16.0 Water Quality Management Criteria for Developed Land

16.1 Introduction

Stormwater quality control is an integral part of any stormwater management system in the City of Greenwood Village (Village). The Major Drainageways, reservoirs, and wetlands in and near the Village are valuable resources, which must be protected against the adverse water quality effects of stormwater discharges.

The Village has adopted stormwater discharge water quality standards as described in Chapter 15.0. The purpose of this Chapter is to describe the types of facilities and the plans required by the Village.

The design of the facilities shall be in accordance with the criteria presented in the Structural Best Management Practices (BMPs) Chapter, Volume 3 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the Village are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. The guidelines are intended to serve as a minimum standard and are not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

16.2 Stormwater Quality Management Plans

A Stormwater Quality Management Plan shall be prepared as an integral part of all drainage studies, submitted to the Village. The purpose of the Stormwater Quality Management Plan will be to describe, in sufficient detail, the stormwater management improvements necessary to meet the water quality standards of the Village described in Chapter 15.0. The improvements shall include new facilities to be constructed, repairs to existing facilities, and the long-term maintenance activities necessary to keep the facilities fully functional. All water quality management facilities shall be located on the property on which the land development will occur unless approval is received from the City Manager or designee.

16.2.1 Stormwater Quality Management Plan Submission

The Stormwater Quality Management Plan shall be submitted in conjunction with all drainage studies. The Construction Drawings and Record Drawings shall include the improvements identified in the Final Drainage Study. For projects with a disturbed area greater than 1 acre, the

proposed Stormwater Quality Management Plan shall be certified by a professional engineer licensed in the State of Colorado using the following form:

> I hereby certify that this Stormwater Quality Management Plan for (name of site) was prepared by me or under my direct supervision in accordance with the Greenwood Village Drainage Criteria Manual.
>
> _____
> Signature
>
> _____
> Colorado License Number
>
> _____
> Seal and Date

The Stormwater Quality Management Plan shall also be certified by Owner of the property using the following form:

> I hereby certify that the stormwater management facilities proposed for (name of site) shall be constructed and maintained in accordance with the design presented in this Stormwater Quality Management Plan. I understand that the City of Greenwood Village does not and will not assume liability for the proposed stormwater management facilities.
>
> _____
> Signature
>
> _____
> Date

Separate certifications are not required if the Stormwater Quality Management Plan is submitted as a part of a drainage study.

16.2.2 Contents of Stormwater Quality Management Plan

The Stormwater Quality Management Plan shall include, as a minimum, the information shown in Table 16-1.

Table 16-1: Stormwater Quality Management Plan Checklist

Item
Engineer's Certificate
Owner's Certificate
1) General Location and Description
a. Location
i. Local streets within and adjacent to the development.
ii. Township, range, section, and ¼ section.
iii. Major Drainageways, drainage facilities, and wetlands near the development.
iv. Names of surrounding developments.
b. Description of Property
i. Area in acres.
ii. Ground cover (type of trees, shrubs, and vegetation).
iii. Major Drainageways, drainage facilities, perennial streams, and wetlands within the development.
iv. General project description and schedule.
v. Groundwater recharge areas and areas of high groundwater.
c. Receiving Waters
i. Existing water quality conditions of Major Drainageways and wetlands that will receive discharges from the property.
ii. Classified uses of Major Drainageways and wetlands that will receive discharges from the property.
iii. Water quality standards of major drainageways and wetlands that will receive discharges from the property.
2) Stormwater Quality Design Criteria
a. Regulations
i. Discussion of compliance with or deviation from this Drainage Criteria Manual.
b. Development Criteria Reference and Constraints.
i. Discussion of previous drainage studies for the property.
ii. Identify facility outlet design method.
iii. Identify hydraulic structure criteria used.
iv. Discussion and justification of other criteria or calculation methods used that are not presented in or referenced by this Drainage Criteria Manual.

Item
3) Stormwater Quality Facility Design
a. General Concept
i. Discussion of existing drainage patterns.
ii. Discussion of proposed drainage patterns.
iii. Discussion of the content of all tables, charts, figures, or drawings.
b. Specific Details
i. Discussion of each water quality treatment measure used to meet the requirements of this Drainage Criteria Manual.
ii. Discussion of facility design.
iii. Discussion of maintenance access to facilities.
4) Maintenance Plan
a. Maintenance Activities
i. Description of routine maintenance activities, including frequency, to maintain the water quality functions of the facilities.
ii. Description of extraordinary maintenance activities following a minor or major storm to maintain the water quality functions of the facilities.
b. Estimated Maintenance Costs
i. Cost estimate for each routine and extraordinary maintenance activity.
ii. Description of the methods by which maintenance costs will be paid, including assurances that sufficient funds will be available at all times.
5) Conclusions
a. Compliance with Standards
i. Drainage Criteria Manual.
ii. UDFCD Drainage Criteria Manual.
b. Stormwater Quality Management Concept
i. Effectiveness of facility design to control pollutants from runoff.
ii. Influence of facility design on the recommendations of other previously approved drainage studies.
6) References
a. Reference all criteria and technical information used.
7) Appendices
a. Pollutant Computations
i. Calculation of average annual pollutant loads without control measures for each land use type and for the entire area proposed for development.
ii. Total phosphorus removal required.

Item
b. Control Measure Computations
i. Net phosphorus into each control measure.
ii. Control measure effectiveness.
iii. Net phosphorus out of each control measure.
iv. Total phosphorus removal at discharge location.
8) Maps
a. General Location Map
i. A general location map showing the general drainage patterns around the property. The map should be at a scale of 1” = 1000’ or 2000’ and show the path of all drainage to and from any off-site basins. The map shall identify any development or facilities (i.e., irrigation ditches, existing flood attenuation facilities, culverts, and storm sewers) along the entire path of the off-site and on-site drainage.
b. Facility Plan
i. Plan of the proposed development shall be provided at a scale of 1” = 20’ to 1” = 200’ on 24” x 36” sheets.
ii. A topographic map shall be provided with two-foot existing and proposed contours tied to the Greenwood Village “Control Diagram” (Figure 2-1). The topographic map shall extend a minimum of 50-feet beyond the property lines.
iii. Property lines, easements, and purposes of easements.
iv. Streets.
v. Existing drainage facilities and structures, irrigation ditches, Major Drainageways, and existing wetlands. All pertinent information such as materials, size, shape, slope and location shall also be included.
vi. Overall drainage area boundary and drainage sub-area boundaries.
vii. Proposed type of street flow, roadside ditches, gutters, and cross pans.
viii. Proposed drainage structures and open channels.
ix. Routing and accumulation of phosphorus at each control measure.
x. Details of control measures.
xi. Location and elevations of all floodplains affecting the property.

When the Stormwater Quality Management Plan is included as part of a drainage study, the additional information that is required above can be incorporated into the appropriate sections of the drainage study.

16.3 Potential Pollutant Loads

The first step in the preparation of a Stormwater Quality Management Plan is to estimate the potential average total annual pollutant load for the proposed land use. Once this load has been estimated, plans can be prepared to remove 60% of the total annual phosphorus load to meet the criteria of this Drainage Criteria Manual.

The average total annual pollutant load shall be estimated using the event mean concentration (EMC) for the pollutant of interest and the annual runoff volume. The EMC for phosphorus and different land uses is shown in Table 15-2. The runoff volume shall be calculated for the various major soil types and proposed impervious area using Figure 16-1. Figure 16-1 was derived by analyzing the distribution of storm events in an average year, estimating the runoff for each event based on Figures 6-2 and 6-3 and summing the runoff from each event for the entire year. The average total annual phosphorus load shall be estimated using Equation 16-1 as follows:

$$\text{Total P} = 0.2266\ (\text{EMC})\ (\text{R})\ (\text{A}) \qquad (16\text{-}1)$$

Where: EMC = EMC for phosphorus from Table 15-2
R = runoff volume in inches from Figure 16-1
A = tributary area in acres

16.4 Effectiveness of Control Measures

A wide range of management options can be selected to meet the stormwater management goals of the Village. The optimum combination of management options can vary substantially from site to site based on local soil conditions and the proposed land use. It is likely that some trial and error will be required in the review of options before a preferred plan can be prepared. The following Sections provide guidance on the effectiveness of removal for water quality facilities.

The options included in the following Sections are not intended to be exclusive. Other options may be available and may receive favorable review from the Village. It is the burden of the applicant to provide credible evidence concerning the effectiveness and reliability of the option.

In order to calculate the effectiveness of a proposed design in terms of the percent removal of the annual total phosphorus load, the removal percentage for each facility must be combined with the percentage that is captured by the facility. This calculation is illustrated by equation 16-2:

$$\text{Annual \% Total P Removed} = (\text{Annual \% Total P Captured})\ (\text{\% Removal Total P}) \qquad (16\text{-}2)$$

Where: Annual % Total P Captured is selected from Figures 6-5, 6-6, or 6-7 based on selected design storm, soil type, and percent impervious of basin discharging into facility.
% Removed Total P is selected from the following Sections for each facility.

For basins with multiple land uses, multiple soil types, and multiple percent impervious areas, area-weighted values can be used in Equation 16-2.

16.4.1 Minimization of Impervious Area

The peak rate and volume of runoff from a site can be significantly reduced by reducing the amount of impervious area. Several options are available for reducing impervious area, including innovative site layouts that minimize paved areas, use of heavily vegetated areas in landscape plans, and inclusion of porous block pavement in parking areas or driving lanes.

The management techniques are intended to reduce the runoff that occurs from a site. For Development projects, the techniques do not contribute directly to a percent reduction for the purpose of literally meeting the Village's water quality goals, but the techniques do improve the economics of the overall management system by reducing the size of the facilities needed to achieve the required percent reductions. For Redevelopment Projects, the techniques do contribute directly to a percent reduction in meeting the Village's water quality goals when the amount of impervious area is reduced as compared to the existing conditions. This can have a significant impact on improving the economics of the overall management system by reducing the size of the additional facilities needed to achieve the required pollutant reductions.

Another technique that relates to management of impervious areas is to reduce the "directly connected" impervious areas. This is a different management technique than reducing the impervious area itself. It includes directing the runoff from impervious areas through buffer strips, into grass swales, or into infiltration basins before it is discharged to other drainage facilities. These techniques are described in more detail in the Structural BMPs Chapter, Volume 3 of the UCFCD Drainage Criteria Manual.

16.4.2 Extended Detention Facilities

Stormwater storage facilities can be designed to achieve the multiple purposes of attenuation of peak flood discharges and water quality management. The capacity of the detention facility can be expanded to provide temporary storage space for the capture of the smaller, non-flood storms that carry the majority of the annual pollution load.

16.4.2.1 Design of Extended Detention Facilities

As discussed in Chapter 13.0, water quality treatment capacity must be provided in addition to the capacity for flood attenuation purposes with no overlap. There is no overlap allowed because the stormwater must be held within the water quality portion of the facility for an extended period of time and that portion of the facility may still be full, or nearly full, at the onset of flood-related runoff event. A reserve capacity equal to 20 percent of the water quality management volume must also be provided for sediment storage. This will provide space for the accumulation of sediment and flexibility for its removal when required.

16.4.2.2 Extended Detention Facility Phosphorus Removal

Extended detention facilities meeting the design criteria in Section 16.4.2.1 will remove 65% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 65% removal rate.. . The. The annual
The water quality capture volume (WQCV) is based on the design storm, not the WQCV from Volume 3 of the UDFCD Drainage Criteria Manual.

16.4.3 Retention Ponds for Water Quality

A retention pond has a permanent pool of water that is mixed with stormwater during storm events. Retention ponds are designed to capture and hold a volume of runoff equal to the design storm selected for water quality control. The drain time for the captured volume is typically 12 hours. After 12 hours, the only volume of water remaining in the facility is the permanent pool.

16.4.3.1 Design of Retention Ponds

Retention ponds are more efficient than extended detention facilities for water quality treatment. Care must be taken, however, in the design of such facilities to be sure that an adequate water supply is available to maintain the permanent pool, which can attract and support aquatic life and waterfowl. The aesthetic considerations of the permanent pool must also be addressed. Landscaping with transitional wetland vegetation and the potential maintenance requirements for removing sediment and excess algae growth from the permanent pool must also be considered.

Retention ponds are typically more effective in removing total phosphorus because during the water quality design storm event, a portion or all of the permanent pool is displaced by the runoff and mixes with the runoff during the storm event. The time interval between storm events can improve the quality of the permanent pool because of biological uptake of soluble phosphorus by plants and algae and the additional detention time for settling of particulate phosphorus. The effectiveness of these processes in removing total phosphorus can be in the range of 10 to 30 percent greater than an extended detention facility with the same water quality capture volume.

16.4.3.2 Retention Pond Phosphorus Removal

Retention ponds meeting the design criteria in Section 16.4.3.1 will remove 75% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 75% removal rate.

The WQCV is based on the design storm, not the WQCV from Volume 3 of the UDFCD Drainage Criteria Manual.

16.4.4 Grass-Lined Swales and Roadside Ditches

Grass-lined swales and roadside ditches can be an effective water quality control design feature in a stormwater management system. Grass-lined roadside ditches can be used as an alternative to curb and gutter. Berms or check dams can be installed in swales and roadside ditches perpendicular to the flow as needed to slow it down and to encourage settling of sediment, filtration by the vegetation, and infiltration. The potential also exists for the development of wetland vegetation in the swales and ditches if there is a reasonably persistent base flow.

A grass-lined swale can also be more aesthetically pleasing and less expensive to construct than a concrete or rock-lined drainage channel. The Village strongly encourages the use of grass-lined swales and roadside ditches because of their aesthetic appearance, their ability to provide some flood attenuation due to slower flow velocities, and their effects on stormwater quality.

16.4.4.1 Design of Grass-Lined Swales and Ditches

There is a wide range of design consideration for an effective grass-lined swale or roadside ditch. It must effectively carry both the flood flow as well as the water quality design storm flow. The most critical parameters in a design flood flow typically include non-erosive velocities and adequate flow capacity. Chapter 7.0 discusses typical design criteria required for open channels. For water quality control, the critical parameters include minimum flow lengths, minimum bottom area for filtration by vegetation, maximum flow velocity, and maximum flow depth.

The channel must be designed to support a hearty turf grass cover or wetland vegetation to be effective in removing pollutants. In some cases, a permanent irrigation system may be required to sustain a hearty turf grass cover.

All grass-lined swales or roadside ditches used for meeting total phosphorus removal goals shall meet the following design criteria for water quality design storm conditions:

1) Maintain irrigated turf grass at 2 to 4 inches tall and non-irrigated native grass at 6 to 8 inches tall,
2) Assume Manning's $n \geq 0.035$ for turf grass or higher as appropriate for wetland vegetation,
3) Maximum velocity for water quality storm is ≤ 1.5 feet per second,
4) Overall swale length ≥ 900 feet or maximum extent practicable,

Refer to Chapter 8.0 for flow velocity limits for design flood conveyance purposes for ditches.

16.4.4.2 Grass-Lined Swales and Ditches Phosphorus Removal

Grass-lined swales and ditches meeting the design criteria summarized in Section 16.4.4.1 will remove 15% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 15% removal rate.

16.4.5 Constructed Wetlands

The Village strongly encourages the inclusion of artificial or constructed wetlands as an integral part of an urban drainage system design.

Constructed wetlands differ from "natural" wetlands because they are constructed for specific purposes such as stormwater quality enhancement. In some cases it may be possible to enlarge a natural wetland to perform this same function. This, however, would likely require both federal and state permits and the applicant is responsible for obtaining the required permits in accordance with Chapter 14.0. The Village also requires the applicant to obtain the necessary federal and state permits for isolated constructed wetlands. The maintenance of the water quality functions of a constructed wetland will likely require occasional dredging and other maintenance activities. These maintenance activities must be specified and allowed by the permit.

16.4.5.1 Constructed Wetland Design

Constructed wetlands can be effectively integrated into extended detention ponds, retention ponds, and open channels. The primary drawback to wetlands is the need for a virtually continuous presence of surface water or groundwater to sustain the wetland vegetation in a healthy state between storm events.

16.4.5.2 Constructed Wetland Phosphorus Removal

Significant research has been completed on the long-term effectiveness of wetland systems for total phosphorus removal. The art and science of effective wetland design is undergoing rapid change. It can be expected that significant advances in this area will be made over then next several years. The Village will consider the merits of these changes and their applicability to a specific proposal by an applicant on a site by site basis. In the interim, the Village will use the following guidelines for the review and approval of wetland designs.

An open channel wetlands will function in a manner similar to grass-lined swales for total phosphorus removal. The same design criteria for the grass-lined swales included in Section 16.4.4.1 will apply to open channel wetland designs. For these design criteria, the total phosphorus removal will be assumed to be 40% for the design storm condition. The annual phosphorus removal can be estimated using Equation 16-2 with a 40% removal rate.

The retention pond wetlands will function in a manner similar to an emergent marsh or a subsurface flow wetland. The key parameters for determining the effectiveness of such a design for the removal of total phosphorus are the annual flow rates and the retention time for the stormwater in the wetland area. In order to provide the maximum effective total phosphorus removal, all ponds with wetlands shall be designed for a 24-hour drain time of the water quality capture volume.

A first-order model has been established for estimating the performance of a retention pond wetland based on water and phosphorus mass balances with some acknowledgement of site-specific factors. The model describes the long-term removal rate which will typically require a few years of adaptation by the plants to local conditions before the long-term steady-state removal rates can be achieved. This model is represented by Equation 16-3:

$$\ln\left(\frac{C_O}{C_i}\right) = -\frac{k}{q} \qquad (16\text{-}3)$$

where: C_i = inflow total phosphorus concentration
C_o = outflow phosphorus concentration
K = 38 ft/year.
q = effective design storm flow rate, feet per year = d_e/t_e
d_e = equivalent depth, feet = V_{ar}/A_w
t_e = equivalent exposure time, 0.10 years
V_{ar} = volume of annual runoff, acre feet
A_w = area of wetland, acres

The equivalent exposure time (t_e) of 0.10 years is based on 35 runoff events per year times the average duration, 24 hours, that each runoff event is exposed to the wetland area.

16.4.6 Infiltration

Infiltration of stormwater into the ground is potentially an effective stormwater quality management tool. Most soils have a high absorption capacity for dissolved phosphorus and excellent physical filtration characteristics for particulate phosphorus. The on-site storage facilities and open grass-lined swales that are used for the attenuation of flood discharges and to provide water quality enhancement through settling and filtration by the vegetation, can provide further water quality enhancement by infiltration of a portion of the stormwater runoff.

16.4.6.1 Infiltration Design

The rate at which stormwater can infiltrate into the ground is limited by the soil infiltration rate (Q_i) or the rate at which it can move laterally through the soil (Q_s) once it has infiltrated into the ground, whichever is less. This is shown schematically in Figure 16-2.

The Q_i is a function of the soil infiltration rate and the surface area available for infiltration. The infiltration rate is dependent upon soil type and the antecedent moisture conditions in the soil at the beginning of the runoff event. The Q_i can be reduced substantially over an extended period of time if the soil becomes plugged by clay and silt sized particles. The Q_s is a function of the saturated hydraulic conductivity of the soil, the slope of the saturated soil water surface and the available cross sectional area through which the water can flow. Both Q_i and Q_s would be the same if the following conditions were true:

1) The soil is homogeneous throughout,
2) a zero head of water is maintained at the soil surface,
3) there is no lateral movement of water,
4) the surface soil does not restrict water movement, and
5) there is atmospheric pressure at all times at the base of the downward advancing water front.

These conditions might occur in sandy soils where the water table or an impermeable layer is very deep. These conditions rarely occur in the Village, thus it is usually necessary to estimate both Q_i and Q_s to determine the limiting rate. In most cases, Q_s will be the limiting rate.

For preliminary planning purposes, assumed values can be used for the hydraulic conductivity (K), groundwater gradient (I), depth to groundwater, and infiltration rates. The following is a summary of these assumptions.

1) For subsurface flow rate calculations, the hydraulic conductivity (K) can be based on the published ranges for hydraulic conductivity for the applicable soil type.
2) Groundwater gradient (I) can be assumed to be equal to the general topographic slope of the area as shown on the Village topographic maps.
3) Depth to groundwater can be assumed to be four feet.
4) The infiltration rate can be assumed to be the same as the hydraulic conductivity rate.

The Village requires field tests to confirm infiltration rates, hydraulic conductivity rates, depth to groundwater, and groundwater slope for any infiltration credits included in a Final Drainage Plan. Methods for field testing infiltration rates and hydraulic conductivity rates are described in the U.S. Department of the Interior Bureau of Reclamation, Drainage Manual. Factors influencing infiltration rates include the structure of the ground surface, the type and condition of vegetation, soil moisture, the type of underlying soil, and the depth to groundwater.

Each of these factors shall be considered when completing infiltration field measurements. Field measurements should be completed in areas were conditions are as similar as possible to the expected future detention facility bottom conditions. Unless there is a good reason to do otherwise, the lowest measured infiltration rates should be used for the basis of design. Factors influencing hydraulic conductivity field tests include soil type, soil density, bore hole wall disturbance, and soil type layering.

Each of these factors shall be considered when completing hydraulic conductivity field measurements. Field measurements should be completed in areas were conditions are as similar as possible to the expected future conditions. Unless there is a good reason to do otherwise, the lowest hydraulic conductivity rate tested should be used for design calculations.

Depth to water can be measured by installing piezometers or observation holes. Installation of piezometers and observation holes is described in the U.S. Department of the Interior Bureau of Reclamation, Drainage Manual. Three or more piezometers or observation holes are required at each detention facility location and piezometers or observation holes must be located at least 100 foot intervals in an open channel to determine groundwater slopes. Field tests must be completed as necessary to determine the depth to the first impermeable layer encountered under the proposed infiltration area.

16.4.6.2 Infiltration Phosphorus Removal

The total phosphorus removal for infiltrated stormwater shall be assumed to be 100% for Type I (clay) and Type II (clay loam) soils and 50% for Type III (sandy) soils. The detention duration for calculating the infiltration volume shall be 40 hours for an extended detention facility, 24 hours for a retention pond, and 1 hour for an open channel. A modification of Equation 16-2 shall be used to estimate the total annual phosphorus removal rate:

$$\text{Annual \% Total P Removed} = (\text{\% of Design Storm Infiltrated})\,(\text{Annual \% Total P Captured})\,(\text{\% Removal Total P}) \qquad (16\text{-}2a)$$

where: % of design storm infiltration is calculated based on the limiting value (Q_i or Q_s) for the required infiltration duration.

The application of equation 16-2a implicitly assumes that the infiltration rate can be sustained indefinitely at the facility. This is unlikely due to plugging of the soil by the clay and silt in the infiltrated water. The Village will not accept this assumption unless the plan includes a reliable maintenance program for maintaining the assumed infiltration rate. The proposed plan must also evaluate potential damage to streets, sidewalks and other structures which may be caused by the infiltrated water.

16.4.7 Filtration

The use of sand and other media filters are gaining acceptance in the field of stormwater quality management. Considerable field testing of filtration devices has occurred over several years and the results have proven that a properly designed filter can provide good performance with reasonable maintenance.

The Village strongly encourages the use of constructed filters as a part of the stormwater management system. The primary concern with filters is the maintenance required to sustain the design filtration rate. Excess sediment accumulation can significantly reduce filtration capacity and the media must be cleaned or replaced. Sand and other open media filters can be used only if they are preceded by an extended detention pond, retention pond, or wetlands to remove at least 50 percent of the total sediment load for the design water quality storm.

16.4.7.1 Filter Design

All filters shall be designed to filter the peak rate of discharge from the upstream extended detention pond, retention pond, or wetlands for the water quality design storm. Provisions shall be included in the design to bypass all flows greater than the design flow rate around the filter.

Other well-designed systems using other media and configurations can be accepted by the Village. The Village strongly encourages filter designs that use landscaped earthen berms to contain the media and landscaping designed to screen the visual impact of a media surface.

16.4.7.2 Filter Phosphorus Removal

The total phosphorus removal for a sand filter system shall be assumed to be 50% of the total phosphorus not removed by the upstream extended detention pond, retention pond, or wetlands. The annual phosphorus removal can be estimated using Equation 16-2 with a 50% removal rate. The removal rates for other media will be determined on a case-by-case basis.

16.4.8 Mechanical Stormwater Treatment Systems

Mechanical systems are also available for treatment of stormwater runoff, including swirl separators and cartridge filters. Systems of this nature usually have higher capital costs and require a higher degree of maintenance than ponds and open channel systems. The applicant, however, may prefer these systems for commercial properties where land may be at a premium.

The Village will consider such systems on a case-by-case basis. The long-term maintenance costs and the proven reliability of these systems will be major factors to be included in the review of these systems by the Village.

16.4.9 Grass Buffers

Grass buffers can be an effective water quality control feature in a stormwater management system and are discussed in detail in Volume 3 of the UDFCD Drainage Criteria Manual.

A grass buffer can also be aesthetically pleasing and incorporated into the landscape design for the site. The Village encourages the use of grass buffers in stormwater management designs because of their aesthetic appearance, their ability to provide some flood attenuation due to slower flow velocities, and the treatment of stormwater runoff.

16.4.9.1 Design of Grass Buffers

There is a wide range of design consideration for an effective grass buffer. The critical parameters include minimum flow lengths and widths, maximum slope, and flow distribution. The grass buffer must be designed to support a hearty turf grass to be effective in removing pollutants. A permanent irrigation system may be required to sustain a hearty turf grass cover.

All grass buffers used as a part of a stormwater management system for meeting total phosphorus removal goals shall maintain irrigated turf grass at 2 to 4 inches tall and non-irrigated native grass at 6 to 8 inches tall.

16.4.9.2 Grass Buffer Phosphorus Removal

Grass buffers meeting the design criteria summarized in Subsection 16.4.9.1 will remove 10% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 10% removal rate.

16.4.10 Porous Landscape Detention

Porous Landscape Detention can be an effective water quality control design feature in a stormwater management system with limited opportunities for larger facilities and are discussed in detail in Volume 3 of the UDFCD Drainage Criteria Manual.

Porous Landscape Detention can also be aesthetically pleasing and incorporated into the landscape design for the site. The Village encourages the use of porous landscape detention in stormwater management designs because of their aesthetic appearance and the treatment of stormwater runoff.

16.4.10.1 Design of Porous Landscape Detention

There is a wide range of design consideration for an effective porous landscape detention. One critical parameter is accurately determining the tributary area to ensure that design storm that is selected is appropriate for the size of the facility.

The porous landscape detention must be designed to support a hearty turf grass to be effective in removing pollutants and minimize clogging. In some cases, a permanent irrigation system may be required to sustain a hearty turf grass cover.

Porous Landscape Detention used as a part of a stormwater management system for meeting total phosphorus removal goals shall maintain irrigated turf grass at 2 to 4 inches tall and non-irrigated native grass at 6 to 8 inches tall.

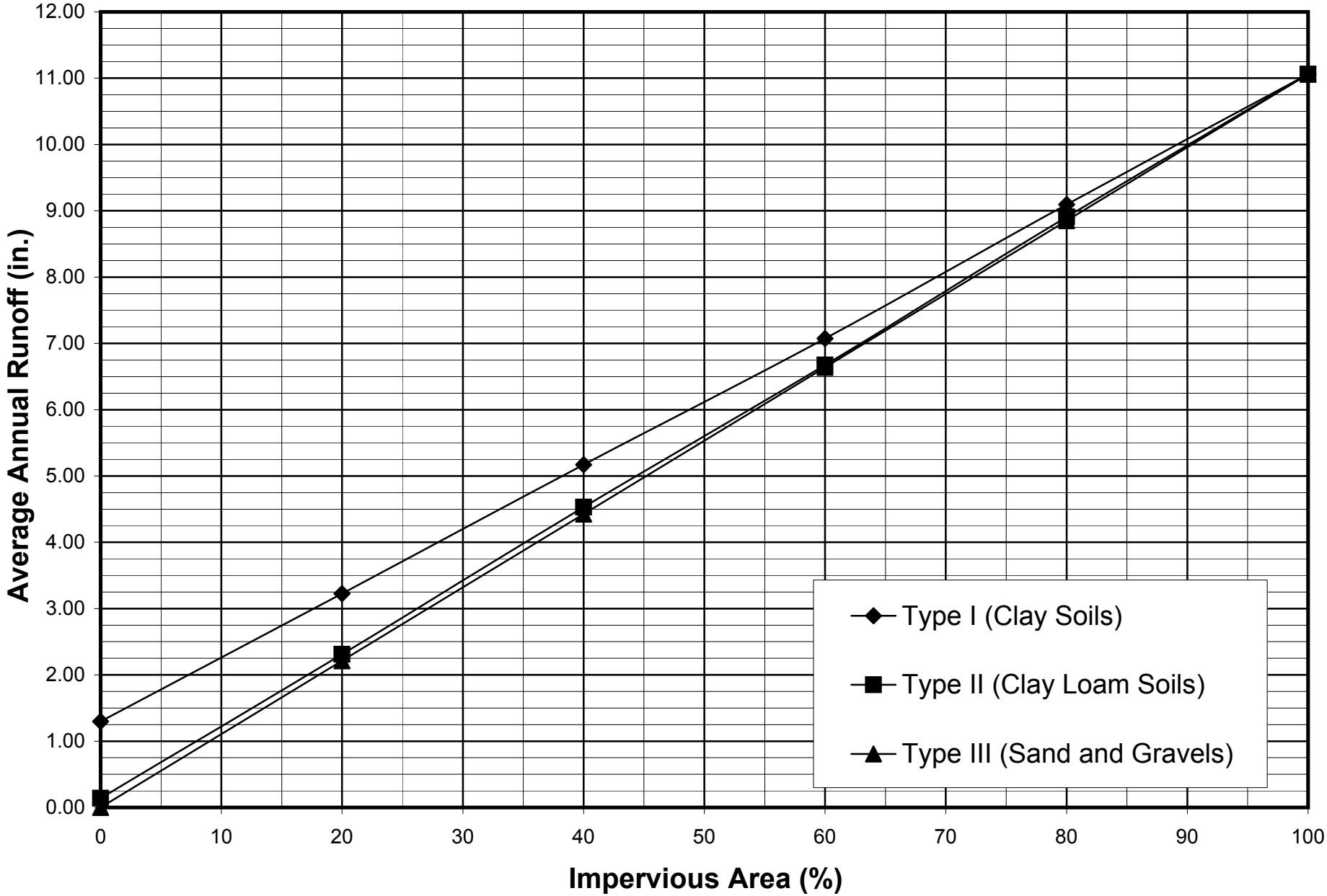
16.4.10.2 Porous Landscape Detention Phosphorus Removal

Porous landscape detention meeting the design criteria summarized in Subsection 16.4.10.1 will remove 60% of the total phosphorus for the selected design storm. The annual phosphorus removal can be estimated using Equation 16-2 with a 60% removal rate.

Insert Figures 16-1 and 16-2

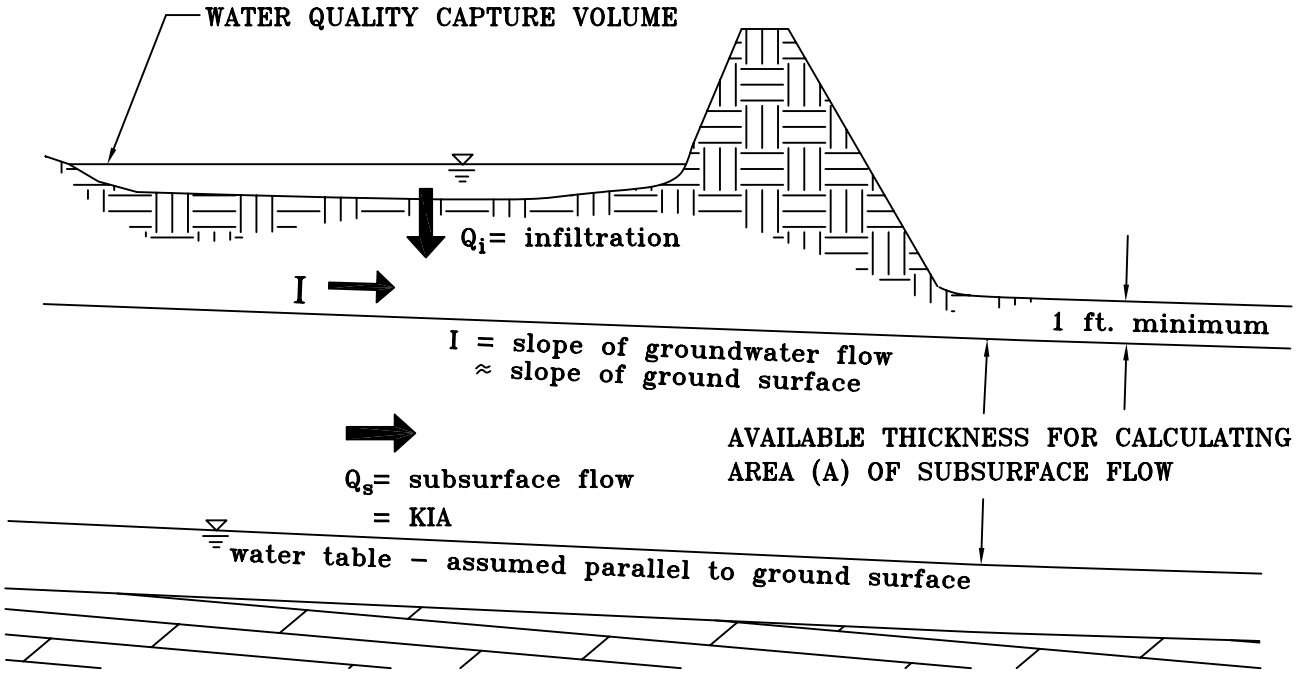
16.0 WATER QUALITY MANAGEMENT CRITERIA FOR DEVELOPED LAND 1

16.1 INTRODUCTION.....1
16.2 STORMWATER QUALITY MANAGEMENT PLANS 1
16.2.1 Stormwater Quality Management Plan Submission.....1
16.2.2 Contents of Stormwater Quality Management Plan.....2
16.3 POTENTIAL POLLUTANT LOADS 6
16.4 EFFECTIVENESS OF CONTROL MEASURES.....6
16.4.1 Minimization of Impervious Area.....7
16.4.2 Extended Detention Facilities 7
16.4.2.1 Design of Extended Detention Facilities.....7
16.4.2.2 Extended Detention Facility Phosphorus Removal.....8
16.4.3 Retention Ponds for Water Quality 8
16.4.3.1 Design of Retention Ponds.....8
16.4.3.2 Retention Pond Phosphorus Removal 8
16.4.4 Grass-Lined Swales and Roadside Ditches.....9
16.4.4.1 Design of Grass-Lined Swales and Ditches 9
16.4.4.2 Grass-Lined Swales and Ditches Phosphorus Removal.....9
16.4.5 Constructed Wetlands 10
16.4.5.1 Constructed Wetland Design 10
16.4.5.2 Constructed Wetland Phosphorus Removal.....10
16.4.6 Infiltration.....11
16.4.6.1 Infiltration Design.....11
16.4.6.2 Infiltration Phosphorus Removal 13
16.4.7 Filtration.....13
16.4.7.1 Filter Design 14
16.4.7.2 Filter Phosphorus Removal.....14
16.4.8 Mechanical Stormwater Treatment Systems 14
16.4.9 Grass Buffers 14
16.4.9.1 Design of Grass Buffers.....14
16.4.9.2 Grass Buffer Phosphorus Removal 15
16.4.10 Porous Landscape Detention 15
16.4.10.1 Design of Porous Landscape Detention 15
16.4.10.2 Porous Landscape Detention Phosphorus Removal.....15

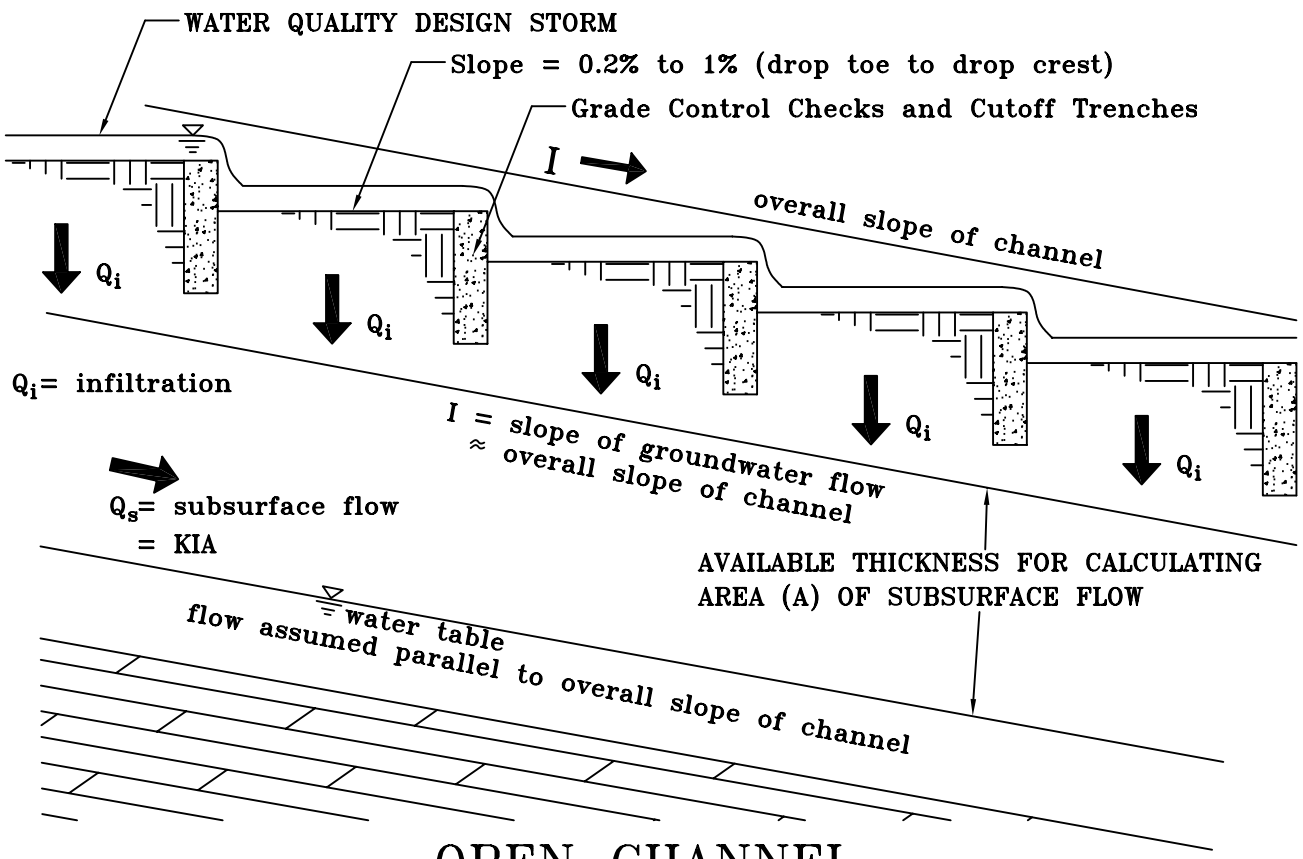


Greenwood Village
October 2003

Figure 16-1
Annual Runoff
for Greenwood Village



STORAGE FACILITY



OPEN CHANNEL

Greenwood Village
Stormwater Quality Control
October 2003

Figure 16–2
Schematic of Infiltration
and Subsurface Flow

FIG16–2.dwg

P:\97003\027 Drainage Code Update 2003\Figures\FIG 16-2.dwg, Layout1, 10/15/2003 11:51:15 AM, 1:0.945309