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1.1 INTRODUCTION

Increasing amounts of forest and grass lands in the U.S. Virgin Islands are being converted to housing, roads, and commercial and industrial land uses each year. These construction activities take place on many different kinds of topography and soils, each having different properties and limitations. Such activities and land uses alter natural water flow paths and seepage of water into the soil (change hydrology) and increase erosion and sedimentation, damaging the environment. Ecosystem degradation also results from poor land clearing and landscaping practices that negatively impact plants, wildlife, soil, and water resources. Large-scale removal of vegetation reduces wildlife habitat, promotes soil erosion and sedimentation, and threatens biological diversity. Construction along ridge lines and in guts (intermittent streams) is rapidly depleting moist forest habitat and changing microclimates in the territory.

Increased runoff causes severe erosion and more frequent flooding and has created serious problems in many areas of the Virgin Islands. Eroding road beds and cut slopes (e.g. behind houses or next to roads) cause costly property damage. Sediment and other pollutants run off uphill construction sites, roads, parking lots and other land areas and are deposited along roadways, in guts, on lower-lying property, and in ponds and coastal waters, polluting surface and ground water.

Decreased water seepage into the ground (infiltration) also reduces the islands' critical fresh water supply. As paved areas increase, the amount of rainfall that seeps into the soil and into ground water is decreased. This reduces the water available for plant growth and as ground water for public consumption. In order to provide fresh water to the growing population of the Virgin Islands, and to ensure healthy terrestrial ecosystems, it is critical to retain as much rainwater as possible within the ground, in guts and in other surface water bodies.

The beauty and health of the Virgin Islands' environment is vital to the health and well being of all Virgin Islanders. Many residents enjoy the islands' beaches and coastal waters for swimming, bathing, snorkeling, diving, sailing, and fishing. The Virgin Islands fishing industry depends upon healthy coastal waters and reefs for its livelihood. Many residents also use native plants for cultural or medicinal purposes. However, these uses and environmental health, in general, are often considered to be secondary to the development process. Ugly raw excavation scars remain long after land development has been completed. Coastal water quality has been steadily deteriorating due to the influx of sediment, sewage and other pollutants. The health of the coral reefs is correspondingly declining. Many native plants and animals have become rare, threatened or endangered. This degradation is a long-term threat to the Virgin Islands economy, especially since that economy is dependent upon its environmental health and beauty to attract tourism, the largest industry.

Concern for the environment, including plant, soil and water resources, was made a matter of public policy through passage of the Soil and Water Conservation District Law and the Environmental Protection Law of 1971, as amended. The Environmental Protection Program, overseen by the Virgin Islands Department of Planning and Natural Resources (DPNR), promulgates rules and regulations in accordance with the Environmental Protection Law in order to "*...prevent improper development of land and harmful environmental changes*" (VIDCCA, 1979). This Program includes comprehensive erosion and sediment control measures applicable to both public and private developments, including the construction and maintenance of streets and roads. These rules and regulations are modified as necessary to meet the requirements of new Federal Programs.

1.2 STORMWATER RUNOFF, EROSION AND SEDIMENTATION PROCESSES

Stormwater runoff and ***erosion*** are natural processes that occur in the environment. However, as human activities alter the landscape, adverse impacts to receiving waters (guts, ponds, bays and other coastal areas) may result from changes in the quantity and quality of stormwater runoff. If left unmanaged, the ***hydraulic*** impacts (flooding, erosion, channelization) associated with increased stormwater runoff can be significantly higher than that of undisturbed areas. In addition to causing flooding, this stormwater is also a major ***nonpoint*** (diffuse) pollution source.

Nonpoint source pollution of water resources comes from many sources and is caused by rainfall moving over and through the ground. As the rainwater moves, it picks up and carries away pollutants such as sediment, excess nutrients, bacteria and other pathogens, oil and grease, and other toxic materials. These pollutants are then deposited onto roadways and downhill properties, and into guts, ponds wetlands, ground water, and coastal waters. Nonpoint source pollution in the Virgin Islands results from construction activities, urban runoff, failing septic systems, marina and recreational boating operations, and agriculture.

Urbanization (the conversion of rural areas or open spaces to suburban, commercial, or industrial land uses) typically results in changes to the physical, chemical, and biological characteristics of a ***watershed*** (or drainage basin). A watershed is the area of land that drains water, sediment, and other pollutants to a common outlet along the coastline (bay, lagoon or other coastal area, see Figure 1.1). The physical processes by which construction and other urban activities adversely affect water volumes and quality are ***stormwater runoff***, ***erosion*** and ***sedimentation***. Each of these processes has different impacts upon receiving waters.

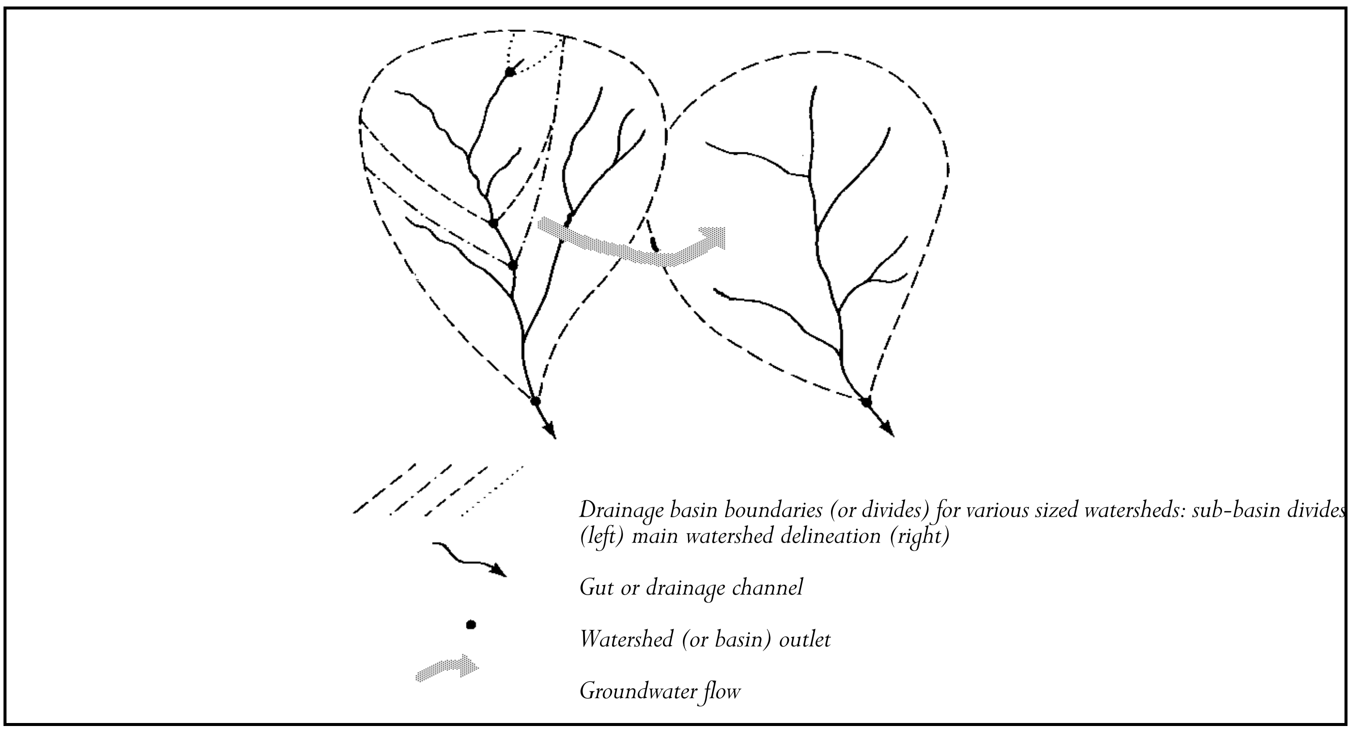

Figure 1.1. Watersheds (or drainage basins) and their boundaries (Dunne and Leopold, 1978).

1.2.1 Stormwater Runoff

Natural vegetated and open forest areas are ***pervious*** areas – under natural conditions, rainwater that falls on these areas seeps into the soil and does not run over the land surface. Vegetation (trees, grasses, bushes and other ground covers) slows rainfall, natural depressions temporarily hold water, and the humus layer of the forest floor absorbs rainfall. Plants also reduce raindrop impacts on the soil surface, reducing the detachment and erosion of soil particles through raindrop splashing (Donahue, Miller, and Shickluna, 1983). During development and urbanization, however, the soil's plant cover and humus layer are stripped from the land by clearing and grading. These activities increase the amount of rainwater that runs off the land surface as ***stormwater runoff***. When pervious areas are converted to ***impervious*** land uses (housing, roads, parking lots, or commercial areas) the amount of vegetation (and therefore the perviousness of the land) is decreased and stormwater runoff volume and velocity increases. Therefore, rain falling onto the surface of unmanaged, urbanizing watersheds results in a predictable increase in the quantity of runoff flowing to coastal waters (see Figure 1.2).

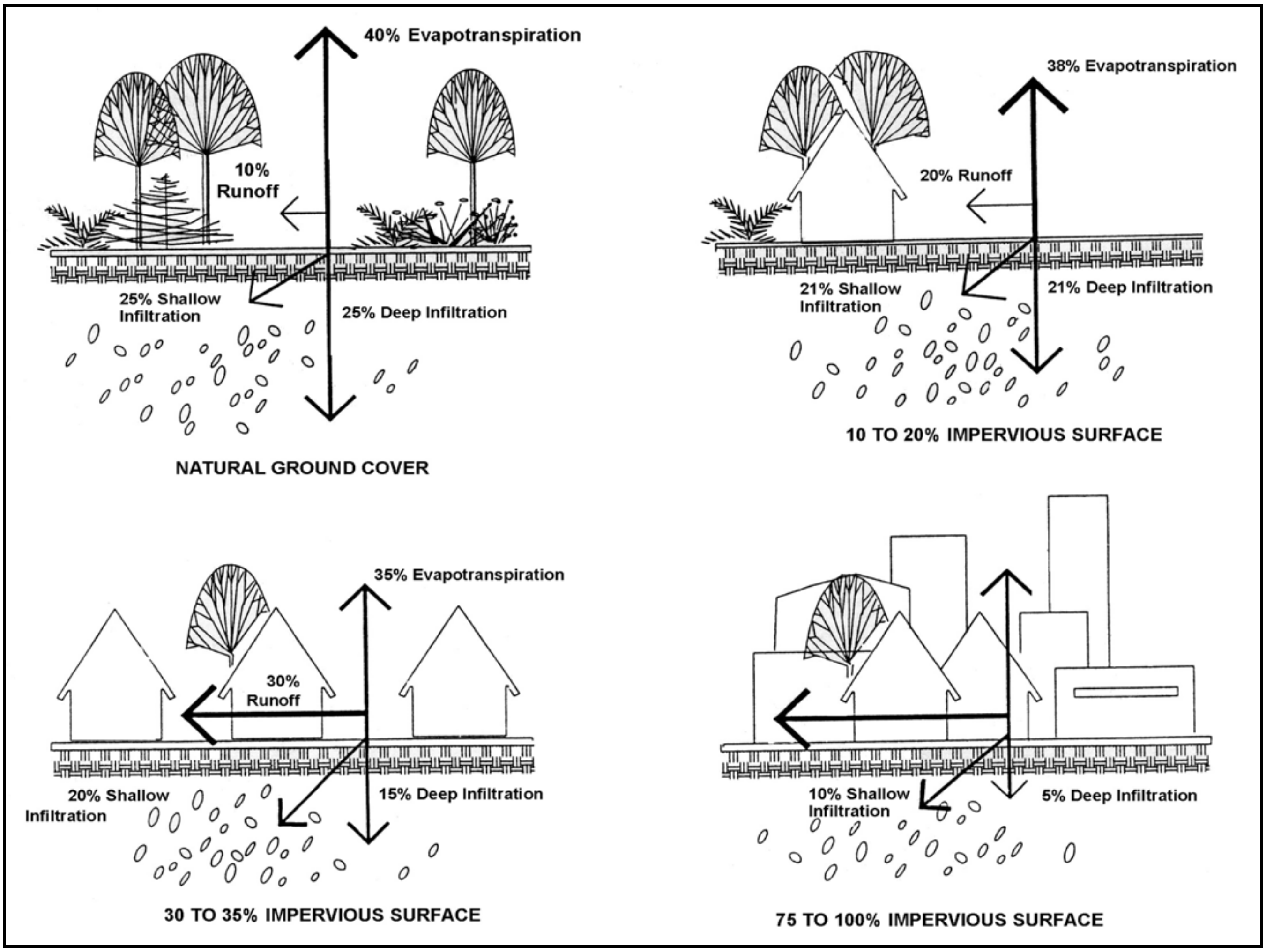

Figure 1.2. Water cycle changes associated with urbanization and resulting increases in impervious surfaces (*Arnold & Gibbons, 1998*).

1.2.2 Changes in Hydrology

The great increase in stormwater runoff due to urbanization changes the ***hydrology***, or the natural water movement, of the watershed. Hydrologic changes in a watershed are magnified after the completion of construction. Impervious surfaces prevent rain seepage into the soil, resulting in much increased volumes and speed (rate or velocity) of runoff. Control of higher stormwater flows requires the construction or "improvement" of runoff culverts, swales or other stormwater channels or the modification of existing drainage systems to avoid erosion of gut banks and steep slopes. The hydrologic changes in drainage channels or natural guts resulting from urbanization include:

- Increased peak runoff discharges two to five times pre-development levels;
- Increased volume of stormwater runoff produced by storms (a moderately developed watershed can produce 50% more runoff than a forested watershed during the same storm);
- Increased frequency and severity of flooding;
- Greater runoff velocity during storms; and
- Reduced water levels in soils, guts, and aquifers due to the reduced level of infiltration in the watershed. This change in the hydrologic cycle (Figure 1.3) can result in microclimate change in small, insular, tropical island ecosystems, such as the Virgin Islands.

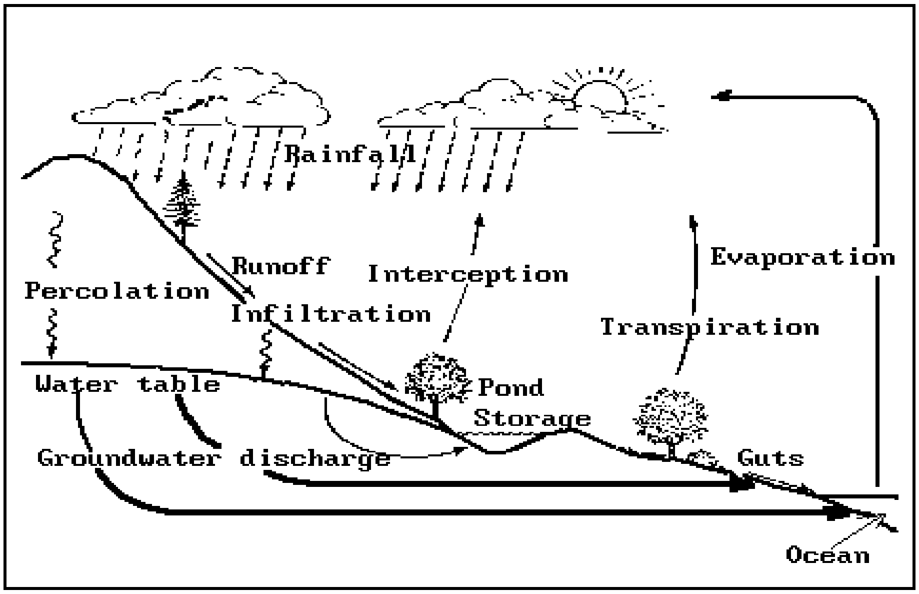

Figure 1.3. The hydrologic cycle (modified from Dunne and Leopold, 1978).

1.2.3 Erosion

Increased stormwater runoff volume and velocity results in increased ***erosion***. Water erosion is the loosening and removal of soil particles from the land surface by running water. The rate of erosion is directly related to stormwater runoff velocity and volume. There are many different types of erosion: raindrop, sheet, rill, gully, and stream channel erosion. Removal of vegetation from the land surface during construction and other land-clearing activities increases all these types of erosion. (Erosion can also be caused by wind – many wind erosion control practices are similar to water erosion control practices.)

The primary factors affecting erosion are rainfall intensity and frequency, soil characteristics, vegetative and other surface cover, topography (slope), climate, and aspect (i.e., degree of exposure to sun and tradewinds). Rainfall ***intensity*** (the volume of rainfall in a given time period) and slope steepness are the most significant factors affecting erosion. Soil physical factors (texture, structure) that affect infiltration capacity and soil detachment and transport are also important. Plants help to reduce erosion by intercepting rainfall and reducing raindrop energy, slowing runoff velocity, holding soil in place with roots, and improving soil porosity.

1.2.4 Sedimentation

Sedimentation occurs when eroded soil particles suspended in stormwater runoff are deposited onto flood plains, roadways or downhill properties, or into guts, ponds and coastal waters. Sediment can travel either suspended in runoff water or it can travel along the ground surface or the bottom of a channel or gut. Suspended sediment in stormwater runoff is the largest pollutant, by volume, in Virgin Islands' waters. Factors affecting sedimentation include runoff velocity, soil particle size, drainage channel roughness, and flow obstructions. Obstructions in the path of runoff water and rough channels slow runoff, causing sediment to settle to the bottom of the channel, gut or pond. Soil particle size and weight also affect sedimentation: finer particles (clays) will stay suspended in runoff water for a longer period of time and will travel farther than larger, heavier particles (like sands).

1.3 POLLUTANTS AND THEIR IMPACTS

As the population density of an area increases, there is a corresponding increase in pollutant loadings generated from human activities. Pollutant export increases dramatically both during and after development. During construction, soils are exposed and large amounts of sediment, along with attached soil nutrients and other pollutants, can run off into surface waters if proper erosion and sedimentation controls are not used. Once a construction site is stabilized, pollutants accumulate rapidly on impervious surfaces and are easily washed off. The primary pollutant carried by stormwater runoff is sediment. However, many other pollutants are transported to coastal waters by stormwater runoff: excess nutrients, harmful bacteria and viruses, oil and grease, and heavy metals and other toxic substances. The primary source of many of these pollutants is from the atmosphere (car and truck emissions), building surfaces and paving materials, and vehicles (Schueler, 1987). Some of these pollutants, such as nutrients, heavy metals, and hydrocarbons, also travel attached to sediments. Pollutants typically enter surface water through untreated stormwater runoff. The overall effect of development results in a 10-fold increase in the amount of pollutants entering surface waters (after Schueler, 1987).

1.3.1 Sediment

Sediment is the most prevalent pollutant, by volume, polluting surface waters in the U.S. Virgin Islands. Uncontrolled construction site sediment loads have been reported to average 35 to 45 tons/acre/year in the continental United States (Novotny and Chesters, 1981). However, a 1986 study of erosion rates on St. Thomas and St. Croix estimated erosion from a disturbed dirt road site to be 591 tons/acre/year (Wernicke, Seymour and Mangold, 1986). Studies of erosion rates in the Fish Bay watershed on St. John have soil loss from dirt roads of between 100 to 600 tons per year (MacDonald, et. al., 1997; Sampson, 1997).

Sediment has many short and long term harmful impacts on aquatic ecosystems. These include: increased turbidity, reduced light penetration (which inhibits coral and seagrass growth), reduced prey capture for sight-feeding fish, clogging of gills and filters in fish and shellfish, reduced spawning and juvenile fish survival, and decline of commercial and recreational fishing success (Schueler, 1987). Heavy sediment deposition in coastal waters smothers seagrass beds and coral reefs, increases sedimentation of channels and harbors (requiring more frequent dredging), changes bottom composition, and leads to loss of use for recreational purposes (such as swimming and snorkeling) (U.S. EPA, 1993). The primary cause of coral reef degradation in coastal areas is attributed to land disturbances and dredging activities due to development activities (Rogers, 1990). Additional chronic effects may occur where there are sediments rich in clay or organic matter (as is frequently the case in the Virgin Islands). Heavy metals and other toxic pollutants can tightly attach to soil particles. When these contaminated sediments settle to the bottoms of ponds, bays, channels and lagoons, they present a continued risk to aquatic and benthic life (organisms that live in the sediments at the bottom of bays, estuaries, and other waterbodies), especially when the sediments are disturbed and resuspended (U.S. EPA, 1993).

1.3.2 Nutrients

Excess levels of ***nutrients*** (particularly nitrogen and phosphorus) that runoff to coastal waters cause an imbalance in the natural nutrient cycle, leading to unwanted and excessive algae growth. This process is called ***eutrophication*** (Arms and Camp, 1988; Dunne and Leopold, 1978; Miller, 1982). Excessive algae growth uses up dissolved oxygen in the water and results in decreased fish, coral, and seagrass populations, and in extreme cases, can result in fish kills and widespread destruction of benthic habitats. Algal blooms can also cause discoloration and odors, cover water surfaces depriving aquatic organisms of light, and clog waterways. Surface algal scum and the release of toxins from sediment may also occur.

1.3.3 Bacteria, Viruses and Other Pathogens

Stormwater runoff from residential, commercial, and industrial areas usually contains levels of ***bacteria*** and other harmful (pathogenic) organisms (viruses, parasites) that exceed public health standards for water-contact recreation or seafood consumption. The presence of pathogens in runoff may result in beach closings for recreational uses due to public health hazards, as well as contaminated fish and shellfish catches. In the Virgin Islands, beach closures frequently occur due to sewage bypasses. However, as more stringent water quality monitoring is put in place, it is very likely that more beach closures will occur due to contamination by bacteria, viruses and other pathogens.

1.3.4 Petroleum Hydrocarbons (Oil and Grease)

Most of the oil, grease and other petroleum hydrocarbon pollutants found in stormwater runoff come from car and truck engines that leak oil and other fluids. Therefore, hydrocarbon levels are highest in stormwater runoff from parking lots, roads, and gas stations. Some do-it-yourself auto mechanics also dump used oil directly on the ground, in guts, or into storm drains. Petroleum-based hydrocarbon levels in surface waters are often high enough to kill aquatic organisms.

Oil and grease contain a wide variety of hydrocarbon compounds. Some of these are known to be toxic to aquatic life at low concentrations, and many are human carcinogens. Hydrocarbons also tend to collect in bottom sediments where they may persist for long periods of time and result in adverse impacts to benthic communities. Waterbodies with poor circulation (such as enclosed marinas) are particularly susceptible to this phenomenon.

1.3.5 Heavy Metals and Toxic Substances

Heavy metals and other toxic materials found in stormwater runoff are of concern because of their poisonous effects on aquatic life and their potential to contaminate ground water. Copper, lead, and zinc are the most common metals found in stormwater runoff (many come from trucks and cars). A large amount of the metals present in stormwater runoff are attached to sediment. Metals and toxic compounds that enter coastal waters can accumulate in the tissues of fish and shellfish, harming human health.

1.4 PROPER PLANNING

Proper planning recognizes that land is a limited resource and has many physical variations that need to be considered prior to development. Proper planning provides for the conservation and wise use of soil, water, plant and other natural resources. Use of this publication, along with the *Soil Survey of the Virgin Islands* (USDA-NRCS, 1995; USDA-SCS, 1970, http://www.statlab.iastate.edu/soils/soildiv/surveys/virgnis.pdf) to get information about the particular site, including soils and erosion and sediment control information, is one of the first steps to proper planning.

1.4.1 Land is a Limited Resource

Primary consideration must be given to critical habitats and environmentally-sensitive areas (coastal areas and wetlands such as guts, salt ponds, and mangrove lagoons) when planning for development. Available farmland must also be considered in the process. Developments that result in irreversible land use changes represent a loss of valuable resources. The long-term impacts of land conversion on the quality of the Virgin Islands' remaining natural ecosystems and coastal water resources, as well as to the productive capacity of our farmland, should be evaluated.

Most of the land in the Virgin Islands (St. John, St. Thomas and the North Shore of St. Croix) is steep and very susceptible to soil erosion and sediment loss. Since constant development pressures are making this resource more and more valuable, it becomes increasingly evident that future developmental pressure is going to be on steeper, more erodible soils. Therefore, careful assessment of the land as a natural resource base is a necessary first step toward planning the future development of an area. Development must be carefully adjusted to that base if serious environmental problems are to be avoided.

1.4.2 Know Your Soil

One of the first steps in sound development planning is to know the soils and select the best possible site for the use intended. Soil properties have a strong influence on the way that people use and should use the land. With the limited flat land in the Virgin Islands, and much of that subject to flooding, development will increase on the steeper upland areas. Soil properties of each parcel need to be determined prior to development to prevent costly mistakes.

The use of the *Soil Survey of the Virgin Islands* is a necessity in planning for development. The Soil Survey is a basic inventory of the soil resources of the islands. The survey includes soil maps, soil descriptions, and soil interpretations. It can be used as a tool in determining soil limitations for many suburban and urban uses and in selecting sites and designing structures to minimize environmental and soil-related problems. Digital copies of the text of the *Soil Survey of the Virgin Islands* revised in 1995 can be found and downloaded from: http://www.statlab.iastate.edu/soils/soildiv/surveys/virgnis.pdf. Maps can be obtained digitally from the UVI Conservation Data Center, or the USDA-NRCS Caribbean Office in Puerto Rico.

1.5 ORGANIZATION OF THIS HANDBOOK

Chapter 2 discusses planning strategies and practices that can be used during development planning phases. Before development occurs, land in a watershed is available for a number of pollution prevention options, such as setbacks, buffers, or open space requirements. Siting requirements or restrictions and other land use ordinances, which are highly effective in reducing pollution, are also more easily implemented during this period. If development has started before these practices can be implemented, then these options may not be practicable or cost-effective.

Chapter 3 presents practices to control construction-related erosion and soil loss (sedimentation). The implementation of proper erosion and sediment control practices during construction can significantly reduce erosion of valuable topsoil and damage associated with sedimentation.

Chapter 4 presents practices to control stormwater runoff from new and existing development. Practices such as detention ponds or constructed wetlands that treat stormwater runoff are most easily implemented in new projects where their design can be incorporated into the overall development plan. After development has occurred, the lack of available land severely limits the implementation of cost-effective treatment options. This chapter also presents information on improving pollution prevention through controls that reduce stormwater runoff and pollution generated from ongoing residential and commercial activities.

Chapter 5 provides information and examples for estimating soil erosion from proposed construction activities using the Revised Universal Soil Loss Equation (RUSLE) developed by the USDA Natural Resources Conservation Service (USDA-NRCS Caribbean Area, 1995).

Chapter 6 provides information on use of TR55, a computer model that uses the USDA-SCS Curve Number method to predict stormwater runoff from development sites.

The Handbook also includes a number of appendices. Appendix A provides a Glossary of terms used in this handbook. Appendices B and C provide design and construction specifications for erosion and sediment control practices and stormwater practices, respectively, that are presented in the Handbook. Appendix D contains existing Territorial legislation for the control of erosion, sedimentation, and stormwater runoff from development. This legislation is modified, as necessary, to meet the requirements of any new Federal Programs. Finally, Appendix E is a list of References used to develop this Handbook.

1.6 PURPOSE OF THIS HANDBOOK

The prevention and control of nonpoint pollution from construction activities and other sources in coastal areas require comprehensive solutions to protect and enhance coastal water quality. This handbook will supersede the Virgin Islands Environmental Protection Handbook printed in 1976 (VICD, 1996) and updates the 1995 Revised Handbook (Wright, 1995). You will find many new practices in this handbook that reflect the growing body of knowledge regarding stormwater, runoff and sedimentation control. Many studies conducted following the development of the 1976 Handbook have refined the information available regarding the impacts of nonpoint pollutants from construction sites and other developing areas and the effectiveness and limitations of control practices. The U.S. Environmental Protection Agency has also promulgated new rules, regulations and guidance governing stormwater discharges from construction and urban areas, including the NPDES (National Pollution Discharge Elimination System) Stormwater Rules of 1990 and the 1993 Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters that may apply under certain conditions. This handbook was developed using the most current information available regarding practices to control or prevent nonpoint pollution from urbanizing areas.

The Environmental Protection Handbook is intended for use **only** as a **guide** to the reader, indicating what practices, standards, and procedures should be utilized in the development planning process in order to comply with the Virgin Islands Environmental Protection Legislation, Title 12, Chapter 13 of the Virgin Islands Code and the corresponding Virgin Islands Rules and Regulations. It is designed to assist contractors, developers, architects, engineers, draftsmen and home builders implement a Stormwater, Erosion and Sediment Control Plan specifically designed for their construction site.

The handbook provides useful information on stormwater, erosion, and sediment control practices that can be used to prevent or reduce the discharge of sediment and other pollutants in stormwater runoff from your construction site. It also describes the practices and controls, and details how, when and where these practices are applicable. However, careful consideration must be given to selecting the most appropriate control measures based on site-specific conditions, and on properly installing the controls in a **timely** manner.

The drawings presented in this Handbook are samples derived from publications developed by Federal, state and local agencies regulating erosion and sediment control. These drawings are used for example purposes **only**, they are not intended to be extracted for Erosion and Sediment Control Plans without prior review by a licensed engineer and/or architect before construction.

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