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Regional planning can facilitate environmental protection and reduce pollution control costs. This subject is the focus of chapter 2 of "Industrial Pollution Control, Technological Strategies" which describes the effects and control of industrial discharges, and technologies for reducing the environmental impact of industrial air and water pollutants. The problem facing regional planners is to design a system to encompass air and water use, water residue management, treatment, and discharge for all industrial, agricultural, and municipal activities in order to supply consumers with quality air and water and to meet sanitary and ecological limitations. This chapter discusses air and watershed basins; general regional planning considerations; approaches to industrial zoning; inter-related problems of water supply, industrial development and wastewater discharges; the significance of environmental stability for industrial siting; and basic regional characteristics which may affect industrial pollution.

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TECHNOLOGICAL STRATEGIES

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BY

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PREFACE

A two-volume study was prepared to provide information relating to the impact and control of environmental pollution from industrial sources. It is intended for the use of government leaders, industrialists, and other concerned individuals who may have widely differing technical and national backgrounds.

Volume I provides background information and reference sources to facilitate general policy decisions relating to the control of industrial pollutants.* Volume II is concerned with the technical application and comparative costs of pollution abatement in manufacturing operations.

Although the purpose of the report is to describe the effects of industrial discharges and their control, it is recognized that other sources of pollution contribute to environmental problems. The problems of pollution abatement, however, are similar wherever they originate. The general principles and control methods discussed in the report will therefore usually be applicable to pollutants from both industrial and non-industrial sources.

* See inside back cover for information on ordering Volume I.

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CHAPTER 1

INTRODUCTION

The primary purpose of this volume is to provide information on commonly used technologies for reducing the environmental impact of industrial air and water pollutants, and to indicate their relative costs for removing different quantities of pollutants from industrial waste streams.

The topics discussed include:

- Pollution abatement approaches which may supplement, facilitate, or replace end-of-pipe treatment processes.
- The potential adverse effects of major air and water pollutants generated by industrial sources.
- Available techniques, processes, and equipment which may be used separately or as parts of a system for removing or reducing pollutants in industrial discharges to the air and water environment.
- Pollutants generated by selected basic industries, and examples of suitable treatment systems for their control.
- Actual pollution abatement practices used by specific industrial plants in three case study industries.
- Related economic data and cost curves.

MINIMIZING POLLUTION CONTROL COSTS

A major objective of industry is to maximize profits. Industrial firms will therefore usually seek the most cost-efficient method of achieving desired or required levels of pollution control. Two related factors should be considered: the need to comply with both present and anticipated future control requirements, and the alternative means by which pollution abatement may be achieved.

The first factor is important because retrofitting can be excessively difficult and costly. Industrial planners should therefore consider the advisability of installing at least the basic fittings for future control devices during initial construction of new plants or additions to existing plants. The actual control devices can then be attached later at minimum cost whenever stricter pollution control programs require their installation.

The second factor is important because consideration of alternative options for pollution control will help in the selection of the most suitable and least costly system of control for an individual industrial plant or operation. Approaches which can advantageously supplement, and sometimes replace, end-of-pipe treatment include: substituting

alternative non-polluting manufacturing processes, modifying existing processes to reduce their polluting effects, substituting less-polluting raw materials, preventing pollution through the recycling and by-product recovery of waste discharges, and appropriate land use and plant siting--especially industrial parks which permit comprehensive, multi-plant pollution control treatment and waste reuse methods.

NATURAL PURIFICATION--PROS AND CONS

Natural cycles involve a combination of physical, chemical, and biological processes which maintain a dynamic equilibrium among organic and inorganic matter, living organisms, and inanimate objects. Major natural self-purification processes include the mixing and dilution of wastes, absorption of particulates and gases by rainfall, adsorption of gases by plants, settling of particulates discharged into the air onto the ground and surface water, precipitation of suspended solids discharged into water bodies onto the bottoms, biological decomposition of organic matter, and chemical conversion of organic and inorganic matter.

Industrial and other pollutants enter natural cycles when discharged into the environment. In most developed regions, however, self-purification processes cannot eliminate all the potential harmful effects of untreated industrial discharges. Some pollutants are generated and released into the environment more quickly than the natural processes can reduce their harmful effects; others interfere with desirable ecological relationships, or have toxic effects which resist or interfere with self-purification processes.

The full impact of some toxic substances may be delayed for years. Certain pollutants, for example, may be concentrated in the food chain by plants and animals, and in their higher forms become highly toxic; or the effects may become evident later or in succeeding generations as a cause of cancer, failure to reproduce, or genetic damage. Other pollutants, such as nutrients (organic carbon or carbon dioxide, nitrogen and phosphorus compounds), may cause an over-development of particular links in natural food chains, with secondary effects which cause environmental degradation. Even small nutrient discharges into a water body may stimulate excessive algal growth and, as a consequence, contribute to eutrophication and resulting damage to fish and other desirable aquatic life. In addition, since even effective self-purification processes generally require considerable time to restore environmental quality, they are of little value in reducing the immediate local harmful impacts of industrial pollutants on nearby human, animal, and plant life.

There has been an optomistic tendency to overestimate the capacity of environmental self-purification mechanisms, and to perceive actual or potential damage as insignificant when compared with the benefits of industrial development. The subsequent damage to important natural systems, however, has pointed up the limitations of natural purification processes, the costs of environmental pollution, and the need to weigh these costs against the costs and benefits of controlling pollution from industrial sources. In general,

therefore, natural self-purification processes cannot be relied upon to control the potential adverse effects of industrial pollutants. Photographs 1-3, 1-4 , and 1-5 show three examples where natural purification failed to make polluted lake water safe for drinking, fishing or recreation.

TYPES OF INDUSTRIAL POLLUTION CONTROL OPTIONS

Figure 1-1 summarizes the basic types of industrial pollution control measures which can be used to protect the environment. A pollution control program may combine all or several. For each basic type of strategy, the report will describe commonly used methods with broad industrial applications. Technological process changes which are very specific to individual industries are multitudinous and beyond the scope of this book.

MEETING POLLUTION ABATEMENT OBJECTIVES

In most countries, protecting the natural environment is either a current objective or is being reviewed as a future national objective. The information provided in this volume can assist industrial planners to develop pollution abatement programs which meet present or anticipated discharge standards. Further helpful information can be secured from appropriate government, industry, and institutional agencies in countries and regions where programs to control industrial discharges are already in effect. Direct observation, personal contacts, and a search of available literature may all be useful. The last chapter of Volume I offers further suggestions on possible sources of information. *

Although the scope of this guidebook is limited to industrial pollutants, most of the discussion and control methods will apply equally well to polluting discharges from other commercial and municipal sources.

* See inside back cover for information on ordering Volume I.

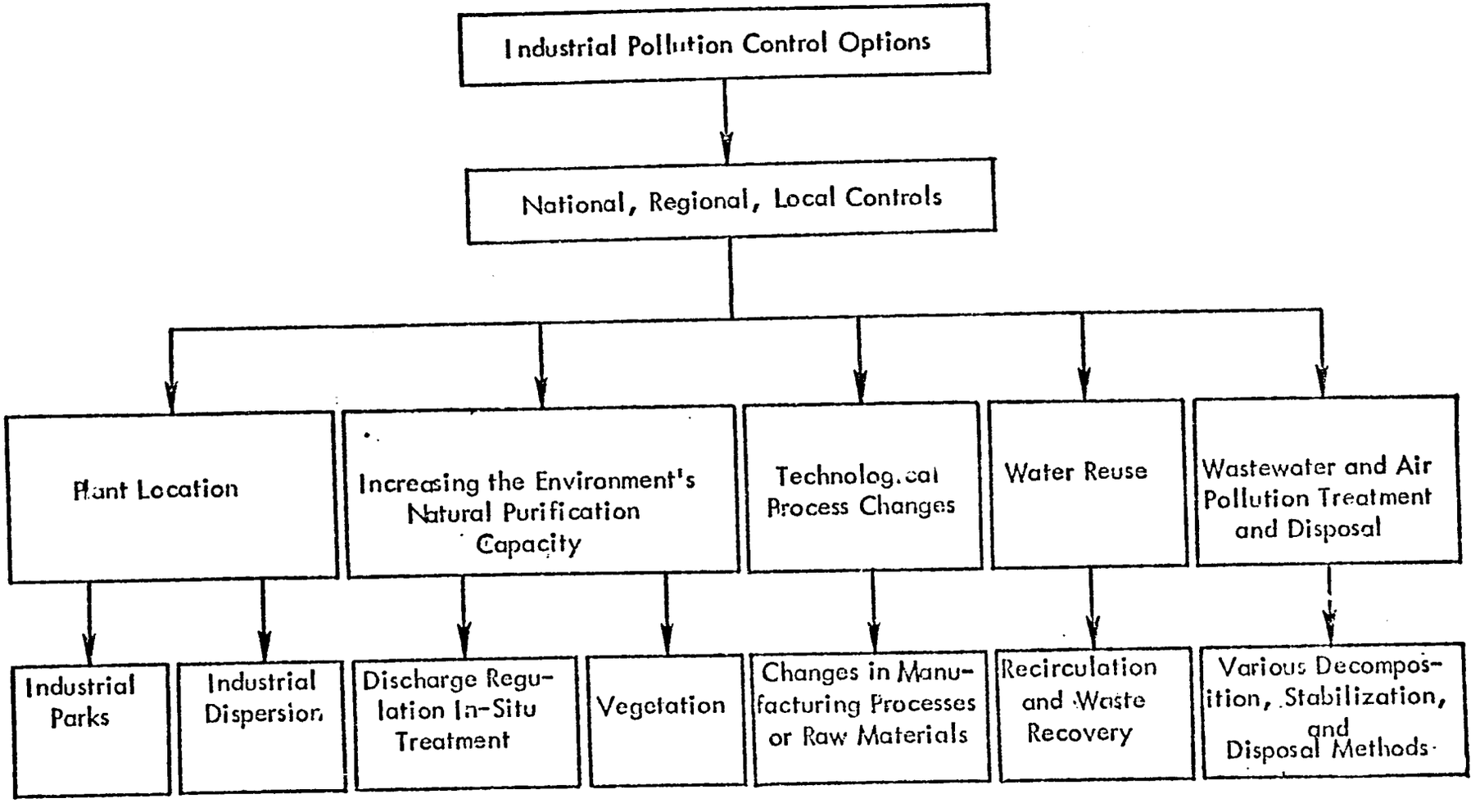

FIGURE 1-1
INDUSTRIAL POLLUTION CONTROL OPTIONS

REGIONAL PLANNING AS AN APPROACH TO POLLUTION CONTROL

April 1977

(Chapt. 2 of Industrial Pollution Control, Technological Strategies)

by

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CHAPTER 2

REGIONAL PLANNING AS AN APPROACH TO POLLUTION CONTROL

Regional planning can facilitate environmental protection and reduce pollution control costs. The problem is to design a system or program encompassing air and water use, waste residue management, treatment, and discharge for all industrial, agricultural, and municipal activities under the following conditions: supplying consumers with water and air of acceptable quality and quantity; meeting all the sanitary and ecological limitations; and minimizing the cost of the whole system.

Planning elements to reduce pollution impacts include: defining the regional air and watershed basins; overall land use zoning; sources of water supply, air and water pollution, and solid waste; pollution control methods; the assimilative capacities of the natural systems; and measures to improve the self-purification processes. Industrial pollutants, solid wastes, control methods, and control costs are the subject matter of Chapters 3, 4, and 5. Domestic, agricultural, and transportation activities and pollutant generation are beyond the scope of this study; they are, however, important elements in regional land use planning for both development and pollution control purposes. This chapter discusses: air and watershed basins; general regional planning considerations; alternative approaches to industrial zoning; inter-related problems of water supply, industrial development, and wastewater discharges; the significance of environmental stability for industrial siting; and basic natural regional characteristics which may affect the polluting impacts of industrial development.

REGIONAL AIR AND WATERSHED BASINS

For effective environmental planning, a planning area should include the entire watershed or air basin. These may not coincide, and either may cross local, regional, or national political boundaries. For example, water pollutants from petroleum facilities near the Persian Gulf will flow from the Persian Gulf into the Gulf of Oman. Air pollution from the same oil processing and storage facilites will concentrate in the Arabian Peninsula, Iran, and over the Persian Gulf. Effective regional planning may therefore require coordinated efforts by several local, regional, or national jurisdictions, including appropriate air and water regulatory agencies.

An air basin for pollution control purposes refers to an area which includes identifiable regional sources and downwind receivers of air pollutants. The distribution of air pollution in the basin depends primarily on prevailing wind patterns, and partially on topography. Pollutants will tend to accumulate in valleys, and to be contained by barrier mountains. Polluted air, however, can flow in any direction, including upwards, and may seep past mountains. Air basins are less clearly defined than water basins because: 1) winds can shift more radically than natural water flow patterns, 2) storms have greater impact on air pollution than on water pollution, and 3) topography and geography have less influence on air currents than on water currents.

A watershed basin is the natural drainage basin for surface water flows. These flows or currents depend on topography and are consistent in direction. Since pollutants discharged to receiving waters will flow along water currents, water pollution is largely confined within the watershed or hydrologic basin.

Both air and water have thermal layering, but the layering (or lateral temperature differences) are less dependable for air than for water. Pollution-causing temperature inversions (denser, cooler layers over lighter, warmer layers) are therefore more common in the air where they frequently contribute to smog conditions. The differences in air and water densities or layers have been used to restrict pollutant spread. They are the basis for using high smokestacks to disperse air pollutants, and low outfalls to confine water pollutants. In fact, there will be mixture and distribution of both the air and water pollutants, making pretreatment important to reduce environmental pollution.

DEVELOPING THE REGIONAL PLAN

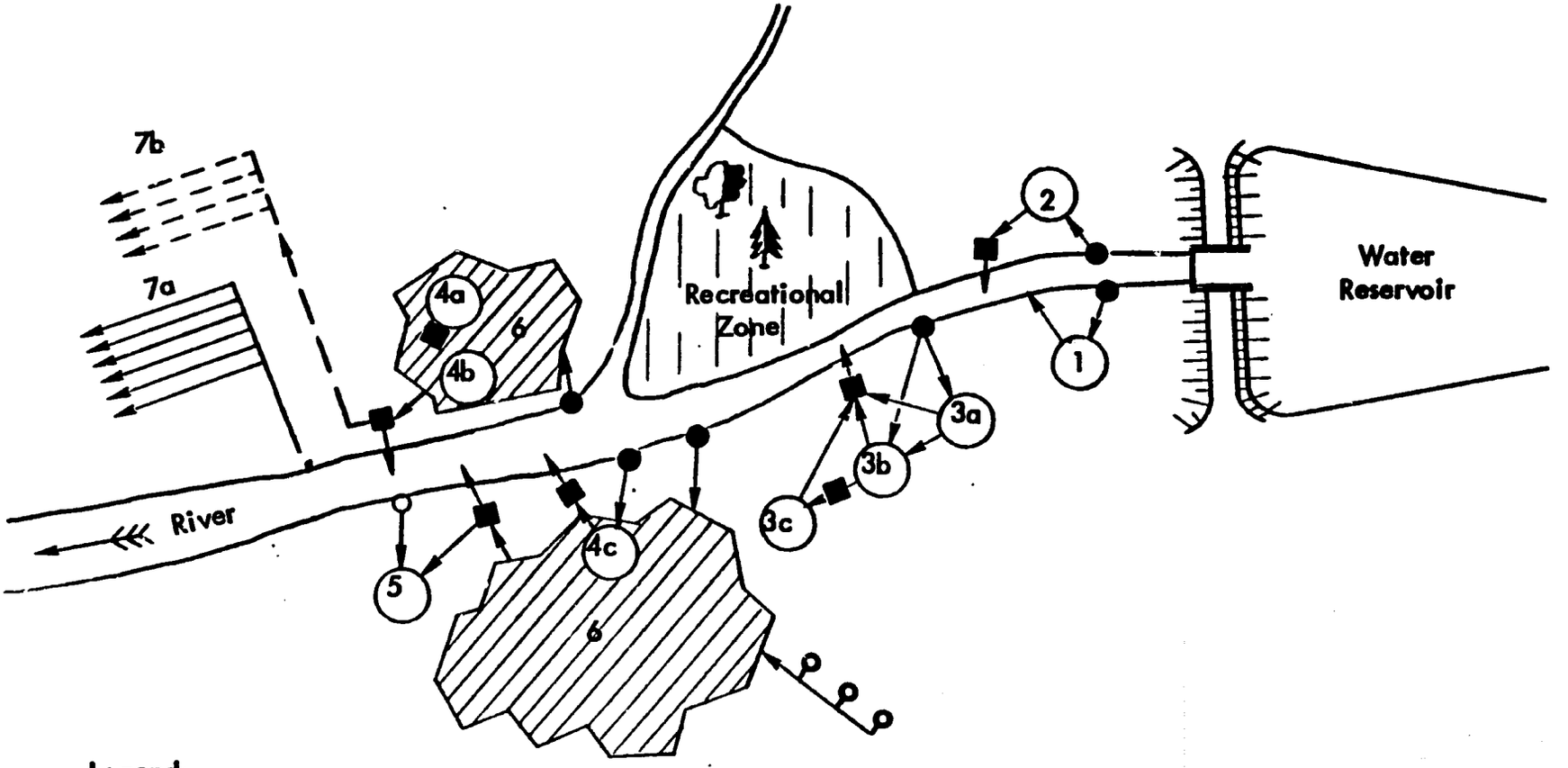
Regional land use planning for industrial pollution control usually involves a complex mix of social, economic, and environmental considerations. The major step in the planning decision process is to develop several alternative schemes for regional development based on a comprehensive evaluation of the available natural resources, manpower, energy sources, transportation and other factors. To evaluate probable environmental impacts, each alternative plan should depict existing and desired locations for industrial plants, agriculture, open space, recreation, residential and other urban uses, and should include a feasible environmental protection program with specific protection measures. Photographs 2-1 and 2-2 show two examples of areas where industrial pollution and development would cause social and economic losses.

The critical first step is to determine anticipated pollution loads, that is, the balances of wastes discharging into the water and air. For all source units (industrial plants, cities, etc.), the water consumption, wastewater effluent and treatment, gaseous emissions and treatment should be determined based on the available technology. The limitations of self-purification and assimilative capacities of the receiving air and water in the appropriate region should also be evaluated as follows: 1) estimate the existing air and water quality before industrial development; 2) determine the minimum level of receiving air and water quality which will be tolerated after construction of manufacturing plants. If a zero discharge level is desired, polluting discharges will have to be controlled so that no significant degradation of air or water quality occurs; if higher levels of pollution are acceptable, they must be defined. Each industrial works should be allowed to use any method or methods that meet discharge requirements, and if innovative methods cost less than conventional ones, the plant could realize an additional profit.

The objective of regional environmental planning is to achieve desired environmental quality and resource conservation at the lowest total economic cost to society. Land use zoning can control the quantity, type, and impact of pollution. For example, Figure 2-1 illustrates a theoretical regional scheme for water quality control. Some plants are

Photographs 2-1 and 2-2

Regional planning can help protect fragile coastal/mountain and farmland areas from industrial or other development which may destroy irreplaceable natural resources such as scenic tourist attractions and prime agricultural land.



Legend:

- o Water Purification and Pump Stations
- ● Groundwater Wells
- ■ Wastewater Treatment Plants
- 1-5 Industrial Plants
- 6 Cities
- 7 Agricultural Fields

FIGURE 2-1
CONCEPTUAL REGIONAL PLAN FOR
WATER USE AND POLLUTION CONTROL

dispersed (1,2,4,5), while others are concentrated (3a, b, c) to form an integrated industrial park. Although plants 4a, b and c are located within cities, not all use the municipal water supply and wastewater systems (4c) or have local treatment plants (4a). Plant 1 discharges some relatively clean water, such as cooling water, with minimum treatment. Irrigation employs both fresh water and treated wastewater. Some plants reclaim treated industrial (3 b,c,) and municipal (5) wastewaters. Plant 5 uses land disposal and has no direct wastewater discharge into water bodies. An upstream reservoir has been constructed to equalize and store the high quality potable water supply and dilute the downstream peak pollutant concentration. Recreational zones and urban areas are separated from the industrial emissions sources (1,2,3) by buffer greenbelts (8). These and other zoning measures have both advantages and disadvantages from an environmental point of view; their major features are discussed below.

Concentration of Industrial Plants Versus Dispersion.

The advantages of industrial parks or land zoning include possibilities for combining water supply systems, centralizing wastewater treatment, and achieving more complete water reuse. The scale economies inherent in larger facilities compared with individual treatment can result in substantially lower costs to each plant. Industrial parks are often formed by related manufacturers (such as mechanical equipment, supply, assembly, and metallurgical plants, or refinery and petrochemical plants) which have similar products, energy sources, water requirements, and waste effluent and air emissions discharges. This facilitates collective pollution control. The close proximity of plants may allow one plant's by-products and recovered waste products to be profitably used as a raw material by another plant. However, unless appropriate pollution control methods are used, discharges from one plant may also interfere with the operations of nearby plants. Industrial parks enable the concentration of industry away from residential zones, tourist areas, or environmentally sensitive regions. Usually they are downstream and downwind from sensitive areas and may be easily separated from them by greenbelts, mountains, or other natural barriers.

The dispersion of industrial plants allows a more even distribution of pollutants for lower concentrations in the environment, and thus may diminish the average pollutant load. This could be an acceptable strategy when large undeveloped land areas are available or where each plant can be included in a future industrial park as development increases. But dispersion of industry is usually not a permanent, long-term means of achieving good environmental protection.

Whether plants form industrial parks or are located separately, sources of air pollution should be separated from residential and recreational zones by greenbelts or other open-space buffer zones, and air circulation enhanced by separating air drainage basins. Wind direction and type of pollutant are important factors in determining the location and size of efficient greenbelts (Figure 2-2) or other barriers. In certain areas, wind patterns, land costs and availability, and other factors may limit the applicability of greenbelts or other natural barriers.

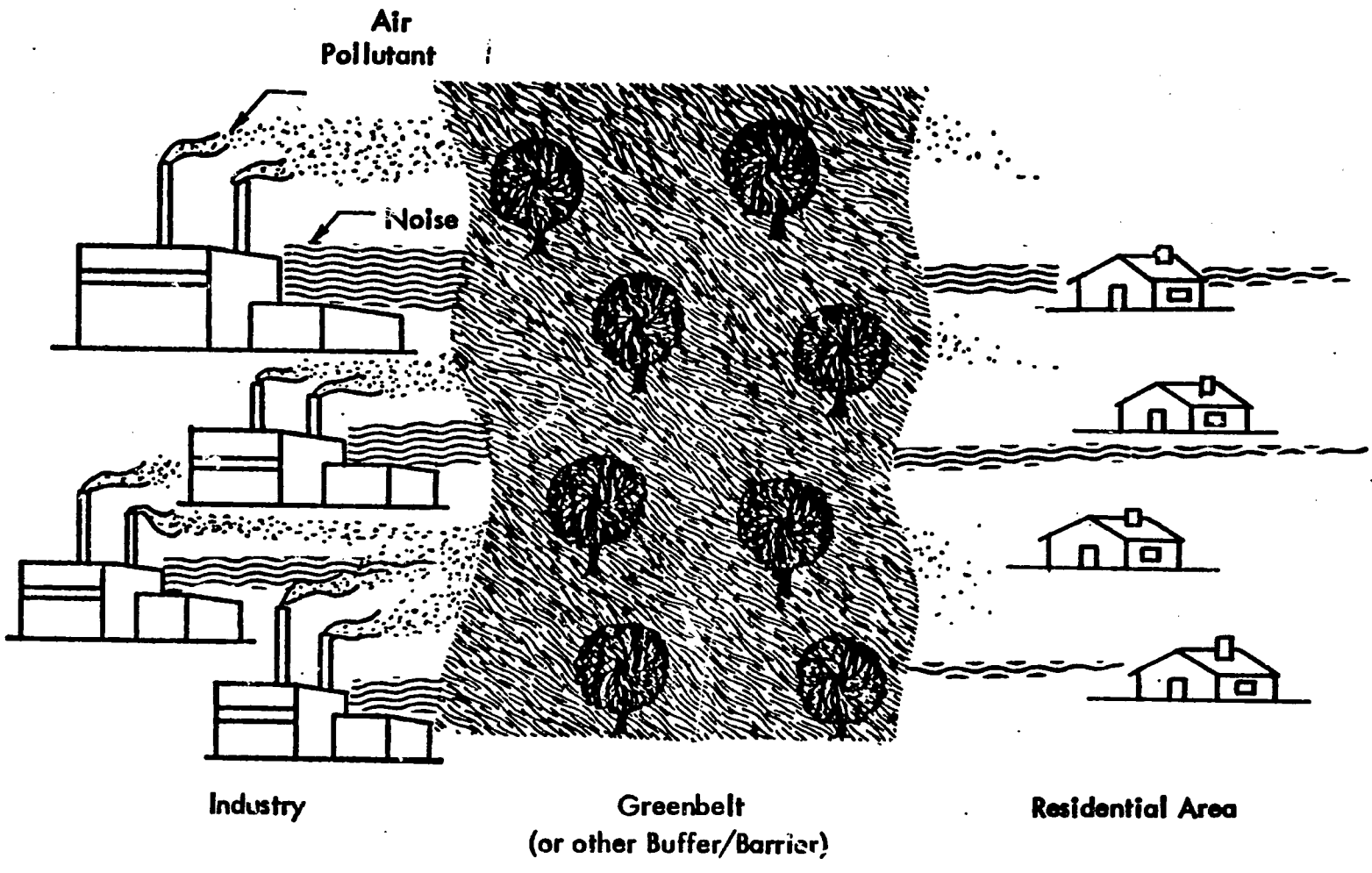


FIGURE 2-2
GREENBELT BARRIER

Locating plants where there is improved air circulation can help disperse air pollutants and reduce peak, localized concentrations. Establishing air drainage sheds is one method of doing this. Air drainage sheds should extend beyond the air pollution sources toward the directions from which winds are anticipated during temperature inversions (Figure 2-3). Polluting industries should not be permitted in urbanized air drainage corridors.[45] High-rise buildings should also be prohibited within air drainage sheds (where they would obstruct local wind movements), and along their edges (where they might create a wind tunnel effect which would increase local wind speed excessively).

Industrial Plants in the City.

Every town or city is a relatively complicated subsystem of the regional system and its own local problems and requirements for industrial plants, including those related to air and water. Some industries (such as food processing, pharmaceutical, and other light industries) consume water of high potable quality. Since the quantity of water consumed is not large, municipal water may serve as a source, although it may require additional pre-treatment. Other industries (such as power plants and many chemical manufacturers) can consume large quantities of both high and lower quality waters. They usually have some separate on-site water supply, collection treatment and disposal systems.

Wastewater Treatment. The municipal sewer system and wastewater treatment facilities may be used by industrial plants located near a city, provided their wastewater discharges meet municipal requirements. Specific components or excessive concentrations in their industrial waste effluents which cannot be removed at the municipal treatment plant should be removed by in-plant pre-treatment facilities. The plant can use any feasible means to meet local discharge standards, whether by end-of-the-pipe treatment or process alterations. For example, machinery plants including electroplate processing usually prefer in-plant wastewater pre-treatment in order to remove cyanides and heavy metals from their end-of-the-pipe discharges. The latter wastes are sometimes recovered and reused.

Table 2-1 shows typical maximum effluent concentrations of trace elements and other wastewater components which should not be exceeded to allow for normal secondary biological treatment processes. Some toxic organic compounds may have adverse effects on a municipal waste treatment plant; some are biodegradable, some are not, and others may be toxic in either low or relatively high concentrations. For example, phenols are biodegradable, but their decomposition is a relatively slow process, and at high concentrations (approximately more than 50 mg/l) they interfere with normal biological wastewater treatment processes. Textile dyes are often slowly degrdable in biological processes. They may be partially adsorbed by micro-organisms but a conventionally treated final effluent may still be highly colored. Oil and grease in concentrations above 30-40 mg/l may be similarly hard to treat. Many other industrial wastes require special handling.

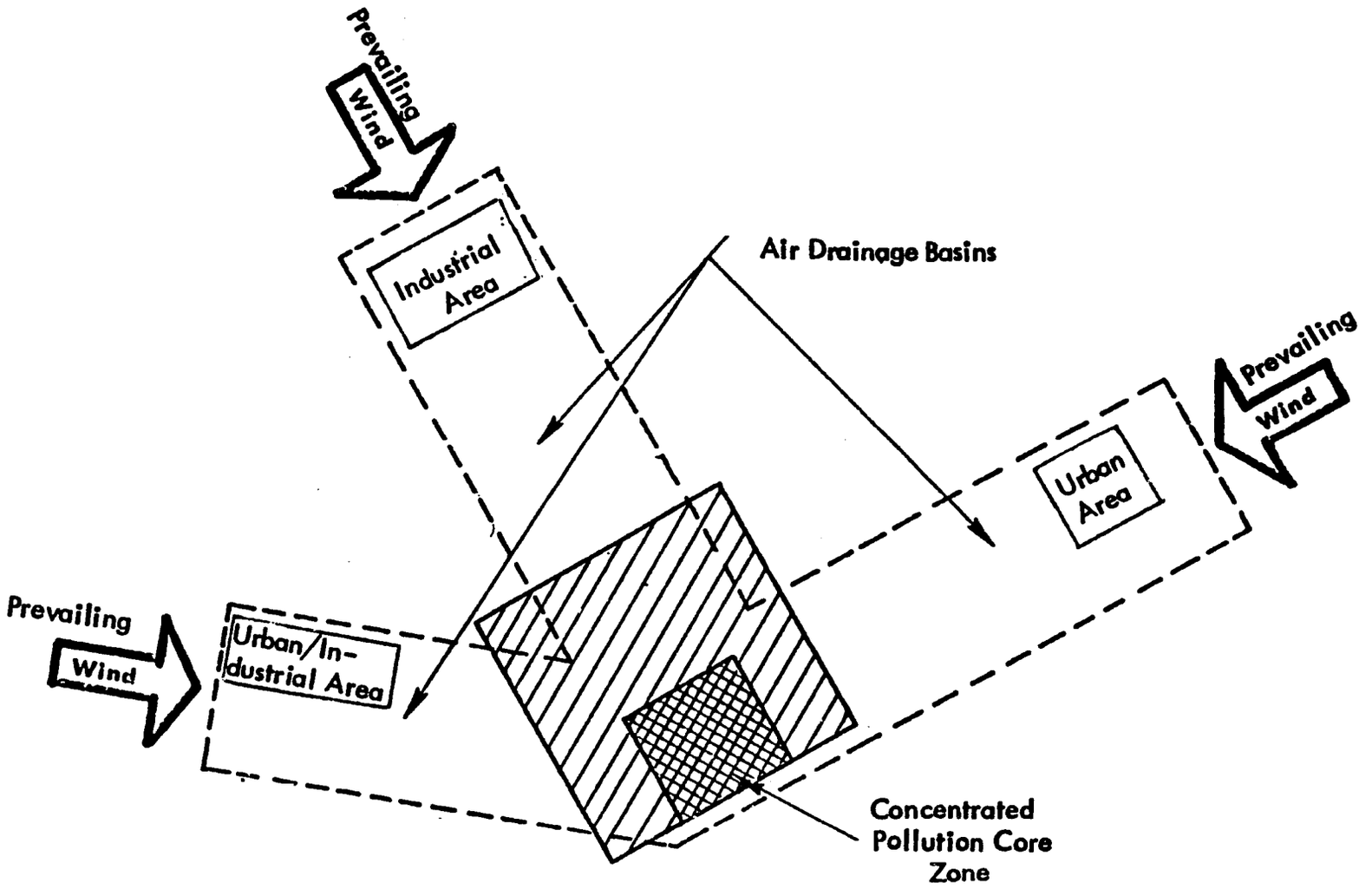


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FIGURE 2 - 3
AIR BASINS

TABLE 2-1

ESTIMATED MAXIMUM INORGANIC CONCENTRATIONS FOR BIOLOGICAL TREATMENT OF INDUSTRIAL EFFLUENT

Component	Valency	Concentration (mg/l)
Beryllium	2	0.01
Boron	3	0.05
Vanadium	2	0.1
Bismuth	5	0.1
Bismuth	3	0.5
Iron	2	0.5
Iron	3	5.0
Cadmium	2	0.1
Potassium cyanide	--	2.0
Cobalt	2	1.0
Copper	1	0.5
Copper	2	0.2
Molybdenium	6	5.0
Arsenic	3	10
Sodium metasilicate	2	10
Nickel	2	0.1-1
Mercury	2	0.01
Lead	2	0.8
Selenium	4,6	10
Antimony	3	0.5
Antimony	5	0.5
Tetraethyl lead	--	0.001
Titanium	4	0.1
Chromium	3	6
Chromium	6	0.1
Zinc	2	10

The most important wastes should be identified in each plant and their discharge appropriately limited. Industrial wastes may be evaluated by their COD (chemical oxygen demand) strength. A desirable limit for industrial wastewater COD is approximately 500 mg/l, and about half should be removed in the final treatment processes. Some industrial plants in arid regions may use treated municipal wastewater as their major or sole reclaimed source of industrial water supply. More detailed information on this application is provided in Chapter 3.

Air Emissions. Problems of industrial air pollution in the city may be mitigated by location of manufacturing plants on the leeward borders of residential zones, and their separation by greenbelts or other air drainage barriers. Appropriate end-of-pipe gaseous discharge standards may be required to achieve air quality control.

WATER SUPPLY SOURCES

Location of Water Intake and Wastewater Discharge.

Although there are exceptions, plant water intakes are usually located upstream and effluent discharges downstream. In a region with many water intakes and waste discharges, water quality in natural water bodies varies both along the stream length as well as in cross-section. Proper placing of intakes and discharges may, therefore, reduce the extent of water purification before consumption, since there can be dilution of wastewater by the river water, and some self-purification. For example, in order to avoid the dirtier water along a stream bank, a water intake may be located above the bottom and near the midstream. Accelerated mixing of wastewater discharged into the river flow may be achieved by spacing wastewater outlet diffusors at several points in the receiving zone, or by using a special mixing device, such as a venturi nozzle.

Improving Natural Conditions.

Many arid regions have a limited water supply which restricts their economic development. Critical shortages of water supply for municipal, industrial, and agricultural users have led to such large-scale programs as: pumping and transmission systems which cross watershed boundaries; construction of reservoirs to regulate seasonal and long-term flow; recharge and storage in groundwater;and plant forests for reducing water runoff and improving air pollution control. Such large-scale projects usually have several objectives, including improvement of environmental conditions as well as regional development. Other examples of improvement projects include desilting by dredging natural water bodies, artificial aeration of river and lake waters, channeling to accelerate flow, and regional treatment facilities.

ENVIRONMENTAL STABILITY

Fragile Environments.

Some environments are unsuitable for industrial development because they are extremely fragile, and any change could cause deterioration. Examples include arctic and alpine

tundra, deserts, steep mountains, and small oceanic islands. Special problems related to tundra are: (1) melting of permafrost leading to unstable foundation conditions and overloading of the drainage and groundwater systems; (2) disruption of the short growing season food chains, thereby threatening many fauna and flora species; and (3) extreme exposure of the ground surface to wind. Problems prevalent in desert areas include: (1) pollution of groundwater by increasing the recharge area, thereby leaching alkaline salts out of the soil; (2) permanent defacing of the appearance of the land, (3) increasing erosion, especially due to wind, by removing what little groundcover exists. Problems associated with small oceanic islands may be related to the force extinction of their rare indigenous species caused by disrupting the short food chains. Small islands may have low environmental carrying capacities and, consequently, their potential for disruption is high.

Certain aquifer recharge areas and areas of natural hazard are suited for development if the environmental carrying capacity is not exceeded. A different sort of problem occurs when the recharge area is significantly increased by removing groundcover and thus decreasing the soil permeability. This could also result in reduced groundwater recharge and related salt buildup. Locating an individual plant on a recharge area may present only minor problems of groundwater pollution; developing many plants such as in an industrial zone, however, could significantly affect local groundwater.

Steep mountains can be readily eroded and their shallow soil cover lost, thus upsetting the ecology of the region. Mountainous areas with steep slopes are suited for development only if adequate precautions are taken to decrease the risk; care should be taken not to increase erosion through changes in the drainage runoff patterns, and not to increase foundation instability due to cutting, filling, or flooding. Landslides and foundation failures may result if these precautions are not observed.

Stable Environments

Large, relatively flat areas are generally suitable for low-cost industrial development since they can provide a high environmental carrying capacity (the amount of disruption a natural environment can tolerate before an irreversible change occurs), and minimum transportation and other supply problems. These environments should have complex, stable food webs, diverse large-scale fauna and flora populations, low or moderate slopes, relatively stable natural drainage, and deep soils with suitable foundation bearing strength.

BASIC NATURAL CHARACTERISTICS

Regional planning to protect environmental quality should consider the area's unique natural characteristics. The following basic natural factors may influence the potential environmental impacts of industrial siting, construction, discharges, and pollution control methods. A few examples of their respective importance are cited.

Bedrock Geology.

Bedrock, or the solid rock underlying all soil, will largely determine the types of raw materials available in the region, groundwater quality and quantity, building site foundations, agricultural productivity of the soil mantle, and to some extent, the topography resulting from the different erosion susceptibilities of rocks.

The structure of the bedrock is defined by the location of the formations and the type and degree of deformation to which they have been subjected. Topography probably expresses the most obvious effect of geological deformation in an area.

The extent, permeability, and location of sedimentary deposits or rock fractures will influence the groundwater flow. It is especially important to know the locations of active faults in a seismically active area. Knowledge of a region's bedrock geology is also important for deep well waste disposal injection, underground water supply pumping, and many other activities and impacts related to groundwater. Bedrock geology is important for mining since the economics of a particular deposit are dependent on location, quantity, and quality.

Climate.

Two ways in which climate affects the regional environment are: (1) the present day climate will greatly influence the distribution of pollution discharges, particularly those released into the atmosphere; and (2) through time, the climate has acted upon the bedrock to produce a soil mantle, which in turn influences the vegetative cover and the environmental pollution carrying capacity of an area. The three major parameters defining an area's climate are precipitation, wind, and temperature. Important climatic considerations include: their seasonal and daily variations; the direction of movement of precipitation and wind; and any special aspects of particular areas (such as length of time between killing frosts, frequency of flooding during rainy seasons, frequency of dust storms, or air inversions, etc.). Climatic conditions will largely determine the impacts of all pollution: its dilution by air and water, biological/chemical stabilization, and other parameters in natural cycles. Climatic data are therefore important in evaluating the impacts of industrial pollutant discharges.

Topography.

Although bedrock structure determines gross topographic features, climate alters the bedrock by erosion and weathering. An accurate topographic map is needed for effective regional planning. Any significant local features (such as landslides, steep slopes, drainage basins, lakes, etc.) should be noted, since these are constraints for plant site selection and optimal land use planning. Topography will also determine the possibility of using a gravity network for wastewater discharges, and appropriate siting of treatment plants to take advantage of gravity flow or prevailing winds.

Soils.

Soils are highly influenced by man's activity--often irreversibly. A regional soil survey should give a detailed presentation of soil types, variations in physical properties, and locations. Major properties that should be considered are the soil's permeability, triaxial shear and dynamic strength, organic and chemical content, erosion problems, capabilities, and its uses, both present and optimal. The location and degree of present soil erosion can indicate current problem areas and the types of erosion that new facility

construction may cause. Erosion problems are likely on steep slopes, flood plains, stream beds, and areas where vegetation is lacking and where exposure is great, such as ridge-tops or new construction areas. The chemical and biochemical properties of soil are important factors in determining a site's suitability for wastewater treatment and land disposal.

Groundwater.

Once soluble pollutants are introduced into the groundwater, it may be difficult to stop their spread or to remove them. Extensive pollution of groundwater can preclude its use for drinking water. (See Figure 2-4). Important parameters of the groundwater system are: the depth of the water table, including seasonal variation; chemical content; location of important aquifers and their recharge areas; yield and pumping head (artesian or unconfined); direction of underground flow; and present or optimal future uses of the groundwater. In many areas, groundwater can be divided into two classes on the basis of depth. Shallow groundwater systems (< 30 m depth) are those in which the aquifer is generally within the soil mantle. Artesian pressure is absent, the chemical quality is variable, the concentration of dissolved solids is usually high, yield is variable and is influenced to a great degree by the rainfall, and the recharge is spread over a large area. The uses of shallow groundwater systems are largely limited to irrigation, but in some areas they may also be an important source of drinking water.

In deeper groundwater systems (> 30 m depth), the aquifer may be in sediments or even bedrock. Artesian pressure may occur, and the deep groundwater chemical quality may be more stable than shallow systems. Recharge is usually localized in the upland or piedmont zones. The deeper groundwaters are the primary industrial and municipal supplies, since they generally yield larger flows.

Surface Water Resources.

In assessing the possible impact of an industrial plant on surface drainage, it should be realized that damage to a surface water body may be irreversible, and that a water body is almost always a multiple-use natural feature. To this end, base data on stream volumes and behavior variations are often important for their environmental assessment.

Graphic stream characterization can provide a basis for predicting the impact of discharged waste effluents. Surface water streams flowing over a recharge area should be noted, since discharge into such areas may introduce pollutants directly into the groundwater system. To minimize data requirements, only the important streams in a region, or those most likely to be associated with industrial development, might be described in detail. This description should be a section-by-section analysis of the chemistry, temperature, flow rates, erosion problems, flood plains, frequencies of flooding, and existing pollution problems. The water uses (recreational, water supply, fishing, commercial) in an area should be evaluated.

Flood plains are often wetlands in humid or semi-humid areas. These areas act as storage reservoirs for excess runoff drainage and also provide wildlife habitats. Wetlands are

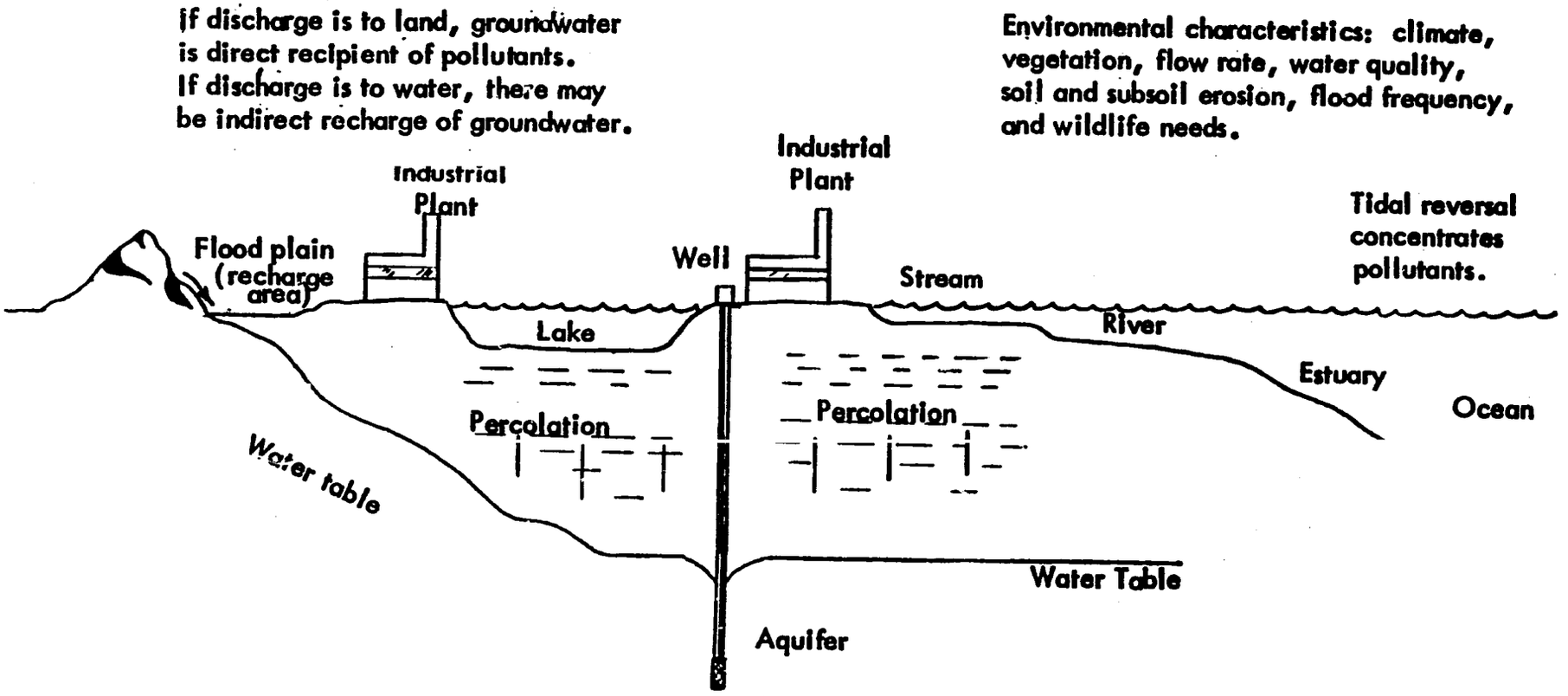

FIGURE 2-4
INDUSTRIAL POLLUTION DISCHARGE IMPACTS ON WATER RESOURCES

important to the environmental quality of a region. Draining and filling wetlands disrupts water use patterns by adversely affecting the swamp area habitats. Wildlife dependent on wetland habitats are frequently nearly eliminated when they lose their feeding and nesting areas.

Stream characteristics relevant to plant siting decisions are dependent on the portion of the stream being considered. At a stream's headwaters, problems may be associated with variable and often insufficient flow, flooding, erosion, entrenching, blockage, and easily disrupted wildlife populations. Along the midsection of streams, typical characteristics for many rivers are: insufficient flow rate (especially where population density is high), slow flow speed which causes silting, and secondary pollution by organic and nonorganic materials as a result of the silting. At the mouth of streams in estuaries, a major consideration is flow reversals caused by salt water tidal action. Effluent discharged into an estuary travels both down and upstream depending on tide conditions. Pollution carried out into the ocean may return to damage beaches, since pollutants in estuaries can react with dissolved ions in the more saline oceanic environment.

The considerations of locating an industrial plant beside a lake or ocean are different from those for streams. In streams, the major problem is transport of the effluent away from the location of the plant; in a lake or ocean, it is the possible buildup of pollutant concentrations so that the environmental carrying capacity is exceeded. Accelerated eutrophication or pollution may result in polluting beaches and fishing/recreation areas. Hence, industrial plant pollution is a major concern near water bodies having multiple uses.

An important parameter for lakes is the existing degree of eutrophication. Eutrophication is a natural process of aging characterized by three variables: (1) an increase in biomass potential and a decrease in biological diversity; (2) an increase in biological oxygen demand (BOD); and (3) at times a depletion in dissolved oxygen (DO). The rate of eutrophication is controlled by the nutrient quantities present. Excessive introduction of these nutrients as pollutants can cause unchecked eutrophication and eventual conversion of a lake to a swamp and land area. Many important gamefish, such as trout, salmon, and sturgeon, die when their oxygen requirements cannot be satisfied because of the nutrient impact.

In some cases, industrial plants not located near a lake or stream may indirectly disrupt surface drainage by increasing or changing drainage runoff rates. This is particularly evident when the topography and permeability of an area is changed during construction.

Vegetation and Wildlife.

Adverse impacts on vegetation and wildlife could result in decreased recreational opportunities, lowered economic benefits, and increased runoff when vegetative cover is removed, and paved areas are created. Developed communities may absorb such adverse impacts to a greater degree than immature ones, since they have developed flood/drainage control systems. A location map of local vegetation and animal

distributions can show an area's relative development. Any trends in biotic distribution or successional pattern should also be noted. The commercial value of various natural species can act as a constraint in industrial plant site selection. Unique or rare species may have to be protected. Any particular relationships with soils, groundwater, or surface drainage should be noted, since impacts on these areas will also affect associated species. The sensitivity of native vegetation and animal life to allowable air/water pollutants should be determined before locating a factory.

FOR FURTHER READING

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