Pasture

Management Table 2, the livestock should be moved to another grazing unit.

Periods of grazing and rest may vary from those in Pasture Management Table 1 if there are definite grazing and rest periods and the objectives of the practice are met.

Control brush by hand or with herbicides. Follow the manufacturer's label and legal regulations in applying herbicides.

Exercise caution when using herbicides as described at beginning of Section 4.

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Pasture Management Table 1: Rotation Grazing Systems

No. of Units in System	Grazed (No. of Days)	Rest (No. of Days)	Total Grazing Period (No. of Days)
2	30	30	60
3	15	30	45
4	12	36	48

Note: These grazing and resting periods are averages applicable for all grasses.

Pasture Management Table 2: Proper Use Heights for Selected Grasses

Species	Minimum heights to start grazing (inches)	Minimum heights during grazing season and height of cut for green chop or silage. (inches)
Guinea grass	24	8
Pangola grass	12	4
St. Augustine grass	6	3
Elephant grass	36	8
Star grass	12	4
Coastal bermuda grass	12	4

PASTURE PLANTING

Definition

Establishing adapted forage plants for long-term use.

Purpose

To provide proper quality forage for grazing, cutting, or haying; and to cover the soil for protection against erosion.

Planning Considerations

Pasture planting should be applied carefully and management checked closely. Base the choice of the grass on the type and quality of forage needed by animals that are to utilize it. Also consider fertility management and available rainfall. For example, do not plant a grass that requires annual application of fertilizer if the pasture will not get this treatment. On steep land needing clearing, it may not be desirable to clear large areas at the same time. Doing so may increase the erosion hazard. However, an entire field (paddock) should be planted at the same time to normalize palatability over the entire paddock. In addition, specific attention should be given to providing adequate water and shade for animals.

Specific attention should be given to providing adequate water and shade for animals.

Specifications

1. Land preparation

Land that has been cleared of trees, brush, or stumps should be loosened and smoothed to prepare a good seedbed. The field can be ripped and planted in the furrows. A pre-emergence herbicide application, as appropriate, may be made if vegetative materials are to be planted.

When complete land preparation is not possible because of steepness, stones, or other factors, graze the area heavily and cut back tall-growing weeds. Controlled burning may be used if adequate firebreaks as prescribed by law are provided and manned during the burn. Herbicides may be applied.

2. Planting

Depending upon normally expected periods of rainfall on Nevis, plant between September to mid-November or plant after any period where there has been an accumulated rainfall of one (1) inch

over three (3) days. Plant vegetative material on the contour in furrows or holes 2 to 3 feet apart. (See Pasture Planting Table 1.) To avoid stimulating weeds, apply the fertilizer near the seedling but not in the row middles. After planting pack the soil over or around the planted material by walking on it, pressing the holes with the heel of the foot, or rolling the row with a heavy wheel or cultipacker. On clay or clay loam soils, pack after the surface is dry enough not to crust nor stick to packer or feet. The specified planting depths are those obtained after packing the soil. If mechanical equipment is to be used for maintenance (mowing, etc.), plant and cover in such a way that the land is smooth after planting.

3. Fertilizer

Base treatment on soil fertility analysis or apply 30 pounds of nitrogen (N) and 30 pounds of potash (K) per acre at planting. Ninety days after planting apply 30 pounds of nitrogen per acre.

4. Weed control after planting

Tall-growing weeds in the lower-growing grasses like pangola grass can be controlled by repeated close mowing. Low-growing weeds will be shaded out by tall-growing grasses, such as elephant grass and guinea grass by delaying grazing. Weeds in newly planted pastures can also be controlled with herbicides.

5. Beginning use

Except for weed control, do not graze pangola grass, star grass, or coastal bermuda grass until it reaches a height of 12 inches. Do not graze elephant grass and guinea grass until they reach a height of 36 and 24 inches, respectively.

6. Herbicide use

Exercise caution when using herbicides as described at beginning of Section 4.

Pasture Planting Table 1: Planting Specifications for Selected Pasture Grasses

Plant	Planting Rate (per acre)	Other Factors
Guinea grass	20-30 lbs. of good quality seed[1] or clumps 18" apart in rows 2-3' apart. (Seed and clumps can also be mixed in the same planting.)	Cover seed no deeper than 1/4 inch.
Elephant grass	1 1/2 tons of mature stemcuttings.	Plant whole stems lengthwise in rows 2 to 3 feet apart. Cover with 3 inches of soil.
Pangola grass Star grass Coastal bermuda grass	1 ton of mature stem-cuttings or one-half ton coastal bermuda grass rhizomes	Plant in furrows or holes. Cover furrows with soil so that the stems or rhizomes are placed at depths that vary from one (1) inch to three (3) inches with the deepest depth alternating with the shallowest depth every 18 inches. Leave portions of coastal bermuda grass stem-cuttings uncovered. With hole plantings use 3 or 4 stem cuttings 3 nodes in length in each hole and half cover with soil.

[1]Viability of seed should always be checked and planting rates adjusted accordingly

PIPELINE

Definition

Pipeline installed for conveying water for livestock, irrigation, recreation, or domestic use.

Purpose

To convey water from a source of supply to points of use.

Planning Considerations

St. Kitts has a shortage of available water and the further problem of getting water to homes, livestock and irrigated fields where needed. Pipelines are an economical and efficient way to move water from a source to the using point. This section provides details on quality of pipe, material, friction loss and protection needed.

Pipeline Tables 1 and 2 may be used in selecting pipe. Other tables may be used if better data on conditions are available. The following problem demonstrates how the tables are used.

Problem: Determine pipe size requirements.

Given: Pond at elevation 460 feet
Stock tank at elevation 406 feet
Length of pipeline 803 feet
Desired flow rate 30 gallons/min.
Select Pipe

Head available per 100 feet is:

$$\frac{460-406}{8.03} = 54/8.03 = 6.72 \text{ feet per 100 feet}$$

For plastic pipe, from Table 1, read opposite 30 gallons/min.:

--3.78 feet for 1-1/2 inch pipe
(acceptable because it is less than the available head).

--7.32 feet for 1-1/4 inch pipe
(not acceptable, because it is more than the available head)

For steel pipe, from Table 2, read opposite 30 gallons/min.:

--3.84 feet for 2 inch pipe (acceptable)

--11.00 feet for 1-1/2 inch pipe (not acceptable)

Either the 1-1/2 inch plastic pipe or the 2 inch steel pipe is acceptable from a capacity standpoint.

PIPELINE 2

Specifications

1. Capacity

For supplying livestock water, the installation shall have a capacity to provide at least 12 gallons (US) per head per day for beef cattle and horses, 25 gallons (US) for dairy cattle, and 1 gallon (US) for sheep and goats. The capacity shall be adequate for all planned uses of water. The pipe shall meet service requirements without exceeding the rated pressure of the pipe. An operating pressure of 72 percent of the rated pressure is desirable.

2. Pipe

Steel pipe shall meet the requirements specified in ASTM-A-120 or in AWWA Specification C-200 or equivalent.

Plastic pressure pipe shall be suitable for underground use. The pipe shall conform to the requirements of the following ASTM specifications or equivalents:

- D 1785 Polyvinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120;
- D 2104 Polyethylene (PE) Plastic Pipe, Schedule 40;
- D 2241 Polyvinyl Chloride (PVC) Plastic Pipe (SDR-PR);
- D 1527 Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe, Schedules 40 and 80;
- D 2282 Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe (SDR-PR);
- D 2239 Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Inside Diameter;
- D 3035 Polyethylene (PE) Plastic Pipe (SDR-PR), Based on Controlled Outside Diameter;
- D 2447 Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter;
- D 2737 Polyethylene (PE) Plastic Tubing;
- D 2672 Bell-End Polyvinyl Chloride (PVC) Pipe; and
- D 2740 Polyvinyl Chloride (PVC) Plastic Tubing.

Fittings and solvents shall be appropriate for the pipe used.

3. Vents

For design velocities lower than 8 ft/s, some provision shall be included in the design for removing air. If parts of the line are above the hydraulic gradient, periodic use of an air pump may be required.

4. Joints

Watertight joints that have a strength equal to that of the pipe shall be used. Couplings must be of material compatible with that of the pipe. If they are made of material susceptible to corrosion, provisions must be made to protect them.

Rubber gaskets for pipe joints shall conform to the requirements of ASTM Specification F 477, Elastomeric Seals (Gaskets) for joining plastic pipe.

5. Placement

Pipelines shall be placed so that they are protected against hazards imposed by traffic or farm operations. Plastic pipeline shall also be protected against hazards of sunlight or fire. A cover of 6 inches will protect plastic pipe from sunlight. A cover of at least 18 inches will provide protection for pipe from farm operations and traffic. Plastic pipe should be buried 18 inches if fire is likely. Other means of protection must be provided if the depth required for protection is impracticable because of shallow soils over rock of other reasons. Abrupt changes to grade must be avoided to prevent rupture of the pipe.

Trenches for plastic pipelines shall be free of rocks and other sharp-edged materials, and the pipe shall be carefully placed to prevent damage. Plastic pipelines may be placed by plow-in equipment if soils are suitable and rocks and boulders will not damage the pipe.

6. Testing

Pipelines shall be pressure tested by one of the following methods:

- Before backfilling, fill the pipe with water and test at the design working head or at a head of 10 feet, whichever is greater. All leaks must be repaired, and the test must be repeated before backfilling; and

- After backfilling, pressure test at the working pressure for 2 hours. The allowable leakage shall not be greater than 1 gallon (US) per diameter inch per mile. If leakage exceeds this rate, the defect must be repaired until retests show that the leakage is within the allowable limits, but all visible leaks must be repaired.

7. Backfilling

All backfilling shall be completed before the line is placed in service. For plastic pipe, the initial backfill shall be of selected material that is free of rocks or other sharp-edged material that can damage the pipe. Deformation or displacement of the pipe must not occur during backfilling.

Plastic pipelines installed by the plow-in method requires surface compaction and shaping in addition to the normal plow-in operations.

Installation and backfilling shall be done in a workman-like manner. Provisions shall be made for stabilizing disturbed areas and controlling erosion, as necessary.

8. Vegetation

Disturbed areas shall be established to vegetation or otherwise stabilized as soon as practicable after construction.

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Pipeline Table 1: Friction Head Loss in Small Diameter Plastic Pipe
(feet per 100 feet)

Q (gallons per min.)	Diameter of Pipe: 1 in. 1.189 ID	1-1/4 in. 1.502 ID	1-1/2 in 1.720 ID	2 in. 2.149 ID	2-1/2 in. 2.601 ID	3 in. 3.166 ID	3-1/2 in. 3.620 ID
2	.15	.04	.02				
4	.54	.17	.09	.03	.01		
6	1.15	.37	.19	.06	.02		
8	1.97	.63	.32	.11	.04	.01	
10	2.98	.95	.49	.16	.06	.02	.01
15	6.32	2.03	1.04	.35	.14	.05	.02
20	10.79	3.46	1.78	.60	.23	.09	.04
25	16.30	5.22	2.70	.91	.36	.13	.07
30	22.86	7.32	3.78	1.27	.50	.19	.10
35		9.75	5.03	1.70	.67	.25	.13
40		12.46	6.46	2.18	.86	.32	.17
45		15.51	8.02	2.71	1.07	.40	.21
50		18.87	9.75	3.30	1.30	.49	.25
55		22.48	11.64	3.94	1.54	.59	.30
60			13.64	4.62	1.81	.69	.36
65			15.85	5.36	2.10	.80	.41
70			18.19	6.14	2.42	.92	.47
75			20.65	6.99	2.75	1.06	.55
80			23.28	7.86	3.10	1.19	.62
85				8.81	3.47	1.33	.69
90				9.79	3.85	1.48	.77
95				10.82	4.25	1.64	.85
100				11.89	4.69	1.80	.93
110				14.21	5.59	2.14	1.11
120				16.69	6.56	2.52	1.31
130				19.35	7.63	2.92	1.53
140				22.21	8.73	3.36	1.75
150					9.94	3.82	1.99
160					11.20	4.29	2.24
170					12.51	4.80	2.50
180					13.90	5.35	2.79
190					15.39	6.50	3.38
200					16.91	6.50	3.38
220					20.19	7.77	4.04
240					23.73	9.12	4.76
260						10.57	5.51
280						12.11	6.32
300						13.78	7.18
320						15.52	8.10
340						17.37	9.07
360						19.27	10.08
380						21.33	11.13
400						23.45	12.22

Table based on Hazen-Williams equation: $C_1 = 150$

To find friction head loss is PVC or ABS pipe having a standard dimension ratio (SDR) other than 21, the values in the table should be multiplied by the appropriate conversion factor shown below:

(SDR No.)	Conversion Factor
13.5	1.35
17	1.13
21	1.00
26	.91
32.5	.84
41	.785
51	.75

Pipeline Table 2: Friction Head Loss in Small Diameter Standard Steel Pipe
(feet per 100 feet, 15 year old pipe)

Q (Gallons per min)	Nominal Diameter of Pipe (in Inches)									
	1/4	3/8	1/2	3/4	1	1-1/4	1-1/2	2	2-1/2	3
1	27.14	6.06	2.10	.49						
2	99.03	22.22	7.40	1.90						
3			15.80	4.10	1.26					
4			27.00	7.00	2.14	0.57	0.26			
5			41.00	10.50	3.25	0.84	0.39	0.12		
6			54.86	14.15	4.39	1.15	0.52	0.17		
7				18.19	5.63	1.61	0.75	0.23		
8				24.05	7.50	1.93	0.89	0.32		
9				28.58	9.04	2.45	1.18	0.38		
10					11.70	3.05	1.43	0.50	0.17	0.07
12					15.76	4.13	1.93	0.66	0.27	0.10
15					24.05	6.50	3.00	1.00	0.36	0.15
20						11.10	5.20	1.82	0.61	0.25
25						16.60	7.80	2.73	0.92	0.38
30						23.50	11.00	3.84	1.29	0.54

POND

Definition

A water impoundment made by constructing a dam or an embankment or by excavating a pit or dugout.

In the following guidance and specifications, ponds constructed by the first method are referred to as embankment ponds, and those constructed by the second method are referred to as excavated ponds. Ponds constructed by both the excavation and the embankment methods are classified as embankment ponds if the depth of water impounded against the embankment at spillway elevation is 3 ft. or more. A pond may be wet or dry, depending on purpose.

Purpose

To provide water for livestock, irrigation, and other related uses; to reduce erosion; and to provide detention storage for flood control.

Planning Considerations

Ponds may be embankment or excavated, hold water for beneficial use or be designed to be dry for detention storage and erosion control. There is a real scarcity of water on St. Kitts for households, livestock and irrigation. The permeable soils limit the opportunities for ponds, but there are some locations where they can be built successfully. Ponds are an economical source of water and can help meet St. Kitts need for water. Detention storage can sometimes be used to retain runoff and prevent erosion.

The purpose of the pond must be identified from the beginning.

1. Storage

The total number of animals to be served by the pond should be used to calculate the water storage needs.

The average daily consumption of livestock water is:

Kind of Livestock	Gallons (US) Per Head Per Day
Beef Cattle and Horses	12
Dairy Cattle	25
Hogs	4
Sheep and Goats	1

If household water is to be used from the pond, that quantity should be estimated also. If water for irrigation is to be stored in the pond, the quantity should be added to storage needs.

Dry ponds used to control runoff and erosion should store the runoff from the design storm until it can infiltrate the pond bottom or be emptied by a pipe. Dry ponds should store at least the 10 year frequency runoff, and if the spillway is questionable, the 25 or 50 year frequency.

Ponds planned as detention reservoirs or erosion control dams shall provide storage of the design storm and emptying of the reservoir by a pipe or infiltration. All other requirements are the same, such as embankment and spillway requirements. For complex sites, special design including flood routing and the use of pipe spillways may be used in accordance with the USDA SCS Engineering Field Manual.

2. Investigation

The selection of the pond site is important, and preliminary studies are needed before final design and construction. If possible, consider more than one location. A good site is where a dam can be built across a narrow valley and store a large quantity of water.

Site conditions shall be such that runoff from the design storm can be safely passed through a natural or constructed emergency spillway. It must be assumed the pond is full when the design storm occurs; therefore, no allowance for storage can be made.

The topography and soils of the site shall permit storage of water at a depth and volume that ensure a dependable supply, considering beneficial use, sedimentation, season of use, and evaporation and seepage losses. On a pond where permanent water storage is desired and where surface runoff is the primary source of water for a pond, the soils shall be impervious enough to prevent excessive seepage losses or shall be of a type that sealing is practicable.

The pond should have a minimum depth of 5 feet (deeper is better) over at least 1/4 of the water area. Pond capacity can be estimated by multiplying the surface area in acres by 0.4 times the maximum water depth in feet. For example, 0.5 acres surface area times 0.4 times 8 feet maximum depth is 1.6 acre-feet, the approximate pond capacity. (Each acre foot is 325,851 gallons (US).)

The size of the watershed (catchment or drainage area) that will contribute runoff to the pond should be determined. The drainage area above the pond must be protected against erosion to the extent that expected sedimentation will not shorten the planned effective life of the structure. The drainage area shall be large enough so that surface runoff and groundwater flow will maintain an adequate supply of water

in the pond. The quality shall be suitable for the water's intended use. Watershed yield maps should be used, if available, but 5 to 10 acres drainage area should normally provide about one acre foot of pond water per year.

The soil under the dam, in the reservoir area, and that to be used for borrow, must be investigated with a soil auger, backhoe, or bulldozer.

The foundation for the dam must provide support. If the foundation contains enough silts and clays to be impervious, a minimum depth core trench will be required. If the foundation is pervious, such as sands and gravels, a core trench of impervious material should be installed under the dam to prevent leakage.

The best material for a dam contains particles ranging from small gravel to clay. The material should contain about 20 percent by weight of clay particles. To estimate the proportion of sand, silt and clay, fill a jar about one-third full with the sample of material. (Remove all stones larger than 1/4 inch). Fill with water and shake vigorously. Allow the soil to settle for 24 hours. The sand will settle on the bottom, the silt in the middle, and the clay on top.

A survey should be made to determine the topographic conditions at the site, so that volumes of fill materials required to construct the dam can be determined and quantities of suitable borrow materials can be obtained. Enough borrow material must be found to fill any required core trench and build the dam. A rule of thumb is to locate enough borrow for 1.5 times the yardage of the dam. This usually will take care of shrinkage and irregularities in the borrow pit.

The spillway excavation should be used to build the dam if the material is suitable. In all cases, determine the type of material to be excavated and whether it will be used or wasted.

Specifications: Design

1. Embankment pond

After the investigation is complete and the final site is selected, the dam and spillway must be designed.

a. Foundation cutoff

A cutoff of relatively impervious material shall be provided under the dam if necessary. The cutoff shall be located at or upstream from the centerline of the dam. It shall extend up the abutments as required and be deep enough to extend into a relatively impervious layer or provide for a stable dam when combined with seepage control. The cutoff trench shall have a bottom width adequate to

accommodate the equipment used for excavation, backfill, and compaction operations. Side slopes shall not be steeper than one horizontal to one vertical.

b. Earth embankment

The minimum top width for a dam is 8 feet for fills up to 10 feet high and 10 feet for fills over 10 feet high. Dams over 25 feet high require design by an engineer. The upstream slope shall be 3:1 and the downstream slope shall be 2:1.

The design height of the dam shall be increased by the amount needed to ensure that after settlement the height of the dam equals or exceeds the design height. This increase shall not be less than 5 percent.

The minimum elevation of the top of the settled embankment shall be 1 ft. above the water surface in the reservoir with the emergency spillway flowing at design depth. Table 4 (See below) has this allowance included.

From the survey notes (cf. Figures 1A, 1B, 2A, and 2B, in the layout section, below), determine the volume of earth fill required to construct the dam and the volume of suitable borrow materials available (from the reservoir basin, emergency spillway excavation and other borrow areas) for construction. Yardage tables are included as Tables 1 and 2. Table 3 shows an example of how these tables are used to calculate the total volume of fill required.

c. Emergency spillways

Emergency spillways convey large flood flows safely past earth embankments. An emergency spillway must be provided for each dam. It must be assumed the pond is full when the design storm occurs; therefore, no allowance for storage can be made.

The minimum capacity of a natural or constructed emergency spillway shall be that required to pass the peak flow expected from a 10-year frequency, 24-hour storm for ponds with up to 20 acres drainage area, 25-year frequency for up to 50 acres drainage area and 50-year frequency for all others. This frequency requirement is included in Table 3, Emergency Spillway Design. The spillway may be designed according to Table 3, or by special design using the USDA SCS Engineering Field Manual. The following example shows how Table 3 is to be read:

> Given a pond with 25 acres drainage area, read spillway sizes for 25 acres of 81 feet wide by 2 feet deep, or 36 feet wide by 2.5 feet deep, or 27 feet wide by 2.8 feet deep. Use the most appropriate size.

The SCS Engineering Field Manual will need to be used for ponds with over 50 acres drainage area.

The emergency spillway shall safely pass the peak flow and shall provide for passing the design flow at a safe velocity to a point downstream where the dam will not be endangered.

Constructed emergency spillways are open channels that usually consist of an inlet channel, a control section, and an exit channel. They shall be trapezoidal and shall be located in undisturbed or compacted earth. The side slopes shall be stable for the material in which the spillway is to be constructed. Emergency spillways should be covered with good sod and protected from livestock and vehicle travel.

Upstream from the control section, the inlet channel shall be level for 25 feet to protect and maintain the crest elevation of the spillway. The inlet channel may be curved to fit existing topography.

Water supply pipes should be installed under or through the dam to facilitate use. The pipe should have a minimum of 1-1/2 inch diameter steel, or 1-1/4 inch diameter high pressure plastic water pipe with a strainer at the upper end and a cutoff valve below the dam. The pipe should be watertight and have anti-seep collars (usually 2) under the dam.

The completed embankment and spillway should be vegetated. The pond should be maintained by keeping the dam and spillway to proper grade and preventing livestock damage to the pond. If water is to be for household use, the entire pond should have livestock excluded with a good fence.

2. Excavated ponds

a. Overview

Excavated ponds are pits dug in the earth. Because their capacity is obtained by excavation, their size is limited, and their cost is high for the volume of water stored.

If the dam is used to add to the storage capacity, the dam and spillway should meet the minimum requirements for embankment dams. The approximate quantity of excavation may be calculated by averaging the top and bottom areas and multiplying by the depth.

b. Example

Excavated pond with bottom 20 ft by 40 ft
Top area 80 ft by 90 ft
Average depth 6.3 ft

Then Bottom area is 20 x 40 = 800 ft^2
Top area is 80 x 90 = 7200 ft^2

Volume is $\frac{800 + 7200}{2} \times 6.3 \text{ ft} = 25{,}200 \text{ ft}^3$

Volume is $\frac{25{,}200 \text{ ft}^3}{27 \text{ ft}^3/\text{yd}^3} = 933$ cubic yards

Water storage is 25,200 ft^3 x 7.48 gal/ft^3 = 188,500 gallons

c. Runoff

Provisions shall be made for an emergency spillway if necessary. Runoff flow patterns shall be considered when locating the pit and placing the spoil.

d. Side slopes

Side slopes of excavated ponds shall be stable and shall not be steeper than one horizontal to one vertical. If livestock will water directly from the pond, a watering ramp of ample width shall be provided. The ramp shall extend to the anticipated low water elevation at a slope no steeper than three horizontal to one vertical.

e. Inlet protection

If surface water enters the pond in a natural or excavated channel, the side slope of the pond shall be protected against erosion.

f. Excavated material

The material excavated from the pond shall be placed so that its weight will not endanger the stability of the pond side slopes and so that it will not be washed back into the pond by rainfall. It shall be disposed of in one of the following ways:

- Uniformly spread to a height that does not exceed 3 ft. with the top graded to a continuous slope away from the pond;
- Uniformly placed or shaped reasonably well with side slopes assuming a natural angle of repose. The excavated material will be placed at a distance equal to the depth of the pond but not less than 12 ft. from the edge of the pond;
- Used for low embankment and leveling; or
- Hauled away.

Specifications: Layout

After the design is complete, the dam must be staked. Normal procedure is to profile the centerline and determine the maximum fill height that will be required for the dam. Where maximum fill height is less than ten (10) feet, the dam shall have a minimum top width of eight (8) feet. For dams having a maximum fill height of ten (10) to 25 feet the minimum top width shall be ten (10) feet. Then, set back toe stakes for construction. Front toe stakes may be set if desired. The appropriate emergency spillway dimension should be determined from Table 4, or by other design. Then set stakes for excavation of the emergency spillway. The survey notes given in Figures 1a, 1b, 2a, and 2b illustrate the survey for a small dam including a set of bench mark level notes and a simple plan. The yardage and sample calculation (See Tables 1 through 4) presented earlier are also useful.

Specifications: Construction

1. Foundation preparation

The foundation area for the dam and reservoir basin shall be cleared of trees, logs, stumps, roots, brush boulders, sod, and rubbish. If needed to establish vegetation, the topsoil and sod shall be stockpiled and spread on the completed dam and spillways. Foundation surfaces shall be sloped no steeper than a ratio of one horizontal to one vertical. The foundation area shall be thoroughly scarified, using a ripper, before placement of the fill material. The surface shall have moisture added, if necessary, and be compacted so that the first layer of fill material can be compacted and bonded to the foundation.

The cutoff trench, emergency spillway, and any other required excavations shall be dug to the lines and grades shown on the plans or as staked in the field. If they are suitable, excavated materials should be used in the permanent fill. Existing stream channels in the foundation area shall be sloped no steeper than a ratio of one horizontal to one vertical. They shall be deepened and widened as necessary to remove all stones, gravel, sand, stumps, roots, and other objectionable material and to accommodate compaction equipment.

Foundation areas shall be kept free of standing water when fill is placed on them.

2. Fill placement

The material placed in the fill shall be free of detrimental amounts of sod, roots, stones more than 6 in. in diameter (except for rockfills), and other objectionable material. Rock fill is sometimes used downstream from the core if good fill material is not available.

Move rocks larger than 12 inches in diameter to the downstream toe of the dam.

Fill material shall be placed in approximately 12-inch layers and spread beginning at the lowest point of the foundation and then bringing it up in horizontal layers thick enough that the required compaction can be obtained. The fill shall be constructed in continuous horizontal layers. If openings or sectionalized fills are required, the slope of the bonding surfaces between the embankment in place and the embankment to be placed shall not be steeper than a ratio of three horizontal to one vertical. The bonding surface shall be treated the same as that specified for the foundation to ensure a good bond with the new fill. The topsoil can be placed on the crown and the backslope of the dam. The crown should be tilted toward the waterside to help prevent erosion of the blackslope. The complete work shall conform to the lines, grades, and elevations shown on the drawings or as staked in the field.

3. Moisture control

The moisture content of the fill material shall be adequate for obtaining the required compaction. Material that is too wet shall be dried to meet this requirement, and material that is too dry shall be wetted and mixed until the requirement is met.

4. Compaction

Construction equipment shall be operated over each layer to fill to ensure that the required compaction is obtained. Special equipment shall be used if needed to obtain the required compaction.

Fill adjacent to pipe conduits and anti-seep collars shall be compacted to a density equivalent to that of the surrounding fill by hand tamping or by using manually directed power tampers or plate vibrators.

5. Protection

A protective cover of vegetation shall be established on all exposed surfaces of the embankment, spillway, and borrow area if soil and climatic conditions permit. The embankment and spillway shall be fenced if necessary to protect the vegetation.

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Pond Table 1: End Areas for a Dam with 8-Ft Top and 3:1 and 2:1 Slopes

Fill Height (ft)	End Area (ft^2)	Fill Height (ft)	End Area (ft^2)
1.0	11	5.6	123
1.2	14	5.8	130
1.4	16	6.0	138
1.6	19	6.2	146
1.8	22	6.4	153
2.0	26	6.6	162
2.2	30	6.8	170
2.4	33	7.0	179
2.6	38	7.2	188
2.8	42	7.4	197
3.0	46	7.6	206
3.2	52	7.8	215
3.4	56	8.0	224
3.6	61	8.2	235
3.8	66	8.4	244
4.0	72	8.6	255
4.2	78	8.8	264
4.4	83	9.0	275
4.6	90	9.2	286
4.8	95	9.4	297
5.0	102	9.6	308
5.2	109	9.8	319
5.4	116	10.0	330

Pond Table 2: End Areas for Dam with 10-Ft Top and 3:1 and 2:1 Slopes

Fill Height (ft)	End Area (ft^2)	Fill Height (ft)	End Area (ft^2)	Fill Height (ft)	End Area (ft^2)
1.0	13	6.0	150	11.0	412
.2	16	.2	158	.2	425
.4	19	.4	166	.4	439
.6	22	.6	175	.6	452
.8	26	.8	184	.8	466
2.0	30	7.0	193	12.0	480
.2	34	.2	202	.2	494
.4	38	.4	212	.4	509
.6	43	.6	221	.6	523
.8	48	.8	231	.8	538
3.0	52	8.0	240	13.0	552
.2	58	.2	251	.2	568
.4	63	.4	261	.4	583
.6	68	.6	272	.6	599
.8	74	.8	282	.8	614
4.0	80	9.0	293	14.0	630
.2	86	.2	304	.2	647
.4	92	.4	316	.4	583
.6	99	.6	327	.6	680
.8	105	.8	339	.8	696
5.0	112	10.0	350	15.0	713
.2	119	.2	362	.2	730
.4	127	.4	375	.4	748
.6	134	.6	387	.6	765
.8	142	.8	400	.8	783

Pond Table 2: End Areas for Dam with 10-Ft Top and 3:1 and 2:1 Slopes (continued)

Fill Height (ft)	End Area (ft^2)	Fill Height (ft)	End Area (ft^2)	Fill Height (ft)	End Area (ft^2)
16.0	800	19.0	1093	22.0	1430
.2	818	.2	1114	.2	1454
.4	837	.4	1135	.4	1478
.6	855	.6	1156	.6	1503
.8	874	.8	1178	.8	1528
17.0	893	20.0	1200	23.0	1553
.2	912	.2	1222	.2	1578
.4	9[illegible]	.4	1244	.4	1603
.6	950	.6	1267	.6	1628
.8	970	.8	1290	.8	1654
18.0	990	21.0	1313	24.0	1680
.2	1010	.2	1336	.2	1706
.4	1030	.4	1359	.4	1732
.6	1051	.6	1382	.6	1759
.8	1072	.8	1406	.8	1785
				25.0	1813

Example: Volume of Earth Calculation

Station (ft)	Average Fill Height (ft)	End Area (ft^2)	Sum of End Areas (ft^2)	Dist. (ft)	Double Volume (ft^3)
1+00	0	0	0		
1+60	5.0	102	102	60	6120
2+10	7.9	219	321	50	16050
2+50	0	0	219	40	8760
Total					30,930

Divide by 54 to obtain volume in cubic yards $\frac{30.930}{54} = 573$

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Pond Table 3: St. Kitts: Emergency Spillway Design

Drainage Area (acres)	Bottom Width for Indicated Depth (ft)		
	2.0	2.5	2.8
	ft		
5	20	12*	12
10	33	15	12
15	46	20	15
20	56	25	19
25	81	36	27
30	93	41	31
35		46	35
40		50	38
45		55	41
50		60	45

* Minimum width

Spillway sizes calculated for 10 year (0-20 acres) frequency rain of 7 inches; 25 year (21-50 acres), 8 inches; 75 curve, D retardance, flow depth, plus one foot, 25 foot crest length.

E. C. Hibbs — T Gibbs 55

Pond Stakeout — Ø Hays

2/26/86

Elev. Top Dam 101.9 — Top Width - 8 ft

Spillway 12 x 2 Elev. 99.9

Add 10% for settlement

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.				
BM 1	4.03	104.03 104.0		100.00	Top Post 50 ft No Sta 1+00	Left - Down - 2:1		Rt - Up - 3:1
1+00			2.1	101.9	End Dam	F-0.0 2.1/4.0	F-0.0 2.1/0	F-0.0 2.1/4.0
1+60			2.1	101.9		F-4.9 7.0/13.8	F-4.9 7.0/0	F-5.1 7.2/19.3
2+10			2.1	101.9		F-8.0 10.1/20.0	F-7.9 10.0/0	F-7.9 10.0/27.7
2+50			2.1	101.9		F-0.0 2.1/4.0	F-0.0 2.1/0	F-0.0 2.1/4.0
2+56			4.1	99.9	SW Bottom		C-2.3 1.8/0	
2+68			4.1	99.9			C-2.9 1.2/0	
2+77			4.1		Edge of SW Cut		C-3.0 1.1/0	Cut Slope Stake
BM 1			4.03	100.00	Check			

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Pond Figure 1A: Pond Survey Notes

E.C. Hibbs
Pond Check

T Hays
Ø Gibbs

3/4/86

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	10% Settlement	
BM 1	3.81	103.81 103.8		100.00		Top Corner Post 50 ft North Sta 1+00
						2:1 3:1
1+00			1.9	101.9		1.8
1+60			1.4	101.4	0.5	1.4
2+10			1.1	102.7	0.8	9.9/20.0 5.4/12.0 0.8/4.0 1.1 1.3/4.0 5.5/16.0 9.8/27.7
2+50			1.9	101.9		1.7
2+56			3.9	99.9	SW	3.9
2+68			3.9	99.9	SW	3.9
2+77						1.2
			10.9	91.9		Bottom of pond - 2 ft deep over 400 ft².
						Pond meets specs. D Hibbs 3/4/86

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Pond Figure 1B: Pond Survey Notes

BM Level Circuit. Higgins Pond

T McVicker
Ø Beason
7/1/86

Sta.	B.S.	H.I.	F.S. or Grade Rod	Elev. or Planned Elev.	
BM 462	11.41	65.22		53.81	Court BM Corner Long and Acre St, Any City
TP 1	9.64	73.45	1.41	63.81	
TP 2	12.06	82.65	2.86	70.59	
BM 1	1.64	81.25	3.04	79.61	Iron Bar set in concrete Sta 0+12 Dam ℄
TP 3	2.39	71.26	12.38	68.87	
TP 4	5.86	67.10	10.02	61.24	
TP 5	2.14	60.06	9.18	57.92	
BM 462			6.26	53.80	0.01 Error OK
Σ BS	45.14	Σ FS	45.15		
			45.14		
			0.01	Error	

Checked Joe Blaine
7/2/86

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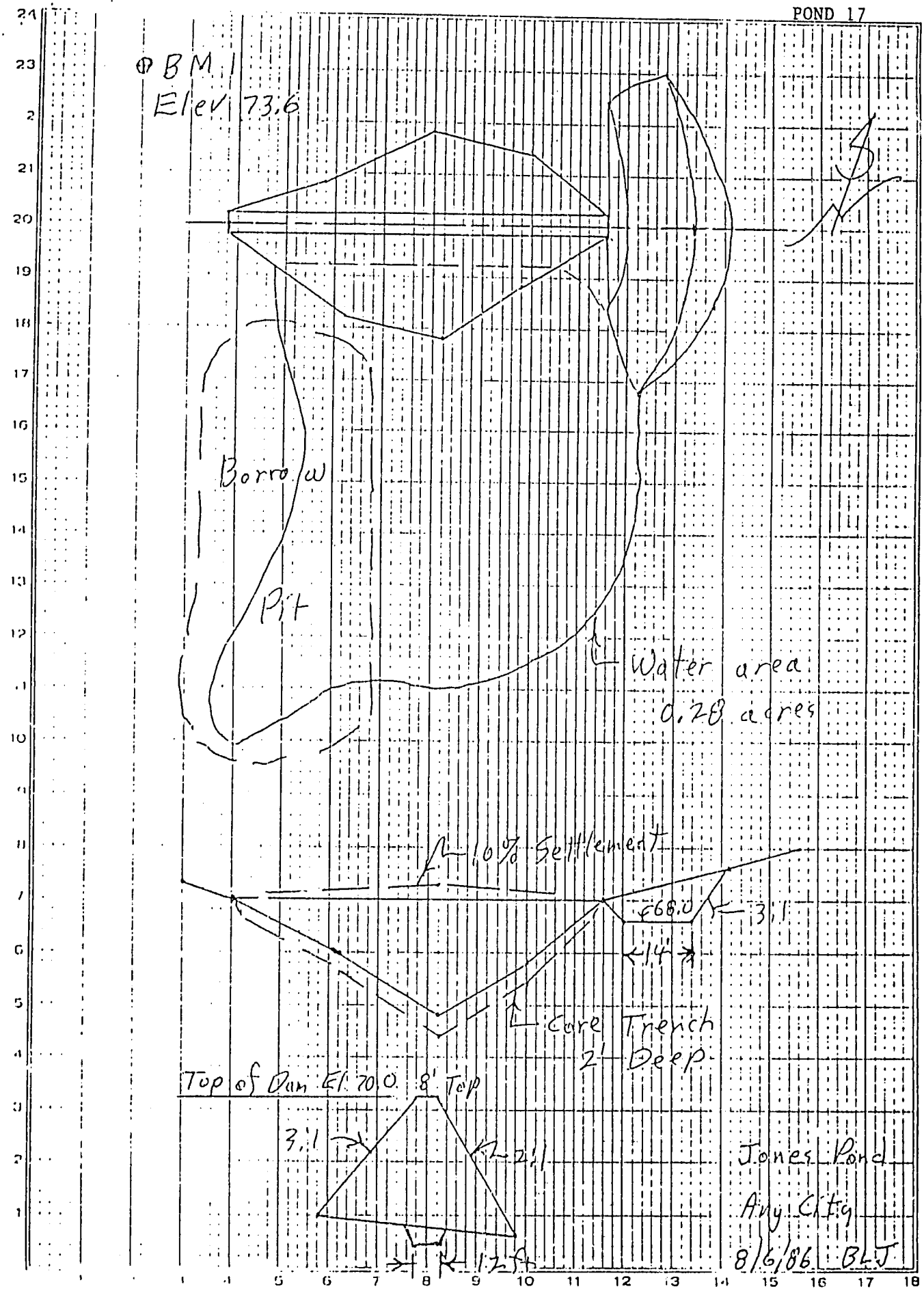
Pond Figure 2A: Pond Survey Notes



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Pond Figure 2B: Pond Plan

PRESCRIBED BURNING

Definition

Applying fire to predetermined areas under such conditions that the intensity and spread of the fire are controlled and beneficial effects outweigh the damage caused by burning.

Purpose

To control undesirable vegetation, prepare sites for planting or seeding, control plant disease, reduce fire hazards, and improve wildlife habitat and forage production.

Planning Considerations

Fire is a useful tool; yet, it is also very destructive, and should be considered as the last alternative. When improperly used it removes vegetative cover from the soil, leaving it susceptible to soil erosion. Frequent burning, for example annually, degrades the soil by preventing organic matter maintenance or build-up. Fire should be used only as specified by law, and specifically for one of the stated purposes listed above and as infrequently as the purpose allows.

Specifications

- Do not burn during prolonged dry periods. Do not burn the same area every year. Soil should be moist at the surface on uplands or saturated on marshes. Humidity should be high in woodlands but may be low in wetlands;

- Prepare adequate fire lanes between areas to be burned and adjacent vegetation;

- Have sufficient firefighting tools and manpower present before attempting to burn as prescribed by law; and

- Existing regulations addressing burning should be complied with at all times.

RECREATION LAND GRADING AND SHAPING

Definition

Altering the surface of the land to meet requirements for recreation facilities.

Purpose

To permit effective use of the land for recreation without erosion or environmental damage.

Planning Considerations

Development for tourism on St. Kitts will no doubt increase with construction of new hotels and related facilities. Good control of all types of recreational development can reduce problems with erosion, parking, access to beaches and help keep St. Kitts a beautiful place that people want to visit. Proper recreation land grading and shaping is a big part of that control.

Plan for access, parking, and any structures to be built. Locate paths, trails and roads to minimize damage to existing trees and other vegetation and in a manner that reduces erosion and drainage problems. Disposal of excess rainfall must be provided to prevent erosion or local flooding.

Specifications

- Shaping--If only shaping is required, the cuts and fills may be estimated by observation or by a minimum amount of work with an engineer's level;

- Grading--If grading to uniform surfaces is required, the design shall be based on a complete topographic or grid survey. Cuts and fills shall be staked and the surface brought to design grade;

- Erosion control and drainage--Required treatments for erosion control and surface and subsurface drainage shall be installed during the shaping and grading;

- Specific uses--Grading and shaping for specific uses, such as athletic fields, shall be according to the requirements of the intended use; and

5. Vegetation: Disturbed areas shall be established to vegetation as soon as practicable after grading. Seedbed preparation, seeding, fertilizing and mulching shall comply with recommendations (see the section on Critical Area Treatment). During construction, special attention shall be given to saving and maintaining key trees and other vegetation that have scenic value, provide shade, reduce erosion and runoff, provide den and food for wildlife, or add to the visual quality of the areas.

ROAD

Definition

A travelway constructed in a manner to reduce soil erosion.

Purpose

To provide a fixed route for travel for moving livestock, produce, equipment, harvested crops, and supplies; to provide access for proper operation, maintenance, and management of conservation enterprises while controlling runoff to prevent erosion and maintain or improve water quality; and to provide access to fields or buildings.

Planning Considerations

Roads are essential for access to fields, springs, ponds, houses and other places. They are especially important on Nevis because of the steep slopes of many small vegetable fields. Roads can serve double duty for traffic and as terraces or diversions. Their location can cause erosion or protect against erosion depending on how they are placed on the landscape. There is an opportunity on St. Kitts to construct roads to benefit conservation.

Roads should be designed to meet the requirements of its intended use with the expected vehicular or equipment traffic. The type of vehicle or equipment, speed, loads, and other conditions under which vehicles and equipment are expected to operate need to be considered. Appearance and environmental values should be considered in planning and designing the road system. The design system should ensure that maintenance requirements are in line with operating budgets.

Specifications

1. Location

Roads shall be located to serve the purpose intended, to facilitate the control and disposal of water, to control or reduce erosion, to make the best use of topographic features, and to include scenic vistas where possible. The roads should generally follow natural contours and slopes to minimize disturbance of drainage patterns. Roads should be located where they can be maintained and so water management problems are not created. To reduce pollution, roads should not be located too near watercourses.

2. Alignment

The gradient and vertical and horizontal alignment shall be adapted to the intensity of use, mode of travel, and the level of development. Grades normally should not exceed 10 percent except for short lengths, but maximum grades of 20 percent or more may be used if necessary for special uses. Roads should be aligned to run across the slope where possible, preferably on terrace grade. Cross slope roads can be utilized as diversions or terraces, thus serving two purposes. Up-slope field roads should be located along ridge tops or along field boundries.

3. Width and Side Slopes

The minimum width of the roadbed is 14 feet for one-way traffic and 20 feet for two-way traffic. Single-land field roads have a minimum width of 10 feet with greater widths at curves and turnouts.

All cuts and fills shall have side slopes designed to be stable for the particular site conditions.

4. Drainage

The type of drainage structure used will depend on the planned use and runoff conditions. Culverts, bridges or grade dips for water management shall be provided at all natural drainageways. The capacity and design shall be consistent with sound engineering principles and shall be adequate for the class of vehicle, type of road, development, or use.

Roadside ditches shall be adequate to provide surface drainage for the roadway. Channels shall be designed to be on stable grades or protected with structures or linings for stability.

Long stretches of up and downhill roads shall be broken up with intercepting dips, cross ditches, water-breaks or bars, or be crowned to remove rainfall runoff.

Intercepting dips are outsloped sections of road that act as water catchments and drainage channels. Length and depth must be adequate to provide drainage but not endanger traffic at normal speeds. The centerline or hydraulic bottom should be at an angle of 45 to 60 degrees with the centerline of the road. A minimum length of 50 feet on the uphill approach slope and 15 feet on the slope leaving the dip is necessary to minimize vehicle jolt and to prevent wheel tracks from channeling storm water down the roadway. The hydraulic bottom should have a grade about 2 percent more than the grade of the road. A raised shoulder or berm may be necessary to retain runoff water until it reaches the hydraulic bottom of the dip.

Cross ditches are small ditches shoveled at an angle across the tread, with the excavated earth piled along the downslope edge of the ditch.

Water-breaks or bars are combinations of the broad shallow trench and low ridge built by bulldozer or grader for diverting runoff water from a road surface.

Intercepting dips, cross ditches, or water-breaks shall be spaced so that storm runoff will be diverted off the road before it gains sufficient volume and velocity to cause erosion damage to the road. The spacing shall be based on the design rainfall, area contributing runoff, roadway slope, experience, and erosion resistance of the road material.

Road runoff should outlet into diversions, terraces, grassed waterways, ghauts, soakers (sluices), or other stable outlets. Soakers or sluices are infiltration pits and should be used if outlets are not available. Specific attention should be given to preventing diverted water from re-entering roadway downslope.

5. Surfacing

Access roads shall be given a wearing course or surface treatment if required by traffic needs, climate, erosion control, or dust control. The type of treatment depends on local conditions, available materials, and the existing road base. If these factors or the volume of traffic are not a problem, no special treatment of the surface is required.

6. General Criteria

Watercourses and water quality shall be protected during and after construction by erosion-control facilities and maintenance. Soakers and other conservation practices shall be used and maintained as needed.

Dead end roads shall be provided with a turnaround. Parking space as needed shall be provided to keep vehicles off the road or from being parked in undesirable locations.

7. Construction

Construction operations shall be carried out in such a manner that erosion and air and water pollution are minimized. The completed job shall present a workmanlike finish. Construction shall be according to the following requirements as specified for the job:

- Trees, stumps, roots, brush, weeds, and other objectionable material shall be removed from the work area;

- Unsuitable material shall be removed from the roadbed area; and.

- Grading, sub-grade preparation, and compaction shall be done as needed.

Any structures or culverts shall be installed to line and grade. All grades, ditches, soakers, access points, and other features shall be installed according to the plans or as staked in the field. If sub-base or surface course is specified, it shall be installed according to the plans and specifications.

ROTATION, CONSERVATION CROPS

Definition

An adapted sequence of crops designed to provide a protective overstory and adequate organic residue for maintenance or improvement of soil tilth.

Purpose

To improve or maintain good physical, chemical and biological conditions of the soil, help reduce erosion, improve water use efficiency or break reproduction cycles of plant pests.

Planning Considerations

The cropping systems for St. Kitts should include high residue crops alternated with other crops in order to produce adequate residues to accomplish the planned purposes. Legumes in the sequence will help maintain soil fertility. High to medium crop residue producers are sugarcane, yams when mulched, sweet potatoes, pumpkins, pigeon peas, and corn, as well as selected agro-forestry trees.

Specifications

- Use the Universal Soil Loss Equation to determine alternative minimum crop sequences and treatments, when combined with other conservation practices, to reduce the soil loss to a tolerable level on cropland;
- On orchards or other production areas where there is inadequate cover, use perennial vegetation or cover crops to increase protection. Use the Universal Soil Loss Equation to determine what is adequate cover for a given field;
- For fertilizing and liming, follow recommendations provided by chemical soil analyses; and
- Protect areas under treatment from burning.

ROTATION, TREES, GRASSES AND LEGUMES

Definition

Using trees, perennial grasses or perennial legumes, separately or in mixtures, in a crop rotation system with annual crops.

Purpose

To maintain or improve soil fertility, protect the soil from erosion, and provide forage when grazing or cutting for forage is compatible with the other purposes.

Planning Considerations

This practice is very effective in protecting the soil where vegetables are grown on steep slopes. Normally grasses and legumes become established naturally after the vegetables are no longer cultivated. It is one of the more important practices for use by the small farmer on the island. Trees also continue to protect steep slopes even during the dry seasons.

Specifications

The rotation used should be based on the degree of erosion control needed as indicated by the Universal Soil Loss Equation. The sequence of annual and perennial crops in rotation should be one of the following:

Rotation System (Years)	Crop (Years)	
	Perennial	Annual
3	2	1
4	3	1
5	4	1
6	5	1
4	2	2
5	3	2
6	4	2
7	5	2

Use native perennial grasses and legume mixtures or establish perennial plants such as guinea grass, pangola grass and siratro and selected trees. Perennial plants that are cash crops, such as sugarcane, may be used if the crop residue remains on the field. The field should not be burnt. When in the perennial vegetation cycle, and forage is utilized, follow the specifications given in the sections on Pasture Management or Proper Grazing Use. Apply fertilizer and lime according to needs specified in soil analysis.

SPRING DEVELOPMENT

Definition

Improving springs and seeps by excavating, cleaning, capping, or providing collection and storage facilities.

Purpose

To collect water from springs and seeps, to improve the distribution of water, or to increase the quantity of water, for livestock, home use, and irrigation.

Planning Considerations

1. Overview

Ground water is located beneath the earth's surface, and if the water flows to the surface, it may be collected and used (Figure 1). Figures 2 and 3 show conditions where springs may be found. Effective development of springs may supply enough water for livestock, household use and very small amounts for irrigation.

2. Investigation

Potential spring sites should be studied during a dry season or the season of intended use. The investigation should determine the nature of the water-bearing material and make measurements if there is flowing water. If the site is only boggy, dig holes and observe after several hours to see if water accumulates. If so, development may be feasible.

3. Development

Flowing springs are developed by removal of obstructions, cleaning cracks and crevices, removing earth cover, removing vegetation and preventing further growth, collection of flow, and lowering the outfall point. Spring Development Figure 4 illustrates the development of a flowing spring in a stream channel. The spring and its collecting structures can be developed so flood flows do not cause damage. A properly located wing wall prevents channel degradation and dewatering of the spring. A wall across the water-bearing strata, with a springbox protected with gravel and large rock, can prevent most flood flow damage. The pipeline can extend down the valley at a flatter grade so it can soon be directed out of the flood plain and away from any flood flow damage.

Boggy areas or areas continually moist are developed into springs by digging a collection ditch across the outlets. If individual openings are present, they should be cleaned. The trench is backfilled

with clean gravel, with or without a perforated pipe, and graded to a collection pipe or spring box. An impermeable wall should be installed immediately downstream of the collection trench. See Figure 5 for typical seep area collection systems. In some cases, a tunnel or infiltration gallery may be excavated into a hilly seep area by following the water that appears.

Very often, the most advantageous method of development may not be apparent until construction starts. Therefore, flexibility and experience of the developer are most important in spring development work.

4. Collection

The collection system usually consists of a perforated pipe laid in a gravel envelope for seep springs or an open ended pipe placed in a spring box for flowing springs. A spring box provides a method of collecting the water, trapping sediment, and preventing trash, etc. from entering the pipeline for both seep and flowing springs (See Figures 3 and 4).

Specifications

1. Fracture and tubular springs

If water issues from rock fractures, the individual openings shall be cleaned and enlarged, as needed, to provide an increase in flow. The water from these individual openings shall be collected and conveyed to a central sump or spring box by means of a tile or perforated pipeline or by a gravel-filled ditch. The collection works shall be constructed an adequate distance below the elevation of the openings to permit free discharge.

If water issues from a single opening, such as a tunnel in lava, the opening shall be cleaned or enlarged, as needed. A collection system usually is not required, but a spring box or a sump shall be installed at an elevation sufficiently low that water will not pond over the spring opening.

2. Perched or contact springs

Perched or contact springs occur where an impermeable layer outcrops beneath a water-bearing permeable layer. These springs shall be developed by intercepting and collecting the flow from the water-bearing formation. Collection trenches shall be used for developing these types of springs.

3. Collection systems

If a collecting trench along the outcrop of the water-bearing formation is to be used, the trench shall be excavated so that it extends into the impervious layer.

An impervious cutoff wall of well-tamped clay, masonry, concrete, or other suitable materials shall be constructed along the downstream side of the trench, if needed, to insure that the flow enters the collection system.

The collection system shall consist of subsurface drainage tubing or perforated pipe not less than 4 inches in diameter, or of a wood box drain enclosed in a sand-gravel filter. Even the perforated pipe should be enclosed in a ground envelope. A crushed rock or gravel backfill, not less than 12 inches deep, may be used instead of these types of drains.

4. Spring boxes

Spring boxes, if needed, shall be of durable material and shall have a tight, removable cover. The boxes shall have a minimum cross sectional area of 1-1/2 ft^2. The floor of the spring box shall be not less than 6 inches below the outlet of the collection system. Spring boxes for perched springs shall be floored with concrete unless the underlying material is solid rock or other stable impervious material.

5. Outlets

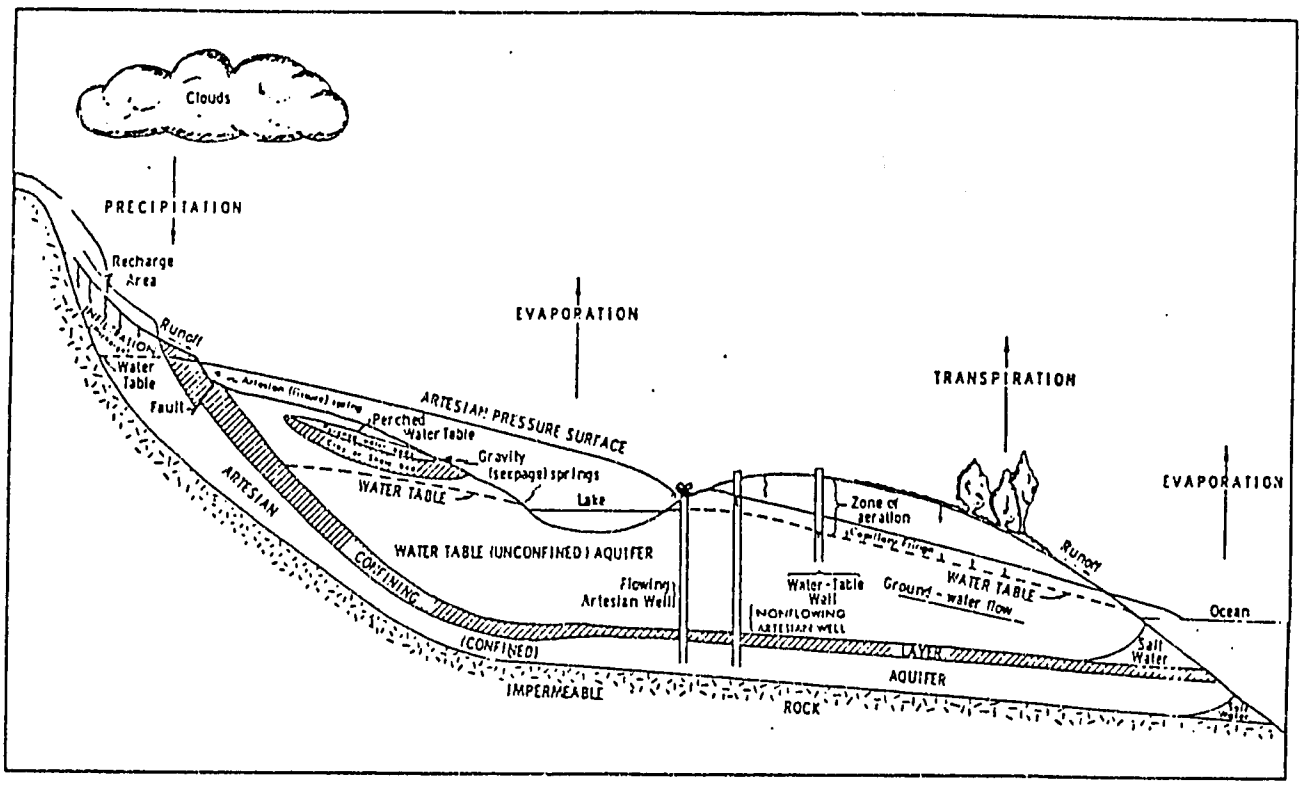
The outlet pipe from a spring box shall be placed not less than 6 inches above the floor of the box to provide a sediment trap. However, the outlet must not be so high as to cause a head on the spring that can reduce flow. The outlet pipe shall be installed so as to insure a watertight connection with the spring box. Measures required to protect the development from damage by flooding, sedimentation, contamination, and livestock shall be included in the design.

6. Vegetation removal

Aquatic plants can be removed mechanically or killed with herbicides. Care must be exercised to prevent water contamination and exposing bare erodible earth that could impair the spring opening or cause sediment damage downstream.

7. Installation

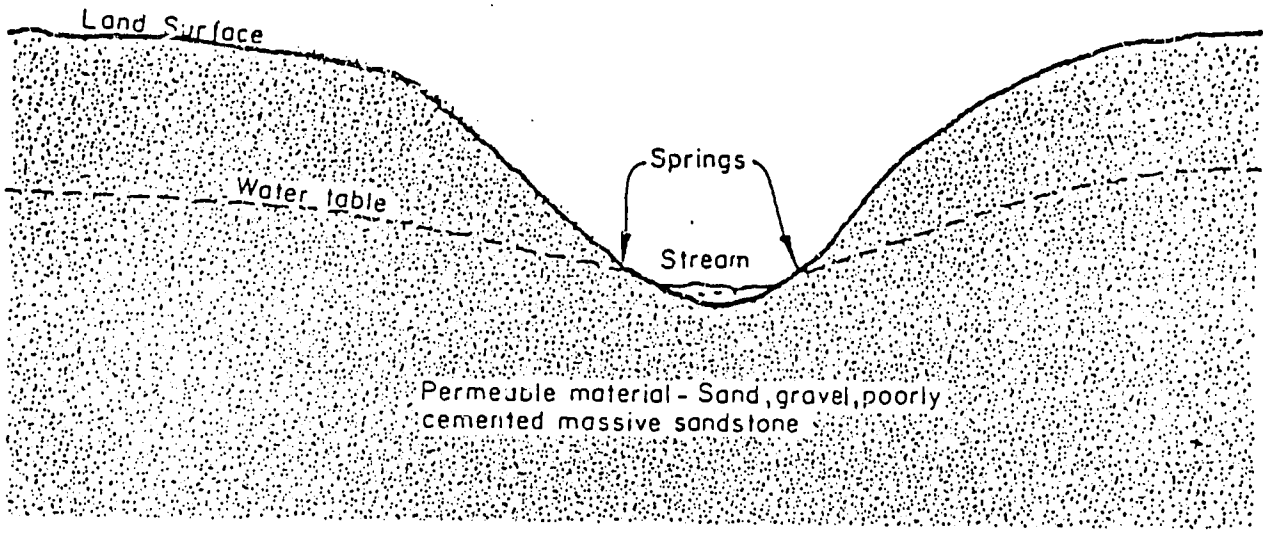
All loose rock, sediment, encrustations, logs, and vegetation that can obstruct the free discharge of the spring shall be removed and disposed of so that they will not endanger the spring development. Collection trenches, drain tiles, perforated pipe lines, sumps and spring boxes shall be constructed to the elevation and grade shown on the plans or as staked in the field. Crushed rock or gravel for collection systems and sand-gravel material for filters shall be composed of clean hard particles. Construction operations shall be carried out in such a manner that erosion and water pollution are minimized.



St. Kitts SOIL CONSERVATION HANDBOOK

Spring Development Figure 1: <u>The Hydrologic Cycle</u>

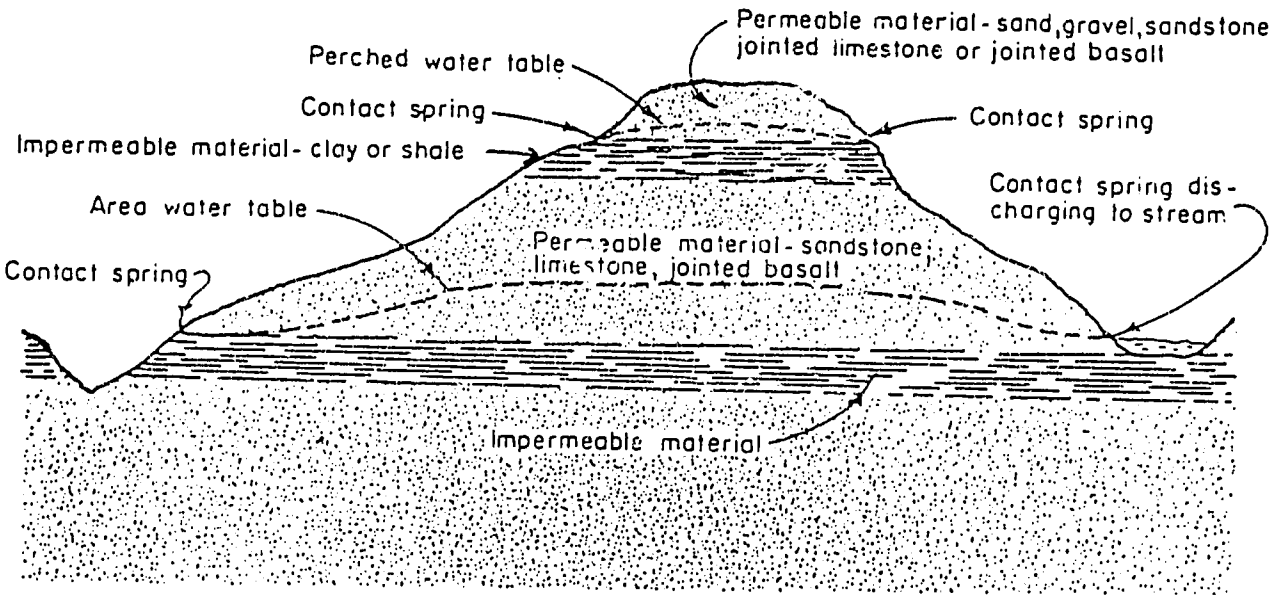
May 1987



ST. KITTS SOIL CONSERVATION HANDBOOK

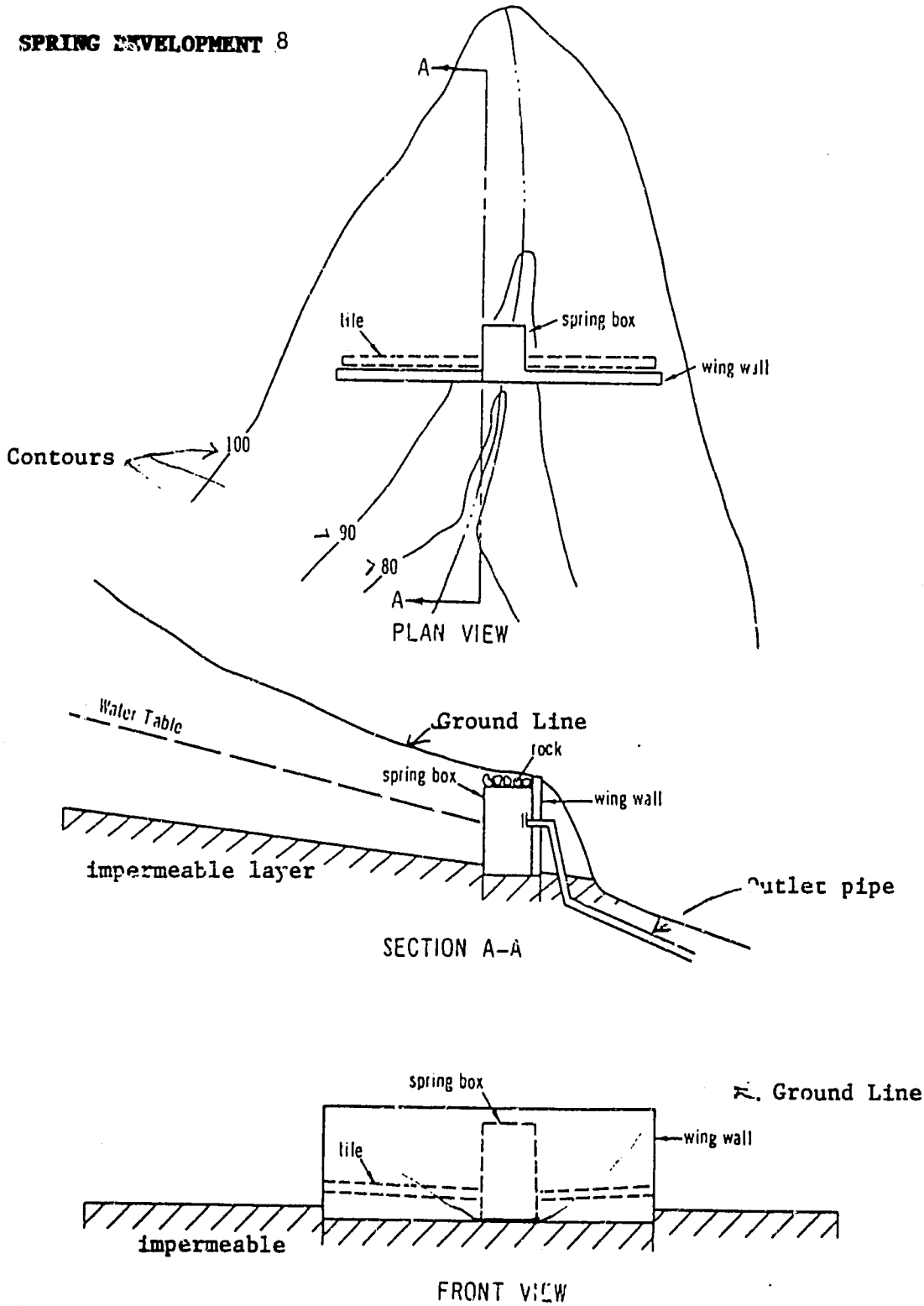
Spring Development Figure 2 : Depression Spring, Seepage or Filtration Type

May 1987



ST. KITTS SOIL CONSERVATION HANDBOOK

Spring Development Figure 3: Typical Contact Spring



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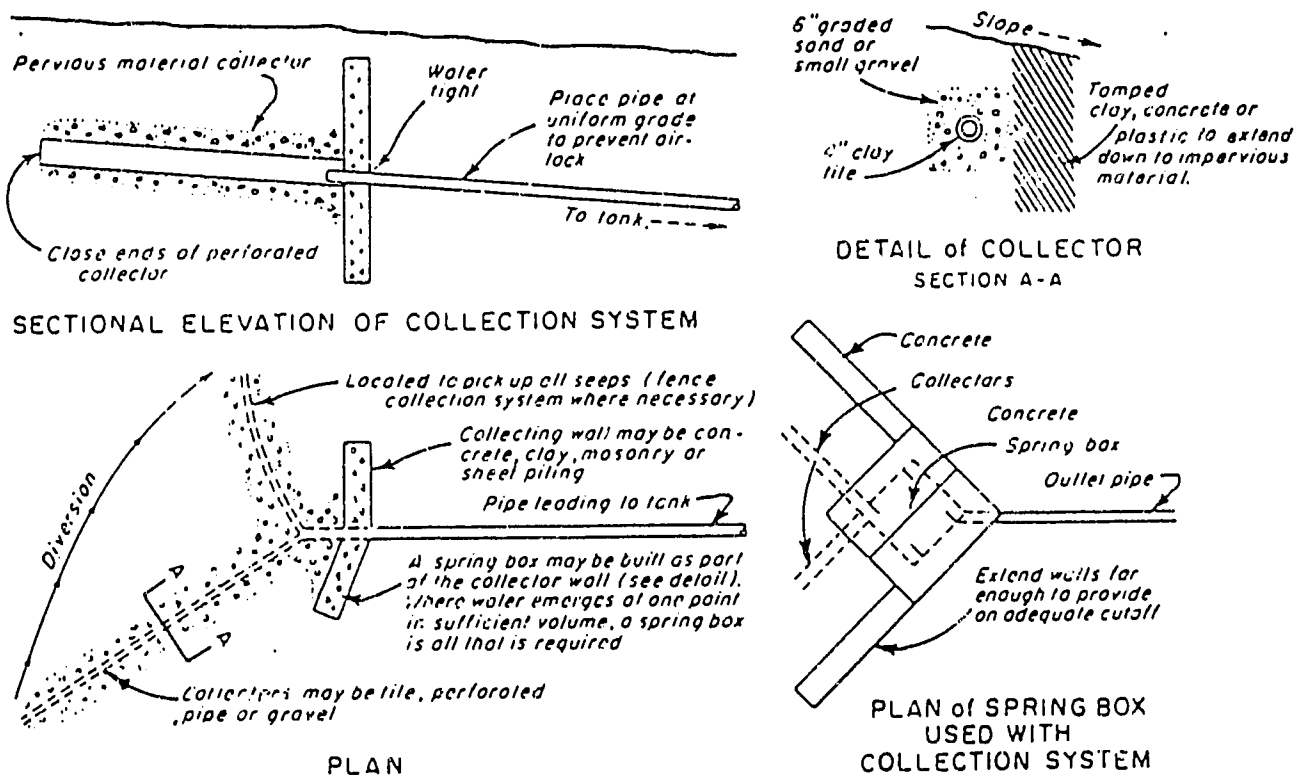
Spring Development Figure 4 : Spring Development in Stream Channel



ST. KITTS SOIL CONSERVATION HANDBOOK

Spring Development Figure 5: Spring Collection System

TERRACE

Definition

An earth embankment, a channel, or a combination ridge and channel constructed across the slope.

Purpose

- To reduce slope length;
- To reduce erosion;
- To reduce sediment content in runoff water;
- To improve water quality;
- To intercept and conduct surface runoff at a nonerosive velocity to a stable outlet;
- To retain runoff for moisture conservation;
- To prevent gully development;
- To re-form the land surface;
- To improve farmability; or
- To reduce flooding.

Planning Considerations

1. Overview

It is estimated that 50% of the sugar cane land on St. Kitts is on lands with slopes greater than 16%. Several steeply sloping fields are in vegetables. Under a previous project 150 acres of sugar cane land was terraced with graded terraces. These have sheet and rill erosion destroying the soil. There are several active gullies eating their way up the slope. Hope Ghaut is an example. Terraces can help control these problems.

2. Selecting the terrace system

The type of problem to be solved determines, in a large part, what type of terracing system is needed. Sheet and rill erosion erodes the topsoil away faster than nature can replenish it. Gullies destroy land and improvements. Once washed into the ocean, these soils are

gone--not to be replaced. In some cases, floods damage houses and other improvements.

The process of selecting a terrace system involves the technician and the land operator. Terraces should be a part of a complete conservation system involving such practices as conservation tillage and contouring. Terraces can serve a variety of purposes:

- Terraces will reduce slope length and provide an additional allowance for a P factor when calculating estimated soil loss using the USLE. This can reduce sheet and rill erosion to allowable rates;

- Terraces can keep water away from gully heads and sides. The contributing drainage area should be completely covered with terraces. The collected water can infiltrate into the soil or be removed by pipe or surface outlets. With no runoff water going into the gully, it will be stopped; and

- Terraces can be used for flood control in much the same manner as gully control, except more storage may be needed if high value property is to be protected.

3. Classifying terraces

Terraces are classified by:

- Alignment;

- Cross section;

- Grade; and

- Outlet.

a. Alignment

Terrace systems are either parallel or non-parallel. Parallel terraces eliminate point rows but construction costs are usually higher. Either type or a combination of both types can be used to solve erosion problems.

b. Cross section

There are four terrace cross sections appropriate for St. Kitts:

- Broadbase--This terrace is constructed generally on flatter slopes usually less than 8% and the cut slope, front slope

and back slope are all farmed. They are best suited for cropland. See Figure 1A;

- Steep backslope terrace--This terrace is constructed with a steep backslope which is vegetated. The cutslope and front slope are usually farmed. If desired, the frontslope may be used for a field road. Normally they are used on slopes of 8 percent or steeper. See Figure 1B;

- Narrow base terrace--This terrace is constructed with steep back and front slopes (1.5:1 or flatter), both vegetated. This cross section takes the least amount of fill of any type. They also are usually located on slopes greater than 8 percent. See Figure 1C; and

- Bench terrace--This terrace is constructed with the terrace interval level from side to side and end to end, and the ridge has a narrow base that is vegetated. This type works on all slopes, for all problems, but should not be used on soils with low permeability because of wetness. See Figure 1D.

  There is very little runoff with this type of terrace. The outlet is infiltration and the interval can be anything reasonable. The minimum farmed width is to provide for one round trip of the widest machinery to be used. Erosion is very low with this type of terrace.

c. Grade

Terraces are classified as level if the grade of the channel and ridge are level. Level terraces use infiltration for an outlet. The ends may be blocked or left open. Terraces are classified as graded if they have grade in the channel to a vegetative or underground outlet. Both level terraces and graded terraces can be used for all kinds of problems.

d. Outlet

Terraces may be classified as:

- Blocked;

- Vegetated outlets, e.g. grassed waterway or other vegetated area; and

- Underground outlets where all water is removed from the terrace channel through underground pipes.

The procedures for design of the latter may be found in the USDA SCS Engineering Field Manual. Blocked terraces with infiltration outlets are usually successful for use on A & B hydrologic group soils (See Section 2.3). They are especially appropriate for gully control. C & D hydrologic group soils usually require surface water removal, unless the terrace channel extends into very permeable subsoils.

4. Spacing

Terrace spacing may be determined by use of the USLE, the spacing formula, or by use of Table 6 (See Specifications section). Terrace spacing for level terraces may be dictated in part by storage requirements because the wider the spacing the larger the terrace section needed to store the runoff water. The spacing for bench terraces will be determined largely by the amount of earth to be moved. Select the optimum spacing considering the above factors.

5. Alignment

Terrace alignment has a large impact on farming, depending on the farm equipment used. Terraces should be made parallel with long gentle curves where practical, especially if tractors and multi-row implements are used. The following methods may be used to improve alignment.

- Use roads or turn strips on long flat ridges;
- Vary grade along the channel. For level terraces, use full blocks in the channel, making part of the terrace at a different elevation than the other part;
- Make extra cut or fill along the terrace line; and
- Vary the amount of excavation or fill along the terrace line, i.e., cut extra in ridges and move extra dirt to the valleys.

6. Capacity

Terraces are designed to control the runoff from a 10-year frequency, 24-hour storm without overtopping. For level terraces, this requires the cross section to store the runoff from the interval above the terrace up to the next terrace ridge above. The gradient terrace, on the other hand, must carry the peak rate of runoff without over topping and at a non-erosive velocity.

7. Grade

- Graded terrace--The grade must provide adequate drainage and capacity to prevent overtopping by the design storm. This size may be calculated or the standard size in the

specification section may be used. Terrace grades may be steeper for short sections or at the upper ends of terraces to improve alignment; and

- Level terraces--The ridge tops for level terraces must be level. The channel bottom for level terraces must be level to provide for uniform infiltration and prevent wet spots in the channel bottom. If grade change is necessary, the channel may be blocked, and different sections of the same terrace installed level, both channel and ridge, but at differing elevations by section.

8. Outlets

Graded terraces must have stable outlets. Grassed waterways, if used, should be established in a dense sod before the terrace is built. Other vegetate areas may be used. In no case should a graded terrace empty into a bare ditch or over a steep unstable bank. Structures may also be used for outlets.

Level terraces infiltrate into the terrace bottom. If infiltration is slowing, unblocking the ends and ripping the channel bottoms should help.

9. Planning terrace systems

Terrace systems are best planned with the aid of contour maps. First, locate field boundaries, natural features, roads, etc. Next locate potential outlets and field roads. Then determine the slope and spacing. Start with a key terrace about the third interval from the top of the hill. Make a trial layout of the key terrace on a transparent overlay, then the ones above and below the key. Cut and try until the best system is planned. You may need more than one key terrace if the slope is long.

Terrace systems may be laid out in the field in the same manner as on contour maps, except the layout is done on the ground with the aid of an aerial photograph or other map, engineer's level and rod. The key terrace is staked; those needed above and below are staked, at enough locations to determine the actual layout, if construction is to be delayed. You may need to pull stakes and start over in some cases. A good layout can be made by field trial, but it takes more work than on a contour map.

10. Layout of terraces

Terrace staking proceeds as described in the preceding section. Stakes should be located at the point where there is no cut or fill on the frontslope. With this method, the stakes can remain in place until construction is complete. If there is extra cut or fill at any point, the stake can be marked to show what is required.

The sample notes, Figure 2, and the following problem illustrate terrace stakeout. Tables 1 through 3 can be used to determine terrace size needed for the required storage.

Problem: Steep slope. Determine size required for storage type Terrace No. 2. (sugar cane--heavy residue, erosive resistant soil)

Given: Land slope--4 percent

Spacing--180 feet

Runoff--2.8 inches

From Table 1, read 23 ft^2 of storage needed for each 100 ft. of terrace spacing. Then storage needed is 23 x 130/100 = 41 ft^2 per foot of length. From Table 2, read 2.3 ft. depth of terrace needed for 41 ft^2 storage.

Specifications

1. Spacing

The maximum spacing for terraces for erosion control shall be determined by one of the following methods:

o Spacing Formula:

$$V.I. = xs + y \text{ or } H.I. = (xs + y)\left(\frac{100}{s}\right)$$

Where:

V.I. = vertical interval in ft.

H.I. = horizontal interval in ft.

x = a variable with values from 0.6 to 0.8
s = land slope in percent
y = a variable with values from 1.0 to 4.0

Values of x for level terraces are 0.8 and for gradient terraces, 0.6. Values of y are influenced by soil erodibility, cropping system, and crop management practices. A value of 1.0 shall be selected for erodible soils with tillage systems that provide little or no cover during periods of intense rainfall. A value of 4.0 shall be used for erosion-resistant soils with tillage systems that leave a large amount of cover (1.5 tons of straw equivalent per acre) on the surface. A value of 2.5 shall be used if one of the factors indicated is favorable and the other unfavorable. Other values between 1.0 and 4.0 may be used according to the estimated quality of the factors. A value of 4.0 should be used for Terrace Figure 2: Sample Notes, with

sugarcane. The horizontal spacing does not have to be less than 90 ft.

- Universal Soil Loss Equation (USLE): The spacing shall not exceed the slope length determined by using the allowable soil loss, the most intensive use planned, the expected level of management, and the terrace P factor (Table 4).

  In no case shall the maximum horizontal spacing exceed that shown in Table 5 for the conditions shown. Table 6 may be used for terrace spacing in lieu of the above two methods. The spacing shall be adjusted to provide for an even number of trips for anticipated row crop equipment. The likelihood of benching of steep slopes by tillage, land forming, and erosion shall be considered when determining the terrace interval.

  Figure 3 shows the horizontal interval or erosion length to be used in calculating terrace spacing.

- Storage: spacing may need to be determined by reasonable maximum storage needs with level terraces.

2. Capacity

The terrace shall have enough capacity to control the runoff from a 10-year frequency, 24-hour storm without overtopping. When the capacity is determined by the formula Q = AV and the V is calculated by using Manning's formula, an n value of 0.06 shall be used. Manning's formula is discussed in the Diversions section of this Handbook. For full coverage on the use of Mannings' formula refer to the SCS Engineering Field Manual.

A standard terrace size for gradient terraces may be used in lieu of making the design. A 6 ft. bottom, 1.5 ft. deep with a 4:1 side slope channel cross section, may be used for spacings up to 125 ft. For spacings over 125 ft., the depth must be increased to 2 ft. The terrace grade must be at least 0.3 percent, but not more than 1.0 percent and the maximum distance water runs is 1000 ft. Bench terrace ridges must be a minimum of one foot high.

3. Cross section

The terrace cross section shall be proportioned to fit the land slope, the crops grown, and the farm machinery used. Additional height shall be added if necessary to provide for settlement, channel sediment deposits, erosion, the effect of normal tillage operations, and safety. The ridge shall have a minimum width of three feet at the design elevation. The slope of a vegetated front or back slope should not be steeper than 1.5:1. The opening at the outlet end of gradient and open-end level terraces shall have a cross section equal to that specified for the terrace channel.

4. End closures

Level terraces may have open ends, partial end closures, or complete end closures. Partial and complete end closures shall be used only on soils and slopes where the stored water will be absorbed by the soil without appreciable crop damage.

The end closures must be installed before the terraces are completed. The end closures shall be designed so that the water flows over the end closure or other spillway area before overtopping the terrace ridge.

5. Channel grade

Channel grades may be uniform or variable, but shall not exceed 1.0 percent for graded terraces. For short distances and in upper reaches, channel grades may be increased to improve alignment. Minimum grades shall be such that ponding in the channel because of minor irregularities will not cause serious damage to crops or delay field operations.

6. Terrace length

The volume of water stored in level terraces is proportional to the length. Therefore, it is necessary that the length be held within reason so that damage in the case of a break is minimized. Level terrace length shall not exceed 1,500 ft. unless the channel is blocked at intervals not exceeding 1,500 ft. Normally, the gradient terrace length is controlled by the capacity and the nonerosive velocity requirements. (Refer to Diversion for information on capacity and nonerosive velocities)

7. Outlets

All terraces must have adequate outlets. Vegetative outlets may be used for gradient terraces. Such an outlet may be a grassed waterway or vegetated area. The outlet must convey runoff water to a point where the outflow will not cause damage. Outlets shall be installed and vegetated before the terrace is constructed if necessary to provide a stable nonerodible outlet or to ensure establishment of vegetative cover. The water surface in the terrace shall not be lower than the water surface in the outlet at their junction when both are operating at design flow.

Soil infiltration may be used as the outlet for level terraces. Soil infiltration must permit drainage of the design storm from the terrace channel within a reasonable period so that crops are not significantly damaged by standing water.

Combinations of different types of outlets may be used on the same system to maximize water conservation and to provide for economical installation of a more farmable system.

8. Construction

All ditches, irregularities, or gullies shall be filled before constructing the terrace or shall be part of the construction. All old terraces, fence rows, hedge rows, trees, crop residues, and other obstructions shall be removed, as necessary, to install a farmable system. After the field is staked, as described in the layout section presented earlier, the top soil is removed and stockpiled in a continuous row off the location for the terrace.

The terraces shall be constructed according to planned alignment, grade and cross section with the specified overfill for settlement and the channel graded to drain reasonably well.

Any ditch or depression at the bottom of the back slope shall be filled and smoothed so that drainage will be away from the terrace and not parallel to it. Terrace ridges constructed across gullies or depressions shall be compacted by machinery travel, or by other suitable means to ensure proper functioning of the terrace.

Construction with a bulldozer is accomplished by making three or more "cuts" and "bucks" at right angles to the ridge. Any extra cut or fills are made at this time. After the terrace is roughed in, two or more rounds are made lengthwise to shape the slopes. If the channel bottom is to be ripped, this is the time to do it. The terrace is then checked for rough grade ridge height and cross section. The top soil is then spread over the terrace to facilitate restoration of productivity, and final grading and shaping are completed. The terrace is then checked for final grade and cross section. If either slope of the ridge is to be vegetated, seeding or sprigging should be carried out immediately to prevent erosion from unexpected rains. The portions of the channel to be farmed should be plowed to loosen the soil compacted by the construction. The surface of the finished terrace shall be reasonably smooth and present a workmanlike finish.

9. Maintenance of terraces

All areas to be vegetated shall be established to grass as soon as practicable after construction. The sod shall be maintained and trees and brush controlled by chemical or mechanical means.

All tillage and planting should be done parallel to the terraces. When planting on broad-based terraced fields, plant the terrace ridges first; plant up from each terrace all the full length rows, and then finish out the rest of the interval with point rows. When planting narrow base or steep backslope terraced fields, plant up from the terrace all the full length rows, then finish out the remaining area with point rows.

Outlets should be checked after heavy rains and at least annually for washing, debris, and sediment deposition. Outlets should be repaired and all obstructions to flow removed. Trees and brush should be sprayed or cut from vegetated areas every year.

TERRACE 10

Each time the terrace is ploughed the accumulated sediment in the bottom of the channel should be ploughed up-slope to the terrace ridge and the cut slope, thus keeping the terrace channel clear and to the designed grade and cross section.

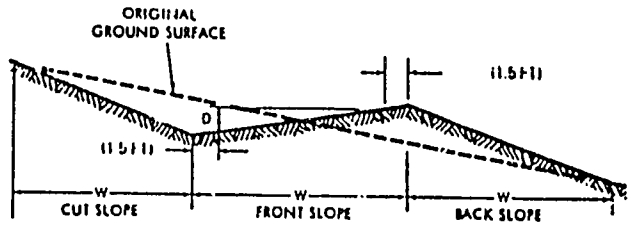


FIG.1A :BROADBASE TERRACE CROSS SECTION

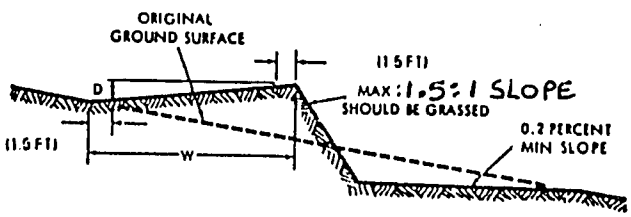


FIG1B :STEEP-BACKSLOPE TERRACE CROSS SECTION

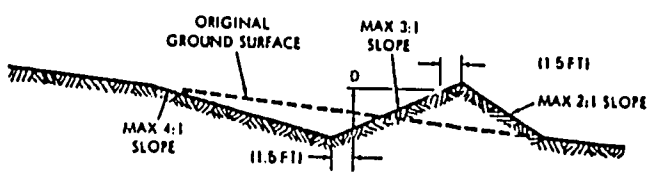


FIG.1C :NARROW-BASE TERRACE CROSS SECTION.

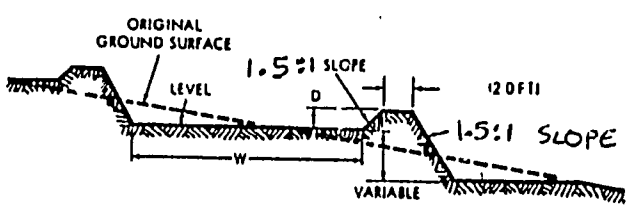


FIG.1D :BENCH TERRACE CROSS SECTION

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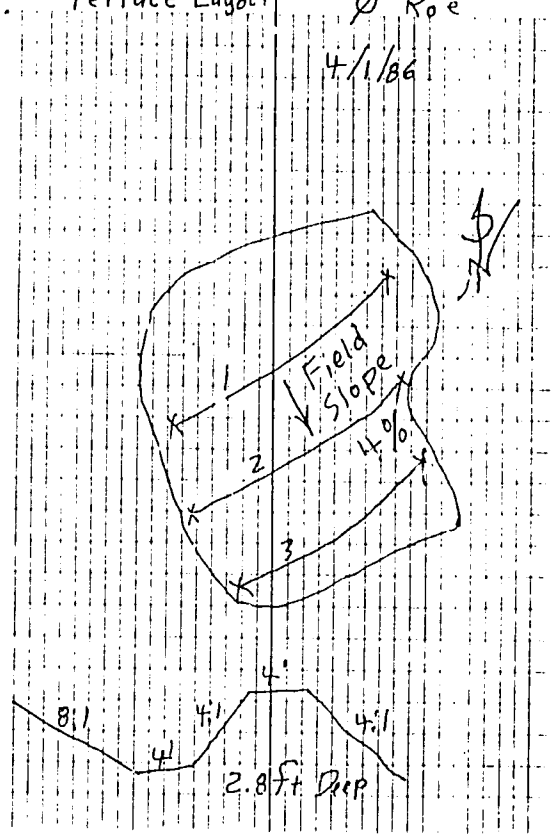
TERRACE FIGURES 1A-1D: Terrace Cross Sections

TERRACE 12

Terrace No 2

R W Jones — Terrace Layout — π Mills, Ø Roe — 4/1/86

Sta	BS Rod	HI	FS or Grade Rod	Elev or Planned Elev
0+40	6.4			
1+00	6.4			
2+00	6.4			
3+00	7.0	Extra fill of 0.6 ft needed Stake marked		
4+00	6.4			
4+60	6.4			



Terrace No 2

R.W. Jones — Terrace Subgrade Check — π Mills, Ø Roe — 4/16/86

Sta	~~BS~~ Chan Rod	~~HI~~ Ridge Rod	~~FS or Grade Rod~~ Min. Depth	Elev or Planned Elev
0+40	6.9	4.0	2.9	OK
1+00	7.0	4.0		
2+00	6.9	3.9		
3+00	7.0	4.0		
4+00	6.9	3.9		
4+60	6.9	3.9		

5.1/20 7.0/4 7.0/0 4.0/12 4.0/16 6.0/24 8.0/32

Terrace ready for top soil back fill.

Note: Final notes for finish grade after backfill would be similar to these.

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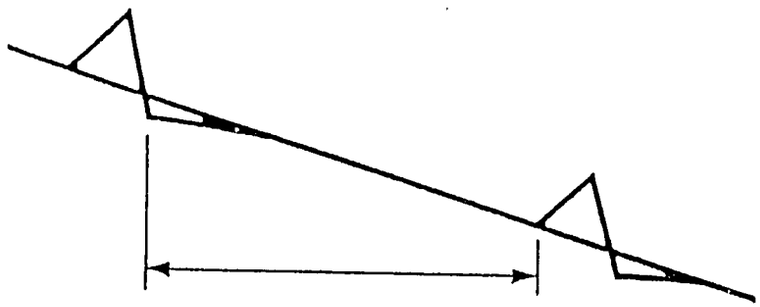
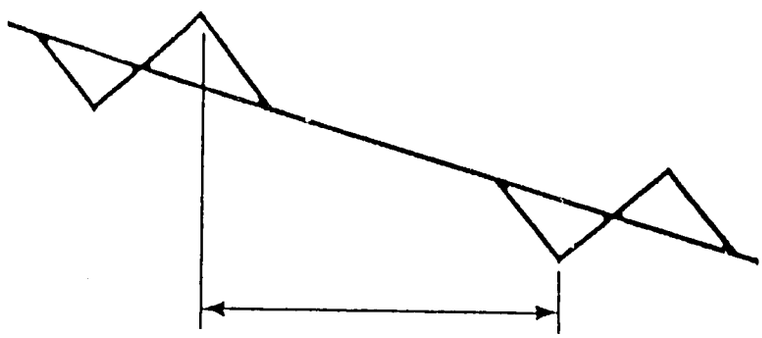
Terrace Figure 2: Sample Notes

May 1987

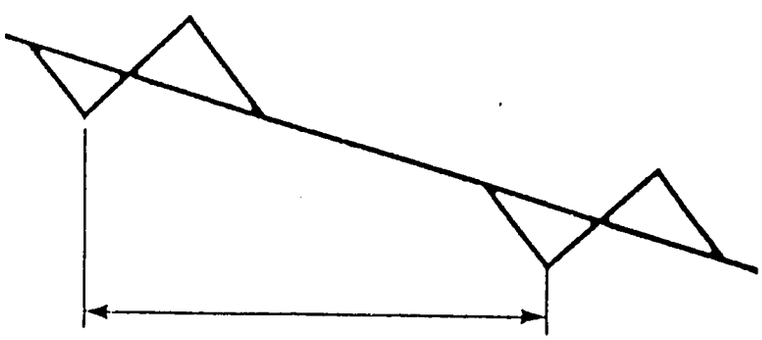
Horizontal Interval for Steep Back-Slope Terraces



Horizontal Interval for Broad-Based Terraces



Terrace Spacing



Terrace Figure 3: Horizontal Interval and Terrace Spacing

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Terrace Table 1: Terrace Runoff

Runoff (in)	Storage per 100 ft. Terrace Spacing (ft^2)
1.5	13
1.6	13
1.7	14
1.8	15
1.9	16
2.0	17
2.1	18
2.2	18
2.3	19
2.4	20
2.5	21
2.6	22
2.7	23
2.8	23
2.9	24
3.0	25
3.1	25
3.2	27
3.3	28
3.4	28
3.5	29
3.6	30
3.7	31
3.8	32
3.9	33
4.0	33

Terrace Table 2: Terrace Storage for 4:1 Cutslope 4-Ft. Bottom and 4:1 Frontslope

(Appropriate for steep slopes, above 5 percent)

Terrace Depth (ft)	Storage (ft^2 per foot of terrace length)
1.0	8
1.1	9
1.2	11
1.3	12
1.4	13
1.5	15
1.6	17
1.7	18
1.8	20
1.9	22
2.0	24
2.1	26
2.2	28
2.3	30
2.4	33
2.5	35
2.6	37
2.7	40
2.8	43
2.9	45
3.0	48
3.1	51
3.2	54
3.3	57
3.4	60
3.5	63

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Terrace Table 3: Terrace Storage for 8:1 Cutslope, 4-Ft, Bottom and 4:1 Frontslope

(Appropriate for flatter slopes, below 5 percent)

Terrace Depth (ft)	Storage (ft^2 per foot of terrace length)
1.0	10
1.1	12
1.2	13
1.3	15
1.4	17
1.5	20
1.6	22
1.7	24
1.8	27
1.9	29
2.0	32
2.1	35
2.2	38
2.3	41
2.4	44
2.5	48
2.6	51
2.7	55
2.8	58
2.9	62
3.0	66
3.1	70
3.2	74
3.3	79
3.4	83
3.5	88

Terrace Table 4: Terrace P Factors
(for use when spacing is based on the USLE)

Horizontal interval (ft)	Closed Outlets[1]	Open Outlets, by percent grade of[2] 0.1 - 0.3	0.4 - 0.7	0.8
Less than 110	0.5	0.6	0.7	1.0
110-140	0.6	0.7	0.8	1.0
140-180	0.7	0.8	0.9	1.0
180-225	0.8	0.8	0.9	1.0
225-300	0.9	0.9	1.0	1.0
More than 300	1.0	1.0	1.0	1.0

Note: If contouring P factors are appropriate, they can be multiplied by the terrace P factor for the composite P factor.

[1]P factors for closed outlet terraces also apply to terraces with underground outlets and to level terraces with open outlets.

[2]The channel grade is measured on the 300 ft. of terrace or the one-third of total terrace length closest to the outlet, whichever distance is less.

Terrace Table 5: Maximum Horizontal Spacing for Terraces

Slope (Percent)	Spacing (ft)
0- 6	400
6- 9	300
9-12	250
12-18	200
More than 18	200
Minimum spacing required, all slopes	100

Terrace Table 6: Terrace Spacing

Land Slope (Percent)	Sugar Cane (ft)	Vegetables (ft)
0- 6	400	250
6- 9	300	150
9-12	250	120
12-15	200	100
15-20	140	*
20-25	110	*
25 up	*	*

* Use level bench terraces.

TREE PLANTING

Definition

Planting tree seedlings or cuttings.

Purpose

To establish, reinforce, or improve a stand of trees to conserve soil and moisture, establish a windbreak for erosion control, beautify an area, protect a watershed, or produce wood crops, provide forage, windbreaks and shade for livestock.

Planning Considerations

This practice will be useful in open fields, in understocked forests, beneath less desirable tree species, or on other areas suitable for producing wood crops; where a windbreak for erosion control,windbreaks, or watershed protection is needed; where greater natural beauty is wanted; where a combination of these is desired; or on agricultural lands where mixed farming is practiced (e.g., intercropping, crop sequencing with perennials, or alley farming). Trees provide good soil cover of litter and help build soil organic matter. This increases rainfall infiltration and enhances spring flow, which are important to the island's water supply. Planting should be done in the September-December period.

Specifications

1. Species

The owner's choice of species will be affected by the product he wishes to grow and the economic potential of the site. Adapted species should be planted. Interplanting with the species already established is desirable if adapted to the site and compatible with management patterns.

2. Site preparation

On areas other than old fields or open areas on well-drained soils, some site preparation is usually necessary. Consideration also should be given to bedding. On old fields and other open areas on well-drained soils, no site preparation is usually necessary unless a heavy accumulation of "rough" is present. In areas of heavy "rough", control burn the dry material. Scalping of turf in a 1.5 radius around planting material and cutting of competing shrubs or trees is usually sufficient.

3. Spacing

Pine species planted for production of wood products (pulpwood, sawlogs, etc.) can be spaced 6 feet x 10 feet (725 trees per acre). On severely eroded and other critical areas, terracing and below ground level planting should be considered. Trees planted for natural beauty can be spaced from 6 feet x 8 feet to 12 feet x 12 feet (305 to 908 trees per acre). When interplanting in scattered stands of desirable trees, seedlings should not be planted closer than "inches of diameter at least height expressed as feet plus 10 feet" from existing desirable trees. For example, interplanting should be done not closer than 20 feet from desirable trees averaging 10 inches diameter breast high (DBH).

4. Methods of planting

Machine or hand planting with any tool which will accomplish satisfactory results is acceptable. Planting should be done under optimum moisture conditions, when the soil is neither too wet nor too dry. On St. Kitts it may be possible some years to have adequate moisture conditions during May. However, Sept-Dec is the normal planting season. The following items are important to ensure satisfactory survival:

- Depth of planting--Seedlings should be planted at the same depth or slightly deeper than they grew in the nursery; and

- Condition of the roots--Excessive roots can be pruned to ensure their being as straight down as possible when planted. Care should be taken to prevent roots from being twisted, balled, or U-shaped.

5. Planting method

Planting method can vary depending on land topography, kind of soil, etc. The most common planting method is dug-hole method, with slight variations, such as the center hole, side hole, or bar dug-hole methods. Any of these methods is acceptable, provided that it is the most economical for the individual site conditions and provided that it meets the following minimum requirements:

- The roots are kept moist;

- The roots are straight or well spread in the slit or hole;

- Leaves and other trash are kept out of the hole;

- The tree is set in the ground at the same depth that it grew in the seedbed; and

- Earth is stamped firmly about the roots.

6. Protect all plantation from fire and grazing

In the third month after planting, a survival check should be made to determine what proportion of the trees planted are still living. If any replanting is needed, make it as soon as weather conditions permit and in no case later than the year following the original planting. The percentage of the trees living at the end of one year considered to be satisfactory depends upon the purpose of the planting. For erosion control, where a great deal of volunteer vegetation can be expected a survival as low as 50 percent may be satisfactory. For fence posts and other economic purposes, a survival of at at least 70 percent of the trees is usually considered essential. Lower survival rates than indicated above calls for careful evaluation of site conditions and protection provided before deciding to replant.

Access trails should be kept open and tree stems and crowns should be kept free of undesirable plants, especially those of the climbing type which might cause tree malformation.

TROUGH OR TANK

Definition

A water supply trough or tank, with needed devices for water control and waste water disposal.

Purpose

To provide watering facilities for livestock at selected locations that will supply an adequate livestock water supply and protect vegetative cover through improved distribution of grazing or through better grassland management for erosion control.

Planning Considerations

There is a need for livestock watering places all over Nevis. One of the best ways to ensure proper gain and well-being of livestock is for the animals to have ready access to a good supply of water. Livestock will lose weight if adequate water is not provided. Troughs installed at appropriate places around Nevis can meet this need.

Specifications

The trough or tank should have adequate capacity to meet the water requirements of the livestock for a minimum of a three-day supply. This includes the storage volume necessary to carry over between periods of replenishment. The total number of animals to be served by the trough or tank should be used to calculate the water storage needs.

The average daily water consumption of mature livestock is:

Kind of Livestock	Gallons (US) Per Head Per Day
Beef Cattle and Horses	12
Dairy Cattle	25
Hogs	4
Sheep and Goats	1

The site should be well drained, or if not, drainage measures provided. Areas adjacent to the trough or tank that will be trampled by livestock should be graveled, paved, or otherwise treated to provide firm footing and reduce erosion.

Automatic water level control and overflow facilities should be provided or arrangements made for timely manual control to prevent waste. Valves or pipes shall be protected by shields or covers to prevent damage by livestock. The quality and durability of all

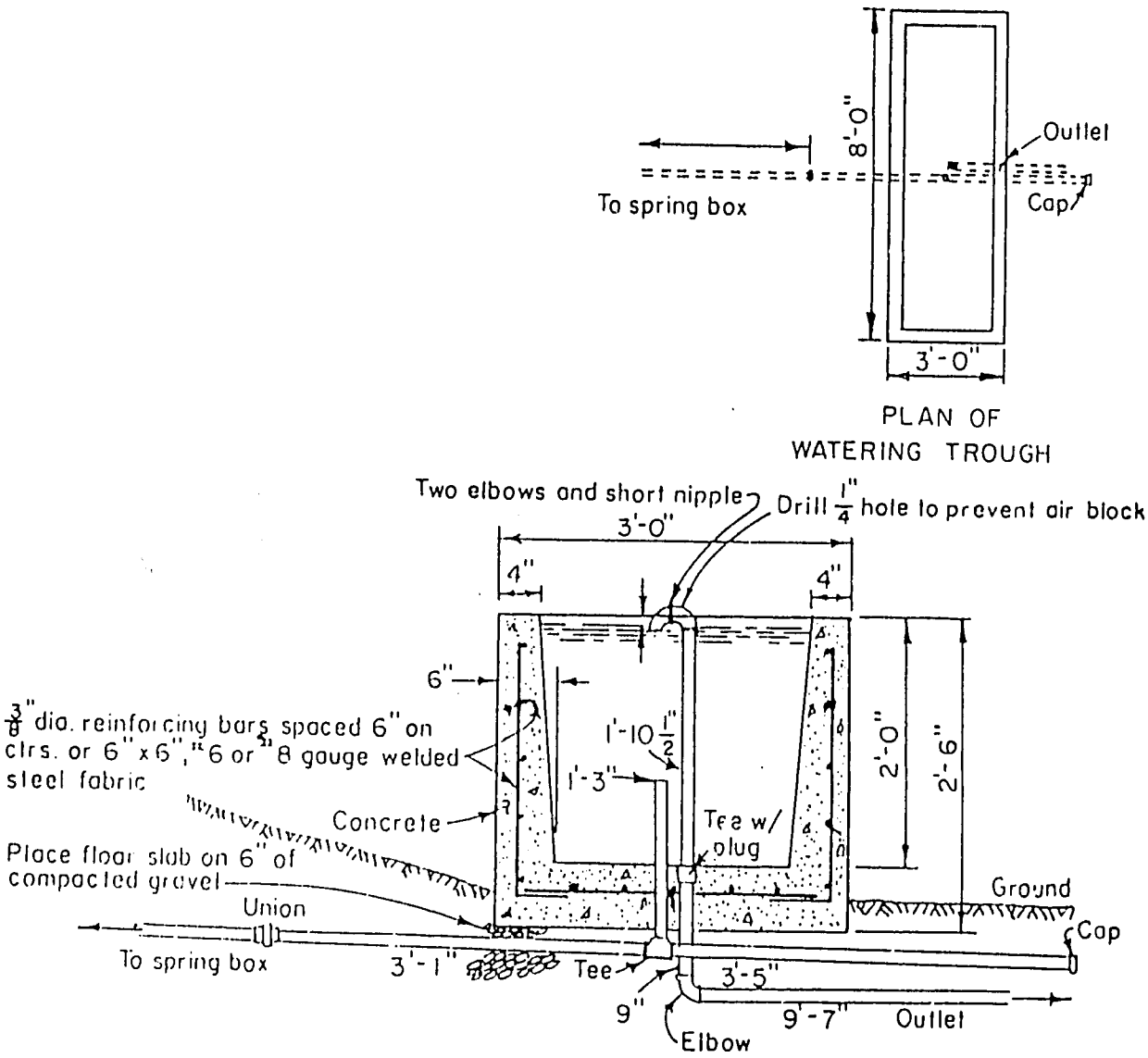
materials should be in keeping with the planned useful life of the installation. Common construction materials are concrete block, reinforced concrete, steel, fiberglass and wood. A typical concrete trough installation is shown in Trough or Tank Figure 1. The same trough or tank may be constructed using reinforced concrete block with holes in blocks filled in completely with concrete. This normal layout may be used with a spring, pond or well.

The foundation area shall be cleared of all material not suitable for the sub-grade. The foundation area and the immediate surrounding area shall be smoothed and graded to permit drainage of surface water. All materials, placement, anchoring, proportioning, and protection shall be as shown on the plans.

All backfill for underground pipes shall be compacted to the degree required to prevent settlement after construction is completed. Regardless of the material used, the tank must be sealed against leakage, the top placed level, and non-toxic materials used. All materials shall be protected as necessary to provide for a reasonable life.

For operation and maintenance, check periodically to see if any type of debris has fallen into the trough which may restrict the inflow or outflow system. Check tank for leaks or cracks and repair immediately if any cracks or wall separations are found. Check the automatic water level device to insure that it is operating properly. Make certain that the area adjacent to the trough is well protected with gravel, paving, or good cover. Be sure that the outlet pipe has a free outlet and is not causing any serious erosion problems.

Algae and iron sludges sometimes are problems in watering facilities. Chemicals such as copper sulfate and chlorine have been used. A short piece of copper pipe is sometimes placed loose in the bottom of the trough to reduce algae growth. Local rules and regulations are to be followed when recommending chemicals.



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Trough or Tank Figure 1: Typical Concrete Trough

May 1987

WINDBREAK, FIELD

Definition

A strip or belt of trees or shrubs established across the prevailing wind direction in or adjacent to a field.

Purpose

To reduce soil blowing; conserve moisture; protect crops, orchards, and livestock from wind and/or salt blast; or increase the natural beauty of an area.

Planning Considerations

Consider the use of trees and shrubs that produce edible products such as fruits, berries and forage. Include legumes as often as possible to enhance soil fertility. Normally this practice will need to be combined with others such as wind stripcropping and crop residue management. To be most effective, field windbreaks should be located at right angles to the prevailing or most damaging winds. However, property lines, other windbreaks, tillage operations, field layout and natural features on the landscape should be taken into account in the design. This practice will be most useful on the windward side of the island, providing protection not only from wind, but from salt spray and sand blowing as well.

Specifications

1. Spacing and growth habit

Spacing and growth habit recommendations for minimum windbreak plantings are given in Windbreak, Field Figure 1. Additional rows of trees or shrubs may be added as desired to a five-row maximum. Where practical, locate shrub rows on the south side of windbreaks running east-west and on the west side of windbreaks running north-south. This allows additional sun to reach the shrub species.

2. Site preparation

Site preparation depends on the species to be used and planting methods. Sites with perennial vegetation and no erosion hazard might only need to be fallowed for three months prior to the major rainy season, and then the tree planting practice can be followed as normal. Sites with crop residues and no erosion hazard may be prepared the same time that the planting is made. Sites with a severe soil blowing or water erosion hazard should use specifically selected species for ease of establishment, and may be protected with perennial vegetation, crop

residues or suitable cover crops prior to planting. Site preparation on sloping land should be limited to small areas at any one time.

3. Planting stock

Plant only viable planting stock from locally adapted seed or vegetative material. Planting stock should be maintained in good condition from time received until planted.

4. Planting

Preference should be given to species that sprout from cuttings or pseudo-cuttings. To ensure proper alignment of rows and spacing, the windbreak should be staked or otherwise marked prior to planting. All bare root plantings should be made during the rainy season, between August 15 and November 15. Containerized stock may be planted at any time with proper care and watering. When hand planting, it is best to use specialized tools, such as planting shovel, dibble or bar. Common tools such as a grub hoe, spike or shovel may be used if adapted to the planting stock and site conditions. Regardless of planting method, the holes or furrows must be wide enough to allow proper placement of roots.

Trim excessive foliage one week before planting. Keep seedlings covered and moist while planting. Plant seedlings in a nearly vertical position with the root collars approximately one inch below the soil surface. Pack soil firmly around planted stock to avoid air pockets.

5. Maintenance

Where plant competition is a problem, control by hand, mechanical or chemical means. Do not disturb or otherwise damage seedlings by improper use of chemicals, tools or machinery. When mechanical cultivation is used, do not cultivate deeper than four inches. As needed, replant until the desired stand is established. Protect the planting from grazing.

Exercise caution when using herbicides as described at beginning of Section 4.

A. Single-row field windbreak

- o Spacing: Trees 3-6 feet apart in row.

x x x x x x x x x

- o Growth habit: Tall growing with thick base foliage

B. Double-row windbreak

- o Spacing: Trees 3-6 feet apart in rows; rows 3-4 feet apart.

x x x x x x x

x x x x x x x

- o Growth habit: 1 row medium height; 1 row tall growing

C. Double-row and shrub windbreak

- o Spacing: Trees and shrubs 3-6 feet apart in rows; shrub row 6-10 feet from trees; tree rows 3-4 feet apart.

x x x x x x x x (shrubs)

x x x x (trees)

x x x x (trees)

- o Growth habit: 2 rows tall growing; 1 row shrubs

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Windbreak Figure 1: Windbreak Spacing and Growth Habit

May 1987

WIND STRIPCROPPING

Definition

Growing wind-resisting crops in strips alternating with row crops or fallow and arranged at angles to offset adverse wind effects. (Includes any herbaceous vegetative wind barrier that reduces wind velocities across a land surface.)

Purpose

To control wind erosion, and to reduce abrasion and wind damage to a crop.

Planning Considerations

Soil damage by wind erosion is a minor problem on St. Kitts. The fairly frequent rains and moderately high amounts of rainfall keep the soil moist much of the time and provide good conditions for vegetative growth. These conditions are not conducive to wind erosion severe enough to damage soil. However, the movement of small amounts of soil coupled with strong wind can damage some crops severely. Vegetables and young cotton are examples of susceptible crops. Fruit bearing trees are also adversely affected by high wind.

Specifications

1. Width of protective strip

The protective strip shall be at least three feet wide when it is broadcast. When the protective crop is planted in rows, at least two rows shall be planted, except one row of sugarcane or elephantgrass is sufficient, provided that voids created by dead plants are immediately replanted.

2. Spacing and orientation of strips

A wind barrier will provide protection for a distance equal to 10 times the height of the barrier on slopes less than 10%. The distance between the protective strips will vary, depending on the slope and the height of the protective planting, erosion tolerance of the crop being grown, and the angle of prevailing winds in relation to the barrier strips. The more the angle of the prevailing wind varies from perpendicular to the barrier strips, the closer together the strips need to be to provide adequate protection.

Wind barriers are most effective when planted perpendicular to prevailing winds. Use the wind direction for the location nearest to where the protective strips will be planted.

3. Plants to use as wind barriers

Suitable plants can be annuals or perennials. Annual barriers are more expensive because they must be established every year, but they allow more flexibility in choosing tillage operations, width of planted strip, and other management decisions.

4. Establishment and management

Prepare a firm seedbed and apply lime and fertilizer based on soil test results. In the absence of a soil test, apply N, P, and K at the rate of 30-30-30 pounds per acre respectively, at planting for grasses. Apply an additional 30 pounds per acre nitrogen to grasses six weeks after planting. For legumes, apply P, and K at the rate of 30 lbs. each at planting.

Plant the barrier strips early enough so they will reach their mature height before planting the crop to be protected. This will ensure that the full width of the tilled strip is protected.

5. Other considerations

Crop or plant residues on the soil surface are very effective in reducing soil blowing. The spacing between protective wind strips may be widened beyond 10 times the height of the barrier if some residue is on the soil surface at planting time.

6. Species and planting information

Species and planting information is given in Wind Stripcropping Table 1.

ST. KITTS SOIL CONSERVATION HANDBOOK

Wind Stripcropping Table 1: Species and Planting Information

Species	Weeks to Maturity	Mature Height (Ft.)	Seeding Rate(lb/ac)	
			Broadcast	Rows
Corn	12-14	8-10		15
Elephantgrass*	14-16	10		**
Millet	10-12	4	30	12-15
Sorghum	10-12	4	20-25	10-12
Sorghum X Sudan hybrids	10-12	10	20-25	12-15
Sugarcane*	18-20	10		**
Guineagrass*	12-14	4-5	7-8	

* Denotes perennial

** Lay stalks lengthwise in a furrow so that the ends overlap by about 1/3 of the length. Cover to a depth of 4 to 5 inches.

ANNEX 1

References

ANNEX 1

LIST OF REFERENCES

References on Soil Resources Management and Conservation available at the Soil Conservation Unit, St. Kitts

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ANNEX 2

Scientific Names of Species Noted in Text

ANNEX 2

SCIENTIFIC NAMES OF SPECIES NOTED IN TEXT

carpet grass (savannah grass)	*Axonopus compressus*
devil grass (common bermuda grass)	*Cynodon dactylon*
elephant grass (Napier grass)	*Pennisetum purpureum*
guinea grass	*Panicum maximum*
pangola grass	*Digitaria decumbens*
saint augustine grass	*Stenotaphrum secundatum*
siratro	*Macroptilium atropurpureum* *Phaseolus atropurpurpeus*
khus khus grass	*Vitiveria zizanioides*

ANNEX 3

Tables

A: Bottom Widths of Diversion Trapezoidal Cross Sections

B: Bottom Widths of Vegetative Waterways Trapezoidal Cross Sections

BOTTOM WIDTHS OF DIVERSION
TRAPEZOIDAL CROSS SECTION WITH 4:1 SIDE SLOPES

Discharge	Velocity for 0.6% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	6	2.1								
30	10	1.8								
40	14	1.8	6	2.2						
50	20	1.7	10	2.0						
60	26	1.7	14	1.9	6	2.5				
70	30	1.6	17	1.8	10	2.3				
80	40	1.5	20	1.8	14	2.1				
90	45	1.5	26	1.8	16	2.1				
100	50	1.5	35	1.7	18	2.1	6	2.8		
120	58	1.5	45	1.6	20	2.1	10	2.6		
140	90	1.4	50	1.6	26	2.1	14	2.5	6	3.0
175	112	1.4	65	1.6	35	1.9	26	2.2	10	2.9
200	129	1.4	75	1.6	50	1.8	30	2.2	20	2.5
250	160	1.4	92	1.6	64	1.8	45	2.0	26	2.4
300	174	1.4	110	1.6	76	1.7	55	2.0	40	2.3

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF DIVERSION
TRAPEZOIDAL CROSS SECTION WITH 4:1 SIDE SLOPES

Discharge	Velocity for 1% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	10	1.4	6	1.6						
30	14	1.4	10	1.5						
40	26	1.2	20	1.3	6	1.8				
50	30	1.2	23	1.3	10	1.7				
60	37	1.2	26	1.3	16	1.6	6	2.0		
70	45	1.2	31	1.3	20	1.5	12	1.8		
80	52	1.2	35	1.3	26	1.4	14	1.8	6	2.2
90	58	1.2	40	1.3	30	1.4	20	1.6	10	2.0
100	64	1.2	46	1.3	35	1.4	26	1.5	14	1.9
120	90	1.1	60	1.3	40	1.4	32	1.5	20	1.8
140	107	1.1	70	1.3	60	1.3	37	1.5	26	1.7
175	137	1.1	90	1.2	74	1.3	45	1.5	32	1.7
200	160	1.1	108	1.2	84	1.3	50	1.5	42	1.6
250	193	1.1	140	1.2	105	1.3	69	1.5	52	1.6
300	231	1.1	170	1.2	119	1.3	86	1.5	63	1.6

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF DIVERSION
TRAPEZOIDAL CROSS SECTION WITH 4:1 SIDE SLOPES

Discharge	Velocity for 2% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	18	0.9	10	1.1	6	1.3				
30	26	0.9	20	1.0	10	1.2	6	1.4		
40	39	0.9	29	1.0	20	1.1	10	1.3	6	1.5
50	52	0.9	36	1.0	26	1.1	19	1.2	10	1.4
60	62	0.9	44	1.0	30	1.1	23	1.2	15	1.3
70	72	0.9	50	1.0	37	1.1	26	1.1	19	1.2
80	83	0.9	59	1.0	42	1.0	30	1.1	22	1.2
90	95	0.9	66	1.0	48	1.0	35	1.1	25	1.2
100	107	0.9	73	1.0	54	1.0	40	1.1	30	1.2
120	132	0.9	88	0.9	64	1.0	48	1.1	36	1.2
140	157	0.9	106	0.9	73	1.0	57	1.1	46	1.2
175	192	0.9	136	0.9	98	1.0	72	1.1	57	1.2
200	222	0.9	158	0.9	114	1.0	83	1.1	66	1.1
250	278	0.9	192	0.9	142	1.0	107	1.1	83	1.1
300	332	0.9	231	0.9	166	1.0	129	1.1	100	1.1

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF DIVERSION
TRAPEZOIDAL CROSS SECTION WITH 4:1 SIDE SLOPES

Discharge	Velocity for 3% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	24	0.8	17	0.8	10	1.0	6	1.1		
30	35	0.8	25	0.8	18	0.9	12	1.0	6	1.3
40	51	0.8	35	0.8	26	0.9	18	1.0	13	1.1
50	65	0.8	44	0.8	33	0.9	25	0.9	17	1.0
60	79	0.8	54	0.8	39	0.9	30	0.9	22	1.0
70	91	0.8	63	0.8	47	0.9	35	0.9	26	1.0
80	103	0.8	71	0.8	54	0.9	40	0.9	30	1.0
90	118	0.8	82	0.8	60	0.9	45	0.9	35	1.0
100	136	0.8	91	0.8	69	0.9	50	0.9	39	1.0
120	161	0.8	111	0.8	83	0.9	62	0.9	46	1.0
140	189	0.8	130	0.8	96	0.8	73	0.9	59	1.0
175	230	0.8	165	0.8	122	0.8	91	0.9	73	1.0
200	261	0.8	192	0.8	142	0.8	106	0.9	84	1.0
250			240	0.0	178	0.8	138	0.9	108	1.0
300					213	0.8	161	0.9	129	1.0

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF VEGETATIVE WATERWAYS
TRAPEZOIDAL CROSS-SECTION WITH 4:1 SIDE SLOPES

10 Yr Discharge	Velocity for 0.6% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	6	2.1								
30	10	1.8								
40	14	1.8	6	2.2						
50	20	1.7	10	2.0						
60	26	1.7	14	1.9	6	2.5				
70	30	1.6	17	1.8	10	2.3				
80	40	1.5	20	1.8	14	2.1				
90	45	1.5	26	1.8	16	2.1				
100	50	1.5	35	1.7	18	2.1	6	2.8		
120	58	1.5	45	1.6	20	2.1	10	2.6		
140	90	1.4	50	1.6	26	2.1	14	2.5	6	3.0
175	112	1.4	65	1.6	35	1.9	26	2.2	10	2.9
200	129	1.4	75	1.6	50	1.8	30	2.2	20	2.5
250	160	1.4	92	1.6	64	1.8	45	2.0	26	2.4
300	174	1.4	110	1.6	76	1.7	55	2.0	40	2.3
350	188	1.4	130	1.6	89	1.7	64	2.0	50	2.2
400	213	1.4	150	1.5	103	1.7	73	2.0	56	2.2
450	240	1.4	168	1.5	114	1.7	98	1.8	62	2.2
500	267	1.4	185	1.5	126	1.7	109	1.8	70	2.2
600			215	1.5	153	1.7	128	1.8	83	2.2
700			246	1.5	180	1.7	149	1.8	99	2.2

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF VEGETATIVE WATERWAYS
TRAPEZOIDAL CROSS-SECTION WITH 4:1 SIDE SLOPES

10 Yr Discharge	Velocity for 1% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	10	1.4	6	1.6						
30	14	1.4	10	1.5						
40	26	1.2	20	1.3	6	1.8				
50	30	1.2	23	1.3	10	1.7				
60	37	1.2	26	1.3	16	1.6	6	2.0		
70	45	1.2	31	1.3	20	1.5	12	1.8		
80	52	1.2	35	1.3	26	1.4	14	1.8	6	2.2
90	58	1.2	40	1.3	30	1.4	20	1.6	10	2.0
100	64	1.2	46	1.3	35	1.4	26	1.5	14	1.9
120	90	1.1	60	1.3	40	1.4	32	1.5	20	1.8
140	107	1.1	70	1.3	60	1.3	37	1.5	26	1.7
175	137	1.1	90	1.2	74	1.3	45	1.5	32	1.7
200	160	1.1	108	1.2	84	1.3	50	1.5	42	1.6
250	193	1.1	140	1.2	105	1.3	69	1.5	52	1.6
300	231	1.1	170	1.2	119	1.3	86	1.5	63	1.6
350	270	1.1	193	1.2	140	1.3	103	1.4	75	1.6
400	308	1.1	219	1.2	160	1.3	120	1.4	90	1.6
450			246	1.2	179	1.3	139	1.4	102	1.6
500			274	1.2	199	1.3	152	1.4	117	1.5
600					238	1.3	182	1.4	142	1.5
700							215	1.4	166	1.5

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF VEGETATIVE WATERWAYS
TRAPEZOIDAL CROSS-SECTION WITH 4:1 SIDE SLOPES

10 Yr Discharge	Velocity for 2% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	18	0.9	10	1.1	6	1.3				
30	26	0.9	20	1.0	10	1.2	6	1.4		
40	39	0.9	29	1.0	20	1.1	10	1.3	6	1.5
50	52	0.9	36	1.0	26	1.1	19	1.2	10	1.4
60	62	0.9	44	1.0	30	1.1	23	1.2	15	1.3
70	72	0.9	50	1.0	37	1.1	26	1.1	19	1.2
80	83	0.9	59	1.0	42	1.0	30	1.1	22	1.2
90	95	0.9	66	1.0	48	1.0	35	1.1	25	1.2
100	107	0.9	73	1.0	54	1.0	40	1.1	30	1.2
120	132	0.9	88	0.9	64	1.0	48	1.1	36	1.2
140	157	0.9	106	0.9	73	1.0	57	1.1	46	1.2
175	192	0.9	136	0.9	98	1.0	72	1.1	57	1.2
200	222	0.9	158	0.9	114	1.0	83	1.1	66	1.1
250	278	0.9	192	0.9	142	1.0	107	1.1	83	1.1
300	332	0.9	231	0.9	166	1.0	129	1.1	100	1.1
350			270	0.9	199	1.0	151	1.0	119	1.1
400			309	0.9	228	1.0	172	1.0	137	1.1
450					257	1.0	196	1.0	155	1.1
500							220	1.0	172	1.1
600									209	1.1

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF VEGETATIVE WATERWAYS
TRAPEZOIDAL CROSS-SECTION WITH 4:1 SIDE SLOPES

10 Yr Discharge	Velocity for 3% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	24	0.8	17	0.8	10	1.0	6	1.1		
30	35	0.8	25	0.8	18	0.9	12	1.0	6	1.3
40	51	0.8	35	0.8	26	0.9	18	1.0	13	1.1
50	65	0.8	44	0.8	33	0.9	25	0.9	17	1.0
60	79	0.8	54	0.8	39	0.9	30	0.9	22	1.0
70	91	0.8	63	0.8	47	0.9	35	0.9	26	1.0
80	103	0.8	71	0.8	54	0.9	40	0.9	30	1.0
90	118	0.8	82	0.8	60	0.9	45	0.9	35	1.0
100	136	0.8	91	0.8	69	0.9	50	0.9	39	1.0
120	161	0.8	111	0.8	83	0.9	62	0.9	46	1.0
140	189	0.8	130	0.8	96	0.8	73	0.9	59	1.0
175	230	0.8	165	0.8	122	0.8	91	0.9	73	1.0
200	261	0.8	192	0.8	142	0.8	106	0.9	84	1.0
250			240	0.0	178	0.8	138	0.9	108	1.0
300					213	0.8	161	0.9	129	1.0
350							186	0.9	152	0.9
400							212	0.9	174	0.9
450									196	0.9
500									216	0.9

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF VEGETATIVE WATERWAYS
TRAPEZOIDAL CROSS-SECTION WITH 4:1 SIDE SLOPES

10 Yr Discharge	Velocity for 5% Slope									
	2.0		2.5		3.0		3.5		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d
20	30	0.7	21	0.7	15	0.8	11	0.9	8	0.9
30	48	0.6	33	0.7	26	0.7	20	0.8	14	0.8
40	65	0.6	46	0.7	35	0.7	26	0.8	20	0.8
50	80	0.6	59	0.7	43	0.7	34	0.8	26	0.8
60	97	0.6	70	0.7	53	0.7	40	0.8	31	0.8
70	115	0.6	82	0.7	62	0.7	50	0.8	36	0.8
80	133	0.6	93	0.7	71	0.7	56	0.8	43	0.8
90	150	0.6	107	0.7	80	0.7	62	0.8	49	0.8
100	165	0.6	120	0.7	89	0.7	70	0.8	55	0.8
120	200	0.6	144	0.7	108	0.7	84	0.8	66	0.8
140			169	0.7	128	0.7	99	0.8	78	0.8
175			220	0.7	160	0.7	127	0.8	98	0.8
200					182	0.7	145	0.8	114	0.8
250					230	0.7	182	0.8	140	0.8
300							218	0.8	170	0.8
350									201	0.8

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

BOTTOM WIDTHS OF VEGETATIVE WATERWAYS
TRAPEZOIDAL CROSS-SECTION WITH 4:1 SIDE SLOPES

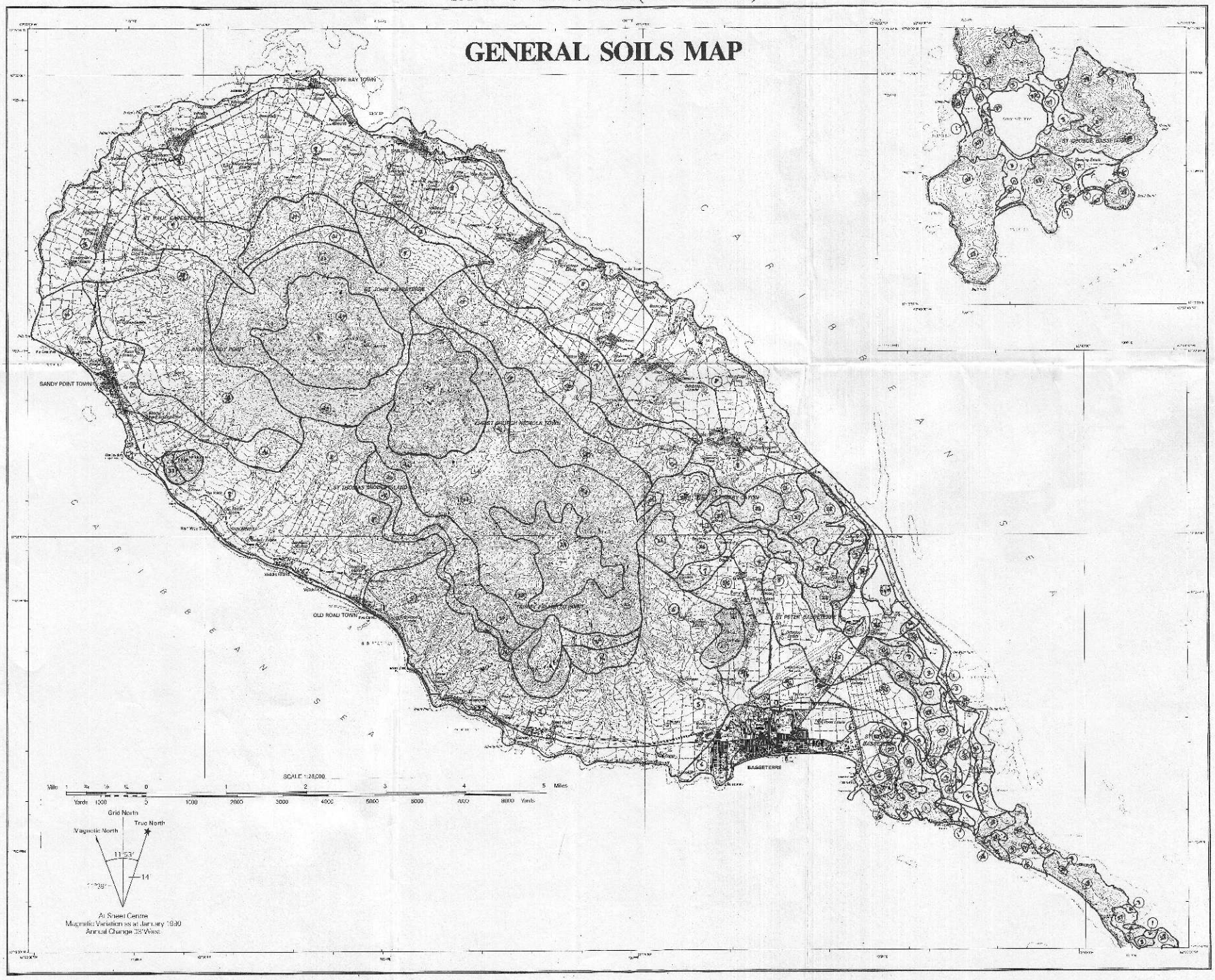
10 Yr Discharge	Velocity for 7% Slope						Velocity for 10% Slope					
	2.0		3.0		4.0		2.0		3.0		4.0	
C.F.S.	b	d	b	d	b	d	b	d	b	d	b	d
20	35	0.6	19	0.6	12	0.7	45	0.5	23	0.6	13	0.6
30	56	0.6	30	0.6	17	0.7	68	0.5	35	0.6	22	0.6
40	74	0.6	40	0.6	24	0.7	90	0.5	51	0.6	29	0.6
50	94	0.6	51	0.6	30	0.7	112	0.5	62	0.6	38	0.6
60	112	0.6	62	0.6	37	0.7	135	0.5	75	0.6	46	0.6
70	132	0.6	72	0.6	44	0.7	158	0.5	88	0.6	54	0.6
80	153	0.6	83	0.6	51	0.7	181	0.5	100	0.6	62	0.6
90	172	0.6	94	0.6	58	0.7	203	0.5	113	0.6	70	0.6
100	190	0.6	105	0.6	65	0.7			126	0.5	78	0.6
120	229	0.6	127	0.6	78	0.7			154	0.5	94	0.6
140			149	0.6	91	0.7			179	0.5	110	0.6
175			187	0.6	113	0.7			223	0.5	140	0.6
200			212	0.6	133	0.7					160	0.6
250			266	0.6	168	0.7					200	0.6
300					201	0.7						
350					235	0.7						

Note: Designed from SCS TP 61
Velocities are for "D" retardance
Flow depths are for "B" retardance
b = bottom width d = flow depth

GENERAL

DIEPPE BAY TOWN
ST PAUL CAPESTERRE
ST JOHN CAPESTERRE
ST ANNE SANDY POINT
SANDY POINT TOWN
CHRIST CHURCH NICHOLA TOWN
ST THOMAS MIDDLE ISLAND
OLD ROAD TOWN
CARIBBEAN SEA
SCALE 1:25,000
Mile 1 ¾ ½ ¼ 0 1 2 3 4 5 Miles
Yards 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 Yards
Grid North
True North
Magnetic North
11°53'
14'
11°39'
At Sheet Centre
Magnetic Variation as at January 1980
Annual Change 08'West

GENERAL SOILS MAP

PN-ABG-700

SAINT CHRISTOPHER (SAINT KITTS)