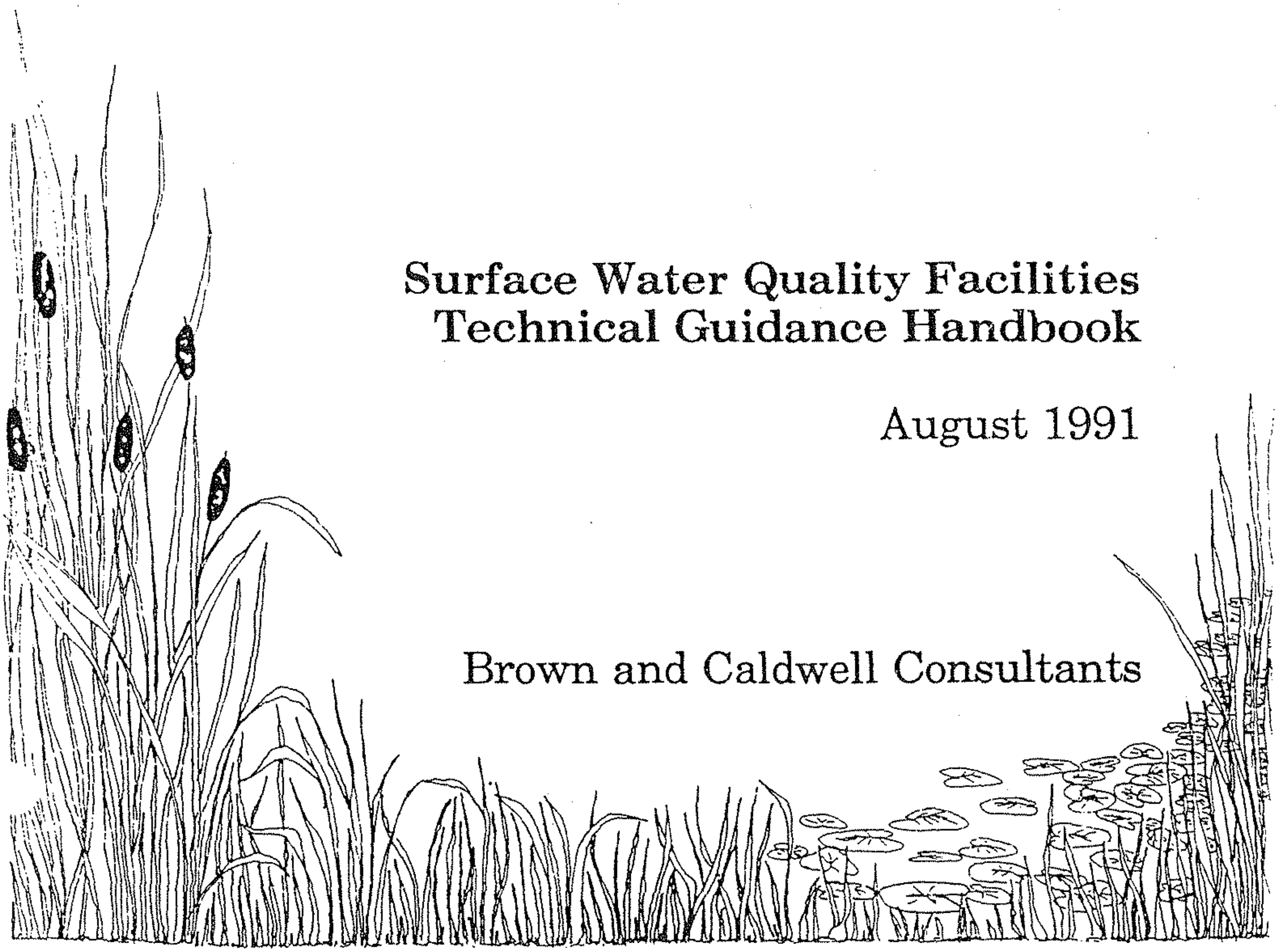
PORTLAND
LAKE OSWEGO
CLACKAMAS COUNTY
UNIFIED SEWERAGE AGENCY

Surface Water Quality Facilities Technical Guidance Handbook

August 1991

Brown and Caldwell Consultants



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INTRODUCTION AND SUMMARY

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INTRODUCTION AND SUMMARY

This chapter summarizes the technical guidance handbook and introduces its format.

PURPOSE

The purpose of this technical guidance handbook is to provide planning and design guidance regarding stormwater quality best management practices (BMPs) and pollutant reduction facilities (PRFs). This handbook is intended to aid land developers and the jurisdictions in evaluating and designing water quality facilities. The immediate goal is to develop phosphorus reduction facilities which will meet the Oregon Environmental Quality Commission's (EQC) Total Maximum Daily Loads (TMDLs) and Load Allocations (LAs) for phosphorus in the Tualatin Basin. Ultimately, the design guidance presented within this handbook can be used with ongoing research efforts to effect overall reduction of urban storm water pollutants, which include metals, bacteria, oil and grease, and suspended solids.

This handbook is designed to be used in conjunction with each local jurisdiction's erosion control standards. The facilities presented in this handbook are generally not suited for areas of intensive construction and are intended to be used in addition to construction site erosion control measures. The handbook also does not discuss hydrologic analysis methods for determining design storm events. The jurisdictions currently specify hydrologic methods which should be used to evaluate the site hydrology.

Preparation of the handbook was funded by the Unified Sewerage Agency (USA), Clackamas County, and the cities of Portland and Lake Oswego.

HOW TO USE

The handbook is organized to allow the user to quickly obtain general information on BMPs and PRFs (Chapter One), find design guidance on a specific BMP or PRF (Chapters Two through Five), and design a water quality facility composed of several BMPs or PRFs (Chapter Six and Appendices B through D). The BMPs and PRFs presented in Chapters Two through Five are grouped based on similar objectives, functions, and pollutant removal mechanisms. These groupings include subsurface infiltration, ponds-marshes, streets and storm sewers, and landscaping.

Each chapter includes a summary, criteria for general selection and siting, discussion of possible variations, and a checklist for planning and design.

The chapters are as follows:

- Introduction and Summary
- Infiltration Facilities
- Pond-Marsh Facilities
- Streets and Storm Sewers
- Landscaping
- Facility Combinations

OVERVIEW OF FACILITY TYPES

The facility groups presented in this handbook include infiltration, pond-marsh, street and storm sewer, landscaping, and various combinations of these facilities. Most of these facilities are not recommended for treating runoff from construction sites because the sediment loads from such activities tends to overwhelm them. The best approach during construction is to minimize erosion through onsite erosion control measures. This is particularly true in the Tualatin Basin due to the preponderance of highly erodible fine-grained soils. Once these soils are eroded and in the stormwater, they are not easily removed by small, passive-type treatment systems. A brief discussion of each facility group is presented in the following paragraphs.

Subsurface Infiltration

Subsurface infiltration is described in Chapter Two. The basic types of facilities which are covered include trenches, basins, sumps, porous pavement, and roof drains. Although infiltration facilities present some of the most promising opportunities for phosphorous removal, they also require intensive site investigation work. The primary constraints involve soil types and groundwater concerns. Low infiltration capacities of many of the soils in the area, potential clogging of the pores by fine soil particles being transported by stormwater, and the exhaustion of the soil sorption capabilities for phosphorus under anaerobic conditions all hamper infiltration effectiveness. Infiltration facilities are particularly unsuited below sites undergoing construction unless frequent cleaning and reconstruction is provided. Any time infiltration occurs, whether natural or enhanced, there is the potential for contamination of groundwater.

Pond-Marsh

Pond-marsh facilities, which are described in Chapter Three, involve the physical, biological, and chemical processes associated with wetland treatment and sedimentation basins. Although effective treatment is generally achieved by such facilities for many stormwater constituents, phosphorus is one of the most difficult parameters to remove with this facility. Its removal varies considerably depending on the season, the facility sizing/design, and anaerobic versus aerobic soil-water conditions. Although vegetative uptake removes some phosphorus, the primary removal mechanisms appear to be the interaction of soluble phosphorus with the substrate soils, removal of phosphorous through the sedimentation process, and infiltration. The types of pond-marshes addressed include treatment wetlands, wet ponds, treatment-detention ponds, and marsh-treatment ponds.

Street and Storm Sewer Systems

A number of small facilities and maintenance practices can be used to reduce suspended sediment and phosphorus levels in runoff within the street and storm sewer systems. These are described in Chapter Four, and include trapped catchbasins, water quality inlets which are variations of catchbasins, sedimentation manholes, vaults/tanks, oil-water separators, conversion of ditches to grassed swales, and practices such as street sweeping and catchbasin cleaning. Overall, significant reductions of suspended solids and phosphorous can be achieved in this portion of the stormwater runoff system. Although maintenance of facilities is important for all of the groups, it is particularly important for street and storm sewer facilities since periodic cleaning is required to prevent resuspension and subsequent flushing of sediment from the facilities.

Landscaping

An almost infinite variety of landscaping techniques can help improve water quality. A number of the most common are described in Chapter Five. They include the establishment or preservation of natural buffer zones/biofilters, landscaping of development sites, and coupling of landscape features with pond-marsh, grassed swale and infiltration concepts. In addition, many of these techniques can also improve the aesthetics of a development site.

Combination Facilities

In the Tualatin Basin and Portland metro area, the nature of the soils make stormwater quality improvement in an urban area difficult. This relates primarily to the low infiltration capacity of some soils, their tendency to erode, their fine colloidal nature in water transport, and their high levels of phosphorus. Given these difficult conditions, reducing suspended solids and phosphorus in storm water is best accomplished through a variety of types of facilities. Combinations allow different mechanisms to treat different portions of the pollutant load. For example, sedimentation basins are good at removing coarse particulates in runoff through physical settling, but are ineffective with the dissolved contaminants. Marshes are one of the best means to remove fine particulates and some dissolved pollutants through biological uptake, but are susceptible to toxic pollutants. Infiltration facilities excel at adsorption of dissolved pollutants, but can be quickly clogged by coarse particulates. Using these facilities in various combinations would provide the most effective pollutant removal by maximizing individual BMP and PRF strengths and minimizing their weaknesses.

PERFORMANCE SUMMARY

The pollutant removal efficiencies of the passive-type treatment facilities described in this handbook are difficult to project, particularly for phosphorus. The processes involved include complex physical, chemical and biological interactions that are only partially understood. Often, the knowledge that does exist does not extend to reliable engineering design functions/criteria, which must be the basis for projecting performance.

In addition to the type of facility and processes involved, a number of variables affect overall performance for a site or drainage area including:

- The location of the facility within the drainage system.
- The relationships to other facilities in the system.
- The amount of construction runoff entering the facility.
- Soil and "street-dirt" particle sizes.
- Levels of pollutants in the runoff (i.e. higher efficiencies will usually occur at the higher concentrations).
- The sensitivity of the design to the site/area involved.
- Adherence to maintenance requirements.

The general removal efficiencies of the various facility groups are represented in Table I-1, with additional information being provided in each chapter concerning that facility group. Table I-1 is based on published information and project team experience. As a general rule, infiltration provides the most certain pollutant reduction with landscaping facilities involving the widest range of removal efficiencies.

A number of assumptions had to be made in developing Table I-1. All efficiency rates in this table are based on single facilities. Combination facilities are discussed separately in Chapter Six. Appendix D contains several examples of how to estimate effectiveness of several facility types including infiltration and pond-marshes.

The high end of the removal efficiency range may be considered to represent "perfect" conditions; i.e., the facility is well designed, well maintained, and has no situations such as construction activity or unusually large storm flows affecting it. The low end of the range may be expected when several adverse influences occur together, such as an undersized sedimentation pond being silted in by construction sediments. The average value is based on a 1 percent catchment ratio and 3-foot water depth where applicable.

Though several facility types are capable of removing many storm water types, they are not recommended for all applications. Infiltration basins, for instance, are capable of removing sediments, but this quickly leads to premature clogging and loss of effectiveness. Infiltration basins, along with pond-marsh facilities are also not recommended for oil and grease removal. Both are quite effective at doing so, but groundwater contamination is very possible with infiltration and toxic pollutants may adversely affect wildlife and vegetation in ponds and marshes.

SITE PLANNING

The first and most important step in selecting the water quality management system and facilities for a drainage area or site is to perform an initial site/drainage area evaluation and develop a concept plan. Most important in that regard is to develop a general understanding of the soils of the site or in the drainage area. To accomplish this the appropriate Soil Conservation Service (SCS) soil survey should be obtained. The most important soils characteristics for water quality purposes are infiltration capacity, erosion potential, phosphorous availability, and particle sizes. The SCS survey contains information on infiltration and erosion. Additional surveys will be needed for information on phosphorus content and particle sizes of the soil.

The initial evaluation should also include an identification of the basic surface water and groundwater systems which are within or impacted by the site/drainage area or which impact it. The important characteristics include the basin area (size) draining into the site, the topography, the groundwater uses downgradient, and the existing conveyance systems including pipe/culverts and open channels.

Table I-1: Removal efficiencies anticipated for treatment facility groups (low-average-high).

Treatment Facility	Pollutant Removal Efficiency (percent)						
	TSS	Total P	N	BOD	Bacteria	Oil\ Grease	Metals
Infiltration							
Infiltration Trenches	NR	65-75-95	30-40-60	65-70-85	80-85-95	NR	NR
Infiltration Basins	NR	50-80-95	30-40-65	70-80-90	80-85-95	NR	NR
Infiltration Sumps	NR	65-75-95	30-50-70	65-75-80	80-90-95	NR	NR
Porous Pavement	NR	40-50-75	20-30-40	10-10-20	10-10-20	NR	NR
Roof Drains	NR	65-75-95	30-50-70	65-75-80	80-90-95	NR	NR
Pond-Marsh							
Treatment Wetlands	65-85-95	20-45-60	10-25-40	40-45-80	50-75-95	NR	55-60-65
Wet Ponds	60-80-90	20-40-50	10-30-45	30-35-70	30-50-70	NR	50-55-65
Extended Detention	50-60-90	10-15-25*	10-15-25*	20-30-40*	NA	NR	15-20-30*
Street & Storm Sewer							
Trapped Catch Basins	20-30-40	10-15-20*	10-15-20*	10-15-20*	NA	NA	10-15-20*
Water Quality Inlets	20-30-40	10-15-20*	10-15-20*	10-15-20*	NA	50-65-75	10-15-20*
Sedimentation Manholes	20-30-40	10-15-20*	10-15-20*	10-15-20*	NA	NA	10-15-25
Vaults/Tanks	20-30-40	10-15-20*	10-15-20*	10-15-20*	NA	20-40-50	10-15-20*
Landscaping							
Vegetated Swales	40-50-75	10-15-60	10-15-55	20-25-60	NA	50-65-80	20-30-50
Constructed Filters Strips	50-60-75	20-30-80	20-30-80	50-55-75	NA	60-70-85	30-45-65
Riparian Filters	50-65-80	20-35-85	20-35-85	50-60-80	NA	60-75-90	30-50-70

Source: Columbia Slough Planning Study (1989); Lake Sammamish Water Quality Management Project (1989); Wright Water Engineers (1990); Schueler (1987); project team experience.
NR = Not recommended for removal by this facility; NA = Not available; * = Estimate assuming 50% particulate fraction. Rates based on single facilities, 1 % catchment ratio, and 3-foot depth where applicable.

It is also important to understand the opportunities for drainage and water quality management available at the site/area such as existing ponds, swales, depressions, and riparian (waterside) biofilters. Related to these are wetlands as defined by the federal regulations now in effect, since such areas may present water management opportunities, but also involve tough penalties for alteration without the proper permits.

In reviewing a site/area for riparian biofilter preservation, the following should be kept in mind:

- The level of pollutant removal obtained within a natural vegetated biofilter is dependent on the site characteristics (i.e. filter slope, width) and the pollutants found in the storm runoff. In general, the removal efficiencies presented for constructed vegetated filter strips (refer to Chapter Five) can be assumed to be the minimum treatment efficiencies found in a natural biofilter.
- The existing vegetation should be capable of meeting the ***pollutant removal*** objectives. If not, the vegetation may need to be augmented with specific species capable of pollutant uptake.
- ***Wildlife habitat*** needs should be considered in concert with pollutant removal objectives. Existing wildlife habitat should be maintained and if possible enhanced while also meeting pollutant removal objectives.
- ***Erosion control*** measures should be implemented adjacent to the vegetated biofilter, especially when steep bank or adjacent slopes are present.
- Natural filter strips do not usually require intensive maintenance activities since their natural life cycle aesthetics are normally desired. However, as natural filter strips are increasingly used for treatment purposes, maintenance may be necessary. Projected maintenance needs may include:
  - Periodic ***cutting and disposal*** of vegetation to prevent decaying vegetation from releasing pollutants into the receiving waters.
  - Removal of ***sediment*** accumulation exceeding 6 inches in depth at any one spot to prevent death of vegetation.
  - Periodic ***inspections***, especially after heavy runoff, are required. Areas exhibiting erosion will require reseeding and protection.
  - Residents in areas adjacent to natural biofilters should be informed through ***public awareness programs*** of the purpose and delicate nature of these facilities. Activities such as severe pruning of vegetation and dumping debris in the natural vegetation strip should be prohibited.

Recognizing the existing or pre-development riparian vegetation at the site/area, and taking advantage of it to provide natural biofilters along streams, ponds and wetlands is very important. Destroying such areas while investing money and effort in the development of features intended to perform the same function is usually not wise or efficient. This is particularly true since federal, state, or local regulations often protect such areas and require mitigation if they are altered.

The ***advantages*** of preserving natural biofilters along streams, ditches, ponds, and wetlands include the following:

- Diverse, native vegetation provides wildlife habitat not usually duplicated in constructed filter strips.
- Preserving existing natural filter strips involves low capital investment and can be readily implemented.
- Maintenance requirements are lower than constructed facilities which normally require more frequent grooming.
- Preserving the existing stream buffers protects the stream bed and bank from equipment and disturbance during and after construction.
- Large trees are more likely to be present than in constructed strips, so shading for temperature control is more likely to occur.
- The older, established vegetation provides better bank stabilization because of the continuation of an extensive root zone.

The ***disadvantages*** are:

- The available width of an existing natural filter strip may not be adequate for pollutant removal objectives.
- Ideal pollutant removal usually requires some maintenance which may change the natural vegetation/appearance.
- The land requirements may be significant for some sites..
- Deciduous trees may provide nutrient and BOD release due to leaf deterioration, but this is generally after the period regulated for phosphorus TMDLs.

FACILITY AND SYSTEM SELECTION

After the site is evaluated and understood, the next task involves deciding which type of facilities might work best. This involves comparing the site opportunities with the information presented in this handbook. When the types of facilities and practices have been initially selected for the site, an approximate estimate of phosphorous removal should be made based on the performance summary in this chapter and the information presented in Chapters Two through Six.

CHAPTER II

INFILTRATION FACILITIES

CONTENTS

INFILTRATION FACILITIES

CONTENTS (continued)

INFILTRATION FACILITIES

CONTENTS (continued)

FIGURES

INFILTRATION FACILITIES

This chapter concerns various types of facilities which can be used for subsurface infiltration. It includes a ***summary*** which gives an overview of the facilities and considerations, a ***selection and siting discussion***, ***general design criteria*** which apply to all of the types of infiltration facilities, ***specific design criteria*** for each type of facility (eg. infiltration trenches), and a ***planning/design checklist***.

SUMMARY

Infiltration facilities consist of a wide variety of design alternatives all intended to enhance the percolation of runoff into the soil and lithic zones. These range from simple roof drain sumps draining residential units to large infiltration basins accepting runoff from drainages up to 50 acres in size, and include:

- ***INFILTRATION TRENCHES*** - Shallow (2 to 10 feet deep) trenches backfilled with coarse stone, a sand filter and filter fabric.
- ***INFILTRATION BASINS*** - Depressions created by excavation, berms or small dams to provide for short-term ponding and infiltration.
- ***INFILTRATION SUMPS*** - Shallow "dry wells", usually 10 to 30 feet deep, with a perforated concrete wall surrounded by gravel backfill; usually with filter fabric and a pretreatment unit such as a sedimentation manhole.
- ***POROUS PAVEMENT*** - A porous pavement material underlain by several permeable layers and filter fabric; usually intended for low intensity traffic areas, such as driveways, and non-industrial parking lots.
- ***ROOF DRAINS*** - Small scale chambers or trenches intended to facilitate infiltration from roof drains only; sometimes filled with coarse gravel.

As treatment facilities for urban runoff, infiltration facilities all work in a similar fashion. Instead of quickly flowing off a site, storm drainage is held long enough to allow it to enter the underlying soil, usually through a zone of coarse gravel. This percolation through the soil serves two purposes. First, in suitable soils, it can effectively remove many of the nuisance pollutants found in urban runoff, particularly nutrients such as phosphorus. Second, if properly designed and constructed, infiltration facilities can decrease the surface runoff peaks and volumes of a given design storm.

Infiltration facilities are only intended to treat the runoff from developed residential, and in some cases commercial, areas. They should not be considered for most industrial areas due to potential groundwater contamination and are not suitable for commercial developments which drain areas where petroleum products, herbicides, pesticides, or solvents may be loaded/unloaded, stored or applied.

They are particularly unsuited for drainage areas undergoing major development, or otherwise expected to produce high sediment loads in the runoff. If frequent cleaning/reconstruction of the facility is acceptable, construction erosion controls are very effective, or pretreatment sedimentation facilities are provided, then infiltration facilities below construction sites may not experience unacceptable levels of clogging, but caution is urged in such applications.

Infiltration facilities in the Portland-Lake Oswego-Clackamas County-USA area are often dismissed because of the perception that most soils in the area are unsuitable. Although there are areas/purposes where this perception may be correct, significant areas of each jurisdiction may accommodate infiltration facilities to varying degrees for water quality improvement purposes. It may be necessary in some cases, however, to adjust the flow rate to take advantage of sites having slower infiltration rates.

SELECTION AND SITING

POLLUTANT REMOVAL

From a stormwater management perspective, infiltration facilities can be one of the most effective BMPs due to the wide array of biological, chemical, and physical processes which occur in soils. This is particularly true for phosphorus removal.

One deficiency inherent in all infiltration facilities is their inability to effectively filter particulate pollutants over the long term. Infiltration facilities can clog, which is a costly and time consuming condition to correct. If there is the possibility of a high sediment load entering an infiltration facility, pretreatment, such as a settling pond capable of removing the majority of the sediment, must be used.

POTENTIAL GROUNDWATER IMPACTS

As with any facility designed to introduce water into the subsurface, there exists a potential for groundwater contamination. This potential requires special considerations, particularly when dealing with urban storm runoff.

CHOOSING THE RIGHT TYPE OF FACILITY

All of the infiltration facilities listed below require good to excellent infiltration/percolation capability of the underlying soils and lithic zones.

Infiltration Trenches

Infiltration trenches are particularly useful for sites where:

- The size and layout of the site are such that a number of linear opportunities exist for such trenches.
- Low-tech solutions are desired, such as single family residential areas.
- Open channels are going to be used within the site for drainage purposes.

Infiltration Basins

Infiltration basins should be considered when:

- Natural depressions such as swales or drainageways exist which are suitable to provide ponding behind a small dam or berm.
- Single facilities are desired to serve relatively large areas of up to 50 acres.

Infiltration Sumps

Infiltration sumps are particularly useful when:

- Open channels or ditches are not planned to be used and storm sewers will be primarily relied upon.
- Swales or natural depressions do not exist which could provide the basis for ponding areas.
- The more permeable zones lie below some shallow confining layer such as the fragipan soil which exists throughout much of the Tualatin Basin.
- Drainage from standard urban streets with curb and gutter systems are to be served through infiltration at intersections.

Porous Pavement

Porous pavement can be considered if:

- Weights of the expected vehicles are relatively light.
- Industrial areas are not involved.
- Commercial areas which might contain more than incidental use of petroleum products, industrial solvents, herbicides and pesticides are not involved.
- The runoff water entering the porous pavement area, or infiltration chamber, is relatively clean and free from suspended solids.

Roof Drains

Roof drains should be considered when:

- The roof is not generally exposed to high levels of industrial air pollution.
- Petroleum products, solvents, or coolants are not stored or used on the roof.

SITING CRITERIA

The following siting criteria should be considered when locating the desired type of infiltration facilities:

Infiltration Trenches

- Around the circumference of parking lots.
- In the bottom of swales or ditches.
- In median strips of streets and highways.
- In some cases, in the yards and greenways of residential and some commercial developments.

Infiltration Basins

- In depressions, swales or natural waterways, where a berm or low dam can create the needed temporary ponding area.
- In depressions to be created by the landscape design.
- Where large regional public facilities, possibly involving detention/treatment ponds, are to be used.
- Adjacent to streams where treated water could return to the stream via subsurface flow.

Infiltration Sumps

Infiltration sumps or drywells are useful:

- At intersections of standard urban street, curb and gutter residential areas.
- If access is available.
- When off-site diversion of stormwater flows from small tributaries is desired and the area that can be used for infiltration is small.
- In conjunction with grass swales, ditches, infiltration trenches or similar facilities.

Porous Pavement

The site conditions particularly suitable for porous pavement are:

- Low-use parking areas such as the overflow parking areas of large commercial centers.
- Residential driveways.

Roof Drains

Roof drains can be used for any residential, commercial or industrial roof provided that industrial air pollutants are not likely to contaminate the roof runoff. Soil percolation capabilities must be adequate for the roof areas involved.

GENERAL DESIGN CRITERIA

The following design considerations apply to all types of infiltration facilities.

SOILS

The most important factor in determining the suitability of infiltration facilities at any site is the soil. Several soil characteristics are relevant for infiltration facilities.

- Because of the rapid infiltration required for a reasonably sized infiltration facility, the infiltration rates for underlying soils need to be 0.5 inch/hour or greater. The hydrologic soil types in the Portland area which fall into this category are the "A" and "B" type soils, which include sand, loamy sand, sandy loam, and loam. The installation of infiltration facilities in "C" soils is not recommended although it can be considered if special allowances are made for the lower permeability of this soil type.
- Soils that have more than 40% silt/clay by weight are vulnerable to frost-heave, and should be evaluated for their damage potential from frost.
- Infiltration facilities should not be placed in fill material because of potentially unstable subgrades, unless the fill material is specially designed and constructed to accommodate the facility.
- An important factor in determining the feasibility of infiltration facilities at various sites is the soil depth from the bottom of any potential facility to some lower confining boundary. A confining boundary is any layer which could impede the percolation of water through the soil. This includes bedrock, impermeable soil layers such as fragipan soils, and the local groundwater table. The minimum allowable depth to the high water table during the season/period of interest is two feet. The minimum allowable depth to low permeability barriers such as fragipan soils or bedrock is four feet.
- The minimum allowable depth to the high water table during the season/period of interest measured from the lowest course of an infiltration facility, is two feet. The minimum allowable depth to low permeability barriers such as fragipan soils or bedrock is four feet.

A good indication of a soil's relative infiltration capacity is the Soil Conservation Service's (SCS) hydrologic soil grouping. This grouping consists of four categories A through D, with A being the most permeable and D being the least. A description of each of these soil groups appears in Appendix A, Table A-1.

Soils in hydrologic soil groups A and B are the best soils for infiltration facilities. Tables A-2 through A-4 in Appendix A list the soils in Multnomah, Clackamas, and Washington County which are listed in the SCS Soil Survey for each county as being in either the A or B hydrologic soil group. Also listed in each table are the total percentage of area each soil type encompasses in each county. At the bottom of each table is included the total percent surface area of all the A and B type soils which occur in each county.

As can be seen in these tables, 57 percent of the soil area in Multnomah County is hydrologic soil type A or B, while approximately 40 percent of the soil area for Clackamas County is of those types. Washington County contains approximately 45 percent type A or B soils. These numbers indicate that large areas within these counties can be considered for infiltration facilities.

SIZING

A U.S. EPA model (EPA, 1986) was tailored to the Portland area for use in establishing infiltration facility sizes. The model is based upon observed and theoretical removal rates of a large number of storm water treatment facilities across the country. The EPA model uses general rainfall statistics and a generalized runoff coefficient (Rv) as its primary input. The rainfall statistics used for the Portland area and an approximate plot of the runoff coefficient (Rv) versus impervious drainage area may be seen in Appendix B.

The model used for infiltration facilities is based solely upon the ability of each facility to capture storm water. It makes no allowances for any storm water storage within the facility which would increase the volume treated and thus, the contaminant mass removed. The model does not account for any of the actual treatment mechanisms, such as sorption, within the facility. It simply predicts the long-term percentage of flow which is captured by the infiltration facility rather than being passed through the facility overflow.

Figure II-1, Figure II-2, and Figure II-3 show the amount of storm water flow which would be treated for an infiltration facility for infiltration rates of 0.5, 5.0, yand 10.0 inches/hour, respectively. The surface area of the infiltration facility is derived from the catchment ratio at the bottom of each figure. The catchment ratio for infiltration facilities is defined as the percentage of infiltration area to drainage basin area. As an example, for a drainage with 100 acres, 2 acres of infiltration area would have a catchment ratio of 2 percent.

The approach used to estimate the required surface area of any infiltration facility (except roof drains) is:

1. Determine the contributing acreage above the potential infiltration site.
2. Calculate the runoff coefficient (Rv) for the site either from Rv = 0.05 + (0.009 x impervious area %) or Figure B-1 in Appendix B.
3. Based on the infiltration rate of the facility site select the appropriate chart.
4. Using the required percent of flow capture, read across from the percent of flow captured scale to the line corresponding to the Rv value calculated in step 2. Interpolate if necessary and read off the catchment ratio.
5. Calculate the minimum required infiltration area (in acres) of the facility by multiplying the catchment ratio (as a percent) by the area found in step 1.

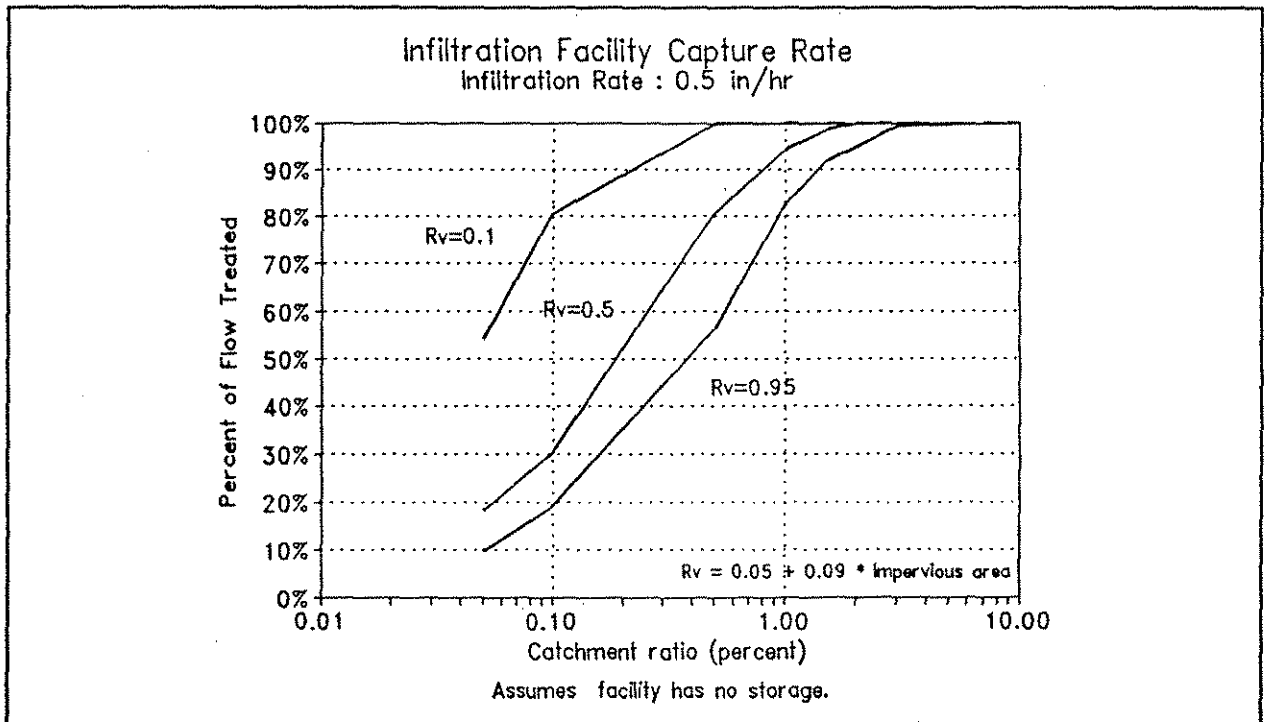

Figure II-1: Infiltration facility capture model (0.5 ft/hr infiltration rate).

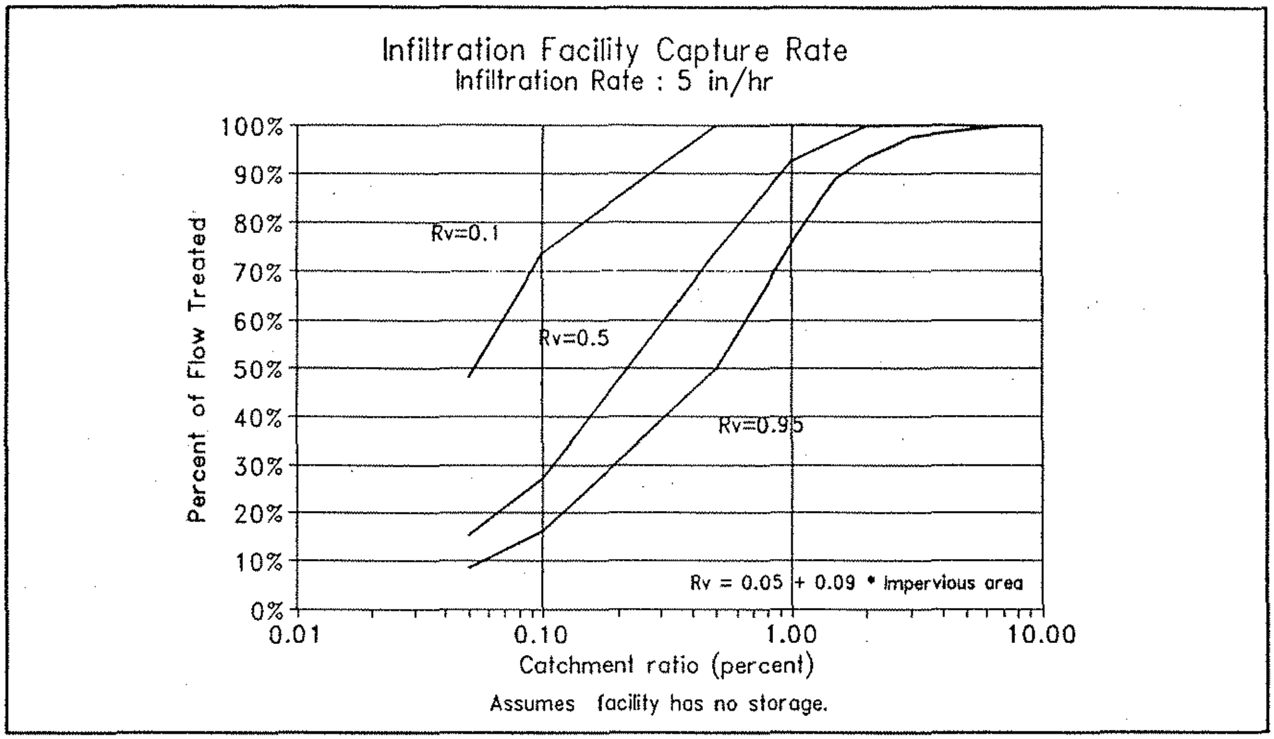

Figure II-2: Infiltration facility capture model (3 ft/hr infiltration rate).

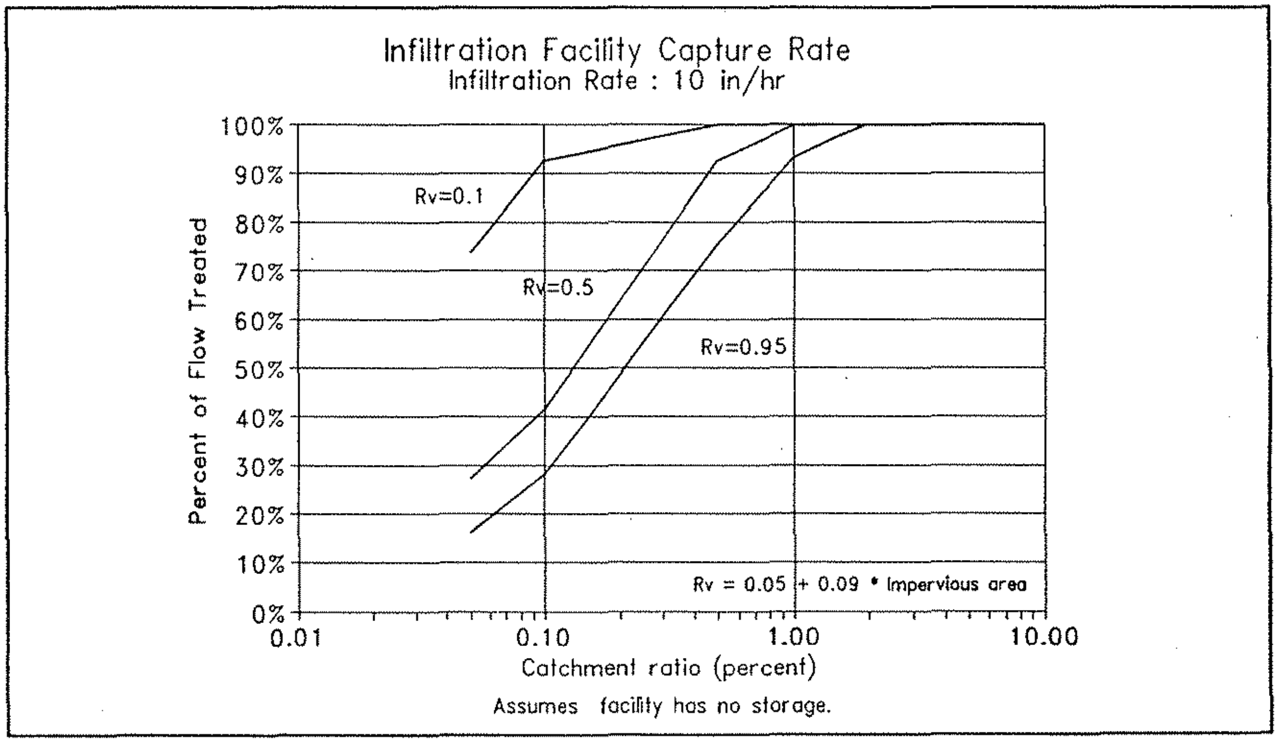

Figure II-3: Infiltration facility capture model (6 ft/hour infiltration rate).

GROUNDWATER PROTECTION

- Infiltration facilities cannot be used in areas identified by the local water purveyor, or the Oregon Department of Environmental Quality as a groundwater area of concern. (Refer to Appendix E).

- No drinking water wells should be within 500 feet of any infiltration facility.

- Infiltration facilities cannot be used in areas where hazardous materials are expected to be present in greater than "reportable quantities" as defined in 40 CFR 302.4. Vehicle parking areas are acceptable provided that no industrial/commercial vehicles are expected, and vehicle maintenance is prohibited.

- A minimum of one observation well shall be placed in each infiltration facility, not including small roof drains or sumps. The well shall extend from the surface down to the bottom of the lowest course in the facility. A detail of a typical observation well is shown in Figure II-4. The primary purpose of the well is to monitor runoff exfiltration after large storm events, as an indication of system performance. Another purpose of the well is the early detection of obvious contamination of the subsurface water within the facility.

- An oil/water separation device is required upstream of all infiltration facilities to minimize the possibility of groundwater contamination.

PRETREATMENT

- In areas where there is potential for a high sediment load in storm runoff, particularly during construction, pretreatment is required for all infiltration facilities. Without pretreatment, excessive sediments can quickly fill the voids in the coarse media and soils. Pretreatment can take the form of settling basins, grit/sedimentation chambers, or filter strips. Infiltration facilities are generally not suitable for construction runoff, and are primarily suited to serve drainage areas that have been developed.

OVERFLOW

The infiltration facility must be designed with an overflow system that is connected to the nearest surface drainage facility of adequate hydraulic capacity to receive overflow during the standard design storm used by the appropriate jurisdiction.

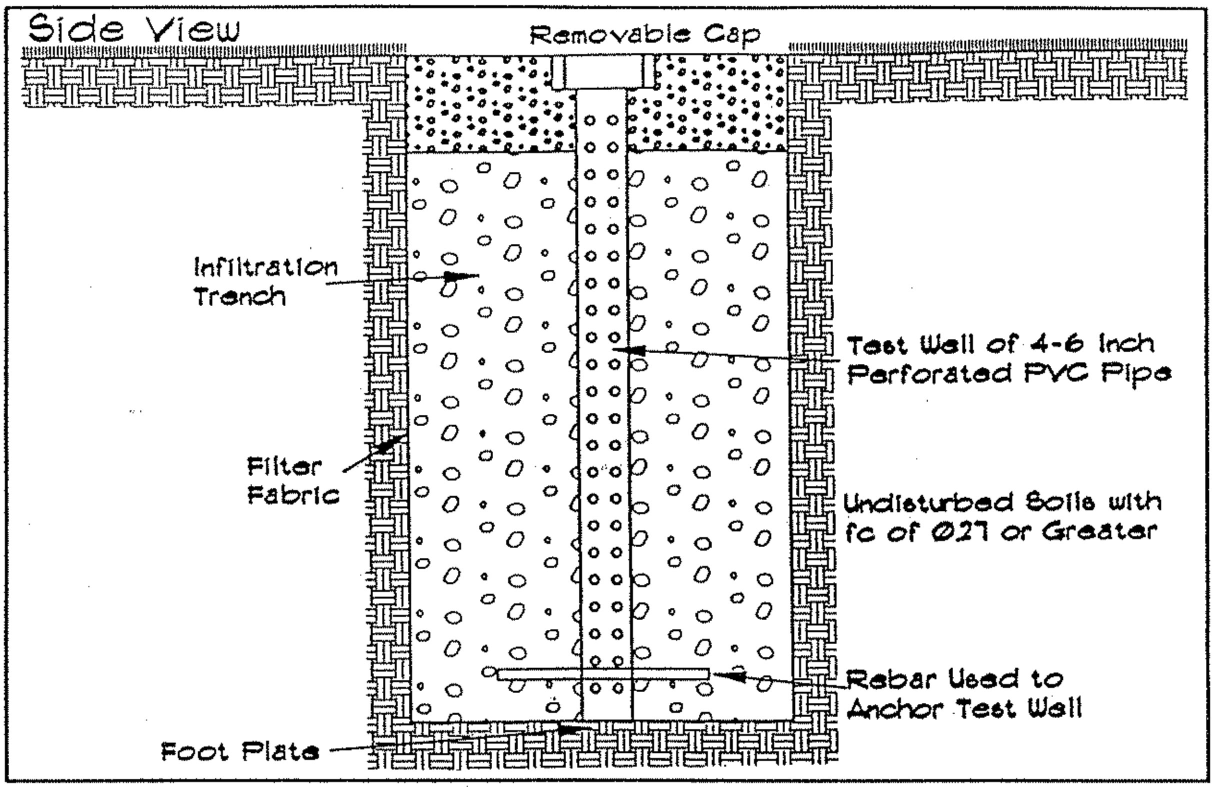

Figure II-4: Typical infiltration trench monitoring well.

TESTING

The following tests have been designed to gather the minimum amount of information necessary for all proposed infiltration facilities. Additional or more extensive tests may be of benefit and may be used if desired. The results must be submitted in the Soils Report discussed later in this chapter.

Maximum surface infiltration test

The maximum surface infiltration test is conducted to estimate the maximum infiltration rate (I_M) of the surface soils in any proposed ponding area or closed depression. The test simulates the physical wetting and infiltrating processes that occur during storm conditions. A vertical pipe is used to limit the test to evaluating only the vertical component of seepage. The test consists of the following:

1. Without disturbing top soil or surface debris, drive a 4-foot-long, 6-inch-ID section of pipe into the soil to a depth of 6 inches.

2. Fill the pipe and maintain a minimum water depth in the pipe of at least a foot above the original ground surface. This minimum depth should be maintained for a minimum of 4 hours.

3. After the minimum 4 hour wetting period, fill the pipe to the top and record the time required for the water level in the pipe to fall each inch down to 6 inches below the top of the driven pipe section. (Note: As this portion of the test could take a prohibitively long time to conduct, it should only be performed on soils that are considered to be reasonably permeable).

4. The rates for each one-inch time are averaged to estimate I_M. Repeat step a total of three times and take average I_M of the three to calculate the final infiltration rate for that area.

Maximum sub-surface infiltration test

The maximum sub-surface infiltration test is conducted to estimate the maximum vertical infiltration rate (I_m) of the soils at the level of the lowest finished grade of the proposed infiltration facility. The test simulates the physical wetting and infiltrating processes that occur during storm event conditions. A vertical pipe is used to limit the test to evaluating only the vertical component of seepage. The test consists of the following:

1. Excavate down to the finished grade of the proposed infiltration facility. In the excavation, allow clearance for a 6-inch-ID pipe section to be driven 6 inches beyond the level of the finished grade.

2. Repeat steps 2-4 of the surface infiltration test.

Once the maximum infiltration rates are determined for the levels of interest, it may be used to develop a stage/discharge rating curve for the particular infiltration facility.

ANALYSIS AND REPORTS

SOILS

A soils report is required for all proposed facilities or projects involving infiltration in the Portland-Lake Oswego-Clackamas County-USA area to verify the mapped soils series and to determine the soil series of areas which have not been previously mapped and the depth of the seasonal maximum water table during the season/period of interest.

A soil log is required of each proposed infiltration facility (not including roof drains) to a minimum depth of 5 feet below the facility's lowest finished grade. Additional soil logs for each infiltration facility must be taken for every 5,000 square feet of infiltrating surface area for that particular facility.

GEOTECHNICAL

Any proposed facilities or projects involving infiltration, except roof infiltration drains, requires the submittal of a geotechnical report if:

- construction is proposed within 200 feet from the top of a steep slope, OR
- on a slope steeper than 15%; OR
- a berm higher than 6 feet is constructed.

If any of these conditions exist, then a geotechnical analysis and report must be prepared and stamped by a geotechnical professional engineer. The report should address, at a minimum, the effects of groundwater interception and infiltration from the infiltration facility. Particular attention should be given to

- potential seepage faces on steep slopes,
- piping near outfall systems,
- lubrication of slip planes,
- or changes to soil bearing strength due to saturation and liquefaction from the increased infiltration,

These impacts should be evaluated assuming both normal and rare conditions. A rare condition is an event such as emergency overflow of the infiltration system due to a plugged outlet pipe. After evaluation, probabilities of failure and the resulting impacts should be determined for the infiltration facility and any impacted downslope areas.

The report should also identify areas potentially impacted by groundwater interflow and any special characteristics of the underlying soils. These should include but not be limited to

- load bearing capacity;
- suitability of site fill, roadway, and pond embankment materials;
- erodibility of soils, particularly during construction; and
- the ability to support vegetation for stabilization.

HYDROLOGY

Except for roof drains, all proposed projects or facilities involving infiltration must include in the site analysis/report:

- A hydrograph of the design storm runoff and infiltration facility overflow for flood conditions as defined by the appropriate local jurisdiction; and for the 100 year storm if the facility/project impacts, or is impacted by, a major waterway.
- Mapping of the flow route to an adequate discharge point and elevation or hydraulic profile of the peak overflow during the design storm, and 100 year flow if appropriate.
- The significant downstream flooding impacts.
- All hydrologic-hydraulic analysis must be done in accordance with the methods required or recommended by Portland, Lake Oswego, Clackamas County, or USA depending on which jurisdictions' authority covers the project.

INFILTRATION TRENCHES

Infiltration trenches are shallow (2 to 10 feet) trenches in relatively permeable soils which are backfilled with coarse stone. These facilities can accept storm runoff from a small area, and depending upon the design, allow for total or partial infiltration of that runoff into the underlying soil. A typical trench design is shown in Figure II-5.

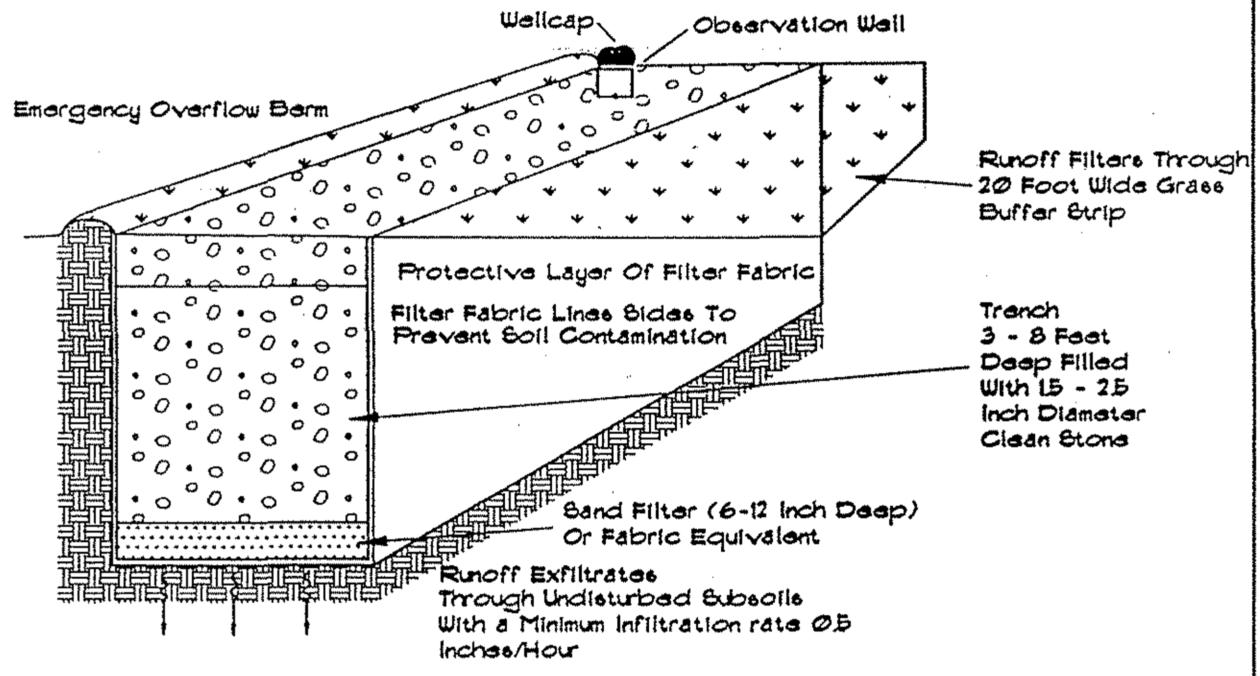

Figure II-5: Typical Infiltration Trench.

Infiltration trenches are generally used on small drainage areas where high sediment loads are unlikely in the runoff. Most infiltration trenches are built in residential subdivisions, small commercial areas, parking lots, and open space areas.

ADVANTAGES AND DISADVANTAGES

Advantages

- Due to their small size, infiltration trenches are well suited to tight areas, particularly around perimeters, in medians, and in other under-utilized areas of most development sites.
- For their size, infiltration trenches provide a high level of pollutant removal.

Disadvantages

- Sediment in the runoff will clog an infiltration trench and pretreatment may be necessary.
- Monitoring the effectiveness of the facility and the degree of clogging, followed by maintenance as needed is required.
- Construction of an infiltration trench requires considerable care and skill.

DESIGN CRITERIA

The following design criteria are specific to infiltration trenches and are in addition to the general criteria for infiltration facilities discussed earlier.

Soils

- A minimum of one ***soils log*** for each proposed trench location, extending a minimum of 5 feet below the bottom of the proposed lowest course of the infiltration trench is required. The ***soils report*** should include as a minimum the SCS series of the soil, the textural class of the soil horizon through the depth of the log, and any indications of the presence of a high seasonal water table (such as mottling).
- A minimum of three ***sub-surface infiltration tests*** should be performed for each proposed infiltration trench of less than 200 foot length, as described in the infiltration testing section. For trenches longer than 200 feet, the number of infiltration tests should be 3 plus one for each 100 feet of length over 200 feet.

Sizing

- Sizing for the ***surface area*** of an infiltration trench should be done according to the general design procedures given in the general design criteria in the introduction to the infiltration chapter.

Miscellaneous

- ***Slopes*** less than 5% are required for any surface infiltration trench and less than 25% for any buried infiltration trench.
- ***Filter fabric*** should be placed entirely around the infiltration trench excavation to prevent fines from entering the system, particularly during construction.
- No infiltration trench should be placed within 10 feet horizontally downgradient or 100 feet upgradient of any ***structure***.
- The ***stone reservoir*** in an infiltration trench system should be sized to drain the design storm in a maximum of 72 hours, to avoid anaerobic conditions.
- For optimal pollutant removal, a minimum ***drainage time*** should be 6 hours for the design storm.

VARIATIONS

Several different types of infiltration trenches are available for use on a site. The following four types of infiltration trenches are shown in Figure II-6 through Figure II-9.

Median Strip Trench

This system (Figure II-6) is often used in roadway medians and parking lot islands. Runoff enters the infiltration trench from both sides after being filtered through a 20 foot wide or wider grassed buffer strip designed to remove most of the larger sediment, which would otherwise clog the infiltration trench. The grassed buffer strip should not have slopes greater than 5% and should be directly connected to the contributing drainage area. An overflow system is used to bypass any excess flow.

Perimeter Trench

This system (Figure II-7) is most often built around the perimeter of parking lots. This system is similar to the Median Strip Trench in that the runoff is filtered by a 20 foot wide grassed buffer strip. To prevent concentrated flow across the filter strip and to avoid possible damage to the strip by automobiles coming off of the paved area, slotted curb spacers are used at the junction of the pavement and the grassed strip.

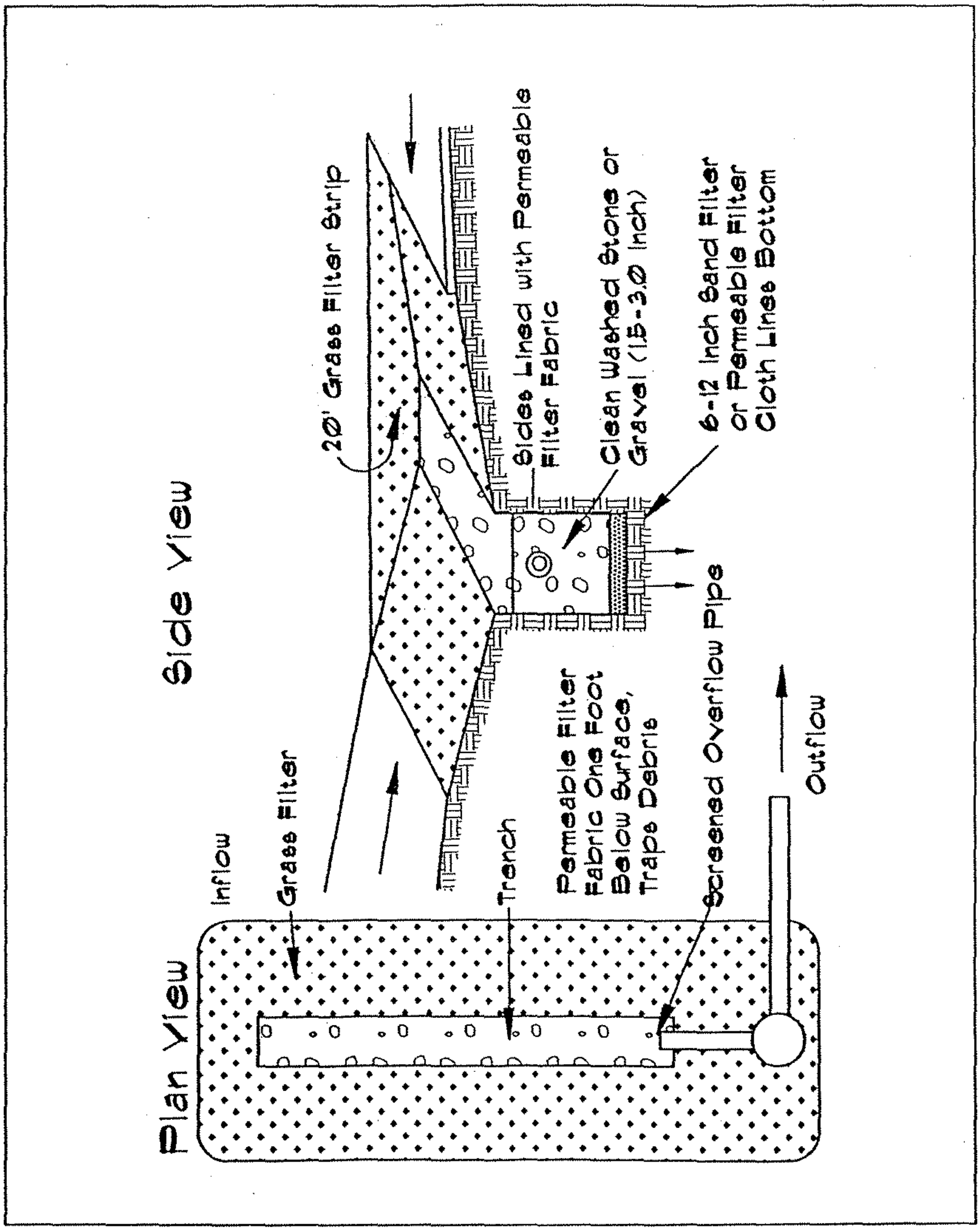

Figure II-6: Median Strip Trench.

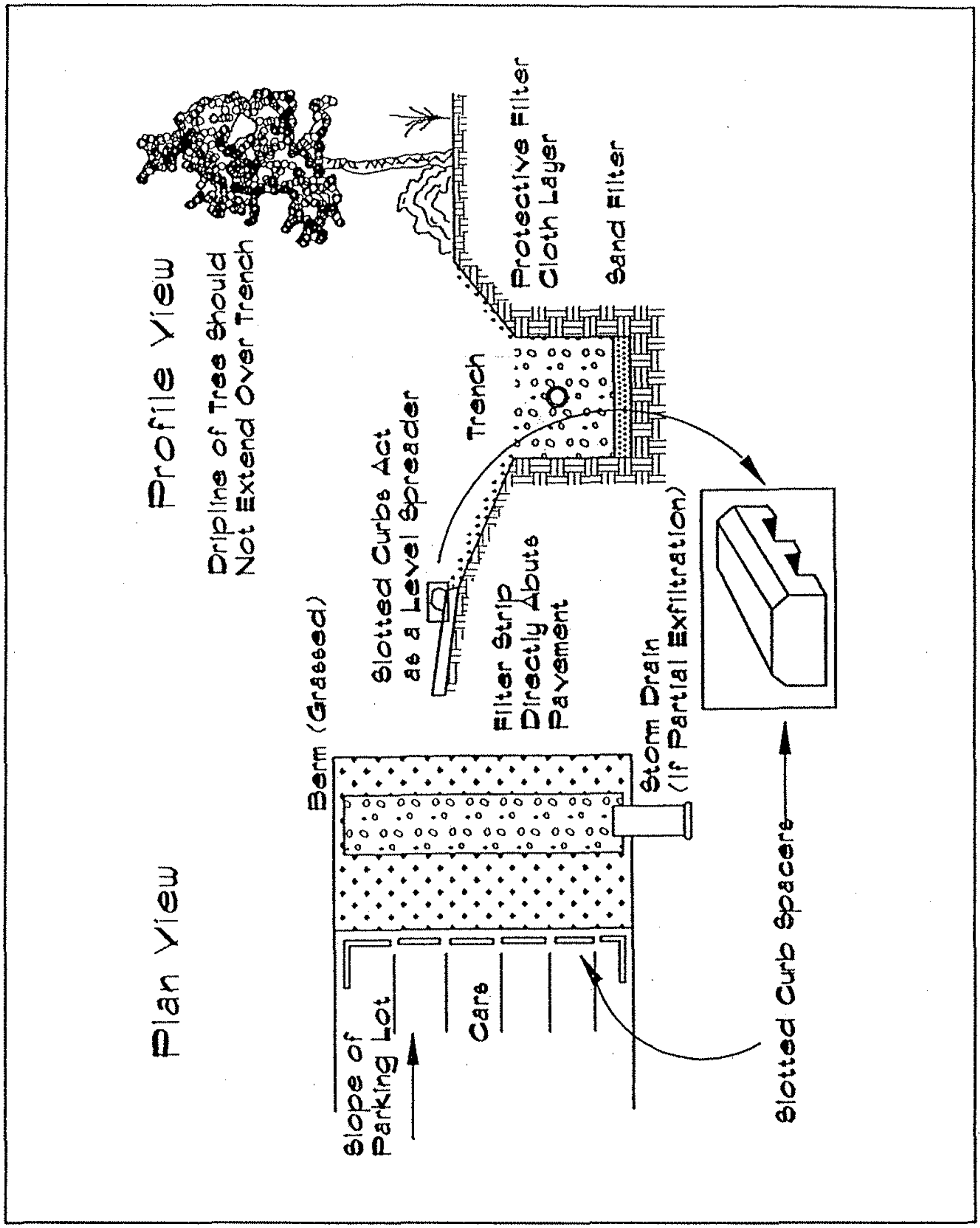

Figure II-7: Perimeter Trench.

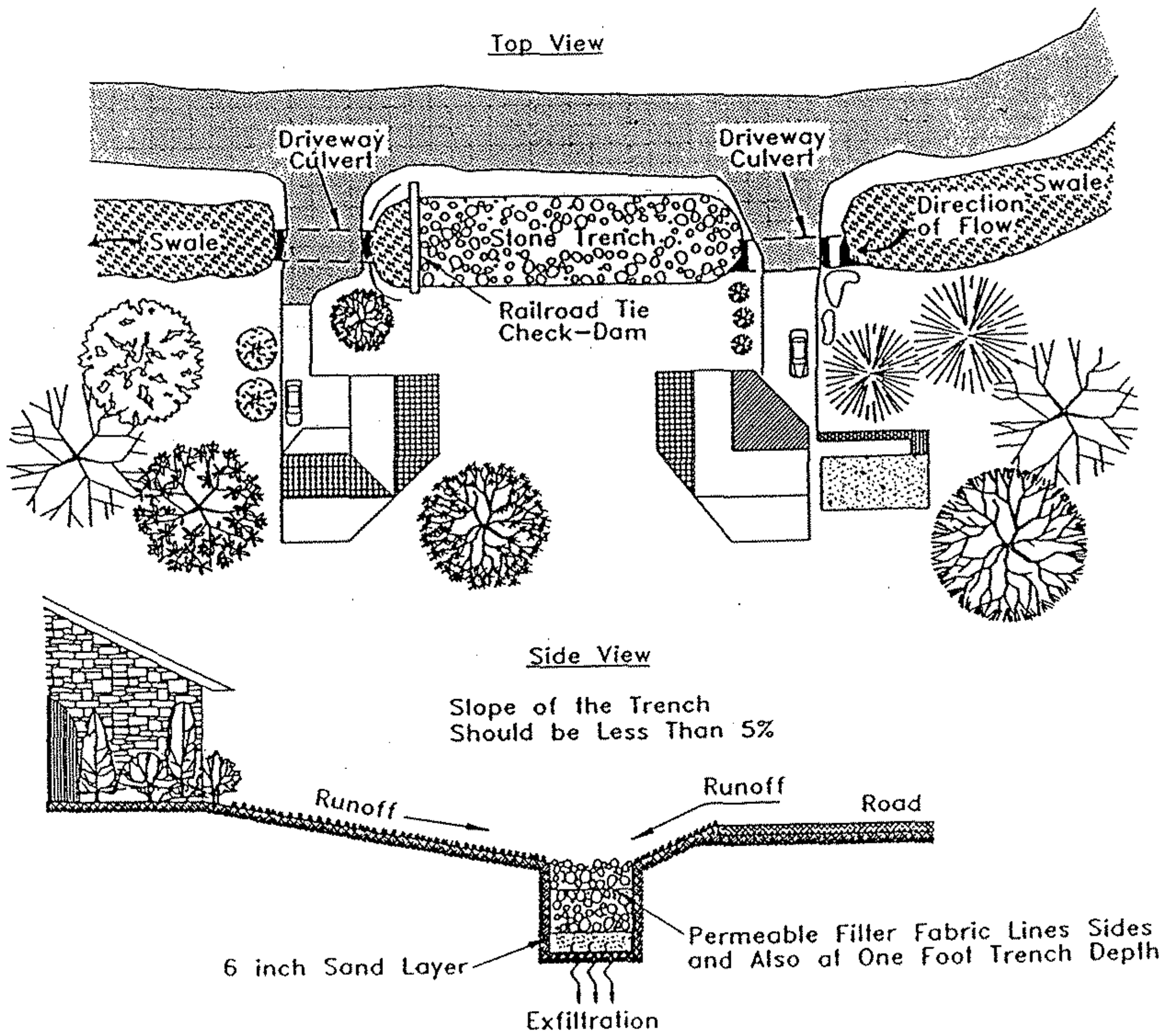

Figure II-8: Swale/Trench.

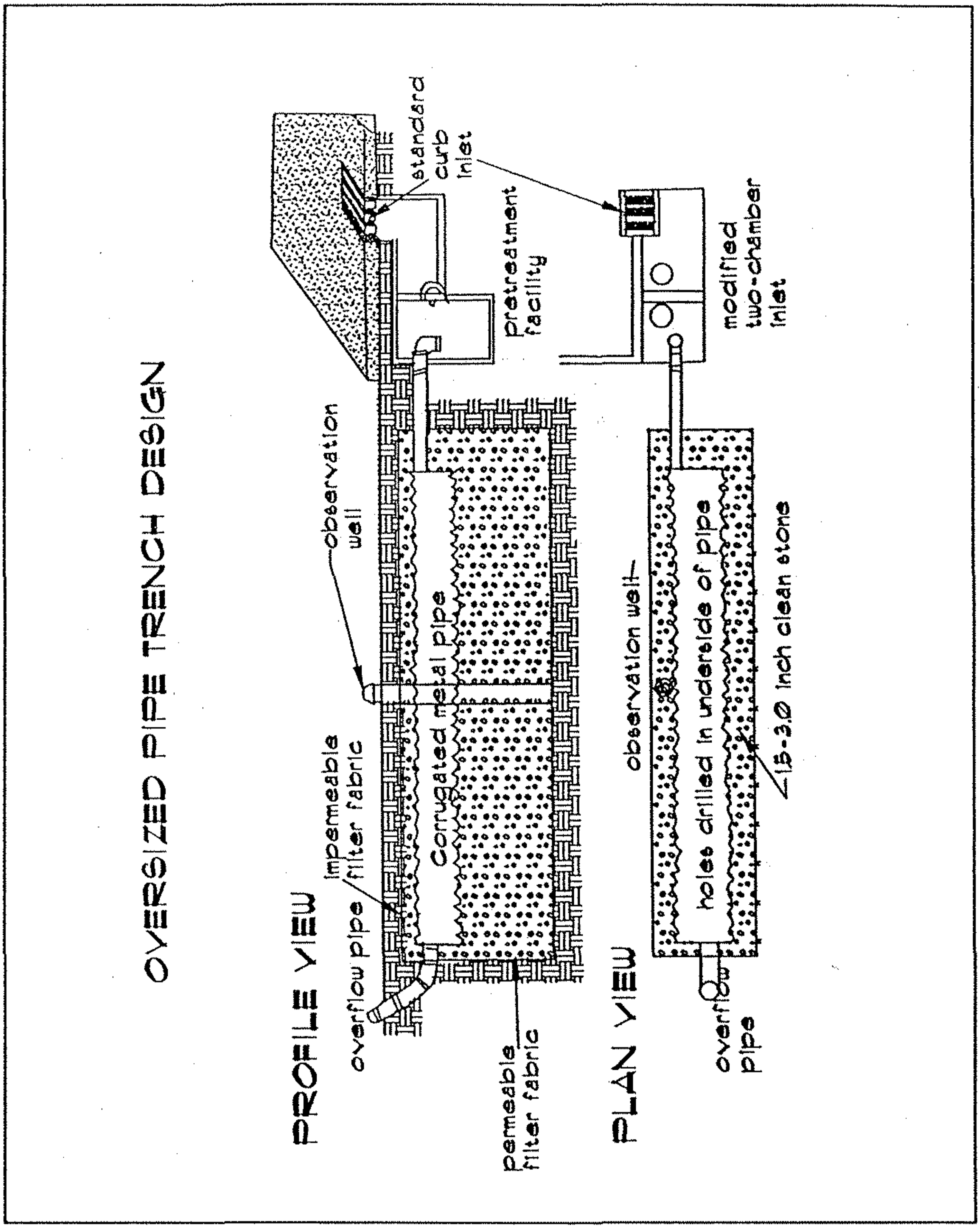

Figure II-9: Buried Pipe Trench.

Swale/Trench

When combined with grassed swales, infiltration trenches (Figure II-8) can provide fairly effective treatment levels in low density residential areas. The primary concern with such a system is the longitudinal slope of the swales, which should not exceed 5%. Steeper slopes can result in concentrated flows which could erode the swales and ultimately clog the trenches. Occasionally, some type of check dam is needed at the end of the infiltration trench portion of such a system, to enhance the infiltration into the trench and to avoid having too much flow bypassing the trench itself.

Buried Pipe Trench

In instances where a surface trench is inappropriate in a Swale/Trench system, or where it is desired to route concentrated runoff through a trench, a buried pipe trench (Figure II-9) could be used. A typical system consists of some type of perforated pipe which accepts the surface runoff and distributes it throughout the stone reservoir for eventual exfiltration to the soil. The main advantage of this system are its aesthetics relative to a surface trench. The primary disadvantages with a buried trench are difficulties in construction, difficulty in routine maintenance, and the general need for pretreatment of runoff through some type of oil/water separator and/or grit chamber.

MAINTENANCE REQUIREMENTS

Routine maintenance requirements of trenches are not great, although, as with all structures of this type, actual performance of maintenance is not always accomplished. Because of their small size, infiltration trenches are often inconspicuous and are therefore likely to be overlooked in most maintenance programs. The potential impacts of their failure, however, indicate the necessity of maintenance.

- The infiltration trench should be ***inspected*** immediately after construction, three times a year for two years, and annually thereafter. Inspections should look for ponding after large storms, which would be an indication of clogging. Hand inspections should also be done in the upper layer of surface trenches to check for excess clogging.
- ***Grass filter strips and slopes*** draining into the infiltration trench should be maintained with dense and healthy growth. Bare spots and eroded areas should be quickly leveled and reseeded. The grass buffer strips should be mowed at least twice a year to prevent the growth of undesirable vegetation, as well as for aesthetics. Residential filter strips may require more frequent mowing in order to maintain consistency with the neighborhood.

- If ***pretreatment chambers*** are used in conjunction with an infiltration trench, these should be checked monthly/bi-monthly from October through June, and cleaned of sediment and oil or grease. The cleaning needs revealed during the first nine months can be the basis of facility specific maintenance schedules.
- ***Trees*** abutting the grass filter strips should be cut back to prevent their drip lines from extending onto the strips. This reduces the chance of trench clogging due to leaf litter. Any volunteer trees which sprout in the immediate trench area should be removed to avoid root penetration into the stone reservoir.
- Occasionally, a trench will ***clog*** regardless of the measures taken to prevent such clogging. Most clogging of this type occurs in the upper layer of the trench, usually above the first layer of filter fabric. To remedy this, the top layer of stone must be removed, and then cleaned or replaced with new stone.

INFILTRATION BASINS

Infiltration basins and ponds are depressions which have been either excavated or bermed to allow for the storage of surface runoff. While many pond facilities are lined in some locations or placed in impervious soils to prevent seepage, infiltration basins are designed to allow for such seepage. This has been shown to effectively remove many surface water contaminants including nutrients such as phosphorus, and reduces the volume and peak of storm runoff.

Infiltration basins can serve relatively large drainage areas and can be sized to provide control of large design storm flows. As such, they can often be used to provide relatively high annual removal rates.

ADVANTAGES AND DISADVANTAGES

Advantages

- Infiltration basins can serve larger areas than most BMPs.
- Infiltration basins can be used as sediment traps during site construction, provided that sediment is removed after construction and the infiltration media is protected during construction or replaced after construction.
- Better groundwater recharge conditions exist at locations where infiltration basins are used, creating a more natural water balance in an urban area.
- Well maintained infiltration basins can enhance the aesthetic value of a development.
- Pollutants can be removed in infiltration basins, by means of settling, percolation/filtering, and soil sorption.
- Infiltration basins are often more cost-effective when compared to other BMPs.

Disadvantages

- Infiltration basins have a higher failure rate than other infiltration facilities, particularly when they are used in unsuitable soils and/or when maintenance is inadequate and/or when significant amounts of disturbed soils exist in the drainage area.
- If not properly maintained, infiltration basin ponding can be a source of several nuisances such as mosquitos, odors, and saturated ground.
- As with detention facilities, the land requirements of infiltration basins can be prohibitive on smaller sites.

- The liability associated with infiltration basins is similar to that of detention facilities, and as such, is higher than most other infiltration facilities.
- Catchment areas should not be served by infiltration basins if hazardous materials are likely to be present.
- Concerns with contamination may lead to groundwater monitoring.

DESIGN CRITERIA

The following design criteria are specific to infiltration basins and are in addition to the general criteria for infiltration facilities discussed earlier. It should be mentioned here that these criteria do not include sizing for flood storage.

Soils

- A minimum of three ***sub-surface infiltration tests*** shall be performed for each proposed infiltration basin as described in the infiltration testing section.

Sizing

- The ***surface area*** of the infiltration basin should be done according to the procedure defined in the introductory section of the infiltration chapter.
- The ***volume*** of an infiltration basin should be adequate to capture 0.5 inches of runoff from the drainage basin. Any excess should be routed through an overflow spillway.

Groundwater

- The ***minimum allowable depth*** from the bottom of each infiltration basin to bedrock or fragipan is four feet unless the infiltration facility penetrates through the fragipan and into a lower permeable layer.

Miscellaneous

- Infiltration basins cannot be constructed on ***slopes*** greater than 25%.
- The ***maximum water surface*** during the 100 year storm of any infiltration basin shall be a minimum of 20 feet horizontally from any structure, property line, or natural gas pipeline, and 100 feet from any septic/drain field.
- All infiltration basins shall be at least 50 feet horizontally from any ***steep (> 15%) slope*** which may be at risk of failure due to additional groundwater recharge from the ponds.

- Infiltration basins should be designed to ***infiltrate*** the first 0.5 inches of storm runoff from the drainage completely after a maximum of 2 days.
- Construction specifications, allowable materials, accessibility, easements, and hydraulic design for any ***flood control*** shall be as specified by the appropriate jurisdiction.

VARIATIONS

Due to the wide variation among potential sites where infiltration basins can be used, the ultimate layout and design will vary. Some general types of infiltration basins are:

Full Infiltration Basin

This design (Figure II-10) is intended to infiltrate an entire design volume of 0.5 inches of runoff. The main outlet structure is an emergency spillway for the larger storms. Riprap should be placed near or around the basin inlet as an energy dissipator and to spread inflow for uniform infiltration. This type of infiltration basin is primarily suitable for smaller drainages, between 5 and 20 acres.

Combined Infiltration/Detention Basin

This design (Figure II-11) is an extension of the full infiltration basin design in that it includes a vertical riser to control the ponding depth and greater storage volumes to reduce the larger design storm peaks (see extended detention ponds in Pond-Marsh chapter). The dead storage below the control orifice is designed to be completely infiltrated. Some type of base flow channel or bypass may be necessary if base flow downstream is to be maintained.

Infiltration Basin with Baseflow Channel

This design (Figure II-12) is a variation of the combined infiltration/detention basin, with the inclusion of a small channel to maintain downstream base flows. This channel usually runs along one side of the bottom of the basin, and routes base flows through the basin via a low-flow orifice in the vertical riser. The channel is typically riprapped with an underlying layer of impermeable geo-textile, and confines baseflow. Once incoming flows exceed design depth, they spill over the channel into the basin bottom for ultimate infiltration into the soils.

Detention/Treatment Pond with Infiltration Sump

This is a wet detention pond, or similar facility, with one or more shallow injection sumps/wells.

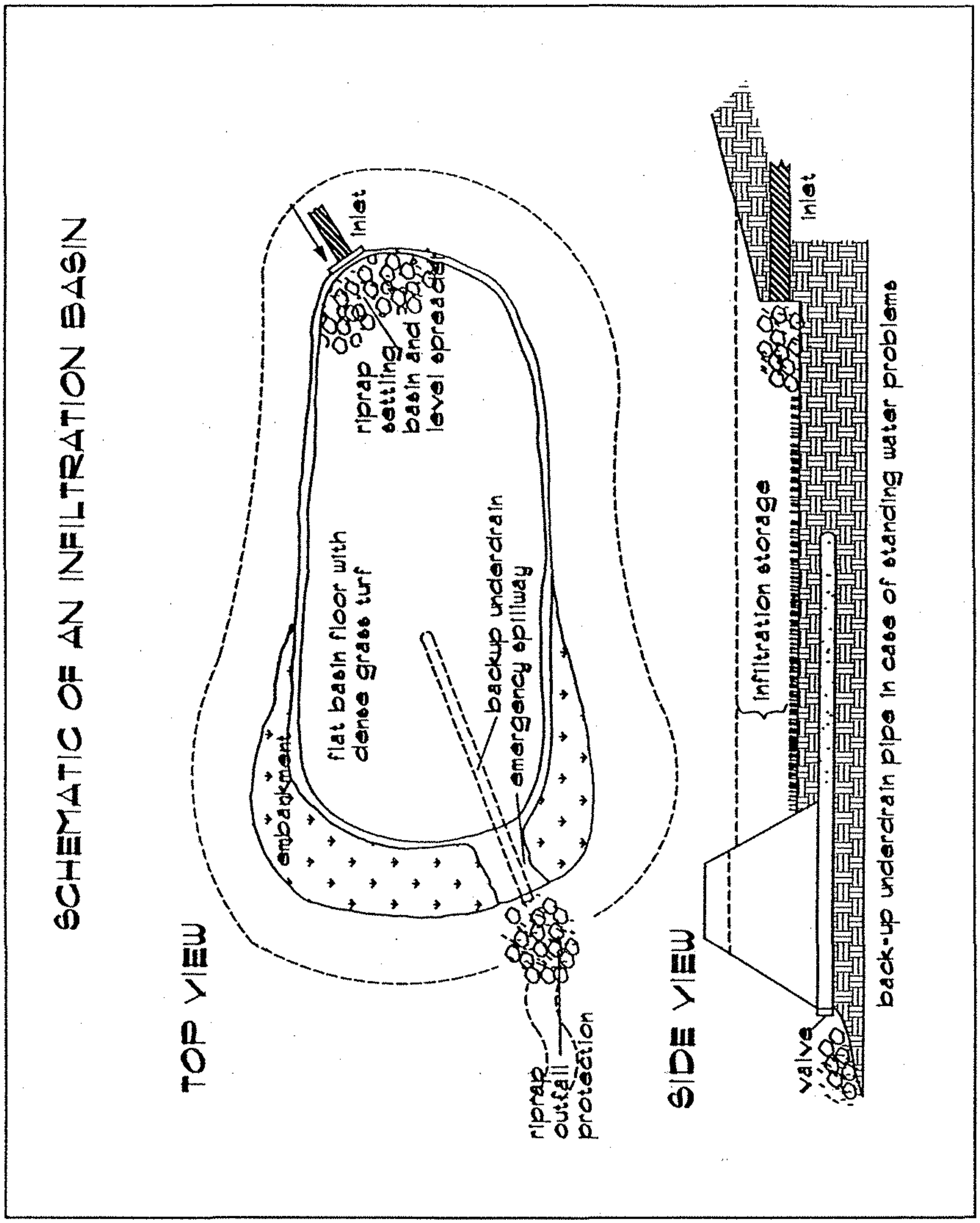

Figure II-10: Full Infiltration Basin.

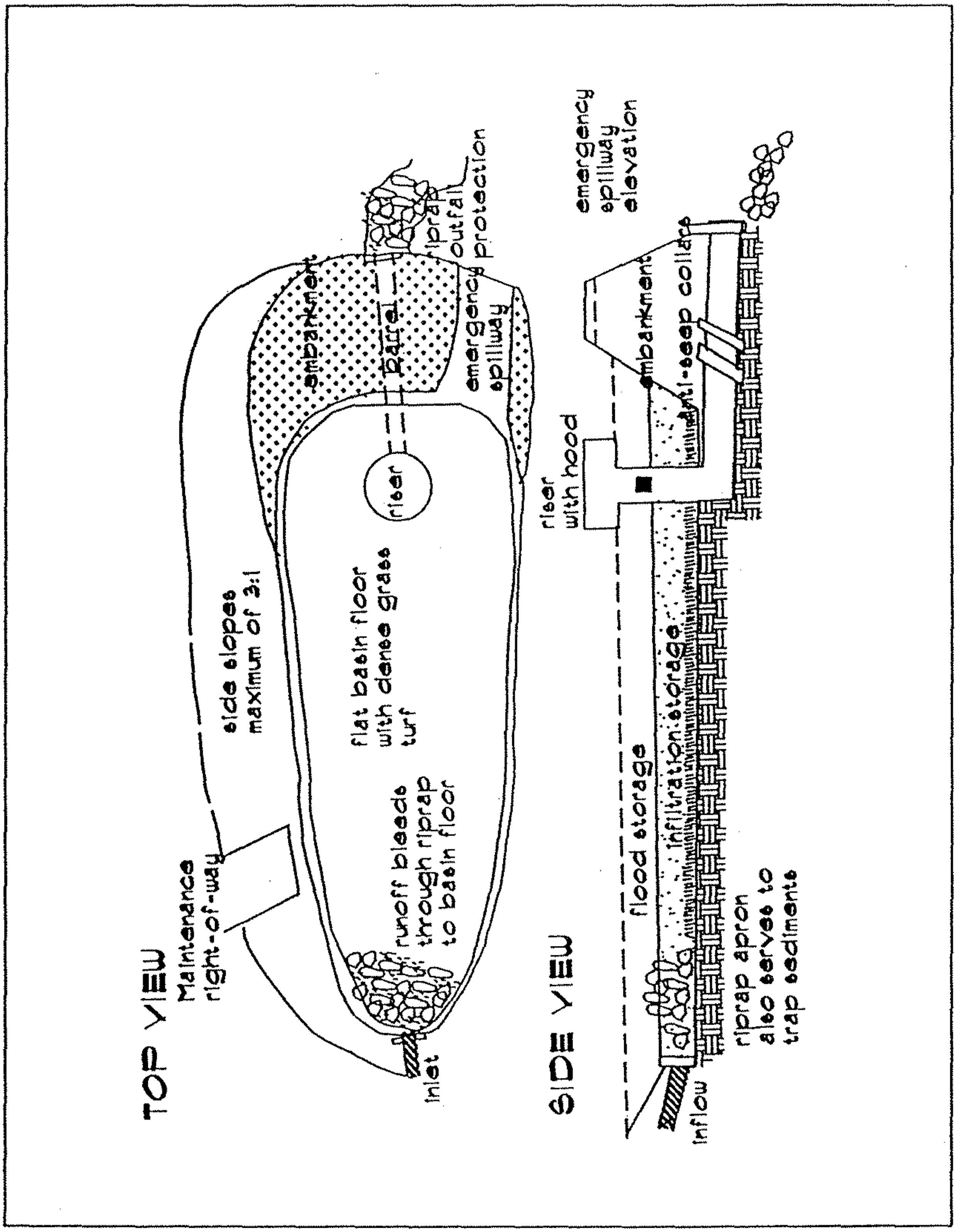

Figure II-11: Combined Infiltration/Detention Basin.

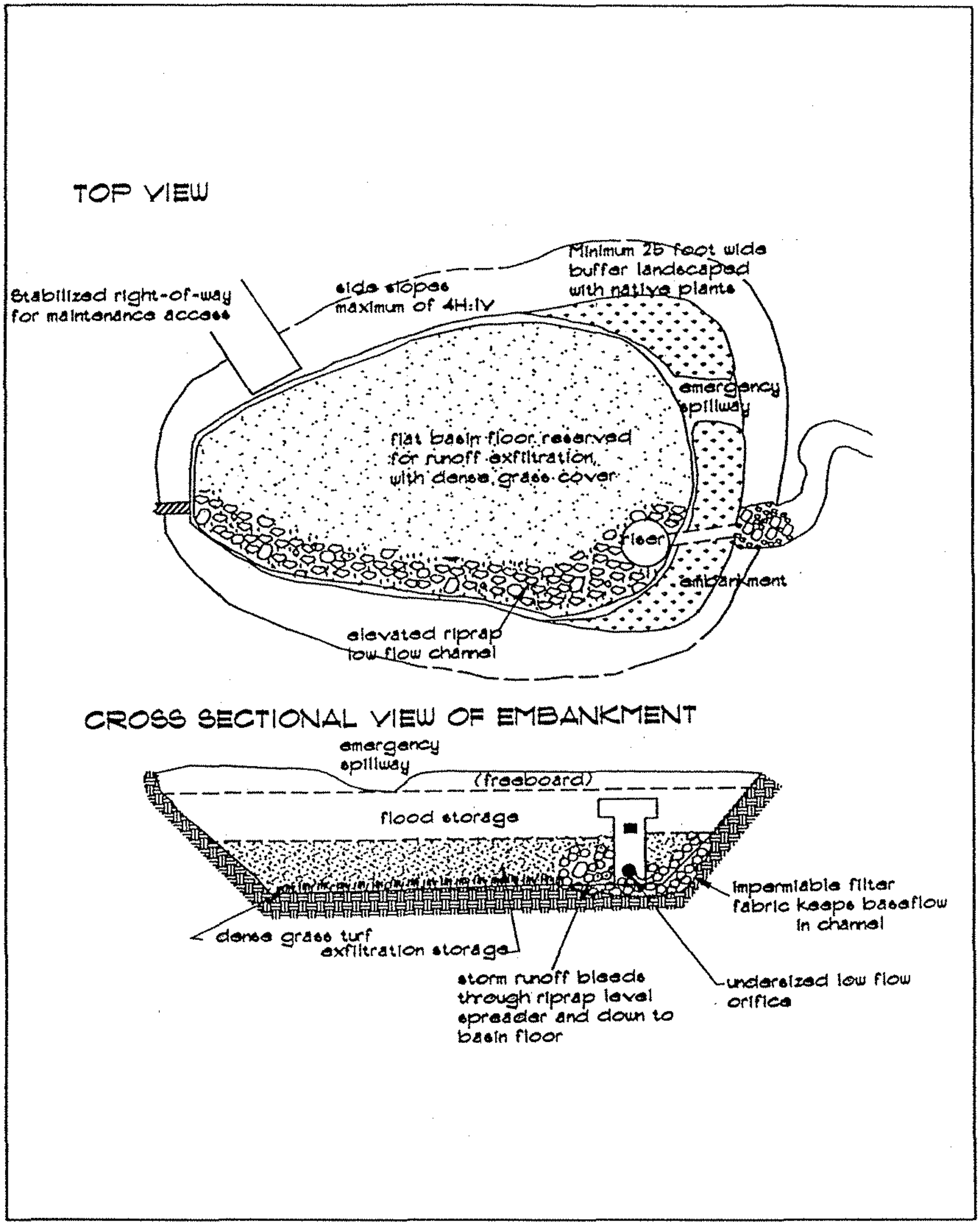

Figure II-12: Infiltration Basin with Baseflow Channel.

MAINTENANCE REQUIREMENTS

The routine maintenance requirements of infiltration basins are greater than those for dry detention facilities and include the following:

- The infiltration basin should be ***inspected*** after every major storm during the first few months after construction and include measuring the amount of time it takes for runoff to completely drain from the facility. Water remaining 48 to 72 hours after the storm event is likely to indicate clogging. Upland erosion, excessive compaction within the basin, low spots, or poor soils, may all contribute to clogging.
- To avoid erosion, ***upland areas/grass filter strips*** should be maintained with dense and healthy growth. Bare spots and eroded areas should be quickly leveled and reseeded.
- Grassed filter strips, side slopes, and basin floor should be ***mowed*** at least twice a year to prevent the growth of undesirable vegetation, as well as for aesthetics. Basins in residential or recreational areas may require more frequent mowing in order to maintain aesthetics.
- If a basin is built in moderately permeable soils, annual or semi-annual ***tilling*** should be considered to enhance the infiltration capacity of the underlying soils. Tilling is not recommended unless experience at the site indicates its necessity. The best time for tilling is in late summer, when soil permeability is at a minimum. Any areas which are disturbed by the tilling should be replanted quickly to avoid erosion damage.
- Over time, sediment accumulations can severely limit the infiltration capacity of any basin. As a result, occasional ***removal of sediment*** is required. Any removal should occur after the basin has thoroughly dried out and should be performed with the lightest equipment possible. This avoids unnecessary compaction of the underlying soils, which would further reduce their infiltrating capacity. An emergency outlet should be included that provides for complete drainage during periods of clogging. Tilling of the basin bottom is required after such sediment removal work.

POROUS PAVEMENT

A porous pavement system consists of a series of permeable courses which are capped with a layer of porous material. This cap material usually is made up of either a porous asphaltic or concrete paving material capable of sustaining limited loads, but with a sufficient number of connected voids to allow for the rapid infiltration of surface water. A schematic cross section of a typical porous pavement system is shown in Figure II-13. and a typical design is shown in Figure II-14.

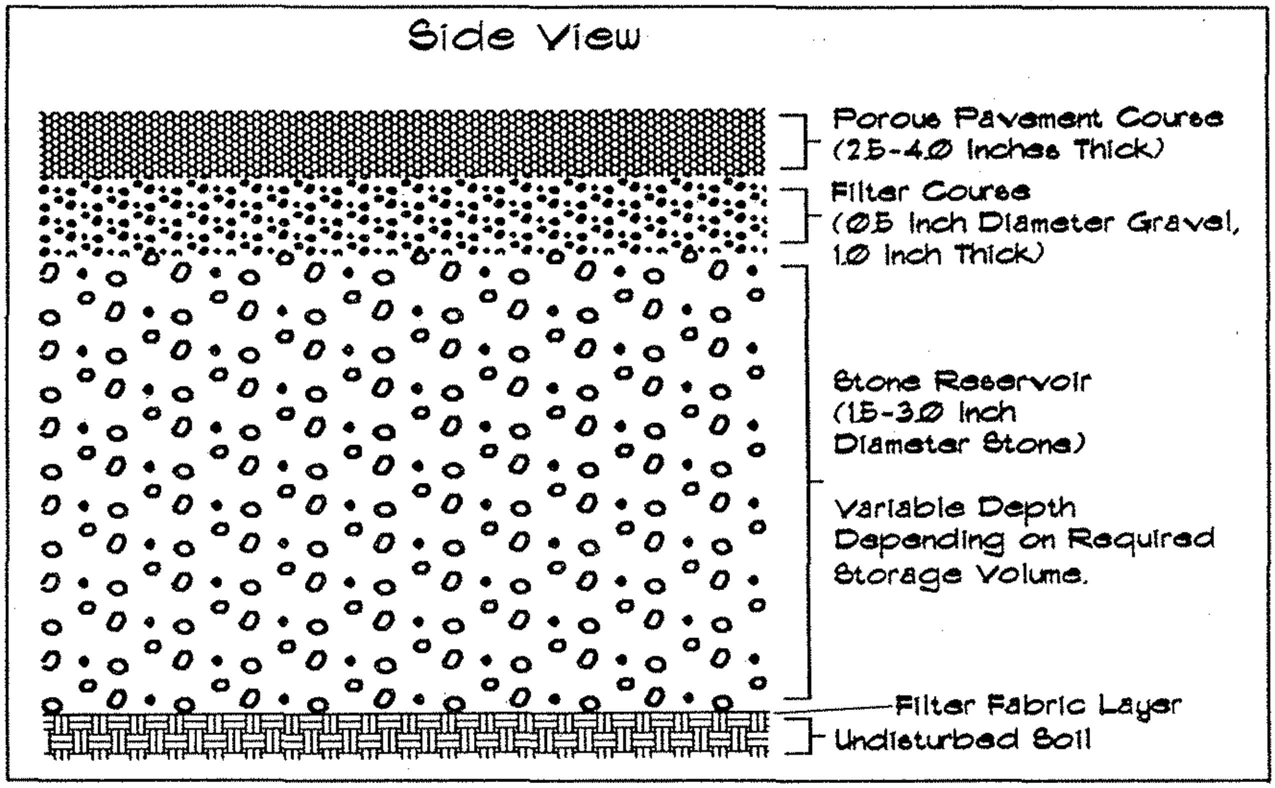

Figure II-13: Typical porous pavement cross-section.

Porous pavement systems are usually limited to low-volume and low-load parking areas. Systems of this type also require gentle slopes, permeable native soils, and water tables with bedrock deep enough to sufficiently accommodate the potentially large recharge volumes which can occur with their use.

Specific areas where these systems can be used are:

- fringe and overflow parking areas;

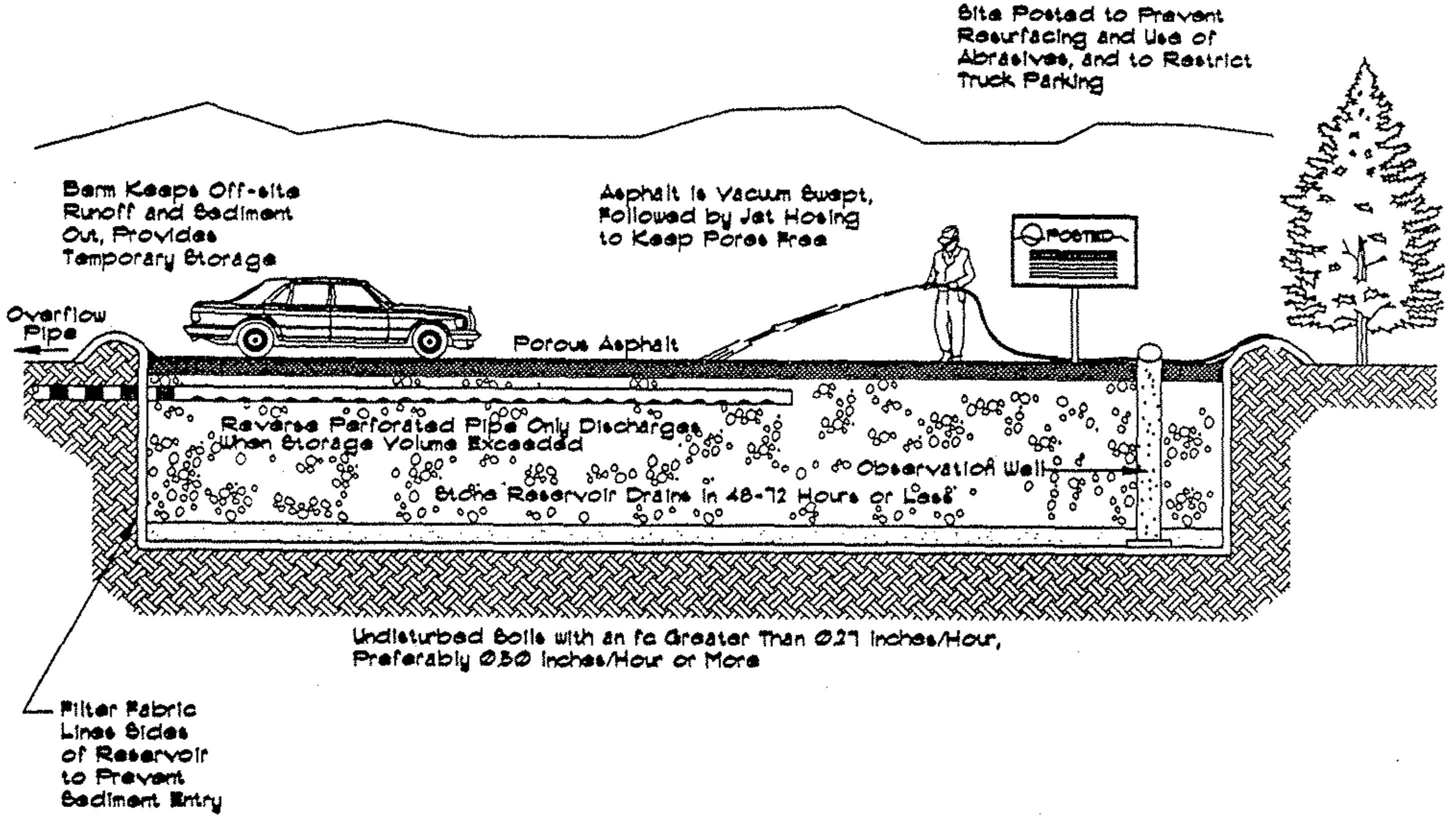

Figure II-14: Typical porous pavement design.

- emergency lanes and vehicle cross-overs on highways not expected to carry large volumes of hazardous materials.
- small airport parking aprons, taxiways, and runway shoulders;
- low-volume roadways.

ADVANTAGES AND DISADVANTAGES

Advantages

A well designed and installed porous pavement system has several advantages over conventional pavement systems.

- Porous pavements can trap pollutants, including phosphorus, and sediments, which would normally be carried off-site.
- They can reduce surface runoff peaks and volumes from small areas.
- At locations where porous pavement is used, groundwater recharge conditions are better, restoring a more natural water balance in an urban area.
- With the rapid infiltration of surface water, ponding and puddling over the area is significantly reduced.

Disadvantages

There are also several disadvantages to porous pavements, particularly with poorly designed or installed systems, or systems which are not maintained properly.

- Porous pavements tend to clog with sediments if they are not properly maintained. Correcting such clogging can be more time-consuming and expensive than for other infiltration systems, with complete replacement of the courses down to native soil sometimes necessary. For this reason, porous pavement is not suitable for construction runoff.
- High groundwater, soils with low permeability, or shallow impervious layers in the immediate area of a porous pavement will reduce or eliminate the effectiveness of the system.
- The threat of groundwater contamination is significant from surface spills over the porous area. Great care must be taken to ensure that spills of a hazardous nature are minimized by the prohibition of porous pavement in critical groundwater areas or where the potential for hazardous materials spills is moderate to high.

- The occurrence of extended periods of wet weather typical of the Pacific Northwest can create anaerobic conditions in the lower courses of a porous pavement system used in conjunction with poor drainage conditions. An extended wet period can also reduce the load-bearing capacity of the pavement.
- Porous pavements are susceptible to frost heave and have poor resistance to abrasion.
- Porous pavement may limit the use of sanding materials during icy conditions.

DESIGN CRITERIA

The following design criteria are specific to porous pavement systems and are in addition to the general criteria for infiltration facilities discussed earlier.

Soils

- A minimum of one ***soils log*** for each 10,000 square feet of the proposed pavement system, extending a minimum of 5 feet below the bottom of the proposed lowest course of the pavement system shall be required.
- A minimum of three sub-surface infiltration tests shall be performed for each proposed pavement system as described in the infiltration testing section.

Sizing

- The ***minimum surface area*** of a porous pavement system should be designed according to the general sizing procedures presented in the introductory chapter to infiltration facilities.

Groundwater Protection

- A minimum of ***one observation well*** shall be placed at the downhill side of the porous pavement area. The well shall extend from the surface down to the bottom of the lowest course in the porous pavement system. The primary purpose of the well is to monitor runoff exfiltration from the stone reservoir after large storm events, as an indication of system performance. Another purpose of the well is the early detection of contamination of the subsurface water within the reservoir course.

Pavement

- Design shall follow ***Oregon State Highway specifications*** for porous pavement construction.

Miscellaneous

- Porous pavement systems can be used only with ***slopes*** with less than a 5% gradient.
- ***Filter fabric*** shall be placed entirely around the bottom and sides of the porous pavement excavation to prevent fines from entering the system, particularly during construction.
- No porous pavement system should be placed horizontally within 10 feet downgradient or 100 feet upgradient of any ***structure***.
- The ***stone reservoir*** in a porous pavement system should be sized to drain the design storm in a maximum of 72 hours. For optimal pollutant removal, a minimum drainage time should be 6 hours for the water quality design storm.

Management

Signs identifying the special nature of the porous pavement system must be placed in and near the porous pavement area. These signs should warn against

- excessive loads;
- introduction of sediment at the surface, particularly sanding for snow removal;
- servicing of vehicles where spills may result;
- entry by any vehicles/containers with hazardous materials; and
- repaving with conventional materials.

VARIATIONS

Variations to a porous pavement system can address several design issues. These variations include the use of drain pipes, french drains, additional sand filter layers, and sumps/dry wells. The first three of these variations may be seen in Figure II-15.

Pipe Drains

These systems are used with less permeable soils. The pipes are usually perforated with 1/4- to 3/8-inch diameter holes along the bottom half of the pipe and should be wrapped in filter fabric. Pipes range in size from 4 to 120 inches and can be plastic, clay, concrete, cast iron, or aluminum alloy.

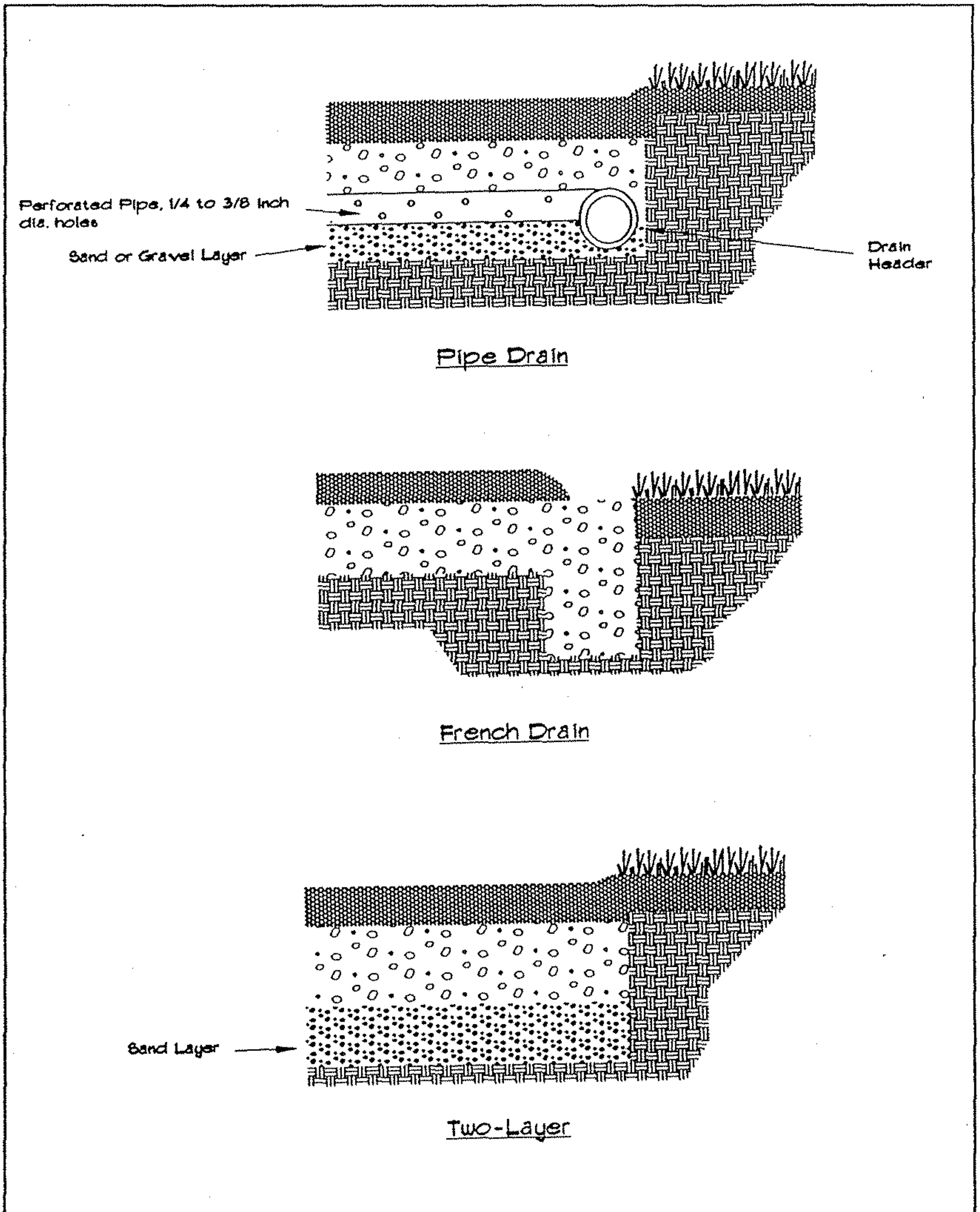

Figure II-15: Variations on porous pavement design.

French Drains

These systems consist of relatively deep trenches dug around the periphery of the porous pavement area, with filter fabric lining the sides. These deep trenches allow more water to be stored, which provides for more percolation time in less permeable soils.

Multi-layer Systems

In these systems, the reservoir course is underlaid by a fine course of sand, which prevents clogging and facilitates drainage.

Sumps/dry wells

These systems are commonly used in the Metro area, particularly in southeast Portland. Generally they consist of a perforated 30' deep concrete cylinder, sometimes enclosed by coarse gravel and/or filter fabric, and usually proceeded by a sedimentation structure.

MAINTENANCE REQUIREMENTS

- Porous pavement should be ***inspected*** frequently; including immediately after construction, and at least twice annually thereafter. Inspections should look for ponding after large storms, which would be an indication of clogging, and petroleum product accumulation.
- Small cracks and potholes can be repaired with conventional ***patching*** materials, provided the overall area repaired with such materials does not exceed 10% of the total porous pavement surface area.
- Maintaining a ***clean surface***, free from debris and potentially clogging sediments, is important to the success of any porous pavement system. The porous pavement surface should be vacuumed at least quarterly, followed by high-pressure water jetting.
- Porous pavements should not be ***sanded***, as the sand will clog the surface course.
- In areas where ***spot clogging*** of the surface occurs, half-inch holes can be drilled through the asphalt layer. In low spots in the porous pavement area, drop inlets with trapped catch basins may be necessary to route runoff into the reservoir course.

ROOF DRAINS

Roof drains are variations on infiltration trenches designed specifically to accept roof drainage only. These drains are not intended to filter any surface runoff which could contain sediment or hazardous materials. A typical roof drain is shown in Figure II-16.

Due to the small size of these systems, they may be easily incorporated into a wide variety of sites, given the proper drainage conditions. They would be particularly suited to large commercial and residential areas, where the combined effect of many roof drains could have a marked impact on overall storm drainage peak flow. They cannot be used in areas where settled airborne pollutants can accumulate, or on roofs containing machinery exposed to precipitation, ponding, or runoff.

ADVANTAGES AND DISADVANTAGES

Advantages

- In appropriate areas, roof drains can reduce the need for additional storm sewers or other stormwater control devices because of peak flow reduction.
- Roof drains are small and simple to install, compared to other control devices.
- Existing developed sites could be retrofitted with roof drains.
- Better groundwater recharge conditions exist at locations where roof drains are used, restoring a more natural water balance in an urban area.

Disadvantages

- As with all infiltration systems, maintenance of roof drains is necessary for their proper operation to prevent clogging of the stone backfill.
- Construction of a roof drain infiltration trench requires considerable care and skill.
- The roof area drained by any roof drain must be kept relatively clean and free of debris such as leaf litter, which can create additional maintenance demands.

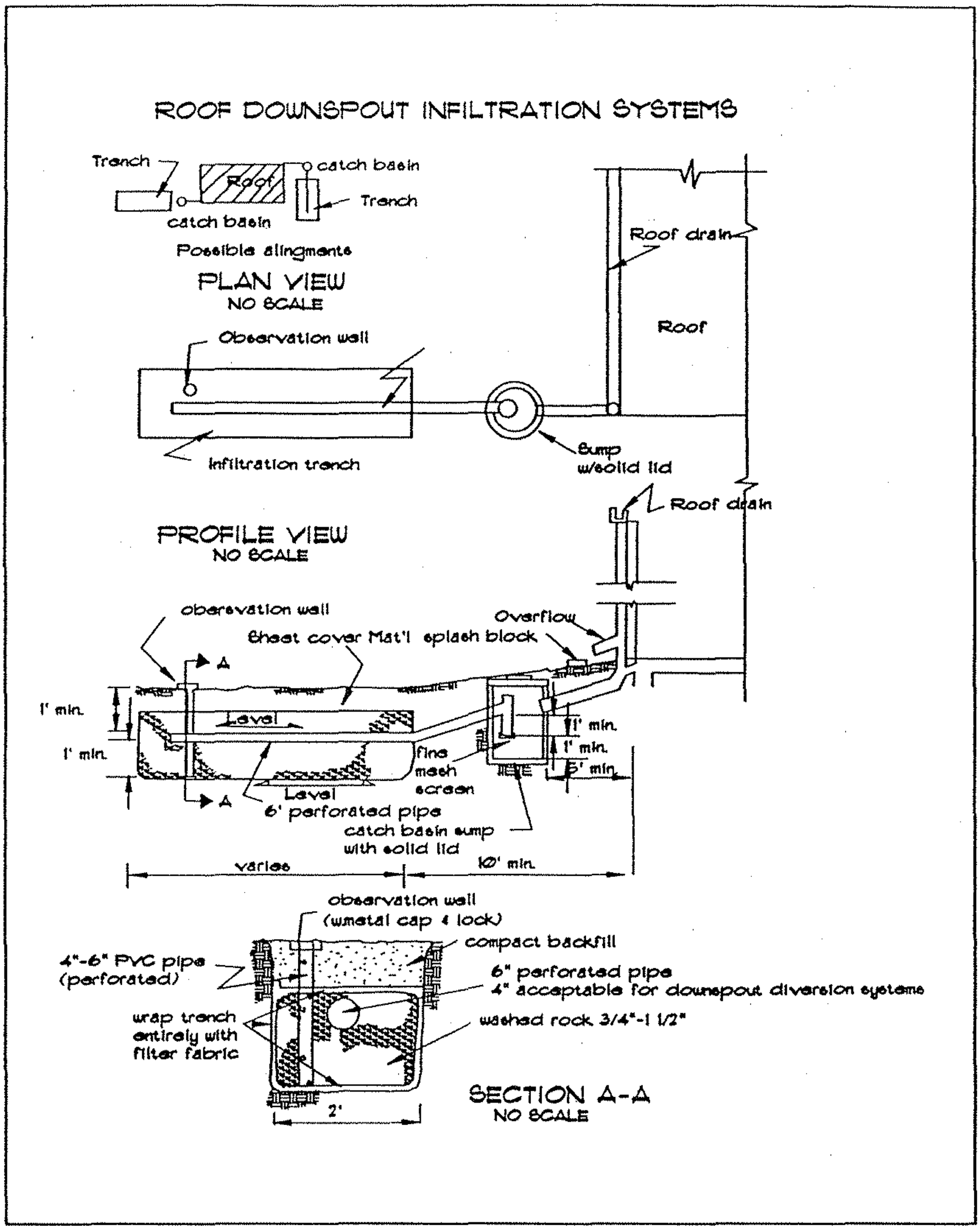

Figure II-16: Typical Infiltration Roof Drain.

DESIGN CRITERIA

The following design criteria are specific to roof drains and are in addition to the general criteria for infiltration facilities discussed earlier.

Soils

- A minimum of ***one soils log*** for each proposed trench location, extending a minimum of 2 feet below the bottom of the proposed lowest course of each two roof drain infiltration trenches should be performed
- A minimum of one ***sub-surface infiltration test*** should be performed for each two proposed roof drain infiltration trenches as described in the infiltration testing section.

Sizing

- The total ***surface area*** provided by a set of roof drains shall be calculated from the sizing procedures presented in the introductory section of the infiltration chapter with the following modifications:
  - The drainage area referred to in step 1 of the general sizing procedures shall be the total contributing area in square feet for each drain.
  - The runoff coefficient (Rv) used in step 2 should be a constant 0.95 for all roofs.
  - The resulting surface area calculated from the catchment ratio will be in square feet, not acres.

Groundwater

Due to the limitations set on the use of roof drains, the quality of runoff entering them probably will not contribute to significant groundwater contamination from infiltration. However, specific precautions should be taken to avoid accidental releases of hazardous materials into the subsurface.

- A minimum of one ***observation well*** should be placed in the center of each roof drain trench serving commercial or multi-family (≥ 4 units) residential buildings. The well should extend from the surface down to the bottom of the lowest course in the trench system. A detail of a typical observation well is shown at the bottom of Figure II-16. The primary purpose of the well is to monitor runoff exfiltration from the stone reservoir after large storm events, as an indication of system performance.

- Provisions are required to reduce the risk of releasing ***hazardous materials*** on the roof of any building drained by roof drain trenches such as warning signs and the prohibition of certain activities. Events such as the failure of roof mounted HVAC equipment, for example, could easily contaminate roof drain systems.

Miscellaneous

- Allowances must be made for ***overflow and safe transport*** of runoff when the infiltration or storage capacity of the roof drain infiltration trench is exceeded. If trenches are built beneath pavement, small drain/catch basins need to be placed at the ends of the perforated drain pipe. These basins should be designed so that any overflow from the trench exits the catch basin at least one foot below the overlying pavement.
- The ***maximum roof area*** served by any single roof drain trench should be ≤ 5,000 square feet.
- ***Screens*** should be placed over each roof drain inlet to prevent roof debris from washing into either the sump or stone drain.
- Roof drain infiltration trenches cannot be used on ***slopes*** with more than 25% grade.
- The ***center lines*** of adjacent roof drain trenches must be at least 6 feet apart.
- Roof drain trenches should not be more than 100 feet from their ***inlet sumps***.
- ***Filter fabric*** should be placed entirely around the bottom and sides of the infiltration trench excavation to prevent fine sediment from entering the system, particularly during construction.
- All roof drain trenches should be at least 50 feet from any slope which may be at risk of failure due to additional ***groundwater recharge*** from the trenches.

MAINTENANCE REQUIREMENTS

Routine maintenance requirements of roof drain trenches are not great, although, as with all on-site structures of this type, actual performance of the maintenance is not always accomplished. Because of their small size, roof drain trenches are inconspicuous and are therefore likely to be overlooked in most maintenance programs. The potential impacts of their failure, however, make such maintenance mandatory.

- The roof drain trench should be ***inspected*** frequently, immediately after construction, and at least twice annually thereafter. Inspections should look for overflowing inlet sumps or surcharged down spouts after large storms, which would be an indication of clogging.
- The roof area drained by any roof drain trench must remain free of debris to prevent ***clogging*** of the stone drain.

PLANNING AND DESIGN CHECKLIST

MAJOR PHASES

A. INITIAL EVALUATION

B. PLANNING

C. DESIGN

A. INITIAL EVALUATION

A.1. Site Review of Opportunities, Constraints, and Characteristics

- Streams, pipes, ditches
- Ponds and depressions
- Downstream drainage system

A.2. Compare Management Techniques with Site Characteristics

- Trenches
- Basins
- Sumps
- Porous pavement
- Roof drains

A.3. Assess Site Specific Infiltration Options

A.4. Initially Choose Infiltration Components of the Site Plan

A.5. Review Concepts with Appropriate Jurisdiction

- Revise if necessary

B. PLANNING

B.1. Assess Tributary Area Characteristics (for site and individual facilities)

- Drainage area boundary and topography
- Size

- Cover and effective impervious area
- Development types
- Slope-side slopes and stream gradients
- Soils reconnaissance (site and tributary area using existing information)
  - SCS soil types
  - Stability (pre- and post-development)
  - Infiltration
  - Erodibility
  - Phosphorus availability

B.2. Develop Flood Hydrology/Hydraulics

- Select analysis points
- Estimate existing conveyance/detention capabilities
- Prepare flood hydrographs for the existing system using the appropriate jurisdiction's design storm and analysis methods
- Prepare flood hydrographs for the site and tributary area assuming full development
- Develop hydraulic profile/elevations for analysis points and at hydraulic constraints during normal and impeded/blocked flow conditions
- Select drainage/flood management options
- Re-analyze flood hydrology superimposing the flood management options

B.3. Screen Options and Develop Site Plan

- Select, locate, size, and hydraulically define various water quality management options for infiltration
- Evaluate hydraulic conditions for:
  - Normal flows for the water quality design storm
  - Impeded/blocked conditions

C. DESIGN

C.1. Perform Soils Analysis

- Confirm or determine the SCS classifications
- Soils logs
- Infiltration tests
- Erodibility of the tributary area
- P availability and removal potential (basin and site)
- Geotechnical stability

C.2. Confirm and Locate Options Selected

C.3. Perform Hydrologic Analysis

- Flood design storm

C.4. Evaluate Hydraulic Profile at Analysis Points

C.5. Prepare Plan View and Cross-Section Drawings

C.6. Select and Describe Materials

C.7. Prepare Plans and Specifications

D. POST CONSTRUCTION

D.1. Perform Infiltration Tests of Facilities

- Perform under wet site conditions resulting from at least one prior test within 24 hours

CHAPTER III

POND-MARSH FACILITIES

CONTENTS

POND-MARSH FACILITIES

CONTENTS (continued)

POND-MARSH FACILITIES

CONTENTS (continued)

FIGURES

TABLES

POND-MARSH FACILITIES

This chapter discusses various types of pond-marsh facilities which can be used for water quality treatment of storm water. These facilities should be distinguished from traditional detention/retention basins whose primary purpose is to provide volume and peak flood control for urban runoff. This chapter includes a ***summary*** which gives an overview of the facilities and considerations, a ***selection and siting discussion***, ***general design criteria*** which apply to all of the types of pond-marsh facilities, ***specific design criteria*** for each type of facility, and a ***planning/design checklist***.

SUMMARY

Pond-marsh facilities consist of a wide variety of design alternatives, all intended to enhance the quality of storm runoff. They do this by means of a diverse array of chemical, physical, and biological processes. The most effective of these facilities are:

- *TREATMENT WETLANDS* - Any facility below a drainage which maintains a permanent shallow pool with benthic (bottom dwelling) vegetation providing water quality treatment for storm water runoff.
- *WET PONDS* - Constructed ponds with a permanent pool for quality control and sufficient live storage for the control of design storm runoff. The permanent pool is usually maintained by some type of riser structure. Flood control is maintained by the use of overflow structures and emergency spillways.
- *EXTENDED DETENTION PONDS* - Constructed ponds whose outlets have been designed to retain the volume of a design storm for some minimum time (usually 24-40 hours) to allow for the settling of particles in storm runoff which are associated with urban storm water contaminants.

As treatment facilities for urban runoff, pond-marsh facilities work by a wide array of removal processes, with treatment wetlands having the widest range and extended detention ponds having the narrowest range. Table III-1 shows the range of removal processes, the contaminants affected, and the likely role each process plays for each of the pond-marsh facilities listed.

Pond-marsh facilities are intended to treat the runoff from both residential and commercial areas. Their use for most industrial areas may be limited due to the toxicity of runoff contaminants, which may inhibit the biological activity of these facilities. Without intensive maintenance, pond-marsh facilities are particularly unsuited for drainage areas undergoing major construction, or otherwise expected to produce high sediment loads in the runoff.

Table III-1: Removal processes in pond-marsh facilities.

Process	SS	CS	BOD	N	P	HM	Org	Bacteria and virus	Wetlands	Wet Pond	Ext. Det. Pond	Description
Physical												
Sedimentation	P	S	I	I	I	I	I	I	1	1	1	Gravitational settling of solids
Filtration	S	S							1	1	2	Mechanical filtration through substrate, root mass, etc.
Adsorption		S							1	1	2	Adsorption by soils
Chemical												
Precipitation				P	P				1	2	3	Formation of insoluble compounds
Adsorption				P	P	S			1	2	3	Adsorption on substrate and plant surfaces
Decomposition							P	P	1	2	3	Decomposition due to UV irrad., oxidation and reduction, etc.
Biological												
Metabolism												
Bacterial		P	P	P			P		1	2	3	Removal by benthic and plant-supported bacteria. Bacterial nitrification/denitrification
Plant							S	S	1	1	3	Uptake and metabolism by plants
Adsorption				S	S	S	S		1	1	3	Under proper conditions, significant quantities may be taken up by plants
Natural Die-off								P	1	2	3	Natural decay of organisms in unfavorable environment.

P=Primary effect, S=Secondary Effect, I=Incidental effect, 1=process highly likely, 2=process somewhat likely, 3=process highly unlikely.

Adapted from: Tchobanoglos, G. and Culp, G.; "Wetland Systems for Wastewater Treatment: An Engineering Assessment" in Aquaculture Systems for Wastewater Treatment. EPA430/9-80-007

SS = Settleable solids, CS = Colloidal Solids, BOD = Bio-oxidation demand, N = Nitrogen, P = Phosphorus, HM = Heavy Metals, Org = Refractory Organics

SELECTION AND SITING

POLLUTANT REMOVAL

As shown in Table III-1, pond-marsh facilities remove pollutants through three distinct processes; physical, chemical, and biological. The relative importance of each process is site and pollutant specific. Biologically available phosphorus (BAP) is usually of greatest concern and it is uncertain the degree each of the three processes play in its removal.

Of the three removal processes, sedimentation is the criteria which most often sets the size of pond-marsh facilities. It is also the process most likely to be active in all types of pond-marsh facilities. From a nutrient perspective, of the settleable particles entering a pond-marsh, the smallest size fractions of influent sediment are usually of the greatest concern. In general, conditions which provide quiescent settling and long detention times are the most effective in removing particulate pollutants.

To ensure optimal nutrient removal, pond-marsh facilities should be used in conjunction with infiltration facilities wherever possible.

SITING CRITERIA

Though each pond-marsh facility requires slightly different siting criteria, each facility must take into account a variety of issues. A typical methodology for site screening of treatment wetlands is shown in Figure III-1. It is meant to be illustrative of the potential complexity of the siting process for such facilities.

Treatment Wetlands

- As treatment wetlands require a permanent pool for a large percentage of the time, they are generally placed in low lying areas with a high water table below large catchments greater than 5 to 20 acres depending upon conditions. These large catchment areas help to provide adequate baseflow to maintain submerged conditions throughout most of the year.
- Unless an impervious liner is used, treatment wetlands are limited to areas with a shallow groundwater table or naturally occurring low-permeability substrate. Also, in areas where groundwater quality is of concern, impervious liners are required to maintain groundwater quality.
- Treatment wetlands require relatively large tracts of land for the shallow ponded areas.

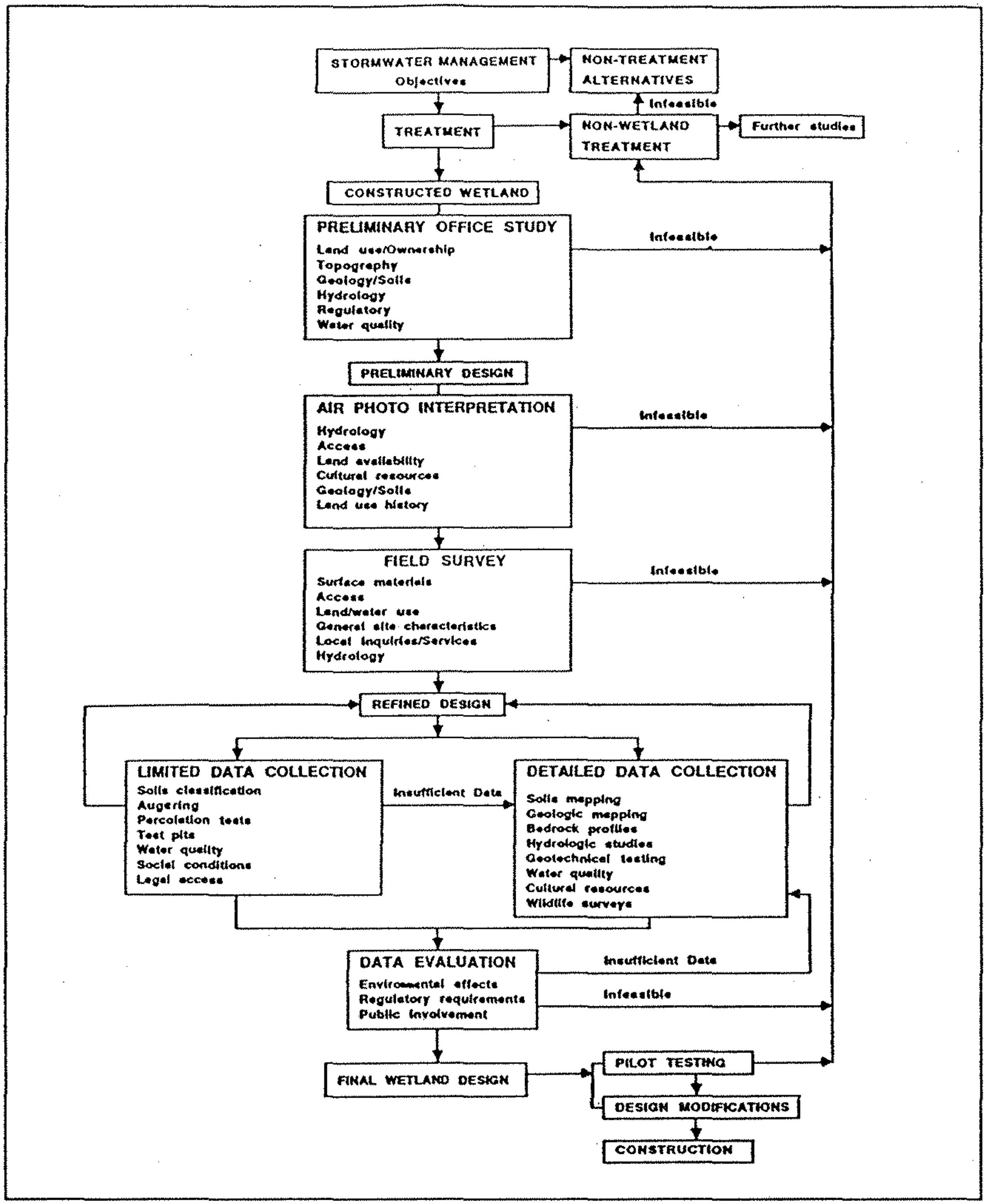

Figure III-1: Example of a generalized approach to treatment wetland siting (Brodie, 1989).

Wet ponds

- Wet ponds are similar to treatment wetlands in their requirements for large catchment areas (> 5-20 acres).
- Wet ponds have steeper side slopes and greater depths than wetlands, and usually require less land area.

Extended detention ponds

- Since permanent dead storage is not required for extended detention ponds, the catchment areas can be much smaller than those for treatment wetlands and wet ponds (<5 acres).
- As extended detention ponds are often retro-fitted dry detention ponds, their areal requirements are similar to conventionally sized flood control facilities.

GENERAL DESIGN CRITERIA

The following design considerations apply to all types of pond-marsh facilities. The design criteria presented in this section pertain to water quality aspects of pond-marsh facility design only. Although the flood control aspects of urban stormwater management are very important and greatly impact the design of any hydraulic structure designed to detain runoff, the details of design for flood control are not discussed in this section. The emphasis has been on providing criteria for water quality only. As such, there has been an intentional effort to keep the discussion of flood control aspects as general as possible. It should be kept in mind that these design criteria are preliminary only. The actual performance of any facility will have to be determined by observation over time.

WATER BUDGET

- One of the key requirements for treatment wetlands and wet ponds is the need for inflows to be high enough to maintain a permanent pool over losses experienced by the facility. Inflows consist of stormwater runoff, base flow, and groundwater. Outflows are direct discharge, infiltration, and evapotranspiration. If the facility cannot maintain a permanent pool, its effectiveness is greatly reduced.

SOILS

- With the exception of the extended detention basins or combination facilities which include infiltration, all pond-marsh facilities must be in soils that are relatively impervious. As opposed to infiltration facilities, discussed in section II, pond-marsh facilities are best placed in soils of the hydrologic soil groups C and D. A survey of the soil types in the tri-county area indicate that most of the native soils are not ideal for the construction of facilities with permanent pools, due to problems with slope stability, excessive seepage, or piping. As a result, most pond-marsh facilities may require importing fill material for their construction.
- If infiltration is an intended part of a wetland or wet pond design, an analysis must be done to ensure that design seepage rates and discharge rates should be low enough and inflows high enough to maintain a permanent pool. If this condition is not met, the outlet structure may have to be redesigned.
- An analysis must be done to ensure stability of downstream slopes possibly impacted by the increased local seepage.

- If infiltration is not an intended part of a wetland or wet pond design, seepage out of the pond must be prevented by: 1) native high clay soils, 2) compaction of suitable native soils (at least 10% clay), 3) construction of clay blankets from material at least 40 percent clay and at least 12 inches thick for water depths up to 10 feet deep, or 4) the use of waterproof linings.

OVERFLOW

- An overflow system must provide a controlled discharge of the design storm flood event without overtopping any part of the facility embankment or exceeding the emergency spillway capacity.

EMERGENCY SPILLWAY

- In addition to the overflow system requirements, an emergency overflow spillway must be provided. The emergency spillway should be designed to safely pass the design storm flood event. The spillway section should be armored or piped accordance with acceptable practices.

BERM EMBANKMENT/SLOPE STABILIZATION

- Wet ponds and extended detention pond embankments must be designed to safely contain the flood design storm event without threat of failure assuming release through the emergency spillway. Embankments higher than 6 feet should require analysis and design by a licensed engineer. A minimum berm top width of 15 feet is necessary in areas requiring access for maintenance.
- A minimum top width of 5 feet should be provided for interior berms separating pond-marshes into cells. The dividing berms should have maximum side slopes of 3H:1V with 1 foot freeboard.
- Berms for exterior embankments less than 6 feet in height should have a minimum top width of 6 feet.
- Embankment sections should be constructed on suitable native consolidated soils free of loose soil materials, roots, and other debris. Other soil bases may be used as recommended by an engineer if adequately placed and compacted.
- The berm embankment should be constructed on compacted soil (95 percent dry density, standard proctor method as per ASTM D1557). Embankment fill should be placed in 8 inch lifts with the following soil characteristics as per the United States Department of Agricultures Textural Triangle: minimum of 30 percent clay, a maximum of 60 percent silt, and nominal gravel and cobble content.

- Outflow pipes placed in the berm embankment impounding water greater than 8 feet in depth at the design water surface should be constructed with anti-seepage collars.
- Pond-marsh facilities to be placed upstream of existing embankment should require analyses of the existing embankment for stability. The maximum allowable water surface which can be safely maintained upstream of the existing embankment must be determined as well as the estimated seepage and infiltration rates.
- For pond-marsh facilities to be retro-fitted from existing flood control facilities, a detailed analysis should be done by a soils specialist or qualified engineer to evaluate the suitability of existing embankments for extended periods of ponding.

OIL/WATER SEPARATORS

- Any pond-marsh facility should incorporate a spill control oil/water separator.

OTHER CONSIDERATIONS

Safety

- All possible safety precautions should be incorporated for pond-marsh facilities readily accessible to populated areas. System features such as side slopes and outlet facilities must be designed to minimize risk to the public. Fencing and signing may also be required.

Fencing

- A chain link fence is required for pond-marsh facilities with vertical walls or side slopes greater than 3H:1V. The fence should be placed on top of the pond wall or at the maximum design water surface.
- The fence should be a minimum of 6 feet in height except for pond impoundments of less than 4 feet in depth. These ponds may have a minimum fencing height of 4 feet.
- Access roads should be provided with gates 16 feet wide with two swinging sections 8 feet in width.
- Pedestrian access gates should be provided where needed.
- Fence material should be as per standards of the appropriate jurisdiction.

- The need for fencing may not be mandatory for certain industrial/ commercial sites, but will be at the discretion of the appropriate jurisdiction for public safety.

Signing

- Permanent pond-marsh facilities should have signs placed so that at least one is clearly visible and legible from all adjacent streets, sidewalks, or paths. The project name, purpose, appropriate jurisdiction, and safety requirements should be listed on each sign.

Safety bench

- A safety bench should be provided if the pond surface areas exceeds 10,000 square feet. The bench should be 5 feet wide with emergent vegetation such as cattails placed on the bench to inhibit public access.

Setbacks

- All facilities should be located a minimum of 20 feet from any structure or property line established by a local government, and 100 feet from any septic tank/drain field. Vegetative strips may be used to complement the facility.
- All facilities should be placed a minimum of 200 feet from any steep slope unless indications exist which allow for such placement. The impact of any impoundment on a steep slope should be analyzed by a qualified engineer.

Aesthetics

- Landscaping of pond-marsh facilities should be provided to enhance the aesthetic value of the system. The planting and preservation of desirable trees and other vegetation should be an major part of the system design.

Heavy Metal Concentrations

- Runoff from urban areas has often displayed high levels of lead, zinc, and copper. Significant heavy metal loads may enter and settle out in pond-marsh facilities. This may require special disposal sites for sediment dredged out of basins during periodic cleaning or placement of a pond liner to prevent leaching to the groundwater. Sediments which are to be removed from a detention facility should be analyzed to verify that the sediment can be safely disposed of by conventional methods.

ANALYSIS AND REPORTS

SOILS

A soils report is required for all proposed facilities or projects involving pond-marsh facilities in the Portland-Lake Oswego-Clackamas County-USA area. The report will verify previously mapped and characterize unmapped soils series. The soils report will include slope and SCS soil class.

A soil log is required for each proposed pond-marsh facility. Each soil log should be a minimum 5 foot depth below the facility's lowest finished grade. Additional soil logs for each water quality basin must be taken for every 5,000 square feet of ponded surface area for that particular basin.

GEOTECHNICAL

Any proposed facilities or projects involving pond-marsh facilities require the submittal of a geotechnical report if:

- construction is proposed within 200 feet from the top of a steep slope, OR
- on a slope steeper than 15%; OR
- a berm higher than 6 feet is constructed.

If any of these conditions exist, then a geotechnical analysis and report must be prepared and stamped by a soils specialist or a qualified engineer. The report should address, at a minimum, the effects of groundwater interception and potential infiltration from any pond-marsh facility. Particular attention should be given to potential seepage faces on steep slopes, piping near outfall systems, lubrication of slip planes, and changes to soil bearing strength due to saturation and liquefaction from any increased infiltration.

These impacts should be evaluated assuming both normal and rare conditions. A rare condition is an event such as emergency overflow of the pond-marsh facility due to a plugged outlet pipe. After evaluation, probabilities of failure and the resulting impacts should be determined for the pond-marsh facility and any impacted downslope areas.

The report should also identify areas potentially impacted by groundwater interflow and any special characteristics of the underlying soils. These should include but not be limited to:

- load bearing capacity;
- general suitability of site fill, roadway, and pond embankment materials;
- erodibility of soils, particularly during construction;
- and, the ability to support vegetation for stabilization.

HYDROLOGY

All proposed projects or facilities involving pond-marsh facilities must include in the site analysis/report:

- A hydrograph of the design storm runoff and pond-marsh facility overflow for flood conditions as defined by the appropriate local jurisdiction; and for the 100 year storm if the facility/project impacts, or is impacted by, a major waterway.
- Mapping of the flow route to an adequate discharge point and elevation of hydraulic profile of the peak overflow during the design storm, and 100 year flow if appropriate.
- The significant downstream flooding impacts.
- All hydrologic-hydraulic analysis must be done in accordance with the methods required or recommended by Portland, Lake Oswego, Clackamas County, or USA depending on which jurisdictions' authority covers the project.
- Test for soil seepage rates.

OTHER ANALYSIS AND REPORTS

- Hydraulic details of pond geometry, cross sections, flow through characteristics, and outlet design should be provided.
- For those facilities where vegetation is intentionally introduced as part of the treatment design, information regarding plant selection, plant placement, and planting methods should be required.
- All proposed construction of treatment wetlands or wet ponds must be preceded by an analysis of the site water budget showing that inflows and/or the facility design are sufficient to maintain a permanent pool.

TREATMENT WETLANDS

A treatment wetland, for the purposes of this handbook, shall be considered to be any facility which consists of a combination of shallow trenches, marshes, and ponded sections constructed below a drainage which maintains a permanent shallow pool with benthic (bottom dwelling) vegetation providing water quality treatment for stormwater runoff.

Treatment wetlands differ from wet ponds in that wet ponds usually give equal consideration to both water quality control and reduction of runoff peaks, while a treatment wetland is primarily designed as a pollution reduction facility (PRF). However, some degree of flood control is realized with the construction of a treatment wetland due to the wide area through which the flow is spread in a well-designed facility. Another difference between a wet pond and a treatment wetland is that a wet pond is usually deeper than a wetland, with steeper side slopes and requiring less area than a wetland.

Treatment wetlands can be effective in controlling many types of pollutants present in urban runoff. Sediments and associated contaminants are removed or stored in a treatment wetland through settling; metals and nutrients bind to soils and are assimilated by plant and animal life; and BOD, nitrogen, and other contaminant loads are reduced through microbial action within the facility waters.

ADVANTAGES AND DISADVANTAGES

Advantages

- Treatment wetlands are sources of wildlife habitat for a multitude of aquatic plants and animals.
- Treatment wetlands lessen the "first-flush" of high pollutant concentrations in stormwater effluent and their effect on the receiving stream.
- Treatment wetlands can serve larger areas than most BMPs.
- Well maintained treatment wetland facilities can enhance the aesthetic value of a development and provide for public education, research, and recreation opportunity.
- Treatment wetlands can provide water quality treatment of varying flows.

Disadvantages

- The land requirements of treatment wetlands can be prohibitive.
- Treatment wetlands can be a source of several nuisances such as mosquitos, odors, saturated ground, etc.
- Treatment wetlands can present a safety hazard, particularly if not carefully designed.
- Most treatment wetlands have an eventual need for sediment removal and maintenance.
- Treatment wetlands can release water low in dissolved oxygen. Wetlands can also release high concentrations of organic matter, particularly humic and fulvic acids which can discolor water.

DESIGN CRITERIA

The following design criteria are specific to treatment wetland facilities for the purpose of providing treatment for stormwater runoff and are in addition to the general criteria for water quality basins discussed earlier. It should be restated here that the emphasis in developing these criteria was on maintaining simplicity in the design process and that these criteria should be considered preliminary only.

Treatment efficiency

Although models exist which simulate treatment wetland performance for specific contaminants in wastewater treatment design, the parameters used in them are difficult to obtain for specific conditions, particularly those found with urban stormwater. However, researchers have reported the removal efficiencies for stormwater from numerous treatment wetlands.

Removals as great as 85 percent have been reported for total phosphorus and 95 percent for total suspended solids. However, the actual performance of any treatment wetland will depend on many variables, most of which are poorly understood in terms of actual facility performance. As a result, actual long-term performance of any treatment wetland will have to be determined by sampling the inflow and outflow to the wetland for the contaminants of interest. There are indications, for instance, that loading rates are a major factor in water quality treatment performance of wetlands.

There are indications that loading rates have some bearing on treatment wetland performance.

- Average ***hydraulic loading rates*** less than 4 inches per day (0.333 ft^3 of inflow/ft^2 of ponded area per day) generally result in nutrient removal rates greater than 50 percent.
- ***Phosphorus loads*** less than 13 and 45 pounds per acre of treatment wetland per year have potential removal rates of at least 70 and 50 percent, respectively.

Size

- When used as an isolated facility, the ***treatment wetland area*** should be no less than 3 percent of the contributing drainage area. This is slightly more conservative than that recommended by EPA (1986).
- The treatment wetland ***retention time*** of stormwater, calculated as the water volume/average outflow rate, should be no less than 2 weeks for the two year, 24 hour storm event to maximize nutrient removal.

Geometry

The ***configuration*** of a treatment wetland should not be limited to one design, but should be tailored to each potential site. Major elements of a wetland can consist of channels or trenches, shallow marshes, and deeper ponded areas. These elements should be combined to take advantage of site topography and save space wherever possible. A successful wetland often combines all elements to provide an array of aquatic zones. A schematic of a typical single-cell treatment wetland is shown in Figure III-2, which illustrates many of the following concepts.

- The minimum ***length to width ratio*** should be 3:1, although if wetland trenches are incorporated and folded within the wetland, this ratio can be reduced.
- ***Side slopes*** should be no less than 5:1 where vegetation is to be planted.
- 25 percent of the wetland area should be a minimum of ***3 feet deep.***
- 50 percent of the wetland area should be between ***6 and 12 inches deep.***
- 25 percent of the wetland area should be less than ***6 inches deep.***
- A ***perimeter zone*** approximately 10-20 feet wide which is flooded temporarily during most storm events should be provided.

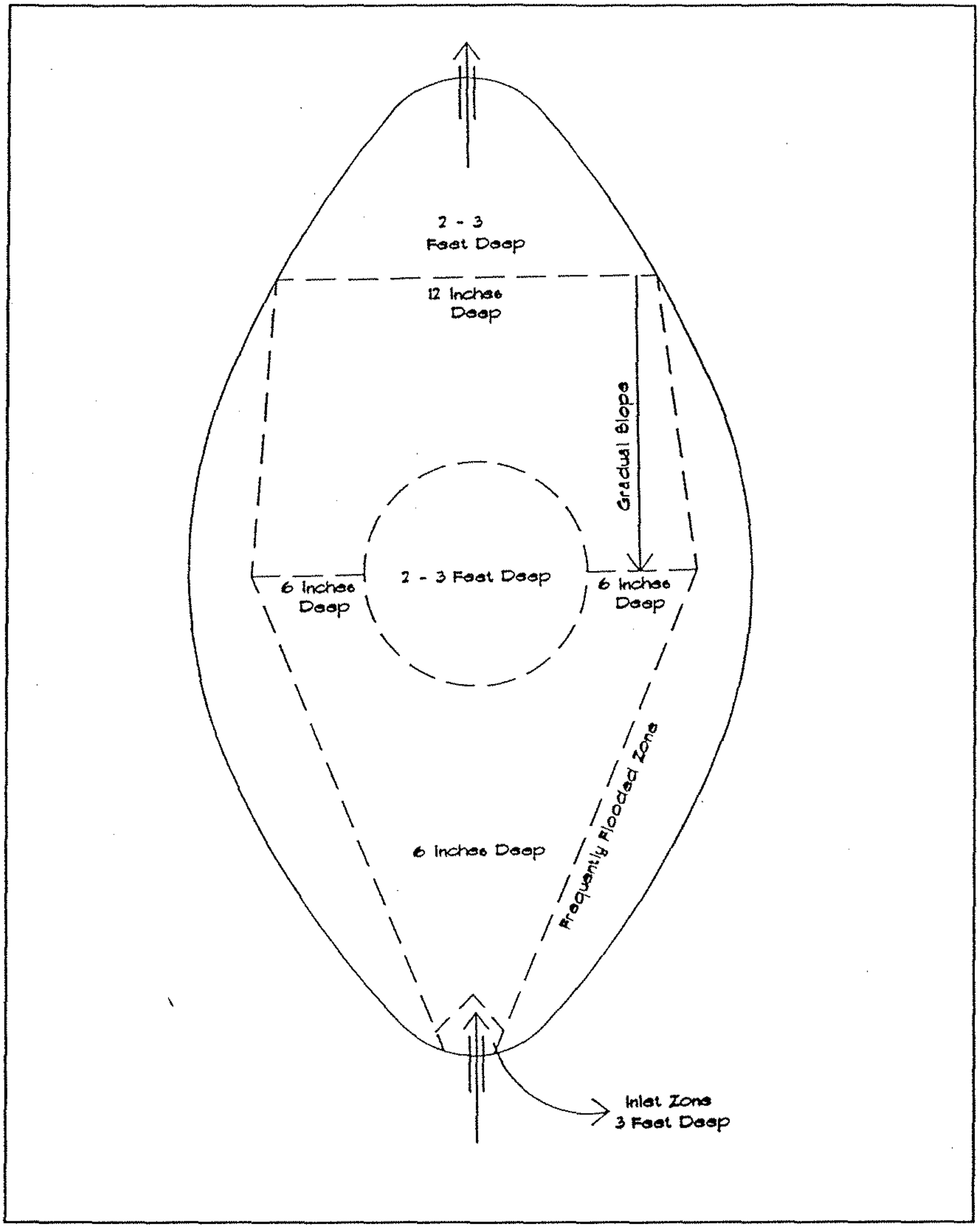

Figure III-2: Typical layout of a single-cell treatment wetland.

Flow

- ***Velocity*** of the flow through the wetland should average less than 0.01 feet per second. If natural slope does not allow for this velocity, berms should be used to create ponded benches.
- Flow through the wetland should be distributed as ***uniformly*** across the marsh and ponded sections as possible. Excessive use of channels can cause short-circuiting and reduce contact time with soils, resulting in reduced treatment performance. Flow distribution barriers or inflow baffles can be constructed to help achieve the desired flow patterns.

Inlet

- The ***inlet area*** should be submerged and should include a ***forebay*** at least three feet deep and having at least 10 percent of the total treatment wetland volume to facilitate the removal of heavier sediment and dissipate energy of the inflow. If area allows, a separate sedimentation pond or cell may be constructed in place of the forebay.

Vegetation

- ***Vegetation*** is a key component in the effectiveness of any treatment wetland. The types and placement of wetland vegetation is determined primarily by water depth and soil saturation. Table III-2 provides a partial list of plant species deemed suitable for wetland vegetation in the Pacific Northwest.
- The actual ***selection and placement*** of treatment wetland vegetation should be done under the direction of a wetlands biologist. When feasible, native wetland species should be included in order to minimize maintenance and avoid establishment of unwanted nuisance species. A mixture rather than a single species is also helpful in assuring maximum nutrient uptake.

VARIATIONS

Single-Cell

For smaller sites with space limitations, a single-cell configuration as shown in Figure III-2 could be used. The facility should be designed using a variety of vegetation and provide multiple zones of different depths.

Table III-2: Partial list of wetland vegetation suitable for the Pacific Northwest.

Zone	Name	Common name
Open water	Potamogeton species	pondweeds
	Sagittaria latifolia	arrowhead
	Nymphaea odorata	pond lily
	Brasenia shreberi	water shield
	Nupahr polysepalum, N. variegatum	cow lily
	Polygonum hydropiper	smartweed
	Lemna minor	duckweed
Emergent	Carex obnupta, C. rostrata, C. arcta, C. stipata, C. vesicaria	sedge
	Scirpus cyperinus	bulrush
	Scirpus microcarpus	small-fruited bulrush
	Eleocharis palustris	spike rush
	Epilobium watsonii	Watson's willow herb
	Phalaris arundinacea	reed canarygrass
	Juncus balticus	baltic rush
	Juncus effusus	diffuse rush
	Typha latifolia	common cattail
	Veronica americana, V. scouleriana	speedwell
	Mentha arvensis	mint
	Lycopus americanus, L. uniflora	cut-leaved water horehound
	Carex aquatilis	water sedge
	Angelica species	angelica
	Oenanthe sarmentosa	water parsley
	Heracleum lanatum	cow parsnip
	Glyceria grandis	manna grass
	Juncus acuminatus	tapered rush
	Juncus ensifolius	daggerleaf rush

Adapted from Stormwater Management Manual for the Puget Sound Basin, Washington DOE, 1990.

Multi-Cell

For sites where space limitations are not as critical, a multi-cell configuration as shown in Figure III-3 could be used. This multi-cell layout has the potential for much greater removal rates for many stormwater contaminants.

The first cell of a multi-cell design also may serve as the main settling pond, removing most of the coarser sediments. This concentrates the removable sediments allowing for easier maintenance and avoiding problems with wetland vegetation in subsequent cells being buried under heavy sediment loads.

Some important design considerations in the construction of treatment wetlands are pointed out in Figure III-3. These include extended contact time with the soil/root zone and dikes to prevent short circuiting.

MAINTENANCE REQUIREMENTS

A maintenance plan must be prepared which outlines the schedule, scope and responsibilities for performing maintenance duties. The design of treatment wetlands must provide for regular maintenance.

- Periodic ***harvesting*** of wetland vegetation may be necessary to prevent excessive decay and release of nutrients and organic material. Harvesting may take place at the end of the growing season, for instance. Harvesting should be done so as to minimize plant removal or disturbance. Harvested material should be composted or disposed of in such a way so as to prevent introduction of the harvested material into surface water. Harvesting should also be done on a rotational basis, leaving some areas undisturbed while harvesting other areas within the wetland to maintain some level of continuous treatment.
- Maintenance of ***sediment*** basins and sediment accumulation within the treatment wetland is extremely important. Sediment deposits should be continually monitored for volume. As soon as the sediment depth has exceeded wetland criteria it should be removed. At this point testing is required to determine the leaching potential and concentrations of heavy metals and pesticides in the sediment. Testing may reveal the need for special disposal techniques. Sediment removal should be timed to avoid impacting sensitive life stages of wetland inhabitants.
- Wetland ***access roads*** are required when wetlands do not abut public right-of-ways. Roads and pads should meet the requirements of the pertinent jurisdiction standard practices.

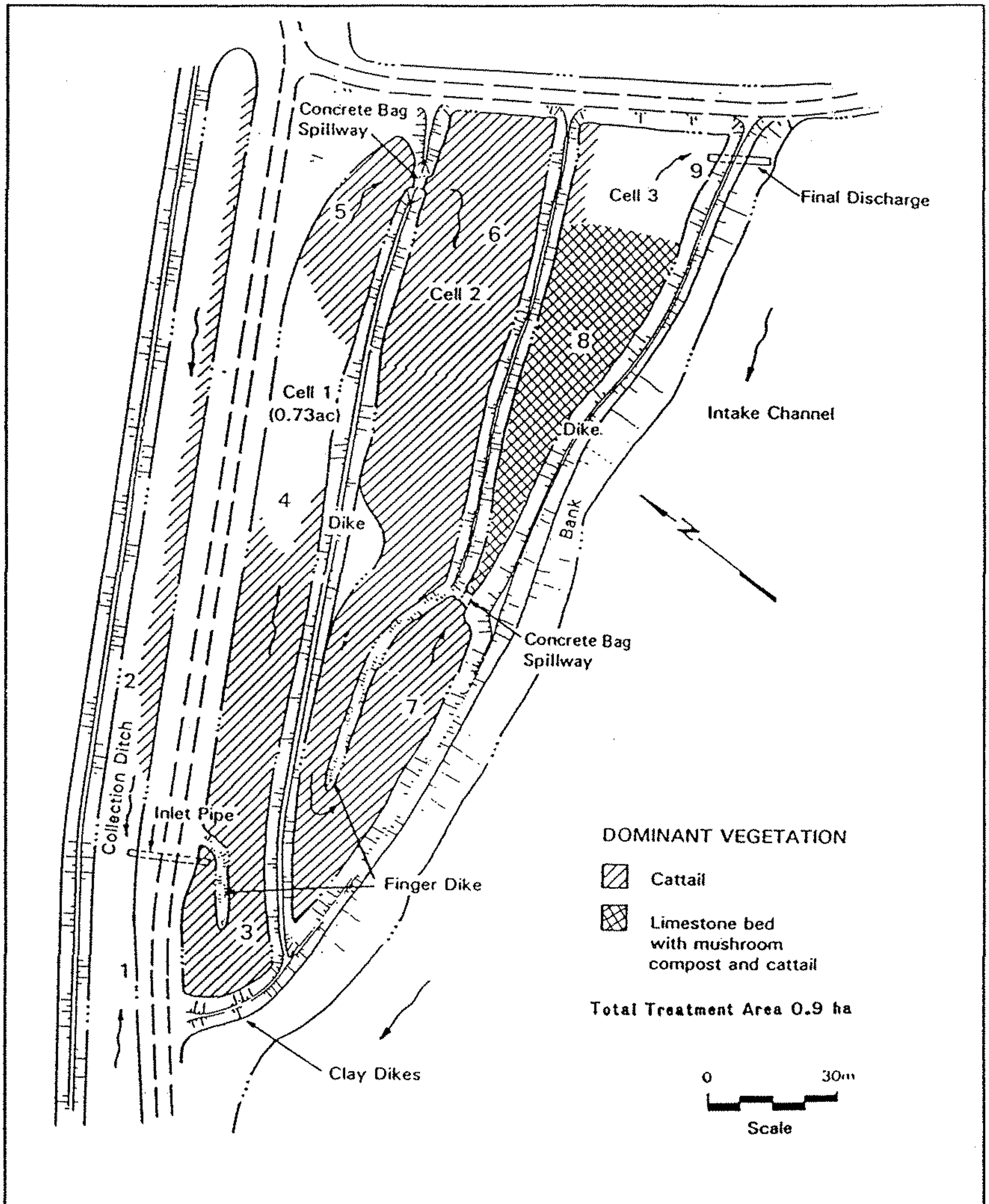

Figure III-3: Typical layout of a multi-cell treatment wetland (Adapted from Brodie, et. al., 1989).

- ***Insects*** such as mosquitoes can become a problem with treatment wetlands. Control of these insects should be provided by stocking with predaceous insects and fish (Gambusia affinis). Location of swallow and bat boxes on adjacent trees will also assist in biological control. Biological methods of insect control will help avoid the need for seasonal draining and its adverse effects on the establishment of wetland species.

WET PONDS

A wet pond is a surface impoundment that maintains a permanent pool (dead storage) throughout most of the year and may also provide a temporary pool (live storage) for flood control. Water level and flood control is maintained by the use of risers, orifices, and other outlet control structures.

Water quality treatment occurs in the permanent pool through a variety of physical, chemical, and biological processes. Although many of the treatment processes are similar to those of a treatment wetland, wet ponds differ from wetlands in that they are deeper, can require smaller areas, and are often designed specifically for some level of flood control in the live storage volume.

When properly designed and maintained, wet ponds can attain high removal efficiencies for many common contaminants found in urban stormwater. These contaminants include sediments, BOD, heavy metals, and organic and soluble nutrients, particularly phosphorus.

ADVANTAGES AND DISADVANTAGES

Advantages

- Wet ponds can provide the foundation for habitat for a multitude of aquatic plants and animals.
- Delayed releases of runoff reduces the loading to the receiving stream of sediment, organic materials, chemicals, and bacteria carried by the storm runoff. Consequently, the effects on the receiving stream of "first-flush" stormwater effluent containing high pollutant concentrations is reduced.
- Wet ponds can serve larger areas than most BMPs.
- Wet ponds can be used as sediment traps during site construction, if the sediment is removed after construction.
- Well maintained wet ponds can enhance the aesthetic value of a development.

Disadvantages

- Wet ponds can be a source of several nuisances such as mosquitos, odors, saturated ground, etc.
- As with conventional detention facilities, the land requirements of wet ponds can be prohibitive.
- Wet ponds can present a safety hazard.

- Wet ponds have an eventual need for sediment removal.

DESIGN CRITERIA

The following design criteria are specific to wet ponds and are in addition to the general criteria for pond-marsh facilities discussed earlier. The emphasis is on simple yet conservative design.

Treatment efficiency

The performance of any wet pond depends on many variables, most of which are poorly understood. As a result, the actual long-term performance of any wet pond will have to be determined by a sampling program for each facility for the contaminants of interest.

Two methods for estimating the treatment efficiency of a wet pond were evaluated and tailored for the Portland area. The first method is applicable to sediments and those contaminants, such as heavy metals and pesticides, that are strongly associated with the sediment (EPA, 1986). This method will be called the sediment model.

The second method is designed to estimate the removal of nutrients, such as phosphorus, which have a large dissolved fraction. These dissolved contaminants may be removed by biological uptake in addition to sedimentation (Walker, 1987). This method is referred to as the nutrient model.

Although the basis for each method is different, they have been presented in a similar fashion to allow for comparisons between them. Estimated removal efficiencies have been plotted against catchment ratios for each of the models. The catchment ratio is defined as the percentage of permanent pool area to drainage basin area. As an example, for a drainage with 1000 contributing acres, a wet pond 20 acres in size would have a catchment ratio of 2 percent.

The removal efficiencies for the sediment model are shown in Figure III-4, Figure III-5, and Figure III-6. Similar plots for the removal efficiencies predicted with the nutrient model are shown in Figure III-7, Figure III-8, and Figure III-9. There are three figures for each model to reflect the differences in the permanent pool for one, three, and six foot average depths. Each figure has three lines, each representing a different runoff coefficient (Rv). Details of the model development are given in Appendix B. The two models should be considered as preliminary sizing criteria only, and will likely require adjustment with time.

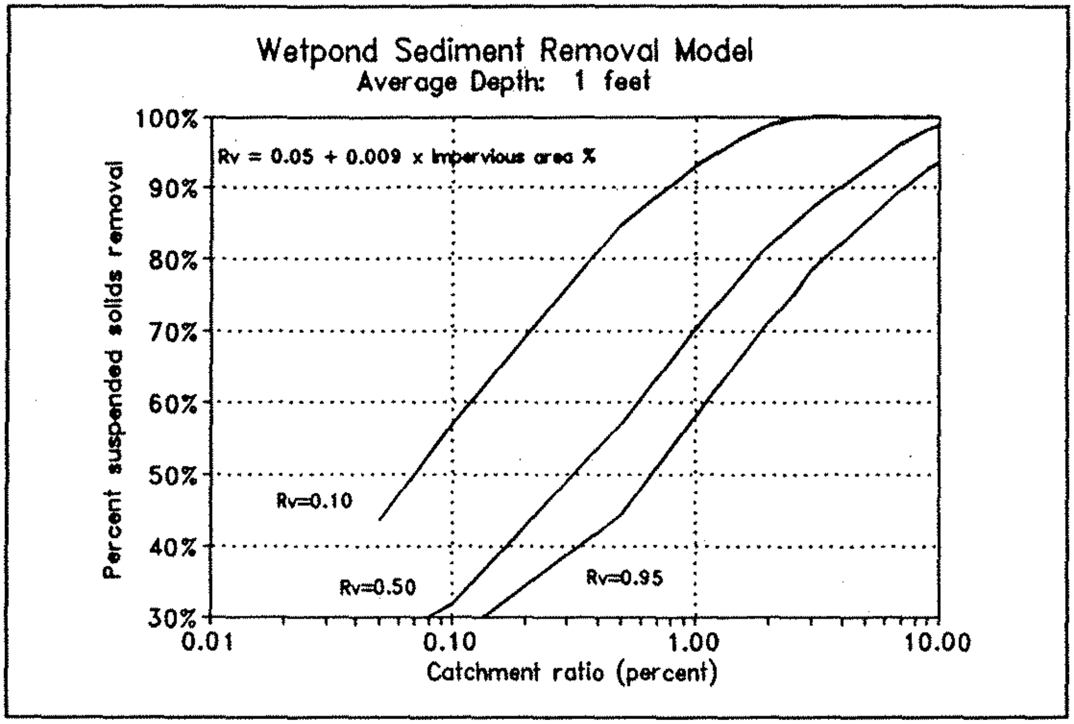

Figure III-4: Wet pond sediment removal model (1 ft average depth).

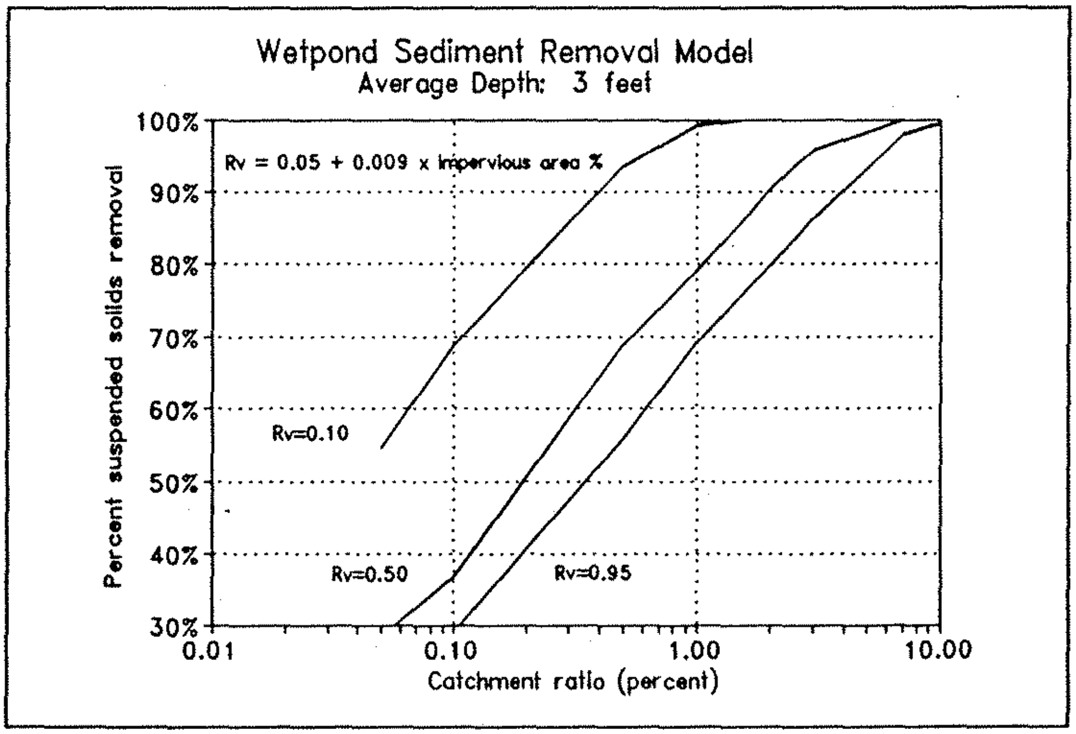

Figure III-5: Wet pond sediment removal model (3 ft average depth).

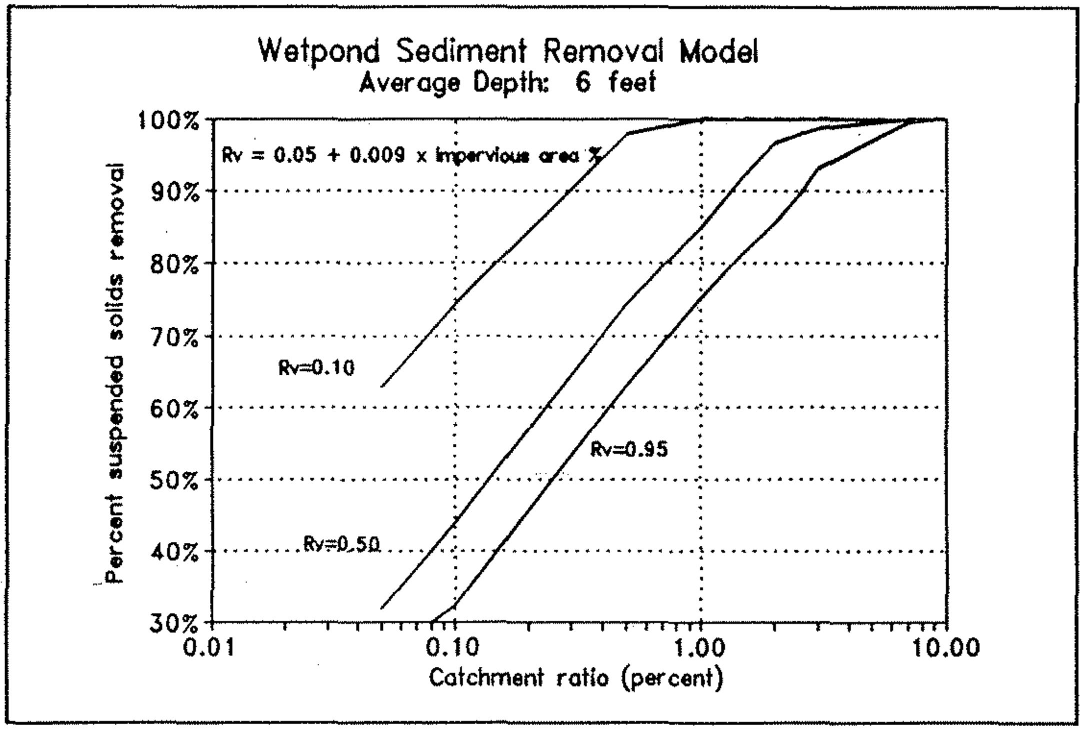

Figure III-6: Wet pond sediment removal model (6 ft average depth).

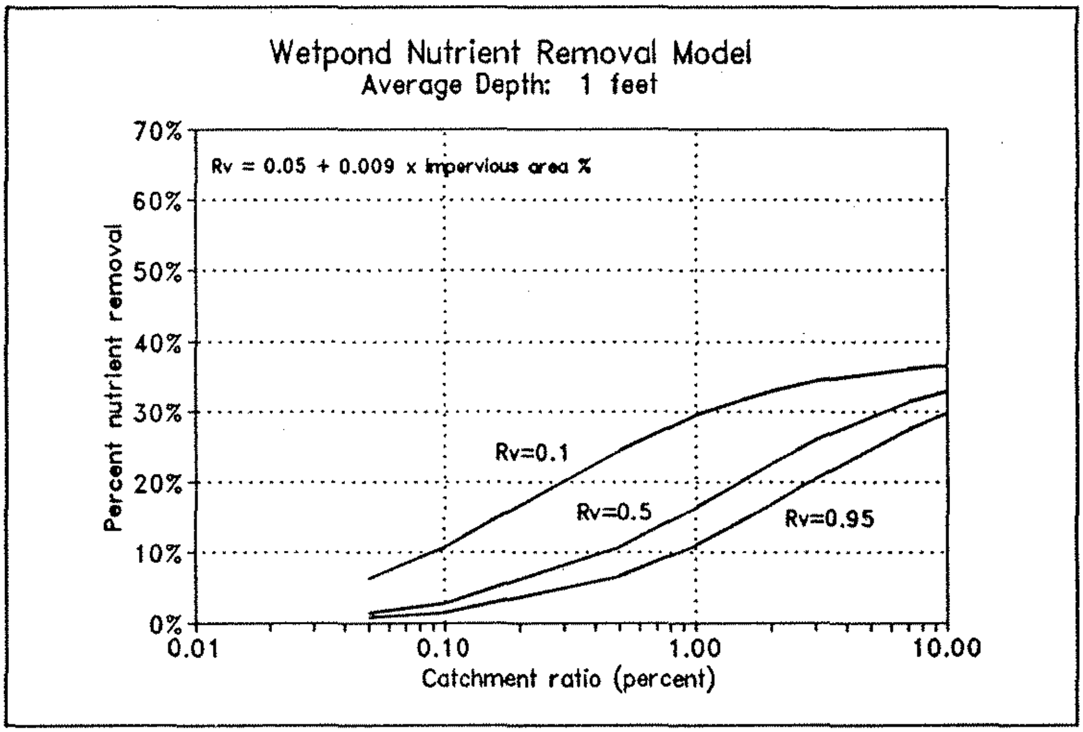

Figure III-7: Wet pond nutrient removal model (1 ft average depth).

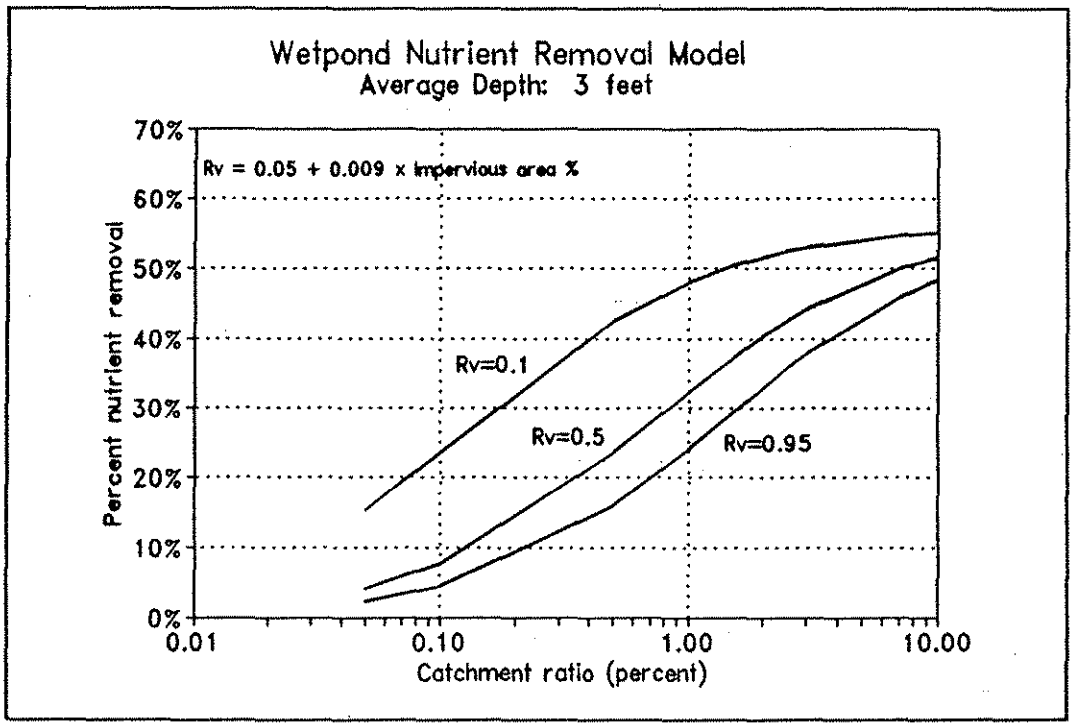

Figure III-8: Wet pond nutrient removal model (3 ft average depth).

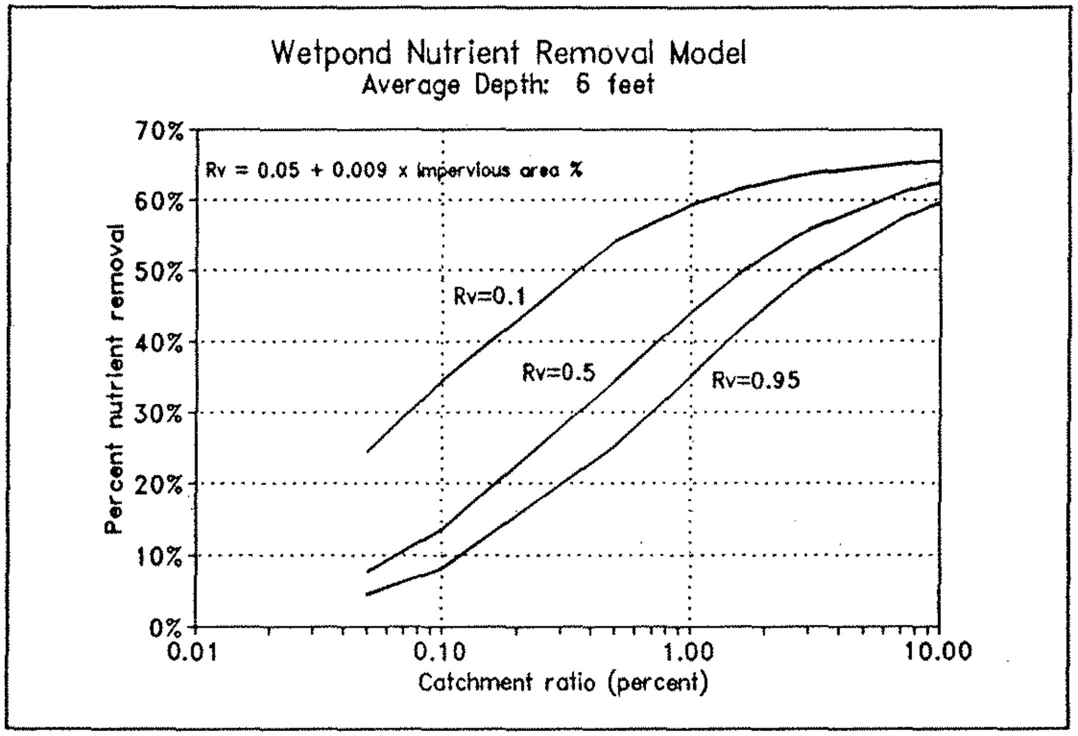

Figure III-9: Wet pond nutrient removal model (6 ft average depth).

Dead storage

- If designed primarily for removal of ***sediment*** and associated contaminants, the minimum ***surface area*** and ***volume*** needed should be calculated from the curves for the sediment removal model (Figure III-4 through Figure III-6).
- If designed primarily for ***nutrient*** removal, the minimum ***surface area*** of the dead storage space should be calculated from the curves for the nutrient removal model (Figure III-7 through Figure III-9).
- The ***maximum depth*** of the dead storage area should be approximately 6 feet. Water depths in excess of 6 feet may develop anaerobic conditions in areas of the pond bottom experiencing little water circulation. Anaerobic conditions often result in the eventual release of pollutants such as metals and phosphorus.

The approach used to estimate the size of the dead storage or permanent pool of a wet pond using either sediment or soluble nutrient model is the same. The steps are:

1. Determine the acreage of the contributing area above the potential wet pond site.

2. Calculate the runoff coefficient (Rv) for the site either from Rv = 0.05 + (0.009 x impervious area %) or from Figure B-1 in Appendix B.

3. Based on an estimated potential average depth of the permanent pool at the site and the model to be used (either sediment or soluble nutrient), select the appropriate chart. If the average depth is between 1 and 3 or 3 and 6 feet, use the shallowest depth from the appropriate range.

4. Using the required removal efficiency, read across from the removal efficiency scale to the line corresponding to the Rv value calculated in step 2. Interpolate if necessary and read off the catchment ratio.

5. Calculate the minimum required area of the permanent pool by multiplying the catchment ratio (as a percent) by the area found in step 1.

6. Reevaluate the potential average depth of the permanent pool based on the minimum surface area calculated from step 5 and repeat steps 3 through 5 if necessary.

Live Storage

- Wet ponds must provide adequate ***live storage*** to contain runoff volumes which ensure acceptable water quality, habitat protection, and should include provisions for flood control if specified as part of the facility design. The live runoff storage volume required to meet these parameters should be determined based on criteria established by the appropriate jurisdiction.

Pond Geometry

- The ***inlet and outlet*** should be located as far apart as possible to prevent short-circuiting and maximize travel time.
- The ***length to width ratio*** should be at least 3:1 and preferably 5:1.
- ***Interior side slopes*** up to the maximum water surface should be no steeper than 4H:1V. Steeper side slopes may be used in some types of areas,or if a fence is provided at or above the maximum water surface to restrict public access to the pond.
- ***Exterior side slopes*** should be no steeper than 2H:1V unless a geotechnical stability analysis has been performed.
- A minimum of ***two cells*** in series should be used where possible, or a ***forebay*** should be provided at the inlet to provide for the removal of heavier sediment.

Inlet

- The inlet area should be submerged and where a multiple cell design cannot be used, should include a ***forebay*** to facilitate the removal of heavier sediment and dissipate energy of the inflow.
- To help in distributing the inflow more evenly to the deeper sections of the pond, ***inflow baffles*** should be used. Alternatives should include but not be limited to submerged weirs and/or berms planted in appropriate standing vegetation.

Outlet

- A ***minimum water level*** for permanent storage must be maintained. This is usually accomplished by means of a riser.
- ***Flood storage and release*** should be provided by a properly sized intake at some level at or above the top of the permanent pool riser.

- An ***emergency spillway*** should be provided to pass the design storm flood event assuming crest-full conditions.
- ***Drainage of the pond*** should be provided by valved outlets which should be capable of draining the permanent pool in a minimum of four hours.
- If a riser pipe outlet is used, it should be protected by a ***trash rack***. If an orifice plate is used, it should be protected with a trash rack with at least 10 square feet of open surface area. In either case, the rack must be hinged or easily removable to allow for cleaning.

VARIATIONS

Multi-cell

Wet ponds which have several small cells in series rather than just a large single cell usually provide greater detention times for runoff, which results in potentially greater removal rates. A typical multi-cell wet pond design is shown in Figure III-10. Provisions must be made for draining each cell of the pond for maintenance and access to each cell by equipment is required. Variation in the placement and configuration of the cells can result in a wider choice of inlet and outlet options over single cell designs. The inlets to each of the cells need to be designed so as to prevent excessive turbulence in each of the cells through the use of forebays and/or inlet baffles.

Single-cell

Where space limitations prevent a multi-cell design from being used, a single-cell pond can be used. As a minimum, a forebay should be used at the inlet to provide early removal of the heavier sediments and distribute the inflow across the pond. An example of a single-cell wet pond with forebay is shown in Figure III-11.

Outlets

Two typical outlet designs are shown in Figure III-12. The first design incorporates a multi-stage riser built into the embankment itself. The reverse slope seen on the permanent pool control outlet prevents clogging and keeps surface debris from entering the pipe. The second design uses a free standing riser whose lip sets the elevation of the permanent pool. Overflow is provided by either a spillway or riser built into the embankment.

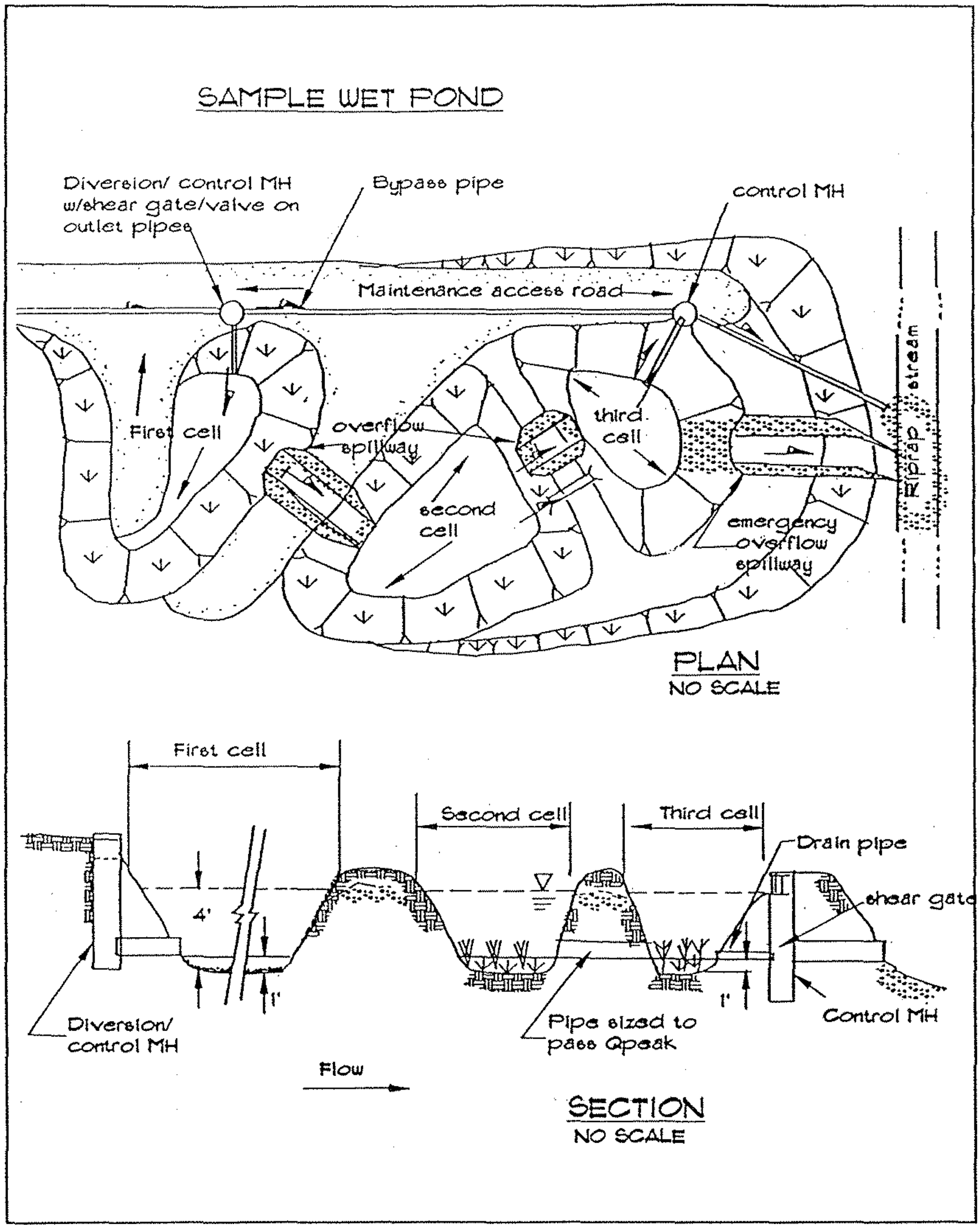

Figure III-10: Multi-cell wet pond design.

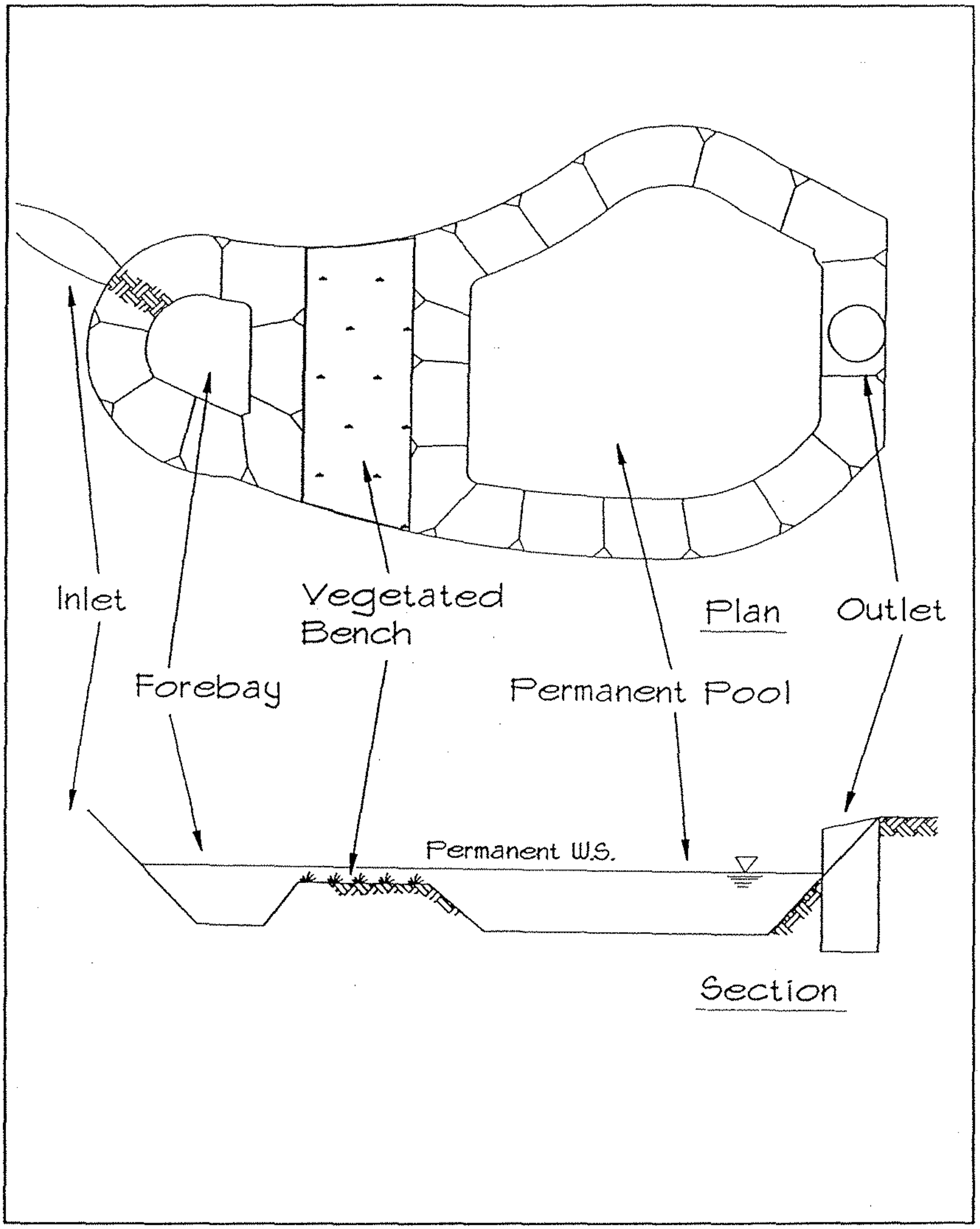

Figure III-11: Single-cell wet pond with forebay.

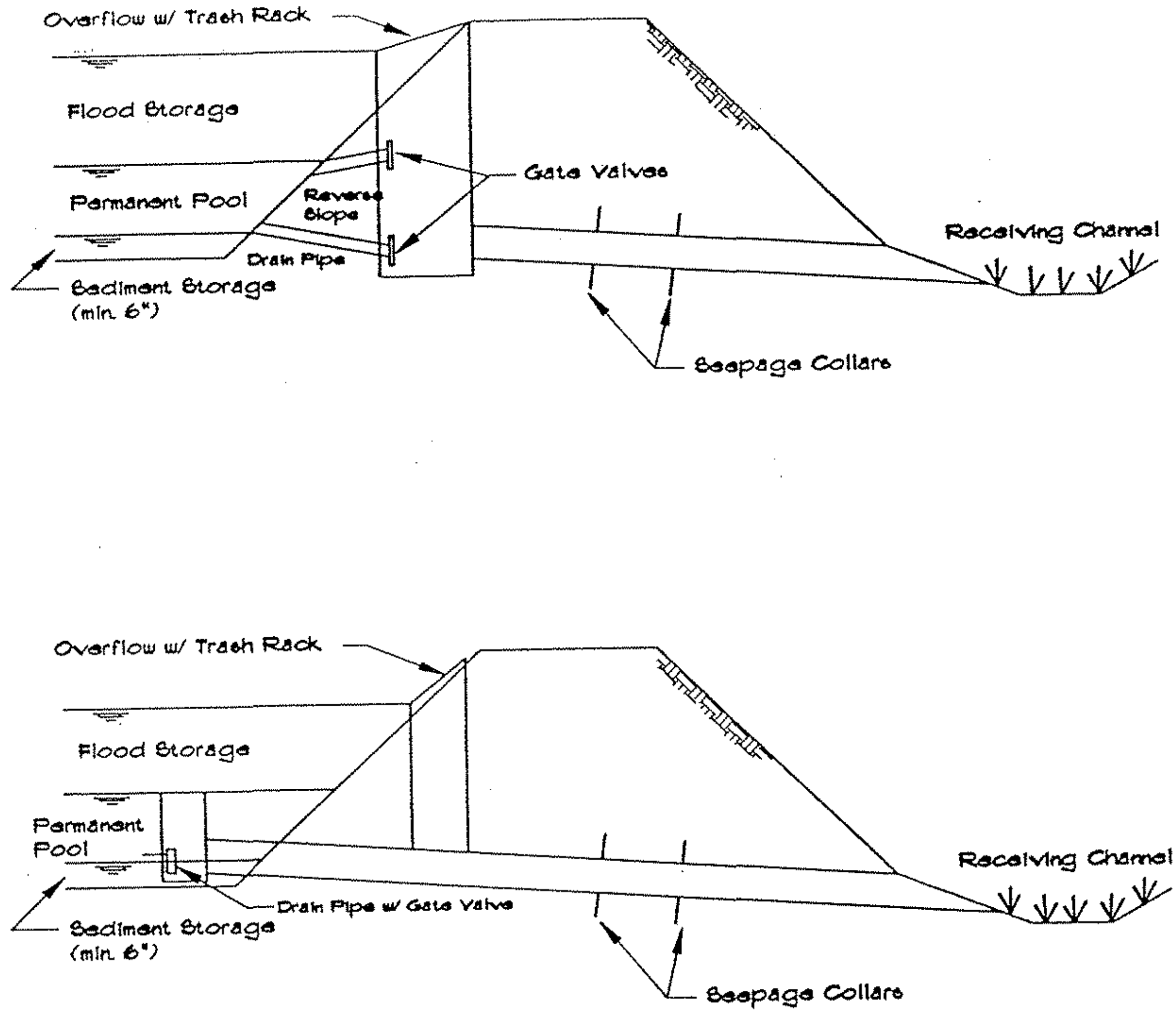

Figure III-12: Typical wet pond outlet designs.

MAINTENANCE REQUIREMENTS

A specific maintenance plan should be prepared which outlines the schedule, scope and responsibilities for performing maintenance duties. Design of wet ponds must provide for maintenance operations.

- Maintenance of ***sediment*** basins and sediment accumulation within the pond is extremely important. Sediment deposits should be continually monitored for both volume and quality since significant concentrations of heavy metals such as lead, zinc, and cadmium in addition to some organics like pesticides can be expected to accumulate on the bottom of these facilities. Testing of sediment should be conducted to determine the leaching potential and levels of accumulation of hazardous material found in the pond.
- Pond ***access roads*** are required when ponds do not abut public right-of-ways. Roads should provide access to the pond bottom and control structure and other pond areas as needed. Roads and pads should meet the requirements of the pertinent jurisdiction standard practices.
- ***Insects*** such as mosquitoes can become a problem with wet ponds of this type. It may be required to occasionally drain any wet pond during the late spring and summer if such a problem arises.
- Side slopes, embankment, and emergency overflow which are above the maximum dead storage water surface require ***mowing*** at least twice a year to prevent the growth of undesirable vegetation, as well as for aesthetics. Basins in residential or recreational areas may require more frequent mowing in order to maintain area aesthetics.
- ***Periodic harvesting*** of wet pond vegetation is required to prevent the release of accumulated nutrients in the biomass. In multi-cell ponds, a rotational harvesting scheme should be used to avoid impacting all of the cells at one time.
- If wet pond is less than six feet in depth, consider adding ***additional depth*** to design to allow longer intervals between required maintenance.

EXTENDED DETENTION PONDS

An extended detention pond is a surface impoundment that temporarily stores excess runoff for a minimum period of time and gradually releases it after the peak of the storm inflow has passed. Extended detention ponds do not generally reduce the volume of storm water runoff but redistribute it over a period of time by providing temporary "live" storage for a certain portion of the storm event. In contrast to a constructed wetland or a wet pond, an extended detention pond does not maintain a permanent pool between storm events. As a result, an extended detention pond will be less effective at removing stormwater contaminants than a similarly sized wet pond. Water level and flood control for extended detention ponds is maintained by the use of risers, orifices, gravel drains, and other outlet control structures.

Water quality treatment occurs in extended detention ponds mainly through sedimentation, but some treatment can occur through infiltration. When properly designed and maintained, extended detention ponds can attain high removal efficiencies for particulate fraction of most contaminants found urban stormwater. These are total suspended solids, heavy metals, BOD, and COD.

ADVANTAGES AND DISADVANTAGES

Advantages

- The area requirements of extended detention ponds are slightly less than those of other pond-marsh facilities.
- Extended detention ponds can provide both flood control and water quality treatment.
- The construction techniques for extended detention ponds are similar to conventional flood control facilities.
- Many existing detention facilities can be modified to allow for extended detention.

Disadvantages

- As with other pond-marsh facilities, the land requirements of extended detention ponds can be prohibitive.
- Extended detention ponds can present a safety hazard.
- Extended detention ponds have an eventual need for sediment removal.

DESIGN CRITERIA

The following design criteria are specific to extended detention ponds and are in addition to the general criteria for pond-marsh facilities discussed earlier.

Treatment efficiency

The method best suited for predicting removal rates for extended detention ponds is the sedimentation model discussed in the preceding section on wet ponds. The removal rates predicted from the use of the model will likely be higher than actual because of the absence of permanent storage in extended detention facilities.

Sizing

Since the primary mechanism of extended detention ponds is solids settling, their performance depends primarily on detention times of the design storm volume. The detention time is defined as the time difference between the centroid of the inflow and outflow hydrographs. One method for sizing extended detention ponds is discussed below (Maryland DOE, 1987). The method assumes triangular shaped inflow and outflow hydrographs. The minimum detention time (T) for an extended detention pond should be 24 hours.

1. Determine the appropriate SCS runoff curve number (CN) for the basin. If more than one land-use type exists in the basin, develop the composite CN value from the total of each CN times its respective surface area divided by the total drainage area of the basin or (CN x respective area)/(total drainage area). CN values for typical urban areas are shown in Table III-3.

2. Compute the time of concentration (t_c) and the one-year, 24-hour after development runoff depth (Q_a) in inches. Calculation of these parameters should be done using methods accepted by the appropriate jurisdiction. If standard accepted methods do not exist, then the SCS TR-55 method (SCS, 1986) may be used.

3. Compute the initial abstraction (Ia) = (200/CN - 2) and the ratio Ia/P, where P is the one-year, 24-hour rainfall depth. The curve number (CN) is the SCS curve number which converts mass rainfall to mass runoff. (SCS, 1986)

Table III-3: Runoff curve numbers for urban areas (SCS, 1986).

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.

4. Using t_c and Ia/P, use Figure III-13 to find unit peak factor (q_u) and then calculate the one-year after development peak discharge using (q_i) = $q_u A Q_a$. A is the drainage area in square miles.

5. Using q_u and detention time (T) with Figure III-14, find ratio q_o/q_i. q_o is the peak outflow and q_i is the peak inflow.

6. Calculate the peak outflow using (q_o) = (q_o/q_i) x q_i (from step 4).

7. Calculate the ratio of storage volume to runoff volume (V_s/V_r) from

$$\frac{V_s}{V_r} = 0.683 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

8. Find the extended detention storage volume from (V_s) = (V_s/V_r) x (Q_a). Convert V_s to acre-feet by applying (V_s/12)A. A is now the drainage area in acres.

9. Determine the required orifice area (A_o) for the pond using

$$A_o = \frac{q_o}{C\sqrt{2gh_o}} = \frac{q_o}{4.81\sqrt{h_o}}$$

where h_o is the maximum depth associated with V_s.

10. Find the required maximum orifice diameter $d = 2\sqrt{\frac{A_o}{\pi}}$ for a single orifice

or configuration for multiple orifices.

Pond Geometry

- The ***inlet and outlet*** should be located as far apart as possible to prevent short-circuiting and maximize travel time.
- The ***length to width ratio*** should be at least 3:1 and preferably 5:1.
- ***Interior side slopes*** up to the maximum water surface should be no steeper than 4H:1V. Steeper side slopes may be used if a fence is provided at or above the maximum water surface to restrict public access to the pond.

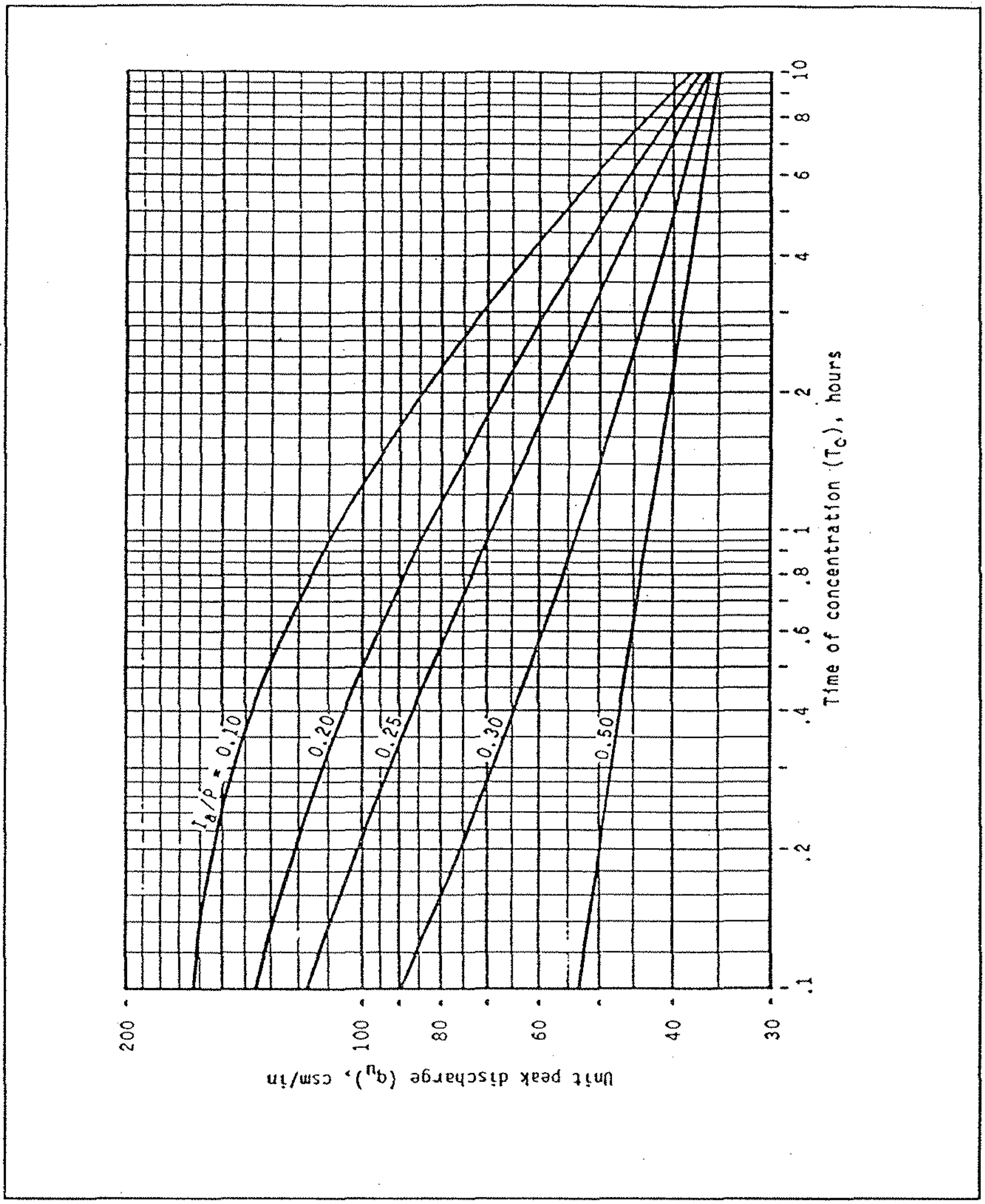

Figure III-13: Unit peak discharge for SCS type IA rainfall distribution (from SCS TR-55, 1986).

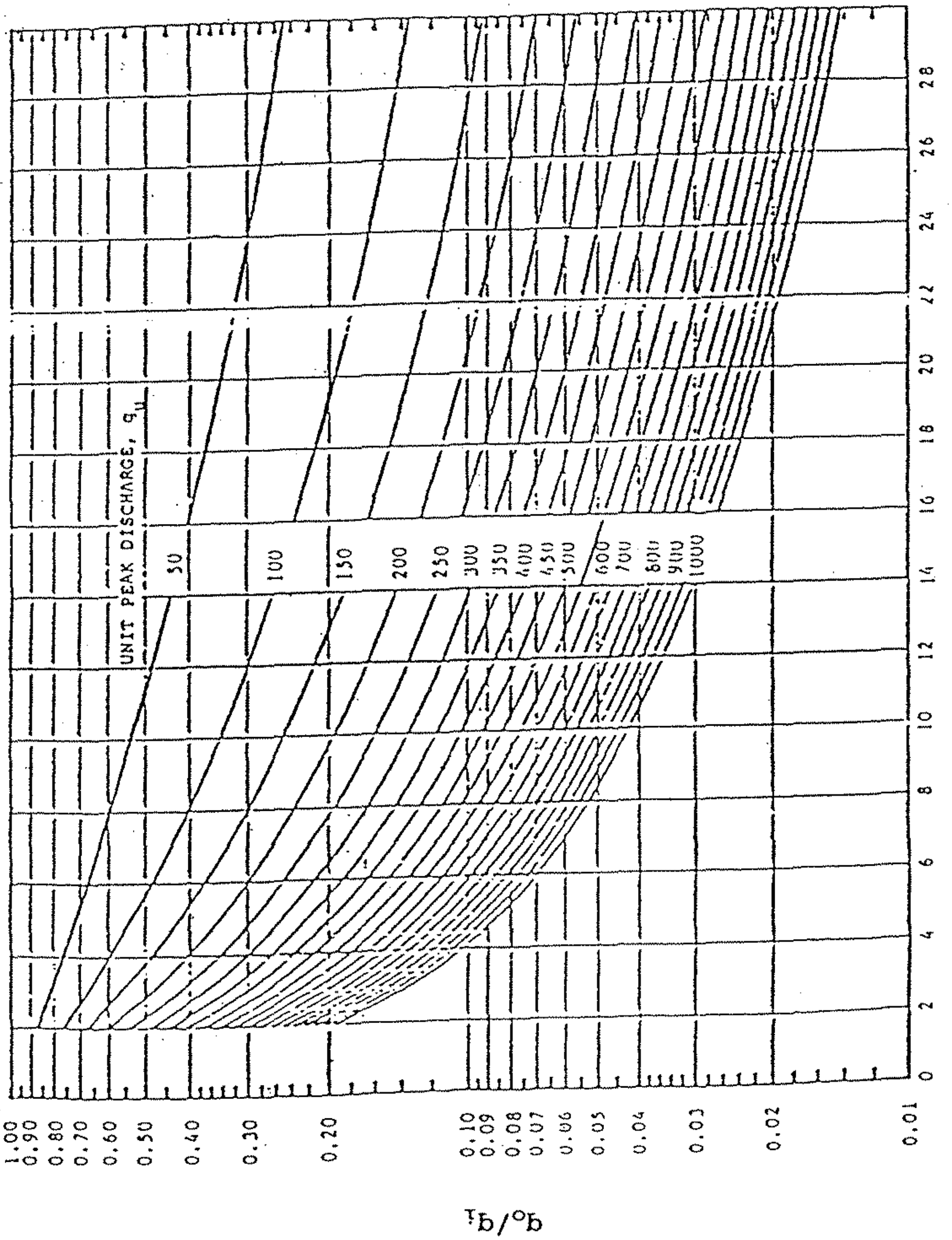

Figure III-14: Detention time versus discharge ratio (Maryland DOE, 1987).

- ***Exterior side slopes*** of fill should be no steeper than 2H:1V unless a geotechnical stability analysis has been performed. Exterior side slopes should also be heavily vegetated.
- The ***pond bottom*** should be level to facilitate sedimentation and the pond bottom should be located at least 6 inches below the inlet and outlet to provide dead storage for sediment.
- The average pond ***depth*** should be a minimum of 3 feet at the design water surface.

Inlet

- The ***inlet area*** should be submerged.
- To help in distributing the inflow more evenly to the deeper sections of the pond, ***inflow baffles*** should be used.

Outlet

- The ***outlet structure*** is perhaps the most important component of an extended detention pond as it defines the detention and release characteristics of the pond. The total area of the outlet orifice(s) which provides the necessary delayed release can be found using the method outlined above. Several alternative designs exist for the outlet structure to an extended detention pond and may be seen in Figure III-15. The main function for the design of the outlet structure is to release the required water quality detention volume over the minimum detention time in as constant a rate as possible.
- Hoods, slots, and gravel filters serve as ***trashguards***.

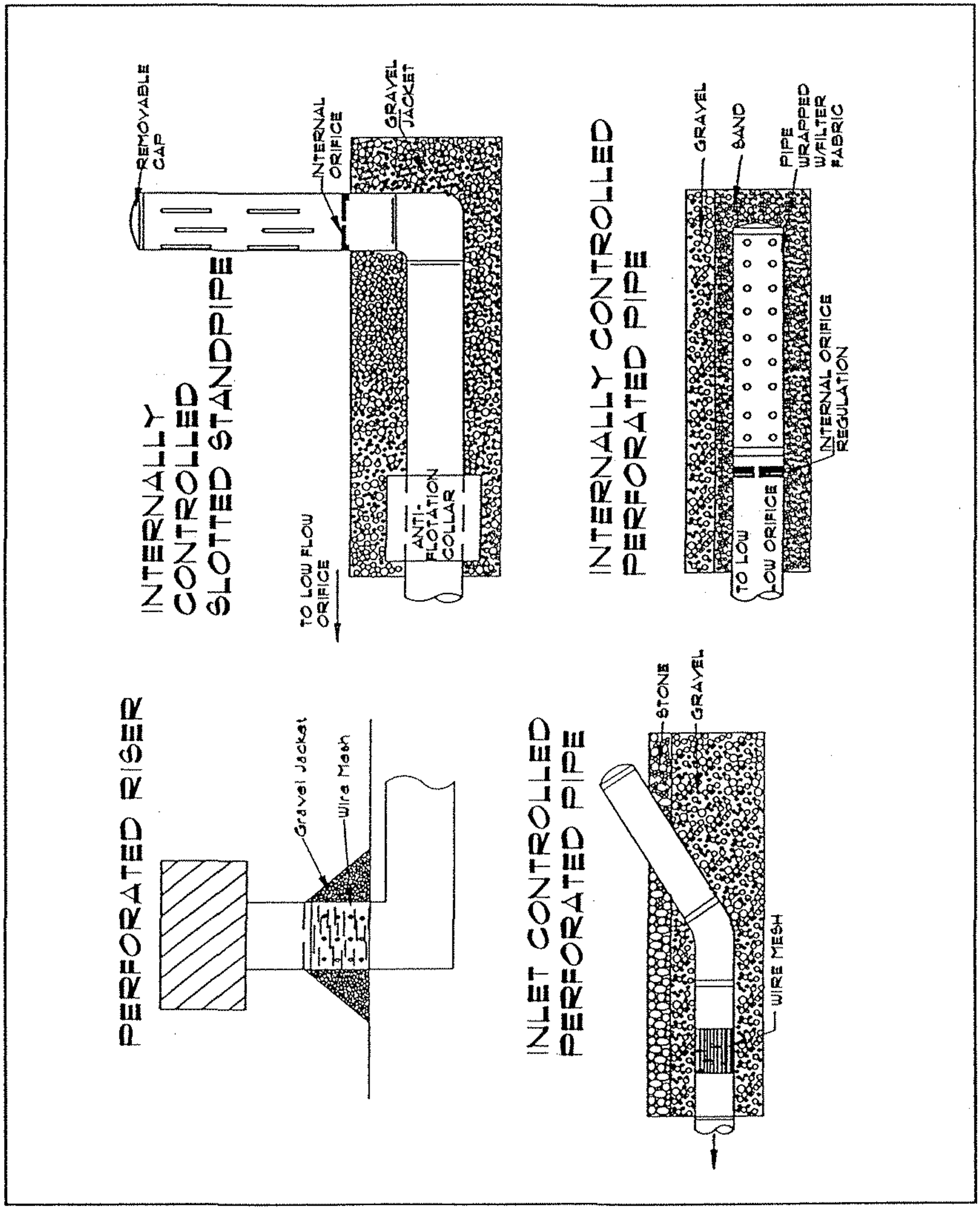

Figure III-15: Outlet schematics for extended detention ponds.

MAINTENANCE REQUIREMENTS

A specific maintenance plan must be prepared which outlines the schedule, scope and responsibilities for performing maintenance duties. Design of extended detention ponds must allow for maintenance operations.

- Periodic removal of ***sediment*** accumulation within the pond is extremely important. Sediment deposits should be continually monitored for both volume and quality since significant concentrations of heavy metals such as lead, zinc, and cadmium in addition to some organics like pesticides can be expected to accumulate on the bottom of these facilities. Testing of sediment should be conducted to determine the leaching potential and levels of accumulation of hazardous material found in the pond.
- Pond ***access roads*** are required when ponds do not abut public right-of-ways. Roads should provide access to the pond bottom and control structure and other pond areas as needed. Roads and pads should meet the requirements of the pertinent jurisdiction.
- The pond's side slopes, embankment, and emergency overflow require ***mowing*** at least twice a year to prevent the growth of undesirable vegetation, as well as for aesthetics. Basins in residential or recreational areas may require more frequent mowing in order to maintain area aesthetics.
- The ***outlet structure*** needs to remain free of debris and should be cleaned on a regular basis to prevent overtopping of the structure.

PLANNING AND DESIGN CHECKLIST

MAJOR PHASES

A. INITIAL EVALUATION

B. PLANNING

C. DESIGN

A. INITIAL EVALUATION

A.1. Site review of opportunities, constraints, and characteristics

- Topography
- Soils
- Groundwater
- Water budget

A.2. Compare management techniques with site characteristics

- Treatment wetlands
- Wet ponds
- Extended detention ponds

A.3. Assess site specific pond-marsh facility options

A.4. Choose initial pond-marsh facility

A.5. Review placement and preliminary sizing with appropriate jurisdiction

B. PLANNING

B.1. Assess tributary area characteristics

- Drainage area boundary and topography
- Size
- Cover and effective impervious area
- Development types

- Slope, side slopes, and stream gradients
- Soils reconnaissance (site and tributary area using existing information)
  - SCS soils type
  - Infiltration
  - Erodibility
  - Phosphorus availability
  - Soil suitability for specific facility type

B.2. Develop flood hydrology/hydraulics

- Select analysis points
- Estimate capacity of existing conveyance/detention capabilities
- Prepare flood hydrographs for the existing system using the appropriate jurisdiction's design storm and analysis methods
- Prepare flood hydrographs for the site and tributary area assuming full development
- Develop hydraulic profile/elevations for analysis points and at hydraulic constraints during normal and impeded flow conditions
- Select drainage/flood management options
- Re-analyze flood hydrology superimposing the flood management options

B.3. Establish vegetation zones and types for treatment wetlands/wet ponds

B.4. Screen options and develop site plan

C. DESIGN

C.1. Perform soils analysis

- Soils logs
- Infiltration tests
- Erodibility of the tributary area
- P availability and removal potential (basin and site)
- Geotechnical stability of embankments and nearby hillsides

C.2. Perform water budget analysis if required for chosen pond-marsh facility

C.3. Confirm and locate options selected

C.4. Perform hydrologic analysis

C.5. Evaluate hydraulic profile at analysis points

C.6. Prepare site plan and cross-section drawings

C.7. Select and describe materials

C.8. Prepare plans and specifications

D. POST CONSTRUCTION

D.1. Water quality monitoring plan

D.2. Monitoring for maintenance

CHAPTER IV

STREETS AND STORM SEWER SYSTEMS

CONTENTS

STREETS AND STORM SEWER SYSTEMS

CONTENTS (continued)

FIGURES

STREET AND STORM SEWER SYSTEMS

This chapter provides a discussion on various types of street and storm sewer facilities which can be incorporated into urban stormwater quality systems. It includes a ***summary*** which gives an overview of the facilities and considerations, a ***selection and siting*** discussion, ***general design criteria*** which apply to all types of street and storm sewer facilities, ***specific design criteria*** (e.g. water quality inlets), and a ***planning/design*** checklist.

SUMMARY

Street and storm sewer facilities are used in urban street systems to reduce pollutant discharges from stormwater runoff. These facilities consist of a wide variety of structures which fall into the following primary groups:

- *TRAPPED CATCH BASINS* - A catch basin which has been modified to include sediment collection and storage capabilities.
- *VAULTS/TANKS* - Underground storage facilities in which particulates are settled out and stored.
- *WATER QUALITY INLETS* - Multi-chambered underground structures designed to remove sediment and hydrocarbons.
- *SEDIMENTATION MANHOLES* - Manholes placed upstream from dry wells/sumps to collect sediment in stormwater runoff prior to discharging into dry wells/sumps.

Pollutant removal in street and storm sewer facilities is primarily through sedimentation. These facilities are designed to provide quiescent conditions which promote gravity settling. Modified facilities such as water quality inlets can provide limited removal of hydrocarbons.

SELECTION AND SITING

POLLUTANT REMOVAL

Pollutant removal in street and storm sewer facilities is usually limited to suspended sediment and pollutants which bind to the sediment particles such as heavy metals. Pitt (1985) found that coarse-grained particles such as grit, sand, some silt, and debris would remain deposited and smaller particles have a tendency to be re-suspended. Pitt estimated that trapped catch basins could remove about 10-25 percent of sediment and trace metals and less than 10 percent of nutrients in urban runoff if regular cleaning takes place.

POTENTIAL GROUNDWATER IMPACTS

Street and storm sewer facilities are used to collect, convey, and discharge stormwater runoff. These facilities do not usually affect groundwater resources.

SITING CRITERIA

Street and storm sewer facilities are intended to provide treatment of urban runoff mainly through sedimentation processes. These facilities are most efficient in pretreatment applications such as preceding an infiltration basin or vegetated facility. Each facility should be limited to service areas no larger than 1 impervious acre.

Trapped Catch Basins

Trapped catch basins are relatively small structures which are capable of removing large sediment particles from urban runoff prior to discharge into the stormwater system, and are particularly useful:

- On residential streets at storm drainage inlets.
- At outlets of open channel conveyance systems such as rural roads.
- At storm drain inlets from parking lots.

Water Quality Inlets

Water quality inlets are particularly appropriate for small development areas that generate high levels of sediment and hydrocarbons. Specific sites of application include:

- Service stations and private refueling facilities.
- Car wash and steam cleaning facilities.
- Outlets of large parking lots and equipment storage areas.

Sedimentation Manholes

Sedimentation manholes are best applied when located upstream from dry well/sump facilities. They can also be used to remove sediment from storm runoff prior to discharge to a storm sewer system. Locations where sedimentation manholes can be used include:

- Intersections of urban streets.
- Dirt or gravel parking areas where significant sediment loads are expected.
- As part of a combination system (see Chapter VI).

GENERAL DESIGN CRITERIA

The following design considerations apply to all types of street and storm sewer facilities.

SOILS

Soils are not usually a limiting factor in the siting, construction, and operation of street and storm sewer water quality facilities except in terms of structural loading capacity and construction requirements. A careful analysis of the soil characteristics and loading limitations should be incorporated into the facility design.

GROUNDWATER PROTECTION

Street and storm sewer facilities do not usually present significant threats to groundwater resources.

ANALYSIS AND REPORTS

Soils

A soils report is required for all proposed street and storm sewer facilities in the Portland-Lake Oswego-Clackamas County-USA area. This report should identify the design constraints related to the overall project; verify the mapped soils series; determine the soil series of areas which have not been previously mapped; and determine the depth of the seasonal maximum water table during the period of interest.

Hydrology

All proposed projects or facilities involving street and storm sewers must include in the site analysis/report:

- A hydrograph of the design storm runoff and facility overflow for flood conditions as defined by the appropriate local jurisdiction.
- A hydrograph of the design storm runoff for water quality control as defined by the appropriate local jurisdiction.
- Mapping of the flow route to an adequate discharge point during the design storm.
- The significant downstream flooding impacts.

All hydrologic-hydraulic analysis must be done in accordance with the methods required or recommended by the cities of Portland, or Lake Oswego, Clackamas County, or USA depending on which jurisdictions' authority covers the project.

TRAPPED CATCH BASINS

Trapped catch basins are located between the curb and gutter and the storm drainage system as shown in Figure IV-1. The main purpose of trapped catch basins are to collect large particles prior to their reaching the storm drainage system.

ADVANTAGES AND DISADVANTAGES

Advantages

- Trapped catch basins collect large sediment particles and prevent them from entering the storm drainage system.
- Installation costs are low when installed during the initial street construction.

Disadvantages

- Periodic maintenance is required to remove accumulated sediment. Frequency of cleaning is dependent on the type of development served (i.e. industrial sites may require more frequent cleaning than residential).
- Trapped catch basins do not have adequate volume to settle out small particles.

DESIGN CRITERIA

The following design criteria are specific to trapped catch basins and are in addition to the general criteria for street and storm sewer systems discussed earlier.

Treatment Efficiency

The small size of trapped catch basins limits pollutant removal to large particles such as grit and sediment. Sediment which deposits in the basin must be removed at least twice a year to prevent sediment re-suspension.

Size

- Each trapped catch basin should serve an ***impervious area*** no larger than one acre.
- The catch basin ***inlet*** must be sized to allow the design storm event to pass into the storm drainage system.

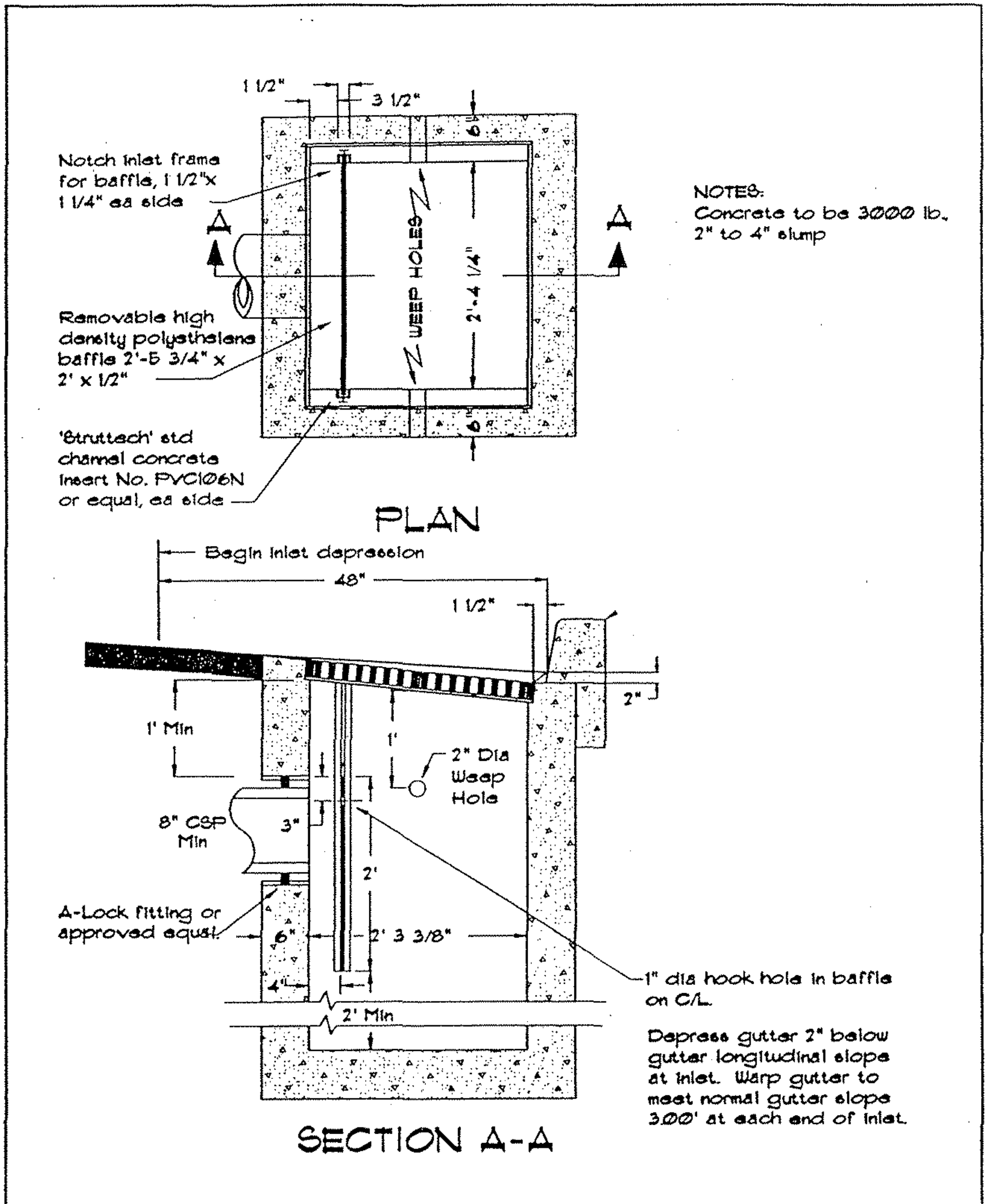

Figure IV-1: Typical trapped catch basin.

Cover

- A ***grated cover*** should be provided to screen leaves and floating debris from entering the catch basin and ultimately the storm drainage system.

Access

- ***Access*** should be provided to allow removal of accumulated sediment.

Baffle

- A ***baffle*** should be installed at the catch basin outlet to prevent floating debris from entering the storm sewer.

VARIATIONS

Standard designs are often used for trapped catch basins to reduce fabrication costs. Variations do occur within jurisdictions, but the basic design parameters as detailed in Figure IV-1 are normally used.

MAINTENANCE REQUIREMENTS

- A specific ***maintenance plan*** should be prepared which outlines the schedule, scope, and responsibilities for performing maintenance duties. Design of trapped catch basins must provide for maintenance operations.
- Accumulated ***sediment*** must be removed at least twice a year. More frequent cleaning may be required in areas where heavy sediment loads are expected.
- ***Leaves and litter*** must be removed from the basin inlet periodically to maintain the flow capacity of the inlet.

VAULTS AND TANKS

Wet vaults and tanks are underground storage facilities used to collect and store urban runoff. These facilities are usually constructed from reinforced concrete (vaults) or corrugated metal pipe (tanks) as shown in Figures IV-2, IV-3, and IV-4. A permanent pool of water is maintained in wet tanks and vaults to provide quiescent settling conditions which initiates pollutant removal.

ADVANTAGES AND DISADVANTAGES

Advantages

- Pollutant reduction occurs through gravity settling of particulates.
- Tanks and vaults can be used in locations where limited space is available.
- Groundwater impacts are eliminated or minimized.

Disadvantages

- Biological assimilation does not occur in tanks and vaults which results in fewer water quality benefits as compared to open ponds.
- Tanks and vaults are more difficult to inspect and maintain because of their underground location.

DESIGN CRITERIA

The following design criteria are specific to wet vaults and tanks and are in addition to the general criteria presented earlier.

Treatment Efficiency

Treatment processes in tanks and vaults are limited primarily to removal of large sediment particles. Vaults and tanks have insufficient volume to provide efficient removal of smaller soil particles. Their underground location precludes biological assimilation processes. In general, sediment removal on the order of 10-25 percent can be expected (Pitt, 1985).

Size

- Contributing ***impervious drainage area*** should be no greater than 3 acres.
- The ***design water surface area*** of the tank/vault shall be a minimum of 1 percent of the impervious area of the contributing catchment drainage.

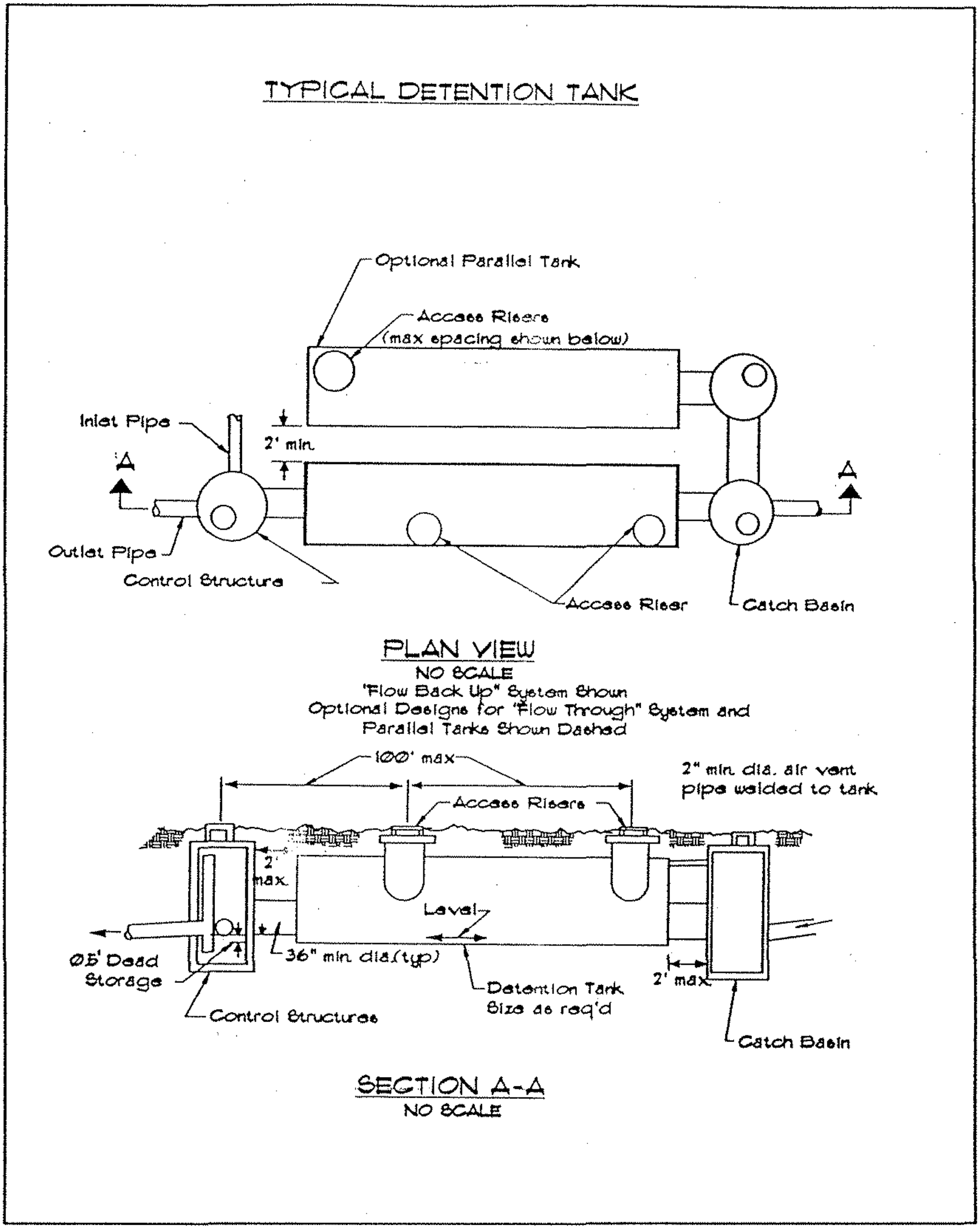

Figure IV-2: Typical detention tank.

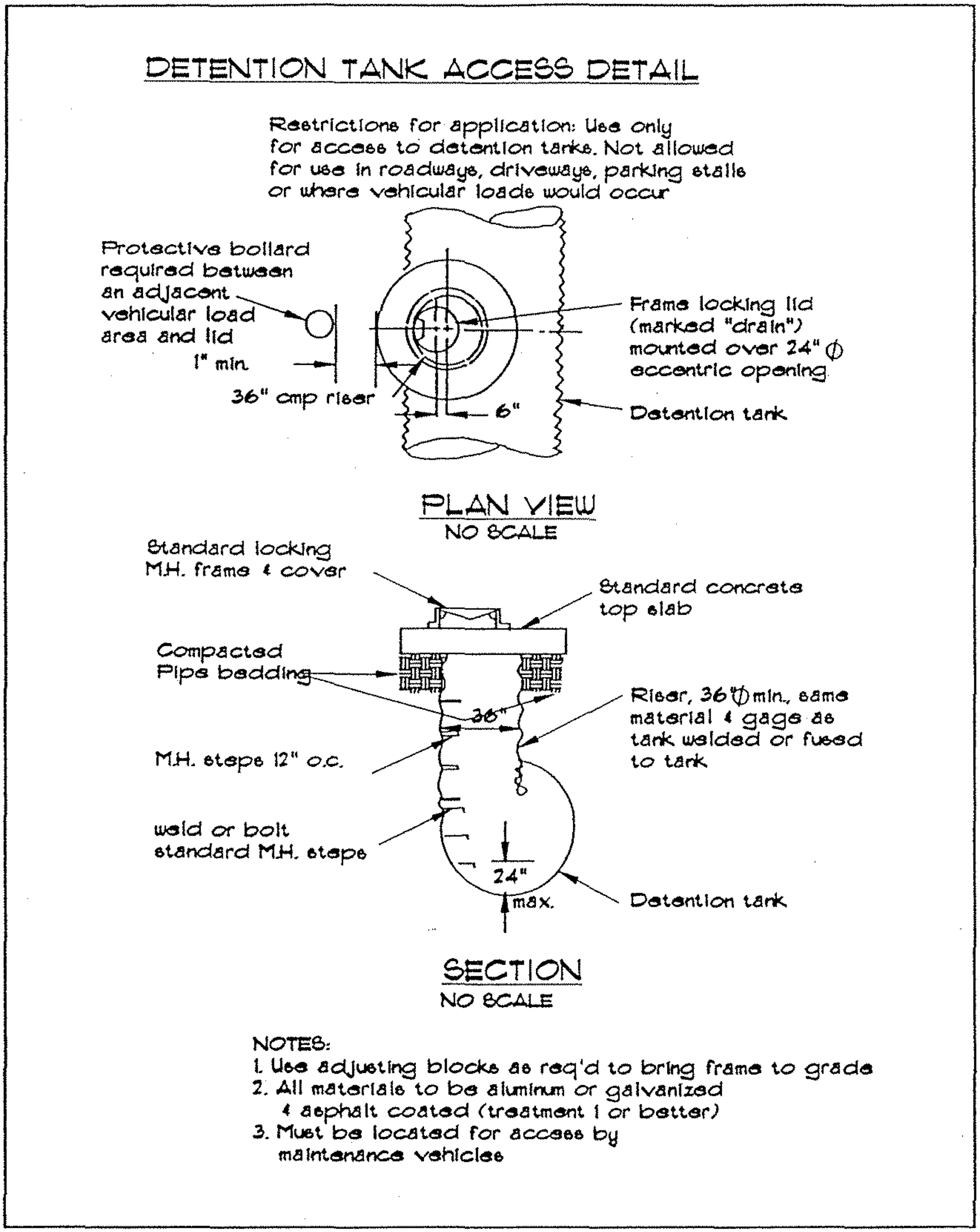

Figure IV-3: Typical detention tank access details.

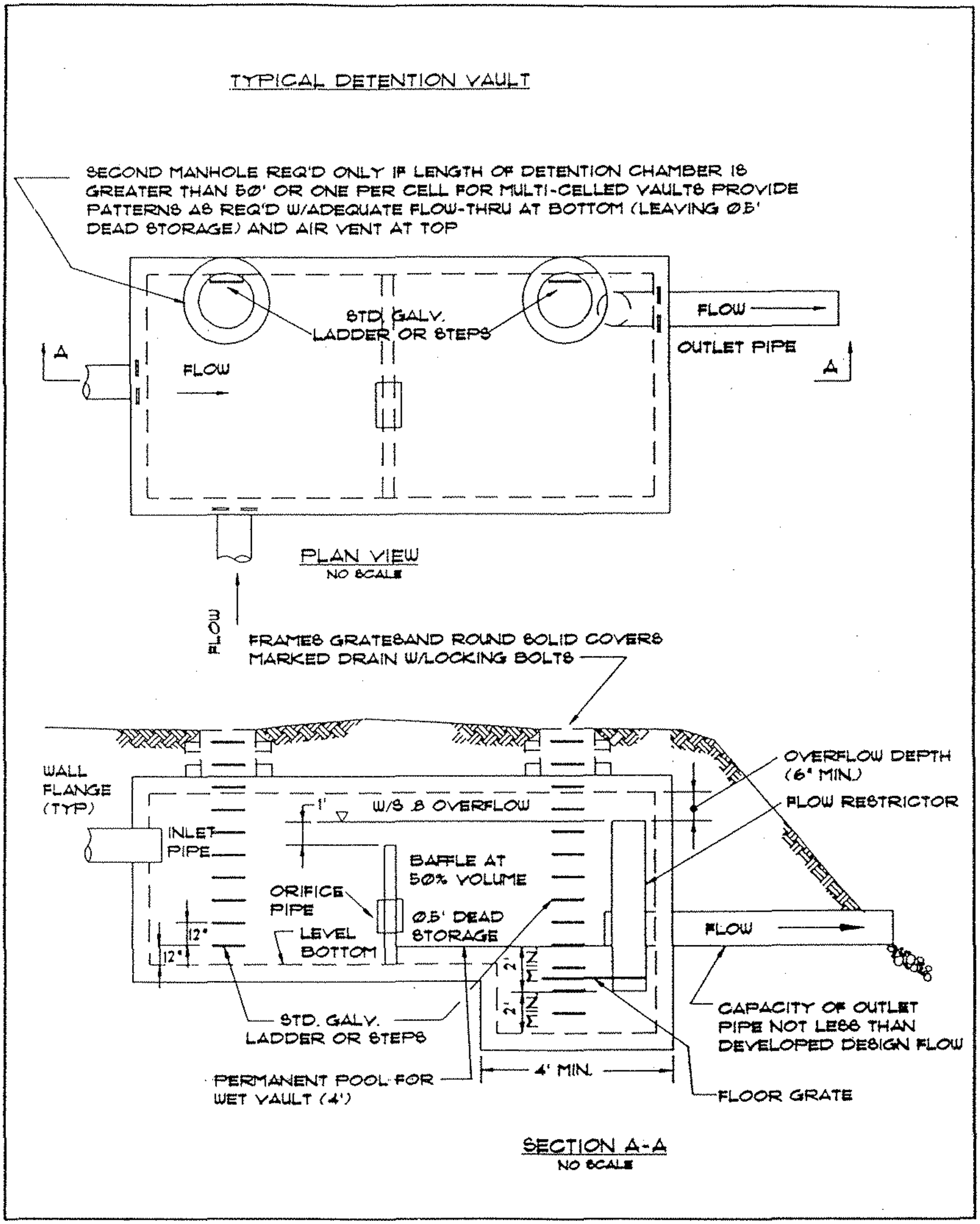

Figure IV-4: Typical detention vault.

- The ***length-to-width*** ratio at the design water surface for water quality should be no less than 3:1 (preferably 5:1).
- A ***permanent pool*** with a minimum depth of 3 feet and maximum depth of 6 feet should be maintained.
- The vault should be divided into ***cells*** by a baffle as shown in Figure IV-4. The top of the baffle wall should be set one foot below the design water surface elevation.

Outlet

- The vault (Figure IV-4) should have a ***pipe orifice*** cast into the wall with an invert set 6 inches above the bottom of the vault. The orifice should be designed to pass the developed flow for the water quality design storm.
- The ***inlet and outlet*** of the tank/vault should be placed to maximize travel time through the facility.

Bypass

- A mechanism should be provided to ***bypass*** the tank/vault for flows exceeding the developed flow for the water quality design storm.

Access

- ***Access*** should be provided for maintenance and inspection purposes. A typical tank access detail is shown in Figure IV-3.

Materials

- Tanks should be constructed of ***materials*** suitable for the site soil conditions, and capable of meeting the structural load requirements.
- Vaults should be constructed of ***reinforced concrete*** and designed to meet the structural load requirements.

Buoyancy

- In moderately pervious soils where groundwater may induce flotation, ***buoyancy tendencies*** should be balanced to restrict the tank from "floating." Buoyancy forces may be controlled by ballasting with either backfill or concrete backfill, providing concrete anchors, increasing the total weight, or by placing subsurface drains to permanently lower the groundwater table.

VARIATIONS

Many different configurations exist for tanks and vaults. Specific site characteristics such as soil type, groundwater location, and depth of the tank will determine the type of tank material and configuration which will best fit the site.

MAINTENANCE REQUIREMENTS

- A specific ***maintenance plan*** should be prepared which outlines the schedule, scope, and responsibilities for performing maintenance duties. Design of vaults and tanks must provide for maintenance operations.
- Tanks and vaults should be ***inspected*** at least twice a year to monitor levels of sediment and debris accumulation, water tightness, and storm-induced damage to the structure.
- ***Sediment and debris*** should be removed at least once a year.

WATER QUALITY INLETS

Water quality inlets (WQI) are multi-chambered structures designed to remove sediment and hydrocarbon loadings from urban runoff prior to discharging into the storm drain system.

ADVANTAGES AND DISADVANTAGES

Advantages

- WQIs are located underground out of the way of traffic and public view.
- Relatively easy access to WQI facilities.
- Most storm drain systems can be retrofitted with WQIs.
- WQIs function well as pretreatment systems for infiltration facilities.

Disadvantages

- WQIs store only a fraction of the design storm event and as a result do not aid in modifying the post development peak discharge.
- WQIs have limited pollutant removal capabilities.
- Frequent cleaning is required.
- Appropriate disposal of accumulated sediment may be a problem.

DESIGN CRITERIA

The following criteria are specific to water quality inlets and are in addition to the general criteria presented for street, storm sewer, and transport facilities presented early.

Treatment Efficiency

Water quality inlets are designed to remove sediment and hydrocarbon loadings from urban runoff prior to discharging into a storm drain system. Water quality inlets normally store only a fraction of the developed flow from the water quality design storm event. Due to their limited capacity, water quality inlets do not modify the post development peak flow rate, and pollutant removal is limited to coarse sediment, oil/grease, and debris. Fine-grained particulate pollutants such as silt, clay, and associated trace metals and nutrients are not effectively removed within a water quality inlet. Soluble pollutants pass through water quality inlets with essentially no removal occurring.

In general, 10-25 percent of the total suspended solids and trace metals and 25-75 percent of oils/grease can be expected to be removed in a water quality inlet (Pitt, 1985). Less than 10 percent of influent nutrients are removed. Higher influent concentrations and larger particle sizes tend to produce greater removal efficiencies.

Size

- Individual ***inlets*** should be used to serve only small areas up to a maximum of one impervious acre. Installation costs increase rapidly for service areas in excess of one impervious acre.
- The ***outlet*** of a WQI must be connected to a storm drain system.
- The volume of a ***permanent pool*** should be maximized. At least 400 cubic feet of wet storage per impervious acre is recommended.
- The permanent pool in each chamber of the inlet should be at least ***four feet deep***.

Enhancing Pollutant Removal

- The ***wet pool volume*** in the first and second chambers should be maximized. The third chamber will provide additional settling benefits if it can be maintained as a permanent pool as well.
- The ***orifice*** connecting the first chamber to the second should be protected by a trash rack to prevent plugging.
- To adequately ***remove oil***, the second and third chambers should be connected with an inverted pipe which extends at least three feet down into the permanent pool.
- ***Baffle plates*** should be installed from the side walls to prevent resuspension of deposited sediment.
- The floor in each chamber should be ***sloped*** away from the outlet to the next chamber to enhance sediment trapping.

VARIATIONS

Several variations of water quality inlets are currently in use. Of these, the Montgomery County Design (Figure IV-5) and the City of Rockville Design (Figure IV-6) are two common variations.

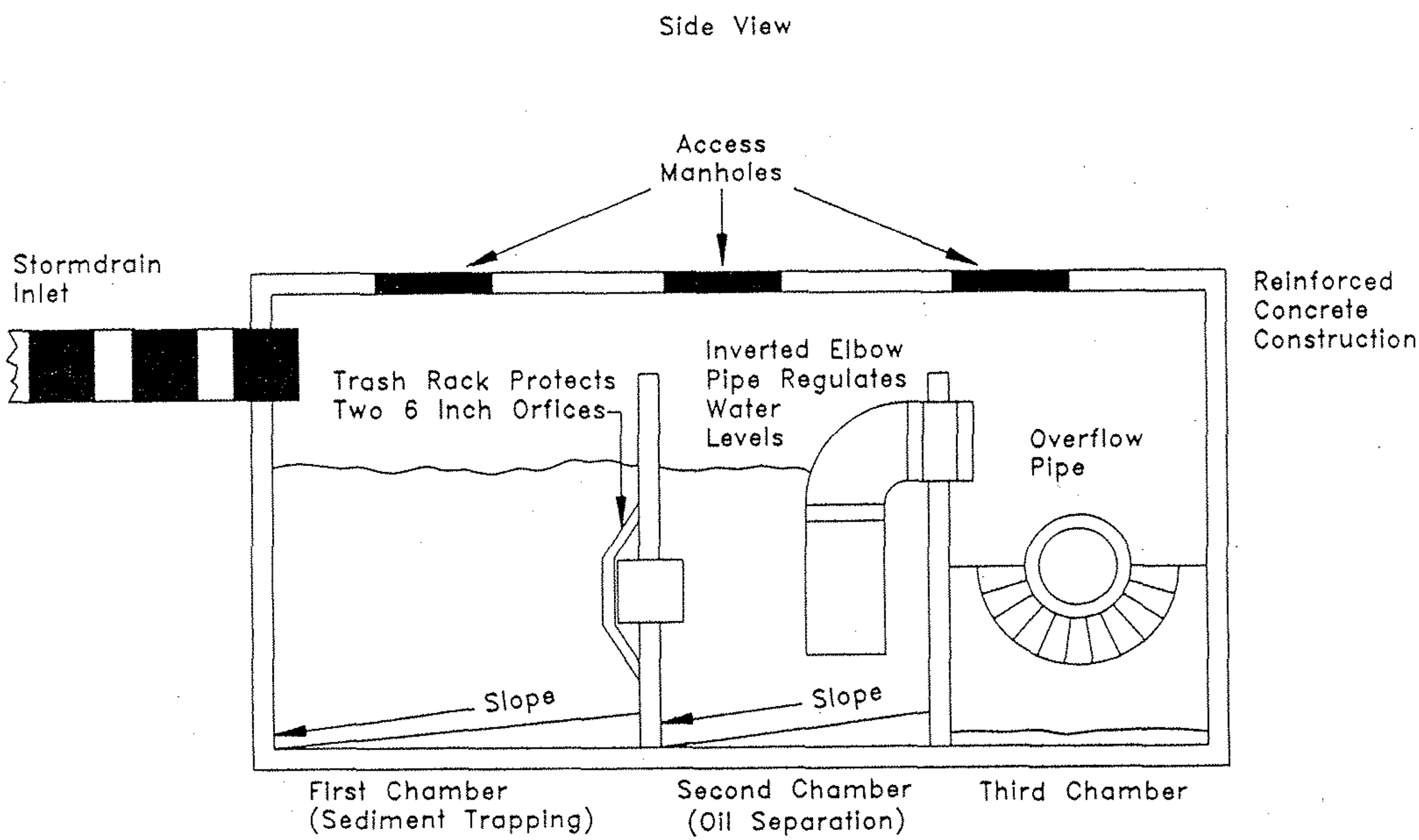

Figure IV-5: Water quality inlet, Montgomery County, MD, three-chamber design.

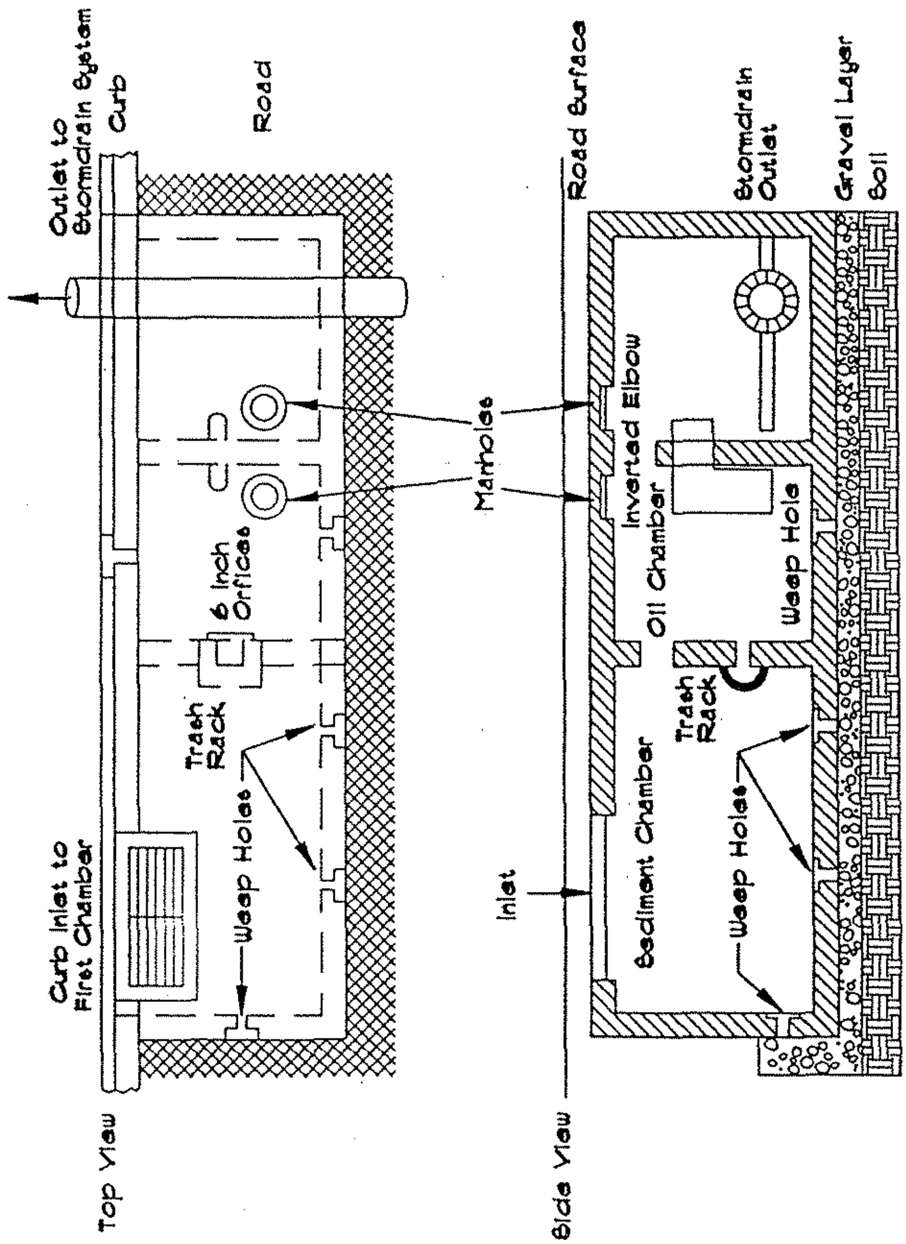

Figure IV-6: Water quality inlet, City of Rockville, MD, percolating inlet design.

Montgomery County Design

This design, developed in Montgomery County, Maryland consists of a long rectangular concrete structure divided into three chambers. Runoff passes through the three chambers that are specifically designed to remove sediment, grit, and oil before being discharged into the storm drainage system.

Permanent pools are maintained in the first and second chambers which are connected by a pair of well-screened six inch diameter holes. Gravity settling of grit and sediments, and floating debris are trapped in the first chamber. The second chamber is fitted with an inverted pipe elbow which regulates water levels in the inlet. Oil and gas films floating on the surface are contained within chamber two by the inverted pipe design. The third chamber is the inlet into the storm drain system.

Rockville Design

The Rockville design is similar to the Montgomery design except that permanent pools are not maintained in the first and second chambers. Rather, runoff drains through a series of well-screened six-inch weep holes located on the floor of each chamber into a layer of stone aggregate and eventually infiltrates into the subsoil. The first and second chambers would only fill during storm events.

The main feature of the Rockville design is enhanced pollutant removal through infiltration into the subsoil. This feature may be significantly limited due to clogging of the weep holes. If the weep holes do clog, the Rockville design will function essentially as a three chamber design with wet pools maintained in chambers one and two. The Rockville design should not be used where high water tables or other conditions may cause contamination of groundwater.

MAINTENANCE REQUIREMENTS

- A specific ***maintenance plan*** should be prepared which outlines the schedule, scope, and responsibilities for performing maintenance duties. Design of water quality inlets must provide for maintenance operations.
- Accumulated ***sediment*** must be removed at least twice a year to maintain pollutant removal efficiency.
- ***Trash racks*** on orifices between chambers must be inspected and cleaned periodically.

SEDIMENTATION MANHOLES

Sedimentation manholes are structures placed upstream from dry wells/sumps in an urban location as shown in Figure IV-7. The primary purpose of sedimentation manholes is to remove large particles from urban runoff prior to discharging flow into dry wells/sumps. If not removed, these particles would eventually plug the coarse gravel layer in the dry wells/sumps and reduce the infiltration capabilities.

ADVANTAGES AND DISADVANTAGES

Advantages

- Sedimentation manholes are available in prefabricated, standard sizes and can be used in series to meet sediment removal objectives.
- Installation of sedimentation manholes in urban settings is relatively simple.
- Large sediment particles, such as grit and sand, are removed from storm runoff in sedimentation manholes prior to discharge to the storm drain system.

Disadvantages

- Sedimentation manholes require cleaning at least twice a year to prevent resuspension of settled particles.
- Inadequate volume is available in sedimentation manholes to remove small particles from urban runoff.

DESIGN CRITERIA

The following design criteria are specific to sedimentation manholes and are in addition to the general criteria previously presented.

Treatment Efficiency

Sedimentation manholes, as the term implies, rely on sedimentation processes to effect pollutant removal. In general, sedimentation manholes have limited volume available to effectively remove small suspended particles. Soluble pollutants flow through the facility with little reduction in concentrations.

With regular cleaning (twice a year), anticipated levels of pollutant removal are expected to be on the order of 30 percent solids removal, 25 percent trace metal removal, and 25 percent phosphorus. These levels of removal are based on the

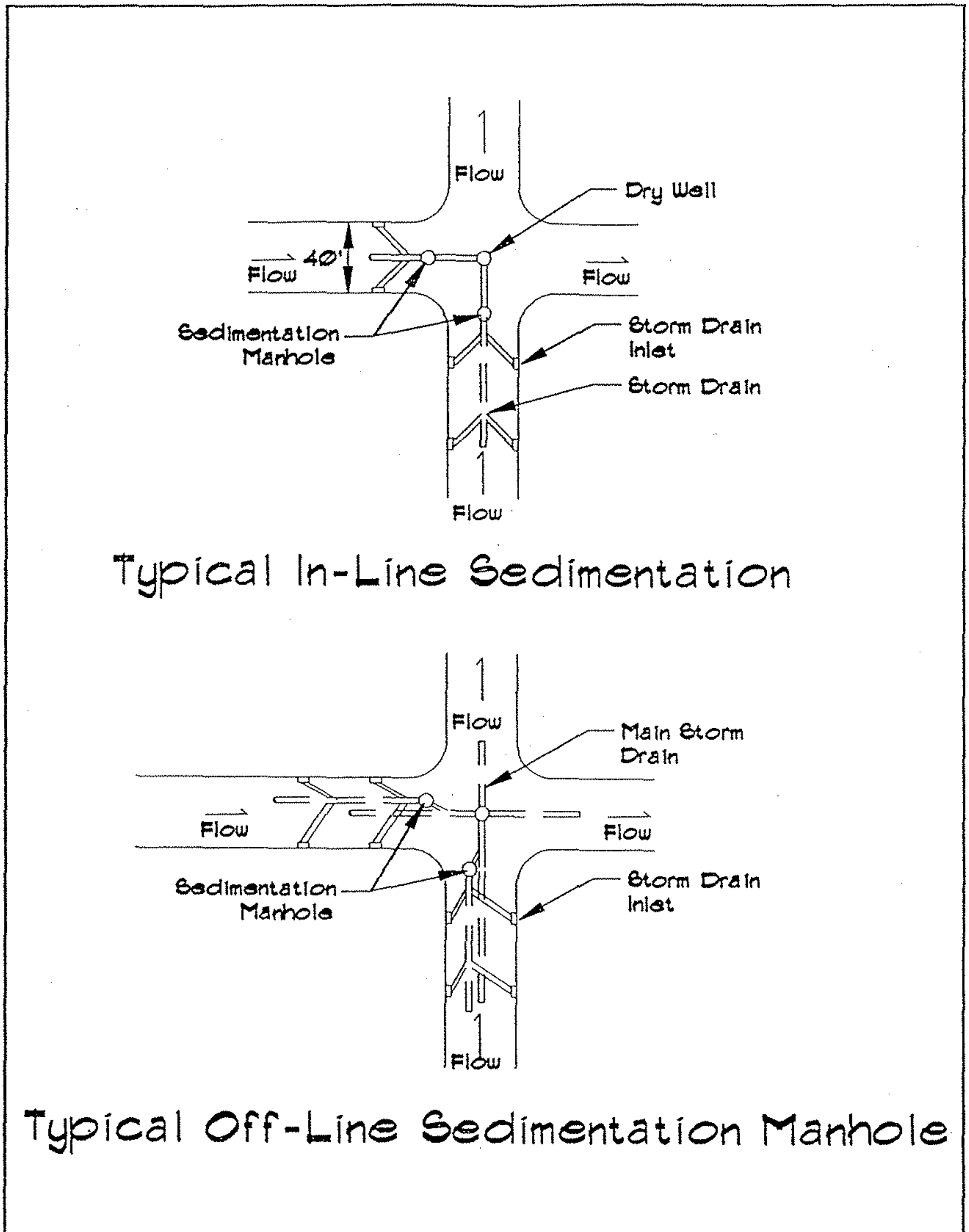

Figure IV-7: Typical sedimentation manhole site layout.

assumption that sufficient volume is available to contain the developed flow volume from the water quality design storm event. Several sedimentation manholes may be placed in series to obtain the required storage volume.

Size

- The manhole should be sized to accommodate the ***water quality*** design storm event hydrograph volume.
- The ***inlet and outlet*** of the manhole should be capable of passing the developed flow from the flood design storm event directly to the storm drain system.
- Each manhole shall serve an ***impervious area*** no larger than 3 acres.

Cover

- A manhole ***cover*** shall be provided for each manhole.

Loadings

- Manholes shall be constructed to meet the appropriate jurisdiction's ***structural design loadings and standard specifications.***

VARIATIONS

Standard manhole sizes are usually used for most sedimentation manholes to reduce costs associated with special fabricated ones. Manholes in series as shown in Figures IV-7 and IV-8, can be used to meet the pollutant removal objectives.

MAINTENANCE REQUIREMENTS

- A specific ***maintenance plan*** should be prepared which outlines the schedule, scope, and responsibilities for performing maintenance duties. Design of sedimentation manholes must provide for maintenance operations.
- Sedimentation manholes must be ***cleaned*** at least twice a year.
- Periodic ***inspections*** of manholes should be performed to monitor sediment levels and possible plugging of the inlet or outlet with debris, especially after large storm events.

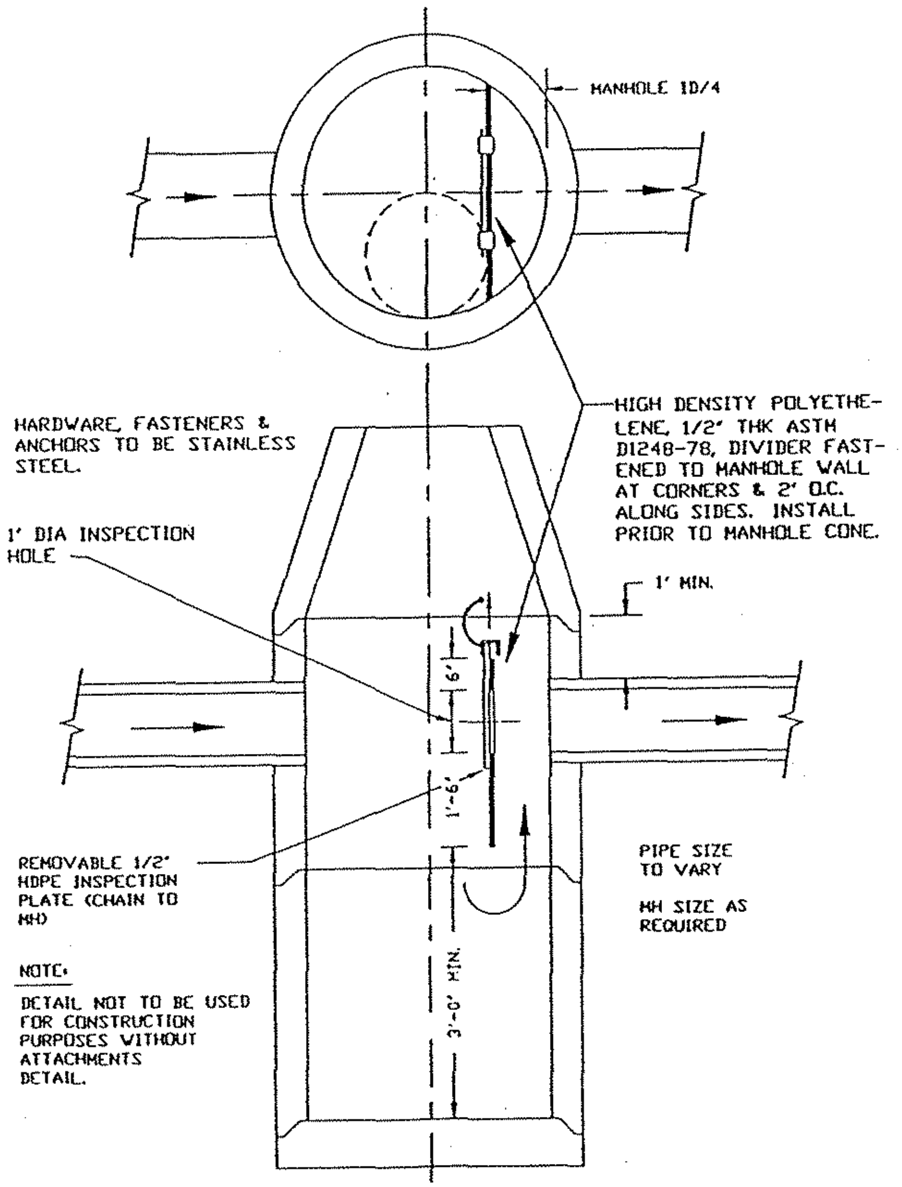

Figure IV-8: Typical sedimentation manhole details.

PLANNING AND DESIGN CHECKLIST

MAJOR PHASES

A. INITIAL EVALUATION

B. PLANNING

C. DESIGN

A. INITIAL EVALUATION

A.1. Site Review of Opportunities, Constraints, and Characteristics

- Topography
- Soils
- Groundwater

B. COMPARE MANAGEMENT TECHNIQUES WITH SITE CHARACTERISTICS

- Trapped catch basins
- Water quality inlets
- Sedimentation manholes

B.1. Assess Site Specific Street and Storm Sewer Facility Options

B.2. Choose Initial Street and Storm Sewer Facility

B.3. Review Placement and Preliminary Sizing with Appropriate Jurisdiction

C. PLANNING

C.1. Assess Tributary Area Characteristics

- Drainage area boundary and topography
- Size
- Cover and effective impervious area
- Development types

- Slope, side slopes, and stream gradients
- Soils reconnaissance (site and tributary area using existing information)
  - SCS soils type
  - Infiltration
  - Erodibility
  - Phosphorus availability
  - Soil suitability for specific facility type

C.2. Develop Flood Hydrology/Hydraulics

- Select analysis points
- Estimate existing conveyance/detention capabilities
- Prepare flood hydrographs for the existing system using the appropriate jurisdiction's design storm and analysis methods
- Prepare flood hydrographs for the site and tributary area assuming full development
- Develop hydraulic profile/elevations for analysis points and at hydraulic constraints during normal and impeded/blocked flow conditions
- Select drainage/flood management options
- Reanalyze flood hydrology superimposing the flood management options

C.3. Develop Water Quality Hydrology/Hydraulics

- Select analysis methods based on the appropriate jurisdiction's requirements/recommendations
- Prepare water quality hydrographs for the existing and future development conditions (site and tributary area)

C.4. Screen Options and Develop Site Plan

D. DESIGN

D.1. Perform Soils Analysis

- Soils logs
- Erodibility of the tributary area
- P availability and removal potential (basin and site)

D.2. Perform Water Budget Analysis if Required for Chosen Street and Storm Sewer Facility

D.3. Confirm and Locate Options Selected

D.4. Perform Hydrologic Analysis

D.5. Evaluate Hydraulic Profile at Analysis Points

D.6. Prepare Site Plan and Cross-Section Drawings

D.7. Select and Describe Materials

D.8. Prepare Plans and Specifications

E. POST CONSTRUCTION

E.1. Water Quality Monitoring Plan

E.2. Monitoring for Maintenance

CHAPTER V

LANDSCAPING

CONTENTS

LANDSCAPING

CONTENTS (continued)

FIGURES

TABLES

LANDSCAPING

This chapter contains various types of vegetated facilities which can be incorporated into landscaping practices. It includes a ***summary*** which gives an overview of the facilities and considerations, a ***selection and siting*** discussion, ***general design criteria*** which apply to all types of landscaping practices, ***specific design criteria*** (e.g. grassed swales), and a ***planning/design checklist***.

SUMMARY

The term landscaping, as used in this manual, represents a broader ecological perspective than the more customary usage. To provide the maximum water quality benefits, ecological landscaping needs must be considered throughout the development process rather than just at the end.

Landscaping practices considered in this chapter include a wide range of vegetated facilities used to enhance biofiltration processes. These facilities range from small vegetated swales to constructed filter strips adjacent to a parking lot. Typical facilities include:

- ***VEGETATED SWALES*** - A vegetated channel sloped similar to a standard storm drain channel, but much wider and more shallow, in which stormwater is treated as it passes through the channel.
- ***VEGETATED FILTER STRIPS*** - Vegetated sloped strips in which flow is distributed broadly along the length of the vegetated area.
- ***ON-SITE LANDSCAPING*** - Landscaping practices used on a site specific basis which incorporate various passive and structural systems to reduce off-site transport of pollutants.

Vegetated treatment facilities rely on biofiltration processes to remove pollutants from urban runoff. As runoff moves over and through a vegetated facility, the simultaneous processes of filtration, infiltration, adsorption, and biological uptake of pollutant's occurs. Vegetation growing in these facilities retards the runoff flow, initiating gravity settling of particulates. Dissolved pollutants are removed through biological uptake by vegetation and through sorption onto soil particles.

SELECTION AND SITING

POLLUTANT REMOVAL

Vegetated treatment facilities use a combination of both physical and biological processes to effect pollutant removal from stormwater. Biofiltration is the term commonly used to describe the simultaneous processes of filtration, infiltration, adsorption, sedimentation, and biological uptake of pollutants in stormwater that occurs as runoff travels over and through vegetated treatment facilities.

The efficiency of pollutant removal is highly dependent on many factors including depth and condition of vegetation, the velocity of flow, the slope of the ground, underlying soil condition, and most importantly, the residence time of stormwater in the biofilter. Biofiltration practices have been shown to be effective in removing total suspended solids, fine sediments, non-soluble heavy metals, and nutrients from stormwater runoff. (USEPA, 1983)

POTENTIAL GROUNDWATER IMPACTS

Though not specifically designed to provide infiltration, vegetated facilities often introduce water into the subsurface. The degree of infiltration and subsequent potential for groundwater contamination is dependent on several factors including soil type and residence time of water within the biofilter. This potential should receive special attention during the site selection and design process.

SITING CRITERIA

Vegetated facilities are intended to provide treatment of urban runoff while remaining aesthetically appealing. Consequently, the selection and siting of a facility must include the efficiency of pollutant removal and how the facility fits the site. Existing natural filter strips should be maintained wherever possible.

Vegetated Swales

Vegetated swales may be used in a wide variety of locations where natural topography lends itself to maintaining open channels. Swales are particularly useful:

- Around the circumference of parking lots.
- Downstream from detention facilities.
- In median strips of streets, highways, and parking lots.

- In some cases, in the yards and greenways of residential and some commercial developments.
- In residential developments as an alternative to curb and gutter drainage systems.

Vegetated Filter Strips

Natural or constructed vegetated filter strips are used in locations where ample space is available to spread the flow over a wide area at a small depth. Natural filter strips are usually self-maintaining, requiring only periodic removal of dead/decaying vegetation and debris. Constructed filter strips are normally maintained in a groomed condition with grasses composing the primary vegetation. Specific areas of application include:

- In riparian areas (along rivers, streams, or ponds).
- Between parking lots and stormwater inlets.
- Adjacent to vegetated swales.
- Upstream from infiltration facilities.

On-site Landscaping

The term on-site landscaping is used to describe a broad range of landscaping facilities which can be used to improve water quality. These facilities range from simple storage depressions in a residential yard to grass-lined swales around commercial facilities. The purpose of on-site landscaping practices is to use natural site characteristics to improve water quality while also maintaining the aesthetic appeal. Common landscaping practices include:

- Using wide-shallow profile swales rather than closed pipe drainage systems.
- Maintaining vegetated strips around the circumference of parking lots and large roofed areas.
- Discharging roof drains into vegetated swales or strips prior to entering piped storm drainage systems.
- Discharging site drainage and roof drains into grassed depressions with an infiltration facility.

GENERAL DESIGN CRITERIA

The following design considerations apply to all types of vegetated treatment facilities.

SOILS

- Gravelly and coarse sandy soils are better suited for infiltration and have reduced biofiltration benefits.
- Less permeable soils provide greater contact time with vegetation and the soil surface, so they are generally better suited for vegetated treatment.
- Soils should be selected or amended to provide a good rooting zone. Heavy clay soils often do not provide suitable support for vegetation.
- Most soils in the Portland metro area are best suited for facilities which combine vegetated treatment with infiltration, and at times other types of treatment such as pond-marsh.

GROUNDWATER PROTECTION

Vegetated treatment facilities do not usually present a serious threat to groundwater sources since most facilities are placed on soils with low permeability. If a facility is located on pervious soils and contributions to the subsurface are expected, the criteria described in Chapter II should be followed.

PRETREATMENT

- Vegetated facilities should be protected against siltation with a permanent pre-settling basin in locations where there is a potential for high sediment loads during storm runoff. In general, vegetated facilities should not receive construction-stage runoff unless pre-settling is provided. Excess sediments should be removed and vegetation restored in biofilters receiving construction runoff.

VEGETATION

- Select vegetation which meets pollution control objectives and will establish and survive at the site.
- Wildlife habitat development needs should be considered and incorporated where they are compatible with water quality objectives.

- Fine, dense water-resistant plants should be used in general applications. Areas experiencing periods of soil saturation or specific requirements for pollutant uptake may require emergent wetland plant species. Table V-1 contains characteristics of grasses suitable for lining landscaping facilities. Table III-1 contains a partial list of wetland vegetation suitable for use in the Pacific Northwest.
- Grasses should be established as follows (on a weight per 1000 square feet basis as recommended by Horner (1988)).

If hydroseeding

- 5 lb. seed mix
- 7 lb. 10-20-20 (N-P-K) fertilizer
- 50 lb. wood cellulose fiber mulch

If broadcast seeding

- 5 lb. seed mix
- 7 lb. 10-20-20 (N-P-K) fertilizer
- 70 lb. wood cellulose fiber mulch

- If possible, divert flow during the vegetation establishment period.
- In areas where soils already contain high concentrations of available phosphorus, fertilizers containing little or no phosphorus may be more appropriate to limit phosphorus runoff.
- Applying fertilizer in smaller amounts on two or three occasions, rather than a single large dose may help limit nutrient export.

OVERFLOW

The vegetated treatment facility must be designed with adequate hydraulic capacity to convey the standard design storms used by the appropriate jurisdiction. An overflow to the nearest surface drainage system may be required with the capacity to carry the standard design storm and the 100 year event.

Table V-1: Characteristics of grasses suitable for lining vegetated facilities.

Common Name	Persistence/ Growth Form	Description	Rating[a]
Annual ryegrass or Italian ryegrass	Annual/ bunchgrass	Common erosion control grass; establishes rapidly on bare soils but does not reseed well	3
Kentucky bluegrass	Perennial/ sod-forming	Common turf grass; may require irrigation in dry season	3
Reed canarygrass[b]	Perennial/ sod-forming	Tolerates flooding and standing water; may require irrigation if dry	3
Tall fescue	Perennial/ bunchgrass	Common turf grass; can be used alone; may require irrigation in dry season	4
Western wheatgrass	Perennial/ sod-forming	Tolerates drought	3

[a] Ratings are for erosion protection: 1-fair, 2-good, 3-excellent, 4-superior
[b] Reed canarygrass has a tendency to dominate plant communities and should not normally be planted in constructed biofilters. Data is given to analyze a natural biofilter that contains reed canarygrass.

ANALYSIS AND REPORTS

Soils

A soils report is required for all proposed landscaping facilities or projects involving infiltration in the Portland-Lake Oswego-Clackamas County-USA area. this report should identify the design constraints related to the overall project; verify the mapped soils series; determine the soils series of areas which have not been previously mapped; and determine the depth of the seasonal maximum water table during the season/period of interest.

It is recommended that, in areas requiring extensive grass seeding, soils tests to characterize nutrient availability also be run. The county Soil Conservation Service can help determine the best fertilizer mixture to use.

Hydrology

All proposed projects or facilities involving landscaping treatment must include in the site analysis/report:

- A hydrograph of the design storm runoff and vegetated facility overflow for flood conditions as defined by the appropriate local jurisdiction; and for the 100 year storm if the facility/project impacts, or is impacted by, a major waterway.
- A hydrograph of the design storm runoff for water quality control as defined by the appropriate local jurisdiction.
- Mapping of the flow route to an adequate discharge point and key elevation or a hydraulic profile of the peak overflow during the design storm, and 100 year flow if appropriate.
- A description of the significant downstream flooding impacts including type, location, and magnitude.
- All hydrologic-hydraulic analyses must be done in accordance with the methods required or recommended by Clackamas County, USA, or the cities of Portland or Lake Oswego depending on which jurisdictions' authority covers the project.

VEGETATED SWALES

Vegetated swales have historically been used to convey stormwater runoff. Design procedures in the past have centered on providing maximum capacity while minimizing channel erosion. For biofiltration, the design emphasis is on maximizing residence time to achieve pollutant removal. The vegetated lining acts as a physical filter which retards flow velocity and initiates sedimentation while concurrently providing biological uptake of pollutants.

Pollutants are also removed through soil sorption and infiltration into the subsurface. The degree to which these mechanisms function is dependent on the soil type and the hydraulic residence time.

Vegetated swales are often used along highways, downstream from detention facilities, and around parking lots. A typical vegetated swale is shown in Figure V-1.

ADVANTAGES AND DISADVANTAGES

Advantages

- Vegetated swales provide both conveyance and treatment functions.
- There is relatively low maintenance associated with vegetated swales, unless construction sites are served which should generally be avoided. If construction sites are served, the swale must be cleaned and repaired once the project is completed.
- Vegetated swales are aesthetically appealing.
- Generally, vegetated swales involve lower capital costs than curb, gutter, and storm sewer conveyance systems. The lower maintenance costs often attributed to curb, gutter and storm sewer systems primarily apply if water quality features, such as trapped catch basins, are not included and maintained.
- Peak runoff discharges are reduced due to flow retardance by the vegetation in a vegetated swale.

Disadvantages

- High sediment loads in storm runoff, such as occur from a construction site, will silt in a vegetated swale and pretreatment, and/or re-establishment of the swale, may be necessary.

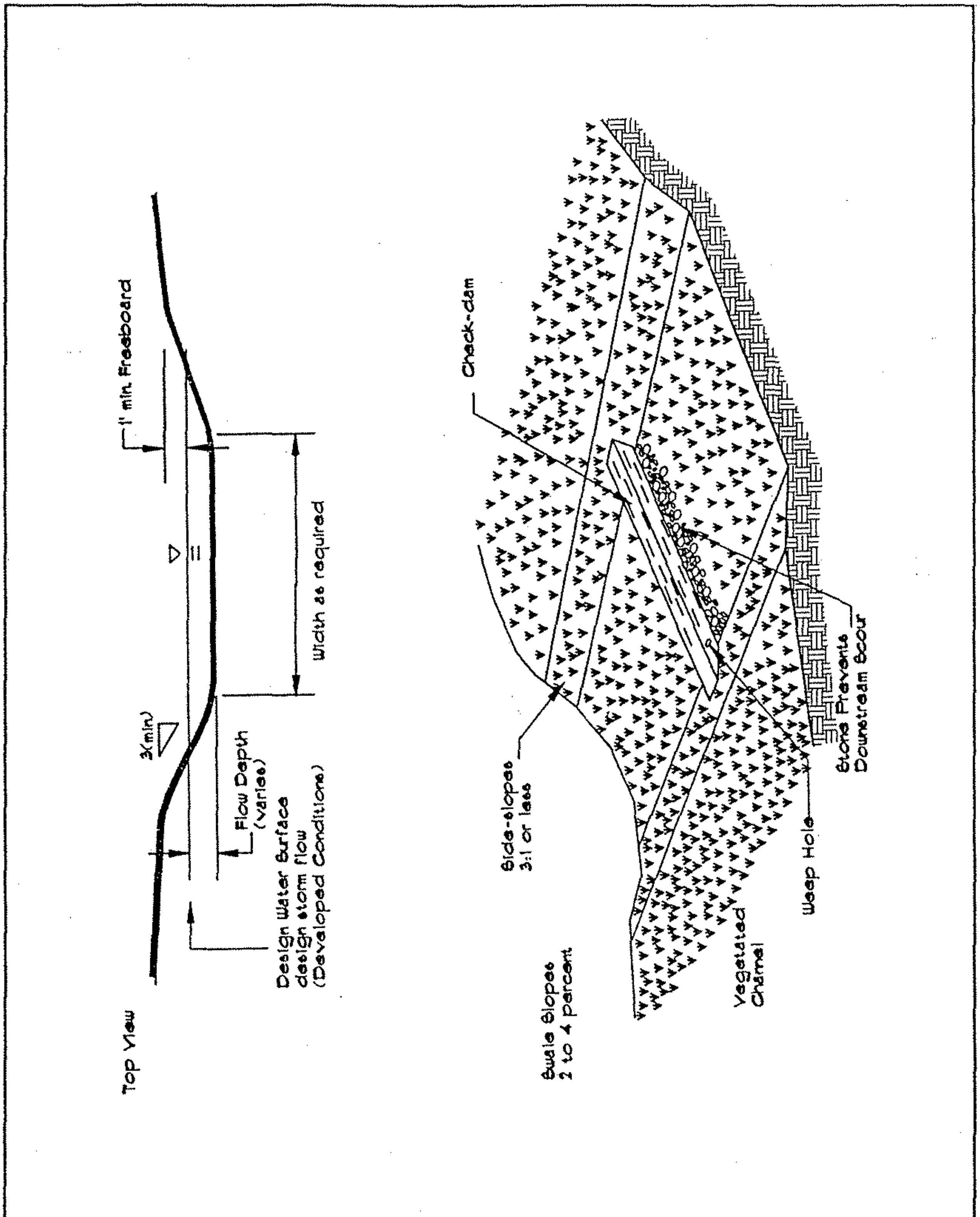

Figure V-1: Typical vegetated swale.

- Periodic mowing and disposal of cuttings will be required to prevent release of pollutants during decay and subsequent transport to the receiving waters.
- Vegetated swales may be subject to erosive forces during large storm events which may require increased inspection efforts, especially after large runoff events.

DESIGN CRITERIA

The following design criteria are specific to vegetated swales and are in addition to the general criteria for vegetated treatment facilities discussed earlier.

Treatment Efficiency

Treatment efficiency data for pollutant removal in vegetated swales has been compiled mainly from highway studies completed in Florida and Washington. Studies completed by Wang (1982), Little (1983), and others as presented by Horner (1988) indicate that vegetated swales are capable of removing up to 85 percent of total phosphorus, 40-85 percent nitrogen, and 60-90 percent oils and grease. Limited removal of trace metals was also found by Yousef (1985) and Harper (1985).

Geometry

- A ***channel slope*** between 2 and 4 percent should be maintained. Slopes greater than 4 percent should be considered only if check structures are placed at a maximum spacing of 50 feet. Underdrains may be required for slopes less than 2 percent to control ponding.
- A ***trapezoidal cross section*** should be used to simplify construction. Since a parabolic shape will eventually occur, design considerations should be based on a parabolic shape.
- A minimum swale ***length*** for water quality purposes of 200 feet, or 2,000 square feet of surface area per impervious acre, whichever is larger, shall be provided for all developments. A value of 500 square feet per impervious acre may be used for a swale that follows a detention facility.
- The ***water velocity*** along the swale for water quality purposes should not exceed 1.5 feet per second.
- The vegetated swale should be designed to meet the water quality goals and convey the design storm event. The ***design procedure*** presented in Appendix C should be used to determine the channel dimensions.

- The swale ***side slopes*** should not be steeper than 3 horizontal to 1 vertical.
- ***Sharp bends*** should be avoided to minimize erosion potential.

Erosion Control

- ***Water velocity*** along the swale should not exceed maximum permissible velocities as presented in the swale design procedure (Appendix C).
- An ***erosion control blanket*** with at least four inches of topsoil and the selected biofiltration seed mix should be placed below the design water depth. An erosion control seed mix with straw mulch or sod should be used above the design water surface.

Sizing

The method used for sizing vegetated swales is based on the flow retardance method developed by Chow and applied to vegetated swales by Horner (1988). Horner's method designs first for biofiltration capacity at the water quality design storm runoff, then checks for channel stability and capacity at the flood design storm runoff. The step-by-step design procedure developed by Horner is contained within Appendix C. A summary of the general design steps is as follows:

Initial steps

- Estimate the runoff flow rate (Qw) for the water quality design storm event.
- Estimate the runoff flow rate (Qf) for the flood design storm event.
- Select the swale slope and shape.

Design for biofiltration capacity

- Based on a maximum velocity of 1.5 fps, determine the swale dimensions required for biofiltration capacity using Manning's equation.
- Check for swale stability
- Assume vegetation is short with a low retardance value.
- Select the maximum permissible velocity for the assumed vegetation type and condition.
- Determine the maximum velocity which occurs in the swale at the peak runoff discharge, Qf, using the flow retardance method presented in Appendix C.

- If the computed maximum velocity is greater than the permissible velocity, use a trial-and-error solution to determine new swale cross-section dimensions.

Check for channel capacity

- Assume vegetation is tall with a high retardance value.
- Determine the maximum swale velocity using the flow retardance method.
- If the computed maximum swale velocity is greater than the permissible velocity, use a trial-and-error solution to determine a new swale cross-section dimensions.

Completion steps

Lay out the swale to obtain the maximum possible length. A minimum flow length of 200 feet is recommended. (New data seems to indicate that 100 feet may be sufficient. However, the publication presented in Appendix C represents the most recent accepted design criteria). If sufficient space is not available to obtain a 200 foot length, increase the cross-sectional area by an amount proportional to the decrease in length to maintain the same hydraulic residence time. The channel dimensions can be recalculated using the methods presented in Appendix C.

If sufficient space is still not available for the swale, the following solutions should be considered:

- Distribute the site runoff to multiple swales.
- Incorporate detention into the site to provide lower runoff rates to the swale.
- Increase the vegetation height and design depth, as long as the vegetation remains standing during the design discharge.
- Increase the swale longitudinal slope.
- Increase the cross-sectional flow area by increasing the swale side-slopes.

VARIATIONS

Vegetated swales can be used in variable locations and in conjunction with other facilities, such as infiltration trenches. One particularly beneficial arrangement is in the median area of a parking lot as shown in Figure V-2.

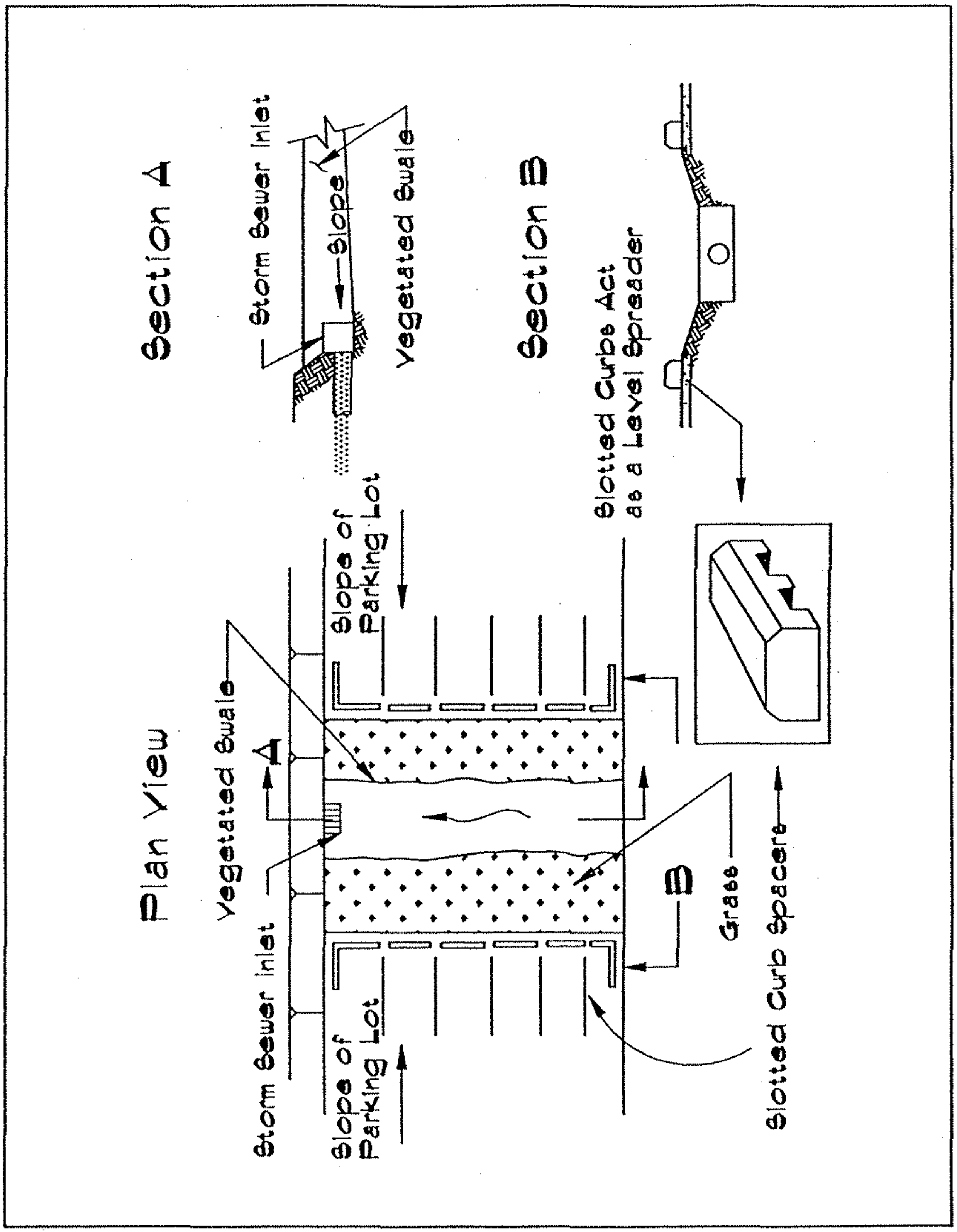

Figure V-2: Typical vegetated swale in parking lot median.

Stormwater from the parking lot is distributed evenly into the swale by slotted curbs. A raised inlet is provided at the downstream end of the swale to allow ponding within the swale.

MAINTENANCE REQUIREMENTS

- ***Sediment*** should be removed when it builds up to 6 inches in depth at any location. The swale should be cleaned with equipment which operates similar to a Ditch Master rather than backhoe dragging to minimize damage to the swale vegetation.
- Vegetated swales should be ***inspected*** at least three times a year, especially after heavy runoff.
- Most swales should be ***mowed*** at least twice a year to maintain aesthetics and restrict growth of undesirable vegetation. Cuttings should be promptly removed and properly disposed of to prevent pollutants from entering the receiving waters.
- Residents near swales should be informed through ***public awareness*** programs of the function of swales and the importance of not depositing their lawn clippings or oil/grease in the swale.
- Vegetation may require ***watering*** in times of drought, particularly in the first months of establishment.

VEGETATED FILTER STRIPS

Vegetated filter strips may occur naturally or be constructed. The term riparian filter strip refers to a strip of vegetation which naturally occurs along a river, stream, pond, or other body of water. Constructed filter strip describes vegetated strips which are constructed in and around residential, commercial, and pond-marsh facilities.

When possible, it is preferable to use riparian filter strips. Installation and maintenance costs are minimized; native vegetation is more diverse and provides better wildlife habitat; trees and shrubs are more likely to be present, providing shade and preventing erosion; and disturbances to the waterbody are decreased. However, many times a riparian filter strip is inadequate or nonexistent. In these cases, the filter strip must be constructed. The rest of this section deals specifically with constructed filter strips--although many items are also relevant to riparian filter strips.

Filter strips are similar in many respects to grassed swales except that they are designed to accept only overland flow. A minimum water residence time of 20 minutes is required to achieve pollutant removal. A typical constructed filter strip is shown in Figure V-3.

ADVANTAGES AND DISADVANTAGES

Advantages

- Constructed filter strips can be readily incorporated into on-site landscaping features.
- When used in conjunction with other facilities, constructed filter strips will improve pollutant removal and may help reduce the size and cost of downstream control facilities.

Disadvantages

- High sediment loads in storm runoff will silt in the filter strip and pretreatment may be necessary. Filter strips should not be used below construction sites unless re-established after construction is complete.
- Groomed filter strips will require mowing and proper disposal of clippings to prevent the release of pollutants during decay and subsequent transport to receiving waters.
- Filter strips constructed on relatively steep slopes (greater than 4 percent) may be subject to erosive forces.

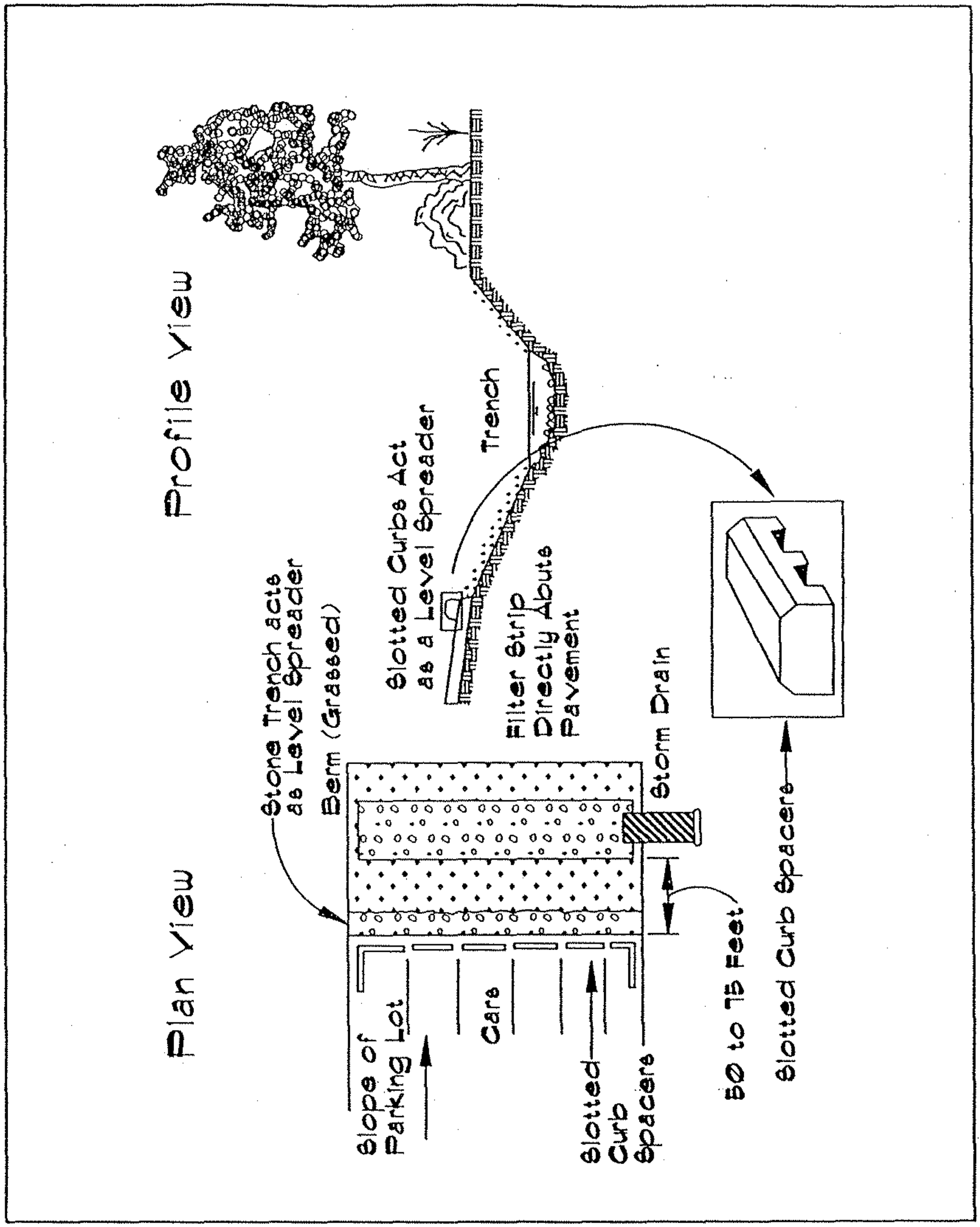

Figure V-3: Constructed vegetated filter strip.

- Runoff has a tendency to concentrate and form a channel which will lead to short circuiting of the filter strip and reduce the detention time within the filter strip. A corresponding reduction in pollutant removal will occur.

DESIGN CRITERIA

The following design criteria are specific to constructed vegetated filter strips and are in addition to the general criteria for vegetated treatment facilities discussed earlier.

Treatment Efficiency

Studies completed by Hinrichs (1980) for overland flow wastewater treatment systems reported that removal of pollutants due to biofiltration alone were: 58-99 percent BOD, 48-99 percent total suspended solids, 25-90 percent total nitrogen, and 10-89 percent total phosphorus. These systems were regularly harvested. The lowest values occurred at a New Hampshire Plant in the winter. Most other plants were located in more moderate climates and performed towards the top indicated ranges.

Constructed filter strips in general have achieved 80-90 percent reduction in trace metals. McPherson (1979) found greater than 85 percent reduction of copper, chromium, lead, and silver; 60 percent removal of nickel; and 40 percent iron reduction. Jenkins (1985) reported 90 percent reduction of 13 trace organic contaminants in a filter strip.

Geometry

- The filter strip should directly abut the contributing ***impervious area.*** Otherwise, runoff may travel along the top of the filter strip rather than through it.
- Filter strips should be a minimum of 20 feet ***wide*** and 50-75 feet in ***length*** as shown in Figure V-3. Overall ***residence time*** within the filter strip should be a minimum of 20 minutes.

Sizing

- Filter strips should be designed based on the ***design procedure*** presented for vegetated swales (see Appendix C).

Flow Distribution

- A ***shallow stone*** or block trench may be needed across the top of the strip to serve as level flow distributor.

- The ***top edge*** of the filter strip should follow the same topographic contour to prevent flow concentration in a low spot.

Construction

- Construction specifications, allowable materials, accessibility, easements, and hydraulic design shall be as specified by the ***appropriate jurisdiction***.

MAINTENANCE REQUIREMENTS

- Groomed filter strips should be ***mowed*** at least twice in the summertime to promote growth and pollutant uptake. Cuttings must be removed and properly ***disposed*** of to prevent pollutants from entering receiving waters.
- ***Sediment*** accumulation exceeding 6 inches in any one spot should be removed.
- Curb cuts should be ***cleaned*** periodically to remove soil and vegetation buildups.
- Filter strips should be ***inspected*** periodically, especially after heavy runoff. Sediments should be promptly removed and reseeding completed where bare spots occur.
- Residents near filter strips should be informed of the function of filter strips through ***public awareness programs***.
- ***Litter*** and other ***debris*** should be removed to keep the filter strip attractive.

ON-SITE LANDSCAPING

On-site landscaping refers to vegetated practices which can be used in development sites to improve water quality. These practices range from using simple storage depressions in a residential yard to grass-lined swales around commercial facilities. The main focus of on-site landscaping practices is to use natural site characteristics in combination with vegetated practices and infiltration to improve runoff water quality. Figure V-4 provides one example of landscaping practices in a residential setting.

DESIGN CRITERIA

The design criteria specified for vegetated swales, constructed vegetated filter strips, and natural filter strips are the main criteria which should be used in designing individual landscaping components. The efficiency of pollutant removal is dependent on the characteristics of the storm runoff and the landscaping practices incorporated into the site. Specific guidance related to landscaping practices include:

- Use ***natural topographic features*** such as swales and depressions to the fullest extent possible. A natural swale provides effective biofiltration while depressions allow ponding which reduces the peak flow discharge.
- Design the ***site drainage*** such that the flow path through vegetated areas is maximized prior to discharging into a storm drain system. The water quality effectiveness of such features can often be enhanced through the use of check dams, dikes, and infiltration facilities.
- Minimize ***ground slopes*** to control erosion, especially through exposed soil areas such as flowerbeds or gardens. Stepped terraces can be attractive landscaping and soil stabilization practices for steep sites.
- Select ***vegetation*** which will establish itself and survive on the site. Areas designed with depression storage will require more water resistant vegetation.

MAINTENANCE REQUIREMENTS

Maintenance requirements associated with on-site landscaping practices are, in general, those discussed for each of the vegetated treatment facilities.

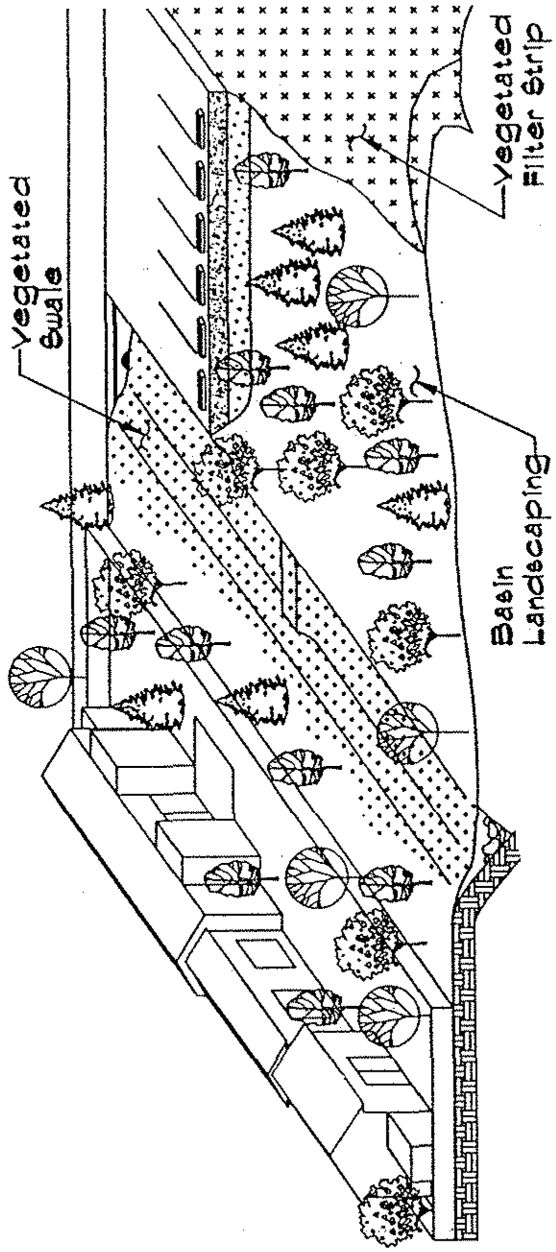

Figure V-4: On-site landscaping practices.

PLANNING AND DESIGN CHECKLIST

MAJOR PHASES

A. INITIAL EVALUATION

B. PLANNING

C. DESIGN

A. INITIAL EVALUATION

A.1. Site Review of Opportunities, Constraints, and Characteristics

- Topography
- Soils
- Groundwater

A.2. Compare Management Techniques with Site Characteristics

- Vegetated swale
- Constructed vegetated filter strip
- On-site landscaping

A.3. Assess Site Specific Landscaping Facility Options

A.4. Choose Initial Landscaping Facility

A.5. Review Placement and Preliminary Sizing with Appropriate Jurisdiction

B. PLANNING

B.1. Assess Tributary Area Characteristics

- Drainage area boundary and topography
- Size
- Cover and effective impervious area
- Development types
- Side-slopes and stream gradients
- Soils reconnaissance (site and tributary area using existing information)

- SCS soils type
- Infiltration
- Erodibility
- Phosphorus availability

B.2. Develop Flood Hydrology/Hydraulics

- Select analysis points
- Estimate existing conveyance/detention capabilities
- Prepare flood hydrographs for the existing system using the appropriate jurisdiction's design storm and analysis methods
- Prepare flood hydrographs for the site and tributary area assuming full development
- Develop hydraulic profile/elevations for analysis points and at hydraulic constraints during normal and impeded/blocked flow conditions
- Select drainage/flood management options
- Re-analyze flood hydrology superimposing the flood management options

B.3. Develop Water Quality Hydrology/Hydraulics

- Select analysis methods based on the appropriate jurisdiction's requirements/recommendations
- Prepare water quality hydrographs for the existing and future development conditions (site and tributary area)

B.4. Screen Options and Develop Site Plan

C. DESIGN

C.1. Perform Soils Analysis

- Soils logs
- Erodibility of the tributary area
- P availability and removal potential (basin and site)

C.2. Perform Water Budget Analysis if Required for the Chosen Facility

C.3. Confirm and Locate Options Selected

C.4. Perform Hydrologic Analysis

C.5. Evaluate Hydraulic Profile at Analysis Points

C.6. Prepare Site Plan and Cross-Section Drawings

C.7. Select and Describe Materials

C.8. Prepare Plans and Specifications

D. POST CONSTRUCTION

D.1. Water Quality Monitoring Plan

D.2. Monitoring for Maintenance

CHAPTER VI

FACILITY COMBINATIONS

CONTENTS

FIGURES

FACILITY COMBINATIONS

The conclusion which must be reached in the Tualatin Basin and Portland Metro area is that a combination of BMPs and PRFs are needed to most effectively reduce suspended solids, phosphorus, and other stormwater pollutants in the region's water courses. This chapter discusses the more obvious combinations of BMPs and PRFs. It does not add technical information for individual facility types, but refers to the appropriate chapters where such information is discussed. An example design problem for developing a combination facility is presented in Appendix D.

DISCUSSION

The EQC has established phosphorus levels as part of the TMDL and load allocation process. Attempts to meet these guidelines by utilization of BMPs and PRFs is challenging. The soils in the Tualatin Basin are highly erodible and generally have a high phosphorus content. In some cases, the soils will actually contribute phosphorus to stormwater when contact is made between the water and the soil. Phosphorus reduction is also complicated by the fact that many of the suspended solids transporting phosphorus in stormwater are fine grain colloidals which are difficult to settle out in PRFs.

The most effective combination facilities are those which employ different mechanisms for removing stormwater pollutants. Different mechanisms help ensure that the facilities are not all acting on the same pollutant fraction, such as coarse particulates, and leaving the colloidals untouched.

Types of facilities which can be used in combination include:

- Sedimentation and pond-marsh
- Sedimentation, pond-marsh, and infiltration
- Sedimentation, vegetated swale, and infiltration
- Pond-marsh and infiltration
- Vegetated swale and infiltration

A brief discussion of the advantages and disadvantages of each combination follows. Discussions of the individual facilities can be found in preceding chapters.

SEDIMENTATION AND POND MARSH

The main idea behind a combination sedimentation and pond-marsh facility is for the sedimentation basin to remove the coarse particulates and the pond-marsh to remove the finer particulates and dissolved pollutants. This accomplishes several things. Alone, a marsh may become filled by stormwater-borne sediments, which adversely affect the vegetation and wildlife of the marsh. Removal of the deposited sediments from a marsh is often quite difficult. A sedimentation basin upstream of the marsh limits the coarse particulate load to the marsh and can be designed for easy removal of accumulated sediments. The marsh, in turn, is more effective at trapping dissolved and fine particulates than the sedimentation basin through several processes, including biological uptake. A marsh also supports wildlife habitat which is not normally found in a sedimentation basin.

DESIGN CONSIDERATIONS

The sedimentation basin can either be a separate facility upstream of the marsh or it can be used as the first cell in a multiple-cell pond-marsh facility. Equipping the sedimentation basin with an oil-water separator or skimming device prior to the pond-marsh facility allows removal of petroleum products and floatable material before runoff reaches the marsh.

The pond-marsh is usually the main component of the combination facility and can be either in-stream, which is the most feasible for most of the smaller tributaries, or off-stream, which would be the approach most likely used along the main Tualatin River. The pond-marsh component can be designed to provide storage space and hydraulic controls for managing peak flows. If groundwater impacts are a concern, the sedimentation basin and marsh may require linings.

SEDIMENTATION, POND-MARSH, AND INFILTRATION

The reasoning behind the sedimentation and pond-marsh components of this combination facility are given above. This facility differs in the addition of an infiltration component. Infiltration facilities may be incorporated into the marsh, but are more commonly added as a separate component due to the difficulty of maintaining an adequate water level in a marsh that also acts as an infiltration basin.

The most effective phosphorus removal occurs through infiltration into the soil media. However, even more than most marshes, infiltration facilities can be overwhelmed by high sediment loads. Coarse-grained sediment quickly clogs the porous soil layers, reducing infiltration. Placing infiltration facilities downstream of the physical removal processes of a sedimentation basin and the physical and biological processes of a marsh, prevent premature clogging. It also lowers the likelihood of toxic substances entering the infiltration basin and subsequently impacting groundwater resources.

DESIGN CONSIDERATIONS

In the Tualatin Basin and some other parts of the Portland metro area, infiltration does not work well for peak flow management due to the high volumes of water which must be infiltrated, generally the flow associated with a 10-year storm event. However, infiltration will work in areas with suitably permeable soils or with the smaller volumes of water resulting from less severe, more frequent storms. Anaerobic soil-water conditions in the infiltration facility must be avoided to prevent release of pollutants bound to the sediments.

Infiltration media that can be used include coarse sand, an infiltration trench, or a sump outlet. Consideration must be given to underlying soils, especially in view of the often differing requirements of the individual parts of the combination facility. For example, permeable soils that work well for infiltration will hinder retention in the sedimentation and marsh components.

SEDIMENTATION, VEGETATED SWALE, AND INFILTRATION

This combination facility is much the same as that just described. However, here a vegetated swale is used in place of the marsh. The swale will not be as effective at pollutant removal due to shorter detention times, but it has several advantages.

A swale requires less space than a wetland and is easier to install. Often, a few simple modifications allow a drainage ditch to serve as a swale. Vegetated swales can also be used to connect PRFs which are physically separated.

DESIGN CONSIDERATIONS

A typical setup involves a sedimentation vault/manhole followed by a vegetated swale which in turn, drains into an infiltration sump. This provides some stormwater treatment even when space is limited.

Swales are more subject to erosion than wetlands. Flattening bank slopes and selecting appropriate vegetative cover will reduce erosion damage.

POND-MARSH AND INFILTRATION

This facility is similar to the sedimentation, pond-marsh, and infiltration combination considered above, but without the preliminary sedimentation basin. In many locations in the Tualatin Basin, this facility would not be appropriate since sediment removal above a pond-marsh facility is highly desired, if not essential. However, there might be locations where this combination would be sufficient. The most likely candidates would be fully-developed areas, unlikely to receive large amounts of eroded materials from construction or agricultural activity.

DESIGN CONSIDERATIONS

The possibility of splitting the pond-marsh into two areas, with the first serving as a forebay to remove sediments should be examined and implemented if at all possible.

VEGETATED SWALE AND INFILTRATION

This facility is similar to a pond-marsh and infiltration facility, with additional problems in terms of sedimentation in the infiltration facility. The swale is not as efficient as the marsh at moderating peak flows or removing incoming sediments. This combination might be considered for areas where space is extremely limited or where flooding poses a major problem.

DESIGN CONSIDERATIONS

The most likely types of infiltration involved are an infiltration trench at the bottom of the swale, or a Portland type infiltration sump.

USING MULTIPLE PRFs

A basin-wide effort to reduce contaminants in stormwater often means using PRFs in a series. One reason for this is to provide multiple treatment to a single volume of stormwater runoff. However, most PRFs tend to act upon the same fraction of the pollutant load, namely the coarser sediment particles and the pollutants bound to those particles. The finer sediments and their associated pollutants are passed through each PRF relatively untouched, especially the dissolved fraction. The finer sediments thus begin to make up a larger and larger proportion of the pollutant load. Because of this, downstream basins have an increasingly difficult time achieving the same removal efficiencies as upstream basins.

The pollutant removal curves presented in this handbook do not take this residual effect into account, largely because the required modeling quickly becomes too complex to easily include in a few graphs. The following figures, however, give some idea of the impact of this residual effect.

The removal rates of three detention ponds in a series is shown in Figure VI-1. A model called METSET (Felstul, 1990a) was used with a series of 3-foot deep basins, each with a surface area of approximately 1 percent of the watershed.

As Figure VI-1 shows, the third basin is only about half as efficient at removing the inflowing sediments as the first basin. The basin's efficiency at removing associated contaminants, such as heavy metals, drops even more quickly. (The contaminants are disproportionately associated with the fine, hard-to-remove sediment particles.)

Thus, the 76 percent total suspended solids removal rate of the first basin should not be assumed for downstream basins. Instead the efficiency declines by approximately 20 percent with each succeeding basin.

The removal efficiencies discussed above assume that no additional inflow is added between basins; i.e., Basin 1 is the only significant source of inflow to Basin 2 and Basin 2 is the only significant source of inflow to Basin 3. If Basin 2, however, receives half of its inflow "pretreated" from Basin 1, and the other half untreated directly from the surrounding watershed, the untreated half would have higher removal efficiencies--because it still has easily-settleable coarse particulates.

A similar residual effect occurs with nutrient removal. A version of the model used to develop the curves found in Chapter III (Felstul, 1990b) was configured with three ponds in a series. The results are shown in Figure VI-2.
The removal efficiency of the model is partially dependent on the incoming phosphorus concentrations. The higher the concentration the more readily the phosphorus is removed. Assuming an incoming phosphorus concentration of 400 ug/l and a catchment ratio of 1.0, the first pond would remove approximately 48 percent of the phosphorus. Phosphorus inflow to a second pond, identical in size, would be 200 ug/l and 36 percent would be removed. The third identical basin would receive 130 ug/l of phosphorus and would be able to remove only 29 percent of it.

Once again, downstream ponds are less effective than upstream ponds at removing pollutants.

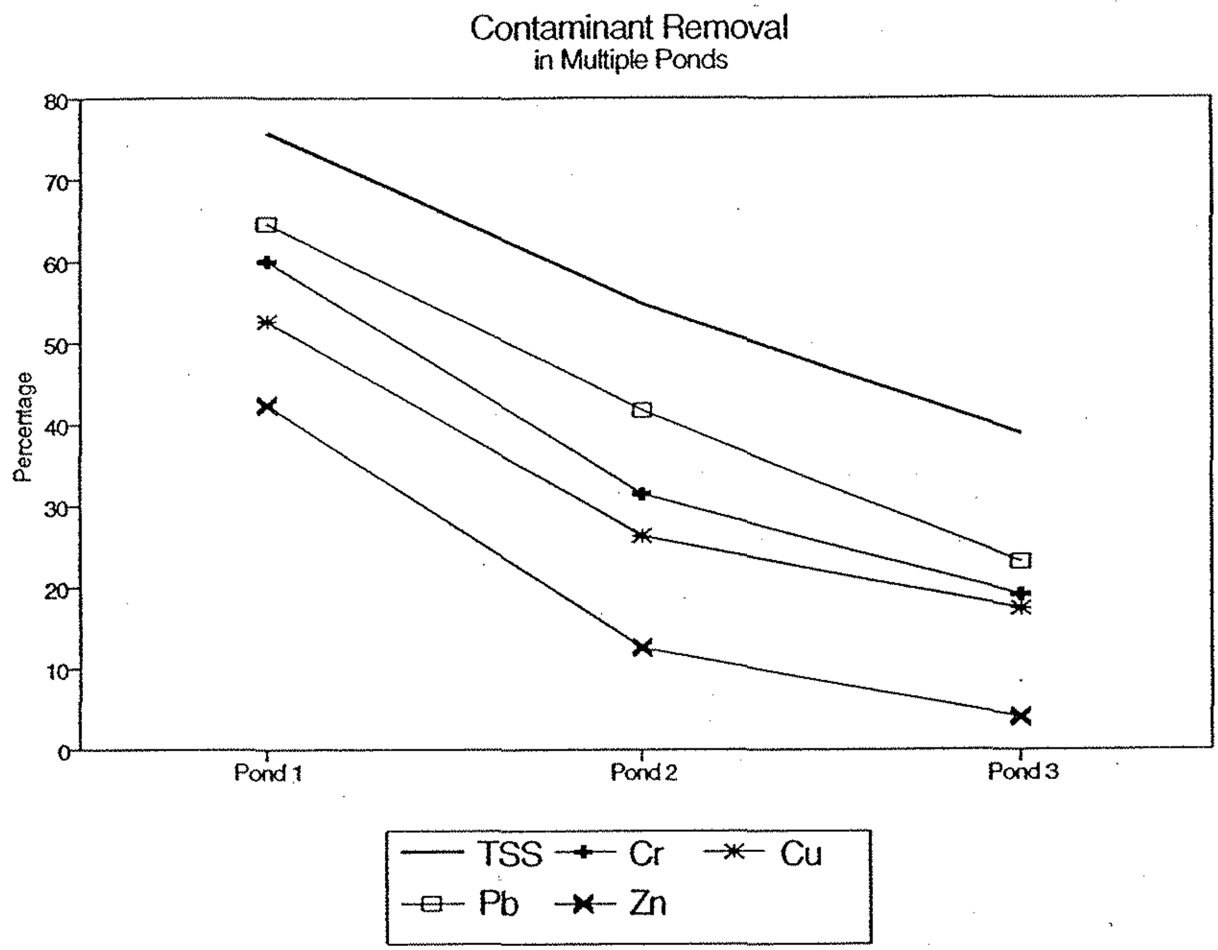

Figure VI-1: Contaminant removal in multiple ponds.

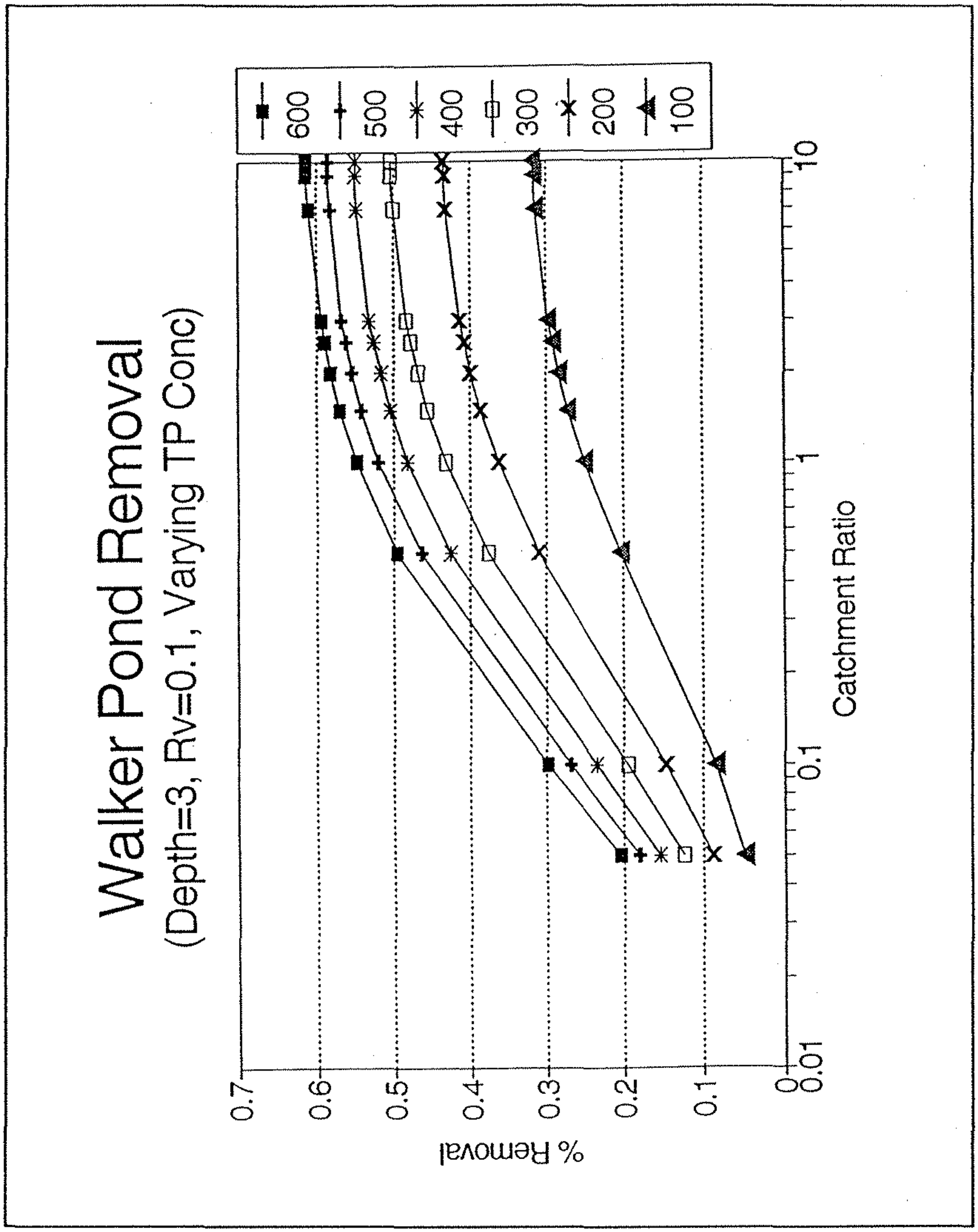

Figure VI-2: Walker Pond removal.

As Figures VI-1 and VI-2 indicate, it is important to consider the declining efficiency of pollutant removal in a series of facilities when estimating the overall efficiency of the combination facility. It also indicates that mixing PRF types should work better than using all the same type. For instance, using a settling pond in conjunction with a wetland provides for two different removal mechanisms, physical settling and biological uptake, which can reduce both the particulate and the dissolved pollutant forms.

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Note: * in the left margin denotes a primary reference.

APPENDIX A

Table A-1: SCS hydrologic soil types.

SCS Hydrologic Soil Groups	Description
Group A	Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist chiefly of Deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.
Group B	Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
Group C	Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils that have a layer that impedes the downward movement of water or soils that have moderately fine texture or fine texture. These soils have a slow rate of water transmission.
Group D	Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clay soils that have a high shrink-swell potential, soils that have a permanent high water table, soils that have a fragipan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

Table A-2: Potentially acceptable soils for Multnomah County.

Soil Name	Hydrologic group	Percent Area
Aschoff	B	7.60
Bull Run	B	2.70
Burlington	A	0.90
Dabney	A	0.40
Faloma	B/D	0.90
Kinzel	B	9.00
Lastance	B	1.50
Latourell	B	6.40
Mershon	B	2.10
Multnomah	B	10.60
Pilchuck	A	2.60
Sifton	B	0.10
Talapus	B	1.20
Wauld	B	0.70
Zygore	B	10.30
Total		57.00

Table A-3: Potentially acceptable soils for Clackamas County.

Soil Name	Hydrologic group	Percent Area
Aschoff	B	5.30
Bull Run	B/D	2.00
Camas	A	.30
Canderly	B	.50
Chehalis	B	.40
Cloquato	B	.80
Dabney	A	.30
Fernwood	B	4.50
Highcamp	B	5.30
Jimbo	B	.10
Kinney	B	1.90
Kinzel	B	2.20
Klickitat	B	2.70
Latourell	B	1.30
Laurelwood	B	.50
Molalla	B	1.30
Multnomah	B	.20
Multorpor	A	.20
Newberg	B	.80
Salem	B	1.60
Talapus	B	.40
Wilholt	B	2.50
Willamette	B/C	.70
Xerocherpts	B/C	2.30
Zygore	B	1.60
Total		39.00

Table A-4: Potentially acceptable soils for Washington County.

Soil Name	Hydrologic group	Percent
Astoria	B	.50
Briedwell	B	.70
Carlton	B	.10
Chehalis	B	1.60
Hembre	B	5.70
Hillsboro	B	.90
Kilchis	B/C	.70
Klickitat	B	3.80
Knappa	B	.30
Laurelwood	B	8.60
McBee	B	2.10
Melbourne	B	3.60
Olyic	B	9.20
Tolke	B	3.90
Udifluvents	B	.50
Willamette	B	1.60
Xerocherpts	B/C	.70
Total		44.50

APPENDIX B

The runoff coefficient (Rv) is a measure of the amount of actual runoff which leaves a site and is a function of the impervious area of the catchment area (EPA, 1986). An approximate relationship for Rv is shown in Figure B-1.

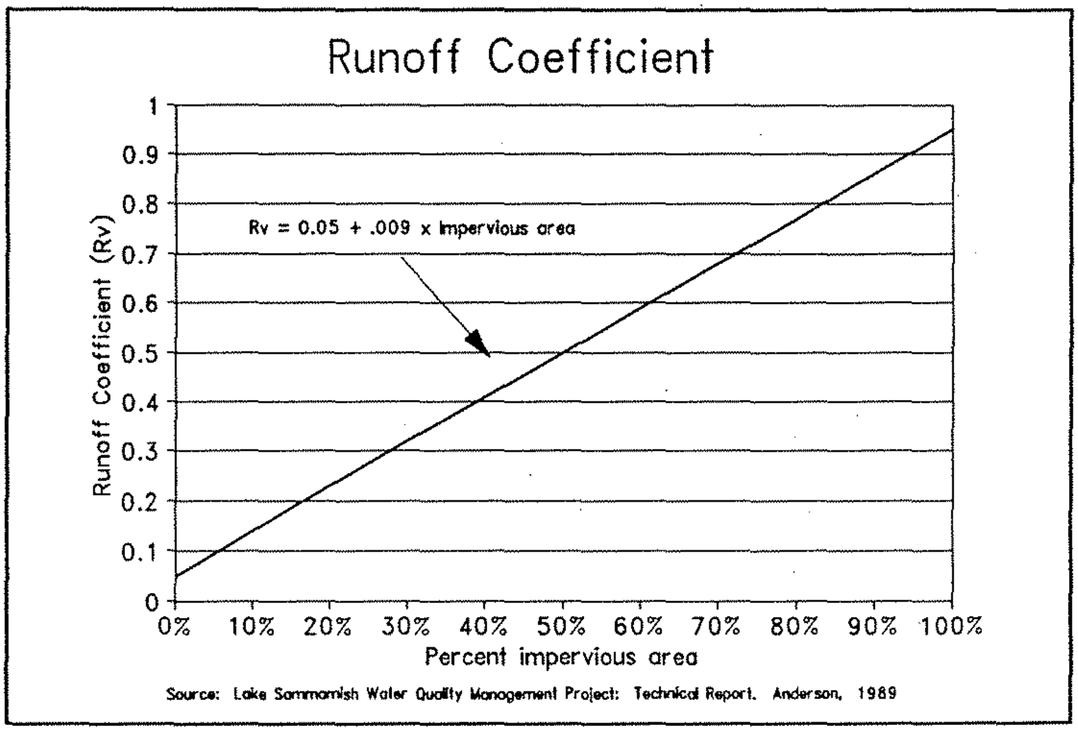


Figure B-1: Approximate relationship between impervious drainage area and runoff coefficient (Rv).

The rainfall statistics used to generate estimated removal efficiencies for the sedimentation and nutrient removal models in Chapter 3 are shown in Table B-1. These values are based on those reported for the Portland area in the National Urban Runoff Program (NURP).

Table B-l: Rainfall statistics used for wet pond removal rates (sedimentation model).

Statistic	Mean	Coefficient of Variation
Volume (inches)	0.36	1.51
Intensity (in/hr)	0.023	0.79
Duration (hr)	15.5	1.09
Inter-event time (hr)	83	1.32

Source: Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality. EPA 440/5-87-001. 1986.

APPENDIX C

Appendix C contains the design procedure for sizing vegetated swales and filter strips. This procedure was developed and presented by Dr. Horner (1988) in his report "Biofiltration Systems for Storm Runoff Water Quality Control." An excerpt from this report is contained within this Appendix.

The design procedure presented herein is intended for design guidance in determining required dimensions of vegetated facilities. Estimates for the developed flows from both the water quality design storm and the flood design storm should be determined based on methods outlined by the appropriate jurisdiction.

BIOFILTRATION SWALE AND FILTER STRIP DESIGN

PROCEDURE

Note: The procedures for swale and filter strip design are basically the same. The steps are given in full for swales, and notes are included to allow the procedure to be applied to filter strips as well.

Preliminary Steps

1. Estimate runoff flow rate (Q) for the 2-year frequency, 24-hour duration storm.

   Use a method acceptable to the jurisdiction and the situation, such as the method outlined in Chapter 6 of the King County Department of Public Works (1988) draft Surface Water Design Manual, or an appropriate computer model.

2. Establish the slope of the proposed biofilter.

   Biofilters should normally be placed on slopes of two to four percent. If it can be demonstrated that adequate drainage to avoid persistent pooling will occur (using underdrains, if necessary), a slope less than two percent can be used. If the site slope exceeds four percent, the jurisdiction should make a determination of the site's suitability for a biofilter, and, if suitable, what special design features should be included. If the slope exceeds six percent, it is recommended that the biofilter traverse the slope or that the site topography be modified to produce a slope under six percent. If stepped, each section should slope at less than six percent. In any swale application with slope greater than four percent, check dams should be placed approximately every 50 feet.

3. Select a vegetation cover suitable for the site.

   Refer to Table C-1 to select grasses. If the site will be persistently wet, consider wetland genera such as Typha (cattails), Scirpus (bulrushes), and Lemna (duckweed), which have relatively high rates of pollutant uptake. Other wetland plants that have been observed to serve well in biofilters are Iris pseudacorus (yellow iris), Carex (sedges), and water cresses (Levesque, personal communication). Use yellow iris only in channels that will have a permanent current flow in order to avoid severe domination by the iris and clogging of the channel (Robel, personal communication). If development of wildlife habitat is an objective, consider habitat needs in selecting vegetation.

Table C-1 Characteristics of Grasses Suitable for Lining Puget Sound Region Biofilters. (a)

Common Name	Persistence/ Growth Form	Description	Rating (b)
Annual ryegrass or Italian ryegrass	Annual/ bunchgrass	Common erosion control grass; establishes rapidly on bare soils but does not reseed well.	3
Kentucky bluegrass	Perennial/ sod-forming	Common turf grass; may require irrigation in dry season.	3
Reed canarygrass (c)	Perennial/ sod-forming	Tolerates flooding and standing water; may require irrigation if dry.	3
Tall fescue	Perennial/ bunchgrass	Common turf grass; can be used alone; may require irrigation in dry season.	4
Western wheatgrass	Perennial/ sod-forming	Tolerates drought	3

(a) Adapted from Goldman et al. (1986). In addition, Mountlake Terrace recommends the following grasses and legumes:

Meadow faxtail	Creeping red fescue	Annual ryegrasses
Creeping faxtail	Timothy	White clover
Redtop		

Other water-resistant grasses that grow well in regional conditions are Poa trivialis (roughstalk bluegrass) and Lolium perenne (perennial ryegrass) (West, personal communication).

The seeding mix specified for the parking lot swales at the West Willows Technical Center in Redmond was as follows:

42% perennial rye	20% reed canarygrass
30% winter rye	8% clover

Shapiro and Associates recommends the following seeding mix for this application (Gorski, personal communication):

40% redtop bentgrass	20% tall fescue	5% Russian wildrye
30% red fescue	5% perennial rye	

(b) Ratings are for erosion protection: 1 - fair; 2 - good; 3 - excellent; 4 - superior.

(c) Reed canarygrass normally should not be planted in contructed biofilters, because of its tendency to dominate plant communities, exclude other species, and become a nuisance. Data are given to analyze a natural biofilter that contains reed canarygrass.

Design for Biofiltration Capacity

Note: There are a number of ways of applying the design procedure introduced by Chow (1959). These variations depend on the order in which steps are performed, what variables are established at the beginning of the process and which ones are calculated, and what values are assigned to the variables selected initially. The procedure recommended here is an adaptation appropriate for biofiltration applications of the type being installed in the Puget Sound region. This procedure reverses Chow's order, designing first for capacity and then for stability. The capacity analysis emphasizes the promotion of biofiltration, rather than transporting flow with the greatest possible hydraulic efficiency. Therefore, it is based on criteria that promote sedimentation, filtration, and other pollutant removal mechanisms. Since these criteria include a lower maximum velocity than permitted for stability, the biofilter dimensions usually do not have to be modified after a stability check.

1. Establish the height of vegetation during the winter and the design depth of flow.

   Maximizing height advances biofiltration and allows greater flow depth, which reduces the width necessary to obtain adequate capacity. However, if nutrient capture is the principal objective, vegetation should be mowed at the end of the growing season to minimize nutrient release. The design depth of flow should be at least two inches less than the winter vegetation height.

   Sheet flow (< 1 inch deep) generally exists in filter strips.

2. Select a value of Manning's n. Use one of the following values for an initial analysis (after U.S. Department of Commerce, 1961):

   Dense grass up to 6 inches tall—0.07
   Dense grass 6-12 inches tall—0.1
   Dense grass >12 inches tall—0.2
   Vegetation with coarser stems (e.g., wetland plants, woody plants)—0.07

3. Select the swale shape. Skip this step in filter strip design.

   A parabolic shape is preferred. Trapezoidal shapes tend toward parabolic over time. Therefore, even if the channel is initially installed as a trapezoid for ease of construction, the parabolic shape should be used in design. Rectangular and V-shapes are the least desirable from the stability standpoint. If one of these shapes is required by the site configuration, specify reinforcement for the side walls in conformance with the standards of the jurisdiction.

4. Use Manning's equation and first approximations relating hydraulic radius and dimensions for the selected shape to obtain a working value of a biofilter width dimension:

$$Q = \frac{1.486}{n} AR^{0.667} s^{0.5} \qquad \text{Eq. C-1}$$

Where:
- Q = design runoff flow rate (ft^3/s, cfs)
- n = Manning's n (dimensionless)
- A = Cross-sectional area (ft^2)
- R = Hydraulic radius =A/wetted perimeter (ft)
- s = longitudinal slope as a ratio of vertical rise/horizontal run (dimensionless)

Refer to Figure C-1 to obtain equations for A and R for the selected shape. In addition to these equations, for a rectangular shape:

$$A = Ty \qquad \text{Eq. C-2}$$

$$R = \frac{Ty}{T+2y} \qquad \text{Eq. C-3}$$

where:
- T = width
- y = depth of flow

If these expressions are substituted in Eq. C-1 and solved for T (for previously selected y), the results are complex equations that are difficult to solve manually. However, approximate solutions can be found by recognizing that T>>y and $z^2 >> 1$, and that certain terms are nearly negligible. The approximations for the various shapes are:

Parabolic: $R \cong 0.67\ y$ Eq. C-4

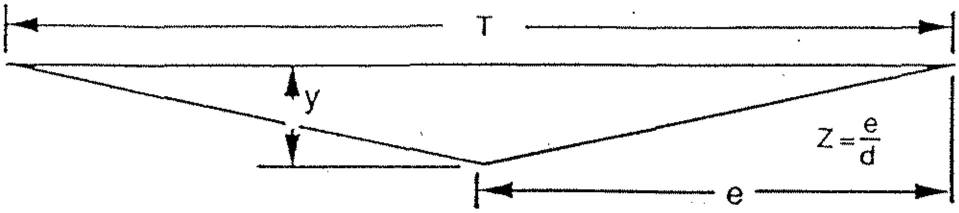
Trapezoidal: $R \cong y$ Eq. C-5

V: $R \cong 0.5\ y$ Eq. C-6

Rectangular: $R \cong y$ Eq. C-7
(Also use for filter strips.)

CHANNEL GEOMETRY

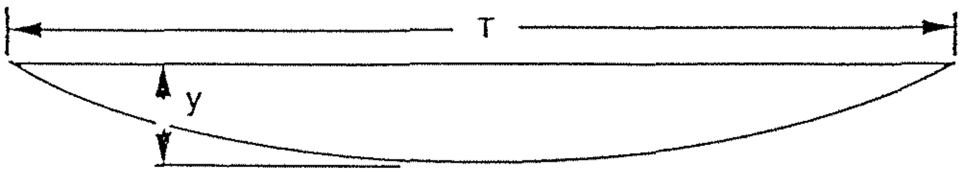
V - Shape



Cross-Sectional Area (A) = Zy^2
Top Width (T) = 2yZ

Hydraulic Radius (R) = $\dfrac{Zy}{2\sqrt{Z^2 + 1}}$

Parabolic Shape

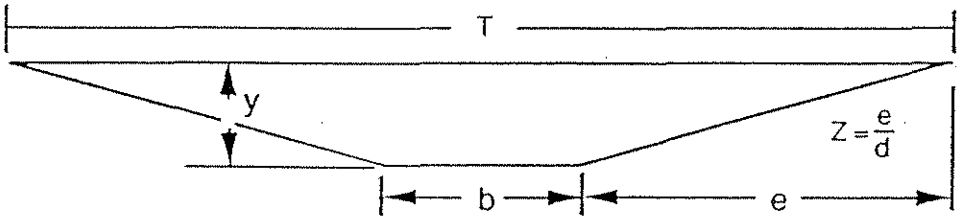


Cross-Sectional Area (A) = $\dfrac{2}{3}Ty$

Top Width (T) = $\dfrac{1.5A}{y}$

Hydraulic Radius (R) = $\dfrac{T^2y}{1.5T^2 + 4y^2}$

Trapezoidal Shape



Cross-Sectional Area (A) = $by + Zy^2$
Top Width (T) = $b + 2yz$

Hydraulic Radius (R) = $\dfrac{by + Zy^2}{b + 2y\sqrt{Z^2 + 1}}$

Figure **C-1** Geometric Formulas for Common Swale Shapes (from Livingston et al., 1984).

Making these substitutions and those for A from Figure C-1, and then solving for T gives:

Parabolic: $$T \cong \frac{Qn}{0.76\ y^{1.667}\ s^{0.5}}$$ Eq. C-8

Trapezoidal: $$b \cong \frac{Qn}{1.486\ y^{1.667}\ s^{0.5}} - Zy$$ Eq. C-9

V: $$T \cong \frac{Qn}{0.47\ y^{1.667}\ s^{0.5}}$$ Eq. C-10

Rectangular: $$T \cong \frac{Qn}{1.486\ y^{1.667}\ s^{0.5}}$$ Eq. C-11

(Also use for filter strips.)

For trapezoidal and V-shapes, select a side slope Z of at least 3.

Solve the appropriate equation for T or b. For a V-shape, check if $Z = T/2y$ is at least 3.

5. Compute A using the appropriate equation from Figure C-1 or Eq. C-2.

6. Compute the flow velocity at design flow rate:

$$V = \frac{Q}{A}$$ Eq. C-12

This velocity should be less than 1.5 ft/s, a velocity that was found to permit the sedimentation of most particles in typical urban runoff (see text). However, the smallest particles (clay and many in the silt fraction) may not be removed. Also, it is not known what velocity will cause grasses to be knocked from a vertical position, thus reducing filtration. Therefore, the velocity should be as low as space allows.

If $V > 1.5$, repeat steps 1–6 until the condition is met.

7. This approximate analysis tends to produce a design that results in $V < 1.5$, often by a substantial margin. This situation is preferred if sufficient space is available. If that is the case, proceed to the stability check. If not, perform a more exact analysis according to steps 8-15.

8. Estimate the degree of retardance to flow created by the vegetation from Table C-2 When uncertain, be conservative by selecting a relatively high degree.

Table C-2 Guide for Selecting Degree of Retardance (a).

Coverage	Average Grass Height (inches)	Degree of Retardance	
Good	> 30	A	Very high
	11-24	B.	High
	6-10	C.	Moderate
	2-6	D.	Low
	< 2	E.	Very low
Fair	> 30	B.	High
	11-24	C.	Moderate
	6-10	D.	Low
	2-6	D.	Low
	< 2	E.	Very low

(a) After Chow (1959). In addition, Chow recommended selection of retardance C for a grass-legume mixture 6-8 inches in height and D for the mixture 4-5 inches high. No retardance recommendations have appeared for emergent wetland species. Therefore, judgment must be used. Since these species generally grow less densely than grasses, using a "fair" coverage would be a reasonable approach.

9. Refer to Figure C-2 and use the selected degree of retardance and Manning's n from step 2 to obtain a first approximation of VR, the product of velocity and hydraulic radius.

10. Compute hydraulic radius, using $V_{max} = 1.5$ ft/s:

$$R = \frac{VR}{V_{max}} \qquad \text{Eq. C-13}$$

11. Use Manning's equation to solve for the actual VR associated with this R and n:

$$VR = \frac{1.486}{n} R^{1.667} S^{0.5} \qquad \text{Eq. C-14}$$

where: VR is in units of ft^2/s

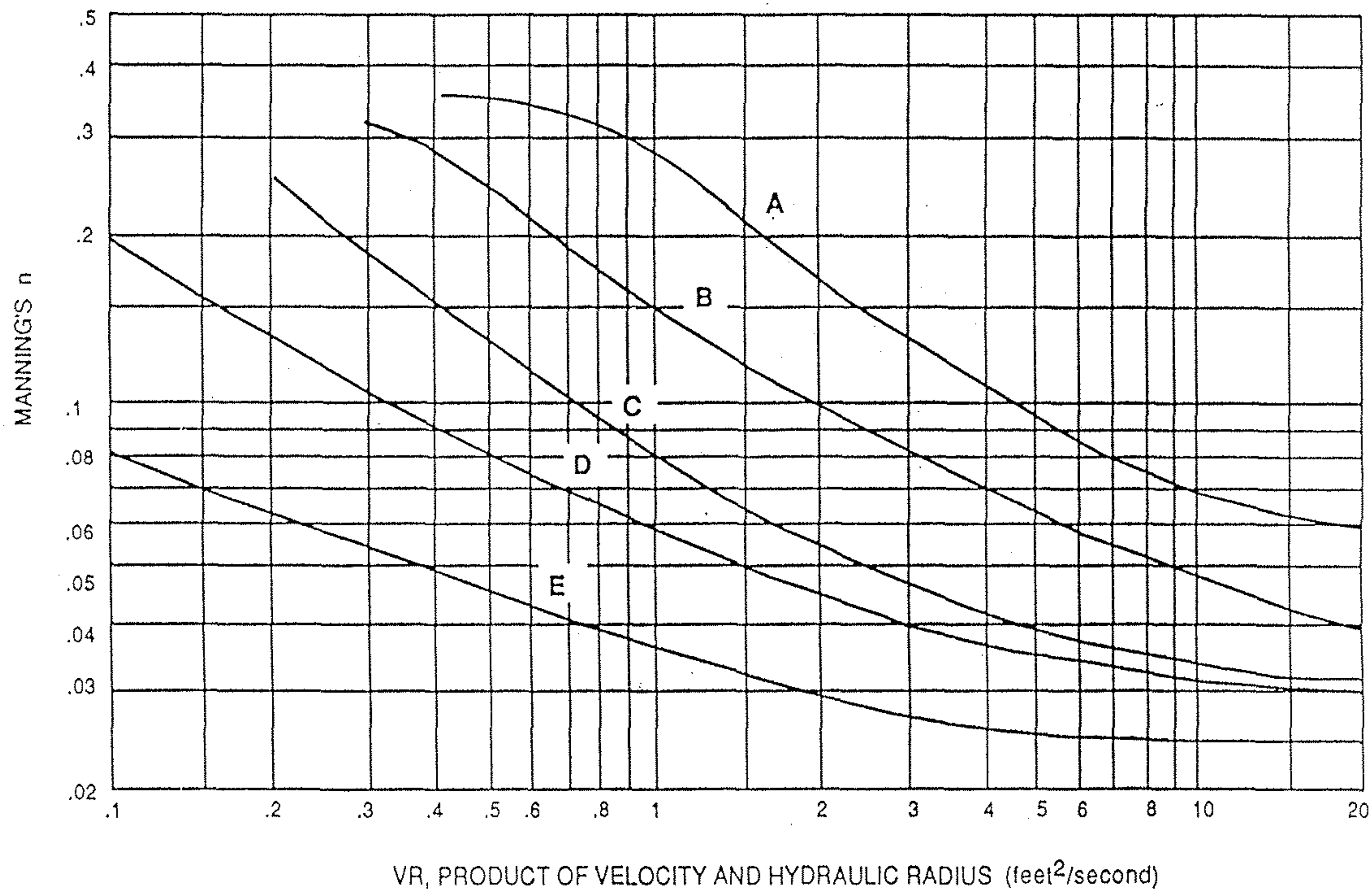


Figure **C–2** The Relationship of Manning's n with VR for Various Degrees of Flow Retardance (A-E) (from Livingston et al., 1984, after U.S. Soil Conservation Service, 1954).

12. Compare the actual VR from step 11 and the first approximation of VR from step 9. If they do not agree within five percent, select a new n and repeat steps 9-12 until acceptable agreement is reached.

13. Compute the actual V for the final design conditions:

$$V = \frac{VR}{R} \qquad \text{Eq. C-15}$$

Check to be sure V < 1.5 ft/s.

14. Use the continuity equation to calculate the flow cross-sectional area (A):

$$A = \frac{Q}{V} \qquad \text{Eq. C-16}$$

15. Use the appropriate equation in Figure C-1 or Eq. C-2 to compute T or b. For trapezoidal and V-shapes, use a Z of at least 3.

16. If there is still not sufficient space for the biofilter, the jurisdiction and the project proponent should consider the following solutions (listed in order of preference):

    a. Divide the site drainage to flow to multiple biofilters.

    b. Use retention to provide lower discharge rates to the biofilter.

    c. Increase vegetation height and design depth of flow (note: the design must ensure that vegetation remains standing during design flow).

    d. Reduce the developed surface area to gain space for biofiltration.

    e. Increase the longitudinal slope.

    f. Increase the side slopes.

    g. Reduce the design storm frequency for the biofilter.

Check for Stability (Minimizing Erosion)

Notes: (1) The stability check must be performed for the combination of highest expected flow and least vegetation coverage and height.

(2) Maintain the same units as in the biofiltration capacity analysis.

1. Unless runoff from events larger than the 2-year, 24-hour storm will bypass the biofilter, perform the stability check for the 100-year, 24-hour storm. Estimate Q for that event as recommended in Preliminary step 1.

2. Estimate the vegetation coverage ("good" or "fair") and height on the first occasion that the biofilter will receive flow, or whenever the coverage and height will be least. Attempt to avoid flow introduction during the vegetation establishment period by timing of planting or bypassing.

3. Estimate the degree of retardance from Table C-2. When uncertain, be conservative by selecting a relatively low degree.

4. Establish the maximum permissible velocity for erosion prevention (V_{max}) from Table C-3

5. Select a trial Manning's n. The minimum value for poor vegetation cover and low height (possibly, knocked from the vertical by high flow) is 0.033. A good initial choice under these conditions is 0.04.

6. Refer to Figure C-2 to obtain a first approximation for VR.

7. Compute hydraulic radius, using the V_{max} from step 4:

$$R = \frac{VR}{V_{max}} \qquad \text{Eq. C-13}$$

8. Use Manning's equation to solve for the actual VR:

$$VR = \frac{1.486}{n} R^{1.667} s^{0.5} \qquad \text{Eq. C-14}$$

9. Compare the actual VR from step 8 and first approximation from step 6. If they do not agree within five percent, repeat steps 5-9 until acceptable agreement is reached.

Table C-3 Guide for Selecting Maximum Permissible Swale Velocities for Stability (a).

Cover	Slope (%)	Maximum Velocity (ft/s [m/s]) Erosion-Resistant Soils	Easily Eroded Soils
Kentucky bluegrass	0-5	6 [1.8]	5 [1.5]
Tall fescue			
Kentucky bluegrass	5-10	5 [1.5]	4 [1.2]
Ryegrasses			
Western wheatgrass			
Crass-legume	0-5	5 [1.5]	4 [1.2]
Mixture	5-10	4 [1.2]	3 [0.9]
Red fescue	0-5	3 [0.9]	2.5 [0.8]
Redtop	5-10	Not recommended	Not recommended

(a) Adapted from Chow (1959), Livingston et al. (1984), and Goldman et al. (1986).

10. Compute the actual V for the final design conditions:

$$V = \frac{VR}{R} \qquad \text{Eq. C-15}$$

Check to be sure $V < V_{max}$ from step 4.

11. Compute the required A for stability:

$$A = \frac{Q}{V} \qquad \text{Eq. C-16}$$

12. Compare the A computed in step 11 of the stability analysis with the A from the biofiltration capacity analysis (step 5 or 14).

    If less area is required for stability than is provided for capacity, the capacity design is acceptable. If not, use A from step 11 of the stability analysis and recalculate channel dimensions (refer to Figure C-1 or Eq. C-2).

13. Calculate the depth of flow at the stability check design flow rate condition for the final dimensions (refer to Figure C-1 or Eq. C-2 and use A from step 11 of the stability analysis).

14. Compare the depth from step 13 to the depth used in the biofiltration capacity design. Use the larger of the two and add 1 ft freeboard to obtain the total depth of the swale. Skip this step in filter strip design.

15. Make a final check for capacity based on the stability check design storm and maximum vegetation height and cover (this check will ensure that capacity is adequate if the largest expected event coincides with the greatest retardance).

    Use Equation C-1, a Manning's n of 0.1, and the calculated channel dimensions, including freeboard, to compute the flow capacity of the channel under these conditions.

    If the flow capacity is less than the stability check design storm flow rate, increase the channel cross-sectional area as needed for this conveyance. Specify the new channel dimensions.

Completion Steps

1. If the biofilter is a swale, lay out the swale to obtain the maximum possible length. This length should be at least 200 ft. In limited spaces, attempt to attain that length by using a curved path. Use the widest radius bends possible to reduce the potential for erosion of the outside of curved sections. If a length shorter than 200 ft must be used, increase A by an amount proportional to the reduction in length below 200 ft, in order to obtain the same water residence time. Recalculate channel dimensions from Figure C-1 or Eq. C-2

   If the swale is a filter strip, select a length for the calculated width that produces at least 20 minutes water residence time (normally 100-200 ft).

2. If the swale longitudinal slope is greater than four percent, design log or rock check dams approximately every 50 ft.

APPENDIX D

EXAMPLE CALCULATIONS

EXAMPLE #1: INFILTRATION

Description: Assume a new 50 acre development is planned up in the hills. The development will be 100 percent multi-family residential. The local planning commission has requested that plans include nutrient reduction in stormwater runoff by approximately 50 percent.

Step 1: Site Review.

A comprehensive review of the drainage area turns up the following important considerations. Only 0.2 acres are available for a pollutant reduction facility (PRF). Slopes in the area are steep. Maps show the soils in the area fall in SCS soil group B. The development will receive its water supply from city water lines since no near-surface aquifers exist.

A detailed soil survey is conducted and reveals an infiltration rate of 0.5 inches per hour. Surveying results show slopes of 20 percent throughout most of the drainage area.

Step 2: Select the Appropriate PRF.

Use Table D-1 to aid in PRF selection. The main concern is with nutrient removal. Infiltration, pond-marsh, and landscaping are all effective at removing phosphorus, street and storm sewer PRFs are not.

The area available for a PRF is small to moderate, ruling out pond-marsh facilities. The soil permeability is the minimum acceptable for an infiltration facility. The slope is too steep for effective use of most landscaping facilities. Groundwater concerns appear to be minimal--no aquifer, no wells, and non-industrial land use.

The best PRF choice appears to be some type of infiltration facility, probably basins or roof drains due to the steep slopes present in the drainage area. Table I-1 shows that these facilities have average nutrient removal rates of 40 to 80 percent, phosphorus removal being on the high end and nitrogen removal being on the low end.

Use the Planning and Design Checklist at the end of Chapter II for guidance on Infiltration Facilities. It is decided to go with an infiltration basin as the main PRF due to easier monitoring.

Step 3: Calculate Runoff Coefficient (Rv).

The planned development will have 60 percent impervious area, slightly on the high side for multi-family housing. The Rv can either be calculated from the formula given in the graph or estimated from Figure B-1 in Appendix B. Figure B-1 shows that Rv = 0.59 for a 60 percent impervious area.

Step 4: Determine Catchment Ratio.

The catchment ratio equals basin surface area divided by contributing drainage area. In this case, 0.2 acres / 50 acres = 0.004 = 0.4 percent.

Step 5: Choose Graph for Infiltration Rate.

Use the Sizing section under General Design Criteria in Chapter II. Three infiltration facility curves for rates of 0.5, 5.0, and 10.0 inches per hour are provided as Figure II-1, II-2, and II-3. For this example use the 0.5 inches per hour curve. (It may sometimes be necessary to extrapolate between the three curves provided.)

Step 6: Determine Percent of Flow Treated.

Locate 0.4 value for the catchment ratio on the x axis. (Note that the axis scale is logarithmic.)

Draw a line up from the 0.4 tick mark. The Rv of 0.59 lies between the 0.5 and 0.95 curves.

The y axis indicates that the percent of flow treated by the infiltration basin is approximately 70 percent.

Step 7: Design Infiltration Facility.

Use the specific criteria found in the section on Infiltration Basins in Chapter II for designing the basin. As this will be a new development, problems with erosion from construction sites need special attention.

EXAMPLE #2: SUSPENDED SOLIDS REMOVAL

Description: Assume a 200 acre drainage area that is 100 percent single-family residential. A 4 acre detention pond, 1 foot in depth, treats runoff from this area. What percentage of the suspended solids is this existing pond removing?

Step 1: Calculate Runoff Coefficient (Rv).

The percent impervious area is 30 percent, typical for single-family residential. Rv can either be estimated from Figure B-1 or calculated from the formula shown on the sediment removal curves. In this case, Rv = 0.05 + 0.009 x 30 percent = 0.32.

Step 2: Determine Catchment Ratio.

The catchment ratio equals basin surface area divided by contributing drainage area. In this case, 4 acres / 200 acres = 0.02 = 2 percent.

Step 3: Choose Appropriate Sediment Removal Graph.

We are interested in suspended solids removal for a 1-foot pond. Figure II-4 is the correct one to use for this example.

Step 4: Calculate Sediment Removal.

Find the catchment ratio of 2.0 percent on the x axis. (Note that the axis scale is logarithmic.)

Draw a line up from the 2.0 tick mark. The Rv value of 0.32 lies between the 0.10 and 0.50 Rv curves.

The y axis indicates that approximately 90 percent of the suspended solids are being removed by the detention pond.

EXAMPLE #3: NUTRIENT REMOVAL

Description: Assume a 100 acre drainage area, 50 percent of which is commercial and 50 percent of which is single-family residential. A 3 acre parcel of undeveloped area remains. The goal is to remove 30 percent of the total phosphorus present in the stormwater runoff.

Step 1: Site Review.

A comprehensive review of the drainage area turns up the following important considerations. Slopes in the area are moderate. Maps show the soils in the area belong to SCS group C. A detailed soil survey is conducted and reveals an infiltration rate of 0.05 inches per hour. Surveying results show that slopes throughout most of the drainage area are about 10 percent.

Step 2: Select the Appropriate PRF.

Use Table D-1 to aid in PRF selection. The main concern is with nutrient removal. Infiltration, pond-marsh, and landscaping are all effective at removing phosphorus, street and storm sewer PRFs are not. Table I-1 shows that many of the effective PRFs can remove 30 percent or more of the phosphorus.

The area available for PRFs is fairly large, so area is not a limitation. The soil permeability is too low for effective use of infiltration facilities, however. The slope is steeper than is ideal for landscaping facilities. Besides which, the almost fully-developed drainage area limits the landscaping possibilities. Groundwater concerns appear to be minimal, judging by the low soil permeability.

The best PRF choice appears to be a pond-marsh facility, either a wetland or a wet pond, since extended detention basins are not as good at removing nutrients.

Use the Planning and Design Checklist at the end of Chapter III for guidance on Pond-Marsh Facilities.

Step 3: Calculate Runoff Coefficient (Rv).

The commercial land is about 70 percent impervious. The single-family residential imperviousness is about 30 percent. The average impervious area for the drainage area is therefore, 50 percent.

The runoff coefficient (Rv) can either be calculated or estimated from Figure B-1, in Appendix B. The formula for calculating Rv is shown on the nutrient removal curves. In this case, Rv = 0.05 + 0.009 x 50 percent = 0.50.

Step 4: Determine the Catchment Ratio.

The catchment ratio equals basin surface area divided by contributing drainage area. In this case 3 acres / 100 acres = 0.03 = 3 percent.

Step 5: Choose Appropriate Nutrient Removal Graph.

The goal is to remove 30 percent of the phosphorus in the runoff.

Usually, the less excavation required, the better, so look first at the graph for a 1-foot deep basin for nutrient removal, Figure III-7. With Rv = 0.5 and the catchment ratio = 3 percent, a 1-foot deep pond would remove 16 percent of the phosphorus. This does not meet the desired removal rate.

If the pond was 3 feet deep, Figure III-8, it would remove 33 percent of the runoff phosphorus. A 3-foot deep pond covering 3 acres would therefore meet the phosphorus removal goal.

However, if the pond depth was increased to 6 feet, Figure III-9, it would remove 45 percent of the phosphorus, exceeding the goal. At 6 feet depth, the pond's surface area could be reduced to 1 acre and the pond would still remove over 30 percent of the phosphorus load. This might be a more attractive option to minimize land acquisition costs, but it would require greater safety measures at the site.

Step 6: Design the Pond-Marsh.

A wetland would remove slightly more phosphorus than the wet pond, but the wet pond requires somewhat less maintenance. Use the General Design criteria found in Chapter III, along with the specific criteria that follows in either the Treatment Wetlands or Wet Ponds sections, depending on which type of pond-marsh is chosen.

EXAMPLE 4: COMBINATION FACILITIES

Description: Assume a 100 acre drainage area which is almost completely developed. Less than 1 acre of undeveloped land remains available for any large PRFs. One-fourth of it is industrial, one-fourth of it is multi-family residential, and the remaining half is single-family residential. The community is required to cut its phosphorus load by 65%. To further complicate matters, a shallow aquifer is known to exist under the area, causing concerns over groundwater contamination.

Step 1: Site Review.

A comprehensive review of the drainage area turns up the following important considerations. Slopes in the area are flat to moderate. Maps show the soils in the area belong to SCS group C. A detailed soil survey is conducted and reveals an infiltration rate of 0.01 inches per hour. Surveying results show slopes ranging from 3-12 percent throughout the drainage area.

Step 2: Calculate Runoff Coefficient (Rv).

A map of the area is planimetered to determine the impervious areas. About 66% of the industrial land, 46% of the multi-family residential land, and 24% of the single-family residential area are identified as impervious.

Average impervious area = ind area * ind imperv. + mult-fam area * mult-fam imperv. + sing fam area * sing fam imperv. =

$$0.25*0.66+0.25*0.46+0.5*0.24 = 0.40$$

$$\text{Rv, using the formula} = 0.05+0.009*0.40 = 0.41$$

Step 3: Choose Main PRF type.

The design process does not have to include designation of a single type of PRF as a "main" type. Multiple types can be examined at the same time if desired. However, designating one type of PRF--usually the most efficient at removing the pollutant of concern--as the main type and then using other types to complement it as necessary is usually easier to evaluate.

Table D-1 shows that Infiltration, Pond-Marsh, and Landscaping Facilities are all suited for removing nutrients. Look up these facilities in Table I-1. Acting by themselves, only infiltration facilities remove over 65% of the total phosphorus in runoff. Average removal efficiencies range between 75-80% for most infiltration facilities. But since groundwater contamination is a concern, infiltration facilities are not feasible.

The next most efficient removal would be a wetland or wet pond, but their average efficiencies are only 40-45%. Even their high range is only 60%. The Table I-1 values are for a single facility, a 1% catchment ratio, and a 3-foot depth, however. Varying one of these parameters might provide enough phosphorus removal to meet the goal.

Step 4: Determine Efficiency Range for Main PRF.

Examine Figure III-8, the graph for a 3-foot deep nutrient removal pond. The Rv from this drainage area is 0.41. With a 1% catchment ratio the pond will only remove about 35% of the phosphorus, slightly less than the average given in Table I-1. (This is due to the higher Rv in this example.) If the catchment ratio was increased to 10%, the wet pond would still remove only 53% of the phosphorus. If the depth was increased to 6 feet, Figure III-9, it would remove about 63% of the phosphorus.

A 63% removal rate is close to the goal, but of course, less than 1 acre is available for such a facility, A catchment ratio of 10 for a 100 acre drainage area means a 10 acre pond. Devoting 10 percent of the available land in a new development is usually not feasible -- in a pre-developed area it is impossible.

In order to achieve a 65% phosphorus removal rate in most situations, it is necessary to use a combination of PRFs.

Step 5: Calculate Removal Efficiency of Main PRF.

The general design criteria for pond-marsh facilities, found in Chapter III, were consulted. It was determined that enough undeveloped land exists for a 0.5 acre pond. That is about 22,000 square feet or 148 feet on a side. To maximize its volume, and therefore, its efficiency, a 6-foot deep pond will be used.

Specific design requirements in Chapter III of the manual necessitate a 4:1 side slope for a wet pond. When ponds are planned for less than 1 acre, as this one is, the slope requirement starts to become a problem. Over half the area of this 0.5 acre pond will have to be used for the side slopes. This will cut down on its volume and thus, its treatment efficiency. Keeping this in mind, the effective catchment ratio is actually just a little under 0.4.

Figure III-9 shows that a pond with a catchment ratio of 0.4 and a drainage area with Rv=0.41 will remove about 40% of the phosphorus entering it. By establishing vegetation in the wet pond we can create a wetland. Wetlands have a slightly higher phosphorus removal rate, about a 5% difference, and are usually shallower, the vegetation serving to slow down the flow rate and increase the effective settling. The side slope must be even more gradual, however, 5:1 or better.

Thus, the end result is a 0.5 acre wetland with a maximum depth of perhaps 4 feet, and an estimated phosphorus removal rate of 45%. Additional reduction measures are still needed.

Step 6: Choose Additional PRFs.

Chapter VI deals specifically with combination facilities. It lists many common variations and notes some of their advantages and disadvantages. Some of the more technical discussion in this chapter illustrates how the efficiency of a series of similar PRFs for nutrient removal declines about 10% with each facility. Keep in mind that using different types of PRFs in combination should not show as much decline. (Very little research has been published on the effectiveness of combination facilities, however.)

Wetlands are better than wet ponds at removing dissolved nutrients (although they are more likely to export particulate nitrogen). Wetlands are also more sensitive to siltation. Sedimentation devices upstream would be a good choice for additional PRFs.

Consult Table D-1 for suggested sediment removal devices. Wet ponds, extended detention basins, and various street and storm sewer PRFs are possibilities. Not enough space exists for the wet ponds or extended detention basins, however.

By using vegetated swales in non-guttered areas and retrofitting curbed/guttered areas with water quality inlets should remove an additional 15% or so of the phosphorus, Table I-1. The total removal would be about 60%. The water quality inlets also remove petroleum products before they reach sensitive areas like the wetland, an added benefit, especially in industrial areas.

Some additional landscaping techniques, such as constructed filter strips, should remove at least another 20%. Since the drainage area is already developed, their layout will likely be less than optimum and they will probably not achieve their average 30% removal rate.

Step 7: Calculate Total Removal Efficiency.

The estimated total phosphorus removal adds up to 80%, but the filter strips, vegetated swales, and wetland all use similar biofiltration techniques, thus decreasing their cumulative efficiency. Placing the filter strips mainly in curbed/guttered areas not served by swales will help to minimize this overlap of removal mechanisms. The final efficiency of these combination facilities will probably be 65-70%.

Step 8: Design Combination Facilities.

Use general and specific design criteria in Chapter III for the main PRF, the wetland. Chapter IV contains design criteria for water quality inlets. Vegetated swale and filter strip design criteria are contained in Chapter V. Each of these chapters contains a Planning and Design Checklist. Following the checklist will help ensure that required data is collected and site characteristics requiring special consideration are noted.

Chapter VI goes over using facilities in combination, but does not include design criteria.

Table D-I: Facility selection.

Treatment Facility Type	Pollutant Reduction Facility Requirements							Recommended Uses			
	Area	Perme-ability	Slope	Vegetation	Maint.	Level of GW Pro.	O&G	SS	PAS	N	O&G
Infiltration											
Infil. Trenches	small	high	<5%	none	high	high	restrict			X	
Infil. Basins	mod.	high	<25%	grass	high	high	restrict			X	
Infil. Sumps	small	high	NA	none	high	high	restrict			X	
Porous Pvmt.	small	high	<5%	none	mod.	high	restrict			X	
Roof Drains	small	high	<25%	none	mod.	high	restrict			X	
Pond-Marsh											
Trtmt. Wetlands	large	low	<15%	wetland	mod.	moderate	restrict			X	
Wet Ponds	large	low	<15%	some wetland	low	moderate	min.	X	X	X	
Ext. Detention	mod.	low	<15%	grass	low	low	min.	X	X		
S&S Sewer											
Trapped Catch Basins	small	NA	NA	none	mod.	low	min.	X	X		
WQ Basins	small	NA	NA	none	mod.	low	okay	X	X		X
Sed. Manholes	small	NA	NA	none	mod.	low	min.	X	X		
Vaults/Tanks	small	NA	NA	none	mod.	moderate	min.	X	X		
Landscaping											
Veg. Swales	small	NA	<5%	grass	mod.	low	min.			X	
Const. Filter Strips	mod.	NA	<5%	grass/trees	low	moderate	min.			X	
Riparian Filters	mod.	NA	<5%	grass/trees	low	moderate	min.			X	

Trtmt. = Treatment, Infil. = Infiltration, Pvmt. = Pavement, Ext. = Extended, S&S = Street & Storm, WQ = Water Quality, Sed. = Sedimentation, Veg. = Vegetated, Const. = Constructed, mod. = moderate, NA = Not applicable, Pro. = Protection, O&G = Oil and Grease, min. = minimize, SS = Suspended Solids, PAS = Pollutants Associated with Sedimentation, N = Nutrients

APPENDIX E

Due to its length, OAR Chapter 340, Division 40, Groundwater Quality Protection is not reprinted here. However, it lists additional requirements that may be requested if a storm water discharge permit is required.

Chapter 340, Division 44 is included in this appendix. These regulations are applicable to projects with the potential to impact groundwater quality.

DIVISION 44

CONSTRUCTION AND USE OF WASTE DISPOSAL WELLS OR OTHER UNDERGROUND INJECTION ACTIVITIES

Definitions

340-44-005 As used in these regulations unless the context requires otherwise:

(1) "Aquifer" means an underground stratum holding water which is capable of yielding a significant amount of water to a well or spring.

(2) "Authorized Representatives" means the staff of the Department or of the local unit of government performing duties for and under agreement with the Department as authorized by the Director to act for the Department.

(3) "Commission" means the Environmental Quality Commission.

(4) "Construction" includes installation or extension.

(5) "Department" means the Department of Environmental Quality.

(6) "Director" means the Director of the Department of Environmental Quality.

(7) "Exempted Aquifer" means an aquifer which contains water with fewer than 10,000 mg/l total dissolved solids, is not currently used as a source of drinking water, and has been excluded as a possible source of drinking water because of one or more of the following:

(a) Its mineral content, hydrocarbon content or physical characteristics, such as temperature, makes its use for drinking water impractical;

(b) It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical; or

(c) The water or aquifer exhibit other characteristics which makes the aquifer unusable for drinking water.

(8) "Municipal Sewerage System" means any part of a sewage collection, transmission, or treatment facility that is owned and operated by an incorporated city.

(9) "Municipal Sewer Service Area" means an area which has been designated by an incorporated city for sewer service and for which preliminary sewer planning has been completed.

(10) "Municipality" means an incorporated city only.

(11) "Owner" means:

(a) Any person who alone, or jointly, or severally with others:

(A) Has legal title to any lot, dwelling, or dwelling unit; or

(B) Has care, charge, or control of any real property as agent, executor, executrix, administrator, administratix, trustee, lessee or guardian of the estate of the holder of legal title; or

(C) Is the contract purchaser of real property.

(b) Each such person as described in paragraphs (a)(B) and (C) of this section, thus representing the holder of legal title, is bound to comply with the provisions of these minimum standards as if he were the owner.

(12) "Person" means the United States and agencies thereof, any state, any individual, public or private corporation, political subdivision, governmental agency, municipality, industry, copartnership, association, firm, trust, estate or any other legal entity whatsoever.

(13) "Property" means any structure, dwelling or parcel of land that contains or uses a waste disposal well for disposing of wastes.

(14) "Public Health Hazard" means a condition whereby there are sufficient types and amounts of biological, chemical, or physical, including radiological, agents relating to water or sewage which are likely to cause human illness, disorders, or disability. These include, but are not limited to, pathogenic viruses and bacteria, parasites, toxic chemicals, and radioactive isotopes. A malfunctioning or surfacing subsurface sewage disposal system constitutes a public health hazard.

(15) "Public Waters" means lakes, bays, ponds, impounding reservoirs, springs, wells, rivers, streams, creeks, estuaries, marshes, inlets, canals, the Pacific Ocean within the territorial limits of the State of Oregon, and all other bodies of surface or underground waters, natural or artificial, inland or coastal, fresh or salt, public or private (except those private waters which do not combine or effect a junction with natural surface or underground waters), which are wholly or partially within or bordering the state or within its jurisdiction.

(16) "Seepage Pit" means a lined pit which receives partially treated sewage which seeps into the surrounding soil through perforations in the lining.

(17) "Sewage" means the water-carried human or animal waste from residences, buildings, industrial establishments or other places, together with such groundwater infiltration and surface water as may be present. The admixture with sewage as above defined of industrial wastes or wastes shall also be considered "sewage" within the meaning of these rules.

(18) "Sewage Drain Hole" means a specialized type of waste disposal well consisting of a drilled or hammered well or natural lava crack or fissure used for sewage disposal in the lava terrain of Central Oregon; but does not include a conventional seepage pit regulated by OAR 340-71-335.

(19) "Standard On-Site Sewage Disposal System" means a drainfield or approved alternative disposal system that complies with the requirements of OAR Chapter 340 Division 71.

(20) "Underground Injection Activity" means any activity involving underground injection of fluids including, but not limited to, waste disposal wells, petroleum enhanced recovery injection wells, liquid petroleum storage wells, in situ mining wells, groundwater recharge wells, saltwater intrusion barrier wells, sand backfill wells, and subsidence control wells.

(21) "Underground Source of Drinking Water" means an aquifer or its portion which supplies drinking water for human consumption, or is an aquifer in which the groundwater contains fewer than 10,000 mg/L total dissolved solids, and is not an exempted aquifer.

(22) "Waste Disposal Well" means any bored, drilled, driven or dug hole, whose depth is greater than its largest surface dimension which is used or is intended to be used for disposal of sewage, industrial, agricultural or other wastes and includes drain holes, drywells, cesspools and seepage pits, along with other underground injection wells, but does not apply to single family residential cesspools or seepage pits nor to nonresidential cesspools or seepage pits which receive solely sanitary wastes and serve less than 20 persons per day.

(23) "Wastes" means sewage, industrial wastes, agricultural wastes, and all other liquid, gaseous, solid, radioactive or other substances which will or may cause pollution or tend to cause pollution of any waters of the state.

(24) "WPCF Permit" means a permit as defined in Division 45.

Stat. Auth.: ORS Ch. 183 & 468
Hist: SA 41, f. 5-15-69; DEQ 35-1979, f. & ef. 12-19-79; DEQ 15-1983, f. & ef. 8-26-83

Policy

340-44-010 Whereas the discharge of untreated or inadequately treated sewage or wastes to waste disposal wells and particularly to waste disposal wells in the lava terrain of Central Oregon constitutes a threat of serious, detrimental and irreversible pollution of valuable groundwater resources and a threat to public health, it is hereby declared to be the policy of the Commission to restrict, regulate or prohibit the further construction and use of waste disposal wells in Oregon and to phase out completely the use of waste disposal wells as a means of disposing of untreated or inadequately treated sewage or wastes as rapidly as possible in an orderly and planned manner.

Stat. Auth.: ORS Ch. 468
Hist: SA 41, f. 5-15-69; DEQ 35-1979, f. & ef. 12-19-79

Construction or Use of Waste Disposal Wells Restricted

340-44-015 (1) After the effective date of these rules, no person shall construct, place in operation, or operate any waste disposal well without first obtaining a WPCF permit from the Department, unless the waste disposal well is exempted by section (2) of this rule.

(2) The following types of waste disposal wells do not require a WPCF permit, although they are regulated as indicated:

(a) Cesspool and seepage pits of less than 5,000 gallons per day capacity (See OAR 340-71-335);

(b) Storm water drains from residential or commercial areas, which are not affected by toxic or industrial wastes (See OAR 340-44-050);

(c) Sewage drain holes serving less than 20 persons per day. (See prohibitions and other limitations in sections (5), (7), (9) and (10) of this rule).

(3) In addition to those waste disposal wells in section (2) of this rule which are exempt from a WPCF permit, the following types of waste disposal wells may be exempted from the permit requirement on a case-by-case basis:

(a) All cesspools and seepage pits which were constructed before January 1, 1982, and which dispose of only domestic waste;

(b) All sewage drain holes which were constructed before January 1, 1980, and which dispose of only domestic waste;

(c) Geothermal reinjection wells which return uncontaiminated water to the same aquifer or to one of equivalent quality; and

(d) Reinjection of air conditioning water or heat pump transfer water to the same aquifer or one of equivalent quality.

(4) The following types of underground injection activities are prohibited:

(a) Wells used to dispose of hazardous waste, as defined in OAR 340 Division 63, or radioactive waste, as defined in ORS 469.300, into, above, or below a formation which contains an underground source of drinking water within one quarter (1/4) mile of the disposal well hole;

(b) Wells used to dispose of other industrial or municipal wastewater into or below a formation which contains an underground source of drinking water within one quarter (1/4) mile of the disposal well hole, excluding wells used for injection of salt water brought to the surface as a result of oil or gas production.

(c) Wells used for underground injection activities, other than disposal, which cause or tend to cause pollution of underground waters of the state. These activities include liquid hydrocarbon storage and injection of fluids for mineral extraction.

NOTE: Because of the widespread availability of usable underground waters in the state, the Department has determined that these underground injection activities are a potential threat to underground waters in all parts of the state and are, therefore, all subject to regulation by the Department. If, at some future date, there is a demonstrated need for any of these other underground injected activities, the Department will initiate procedures to remove the prohibition, provided a program and procedures for adequately protecting underground waters from the activity has been adopted.

(d) Wells used for underground injection activities that allow the movement of fluids into an underground source of drinking water if such fluids may cause a violation of any primary drinking water regulation promulgated under the Federal Safe Drinking Water Act or may otherwise create a public health hazard or have the potential to cause significant degradation of public waters.

(5) After January 1, 1983, use of sewage drain holes is prohibited unless the disposal well is outside the boundaries of an incorporated city, sanitary district, or county service district and municipal sewer service is not available to the property; or unless the Director grants a waiver pursuant to section (6) of this rule.

(6) Within 90 days following written notification by the Department that sewer service is available to a property, the owner of that property shall make connection to the sewer and shall abandon and plug the sewage drain hole in accordance with OAR 340-44-040. Sewer service shall be deemed available to a property when a sewer is extended to within seventy-five (75) feet from the property boundary. On a case-by-case basis, the Director may waive the requirement to connect to sewer if he determines that connection to the sewer is impracticable or unreasonably burdensome. Any waiver granted by the Director shall be temporary and may be revoked when or if the use of the waste disposal well is modified or expanded.

(7) Construction and use of new sewage drain holes is prohibited except those new sewage drain holes that meet the following conditions:

(a) The sewage drain hole is constructed to augment a failing on-site disposal system which was constructed before January 1, 1979; the failing on-site system cannot reasonably be corrected by expansion or replacement with an approved alternative system; all possible leach field area has been fully utilized and water conservation measures instituted; and, there is no reasonable alternative available to dispose of sewage on the lot or adjacent property.

(b) Where conditions warrant, the Department may require additional sewage treatment before a new sewage drain hole will be permitted. In addition, new sewage drain holes shall be constructed within the following limitations:

(A) Sewage drain holes shall not be constructed closer than five hundred (500) feet from a natural stream or lake;

(B) Sewage drain holes shall not be constructed greater than one hundred (100) feet deep;

(C) Sewage drain holes shall not be closer than one thousand (1000) feet from a domestic water well; and

(D) Any new sewage drain hole shall terminate at least 100 feet above any known groundwater aquifer.

(c) Any sewage drain hole constructed shall be abandoned and plugged whenever a feasible alternative on-site system or off-site sewers become available, unless a waiver is granted by the Director pursuant to section (6) of this rule. No authorization for construction of a sewage drain hole within a sewer service area will be granted unless the property owner agrees in writing not to remonstrate against connection to the sewer and abandonment of the sewage drain hole when notified that sewer service is available. This agreement shall be recorded in county deed records and shall run as a covenant with the land.

(8) A permit to construct a waste disposal well shall not be issued if the Director or his authorized representative, determines that the waste disposal well has the potential to cause significant degradation of public waters or create a public health hazard.

(9) Without first obtaining written authorization from the Director or his authorized representative, no person shall modify any structure or change or expand any use of a structure or property that utilizes a sewage drain hole. Except as allowed in section (10) of this rule, the authorization shall not be issued unless:

(a) The property cannot qualify for a standard on-site sewage disposal system including the reserve area requirement; and

(b) The property is inside a designated, municipal sewer service area; and

(c) The owner of the property and the municipality having jurisdiction over the municipal sewer service area shall enter into a written agreement. The agreement shall include the owner's irrevocable consent to connect to the municipal sewerage service when it becomes available and to not remonstrate against formation of and inclusion into a local improvement district if such a district is deemed necessary by the municipality to finance sewer construction to the property; and

(d) The property is a single family dwelling that is not closer than one hundred (100) feet to a municipal sewerage system. (The proposed changes or expansion of the use of the waste disposal serving the single family dwelling shall not be for the purpose of serving a commercial establishment or multiple-unit dwelling); or

(e) The property is not a single-family dwelling, is not closer than 300 feet from a municipal sewerage system, and the proposed change or expansion of the use of the waste disposal well would not create an increased waste flow; or

(f) The property is not a single-family dwelling; existing sewer is not deemed available based upon the criteria established in Oregon Administrative Rules 340-71-160 and based upon the total average daily flow estimated from the property after the proposed modification or expansion of the use of the waste disposal well and a municipality has committed in writing to provide sewers to the property within two (2) years.

(10) The Director shall grant authorization to connect a replacement structure to a sewage drain hole if:

(a) The waste disposal well previously served a structure that was unintentionally destroyed by fire on other calamity; and

(b) The property cannot qualify for a standard on-site sewage disposal system, including the reserve area requirement; and

(c) There is no evidence that the waste disposal well had been failing; and

(d) The replacement structure is approximately the same size as the destroyed structure and the use has not been significantly changed.

Stat. Auth.: ORS Ch. 468
Hist: SA 41, f. 5-15-69; DEQ 35-1979, f. & ef. 12-19-79; DEQ 22-1981, f. & ef. 9-2-81; DEQ 15-1983, f. & ef. 8-26-83

Repairs of Existing Sewage Drain Holes

340-44-017 (1) Without first obtaining a Waste Disposal Well Repair Permit from the Director or his representative, no person shall repair or attempt to repair a plugged or otherwise failing sewage drain hole.

(2) The Director or his authorized representative shall not issue a Waste Disposal Well Repair Permit and shall require connection to a municipal sewerage system if, for a single-family dwelling, the property is within one hundred (100) feet from the municipal sewerage system or if, for other than a single-family dwelling, the property is within three hundred (300) feet from the municipal sewerage system.

(3) The Director or his authorized representative shall not issue a Waste Disposal Well Repair Permit if the property can successfully accommodate a standard on-site sewage disposal system. If the Director or his authorized representative determines that a drainfield can be installed and that it can be expected to function satisfactorily for an extended period of time, the property owner shall install a drainfield and abandon the waste disposal well. The Director or his authorized representative may waive the requirement to install a standard on-site sewage disposal system if a municipality provides written commitment to provide sewers to the property within two (2) years and if the failing waste disposal well can be repaired or operated without causing a public health hazard.

(4) A Disposal Well Repair Permit shall be a written document and shall specify those methods by which the waste disposal well may be repaired. Possible methods for repair shall include, but not be limited to, introduction of caustic or acid, use of explosives, or deepening the waste disposal well. Deepening the waste disposal well shall be limited to a maximum depth of one hundred (100) feet and shall only be permitted if:

(a) The property served by the failing waste disposal well shall be inside a recognized urban growth boundary; and

(b) There is a written agreement between the owner of the property and the municipality having jurisdiction over the urban growth boundary. The written agreement shall include the property owner's irrevocable consent to connect to a sewer when it becomes available and to abandon the waste disposal well. The agreement shall also include the owner's irrevocable consent to participate in the formation and be included in a local improvement district if the municipality determines that such a district is necessary to finance extension of sewer to the property.

Stat. Auth.: ORS Ch. 468
Hist: DEQ 35-1979, f. & ef. 12-19-79; DEQ 15-1983, f. & ef. 8-26-83

Schedules for Eliminating Waste Disposal Wells Inside Incorporated Cities, Sanitary Districts, and County Service Districts

340-44-019 [DEQ 35-1979, f. & ef. 12-19-79;
Repealed by DEQ 15-1983, f. & ef. 8-26-83]

Issuance of Permits Without Director Approval Prohibited

340-44-020 After the effective date of these rules, no person shall issue permits for the construction, modification, maintenance, or use of waste disposal wells unless that permit has been approved by the Director.

Stat. Auth.: ORS Ch. 468
Hist: SA 41, f. 5-15-69; DEQ 35-1979, f. & ef. 12-19-79; DEQ 15-1983, f. & ef. 8-26-83

Waste Disposal Well Permit Areas

340-44-025 [SA 41, f. 5-15-69;
Repealed by DEQ 35-1979,
f. & ef. 12-19-79]

Waste Disposal Wells Prohibited Where Better Treatment or Protection is Available

340-44-030 Permits shall not be issued for construction, maintenance or use of waste disposal wells where any other treatment or disposal method which affords better protection of public health or water resources is reasonably available or possible.

Stat. Auth.: ORS Ch. 468
Hist: SA 41, f. 5-15-69

Permit Conditions

340-44-035 (1) Permits for construction or use of waste disposal wells shall include, in addition to other reasonable provisions, minimum conditions relating to their location, construction or use and a time limit for authorized use of said waste disposal wells.

(2) Permits for construction or use of waste disposal wells used to inject salt water produced as a result of oil or gas extraction shall include conditions as necessary to prevent migration of fluids into an underground source of drinking

‹ater. These conditions could include casing and cementing equirements, fluid and fluid pressure monitoring requireıents, and maximum injection pressure limitations. If other xisting wells penetrate the zone which may be affected by the ıjection activity, conditions will also be included to ensure ıan these other wells will not serve as a conduit for the ıovement of fluids into an underground source of drinking ‹ater.

Stat. Auth.: ORS Ch. 468
Hist: SA 41, f. 5-15-69; DEQ 15-1983, f. & ef. 8-26-83

ıbandonment and Plugging of Waste Disposal Wells

340-44-040 (1) A waste disposal well upon discontinuance r use or abandonment shall immediately be rendered comletely inoperable by plugging and sealing the hole to prevent ıe well from being a channel allowing the vertical movement f water and a possible source of contamination of the roundwater supply.

(2) All portions of the well which are surrounded by "solid ‹all" formation shall be plugged and filled with cement grout r concrete.

(3) The top portion of the well must be effectively sealed ‹ith cement grout or concrete to a depth of at least 18 feet elow the surface of the ground, or wherever this method of ealing is not practical, effective sealing must be accomplished ı a manner approved in writing by the Director or his authorzed representative.

Stat. Auth.: ORS Ch. 468
Hist: SA 41, f. 5-15-69; DEQ 35-1979, f. & ef. 12-19-79

:onstruction or Use of Waste Disposal Wells Prohibited After anuary 1, 1980

340-44-045 [SA 41, f. 5-15-69;
Repealed by DEQ 35-1979,
f. & ef. 12-19-79]

‹aste Disposal Wells for Surface Drainage

340-44-050 (1) Waste disposal wells for storm drainage ıall only be used in those areas where there is an adequate onfinement barrier or filtration medium between the well and n underground source of drinking water; and where construction of surface discharging storm sewers is not practical.

(2) New storm drainage disposal wells shall be as shallow as possible but shall not exceed a depth of 100 feet.

(3) They shall not be located closer than 500 feet of a domestic water well.

(4) Using a waste disposal well for agricultural drainage is prohibited.

(5) Using a waste disposal well for surface drainage in areas where toxic chemicals or petroleum products are stored or handled is prohibited, unless there is containment around the product area which will prevent spillage or leakage from entering the well.

(6) Any owner or operator of a waste disposal well for storm drainage shall have available a means of temporarily plugging or blocking the well in the event of an accident or spill.

(7) Any parking lot which is drained by waste disposal wells shall be kept clean of petroleum products and other organic or chemical wastes as much as practicable to minimize the degree of contamination of the storm water drainage.

Stat. Auth.: ORS Ch. 468
Hist: DEQ 15-1983, f. & ef. 8-26-83

Other Underground Injection Activities

340-44-055 (1) Any underground injection activity which may cause, or tend to cause, pollution of groundwater must be approved by the Director, in addition to other permits or approvals required by other federal, state, or local agencies.

(2) Except for construction and use of waste disposal wells, the Director may enter into an agreement with another state agency which stipulates that the agency's approval of a type of underground injection activity will also constitute his approval, provided he determines that their approval and control program contains adequate safeguards to protect groundwaters from pollution.

Stat. Auth.: ORS Ch. 468
Hist: DEQ 15-1983, f. & ef. 8-26-83