Spokane Regional Stormwater Manual

April 2008

CITY OF SPOKANE

CITY OF Spokane Valley

SPOKANE COUNTY

SPOKANE REGIONAL STORMWATER MANUAL

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Prepared by:

Spokane County
1026 W. Broadway Avenue
Spokane, Washington 99260
(509) 477-3600

City of Spokane
808 W. Spokane Falls Blvd.
Spokane, Washington 99201
(509) 625-6700

City of Spokane Valley
11707 E. Sprague Avenue
Spokane Valley, Washington 99206
(509) 921-1000

A special thanks to the members of the committee who dedicated their time and energy in the development of the manual:

Gloria Mantz, City of Spokane Valley

Kris Becker, City of Spokane

Gary Nelson, City of Spokane

Mike Yake, City of Spokane

Colleen Little, Spokane County

Matt Zarecor, Spokane County

Spokane County, City of Spokane, City of Spokane Valley
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GLOSSARY

DEFINITIONS

All Weather Drivable Surface—Any roadway, driveway, alley or parking lot surface paved with crushed stone, asphalt, concrete or other pervious or impervious material in a manner that will support the weight of anticipated vehicular traffic in all weather conditions and minimize the potential for ruts, potholes or pooling of water.

Antecedent Runoff Condition—The degree of wetness of a watershed or within the soil at the beginning of a storm.

Aquifer—A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Arterial—A road or street primarily for through traffic. A major arterial connects an interstate highway to cities and counties. A minor arterial connects major arterials to collectors. A collector connects an arterial to a neighborhood or local access roads. A local access road connects individual homes to a collector.

Average Daily Traffic—The expected average number of vehicles using a roadway in a day.

Backwater—An unnaturally high stage in a stream caused by obstruction or confinement of flow, as by a dam, a bridge or a levee. Its measure is the excess of unnatural over natural stage, not the difference in stage upstream and downstream from its cause.

Bank—Lateral boundary of a stream; limits confining water flow.

Base Flood—The flood having a 1% chance of being equaled or exceeded in any one year.

Basic Requirement—Any of eight stormwater management measures that must be completed for new development and redevelopment projects that meet the regulatory threshold, unless exempted in this Manual.

Basin (Drainage Basin)—The portion of the earth’s surface upon which falling precipitation runs off to a common point. Often referred to as a drainage basin.

Bedrock—The more or less solid rock in place on or beneath the surface of the earth. It may be soft, medium, or hard and have a smooth or irregular surface.

Berm—A constructed barrier of compacted earth, rock or gravel. In a stormwater facility, a berm may serve as a vertical divider, typically built up from the bottom.

Best Management Practices—The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices approved by Ecology that, when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

Buffer (or Buffer Area or Buffer Zone)—The area adjacent to a critical or sensitive area established to ensure protection of the critical area by separating incompatible uses from the critical or sensitive area. Buffer locations and limits are described by federal, state or local governments.

Capacity—The effective carrying ability of a drainage structure. Generally measured in cubic feet per second.

Catch Basin—A drainage structure that collects water from the side or through a grating.

Cation Exchange Capacity—The amount of exchangeable cations that a soil can absorb at pH 7.0.

Channel—A depression in the earth's surface which conveys water from one location to another. This may be either a natural facility or man made.

Channel Protection—Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, or biological community.

Check Dam—Small dam constructed in a gully or other small watercourse to decrease the stream flow velocity, minimize channel scour, and promote deposition of sediment.

Cleanout—An access opening to a storm drain system. Usually consists of a manhole shaft, a special chamber or an opening into a shallow culvert or drain.

Clear Zone—An unobstructed, relatively flat area provided beyond the edge of a traveled roadway for the recovery of errant vehicles.

Common Plan of Development or Sale- "A site where multiple separate and distinct construction activities may be taking place at different times on different schedules, but still under a single plan. Examples include phased projects and projects with multiple filing or lots, even if the separate phases or filing/lots will be constructed under separate contract or by separate owners (e.g. development where lots are sold to separate builders); a development that may be phased over multiple years, but is still under a consistent plan for long term development; and projects in a contiguous area that may be unrelated but still under the same contract, such as construction of a building extension and a new parking lot at the same facility. If the project is part of a common plan of development or sale, the disturbed areas of the entire plan shall be used in determining permit requirements.

Concentrated Flow—Flowing water that has been accumulated into a single fairly narrow stream.

Concept Drainage Report—A preliminary drainage report to demonstrate that the proposed drainage facilities generally can meet the stormwater requirements for certain land use actions or land development permits. They are needed for sites that have limiting layers or shallow groundwater or are in a critical area.

Conveyance System—The drainage facilities, both natural and man-made, that collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes and wetlands. The man-made elements of the conveyance system include gutters, ditches, pipes, channels, and most detention facilities.

Critical Area—Any of the following areas and ecosystems: wetlands, areas with a critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, and geologically hazardous areas.

Critical Flow Depth—The depth of water in a conduit at which the maximum flow takes place, if the conduit is on the critical slope with the water flowing at its critical velocity and there is an adequate supply of water. The depth of water flowing in an open channel or a conduit partially filled for which the velocity head equals one-half the hydraulic mean depth.

Critical Slope—The slope at which the maximum flow will occur at the minimum velocity.

Critical Velocity—Mean velocity of flow in channel when flow is at critical depth.

Culvert—A conduit for allowing water to pass under a roadway. A culvert differs from a bridge in size.

Design Frequency—The recurrence interval for hydrologic events used for design.

Design Storm—That storm that generates the amount of runoff that drainage facilities are designed to handle. This storm is selected for design on the basis of its probable recurrence.

Detention—The release of stormwater runoff from a site at a slower rate than it is collected by the stormwater facility system, the difference being held in temporary storage.

Detention Facility—An above-ground or below-ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater.

Design Deviation—An administrative approval of design elements that do not conform to or are not explicitly addressed by this Manual.

Development—Any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials located within the area of special flood hazard.

Discharge—The volume of water flowing out of a drainage structure or facility.

Dispersion—Release of surface stormwater runoff from a drainage facility system such that the flow spreads over a wide area, located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

Ditch—A long narrow excavation dug in the earth for drainage with a top width of less than 10 feet at design flow.

Diversion—The change in character, location or direction of flow of a natural drainage course.

Down-Gradient—When used in this manual if may refer to either downstream (surface) or down-gradient (sub-surface) or both.

Drain—A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or groundwater.

Drainage—(1) The process of removing surplus ground or surface water by artificial means. (2) The manner in which the waters of an area are removed. (3) The area from which waters are drained; a drainage basin.

Drainage Basin—The portion of the earth's surface upon which falling precipitation flows to a common point.

Drainage Submittal—The submittal of documentation including narrative, basin maps, plans, calculations and other supporting documentation to demonstrate that a proposed project will adequately treat and dispose of stormwater.

Drywell—A well installed above the water table so that its bottom and sides are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface.

Easement—A right to use the land of others. The right may be from the common law or may be acquired, usually by purchase or condemnation and occasionally by prescription or inverse condemnation. The right is not exclusive, but subject to rights of others in the same land, the lesser right being subservient to a prior right which is dominant. Easements for drainage may give rights to impound, divert, discharge or concentrate surface flow, extend pipelines, deposit silt, erode, scour, or any other necessary consequence of a development.

Energy Dissipation—Use of a structure to slow the flow of water and reduce the erosive forces present in a rapid-flowing body of water.

Engineer—Professional engineer, currently licensed in the State of Washington

Erosion—The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep.

Erosion and Sediment Control Facility—A drainage facility designed to hold surface and stormwater runoff for a period of time to allow sediment contained in the runoff to settle out.

Erosion and Sedimentation Control—Any temporary or permanent measures taken to reduce erosion, control siltation and sedimentation, and ensure that sediment-laden water does not leave a site.

Existing Condition—The site condition prior to development; not necessarily the pre-developed condition.

Floodplain- An area determined by the Federal Emergency Management Agency (FEMA) to have a one percent chance of flooding in any given year.

Floodway—The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

Flow—The movement of water, silt, sand, etc; discharge; total quantity carried by a stream.

Freeboard—The distance between the normal operating level and the top of the sides of an open conduit, the crest of a dam, etc., left to allow for wave action, floating debris or any other condition or emergency, without overtopping the structure.

Freeways—Fully controlled and partially controlled limited access highways, located either inside or outside the urban growth area delineated by a local jurisdiction.

Geotechnical Engineer—Professional engineer, currently licensed in the State of Washington, specializing in geotechnical engineering.

Groundwater—Water in a saturated zone or stratum beneath the land surface.

Groundwater recharge—Inflow to a groundwater reservoir or aquifer.

Groundwater table—The free surface of the groundwater, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

Head—An available force equivalent to a certain depth of water. This force is the motivating force in the movement of water. The height of water above any point or plan or reference. Used also in various compounds, such as energy head, entrance head, friction head, static head, pressure head, lost head, etc.

High-ADT Roadway—Any road with an average daily traffic (ADT) greater than 30,000 vehicles per day.

High-Use Site—Sites that generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil and/or other petroleum products.

Hydraulic Grade Line—A line that represents the relative force available due to the potential energy available. This is a combination of energy due to the height of the water and the internal pressure. In any open channel, this line corresponds to the water surface. In a closed conduit, if several openings were placed along the top of the pipe and an open tube were inserted, a line connecting the water surface in each of these tubes would represent the hydraulic grade line.

Hydraulic Jump—Transition of flow from a rapid state to a tranquil state; rise in elevation of liquid surface. Sudden transition from supercritical flow to the complementary subcritical flow, conserving momentum and dissipating energy.

Hydraulic Radius—The right cross-sectional area of a stream of water divided by the length of that part of its periphery in contact with its containing conduit; the ratio of area (A) to wetted perimeter (P): $R = A/P$

Hydraulically Connected—Impervious areas from which stormwater flows directly onto another impervious area without traveling over a pervious area. May include driveway or sidewalk areas adjacent to curbs from which stormwater collects in the gutter.

Hydrograph—A graph showing stage, flow, velocity or other properties of water with respect to time.

Hydrologic Soil Groups—A soil classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one of four groups (A, B, C, or D) based on infiltration rate and other properties.

Hydrology—The science dealing with the occurrence and movement of water upon and beneath land areas of the earth. Overlaps and includes portions of other sciences such as meteorology and geology. The particular branch of Hydrology that the engineer is generally interested in is surface runoff, which is the result of excessive precipitation.

Impervious Surface—A hard surface area that either prevents or retards the entry of water into the soil mantle. Common impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, packed earthen materials and oiled, macadam or other surfaces that impede the natural infiltration of stormwater.

Infiltration—The passage of water through the soil surface into the ground.

Initial Abstraction—The sum of all water losses before runoff begins, including retention in surface depressions, interception by vegetation, evaporation and infiltration.

Inlet—The portion of a drainage facility through which storm water enters a drainage system.

Intermittent Channel—A stream or portion of a stream that flows only in direct response to precipitation. Intermittent streams receive little or no water from springs, have long-continued supply from melting snow or other sources, and are dry for a large part of the year.

Invert—The bottom of a drainage facility along which the lowest flows pass.

Isopluvial Map—A map with lines representing constant depth of total precipitation for a given return frequency.

Land-Disturbing Activity—Any activity that results in movement of earth or a change in the existing soil cover (vegetative and non-vegetative) or topography. Land-disturbing activities include, but are not limited to clearing, grading, filling, and excavation. Compaction associated with stabilization of structures and road construction is also considered a land-disturbing activity. Vegetation maintenance practices are not considered land-disturbing activity.

Legally Non-Conforming—A project that was constructed, has been approved for construction prior to the adoption of these standards, or is being constructed under a valid permit authorizing the construction.

Level Pool Routing—The basic technique of storage routing used for sizing and analyzing detention storage and determining water levels for ponding water bodies. The level pool routing technique is based on the continuity equation: inflow minus outflow equals change in storage.

Local Jurisdiction—Any county, city, town or special purpose district having its own incorporated government for local affairs.

Maintenance—Activities conducted on structures, facilities, and equipment that involve no expansion or use beyond previously existing use, and result in no significant adverse hydrologic impact.

Manhole—An entrance to a drainage facility for the purpose of inspection and cleaning. This may consist of a circular manhole shaft, frame and round cover or an opening into a structure where the top of the structure is at the surface; in this case, the opening may be round or rectangular.

Manning's Number ("n" Value)—A number used in a mathematical formula to determine the theoretical flow velocity in a drainage facility. This number varies according to the roughness of the material through or over which the water is flowing. Often referred to as a roughness coefficient.

Moderate-Use Sites—Sites that are expected to generate sufficient concentrations of metals that additional runoff treatment is needed to protect water quality in non-exempt water bodies.

National Pollutant Discharge Elimination System—A provision of the Clean Water Act that prohibits point-source discharges of pollutants into waters of the United States unless a special permit is issued; administered by the Washington Department of Ecology as the delegated authority in Washington State.

Native Growth Protection Easement—An easement granted for the protection of native vegetation within a sensitive area or its associated buffer.

New Development—The conversion of undeveloped or pervious surfaces to impervious surfaces. New development occurs on either vacant land or through expansion of partially developed sites.

Non-Flooded Road Width—The portion of a road that is not used to carry water during a storm.

Non-Pollutant Generating Impervious Surfaces (NPGIS)—Impervious surfaces that are insignificant sources of pollutants in stormwater runoff. Roofs that are subject only to atmospheric deposition or normal heating, ventilation and air conditioning vents are considered NPGIS. The following may also be considered NPGIS: paved bicycle pathways and pedestrian sidewalks that are separated from and not subject to drainage from roads for motor vehicles, fenced fire lanes, and infrequently used maintenance access roads.

NRCS Method—The Natural Resources Conservation Service Urban Hydrograph Method; a single-event hydrologic analysis technique for estimating runoff based on the curve number method.

Off-Site Drainage—Runoff that originates outside the site of a development.

Oil/Water Separator—A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

Open Channel—A drainage course with no restrictive top. It is open to the atmosphere and may or may not permit surface flow to pass over its edge and into the channel in an unrestricted manner. In many cases where dikes or berms are constructed to increase the channel capacity, entrance of surface waters is necessarily controlled.

Ordinary High Water Mark—The line on the shore marking the normal highest level achieved during fluctuations in water levels; indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other means that consider the characteristics of the surrounding area.

Orifice—An opening with a closed perimeter and of regular form through which water flows.

Outlet—The portion of a drainage system through which storm waters exit.

Overflow—Flow exceeding the capacity of a drainage system; or the device or pathway through which this flow passes in exiting the drainage system.

Overland Flow—Flow of surface waters before reaching a natural water course.

Peak Flow—Maximum momentary stage or discharge of a stream or flood. Design discharge.

Percolation—The movement of water through soil.

Perennial Stream—A stream reach that does not go dry during a year of normal precipitation. The elevation of the water table is always above the bottom of the stream channel during a year of normal precipitation.

Permeable Soils—Soil materials with a sufficiently rapid infiltration rate to greatly reduce or eliminate surface and stormwater runoff. These soils are generally classified as hydrologic soil types A and B.

Plat—A map or representation of a subdivision showing the division of a tract or parcel of land into lots, blocks, streets, or other divisions and dedications.

Point Discharge—The release of collected or concentrated surface and stormwater runoff from a pipe, culvert, or channel.

Pollutant Generating Impervious Surface (PGIS)—Impervious surfaces that are significant sources of pollutants in stormwater runoff. Such surfaces include those that are subject to vehicular use, industrial activities, or storage of erodible or leachable materials that receive direct rainfall, or run-on or blow-in of rainfall. Metal roofs are considered to be PGIS unless coated with an inert, non-leachable material. Roofs that are subject to venting of manufacturing, commercial, or other indoor pollutants are also considered PGIS. A surface, whether paved or not, shall be considered PGIS if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways.

Precipitation—Rainfall, snow, sleet, fog, hail, dew and frost.

Pre-Developed Condition—The native vegetation and soils that existed at a site prior to the influence of Euro-American settlement.

Project—Any proposed action to alter or develop a site; or the proposed action of a permit application or an approval that requires drainage review.

Project Proponent—The person or entity responsible for oversight of a project; may include the property owner or his sponsor, agent, project manager or engineer.

Rational Method—A means of estimating the amount of stormwater arriving at a given point. Determined by the equation $Q = CIA$; where Q = flow in cubic feet per second, C = runoff coefficient which is a factor based on the imperviousness of the area upon which the water is falling; I = rainfall intensity (inches per hour) based on the time of concentration for the given drainage area; A = the drainage area in acres.

Reach—A length of channel that is uniform with respect to discharge, depth, area and slope.

Redevelopment—The replacement of impervious surfaces on a developed site. Redevelopment occurs when existing facilities are demolished and rebuilt or substantially improved through reconstruction.

Regulatory Threshold— The “trigger” for compliance with the Basic Requirements of this Manual. In Spokane County and the City of Spokane Valley, it is defined as “the addition or replacement of 5,000 square feet or more of impervious surfaces or the disturbance of one acre or more.” In the City of Spokane, the threshold is defined as “the addition or replacement of any impervious surfaces.” The regulatory threshold applies to the total impervious added or replaced at full build-out. Refer to the definition of common plan of development to determine whether a project will trigger the regulatory threshold”. All projects proposing underground injection control facilities must comply with the Basic Requirements, regardless of whether they trigger the regulatory threshold.

Retention—The process of collecting and holding surface and stormwater runoff with no surface outflow.

Riprap—Broken concrete, sacked concrete or rock used for protection against erosion.

Runoff—The portion of precipitation that contributes to flow in streams or drainage systems.

Rural Road—A road outside Urban Growth Areas delineated by local jurisdictions.

Scour—Wearing of the bed of a stream by entrainment of alluvium and corrosion of native rock. Also caused by excessive velocities at the outlet of a concentrated stream of water onto unstable material.

Seasonal Stream—A stream or segment of a stream that normally goes dry during a year of normal rainfall. Seasonal streams often receive water from springs or long-continued water supply from melting snow or other sources.

Sedimentation—Gravitational deposit of transported material in flowing or standing water.

Sheet Flow—Any flow spread out and not confined (e.g. flow across a flat open field).

Silt—(1) Waterborne sediment carried in suspension or deposited by flowing water, ranging in diameter from 0.0002 to 0.002 inches. The term is generally confined to fine earth, sand, or mud, but is sometimes broadened to include all material carried, including both suspended and bed load. (2) Deposits of waterborne material as in a reservoir, on a delta, or on floodplains.

Sorption—The physical or chemical binding of pollutants to sediment or organic particles as a means of pollutant removal.

Special Drainage Areas—Areas that typically have shallow soils, bedrock near the surface of the land and soils or geological features that may make long-term infiltration of stormwater difficult or pose potential problems for adjacent properties. These areas may also contain steep slopes where infiltration of stormwater may be difficult and the potential for erosion is high.

Special Drainage Districts—Special Drainage Areas within the City of Spokane.

Special Flood Hazard Areas (SFHA)- the land covered by the floodwaters of the base flood in the SFHA on the NFIP maps. The SFHA is the area where the NFIP's floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies.

Spillway—A passage for spilling water.

Spring—An issue of water from the earth.

Stabilization—Measures to inhibit soil erosion, including the use of concrete or asphalt paving, quarry spalls at access points, ditch lining, pre-manufactured erosion products, or vegetative cover.

Storage—Detention or retention of water for future flow. Natural storage occurs in channels and marginal soils; Artificial storage occurs in reservoirs.

Storm—A disturbance of the ordinary, average conditions of the atmosphere which, unless specifically qualified, may include any or all meteorological disturbances, such as wind, rain, snow, hail, or thunder.

Storm Drain—Any conveyor of stormwater.

Storm Sewer—A sewer that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a storm drain.

Stormwater—That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows, via overland flow, interflow, pipes and other features of a stormwater drainage system, into a defined surface water body or constructed infiltration facility.

Stormwater Management—An all-encompassing process that includes stormwater volume and rate control and water quality treatment.

Subcritical Flow—Stream flow with velocity below the critical velocity.

Sump—Any low spot that does not permit the escape of water.

Supercritical flow—Flow at velocities higher than the critical velocity..

Surface Runoff—Any movement of water on the earth’s surface, whether over the surface of the ground or through channels.

Surveyor—A professional surveyor currently licensed in the State of Washington

Swale—A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than 1 foot.

Target Soil—The soil deposit or layer into which stormwater is designed to infiltrate. For example, the soil layer that occurs at the active barrel section of a drywell.

Time of Concentration—Time required for discharge from the most distant point in a drainage area to reach the point where all flow in the drainage area is concentrated.

Travel time—The estimated time for surface water to flow between two points of interest.

Treatment Train—A pollutant treatment scenario in which two stormwater best management practices (BMPs) are constructed in series in order to capture pollutants more efficiently. This concept is typically seen when there are very high concentrations of pollutants, such as oil or phosphorus, for which no one treatment BMP can adequately remove the pollutant on its own while meeting the remaining treatment goals of this Manual.

Treatment Zone—The layer of soil in a bio-infiltration swale where water quality treatment occurs. It consists of sod installed over medium- to well-draining soil at least 6 inches thick underlain by a subgrade infiltration layer at least 48 inches thick.

Trip End—The expected number of vehicles using a parking area for the proposed land use. Trip end counts are estimated by using the *Trip Generation Manual* published by the Institute of Transportation Engineers

Type A NLDS—Natural drainage systems that may be considered for use as regional facilities and serve important functions in existing management of stormwater runoff.

Type B NLDS—Natural drainage systems that are generally less prominent, yet are deemed necessary for managing stormwater in its existing location.

Urban Road—A road located within the urban growth area delineated by local jurisdictions.

Water Budget—An analysis used in the design of an evaporation pond that uses average monthly precipitation and pan evaporation values to estimate the net stormwater runoff volume increase over a 2-year cycle.

Water Surface—The top of water in a lake, channel, reservoir or river

Water Table—The upper surface or top of the saturated portion of the soil or bedrock layer, indicating the uppermost extent of groundwater.

Weir—A low overflow dam or sill for measuring, diverting or checking flow.

Wetland—An area characterized by saturated or nearly saturated soils most of the year that forms an interface between terrestrial (land-based) and aquatic environments. Wetlands include marshes around lakes or ponds and along river or stream channels.

ABBREVIATIONS AND ACRONYMS

- **AASHTO—**American Association of State Highway and Transportation Officials
- **ADT—**Average Daily Traffic
- **APWA—**American Public Works Association

- **ARC—**Antecedent Runoff Condition
- **ASA—**Aquifer Sensitive Area
- **ASTM—**American Society for Testing and Materials
- **BFE—**Base Flood Elevation
- **BMP—**Best Management Practice
- **BST—**Bituminous Surface Treatment
- **CARA—**Critical Aquifer Recharge Area
- **CC&R—**Conditions, Covenants and Restrictions
- **CEC—**Cation Exchange Capacity
- **cfs—**Cubic Feet per Second
- **CMP**—Corrugated Metal Pipe
- **CN—**Curve Number
- **DOH—**Department of Health
- **EPA—**Environmental Protection Agency
- **ESC—**Erosion & Sediment Control
- **ETE—**Equivalent Trip End
- **FEMA—**Federal Emergency Management Agency
- **FHWA—**Federal Highway Administration
- **FIRM—**Flood Insurance Rate Map
- **FS—**Factor of Safety
- **GPA—**Grassed Percolation Area
- **GW—**Grate Width
- **GSC—**Geotechnical Site Characterization
- **HDPE**—High-Density Polyethylene
- **HGL—**Hydraulic Grade Line
- **HOA—**Homeowner's Association
- **IBC—**International Building Code
- **IRC—**International Residential Code
- **NLDS—**Natural Location of Drainage Systems
- **NOAA—**National Oceanic and Atmospheric Administration
- **NPDES—**National Pollutant Discharge Elimination System

- **NPGIS—**Non-Pollutant Generating Impervious Surface
- **NRCS —**Natural Resources Conservation Service
- **O&M—**Operation and Maintenance
- **PAM—**Polyacrylamide
- **PGIS—**Pollutant Generating Impervious Surface
- **POA—**Property Owners Association
- **RCW—**Revised Code of Washington
- **SDA—**Special Drainage Areas
- **SDD—**Special Drainage District
- **sf**—Square Feet
- **TMDL—**Total Maximum Daily Load
- **TPH—**Total Petroleum Hydrocarbons
- **TSS—**Total Suspended Solids
- **UIC—**Underground Injection Control
- **USBR—**United States Bureau of Reclamation
- **USGS—**United States Geological Survey
- **WAC—**Washington Administrative Code
- **WRCC—**Western Region Climate Center
- **WSDOT—**Washington State Department of Transportation

REFERENCES

AASHTO Geometric Design of Highways and Streets, Exhibit 2-4, 2004 Edition [Section 11.1.6]

Open Channel Hydraulics, 1959, Ven Te Chow (1959) [Tables 5-4, 8-3, 8-6]

Civil Engineering Reference Manual, 8th Edition [Table 8-2]

Guidance for UIC Wells that Manage Stormwater, Washington State Department of Ecology [Section 7.4.1]

Engman (1983) [Tables 5-3 and 5-4]

FHWA, Hydraulic Engineering Circular No. 22, Second Edition [Table 8-8, Section 8.6.2]

Florida Department of Transportation Drainage Manual (1986) [Tables 5-3 and 5-4]

Guidelines for Stormwater Management, Spokane County, February 1998 [Table 8-5]

Handbook of Applied Hydrology, (Chow, Ven Te, 1964) [Section 5.4]

Handbook of Hydraulics, by Brater and King [Section 8.4.3]

Infiltration Rate and Soil Classification Correlation, File No. 0188-082-00, May 28, 2004; prepared by GeoEngineers, Budinger & Associates, Inc., and Cummings Geotechnology, Inc. [Chapter 4 Appendices]

King County Surface Water Design Manual, 1998. [Figures 6-3 and 6-4]

length of an apron (La) is determined using the following empirical relationships that were developed for the U.S. Environmental Protection Agency, ASCE (1992) [Section 8.3.2]

NOAA Atlas 2, Volume IX, 1973 [Sections 5.3.4 and 5.5.3]

Open-Channel Hydraulics by French. [Section 8.4.3]

WSDOT Standard Plans, July 2001 [Section 8.3.2]

SCS National Engineering Handbook (1985). [Section 5.3.2 and Table 5-2]

Section 3-8 of the U.S. Bureau of Reclamation Drainage Manual. [Chapter 4 Appendices]

Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986). [Section 5.3.3 and Table 5-1]

Special Committee on Irrigation Research, American Society of Civil Engineers, 1926. [Table 8-1]

Standard Plans jointly published by WSDOT and APWA (M21-01) [Section 8.6.1]

Stormwater Management Manual for Eastern Washington [Everywhere]

USGS WRI Report 97-4277, Magnitude and Frequency of Floods in Washington [Section 7.8.2]

WSDOT Highway Runoff Manual (2004) [Tables 5-3 and 5-4]

WSDOT Hydraulics Manual, March 2004 [Tables 5-5 and 5-7, Section 8.3.2]

CHAPTER 1 – INTRODUCTION

Chapter Organization

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1.1 OBJECTIVE AND PURPOSE

Development projects in urban areas generally result in the replacement of open land, where rainfall can infiltrate into the soil, with impervious surfaces that prevent infiltration. This changes the patterns of stormwater runoff, which can lead to flooding problems—at the project site and on properties downstream—and can affect water quality, as sediment and pollutants are transported into streams, wetlands, lakes and groundwater.

The *Spokane Regional Stormwater Manual* establishes standards for stormwater design and management to protect water quality, natural drainage systems and down-gradient properties as urban development occurs. The Manual meets or exceeds applicable criteria from the Washington State Department of Ecology's *Stormwater Management Manual for Eastern Washington* (SWMMEW), available online at www.ecy.wa.gov/programs/wq/stormwater/tech.html, for underground injection and discharge to surface waters.

The purpose of this Manual is to help communities in the Spokane region to protect water quality, prevent adverse impacts from flooding, and control stormwater runoff to levels equivalent to those that occurred prior to development. Acceptable stormwater management should be achieved when the criteria and standards presented in this Manual are met.

1.2 VISION STATEMENT

The *Spokane Regional Stormwater Manual* was developed jointly by Spokane County and the Cities of Spokane and Spokane Valley, whose vision is to provide a document with clearly defined stormwater management design and maintenance criteria to serve the current and future stormwater needs of the Spokane region. The criteria in this document are meant to enhance and promote future development in a way that reasonably protects the health, safety, and welfare of current and future property owners, while at the same time preserving or enhancing the existing natural drainage systems.

1.3 USING THE STORMWATER MANUAL

This Manual provides engineers, developers and the general public with procedures and assistance for designing stormwater management facilities associated with land development, road and drainage projects. It outlines minimum requirements for the design of stormwater management systems. The Manual is sufficiently comprehensive that its contents, along with good engineering judgment, will address the myriad of drainage concerns in the Spokane region.

The Manual provides essential information for development project proponents (owners or their agents) in two key areas: technical guidelines and government policies .

1.3.1 TECHNICAL INFORMATION

Technical information in this Manual consists of design criteria and minimum requirements for use in the analysis and design of specific stormwater management facilities. The technical information is generally organized to match eight basic requirements for stormwater management associated with development:

- Chapter 2 generally describes the eight basic requirements.
- Chapter 3 describes requirements for a "drainage submittal" that verifies compliance with all applicable requirements for a given project (Basic Requirement No. 1).
- Chapter 4 describes geotechnical requirements (Basic Requirement No. 2).
- Chapter 5 describes procedures for hydrologic analysis that are to be used in conjunction with several of the basic requirements.
- Chapter 6 describes requirements for water quality treatment (Basic Requirement No. 3).
- Chapter 7 describes requirements for flow control (Basic Requirement No. 4)
- Chapter 8 describes requirements for conveyance systems (Basic Requirement No. 5).
- Chapter 9 describes requirements for erosion and sediment control (Basic Requirement No. 6).
- Chapter 10 describes requirements for controlling sources of pollutants (Basic Requirement No. 7).
- Chapter 11 describes maintenance requirements (Basic Requirement No. 8).

In general, each chapter describes minimum requirements for compliance with this Manual and explains design procedures and criteria. Appendices to many of the chapters give example calculations to demonstrate procedures for facility analysis and design. Full compliance with this Manual may require exceeding the minimums presented in the chapters.

The Manual is intended to provide project proponents, regulatory agencies, and others with technically sound stormwater management practices which are *presumed* to meet the stated stormwater objectives of federal, state and local regulations. Project proponents always have the option of not following the stormwater management practices in this Manual. However, if a project proponent chooses not to follow the practices in the Manual then the project proponent may be required to individually *demonstrate* that the project will not adversely impact surface waters, groundwater or neighboring properties by collecting and providing appropriate supporting data to show that the alternative approach satisfies all relevant stormwater regulations.

It is the intention of this Manual that project proponents who fully comply with all its requirements will also be in compliance with the requirements of Ecology's *Stormwater Management Manual for Eastern Washington*. Some of the requirements and definitions presented in this Manual are established by Ecology's manual, and future changes to Ecology's manual may affect these requirements and definitions. It is the obligation of the project proponent to refer to the most recent version of the Ecology manual as needed to ensure compliance with its requirements.

1.3.2 POLICY INFORMATION

The policy portions of this manual explain the conditions under which projects are subject to the requirements of this Manual and outline the procedures that are to be followed to ensure compliance. Development that affects stormwater management is subject to requirements laid out in federal, state and local rules and regulations. The Manual identifies the key sources of these rules and regulations and describes the steps toward compliance or directs users of the Manual to other resources for compliance information. Policy information is included throughout the Manual as appropriate.

This Manual was jointly developed by Spokane County and the Cities of Spokane and Spokane Valley. It generally applies to development projects in unincorporated County areas or within the limits of the two cities. It is not intended for use outside Spokane County or in incorporated areas of the County other than Spokane and Spokane Valley. Developers of projects in other jurisdictions should contact those jurisdictions for guidance.

1.4 RELEVANT PROGRAMS AND CONCEPTS

A number of regulatory programs and technical concepts are more broadly relevant to the goals of this manual than specifically applicable to individual requirements or procedures. Brief discussions of these topics are presented below to familiarize users of the Manual with their history and implications.

1.4.1 UNDERGROUND INJECTION CONTROL PROGRAM COMPLIANCE

Stormwater can contain contaminants such as oil, grease, pathogens, nitrates, pesticides, and metals such as cadmium, chromium and lead. When stormwater is infiltrated into the ground through underground injection facilities such as drywells, these contaminants can pollute groundwater.

The U.S. Congress created the Underground Injection Control (UIC) Program to protect underground sources of drinking water from discharges of fluids to the ground. The UIC Program in the State of Washington is administered by the Department of Ecology. To implement the program, the Department of Ecology adopted Washington Administrative Code (WAC) Chapter 173-218—Underground Injection Control in 1984. The two requirements of the UIC Program are as follows:

- Register UIC wells with the state.
- Ensure that current and future underground sources of groundwater are not endangered by pollutants in the discharge (non-endangerment standard).

Pollution of groundwater from stormwater discharges can be prevented by proper design, siting, operation and maintenance of the UIC well, by the use of treatment before discharge to the sub-surface, and by reducing the stormwater contact with potential sources of contamination.

The entire Spokane region is subject to the Department of Ecology's UIC regulations.

1.4.2 SPOKANE VALLEY-RATHDRUM PRAIRIE SOLE-SOURCE AQUIFER

Aquifer Description and Potential Water Quality Threats

The only source of water for most of the people in Spokane County, Washington and Kootenai County, Idaho is a high quality underground water body called the Spokane Valley-Rathdrum Prairie Aquifer. This aquifer extends across an area of about 325 square miles and provides drinking water for more than 500,000 people. Most of the developed areas in the Spokane region and in North Idaho lie directly over the aquifer.

Unlike many other aquifers, the Spokane Valley-Rathdrum Prairie Aquifer does not have protective layers of clay or rock to deter infiltration of surface contaminants. The soil layer above the aquifer is relatively thin in most areas, and fluids readily infiltrate into the porous sands and gravel that make up the aquifer materials. Potential contamination is the most important issue that must be addressed to preserve and maintain the aquifer as a regional drinking water resource. A contaminant on the surface may reach the aquifer water table in a matter of hours or days, particularly contaminants that are dissolved in water that is recharging the aquifer. Contamination in the aquifer may be cleaned up, or remediated, but the clean-up process is costly and does not eliminate 100% of the contamination.

The water quality of the aquifer has been tested since 1977 and the monitoring suggests that human activities on the land surface over the aquifer are deteriorating the water quality. Contaminants are conveyed to the aquifer by stormwater, septic tank leachate, fertilizer leachate, leakage from underground storage tanks and other sources that percolate downward from the surface. Stormwater accounts for about 30% of the pollution reaching the aquifer. Stormwater can collect a large variety of contaminants as it flows across roads, parking lots, roofs and other impervious surfaces. Pollutants such as coliform bacteria, nitrates and volatile organic compounds have been detected in aquifer water samples.

Regulatory Steps to Protect the Aquifer

Sole-Source Aquifer Designation: One of the first important steps to protect the aquifer was taken by the U.S. Environmental Protection Agency (EPA) in 1978 when it designated the Spokane Valley-Rathdrum Prairie a “Sole-Source Aquifer” under Section 1424(e) of the federal Safe Drinking Water Act. It was the second aquifer in the nation to receive this designation.

Aquifer Sensitive Area: Groundwater recharge areas have critical impacts on aquifers used for potable water, as defined by 365-190-030 (2) WAC. Incorporated areas of Spokane County, including the Cities of Spokane and Spokane Valley, are subject to regulations governing the Aquifer Sensitive Area (ASA), as described in Section 6.2.1.

Critical Aquifer Recharge Areas: By Resolution No. 3-0754, Spokane County has designated Critical Aquifer Recharge Areas (CARA) for the protection of aquifer water quality. Requirements associated with this designation affect all unincorporated areas of the County. Section 6.2.2 provides detailed information about the CARA designation.

1.4.3 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM COMPLIANCE

The National Pollutant Discharge Elimination System (NPDES) permit program was established by the federal Clean Water Act, which is the primary federal law protecting water quality. The Water Pollution Control Act (Revised Code of Washington (RCW) Chapter 90.48) is the primary Washington State law protecting water quality. The Washington Department of Ecology issues and implements combined permits for point source stormwater and wastewater discharges to waters of the United States and waters of the state that are designed to satisfy requirements of the NPDES and the Water Pollution Control Act. “Waters of the state” means all lakes, rivers, ponds, streams, inland waters, ground waters, salt waters, and all other waters and water courses within the jurisdiction of the state of Washington (Washington Administrative Code (WAC) Chapter 173-216-030(20)).

In December 1999, the U.S. EPA adopted NPDES Phase II stormwater regulations, identifying municipalities that are subject to NPDES municipal stormwater permitting requirements. Federal regulations required that Phase II permits be issued by December 2002 and that designated Phase II communities submit an application for permit coverage by March 2003. The Department of Ecology issued the *Eastern Washington Phase II Municipal Stormwater Permit* on January 17, 2007, effective February 16, 2007, which applies to Spokane County and the Cities of Spokane and Spokane Valley. The Phase II Permit requires the development of a Stormwater Management Program (SWMP).

This Manual is intended to be technically equivalent to the Department of Ecology’s *Stormwater Management Manual for Eastern Washington* in order to meet the NPDES requirements for both permitted and non-permitted communities in Spokane County.

1.4.4 POLLUTANT GENERATING IMPERVIOUS SURFACE

Pollutant generating impervious surface (PGIS) areas are significant sources of pollutants in stormwater runoff. These areas include surfaces subject to vehicular use, industrial activities, or storage of erodible or leachable materials that receive direct rainfall. The following are considered PGIS areas: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, hydraulically connected sidewalks, parking lots, some roofs, fire lanes, vehicular equipment storage yards and airport runways. Please refer to Section 6-4.

1.5 GENERAL REQUIREMENTS

The owner or project proponent and his agent are responsible for the following:

- Coordinating project consultants
- Providing complete drainage submittals
- Ensuring adherence to:
    - The standards and criteria presented in this Manual
    - The Administrative Conditions of Approval, if applicable
    - Any conditions established by local jurisdiction staff
- General project management.

The owner or project proponent and his agent are required to obtain acceptance of the drainage submittal from the local jurisdiction prior to any of the following:

- Final plat approval
- Final short plat approval
- Binding site plan approval
- Issuance of a building permit
- Issuance of a road approach permit
- Any other land use action as defined by code, regulation or resolution of the local jurisdiction.

The drainage submittal shall be prepared in accordance with this Manual, the applicable version of the local jurisdiction's design standards, the International Building Code (IBC) and the International Residential Code (IRC). The submittal shall be prepared by a professional civil engineer currently licensed in the State of Washington and shall be submitted to the local jurisdiction for review and acceptance.

The rate and volume of stormwater runoff originating on any proposed land development, road or area draining to, across or through the project site shall be estimated in accordance with the criteria presented in this Manual. These estimates shall be the basis of the drainage report. Unless specifically approved by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required. Exceptions with regard to rate and volume control can be made for regional facilities planned by the local jurisdiction.

Stormwater runoff from a developed site shall leave the site in the same manner and location as it did in the pre-developed condition. Flow may not be concentrated onto down-gradient properties where sheet flow previously existed. Drainage shall not be diverted and released downstream at points not receiving drainage prior to the proposed development.

1.6 STANDARD OF CARE

The standards presented in this Manual should be considered the minimum requirements to be used in the design of stormwater facilities. Due to special site conditions, environmental constraints, or other applicable laws, stormwater management designs may frequently need to exceed the minimum requirements. It is incumbent upon the engineer to use good engineering practice and to be aware of, and implement, new design practices and procedures that reflect current techniques in stormwater design, providing sufficient measures to ensure that the drainage facilities function as intended. Good engineering practice is defined in these standards as professional and ethical conduct that meets the current codes and regulations adopted for engineers. The proposed design shall consider functionality, constructability and maintenance, including the health, safety and welfare of the public.

1.7 SEVERABILITY

If any section, sentence, clause or phrase of this Manual should be held invalid or unconstitutional, the validity or constitutionality thereof shall not affect the validity or constitutionality of any other section, sentence, clause or phrase of this Manual.

CHAPTER 2 – BASIC REQUIREMENTS

Chapter Organization

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2.1 INTRODUCTION

This chapter introduces the eight Basic Requirements for stormwater management for new development and redevelopment projects in the Spokane region:

- Basic Requirement No. 1 – Drainage Submittal;
- Basic Requirement No. 2 – Geotechnical Site Characterization;
- Basic Requirement No. 3 – Water Quality Treatment;
- Basic Requirement No. 4 – Flow Control;
- Basic Requirement No. 5 – Natural and Constructed Conveyance Systems;
- Basic Requirement No. 6 – Erosion and Sediment Control;
- Basic Requirement No. 7 – Source Control; and,
- Basic Requirement No. 8 – Operation and Maintenance.

The applicability of these requirements depends on the type, size and location of the project. It is the responsibility of the project proponent to become familiar with the Basic Requirements in order to determine when they are applicable.

2.1.1 REGULATORY THRESHOLD

The regulatory threshold is the "trigger" for requiring compliance with the Basic Requirements of this Manual. This threshold varies from jurisdiction to jurisdiction. In Spokane County and the City of Spokane Valley, it is defined as "the addition or replacement of 5,000 square feet or more of impervious surfaces or the disturbance of 1 acre or more." In the City of Spokane, the threshold is defined as "the addition or replacement of any impervious surfaces." The regulatory threshold applies to the total impervious area replaced or added at full build-out. Refer to "common plan of development or sale" definition to determine whether your project will trigger the regulatory threshold.

All projects proposing underground injection control (UIC) facilities must comply with UIC requirements, regardless of whether they trigger the regulatory threshold.

2.1.2 NEW DEVELOPMENT

New development is the conversion of previously undeveloped or permeable surfaces to impervious surfaces and managed landscape areas. New development occurs on vacant land or through expansion of partially developed sites.

All new development projects, regardless of whether the project meets the regulatory threshold, shall comply with the following:

- Basic Requirement No. 5 – Natural and Constructed Conveyance Systems;
- Basic Requirement No. 6 – Erosion and Sediment Control; and,
- Basic Requirement No. 7 – Source Control.

All new development projects that meet the regulatory threshold or propose UIC facilities shall comply with the following:

- Basic Requirement No. 3 – Water Quality Treatment
- Basic Requirement No. 8 – Operation and Maintenance.

All new development projects that meet the regulatory threshold shall comply with the following:

- Basic Requirement No. 1 – Drainage Submittal, unless exempted per Sections 2.1.4 or 2.1.5. All projects shall provide for stormwater management in their design regardless of whether the local jurisdiction requires a drainage submittal.
- Basic Requirement No. 4 – Flow Control (refer to Section 2.2.4 for additional information);

Review Section 2.2.2 to determine if Basic Requirement No. 2 – Geotechnical Site Characterization is applicable.

The local jurisdiction reserves the right to require compliance with any or all of the Basic Requirements regardless of the size of the project or the amount of impervious area added or replaced.

2.1.3 REDEVELOPMENT

Redevelopment is the replacement of impervious surfaces on a developed site. Redevelopment occurs when existing facilities are demolished and rebuilt or substantially improved through reconstruction. Rebuilt or reconstructed facilities are regarded in the same manner as new development (refer to Section 2.1.2) and shall generally comply with the Basic Requirements of this Manual, as applicable. On redeveloped sites where pre-existing facilities remain, the old facilities are not subject to the requirements of this Manual if they remain hydraulically isolated from the new facilities. For projects that are implemented in incremental stages, the redevelopment threshold applies to the total amount of impervious surface replaced at full build-out; the new development thresholds apply to the total amount of new impervious surfaces added at full build-out.

The long-term goal of the redevelopment standard is to reduce stormwater pollution from existing developed sites, especially when a water quality problem has been identified or the site is being improved to accommodate a use with a greater potential to contribute pollution to the receiving waters. More stringent redevelopment thresholds and requirements may be identified through a water cleanup plan such as a Total Maximum Daily Load (TMDL) study and allocation.

A project may be granted a design deviation when site conditions prevent full compliance with the Basic Requirements; however, every effort should still be made to find creative ways to meet the intent of the Basic Requirements. Design deviations will generally not be granted waiving stormwater requirements for new impervious surfaces. The local jurisdiction may allow the Basic Requirements to be met for an area with equivalent flow and pollution characteristics within the same site.

Sites with 100% existing building coverage that are currently connected to a municipally owned storm sewer or combined sewer must be evaluated on a case-by-case basis to continue to be connected without treatment; additional local requirements such as flow restrictors may also be required.

2.1.4 EXEMPTIONS

Projects are exempt from the Basic Requirements when falling under any of the following categories:

- Commercial agriculture as regulated under Revised Code of Washington (RCW) Chapter 84.34.020, except for the construction of impervious surfaces related to commercial agriculture;
- Forest practices regulated under Washington Administrative Code (WAC) Title 222, except for Class IV General Forest Practices that are conversions from timberland to other uses;
- Oil and gas field activities or operations including construction of drilling sites, waste management pits, access roads, and transportation and treatment infrastructure such as pipelines, natural gas treatment plants, natural gas pipeline compressor stations, and crude oil pumping stations;
- Actions by a public utility or any other governmental agency to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic;
- Records of survey, boundary (i.e. minor lot line) adjustments, and property aggregations, unless the action affects drainage tracts or easements;
- Projects that, when completed, will not have physically disturbed the land;

- Road and parking area preservation and maintenance projects such as:
  - Pothole and square cut patching;
  - Crack sealing;
  - Shoulder grading;
  - Reshaping or regrading of drainage systems;
  - Vegetation maintenance; and,
- Operation and maintenance or repair of existing facilities.

2.1.5 GENERALLY EXEMPT

The practices below are generally exempt from all of the Basic Requirements except for Basic Requirement No. 5 – Natural and Constructed Conveyance Systems, Basic Requirement No. 6 – Erosion and Sediment Control, and Basic Requirement No. 7 – Source Control. However, they may be required to comply with any or all of the Basic Requirements as determined by the local jurisdiction:

- Projects that do not meet the regulatory threshold as defined in Section 2.1.1 and do not include new UIC facilities;
- Certificates of exemption;
- Single-family residential/duplex building permits without special conditions (A surface drainage plan and other information may be required in the City of Spokane; however, a full drainage submittal is generally not required);
- Temporary use permits, unless the use could cause adverse water quality or other drainage-related impacts;
- Land-disturbing activities that do not require a permit, unless the activity could cause adverse water quality or other drainage-related impacts;
- Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics;
- Projects to improve motorized or non-motorized user safety that do not increase the traffic capacity of a roadway. Certain safety improvement projects such as sidewalks, bike lanes, bus pullouts and other transit improvements shall be evaluated on a case-by-case basis to determine whether additional Basic Requirements apply. A safety project that increases the traffic-carrying capacity of a roadway is not exempt from other Basic Requirements;
- Legally non-conforming projects, except those that drain to the new construction area and drainage improvements;

- Maintenance projects that do not increase the traffic capacity of a roadway or parking area such as:
  - Removing and replacing a concrete or asphalt roadway to base course or subgrade or lower without expanding or improving the impervious surfaces;
  - Repairing a roadway base or subgrade;
  - Resurfacing with in-kind material without expanding the area of coverage;
  - Overlaying existing asphalt or concrete pavement with bituminous surface treatment (BST, commonly referred to as chip seal), asphalt or concrete without expanding the area of coverage;
  - Overlaying existing gravel with BST, asphalt or concrete, or overlaying BST with asphalt; in either case, without expanding the area of coverage. This partial exemption only applies if the overlaid surface continues to drain to the existing facilities or structures and if:
    - ♦ The road traffic surface will be subject to an average daily traffic (ADT) volume of less than 7,500 on an urban road or less than 15,000 on a rural road, freeway, or limited access control highway;
    - ♦ The parking area traffic surface will be subject to less than 40 trip ends per 1,000 square feet of building area or 100 total trip ends; or,

2.1.6 DESIGN DEVIATION

A design deviation is an administrative approval of design elements that do not conform to or are not explicitly addressed by this Manual. Contact the local jurisdiction for specific design deviation procedures.

The requirements of this Manual represent the minimum criteria for the design of stormwater management systems. Designs that offer a superior alternative to standard measures, or creative means not yet specified in the standards, are encouraged.

Applicability

The project proponent shall request a design deviation when either of the following situations apply:

- The project proposes non-standard methods, analysis, design elements or materials; or,
- The project proposes design elements above maximum criteria or below the minimum criteria found in this Manual.

A design deviation will only be considered for review if:

- The design elements proposed do not conflict with or modify a condition of approval; and,
- The design elements proposed are based on sound engineering principles and best management practices, and are not inconsistent with the public interest in stormwater control and environmental protection.

Submittal

For consideration of a design deviation, the project proponent shall submit a design deviation request and supporting documentation. Contact the local jurisdiction for a design deviation form or acceptable alternative. The supporting documentation shall include sufficient information for the local jurisdiction to make a decision as to the adequacy of the proposed facility or design. If infiltration is proposed, negative impacts on down-gradient properties are of concern, or seasonal high groundwater is suspected, then a geotechnical site characterization shall be submitted as part of the design deviation package. The design deviation package shall demonstrate that:

- There are special physical circumstances or conditions affecting the property that may prohibit the application of some of the Basic Requirements in this Manual;
- Every effort has been made to find alternative ways to meet the objectives of the Basic Requirements;
- Approving the design deviation will not cause adverse impact on down-gradient properties, public health or welfare; and,
- Approving the design deviation will not adversely affect the recommendations of any applicable comprehensive drainage plan.

2.2 BASIC REQUIREMENTS

2.2.1 BASIC REQUIREMENT NO. 1 – DRAINAGE SUBMITTAL

Objective

Projects are expected to demonstrate compliance with all applicable Basic Requirements through the preparation of a Drainage Submittal. The Drainage Submittal shall include road and drainage construction plans, a drainage report that describes the proposed measures to dispose of stormwater, and other supporting documentation as needed. The contents of the Drainage Submittal will vary with the type, size and location of the project, individual site characteristics, and requirements of the local jurisdiction.

The local jurisdiction reviews the Drainage Submittal for compliance with this Manual and other applicable standards. Specific requirements for the Drainage Submittal are discussed in Chapter 3.

Applicability

A Drainage Submittal is generally required for any land-disturbing activity. Land-disturbing activities are those that result in a change in the existing soil cover (both vegetative and non-vegetative) or site topography. The sections below summarize the types of activities that require a Drainage Submittal, as well as those that are exempt.

A drainage submittal is always required for the following types of activities:

- Projects that meet the regulatory threshold as defined in Section 2.1.1 or propose UIC facilities;
- Plats and binding site plans; and,
- Manufactured and mobile home parks.

A drainage submittal is generally required for the following types of activities:

- Commercial building permits including institutional and multi-family residential projects;
- Short plats;
- Change of use permits;
- Conditional use permits;
- Grading permits; and,
- Public or private road projects.

The following types of activities are generally exempt from the requirement to prepare a drainage submittal:

- Certificates of exemption;
- Single-family residential/duplex building permits (A surface drainage plan and other information may be required in the City of Spokane, however a full drainage submittal is generally not required);
- Temporary use permits, unless the use could cause adverse water quality impacts or other drainage-related impacts;
- Land-disturbing activities that do not require a permit, unless the activity could cause adverse water quality impacts or other drainage-related impacts;

- Underground utility projects that replace the ground surface with in-kind material, or materials with similar runoff characteristics;
- Projects to improve motorized and/or non-motorized user safety that do not increase the traffic capacity of a roadway. Certain safety improvement projects such as sidewalks, bike lanes, bus pull-outs and other transit improvements shall be evaluated case-by-case. A safety improvement project that increases the traffic-carrying capacity is not exempt;
- Legally non-conforming projects, except those that drain to the new construction area and drainage improvements;
- Maintenance projects that do not increase the traffic-carrying capacity of a roadway or parking area, such as:
    - Removing and replacing a concrete or asphalt roadway to base course or subgrade or lower without expanding or improving the impervious surfaces;
    - Repairing a roadway base or subgrade;
    - Resurfacing with in-kind material without expanding the area of coverage;
    - Overlaying existing asphalt or concrete pavement with BST, asphalt or concrete without expanding the area of coverage;
    - Overlaying existing gravel with BST, asphalt or concrete, or overlaying BST with asphalt; in either case without expanding the area of coverage. This partial exemption only applies if the overlaid surface continues to drain to the existing facilities or structures and if:
        - ♦ The road traffic surface will be subject to an ADT volume of less than 7,500 on an urban road or less than 15,000 on a rural road, freeway or limited access control highway; or,
        - ♦ The parking area traffic surface will be subject to less than 40 trip ends per 1,000 square feet of building area or 100 total trip ends; or,

The following types of activities are exempt from the requirement to prepare a drainage submittal:

- Commercial agriculture as regulated under RCW Chapter 84.34.020, except for the construction of impervious surfaces related to commercial agriculture;
- Forest practices regulated under WAC Title 222, except for Class IV General Forest Practices that are conversions from timberland to other uses;

- Oil and gas field activities or operations, including construction of drilling sites, waste management pits, access roads, and transportation and treatment infrastructure such as pipelines, natural gas treatment plants, natural gas pipeline compressor stations and crude oil pumping stations;
- Actions by a public utility or any other governmental agency to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic;
- Records of survey, boundary line adjustments, and property aggregations, unless the action affects drainage tracts and easements;
- Operation and maintenance or repair of existing facilities; and,
- Road and parking area preservation/maintenance projects, such as:
    - Pothole and square-cut patching;
    - Crack sealing;
    - Shoulder grading;
    - Reshaping or regrading drainage system; or,
    - Vegetation maintenance.

2.2.2 BASIC REQUIREMENT NO. 2 – GEOTECHNICAL SITE CHARACTERIZATION

Objective

A geotechnical site characterization (GSC) is required to demonstrate suitability for stormwater disposal and to determine sub-level structure construction feasibility. A geotechnical engineer shall perform the study in accordance with the criteria specified in Chapter 4.

Applicability

A GSC will be required for most projects. The scope and geographic extent of the investigation may vary depending on the general location and setting of the site, the characteristics of the target soil deposits, and whether there are known or anticipated drainage problems in the vicinity of the site.

A GSC is required for:

- Projects proposing infiltration (drywells, detention facilities receiving credit for pond bottom infiltration, etc.) or non-standard drainage systems;

- Projects located in a Special Drainage Area (SDA) or Special Drainage District (SDD);
- Projects located within or draining to a problem drainage area or study area as recognized by the local jurisdiction;
- Projects with administrative conditions requiring a GSC; or,
- Projects with proposed sub-level structures, as required by the local jurisdiction.

In areas where there has been a long-standing record of satisfactory performance of standard subsurface disposal facilities and no drainage problems are known to exist, the minimum requirements found in Section 4.3 may be reduced or waived after a formal written request from the project proponent's engineer has been reviewed and accepted by the local jurisdiction.

2.2.3 BASIC REQUIREMENT NO. 3 – WATER QUALITY TREATMENT

Objective

Water quality treatment is required to reduce pollutant loads and concentrations in stormwater and can be achieved using physical, biological, and chemical removal. An analysis of the proposed land use at the project site is used to determine the pollutants of concern and the appropriate treatment methods to apply.

The most effective basic treatment best management practices (BMPs) remove about 80% of the total suspended solids contained in the runoff treated and a much smaller percentage of the dissolved pollutants. Additional treatment to remove oil, metals, and/or phosphorus from stormwater runoff may be required.

The BMPs described in Chapter 6 are designed to reduce or eliminate certain pollutants. For discharges to UIC facilities, the selected BMPs must remove or reduce the target pollutants to levels that will comply with state groundwater quality standards when the discharge reaches the water table or first comes into contact with an aquifer (see WAC 173-200). Discharges to surface waters shall comply with WAC 173-201A, Water Quality Standards for Surface Waters of the State of Washington.

The goal of this Manual is for stormwater facilities to treat approximately 90% of the annual runoff from the pollutant-generating impervious surfaces (PGIS) at a project site. The total quantity of pollutants removed from the stormwater will vary greatly from site to site based on precipitation patterns, land use, effectiveness of source control, and operation and maintenance of the treatment facilities. When required, treatment facilities shall be designed according to the criteria specified below and in Chapter 6.

Design Criteria

The 6-month NRCS (Natural Resources Conservation Service) Type II 24-hour storm event is the water quality design storm for both volume-based and flow rate-based water quality BMPs. Please refer to Chapter 5 for complete design guidance.

Applicability

Any exemptions for this Basic Requirement are superseded by requirements set forth in any applicable total maximum daily load (TMDL) or other water cleanup plan. At the time of the writing of this Manual, no TMDLs exist for water bodies in Spokane County. Contact the local jurisdiction for current information on whether any TMDLs have been issued.

<u>Basic Treatment Applicability:</u> Basic treatment provides removal of total suspended solids (TSS) and is required for all projects proposing UIC facilities that are:

- Located within the moderate or high susceptibility areas of the Critical Aquifer Recharge Area (CARA);
- Located within Township 26 North Range 43 East (excluding the delineated low susceptibility areas isolated in the northeast corner of this Township and Range);
- Located within a 1,000-foot radius of Group A and Group B wells without reported plans;
- Located within a Department of Health approved wellhead protection area;
- Proposing a moderate-use, high-use or high-ADT site and located in the low or moderate susceptible areas of the CARA;
- Located within the Aquifer Sensitive Area (ASA) boundaries; or
- Located within the City of Spokane.

Basic treatment is also required for all projects:

- Meeting the regulatory threshold and discharging to waters of the state, including perennial and seasonal streams, lakes and wetlands;
- Requiring a 401 Water Quality Certification; or,
- Regulated to provide water quality treatment under other rules outside of Phase II jurisdictions.

Basic treatment is not required for:

- Non-pollutant generating impervious surface (NPGIS) areas unless the runoff from these areas is hydraulically connected to PGIS areas;

- Projects that discharge to the subsurface and are located within the low susceptibility areas of the CARA and are not proposing moderate-use, high-use, or high-ADT sites; or,
- Projects discharging non-waste fluids from roofs (WAC 173-218) directly to drywells.

Oil Control Applicability: All projects that meet the regulatory threshold and are high-use or high-ADT areas are required to provide oil control. High-use sites generate high concentrations of petroleum hydrocarbons due to high traffic turnover or the frequent transfer of oil and/or other petroleum products.

High-use sites and high-ADT roadways and parking areas shall treat runoff from the high-use portion of the site prior to discharge or infiltration. For high-use sites located within a larger project area, only the impervious area associated with the high-use site is subject to oil control treatment, as long as the flow from that area is separated; otherwise the treatment controls shall be sized for the entire area.

Non-high-use sites and non-high ADT sites are exempt from oil treatment requirements.

Metals Treatment Applicability: Metals treatment is required for all projects that are moderate- or high-use sites, and for sites that discharge to a surface water or UIC facility and meet any of the following definitions:

- Industrial sites as defined by the EPA (40 CFR 122.26(b)(14)) with benchmark monitoring requirements for metals;
- Industrial sites that handle, store, produce, or dispose of metallic products or other materials, particularly those containing arsenic, cadmium, chromium, copper, lead, mercury, nickel or zinc;
- High-use or high-ADT roadways or parking areas;
- Urban roads with expected ADT greater than 7,500;
- Rural roads or freeways with expected ADT greater than 15,000;
- Commercial or industrial sites with an equivalent trip end (ETE) count equal to or greater than 40 vehicles per 1,000 square feet of gross building area;
- Parking lots with 100 ETE or more;
- Public on-street parking in commercial and industrial zones;
- Highway rest areas;
- Runoff from metal roofs not coated with an inert, non-leachable material; or

- Discharge to a surface water of the state that has been identified through a TMDL or other water clean-up plan as requiring metals removal.

Stormwater runoff is exempt from metals treatment requirements in the following situations, unless a specific water quality problem has been identified:

- Discharges to non-fish bearing streams;
- Subsurface discharges, unless identified as hydraulically connected to surface waters of the State; the Spokane Valley Rathdrum Prairie Aquifer is hydraulically connected to a surface water of the State;
- Restricted residential and employee-only parking areas, unless subject to through traffic;
- Preservation/maintenance projects and some improvement or safety enhancement projects that do not increase motorized vehicular capacities; and,
- Discharges to some Category 4 wetlands; contact the Washington Department of Ecology for additional information

Phosphorus Treatment Applicability: Phosphorus treatment is required where it has been determined by the federal, state, or local government that a water body is sensitive to phosphorus and that a reduction in phosphorus from new development and redevelopment is necessary to achieve the water quality standard to protect its beneficial uses. Where it is deemed necessary, a strategy will be adopted to achieve the reduction in phosphorus. The strategy will be based on knowledge of the sources of phosphorus and the effectiveness of the proposed methods of removing phosphorus.

Phosphorus treatment may be required for water bodies reported under Section 305(b) of the Clean Water Act and for those listed in Washington State's Non-point Source Assessment required under Section 319(a) of the Clean Water Act.

The Spokane River has been designated as not supporting beneficial uses due to phosphorus, and phosphorus treatment may be required.

Projects that do not propose to discharge to a water body sensitive to phosphorus are exempt from phosphorus treatment requirements.

2.2.4 BASIC REQUIREMENT NO. 4 – FLOW CONTROL

Objective

Flow control facilities are necessary to protect stream morphology and habitat and to mitigate potential adverse impacts on down-gradient properties and floodplains due to the increase in stormwater runoff caused by land development.

Unless specifically approved by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required (refer to Section 3.4.5 for down-gradient analysis criteria). Local jurisdictions reserve the right to deny a request for increased stormwater flows or to condition any approval at their sole discretion.

Exceptions with regard to rate and volume control can be made for regional facilities planned by a local jurisdiction.

When site conditions allow, infiltration is the preferred method of flow control for urban runoff. All projects are encouraged to infiltrate stormwater runoff on site to the greatest extent possible if such infiltration will not have adverse impacts on down-gradient properties or improvements. Flow control facilities shall be designed and constructed according to the criteria in Chapters 5 and 7.

Design Criteria

The NRCS Type IA 24-hour storm event is the design storm for all flow control facilities that use a surface discharge or a combined surface and subsurface system. Flow control facilities that use only infiltration into the subsurface may use either the NRCS Type IA or Type II 24-hour storm event.

Infiltration Facilities: For projects proposing infiltration, the facilities shall be designed based on the 10-year design storm event. The facility shall be designed to bypass storm events that exceed the 10-year design storm frequency and shall provide an overflow path, wherever possible, with the capacity to convey the 100-year storm event. The overflow path shall drain toward the natural discharge point of the contributing basin, such that the overflow route or termination of stormwater does not adversely impact down-gradient properties or structures.

Detention Facilities: For projects proposing to detain and release stormwater runoff, the facilities shall be designed such that the release rate does not exceed the pre-developed conditions for a range of storm events. The analysis of multiple design storms is needed to control and attenuate both low and high flow storm events.

The total post-developed discharge rate leaving the site (including bypass flow) shall be limited to the pre-development rates listed in Table 2-1. Bypass flow is the runoff that leaves the site without being conveyed through the drainage system.

TABLE 2-1
ALLOWABLE DISCHARGE RATES

Design Frequency (24-hour storm)	**Post-Developed Discharge Rate[1]**
2-year	≤ 2-year pre-developed
25-year	≤ 25-year pre-developed
100-year[2] (Emergency Overflow)	Overflow route only

1 Post-developed flow is equal to the release from detention facility plus the bypass flow

2 The emergency overflow shall direct the 100-year post-developed flow safely toward the downstream conveyance system

Evaporation Facilities: For projects proposing to evaporate runoff as the means of stormwater disposal, the facilities shall be designed to control the mean annual precipitation. Design shall meet the criteria described in Section 7.7.2.

Applicability

All projects that meet the regulatory threshold shall comply with this Basic Requirement.

Projects are exempt from flow control if they discharge to any of the following:

- The Spokane River or other exempt water bodies, which are defined in the *Stormwater Management Manual for Eastern Washington* as fifth-order or greater stream channels, as determined from a 1:150,000 scale map;
- A river or stream that is fifth-order or greater as determined from a 1:24,000 scale map;
- A river or stream that is fourth-order or greater as determined from a 1:100,000 scale map;
- A stream that flows only during runoff-producing events. These streams are defined as those that do not discharge via surface flow to a non-exempt surface water following receipt of the 2-year, NRCS Type 1A, 24-hour rainfall event. In addition, for the stream to be exempt, it shall be able to carry the runoff from an average snowmelt event, but shall not have a period of base flow during a year of normal precipitation;

- A lake or reservoir with a contributing watershed areas greater than 100 square miles;
- A reservoir with outlet controls that are operated for varying discharges to the downstream reaches as for hydropower, flood control, irrigation or drinking water supplies (discharges to uncontrolled flow-through impoundments are not exempt).

In order to be exempted the discharge shall meet all of the following requirements:

- The project area must be drained by a conveyance system that consists entirely of manmade conveyance elements (i.e. pipes, ditches, outfall protection); and,
- The conveyance system must extend to the ordinary high water mark line of the receiving water, or (in order to avoid construction activities in sensitive areas) flows are properly dispersed before reaching the buffer zone of the sensitive or critical area; and,
- Any erodible elements of the conveyance system for the project area must be adequately stabilized to prevent erosion; and,
- Surface water from the project area must not be diverted from or increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact. Adverse impacts are expected from uncontrolled flows causing a significant increase or decrease in the 1.5- to 2-year peak flow rate.

Maps shall be standard U.S. Geological Survey (USGS) maps or geographic information system (GIS) data sets derived from USGS base maps.

Floodplains

Projects proposed in or around identified Areas of Special Flood Hazard shall conform to National Flood Insurance Program and the flood ordinance of the local jurisdiction. Refer to Section 7.9.2 for specific requirements. Projects discharging to the Spokane River or other exempt water bodies shall comply with floodplain requirements.

2.2.5 BASIC REQUIREMENT NO. 5 – NATURAL AND CONSTRUCTED CONVEYANCE SYSTEMS

Objective

A conveyance system includes all natural or constructed components that collect stormwater runoff and convey it away from structures in a manner that adequately drains sites and roadways, minimizing the potential for flooding and erosion.

Engineered conveyance elements for proposed projects shall be analyzed, designed, and constructed to provide a minimum level of protection against damage to property and improvements from uncontrolled or diverted flows, flooding and erosion.

Projects shall be designed to protect certain natural drainage features including floodplains, drainageways, and natural depressions that store water or allow it to infiltrate into the ground. These features are collectively referred to as the "natural location of drainage systems" (NLDS). Preserving the NLDS will help ensure that stormwater runoff can continue to be conveyed and disposed of at its natural location. Preservation also increases the opportunity to use the predominant systems as regional stormwater facilities. Refer to Chapter 8 for more information on NLDS.

Stormwater runoff shall be discharged in the same manner and at the same location as in the pre-developed condition, unless otherwise specifically accepted by the local jurisdiction. Stormwater runoff shall not be concentrated onto down-gradient properties where sheet flow previously existed and shall not be diverted to points not receiving stormwater runoff prior to development.

Applicability

All projects shall comply with this Basic Requirement regardless of whether they meet the regulatory threshold.

Design Criteria

Natural and Constructed Channels: Constructed and natural channels shall be designed with sufficient capacity to convey, at a minimum, the depth associated with the 50-year design storm event peak flow rate plus an additional 30%, assuming developed conditions for on-site tributary areas and existing conditions for any off-site tributary areas. Refer to Chapter 8 for additional criteria.

The design shall provide bypass for storm events that exceed the above criteria and shall provide an overflow path with capacity to convey the 100-year storm event, wherever possible. The overflow path shall drain toward the natural discharge point of the contributing basin, such that the overflow route or termination of stormwater does not adversely impact down-gradient properties or structures.

Culverts: New culverts shall be designed with sufficient capacity to convey the 50-year design storm event assuming developed conditions for the on-site basin and existing conditions for the off-site basin.

New culverts shall be designed with sufficient capacity to meet the headwater and tailwater requirements in Chapter 8.

Gutters: Gutter flows in roadways shall allow for the passing of vehicular traffic during the 10-year design storm event by providing non-flooded zones. For paved roadways, the non-flooded width requirement varies with the road classification. The design shall meet the criteria specified in Chapter 8.

Storm Drain Systems and Inlets: The Rational Method and the 10-year design storm shall be used to size the conveyance system regardless of the method used to size the disposal facility.

Enclosed systems may surcharge or overtop drainage structures for storm events that exceed the drainage facility design storm, as long as an overflow path is provided, wherever possible. The overflow path shall be capable of conveying the 100-year storm event and should either drain toward the natural discharge point of the contributing basin (preferred) or away from adjacent buildings, residences, etc. so as to avoid adverse impacts due to flooding.

2.2.6 BASIC REQUIREMENT NO. 6 – EROSION AND SEDIMENT CONTROL

Objective

During the construction phase, sediment-laden runoff can enter newly constructed or existing drainage facilities, thus reducing their infiltration or treatment capacity and their lifetime of operation, or increasing maintenance costs.

Controlling erosion and preventing sediment and other pollutants from leaving the project site during the construction phase is achievable through implementation and selection of BMPs that are appropriate both to the site and to the season during which construction takes place.

The objectives of the erosion and sediment control (ESC) Plan are to:

- Protect existing or proposed stormwater management infrastructure;
- Minimize the impacts of erosion, sedimentation and increased runoff caused by land-disturbing activities on private property, public roads and rights-of-way, and water bodies;
- Protect the health, safety and welfare of the general public (this objective shall not be construed to establish any duties to protect or benefit any particular person or class of persons); and,
- Protect water quality.

Applicability

Land-disturbing activities are activities that result in a change in existing soil cover (vegetative or non-vegetative) or site topography. Land-disturbing activities include, but are not limited to, demolition, construction, clearing and grubbing, grading and logging. An ESC plan may not be required for all of these situations; however that does not relieve the proponent from the responsibility of controlling erosion and sediment during construction nor the liability for damage claims associated with adverse impacts on off-site properties.

The following land-disturbing activities require an ESC plan:

- Major land-disturbing activities involving 1 acre or more of disturbed area; or,
- Minor land-disturbing activities, such as grading, involving less than 1 acre of disturbed area but requiring a permit by the local jurisdiction.

An ESC plan is typically not required for the projects listed in Section 2.1.4.

An ESC plan, when required, shall be submitted with either the road and drainage plans or the permit application, prior to any land-disturbing activity. Clearing and grading activities for developments will be permitted only if conducted pursuant to an accepted site development plan that establishes permitted areas of clearing, grading, cutting, and filling. When establishing these permitted clearing and grading areas, consideration shall be given to minimizing removal of existing trees and minimizing disturbance and compaction of native soils except as needed for building purposes. These permitted clearing and grading areas and any other areas with a preservation requirement, such as critical or sensitive areas, buffers, native growth protection easement areas or tree retention areas, shall be delineated on the site plans and development site plan. ESC plans are only required to address the area of land that is subject to the land-disturbing activity for which a permit is being requested and the area of land that will serve as the stockpile or staging area for materials.

All ESC plans shall adhere to the minimum requirements specified in Chapter 9 of this Manual. Examples and descriptions of the BMPs referenced in this Manual can be found in the most current version of the *Stormwater Management Manual for Eastern Washington (SMMEW) available online at www.ecy.wa.gov/programs/wq/stormwater/tech.html*.

2.2.7 BASIC REQUIREMENT NO. 7 – SOURCE CONTROL

Objective

The intent of source control BMPs is to prevent pollutants from coming into contact with stormwater, thereby reducing the likelihood that pollutants will enter groundwater and violate water quality standards. Source control BMPs are a cost-effective means of reducing pollutant loading and concentrations in stormwater and should be a first consideration in all projects.

Applicability

All projects, unless exempted in Section 2.1.4, shall comply with this Basic Requirement. Project proponents are required to implement applicable source controls through the use of BMPs as specified in Chapter 8 of the *Stormwater Management Manual for Eastern Washington*.

A project proponent is not relieved from the responsibility of preventing pollutant release from coming in contact with stormwater, whether or not the project exceeds the regulatory threshold.

2.2.8 BASIC REQUIREMENT NO. 8 – OPERATION AND MAINTENANCE

Objective

To ensure that stormwater control facilities are adequately maintained and properly operated, documentation describing the applicable preventive maintenance and recommended maintenance schedule shall be prepared and provided to the entity responsible for maintaining the stormwater system.

For drainage ponds and other drainage facilities outside of the public road right of way, the project proponent shall provide the financial means and arrangements for the perpetual maintenance of the drainage facilities.

Proponents shall operate and maintain the facilities in accordance with an operation and maintenance plan that meets the criteria specified in Chapter 11. The operation and maintenance plan shall also include applicable source control BMPs, as described in Chapter 10.

Applicability

All projects that meet the regulatory threshold and that propose drainage facilities or structures shall comply with this Basic Requirement. All projects that propose UIC facilities also must comply with the operation and maintenance requirements, regardless of whether they exceed the regulatory threshold.

CHAPTER 3 – DRAINAGE SUBMITTAL

Chapter Organization

3.1 INTRODUCTION

This chapter describes the contents of a Drainage Submittal and provides a framework for preparing the submittal in order to promote consistency throughout the Spokane region. Specific best management practices (BMPs), design methods and standards to be used are contained in Chapters 4 through 11. Properly drafted construction engineering plans and supporting documents will help facilitate the operation and maintenance of the proposed system long after its review and acceptance.

The Drainage Submittal is a comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater regulations. At a minimum, the Drainage Submittal shall include Construction Plans, Erosion and Sediment Control Plans, and Drainage Calculations. Other supporting documentation shall be submitted as needed. Contents of the Drainage Submittal will vary with the type and size of the project, individual site characteristics, and special requirements of the local jurisdictions.

State law requires that engineering work for the Drainage Submittal be performed by or under the direction of a professional engineer currently licensed in the state of Washington.

3.2 APPLICABILITY

A Drainage Submittal is generally required for any land-disturbing activity. Land-disturbing activities are those activities that result in a change in the existing soil cover (both vegetative and non-vegetative) or site topography. The following sections summarize the activities that require a Drainage Submittal as well as those that are exempt.

3.2.1 REQUIRED

- Projects that meet the regulatory threshold as defined in Section 2.1.1 or propose UIC facilities;
- Plats and binding site plans; and,
- Manufactured and mobile home parks.

3.2.2 GENERALLY REQUIRED

- Commercial building permits including institutional and multi-family residential projects;

- Short plats;
- Change of use permits;
- Conditional use permits;
- Grading permits; and,
- Public or private road projects.

3.2.3 GENERALLY EXEMPT

- Certificates of exemption;
- Single-family residential/duplex building permits (A surface drainage plan and other information may be required in the City of Spokane, however a full drainage submittal is generally not required;
- Temporary use permits, unless the use could cause adverse water quality impacts or other drainage-related impacts;
- Land-disturbing activities that do not require a permit, unless the activity could cause adverse water quality impacts or other drainage-related impacts;
- Underground utility projects that replace the ground surface with in-kind material, or materials with similar runoff characteristics;
- Projects to improve motorized and/or non-motorized user safety that do not increase the traffic capacity of a roadway. Certain safety improvement projects such as sidewalks, bike lanes, bus pull-outs and other transit improvements shall be evaluated case-by-case. A safety improvement project that increases the traffic-carrying capacity is not exempt;
- Legally non-conforming projects, except those that drain to the new construction area and drainage improvements;
- Maintenance projects that do not increase the traffic-carrying capacity of a roadway or parking area, such as:
  - Removing and replacing a concrete or asphalt roadway to base course or subgrade or lower without expanding or improving the impervious surfaces;
  - Repairing a roadway base or subgrade;
  - Resurfacing with in-kind material without expanding the area of coverage;
  - Overlaying existing asphalt or concrete pavement with BST, asphalt or concrete without expanding the area of coverage;
  - Overlaying existing gravel with BST, asphalt or concrete, or overlaying BST with asphalt; in either case, without expanding the

area of coverage. This partial exemption only applies if the overlaid surface continues to drain to the existing facilities or structures and if:

- ♦ The road traffic surface will be subject to an ADT volume of less than 7,500 on an urban road or less than 15,000 on a rural road, freeway, or limited access control highway; or,
- ♦ The parking area traffic surface will be subject to less than 40 trip ends per 1,000 square feet of building area or 100 total trip ends; or,

3.2.4 EXEMPT

- Commercial agriculture as regulated under Revised Code of Washington (RCW) Chapter 84.34.020, except for the construction of impervious surfaces related to commercial agriculture;
- Forest practices regulated under Washington Administrative Code (WAC) Title 222, except for Class IV General Forest Practices that are conversions from timberland to other uses;
- Oil and gas field activities or operations, including construction of drilling sites, waste management pits, access roads, and transportation and treatment infrastructure such as pipelines, natural gas treatment plants, natural gas pipeline compressor stations and crude oil pumping stations;
- Actions by a public utility or any other governmental agency to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic;
- Records of survey, boundary line adjustments, and property aggregations, unless the action affects drainage tracts and easements;
- Operation and maintenance or repair of existing facilities; and,
- Road and parking area preservation/maintenance projects, such as:
  - Pothole and square-cut patching;
  - Crack sealing;
  - Shoulder grading;
  - Reshaping or regrading drainage system; or,
  - Vegetation maintenance.

3.3 CONCEPT DRAINAGE REPORT

3.3.1 INTRODUCTION

Concept Drainage Reports are used by staff of the local jurisdiction to preliminarily assess the drainage requirements on certain land-use actions and land development permits. The purpose of the Concept Drainage Report is to demonstrate that the proposed drainage facilities can meet the intent of this Manual and are feasible with respect to design, construction, and maintenance. Its contents are similar to those of the Drainage Report described in Section 3.4, though for many items the Concept Drainage Report does not require as much detail as the Drainage Report.

Preparation of a Concept Drainage Report is an initial step in the Drainage Submittal process, and acceptance of a Concept Drainage Report does not imply that the concept proposed is accepted as the final design. Acceptance only implies that the project proponent (or his agent) has demonstrated that stormwater disposal is feasible. It does not relieve the project proponent from a geotechnical site characterization (refer to Chapter 4), a down-gradient analysis, or changes to the design that may be necessary in order to meet the criteria and standards presented in this Manual.

3.3.2 APPLICABILITY

The need for a Concept Drainage Report varies depending upon the nature, scope and complexity of the proposed project and the existing drainage conditions. Due to the number of variables involved, this Manual does not include an exhaustive listing of all scenarios that may require a Concept Drainage Report. Concept Drainage Reports will be required for any of the following situations, and the local jurisdiction has the authority to require a Concept Drainage Report for any other project.

- A Certificate of Concurrency is required per the City of Spokane Municipal Code “Concurrency Certification;”
- The project lies within or drains to critical areas, as designated by the local jurisdiction;
- The project lies within or drains to an official 100-Year Flood Zone as mapped by the Federal Emergency Management Agency (FEMA) (See Section 7.9.2);
- The project lies within or drains to a Special Drainage Area (SDA) or study area as recognized by the local jurisdiction (See Section 7.9.1);
- The project lies within or drains to an area identified as having drainage problems;
- The project lies within or drains to an area identified as having floodplains;

- The project is especially large, phased, or master-planned and may require interim facilities;
- The project involves significant off-site drainage and relies upon a predominant drainageway;
- The project site has features that can be classified as Natural Locations of Drainage Systems (NLDS) (refer to 8.2.4 for definition);
- The project has the potential to impact existing or future regional stormwater facilities;
- The project proposes non-standard stormwater treatment BMPs; and,
- The project proposes conventional subsurface disposal systems in areas that are typically not conducive to subsurface disposal (such as where shallow groundwater or other limiting layers may be present).

3.3.3 EXEMPTIONS

In unincorporated Spokane County and the City of Spokane Valley, standard drainage systems proposed in deep free-draining soils are generally exempt from the Concept Drainage Report requirement. This exemption only applies to sites that do not involve significant off-site drainage issues and are not located in or near a known drainage problem area, floodplain or critical area.

3.3.4 SCOPE

The Concept Drainage Report shall demonstrate that the existing or proposed drainage infrastructure is adequate to control the increase in runoff due to the proposed project by meeting the minimum requirements of this Manual.

A detailed design is not required at this stage because the exact nature of the proposal may not be certain. However, the Concept Drainage Report shall provide sufficient information and analysis to demonstrate that adequate infrastructure can be provided. Due to varying design parameters, design challenges, and potential solutions, the level of requirements can change from site to site. For example, if an infiltration facility is proposed in an area known to have shallow groundwater or bedrock, a geotechnical site characterization would be required at the Concept Drainage Report stage to support the use of infiltration. But a concept drainage report proposing an evaporation facility in the same area would not typically require geotechnical work at this stage.

Any alternatives that will be considered by the project proponent during final design shall be included in the Concept Drainage Report. For projects that require a public hearing, all alternatives shall be presented for review by staff and the public prior to the hearing. If the concept does not include any other alternatives, it will be assumed that the accepted concept is the final design concept.

The accepted Concept Drainage Report shall be implemented in the final construction plans. New or significantly altered conceptual elements on the final plans are subject to reconsideration or denial.

The Concept Drainage Report shall include the following elements:

- Narrative: The narrative shall generally follow Section 3.4.2 and shall describe all proposed methods and alternatives for stormwater treatment and disposal, as well as provide sufficient information, supporting technical data, assumptions, design criteria, and drainage calculations to demonstrate that the proposed stormwater system will meet the requirements of this Manual. If phasing is anticipated, an explanation of how the drainage system will be phased and constructed shall also be included;
- Schematic: The schematic plan of the proposed stormwater system shall show the approximate size and location of all drainage components;
- Basin Map: The drainage basin maps shall generally follow the requirements for maps presented in Section 3.4.3, but may be less detailed;
- Geotechnical Information: If a non-standard disposal system or infiltration is proposed, then sufficient site characterization work shall be completed in accordance with Chapter 4 to demonstrate that the proposed facilities will function as intended;
- Drainage Features: The report shall generally follow the requirements for pre-development basin information presented in Section 3.4.2, but may be less detailed;
- Critical Areas: The report shall generally follow the requirements for critical areas presented in Section 3.4.2, but may be less detailed;
- Perpetual Maintenance of Facilities: The report shall generally follow the requirements for Perpetual Maintenance of Facilities presented in Section 3.4.2, but may be less detailed;
- Offsite Easements: The report shall follow the requirements for off-site easements presented in Section 3.4.2; and,
- Regional Facilities: The report shall follow the requirements for regional facilities presented in Section 3.4.2.

3.4 DRAINAGE REPORT

3.4.1 INTRODUCTION

The purpose of the Drainage Report is to identify drainage impacts resulting from land development activities and determine the improvements necessary to control the increase in stormwater runoff and to treat the pollutants that can adversely impact water quality.

A Drainage Submittal package is required after a formal decision on a land use action has been made and the conditions of approval have been accepted. If a formal decision is not required for the project, the Drainage Submittal package is submitted as part of the project permit application.

The Drainage Report shall be inclusive, clear, legible, and reproducible. An uninvolved third party shall be able to review the Drainage Submittal and determine whether all applicable standards in this Manual have been met.

The basic elements of a Drainage Report are summarized in the following sections.

3.4.2 NARRATIVE

The drainage report narrative shall include the following elements:

- Project Description: The project description shall include information about the size of the project, the number of lots proposed, the project location (including Section, Township and Range), and background information relevant to drainage design, including topography, surface soils, surface and vegetative conditions, etc.;
- Geotechnical Information: This part of the narrative shall summarize the geotechnical site characterization (GSC) for the project including recommended outflow rates for drywells, infiltration rates and on-site soil descriptions;
- Pre-Development Basin Information: This information shall summarize the pre-development drainage patterns for all basins contributing flow to, on, through, and from the site. This section shall include all assumptions and justifications used to determine curve numbers and/or runoff coefficients used in the analysis, including a table that presents existing impervious and pervious areas as shown in the example in Appendix 3A. The narrative shall identify and discuss all existing on-site and/or off-site drainage facilities, natural or constructed, including but not limited to NLDS, conveyance systems, and any other special features on or near the project;

- Post-Development Basin Information: This information shall summarize all assumptions used to determine the characteristics of the post-developed basins, such as the size of roofs and driveways, and the curve numbers and/or runoff coefficients used in the analysis (refer to Appendix 3A for an example table). In addition, a table shall be included that summarizes the impervious and pervious areas for each subbasin, as shown in Appendix 3A;
- Critical Areas: If the local jurisdiction's Critical Areas Ordinance requires a Critical Areas evaluation for the project proposal, any required mitigation measures shall be incorporated into the proposed drainage facility design and addressed in the Drainage Report and Road and Drainage Plans;
- Down-Gradient Analysis: This analysis shall identify and discuss the probable impacts down-gradient of the project site. Refer to Section 3.4.5 for additional requirements;
- Methodology: The hydraulic methods and storm events used in sizing the drainage facilities, including the BMPs proposed for the project, shall be discussed;
- Water Quality Treatment: A discussion of treatment requirements, based on the criteria in Chapter 6, shall be included;
- Results: The results of the calculations and a description of the proposed stormwater facilities shall be included. When applicable, a table comparing the pre-developed and post-developed conditions including rates and volumes shall also be included. A table shall be provided when applicable, summarizing the maximum water elevation of the facilities for the design storms, outflow structure information, the size of facilities "required" by the calculations, and the size of the facilities "provided" in the proposed design (refer to Appendix 3A for an example table);
- Operational Characteristics: Sufficient information shall be provided about the operation of the stormwater system so that an uninvolved third party can read the report and understand how the proposed system will function under various conditions.
- Perpetual Maintenance of Facilities: A discussion shall be included of the provisions set forth to operate and maintain the drainage facilities. The project proponent's mechanism for funding the operation and maintenance for stormwater facilities, including sinking fund calculations, shall be included (refer to Chapter 11 for operation and maintenance requirements and Chapter 10 for source control requirements);
- Off-Site Easements: The anticipated location of any off-site easements shall be identified either on the basin map or in a separate schematic. Off-site easements will be required for proposed stormwater conveyance or disposal facilities outside the project boundaries. These easements shall be

obtained and recorded prior to the acceptance of the final Drainage Submittal (refer to Chapter 11 for more information); and,

- Regional Facilities: A discussion of any expected future impacts on or connections to existing or proposed regional facilities shall be included (refer to Section 7.10).

3.4.3 FIGURES

Basin Map

The drainage report shall include a basin map. In most cases, both a pre-developed and post-developed basin map shall be provided. The minimum elements required include the following:

- Vicinity map, project boundaries, and section, township and range;
- Basin limits:
    - Basin limits shall include on-site, off-site, and bypass areas contributing runoff to or from the project;
    - In all cases, the engineer shall field-verify the basin limits, including any contributing off-site areas, and shall describe how the basin limits were determined.
    - Drainage basins shall be clearly labeled and correlated with the calculations;
- Time of concentration routes, with each segment clearly labeled and correlated with the calculations;
- Labeled topographic contours:
    - Contours shall extend beyond the project or drainage basin boundaries to the extent necessary to confirm basin limits used in the calculations.
    - For commercial projects, spot elevations may be acceptable in lieu of contours on post-developed basin maps.
    - Projects in an urban area shall use a maximum contour spacing of 2 feet.
    - At the discretion of the local jurisdiction, projects outside an urban area, such as a large lot subdivision, may use the best available topographic information; this may involve contours on a scale larger than the 2-foot minimum.
- Any NLDS including, but not limited to, natural or constructed drainage features, wetlands, creeks, streams, seasonal drainageways, closed depressions, ditches, culverts, storm drain systems and drywells;

- Floodplain limits, as defined by FEMA or other studies;
- Any geologically hazardous areas;
- Footprint of proposed drainage facilities such as ponds, infiltration facilities, pipes, and ditches;
- North arrow and scale;
- Existing and proposed easements; and,
- Adjacent streets.

Other Figures

- Soils map;
- Site photos;
- Any graphs, charts, nomographs, maps, or figures used in the design, when applicable; and,
- If infiltration is proposed, a geotechnical site characterization is typically required (refer to Chapter 4). As part of that study, a geologic cross-section of the stormwater disposal area drawn to scale shall be included. The proposed stormwater disposal facilities shall be superimposed on the cross-section. All relevant geologic units shall be clearly identified including the target disposal layer and limiting layers.

3.4.4 CALCULATIONS

Calculations shall be presented in a logical format and provide sufficient information to allow an uninvolved third party to reproduce the results. All assumptions, input and output data, and variables listed in computer printouts and hand calculations shall be clearly identified. Basins and design storm events shall be clearly identified on all calculations.

The Drainage Report shall incorporate all calculations used to determine the size of the facilities. Typical calculations include, but are not limited to:

- Hydrologic/hydraulic calculations including pre- and post-developed peak rate and volume calculations, routing calculations, design information for outflow structures, orifice information, a pond volume rating table or pond volume calculations, etc.;
- Time of concentration calculations;
- Curve number (CN) or runoff coefficient (C)
- Water budget calculations;
- Water quality treatment calculations;

- Inlet capacity and bypass calculations;
- Detention/retention storage capacities;
- Calculations for ditches and natural channels;
- Culvert and pipe calculations;
- Non-flooded width calculations; and,
- Energy dissipation calculations.

Refer to Chapters 5 through 8 for additional information regarding the above calculations.

3.4.5 DOWN-GRADIENT ANALYSIS

The purpose of a Down-Gradient Analysis is to inventory natural and constructed down-gradient drainage features and to identify and evaluate adverse down-gradient impacts that could result from the proposed project. Common adverse impacts of land development include erosion, flooding, slope failures, changed runoff patterns and reduced groundwater recharge (to springs, streams, wetlands and wells, etc.). Proposed drainage facilities are to be designed to mitigate adverse impacts identified in the Down-Gradient Analysis.

A Down-Gradient Analysis is required for all projects, unless waived by the local jurisdiction. The level of detail required will vary depending on the location and complexity of the project. Project sites that have well-draining soils, no identified drainage problems nearby and no features that rely on groundwater recharge in the vicinity may require only a minimal level of effort to meet this requirement. Conversely, if the project is located in an SDA or a known problem drainage area, as determined by the local jurisdiction, if non-standard disposal systems are proposed, or if land features of concern have been identified down-gradient of the project site, then the level of analysis shall match the complexity of the site. Typically, the analysis should extend a quarter of a mile down gradient and may be limited in scope by lack of access to adjacent properties.

At a minimum, this analysis shall include:

- A visual inspection of the site and down-gradient area by the engineer that extends to the location where adverse impacts are anticipated to be negligible;
- A site map that clearly identifies the project boundaries, study area boundaries, down-gradient flow path, and any existing or potential areas that have been identified as problematic;
- A written summary addressing the following items:

- Existing or potential off-site drainage problems that may be aggravated by the project;
- The condition and capacity of the conveyance route including all existing and proposed elements, potential backwater conditions on open channels, constrictions or low capacity zones, surcharging of enclosed systems, or localized flooding;
- The presence of existing natural or constructed land features that are dependent upon pre-developed surface or subsurface drainage patterns;
- Potential changes to groundwater characteristics that may negatively impact sub-level structures, foundations, or surface areas due to an increased amount or increased frequency or duration of groundwater intrusion;
- Existing or potential erosive conditions such as scour or unstable slopes on-site or down-gradient of the project; and,
- Flood hazard areas identified on FEMA maps.

If there are existing or potential off-site drainage problems down-gradient of the project, it shall be demonstrated that the proposed stormwater disposal system has been designed to meet all of the following conditions:

- The stormwater runoff leaves the site in the same manner as that of the pre-developed condition;
- Reduced or increased groundwater recharge has been considered with respect to potential adverse impacts on downgradient features; and
- The proposed design does not aggravate an existing drainage problem or create a new drainage problem.

If down-gradient surface release at a rate or volume greater than the pre-developed condition is proposed, then the following items shall also be addressed in detail:

- Potential adverse impacts on natural or constructed drainage channels due to an increase in stormwater rate, velocity and flow duration; and
- Potential adverse impacts on undeveloped down-gradient properties that, if developed in the future, could be adversely impacted.

3.5 ROAD AND DRAINAGE PLANS

3.5.1 INTRODUCTION

Construction drawings shall be submitted for review by the local jurisdiction. The submittal and acceptance process shall be in accordance with the local jurisdiction's standards and specifications

All plan sheets for every submittal shall be signed and dated by the project proponent, or his authorized agent, and all plan sheets shall be stamped and signed by the project engineer. Road and drainage plans shall include the local jurisdiction's standard notes for construction (refer to Appendix 3B).

Once the Drainage Submittal has been accepted by the local jurisdiction, a set of Road and Drainage plans shall be submitted on good quality, reproducible Mylar media. The Mylar set shall be stamped and signed by the engineer and signed and dated by the project proponent or his authorized agent.

3.5.2 MINIMUM PLAN ELEMENTS

The road and drainage plans shall provide enough detail for a third party to construct the proposed facilities per the engineer's design. At a minimum, the plans shall meet the criteria of the local jurisdiction's standards and specifications, and provide the following information:

- Flow line and/or spot elevations, slopes, lengths, and cross-sections of ditches;
- Rim elevations of inlet grates, drywells, and other structures;
- A profile of the stormwater conveyance system including pipes, culverts, ditches and connections, where applicable. The profile shall include the sizes, material types, lengths and invert elevations of all conveyance elements.
- For lateral pipe connections to storm drain lines in existing right of way (i.e. from a catch basin to a drywell, a main line stormwater system, a pond or a swale), fixed invert elevations are preferred but not required. The minimum depth from finish grade to pipe invert and the minimum pipe slope necessary to satisfy the freeboard and self-cleaning velocity requirements shall be provided. If necessary, invert elevations may be adjusted during construction to avoid potential conflicts with existing utilities in the right of way;
- Where drainage infrastructure such as roadside swales or parallel conveyance ditches or channels may interfere with driveway locations,

driveway locations shall be fixed as part of the road and drainage plans and shown on the lot plans;

- Record drawing information, including invert elevations of any existing drainage system elements that will be used in the new design;
- Construction details drawn to scale or a referenced standard drawing for all structures. Standard details shall be referenced, not reproduced, on the construction drawings;
- Drainage easements with all survey information shown and a recording number if applicable;
- Grading plan for drainage ponds and swales. The grading plan shall include existing and proposed one foot contours and catch points. A cross-section of each pond or swale shall be provided in the plans, showing pond/swale bottom elevation, maximum water surface elevation for the design storm(s), inlet and outlet elevations, berm elevation and slopes, landscaping and vegetation requirements, compaction requirements and keyway location and dimensions;
- Each drainage pond/swale corner, pipe inlet or outlet, pipe system angle point, ditch, and drainage structure, shall be horizontally defined with respect to property corners, street stationing, or a coordinate system; and,
- Material gradation, thickness, and dimensions of riprap pads.

3.5.3 REVISIONS AFTER PLAN ACCEPTANCE

When changes to the design are necessary, acceptance of any proposed plan changes shall be obtained in writing from the local jurisdiction. The proposed revisions shall be stamped and signed by an engineer and submitted to the local jurisdiction for review and acceptance prior to construction. The submittal shall include:

- A brief description of the proposed changes and the purpose for the change;
- Substitute pages of the originally accepted construction plans that include the proposed changes; and,
- Calculations and supporting documentation for the proposed change demonstrating that the proposed modified design is at least equivalent to the originally accepted design.

3.6 OTHER SUBMITTAL ELEMENTS

As determined by the local jurisdiction, the following items shall be included as part of the Drainage Submittal:

- Acknowledgement (acceptable in the form of a letter) of inspection responsibilities. Contact the local jurisdiction for specific project inspection requirements;
- A geotechnical site characterization, which may also include a sub-level structure feasibility analysis, pavement analysis, pavement subgrade sampling, down-gradient analysis, etc. (refer to Chapter 4);
- An erosion and sediment control plan (refer to Chapter 9);
- A draft copy of the Conditions, Covenants and Restrictions (CC&Rs) for the homeowners' association in charge of operating and maintaining the drainage facilities (refer to Chapter 11);
- An operations and maintenance manual (refer to Chapter 11);
- A financial plan (refer to Chapter 11);
- On-site and/or off-site easement documentation (refer to Chapter 11);
- Lot Plans (refer to criteria and example in Appendix 3C).
  Note that lot plans are not required when the only drainage facilities for a given project are located within the public right of way. However, when a lot plan is required, and facilities are located both on private property in an easement and in the public right of way, the facilities within the right of way shall be identified and dimensioned as noted.
- UIC registration forms (refer to Section 6.3.2).
- Documentation that applicant has contacted Ecology regarding the need for a NPDES Construction Stormwater Permit

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APPENDIX 3A – EXAMPLE TABLES FOR DRAINAGE REPORT

BASIN INFORMATION SUMMARY TABLE

	Pre-Development Condition	**Post-Development Condition**
Total Site (acres)	**15**	**15**
Pollutant Generating Impervious Surface (acres)	**n/a**	**4.2**
Surface Cover	n/a	roads & driveways
NRCS Soil Type	n/a	Type B
CN Value	n/a	98
Hydraulically Unconnected Impervious Surfaces (acres)	**1.1**	**2.4**
Surface Cover	dirt road	roofs & sidewalks
NRCS Soil Type	Type B	Type B
CN Value	85	98
Pervious Surfaces (acres)	**13.9**	**8.4**
Composite CN	**52**	**59**
Surface Cover #1	woods, good	woods, good
Sub-Area #1 (acres)	3.9	0.6
NRCS Soil Type #1	Type A	Type A
CN Value #1	30	30
Surface Cover #2	brush, fair	open space & lawn area, good
Sub-Area #2 (acres)	3	6
NRCS Soil Type #2	Type B	Type B
CN Value #2	56	61
Surface Cover #3	herbaceous, good	herbaceous, good
Sub-Area #3 (acres)	7	1.8
NRCS Soil Type #3	Type A	Type A
CN Value #3	62	62

NRCS – Natural Resources Conservation Service

TREATMENT AND FLOW CONTROL REQUIREMENT SUMMARY TABLE

	Treatment Volume (cubic feet)		10-Year Storm Event Required Volume (cubic feet)	Total Volume Provided (cubic feet)
	Required	Provided		
Basin A	135	150	75	300
Basin B	110	120	95	240
Basin C	255	280	155	560

POLLUTANT-GENERATING IMPERVIOUS SURFACE SUMMARY TABLE

	Total Basin Area (sf)	Grass (sf)	Roof Number	Roofs (sf)	Driveway Number	Driveway Area (sf)	Pavement (sf)	Sidewalk (sf)	PGIS Area (sf)
Basin A	37,575	5,000	10	15,000	10	5,000	12,000	575	17,000
Basin B	16,750	3,500	5	7,500	4	2,000	3,500	250	5,500
Basin C	36,075	4,500	10	15,000	8	4,000	12,000	575	16,000

APPENDIX 3B – STANDARD NOTES FOR ROAD AND DRAINAGE PLANS

1. All work and materials shall be in conformance with the local jurisdiction road standards (insert applicable road standards name), 20XX (insert applicable year per land-action conditions of approval or the most current version for municipal road projects).
2. Prior to site construction, the Contractor is responsible for locating underground utilities. Call the underground utility location service at 1-800-424-5555 before you dig.
3. Locations of existing utilities shown in the plans are approximate. The Contractor shall be responsible for locating all underground utilities. Any conflicting utilities shall be relocated prior to construction of road and drainage facilities.
4. The Contractor is required to have a complete set of the accepted road and drainage plans on the job site whenever construction is in progress.
5. If the Contractor discovers any discrepancies between the plans and existing conditions encountered, the contractor shall immediately notify the design engineer.
6. The Contractor should take precautions to protect the infiltration capacity of stormwater facilities (e.g., line the facility with filter fabric, over-excavate upon completion of the infrastructure, etc.)

Supplemental notes used when applicable

7. For any curb grades less than 0.8% (0.008 ft/ft), a Professional Land Surveyor currently licensed in the State of Washington shall verify that the curb forms are at the grades noted on the accepted plans, prior to placement of concrete. The Contractor is responsible for arranging and coordinating work with the Surveyor.
8. The Contractor shall employ a Professional Land Surveyor currently licensed in the State of Washington to verify that the cross-gutter forms are at the correct plane grade prior to concrete placement. The cross-gutters shall be constructed prior to paving, and the pavement shall then match the edge of concrete gutter.
9. For construction of drywells, install filter fabric (Amoco 4545 or approved equivalent) between the washed drain rock and the native soils.
10. Bio-infiltration ponds/swales shall have a maximum treatment design depth (from pond/swale bottom to elevation of drywell grate or first overflow/outflow mechanism) of 6 inches. Either organic matter content or Cation Exchange Capacity (CEC) testing shall be completed in order to substantiate the treatment soil composition. The tests shall be performed on composite samples taken from the treatment soil layer from the constructed pond bottom. A composite sample consists of well-mixed soil obtained from at least four cores, to a depth of at least 6 inches, randomly distributed over the pond bottom test area. Stockpile samples from on-site or a material supplier can be tested for informational purposes to determine initial

suitability and possible soil amendments, but will not be accepted in-lieu of in-place testing. A minimum of one test shall be performed for each bio-infiltration pond/swale 1,500 square feet or less, with one additional test for each additional 2,000 square feet of pond/swale bottom, or fraction thereof. “One test” is equal to four core samples taken as described above. Testing results shall be submitted as part of the Construction Certification Submittal required for release of surety posted on project.

11. Concrete aprons are required at the inlet into any swale or pond. The finish grade of the swale/pond side slope, where the concrete inlet apron ends, shall be a minimum of 2 inches below the finished elevation of the concrete curb apron extension. The intention is to allow stormwater runoff to enter the swale/pond unobstructed, without backing up into the street and gutter due to sod overgrowth at the inlet.

12. Unlined pond and bioinfiltration swale bottoms are expected to infiltrate via the pond floor, and therefore, shall not be heavily compacted; equipment traffic shall be minimized on the pond bottoms. The facility subgrade shall be a medium- to well-draining material, with a minimum thickness of 48 inches and a minimum infiltration rate of 0.15 in/hr. The facility shall drain within 72 hours of a storm event. If the pond also serves as a water quality treatment facility, the treatment zone (sod and 6 inches of treatment soil) shall be a medium- to well-draining material, with a minimum infiltration rate of 0.25-0.50 in/hr.; silty loam or loamy soils are presumed to have an infiltrative rate that falls within this range. Scarify the finish grade of the pond bottom prior to hydroseeding/sodding. Testing that verifies subgrade minimum infiltration rate is required by the local jurisdiction prior to construction certification to ensure adequate drainage. Infiltrative testing of the treatment zone is only required if soils other than silty loam or loamy soils are proposed.

13. If, during final inspection, it is found that the constructed pond or swale does not conform to the accepted design, the system shall be reconstructed so that it does comply.

Refer to Appendix 9A for Erosion and Sediment Control Standard Notes.

APPENDIX 3C – LOT PLAN CRITERIA AND EXAMPLE

Lot plans, stamped and signed by a Professional Engineer, shall be prepared for residential lots containing any of the following elements:

- Drainage facilities in easements on the lot;
- Drainage facilities located in the public right of way or private road tract which are in front of or adjacent to the lot;
- Floodplain encroachment;
- An easement or tract is located on the lot, including but not limited to sewer, domestic water, access, sight distance, NLDS (refer to Section 8.3.4), aviation, petroleum or utility.

A separate lot plan* shall be prepared for each lot meeting the above conditions and shall contain the following elements or adhere to the following criteria:

- The lot plan and attached section sheets shall be on letter or legal size paper and shall be signed and stamped by an engineer;
- The lot plan shall include a north arrow, scale, lot address (if available), name of adjacent street(s); curb sidewalk and/or edge of asphalt, lot dimensions, lot number, block number and the name of the sub-division;
- All easements shall be labeled and dimensioned with respect to property lines or corners;
- Elevations and dimensions of the pond bottom area shall be clearly shown if applicable;
- Invert or rim elevations for any curb drops, sidewalk inlets, grates, and drywells shall be clearly shown;
- The locations of any required ditches shall be shown, including ditch flow line grade and riprap if required;
- The final/fixed location of driveways shall be shown, including any information about the culvert (material, diameter, length, invert elevation(s), depth of cover, etc.);
- A standard detail for all structures shall be called out;
- Locations of all utilities shall be shown (City of Spokane only);
- Text placed inside the lot lines should be limited to lot line dimensions with all remaining text placed outside of the lot lines for clarity; and,
- The scale of the drawing shall be such that each lot is depicted as large as possible while still including the curb line(s) of the adjacent street(s).

* A "typical" lot plan will be considered representative for more than one lot only if the drainage facility geometry is consistent with regard to length, width, depth and grade, subject to local jurisdiction approval.

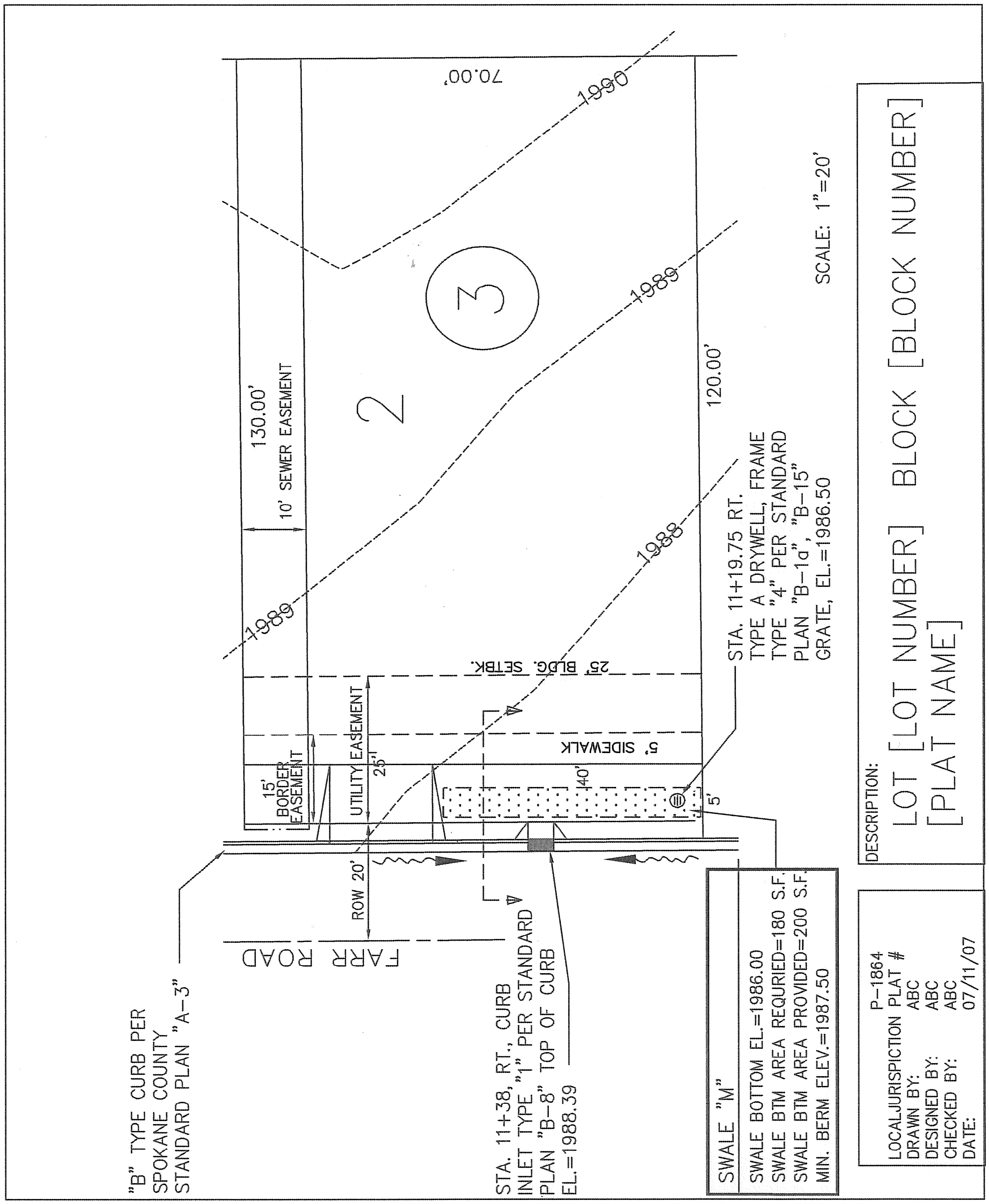
Lot plans shall be accompanied by a dimensioned cross-sectional drawing through the drainage facility. Cross-sections shall be drawn to scale and depict the following items as applicable:

- Property and right of way lines;
- Easements;
- Curb and sidewalk;
- Edge of asphalt;
- Swale side slopes;
- Total depth of swale or ditch;
- Rim elevation of the drywell;
- Spot elevations for normal gutter line, the required 2-inch drop to finish grade below the concrete apron, and the finish grade of the swale bottom;
- Grass, seeding or vegetation requirements; and,
- Any other applicable information which would further assist in achieving the proper construction.

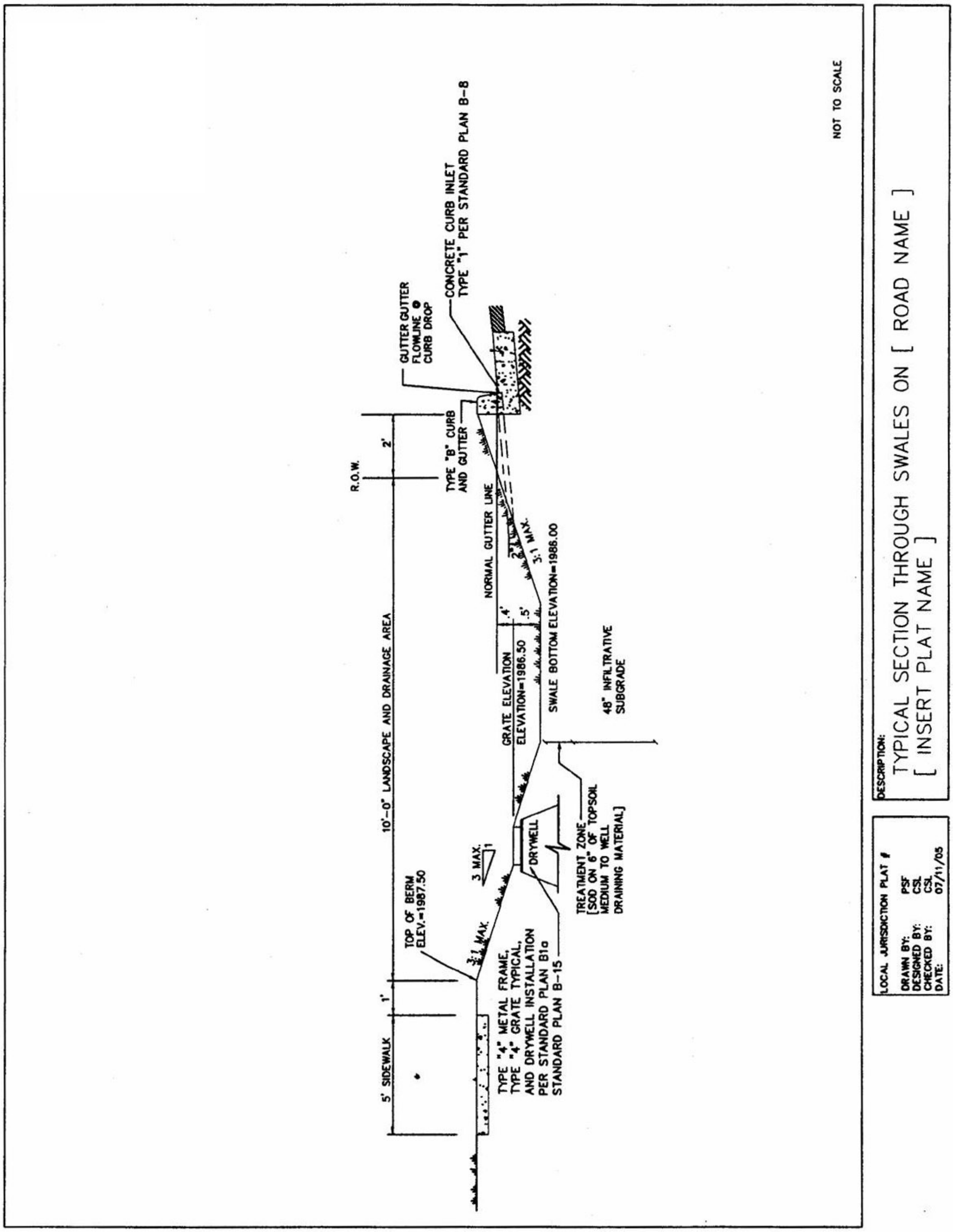
Example plan and cross-sectional drawings are shown on the following pages.

Note that lot plans are not required when the only drainage facilities for a given project are

located within the public right of way. However, when a lot plan is required, and facilities are located both on private property in an easement and in the public right of way, the facilities within the right of way shall be identified and dimensioned as noted above for informational purpose.



"B" TYPE CURB PER SPOKANE COUNTY STANDARD PLAN "A-3"
FARR ROAD
ROW 20'
STA. 11+38, RT., CURB INLET TYPE "1" PER STANDARD PLAN "B-8" TOP OF CURB EL.=1988.39
SWALE "M"
SWALE BOTTOM EL.=1986.00
SWALE BTM AREA REQURIED=180 S.F.
SWALE BTM AREA PROVIDED=200 S.F.
MIN. BERM ELEV.=1987.50
LOCALJURISPICTION PLAT # P-1864
DRAWN BY: ABC
DESIGNED BY: ABC
CHECKED BY: ABC
DATE: 07/11/07
DESCRIPTION:
LOT [LOT NUMBER] BLOCK [BLOCK NUMBER]
[PLAT NAME]
SCALE: 1"=20'
STA. 11+19.75 RT. TYPE A DRYWELL, FRAME TYPE "4" PER STANDARD PLAN "B-1a", "B-15" GRATE, EL.=1986.50
15' BORDER EASEMENT
UTILITY EASEMENT
25'
40'
5'
5' SIDEWALK
25' BLDG. SETBK.
10' SEWER EASEMENT
130.00'
120.00'
70.00'
1988
1989
1990
2
3


NOT TO SCALE
5' SIDEWALK
1'
10'-0" LANDSCAPE AND DRAINAGE AREA
R.O.W.
2'
TOP OF BERM
ELEV.=1987.50
3:1 MAX.
3 MAX.
1
GRATE ELEVATION
ELEVATION=1986.50
NORMAL GUTTER LINE
.4'
.5'
3:1 MAX.
SWALE BOTTOM ELEVATION=1986.00
TYPE "B" CURB
AND GUTTER
GUTTER GUTTER
FLOWLINE @
CURB DROP
CONCRETE CURB INLET
TYPE "1" PER STANDARD PLAN B-8
DRYWELL
48" INFILTRATIVE
SUBGRADE
TYPE "4" METAL FRAME,
TYPE "4" GRATE TYPICAL,
AND DRYWELL INSTALLATION
PER STANDARD PLAN B1a
STANDARD PLAN B-15
TREATMENT ZONE
[SOD ON 6" OF TOPSOIL
MEDIUM TO WELL
DRAINING MATERIAL]
LOCAL JURISDICTION PLAT #
DRAWN BY: PSF
DESIGNED BY: CSL
CHECKED BY: CSL
DATE: 07/11/05
DESCRIPTION:
TYPICAL SECTION THROUGH SWALES ON [ROAD NAME]
[INSERT PLAT NAME]

CHAPTER 4 – GEOTECHNICAL SITE CHARACTERIZATION

Chapter Organization

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4.1 INTRODUCTION

This chapter outlines the minimum requirements for a geotechnical site characterization (GSC), which is used in developing recommendations for stormwater disposal and determining the feasibility of constructing sub-level structures. A qualified geotechnical engineer (a professional engineer currently licensed in the State of Washington with geotechnical engineering as a specialty) is required to perform the GSC. Hydrogeologists and engineering geologists may prepare geotechnical site characterization studies, excluding structural, foundation and pavement design. The following geotechnical studies, if required, can be performed at the same time as the GSC:

- Geohazard analysis;
- Pavement subgrade evaluation;
- Down-gradient analysis (refer to Section 3.4.5);
- Evaporative or detention pond liner recommendations, including potential groundwater effects on impervious pond liners (mounding, uplift, etc.);
- Embankment recommendations for proposed disposal facilities that would impound stormwater (refer to Section 7.8.6 for embankment criteria).
- Recommendations for all cut and fill slopes.

Contact the local jurisdiction for specific requirements with regard to geohazardous areas and road surfacing. The requirements of this chapter are in addition to any field or laboratory testing that may be required, or recommended by the project engineer, with regard to footings, foundations, utility work, etc.

In areas other than Special Drainage Areas (SDAs) and known drainage problem areas, the geotechnical engineer may make recommendations on the feasibility of sub-level structures based on the information available from the initial site investigation.

4.2 APPLICABILITY

A GSC will be required for most projects. The scope and geographic extent of the investigation may vary depending on the general location and setting of the site, the characteristics of the target soil layer, and whether there are known or anticipated drainage problems in the vicinity of the site.

A GSC is required for:

- Projects proposing infiltration (drywells, detention facilities receiving credit for pond bottom infiltration, etc.) or non-standard drainage systems;

- Projects located in a Special Drainage Area (SDA) or a Special Drainage District (SDD);
- Projects located within or draining to a drainage problem or study area as recognized by the local jurisdiction;
- Projects with administrative conditions requiring a GSC; or,
- Projects with proposed sub-level structures, as required by the local jurisdiction.

In areas where there has been a long-standing record of satisfactory performance of standard subsurface disposal facilities and no drainage problems are known to exist, the minimum requirements found in Section 4.3 may be reduced or waived after a formal written request from the project proponent's engineer has been reviewed and accepted by the local jurisdiction.

4.3 GEOTECHNICAL SITE CHARACTERIZATION REPORT

The following are minimum requirements for the GSC:

- The Study shall include:
  - A surface reconnaissance of the site and adjacent properties to assess potential impacts from the proposed stormwater system and to verify that the conditions are consistent with the mapped information. Typically, the evaluation should extend a quarter of a mile down gradient. Where access to adjacent properties is unavailable, the project proponent shall rely upon the best known information for the area, supplemented with information available from the local jurisdiction, including any existing geotechnical engineering reports or studies for sites in the vicinity;
  - A review of available geologic, topographic, soils, and Critical Areas maps to identify any site conditions that could impact the use of storm drainage systems or the construction of sub-level structures. This review shall include all available previous geotechnical engineering reports or studies for sites in the vicinity; and,
  - An evaluation of the potential impacts of groundwater on the proposed storm drainage facilities and roadways, when a seasonally high groundwater table is suspected.
- The Report Narrative shall include:
  - A brief project description including size, number of lots proposed, project location (section, township and range), and background information relevant for drainage design;
  - A discussion of the study investigations;
  - A description of the soil units on the site and in the vicinity of the site;

    - A description of the site including surface, soil, and groundwater conditions, etc; and,
    - Conclusions and recommendations

- The Site Plan shall include:
    - Project boundaries (including all existing and proposed property lines);
    - Labeled topographic contours, extending beyond the project and drainage basin. Projects in an urban area shall use a maximum contour spacing of 2 feet. At the discretion of the local jurisdiction, projects outside an urban area, such as a large lot subdivision, may use the best available topographic information, which may involve contours with spacing of more than 2 feet. In either case, the engineer shall field verify the basin limits;
    - Location of the soil units identified;
    - Location of significant structures, properties or geologic features (such as basalt outcroppings, etc.) on site and in the project vicinity;
    - Location of existing natural or constructed drainage features on site and in the project vicinity; and,
    - Location of proposed site infrastructure including roadways and drainage features such as ponds, drywells, etc.

- Test Method Documentation shall include:
    - A map with the location of all subsurface field explorations and any in-place field tests;
    - A description of any difficulties encountered during excavation and testing;
    - A description of the equipment used to perform the field explorations or tests. When applicable, describe the type of fabric lining and gravel backfill used;
    - Logs of subsurface explorations which shall identify the depth to groundwater, the presence of any limiting layers and the target soil layer; include test pit or excavation dimensions, with photographs, where applicable;
    - Report test data in a format that includes time of day, flow meter readings, incremental flow rates, observed head levels, water depths and total flow volumes in the drywell, test pit or infiltrometer;
    - A description of the condition of any existing facilities being tested, noting any silt build-up, water level, connections to other structures (including distance to inverts of any interconnecting pipes), measured depths and dimensions, etc.;

- Results of field and laboratory testing conducted, including the grain size analysis represented both graphically and in tabular format (refer to Section 4.3.1). For the Spokane 200 method, results shall also be summarized using the formatting shown in Table 4-1.;
- A report on the normalized outflow rates for drywells, and the actual and proposed design outflow rates for test pits;
- Results of the sub-level structure feasibility study (refer to Section 4.3.2) and a summary of the down-gradient analysis (refer to Section 3.4.5), as applicable;
- A geologic cross-section of the stormwater disposal area drawn to scale, with the proposed stormwater disposal facilities superimposed on the cross-section. All relevant geologic units shall be clearly identified including the target disposal layer and limiting layers; and,
- For the Spokane 200 Method, results summarized using the formatting shown in Table 4-1, as well as the sieve analysis data, presented both graphically and in tabular format.

TABLE 4-1
SPOKANE 200 METHOD RESULTS SUMMARY

Exploration ID	Sample Depth	USCS Classification	Percent Fines	Hydraulic Conductivity	Normalized Drywell Outflow Rate	Factor of Safety
TP #2	4.0’	SP-SM	6.3%	0.011 cm/sec	0.032 cf/ft	2.0
TP #2	10.5’	GP	4.5%	0.035 cm/sec	0.090 cf/ft	1.3

4.3.1 FIELD AND LABORATORY TESTING

The subsurface exploration, testing, and associated engineering evaluations are necessary to identify permeable soils and to determine the thickness, extent, and variability of the soils. This information is necessary to properly design stormwater disposal facilities.

Field explorations and laboratory testing shall be conducted under the direct supervision of a geotechnical engineer.

Test Methods

Soil infiltration and drywell outflow rates shall be determined using one or more of the following methods:

- The Spokane 200 Method (refer to Appendix 4A) uses “percent fines” (i.e. soil gradation data) to estimate drywell outflow rates for design purposes. This test method is an option provided to the geotechnical engineer to initially assess the suitability of the on-site soils for subsurface stormwater disposal in drywells;
- The full-scale drywell test (refer to Appendix 4B) uses field data to determine the actual outflow rates of a drywell. This test method is required for all existing drywells to verify the condition and capacity of the structure;
- The test pit method (refer to Appendix 4C) uses field data to estimate the outflow rates of drywells and other subsurface disposal facilities. A geotechnical engineer may elect to use this test method to further verify the design outflow rates used in the drainage design when soil gradations indicate marginal outflow rates, as determined by the Spokane County 200 Method. Also, this test method may be used for estimating outflow rates for non-standard subsurface disposal systems (infiltration galleries, under-drain systems, etc);
- The single-ring infiltrometer test (refer to Appendix 4D) or pond flood test (refer to Appendix 4F) can be used to verify pond drawdown times as required in Section 7.8.3, as well as the infiltration rates of the subgrade and treatment zone of a water quality facility as discussed in Section 6.7.1. The single-ring infiltrometer test uses field data to determine the hydraulic conductivity of surficial soils;
- The swale flood test (refer to Appendix 4E) uses field data to verify swale drawdown times and functionality; and,
- Additional or alternate test methods, upon approval from the local jurisdiction.

Minimum Requirements

The following minimum requirements, when applicable, shall be met for field explorations and laboratory testing when subsurface disposal is proposed:

- Test borings and/or test pits shall be located within the footprint of proposed stormwater disposal facilities;
- For each facility, a minimum of one subsurface exploration shall be performed for up to 1200 square feet of disposal area. Another subsurface exploration shall be performed for each additional 15,000 square feet, or fraction thereof, of disposal area. For a linear roadside swale, a minimum of one subsurface exploration shall be performed every 500 feet, staggered on both sides of the road, unless site conditions or test results indicate that additional explorations are necessary. Subsurface explorations and sampling shall be conducted

according to applicable standards of the American Society for Testing and Materials (ASTM);

- Unless otherwise recommended by the geotechnical engineer, subsurface explorations shall extend to a depth of H plus 5 feet below the stormwater facility, where H is equivalent to the maximum head of water within the facility. For example, for a double depth drywell with a maximum head of 10 feet, the minimum required depth of exploration below the drywell is 15 feet, or 25 feet below the proposed rim of drywell; and,
- When the Spokane 200 Method is used, a minimum of two "percent fines" tests shall be performed per subsurface exploration. Tests should be performed on samples taken at varying depths below the ground surface, within the target soil layer, in order to adequately characterize the proposed disposal site soils. Laboratory testing shall be conducted according to applicable ASTM standards.

Post-Construction Testing

Newly constructed drywells may require a full-scale drywell test prior to project certification. Swales may also require a flood test or infiltrometer test prior to project certification, bond release or issuing a Certificate of Occupancy. Contact the local jurisdiction for additional information.

4.3.2 SUB-LEVEL STRUCTURE FEASIBILITY

If sub-level structure construction is being considered, a sub-level structure feasibility study is required. In the City of Spokane Valley, contact the Building Department for basement restriction information. The sub-level structure feasibility study shall include the following, at a minimum:

- A layout of the site showing lot lines and lot and block numbers;
- Identification by lot and block number of sites where sub-level structure construction is feasible. Provide recommendations with details of construction (i.e. maximum below grade floor elevations, minimum drainage system requirements, and any site specific recommendations). Recommendations shall be coordinated with the International Building Code (IBC) and International Residential Code (IRC);
- Discussion of the effects of hydrostatic pressure that may lead to basement flooding and recommendations as to the effectiveness of waterproofing;
- If infiltration is proposed as a method for stormwater disposal, discussion of any potential adverse impacts on proposed sub-level

structures, taking into consideration the contribution of imported water (due to lawn watering, etc.); and,

- Identification of locations where sub-level structure construction is not feasible.

In-lieu of conducting a sub-level structure feasibility study, the owner may elect to prohibit sub-level structure construction throughout the entire plat. If a potential buyer would like to construct a sub-level structure, then a site specific geotechnical evaluation shall be performed by a geotechnical engineer for the individual lot prior to a building permit being issued. Language regarding sub-level structure restrictions, as provided by the local jurisdiction, shall be placed or referenced on the face of the plat.

Recommendations shall be summarized and provided electronically in Microsoft Excel, per the format found in Table 4-2.

TABLE 4-2
EXAMPLE SUB-LEVEL STRUCTURE FEASIBILITY SUMMARY

Block No.	Lot No.	Sub-Level Construction Feasible?	Maximum Depth Below Finish Grade[1]	Depth to Limiting Layer[2]	Summary of Geotechnical Recommendations[3]
Block 1	Lots 1-8	yes	Maximum allowable	C=15 feet GrW=25 feet B=30 feet	Based upon the clean nature of the soils at the sub-level elevations and the depth to groundwater, footing drains are not required. However, below-grade walls shall be well reinforced to reducing cracking and thoroughly damp-proofed with a water-resistant bituminous emulsion or modified cement base coating. Backfill material shall consist of only clean granular material which is free of fine-grained soils, organic material, debris and large rocks.
Block 2	Lots 1-3	yes	4 feet	GrW=13 feet	Below-grade walls shall be well reinforced to reduce cracking and waterproofed with a membrane (per IRC) which is lapped and sealed from the top of the footing to the finished grade. An under slab waterproof membrane (per IBC) which is lapped and sealed shall be integrated with the wall membrane. Backfill material shall consist of only clean granular material which is free of fine-grained soils, organic material, debris and large rocks. Walls and footings shall have a drain system with cleanouts, emptying a minimum of 15 feet in a down-slope direction away from structures. Precautions shall be taken not to excavate a closed depression over rock or clay that is intended to dispose of sump water from a foundation drain system.
Block 2	Lots 4-8	no	n/a	GrW=3 feet B=7 feet	Due to the very shallow presence of groundwater, sub-level structures are not recommended on these lots. If a crawl space is proposed, a drain system with cleanouts shall be provided that empties a minimum of 15 feet in a down-slope direction away from structures. Precautions shall be taken not to excavate a closed depression over rock or clay that is intended to dispose of sump water from foundation drain system.

[1] Maximum depth measured from original pre-construction/pre-grading ground surface elevation or existing ground surface, whichever provides a greater distance between the lowest floor elevation and the limiting layer.

[2] GrW=groundwater, B=bedrock or basalt, C=clayey-silty soils

[3] Refer to the Geotechnical Report for this project for further information, which may include construction details that support these recommendations.

APPENDIX 4A – SPOKANE 200 METHOD

PURPOSE AND APPLICABILITY

The Spokane 200 Method estimates the normalized outflow rates for drywells and the hydraulic conductivity of a soil using the results of laboratory soil gradation tests.

The geotechnical engineer may use this method to initially assess the suitability of site soils for stormwater disposal. A full-scale drywell test, as deemed necessary by the local jurisdiction, may be required prior to final project certification in order to verify design outflow rates determined by this method.

PROCEDURE

The following procedure for the Spokane 200 Method is taken from *Infiltration Rate and Soil Classification Correlation* (File No. 0188-082-00, May 28, 2004; prepared by GeoEngineers, Budinger & Associates, Inc., and Cummings Geotechnology, Inc.)

1. Determine the percent of fines (percent passing the #200 sieve) for the target soil layer, based on a minimum of 2 gradation tests.

2. Estimate the hydraulic conductivity (k) using the percent fines value and the best-fit line on Figure 4A-1. Enter the figure on the x-axis with the percent fines value from Step 1. Extend a vertical line from that value until the Best Fit Line is intersected. Drawing a horizontal line from that point to the y-axis will yield the hydraulic conductivity. Alternatively the equation $K = 0.6392 F^{-1.8796}$ may be used, where K is the hydraulic conductivity and F is the percent fines.

3. Determine the normalized outflow rate for a drywell using the estimated hydraulic conductivity from Step 2, and the best-fit line-drywell data on Figure 4A-2. Enter the figure on the x-axis with the estimated hydraulic conductivity (k) from Step 2. Extend a vertical line from that value until the Best-Fit Line-Drywell Data is intersected. Drawing a horizontal line from that point to the y-axis will yield the normalized outflow rate. Alternatively the drywell equation $q_a = 1.5582 K^{0.8601}$ may be used, where K is the hydraulic conductivity and q_A is the normalized outflow rate.

4. Determine the actual outflow rate for a drywell (q_A) by multiplying the normalized outflow rate by the maximum design drywell head (6 feet for a single-depth drywell and 10 feet for a double-depth drywell).

5. Determine the design outflow rates for a drywell (q_D) by applying the appropriate factor of safety (FS) from Table 4A-1. $q_D = \frac{q_A}{FS}$

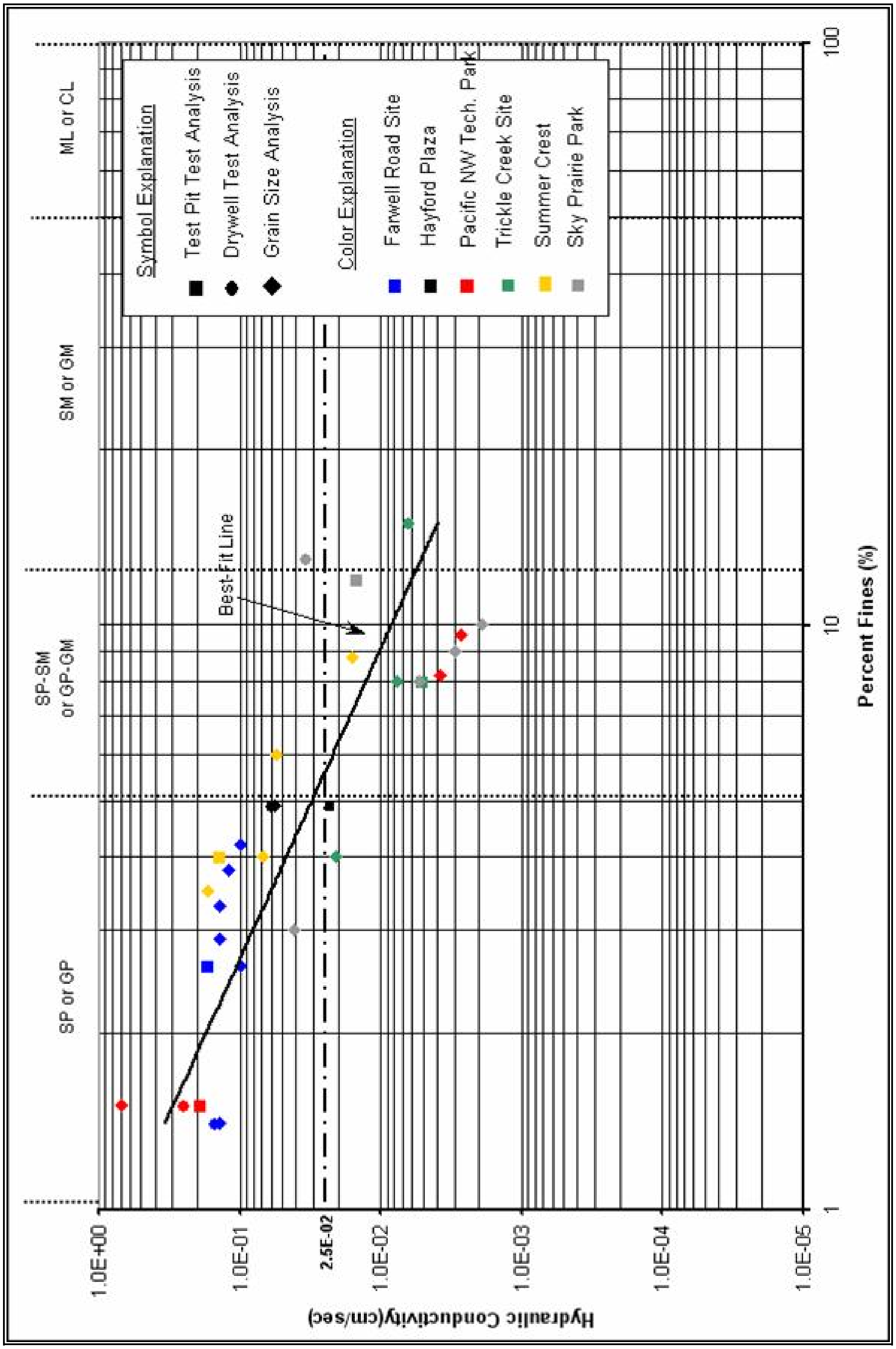

Figure 4A-1 – Percentage of Fines (% passing the No. 200 Sieve) vs. Hydraulic Conductivity (k)

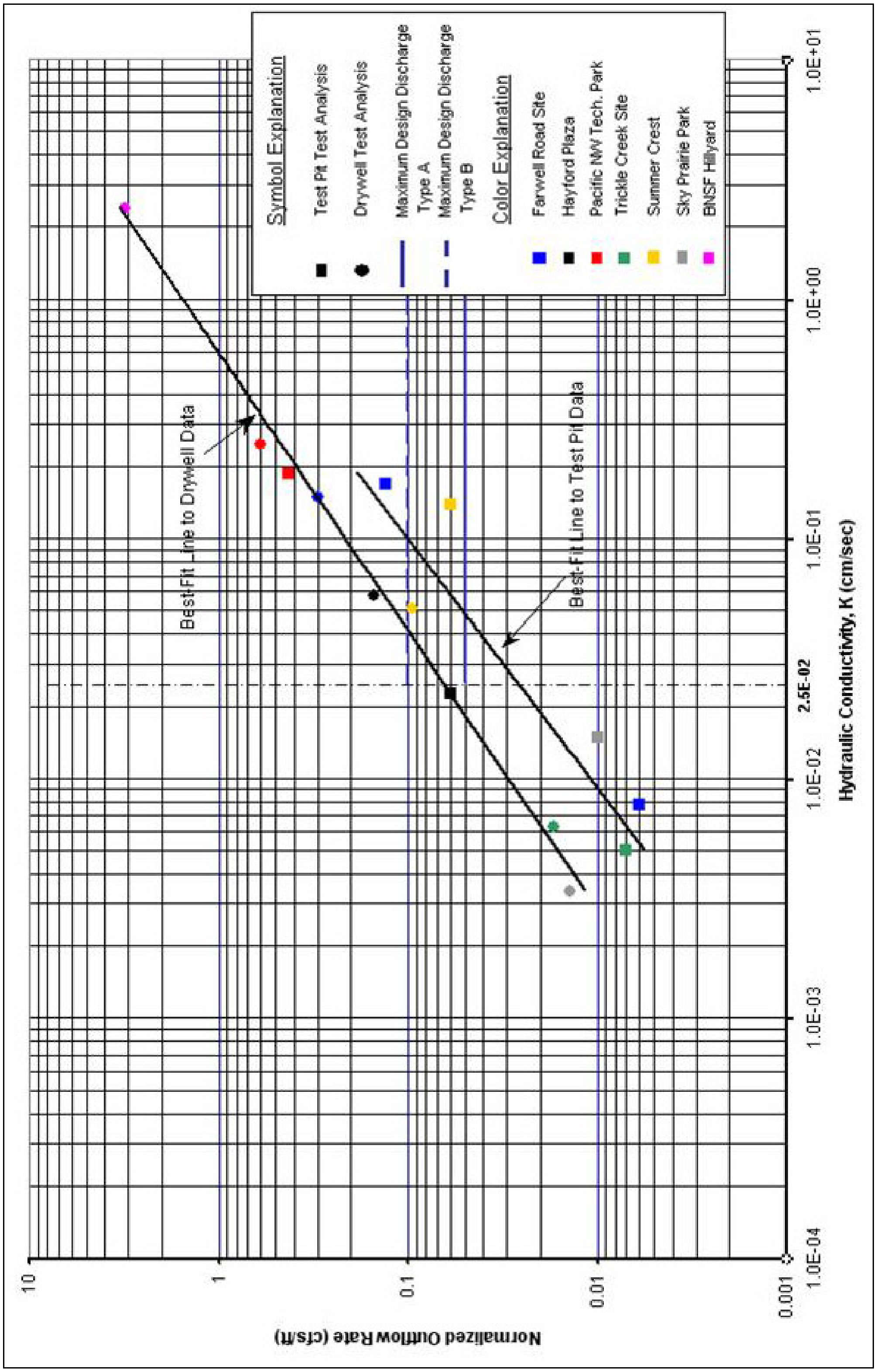

Figure 4A-2 – Hydraulic Conductivity (k) vs. Normalized Outflow Rate

TABLE 4A-1
OUTFLOW RATE FACTORS OF SAFETY
FOR SPOKANE 200 METHOD

Percent Finer than U.S. No. 200 Sieve	Minimum Factor of Safety
0 to 5%	1.3
>5 to 6%	1.5
>6 to 8%	2.0
>8 to 10%	2.3
>10 to 12%	2.7
>12%	not suitable for drywell disposal

The factors of safety listed in Table 4A-1 are based on optimal separation between the bottom of a drywell and a limiting layer (bedrock, groundwater, clay lens, etc.). The optimal separation between the bottom of the drywell and the limiting layer shall equal the maximum head (H) in the drywell, which is 6 feet for single depth drywells and 10 feet for double depth drywells.

When the distance between the bottom of the drywell and the limiting layer is less than the above requirements, the factor of safety from Table 4A-1 shall be increased by 0.1 for each foot of separation less than H. The separation shall not be less than 4 feet between the bottom of the drywell and the limiting layer. For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 ft below the pond bottom, to allow for a 6-inch treatment zone and 48 inches of subgrade infiltrative soil. The local jurisdiction reserves the authority to increase the required depth to the limiting layer should there be evidence that the subgrade will be negatively impacted by the limiting layer such as groundwater.

The factors of safety shown in Table 4A-1 are minimums. The geotechnical engineer may recommend a factor of safety greater than those shown based on site specific conditions.

For infiltration facilities other than drywells, a geotechnical engineer shall make a conservative recommendation for design outflow rates.

6. Hydraulic conductivities estimated using Figure 4A-1 may be used to estimate design outflow rates for infiltration facilities other than drywells.

APPENDIX 4B – FULL-SCALE DRYWELL TEST METHOD

PURPOSE AND APPLICABILITY

The full-scale drywell test method determines the normalized outflow rates for drywells. This testing is required for drywells if requested by the local jurisdiction.

PROCEDURE

1. Install the drywell per the local jurisdiction's standard plans, specifications and applicable construction guidelines.

2. Inspect the drywell and take photographs, if necessary.

3. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a calibrated 55-gallon barrel.

4. Introduce clean water into the drywell. Monitor flow using an in-line flow meter.

5. Raise the water level in the drywell until it reaches the top of the active barrel section. In the case of drywells interconnected by pipes, raise the water level to the invert elevation of the connecting pipe, or use an expandable pipe plug to seal the connecting pipe.

6. Monitor and record the flow rate required to maintain the constant head level in the drywell at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

7. Maintain the water level in the drywell, by adjusting the flow rate, for a minimum of 2 hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the drywell has reached the top of the active barrel section, or the invert elevation of any interconnecting pipes. The flow rate is considered stable when the water level in the drywell is maintained and the incremental flow rate does not vary by more than 10%.

8. Upon completion of the constant head period, discontinue flow and monitor and record the water level in the drywell at intervals of no longer than 5 minutes, for a 30-minute time period. This time may need to be extended depending upon the soil performance.

CALCULATIONS

1. Calculate the normalized outflow rate (q_A)

$$q_A = \left(\frac{Q}{H}\right) * H_D$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test, in cubic feet per second (cfs);

H = level of water within the drywell (feet); and,

H_D = maximum design drywell head (6 feet for single-depth, 10 feet for double-depth).

2. Determine the design outflow rates for a drywell (q_D). Apply the appropriate factor of safety (FS) from Table 4B-1. When sieve analysis data is unavailable a FS of 2.5 shall be used.

$$q_D = \frac{q_A}{FS}$$

TABLE 4B-1
OUTFLOW RATE FACTORS OF SAFETY
FOR FULL-SCALE DRYWELL TEST METHOD

Percent Finer than U.S. No. 200 Sieve[1]	Minimum Factor of Safety
0 to 5%	1.1
>5 to 6%	1.3
>6 to 8%	1.8
>8 to 10%	2.1
>10 to 12%	2.5
>12%	not suitable for drywell disposal

[1] When no sieve analysis data are available, a factor of safety of 2.5 shall be applied to field-determined outflow rate.

The factors of safety listed in Table 4B-1 are based on optimal separation between the bottom of a drywell and a limiting layer (bedrock, groundwater, clay lens, etc.). The optimal separation between the bottom of the drywell and the limiting layer shall equal the maximum head (H) in the drywell, which is 6 feet for single-depth drywells and 10 feet for double-depth drywells.

When the distance between the bottom of the drywell and the limiting layer is less than the above requirements, the factor of safety shall be increased by 0.1 for each foot of separation less than H. The separation shall not be less than 4 feet between the bottom of the drywell and the limiting layer. For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 ft below the pond bottom, to allow for a 6-inch treatment zone and 48 inches of subgrade infiltrative soil. The local jurisdiction reserves the authority to increase the required depth to the limiting layer should there be evidence that the subgrade will be negatively impacted by the limiting layer such as groundwater.

The factors of safety shown in Table 4B-1 are minimums. The geotechnical engineer may recommend a factor of safety greater than those shown based on site specific conditions.

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APPENDIX 4C – TEST PIT METHOD

PURPOSE AND APPLICABILITY

This test method is used to estimate drywell outflow rates using test pits. This test method may also be used for analyzing non-standard subsurface disposal systems (infiltration galleries, under-drain systems, etc). However, more complex calculations that are not presented in this Manual may be required to correlate the results and substantiate the recommended infiltration rates.

PROCEDURE

1. Excavate a test pit to an elevation such that the walls and the bottom of the test pit expose the target soil layer being tested. As much as practical, excavate the pit to neat-line dimensions, and keep it free of surface slough, organics, and other deleterious material.

2. Measure and record the dimensions (length, width, depth) of the test pit. Include photographs of the test pit.

3. Line the walls and bottom of the pit with a highly porous, non woven, geotextile fabric. Install a vertical, PVC observation pipe in the pit. Then backfill the pit with clean, uniform, pervious, fine gravel; or clean, uniform, pervious, open graded coarse gravel. The omission of the PVC observation pipe and pervious gravel backfill is an allowable practice if the test pit walls will not slough when water is introduced.

4. Introduce clean water into the test pit. Monitor flow using an in-line flow meter. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a calibrated 55-gallon barrel.

5. Raise the water level in the pit until a level consistent with the operating head anticipated in the proposed drainage structure is achieved.

6. Adjust the flow rate as needed to maintain a constant head level in the pit. Monitor and record the flow rate required to maintain the constant head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

7. Maintain the water level in the pit, by adjusting the flow rate, for a minimum of two hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the pit has reached the operating level of the proposed structure. The flow rate is considered stable when the water level in the pit is maintained and the incremental flow rate does not vary by more than 10%.

8. Upon completion of the constant head period, discontinue flow, then monitor and record the water level in the test pit at intervals of no longer than five minutes, for a

30-minute falling head time period. This time may need to be extended depending upon the soil performance.

CALCULATIONS

1. Calculate the normalized outflow rate of the test pit (q_N):

$$q_N = \left(\frac{Q}{H}\right) \qquad \text{(cfs/foot)}$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test (cfs); and,

H = level of water in the test pit (feet).

2. Estimate the hydraulic conductivity of the soil using Figure 4C-1, from Step 1, and the Best Fit Line to Test Pit data. Determine the normalized outflow rate of the drywell (q_{ND}). Enter into Figure 4C-1 on the y-axis with the normalized outflow rate (q_N) calculated in Step 1. Extend a horizontal line from that value until the Best-Fit Line to Test-Pit Data is intersected. From that point, draw a vertical line to the Best-Fit Line to Drywell Data. The normalized outflow rate of the drywell may then be obtained by drawing a horizontal line from that point on the Best-Fit Line to Drywell Data back to the y-axis. Alternatively the test pit equation $q_{ND} = 0.9242K^{0.9646}$ may be used, where K is the hydraulic conductivity and q_{ND} is the normalized outflow rate of the test pit. Then the K can be inserted into drywell equation $q_{ND} = 1.5582K^{0.8601}$, where K is the hydraulic conductivity and q_{ND} is now the normalized outflow xof the drywell.

3. Calculate the actual outflow rate (q_A):

$$q_A = q_{ND} * H_D \qquad \text{(cfs)}$$

Where: H_D = maximum design drywell head (6 feet for single-depth, 10 feet for double-depth).

4. Determine the design outflow rates for a drywell (q_D). Apply the appropriate factor of safety (FS) from Table 4C-1. When sieve analysis data is unavailable, a FS of 2.5 shall be used.

$$q_D = \frac{q_A}{FS} \qquad \text{(cfs)}$$

For infiltration facilities other than drywells, a geotechnical engineer shall make a conservative recommendation for design outflow rates. The above calculations shall be considered when determining the design outflow rates.

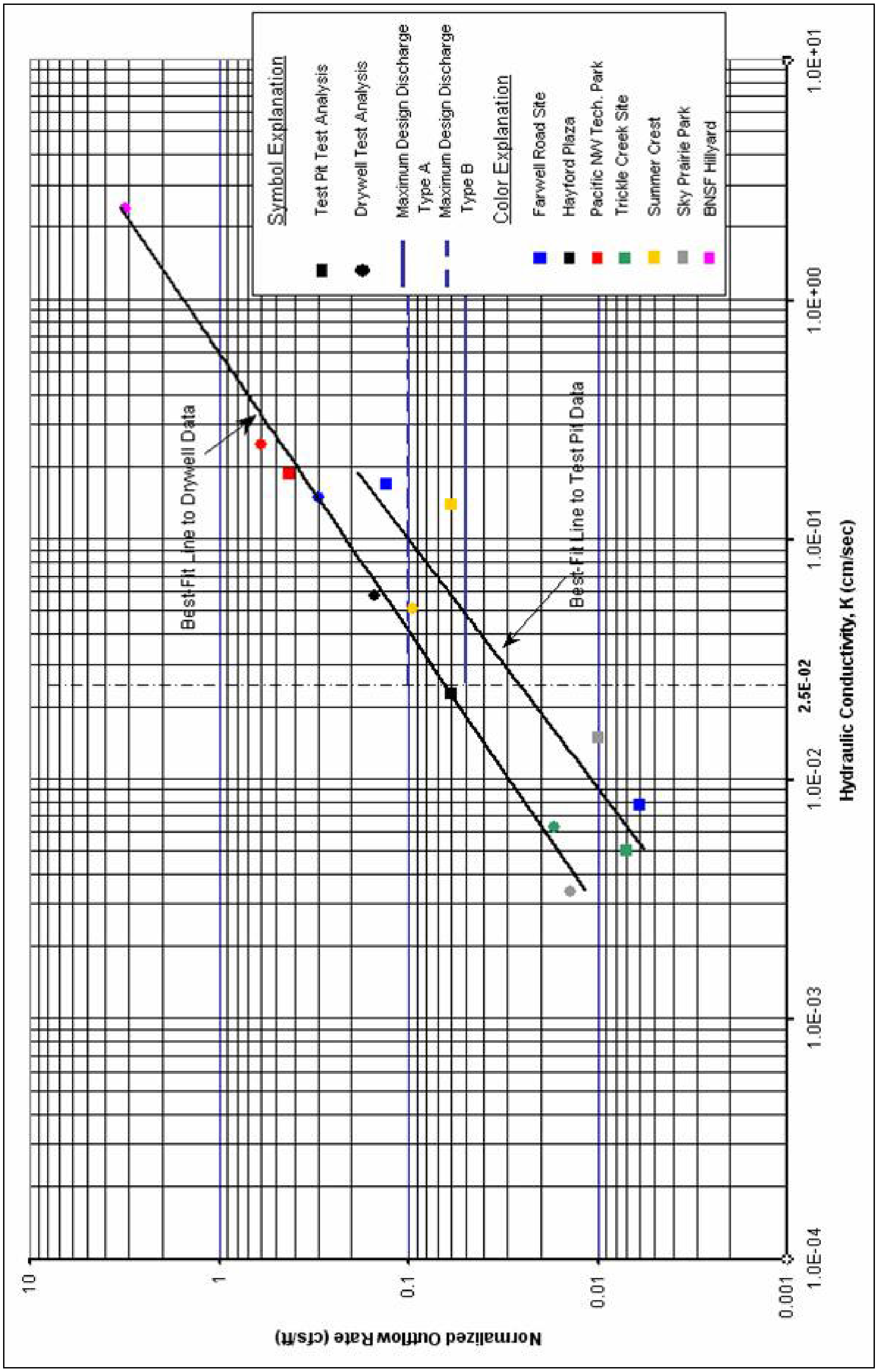

Figure 4C-1 – Hydraulic Conductivity (k) vs. Normalized Outflow Rate

TABLE 4C-1
OUTFLOW RATE FACTORS OF SAFETY
FOR TEST PIT METHOD

Percent Finer than U.S. No. 200 Sieve[1]	Minimum Factor of Safety
0 to 5%	1.1
>5 to 6%	1.3
>6 to 8%	1.8
>8 to 10%	2.1
>10 to 12%	2.5
>12%	not suitable for drywell disposal

[1] When no sieve analysis data are available, a factor of safety of 2.5 shall be applied to field-determined outflow rate.

The factors of safety listed in Table 4C-1 are based on optimal separation between the bottom of a drywell and a limiting layer (bedrock, groundwater, clay lens, etc.). The optimal separation between the bottom of the drywell and the limiting layer shall equal the maximum head (H) in the drywell, which is 6 feet for single-depth drywells and 10 feet for double-depth drywells.

When the distance between the bottom of the drywell and the limiting layer is less than the above requirements, the factor of safety from Table 4C-1 shall be increased by 0.1 for each foot of separation less than H. The separation shall not be less than 4 feet between the bottom of the drywell and the limiting layer. For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 ft below the pond bottom, to allow for the 6-inch treatment zone and 48 inches of subgrade infiltrative soil. The local jurisdiction reserves the authority to increase depth to the limiting layer should there be evidence that the subgrade will be negatively impacted by the limiting layer such as groundwater.

The factors of safety shown in Table 4C-1 are minimums. The geotechnical engineer may recommend a factor of safety greater than those shown based on site specific conditions.

APPENDIX 4D – SINGLE-RING INFILTROMETER TEST METHOD

PURPOSE

The single-ring infiltrometer test method is applicable for estimating infiltration and permeability rates of surficial soils to verify drawdown times in bio-infiltration swales and detention ponds.

PROCEDURE

1. Drive, jack, or hand advance a short section of steel or PVC pipe, at least 20 inches long and with a minimum inside diameter of 12 inches and a beveled leading edge, (referred to as a "ring" in this test method) into the soil surface to a depth of about 8 inches, leaving approximately 12 inches of pipe exposed above the ground surface. If after installation the surface of the soil surrounding the wall of the ring shows signs of excessive disturbance such as extensive cracking or heaving, reset the ring at another location using methods that will minimize the disturbance. If the surface of the soil is only slightly disturbed, tamp the soil surrounding the inside and outside wall of the ring until it is as firm as it was prior to disturbance.

2. Introduce clean water into the ring. Use some form of splash guard such as a sheet of thin aluminum or a diffuser apparatus such as a highly porous, non woven, geotextile fabric to prevent erosion at the surface of the soil during filling and testing. Monitor flow using an in-line flow meter. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a 5-gallon bucket or a 55-gallon barrel.

3. Raise the water level in the ring until a head level of at least 6 inches above the soil surface is achieved.

4. Monitor and record the flow rate required to maintain the constant head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

5. Maintain the water level in the ring, by adjusting the flow rate, for a minimum of 2 hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the ring has reached 6 inches above the soil surface. The flow rate is considered stable when the water level in the ring is maintained and the incremental flow rate does not vary by more than 10%.

6. Upon completion of the constant-head period, discontinue flow, and monitor and record the water level in the ring at intervals of no longer than 5 minutes, for a 30-minute period.

7. One single-ring infiltrometer test shall be performed for every 2,500 square feet of bio-infiltration swale/pond bottom area or detention pond bottom area, with a minimum of one per swale or pond or as required by the local jurisdiction.

CALCULATIONS

1. Calculate the surface infiltration rate (I)

$$I = \frac{Q}{A} \qquad \text{(feet/second)}$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test (cfs); and,

A = area of soil inside the ring (square feet).

2. Compute the permeability rate (K)

$$K = \frac{(Q * L)}{(A * H)} \qquad \text{(feet/second)}$$

Where: L = depth of soil contained within the ring (inches);

A = area of soil inside the ring (square feet); and,

H = constant level of water within the ring, measured from the base of the ring to the free water surface (inches).

APPENDIX 4E – SWALE FLOOD TEST

PURPOSE

The swale flood test verifies the path of flow into a swale and the drawdown time of a bio-infiltration swale. The flood test shall be conducted, when required, after the swale has been constructed and the vegetation has been established (i.e. is not in danger of being washed out when water is introduced into the swale).

PROCEDURE

1. Introduce clean water into the swale by directing the water (via hose from a hydrant or other clean water source) along the curb and gutter upstream of the swale inlet.

2. Raise the water level in the swale until it reaches 6 inches in depth (typically to the rim of the drywell or catch basin). Discontinue flow and note the time; this is the beginning of the flood test.

3. If the swale is draining rapidly, the progress is observed, and when the swale is empty, the time is documented, and the flood test has ended.

4. If the swale is not draining, measure the depth of water currently in the swale, documenting the time, and return to the swale site at a later time in order to verify that the swale has completely drained within 72 hours.

NOTE: Contact the local jurisdiction for specific requirements for this Test Method.

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APPENDIX 4F – POND FLOOD TEST

PURPOSE

The Pond Flood Test Method verifies drawdown time of a stormwater disposal facility, such as a detention pond. The pond flood test shall be conducted, when required, after the pond has been constructed, and after vegetation has been established (i.e. is not in danger of being washed out when water is introduced into the pond).

PROCEDURE

1. Introduce clean water into the pond. Use some form of splash-guard or diffuser device to prevent surface erosion of the pond.

2. Raise the water level in the pond until it reaches operational depth (i.e. to the invert elevation of the first outlet device (culvert, orifice, weir, etc.)). Discontinue flow.

3. Document the time and measure the depth of water in the pond; this is the beginning of the pond flood test.

4. The pond's ability to drain is observed. If the pond appears to be emptying rapidly, as soon as the pond is empty, the time is documented, and the flood test has ended.

5. If the pond is not draining, or is draining very slowly, measure the depth of water currently in the pond, documenting the time, and return to the pond site at a later time in order to verify that the pond has completely drained within 72 hours.

NOTE: Contact the local jurisdiction for specific requirements for this Test Method.

Some ponds will be large enough that a pond flood test may not be the most efficient method of determining drawdown time or infiltrative ability. Consideration may need to be given to other types of infiltrative test methods, such as the single-ring infiltrometer test. If the pond flood test is pursued for larger ponds, the local water purveyor must be contacted so that water service is not disrupted.

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CHAPTER 5 – HYDROLOGIC ANALYSIS AND DESIGN

Chapter Organization

5.1 INTRODUCTION

This chapter provides the tools for estimating peak flow rates and volumes for sizing conveyance, treatment, and flow control facilities. Standard flow control facilities are detention and retention facilities, drywells, and evaporation ponds. Flow control facilities are necessary to mitigate potential adverse impacts on down-gradient properties due to the increase in stormwater runoff caused by land development.

Unless specifically accepted by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required (refer to Section 3.4.5 for down-gradient analysis criteria). Exceptions with regard to rate and volume control can be made for regional facilities planned by the local jurisdiction.

Stormwater runoff from a developed site shall leave the site in the same manner and location as in the pre-developed condition. Flow may not be concentrated onto down-gradient properties where sheet flow previously existed. Drainage shall not be diverted from a proposed development and released downstream at points not receiving stormwater runoff prior to the proposed development.

Non-standard systems shall be evaluated individually by the local jurisdiction and shall require a geotechnical site characterization report, a down-gradient analysis, and any additional information deemed necessary by the local jurisdiction. Refer to Section 2.1.6 for variance procedures.

All engineering work for hydrologic analysis and design shall be performed by, or under the direction of, a professional engineer currently licensed in the State of Washington.

5.2 HYDROLOGIC ANALYSIS METHODS

The following methods shall be used for the design of flow control and conveyance systems:

- The Curve Number (CN) Method can be used to estimate peak flow rates and volumes; the most commonly used Curve Number Method in the Spokane Region is the Natural Resources Conservation Service Urban Hydrograph Method (NRCS Method); an acceptable but seldom-used alternative method is the Santa Barbara Urban Hydrograph Method;
- The Level Pool Routing Method can be used to route hydrographs;
- The Rational Method can be used to estimate peak runoff rates;

- The Modified Rational Method (Bowstring Method) can be used to estimate peak flow rates and detention volumes; and,
- The Water Budget Method can be used to size evaporation facilities.

5.3 CURVE NUMBER METHOD

5.3.1 INTRODUCTION

Single-event hydrograph methods based on the curve number equation can be used in combination with a routing technique to size detention facilities. These methods are used to develop hydrographs to estimate the peak flow rate and volumes for a specific design storm.

5.3.2 CURVE NUMBER METHOD THEORY

This section presents a general description of this methodology, for additional information refer to the *National Engineering Handbook* (1985). The amount of runoff from a site calculated using the Curve Number Method depends on the precipitation at the site and the natural storage capacity of the soil. The curve number equation and the NRCS rainfall excess equation are shown in Equations 5-1 and 5-2:

$$S = \frac{1000}{CN} - 10 \qquad (5\text{-}1)$$

Where:
- S = maximum storage volume of water on and within the soil (inches);
- CN = curve number (dimensionless);

$$Q = \frac{\left(P - 0.2S\right)^2}{\left(P + 0.8S\right)} \qquad (5\text{-}2)$$

$Q = 0$ for $P < 0.2S$

Where:
- S = maximum storage volume of water on and within the soil (inches);
- Q = runoff (inches);
- P = precipitation (inches); and,
- 0.2S = initial abstraction; the fractional amount estimated as intercepted, evaporated and/or absorbed by the soil (inches).

5.3.3 LIMITATIONS

Another method approved by the local jurisdiction shall be used when:

- The calculated depth of runoff is less than 0.5 inch;
- The value (P-0.2S) is a negative number; or
- The weighted CN is less than 40.

For additional limitations, see the Soil Conservation Service's Technical Release No. 55 (Publication 210-VI-TR-55, Second Ed., June 1986).

Local jurisdictions reserve the authority to limit discharge to public facilities. Regardless of the methodology used, if a given method yields a runoff volume or rate that is inconsistent with the physical site characteristics, the engineer will be required to provide additional supporting documentation.

5.3.4 DESIGN STEPS

The following steps are based on the assumption that the engineer uses a software package that utilizes the Curve Number Method for hydrologic computations and the level pool method for reservoir routing (refer to Section 5.4). If hand calculations are proposed, the engineer can consult currently available technical publications for additional information.

1. Determine the pre-developed and post-developed drainage basin boundaries and identify pervious and impervious areas as described in the Basin Areas subsection below;
2. Determine the hydrologic soil group classifications, as described in the Hydrologic Soil Group Classification subsection below, and correlate to the drainage basin boundaries;
3. Identify the appropriate land uses within the delineated basins and select CN values for each of the pre-developed and post-developed basins, as described in the Curve Numbers subsection below;
4. Determine the time of concentration for both pre-developed and post-developed conditions, as described in the Time of Concentration subsection below;
5. Compute the surface area or volume at incremental stages (heights) of the drainage facility, beginning at the bottom of the anticipated drainage facility to an elevation at least 1 foot above the overflow;
6. Create basin links for combining and/or routing basin hydrographs to the proposed facility. Links may have routing elements, such as pipes or channels;
7. Determine the precipitation for the required design storms specified in Chapter 2. Precipitation maps for the design storms are provided in the Precipitation Maps subsection below;

8. Set the routing and hydrograph time increments in the computer software program to six-minutes or less;
9. Determine the required NRCS Storm Distribution, as described in the Design Storm Distribution subsection below, and select it in the software program;
10. Input the geometry of the anticipated outflow structures (i.e. weirs, orifices, etc.);
11. Input the elevation and storage volume relationship;
12. Compute peak rates and volumes for the pre-developed basins and determine the allowable release rates per the design criteria specified in Chapter 2;
13. Compute the hydrographs of the post-developed basins, combine and route the hydrographs to the drainage facility and route the inflow hydrograph through the facility;
14. Verify that the release from the site does not exceed the allowable release rate (or volume, when required), as determined in step 12. Modify the pond geometry and outflow structure input data if the results indicate that the allowable thresholds are exceeded.

Basin Areas

The basin modeling must reflect the actual runoff characteristics as closely as possible and be consistent with the assumptions within the model used. The impervious and pervious areas must be estimated from best available plans, topography, or aerial photography, and verified by field reconnaissance.

Hydrologic Soil Group Classification

The NRCS has classified over 4,000 soil types into the following four soils groups:

- Group A soils have high infiltration rates, even when thoroughly wetted, and consist chiefly of deep, well-to-excessively drained sands or gravels. These soils have a high rate of water transmission (greater than 0.30 inches/hour) and low runoff potential.
- Group B soils have moderate infiltration rates when thoroughly wetted, and consist chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 inches/hour) and moderately low runoff potential.
- Group C soils have slow infiltration rates when thoroughly wetted, and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of transmission (0.05 to 0.15 inches/hour) and moderately high runoff potential.
- Group D soils have very slow infiltration rates when thoroughly wetted, and consist chiefly of clay soils with a high swelling potential, soils with a

permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious materials. These soils have a very slow rate of transmission (0-0.05 inches/hour) and high runoff potential.

Refer to the current Spokane County NRCS maps for the hydrologic soil group classification for soils common to the Spokane Region.

Curve Numbers

Curve numbers (CNs) indicate the runoff potential of a watershed. The higher the CN value, the higher the potential for runoff. The CN takes into consideration the hydrologic soil group, land use, and cover.

Table 5-1 lists CN values for agricultural, suburban and urban land use classifications. These values are for Antecedent Runoff Condition (ARC) II, which is defined below. See NRCS Publication 210-VI-TR-55 for additional CN values.

Weighting Curve Numbers: Basins often include areas with differing curve numbers based on their soils, land use and cover. Overall CNs for these basins are determined by weighting the CN for each area based on the size of the area. For an example of weighting CNs refer to Appendix 5A.

In most cases, if areas in the same basin have CN values that differ by more than 20 points, separate hydrographs shall be generated for each and the hydrographs shall be combined. As an exception to this rule, separate hydrographs are not required for unconnected impervious areas. Unconnected impervious areas are defined as those that discharge over a pervious area in the form of sheet flow, such as a tennis court in the middle of a lawn or runoff from roofs flowing over lawn. Unconnected impervious areas can be weighted with pervious areas.

Connected impervious areas shall not be weighted with pervious areas. Connected impervious areas can include driveways and sidewalks that are adjacent to (i.e. hydraulically connected to) a pollution generating impervious roadway and discharge directly into a drainage system without first traversing an area of pervious ground.

Basin configurations shall be consistent with surface runoff patterns. For example, the roof and lawn areas of residential neighborhoods can be combined and considered one basin when the roof runoff travels through lawns before getting to the streets or drainage system. The driveway and adjacent sidewalk areas must be combined with the street areas, if they are hydraulically connected and would be considered a separate basin. The impervious and pervious hydrographs shall then be linked with or without a routing element, such as a pipe or a channel.

Antecedent Runoff Condition – Curve Number Adjustment: The moisture condition in a soil prior to a storm event is referred to as the antecedent runoff condition (ARC).

TABLE 5-1
RUNOFF CURVE NUMBERS
ANTECEDENT RUNOFF CONDITION (ARC) II

Cover type and hydrologic condition	Group A Soils	Group B Soils	Group C Soils	Group D Soils
Open Space (lawns, parks, golf courses, cemeteries, landscaping, etc.): [1]				
Poor condition (grass cover <50% of the area)	68	79	86	89
Fair condition (grass cover on 50% to 75% of the area)	49	69	79	84
Good condition (grass cover on >75% of the area)	39	61	74	80
Impervious Areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs, driveways, etc. (excluding right of way)	98	98	98	98
Porous pavers and permeable interlocking concrete (assumed as 85% impervious and 15% lawn):				
Fair lawn condition (weighted average CNs)	91	94	96	97
Gravel	76	85	89	91
Dirt	72	82	87	89
Pasture, Grassland, or Range-Continuous Forage for Grazing:				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed)	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Cultivated Agricultural Lands:				
Row Crops (good) e.g. corn, sugar beets, soy beans	64	75	82	85
Small Grain (good) e.g. wheat, barley, flax	60	72	80	84
Meadow (continuous grass, protected from grazing and generally mowed for hay)	30	58	71	78
Brush (brush-weed-grass mixture with brush the major element):				
Poor (<50% ground cover)	48	67	77	83
Fair (50% to 75% ground cover)	35	56	70	77
Good (>75% ground cover)[2]	30	48	65	73
Woods - grass combination (orchard or tree farm)[3]:				
Poor	57	73	82	86
Fair	43	65	76	82
Good	32	58	72	79
Woods:				
Poor (Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning)	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Herbaceous (mixture of grass, weeds, and low-growing brush, with brush the minor element)[4]:				
Poor (<30% ground cover)		80	87	93
Fair (30% to 70% ground cover)		71	81	89
Good (>70% ground cover)		62	74	85
Sagebrush with Grass Understory[4]:				
Poor (<30% ground cover)		67	80	85
Fair (30% to 70% ground cover)		51	63	70
Good (>70% ground cover)		35	47	55

[1] Composite CNs may be computed for other combinations of open space cover type.
[2] Actual curve number is less than 30; use CN = 30 for runoff computations.
[3] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.
[4] Curve numbers have not been developed for group A soils.

For a more detailed and complete description of land use curve numbers refer to Chapter 2 of the Soil Conservation Service's Technical Release No. 55 (Publication 210-VI-TR-55, Second Ed., June 1986).

The NRCS developed three antecedent runoff conditions:

- ARC I (Dry Condition): soils are dry but surface cracks are not evident.
- ARC II (Average Condition): soils are not dry or saturated. The CN values listed in Table 5-1 are applicable under this condition and do not account for snowmelt or runoff on frozen ground conditions.
- ARC III (Wet Condition): soils are saturated or near saturation due to heavy rainfall or light rainfall and low temperatures within the last 5 days.

The design of detention or infiltration ponds shall be based on ARC II. When ARC III applies, such as when designing evaporation facilities or modeling the winter months, Table 5-2 shall be used to adjust the CN values.

TABLE 5-2
CURVE NUMBER BASED ON ANTECEDENT RUNOFF CONDITION (ARC)

CN ARC II	CN ARC I	CN ARC III		CN ARC II	CN ARC I	CN ARC III
100	100	100		76	58	89
99	97	100		75	57	88
98	94	99		74	55	88
97	91	99		73	54	87
96	89	99		72	53	86
95	87	98		71	52	86
94	85	98		70	51	85
93	83	98		69	50	84
92	81	97		68	48	84
91	80	97		67	47	83
90	78	96		66	46	82
89	76	96		65	45	82
88	75	95		64	44	81
87	73	95		63	43	80
86	72	94		62	42	79
85	70	94		61	41	78
84	68	93		60	40	78
83	67	93		59	39	78
82	66	92		58	38	76
81	64	92		57	37	75
80	63	91		56	36	75
79	62	91		55	35	74
78	60	90		54	34	73
77	59	89		50	31	70

Curve number conversions for different ARC are for the case of initial abstraction (I_a) = 0.2 S. Initial abstraction represents all water losses before runoff begins (water retained in surface depressions, water intercepted by vegetation, evaporation, infiltration, etc.)

Source: U.S. Soil Conservation Service National Engineering Handbook Table 10.1.

Time of Concentration

Time of concentration is affected by the way stormwater moves through a watershed. Stormwater can move in the form of sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type of flow should be verified by field inspection.

The time of concentration for rainfall shall be computed for all overland flow, ditches, channels, gutters, culverts, and pipe systems. When using the Curve Number Method, the time of concentration for the various surfaces and conveyances shall be computed using the procedures presented in this section. These procedures are based on the methods described in the Soil Conservation Service's Technical Release No. 55.

Travel time (T_t) is the time it takes stormwater runoff to travel from one location to another in a watershed. Time of concentration (T_c) is the time for stormwater runoff to travel from the hydraulically most distant point to the point of discharge of a watershed. T_c is computed by adding all the travel times for consecutive components of the drainage conveyance system as given by the following equation:

$$T_c = T_{t1} + T_{t2} + \ldots T_{tn} \tag{5-3}$$

Where: T_c = time of concentration (minutes);

n = number of flow segments; and,

T_t = travel time (minutes) is the ratio of flow length to flow velocity given by:

$$T_t = \frac{L}{60V} \tag{5-4}$$

where: L = flow length (feet);

V = average velocity (feet/second); and,

60 = conversion factor (seconds to minutes).

T_c influences the shape and peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of ponding behind small or inadequate drainage facilities including storm drain inlets and road culverts, or reduction of land slope through grading. T_c shall not be less than 5 minutes.

Sheet Flow: Sheet flow is flow over plane surfaces and shall not be used over distances exceeding 100 feet. Use Manning's kinematic solution to directly compute T_t:

$$T_t = \frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(S_o)^{0.4}} \tag{5-5}$$

Where: T_t = travel time (minutes);

n_s = Manning's effective roughness coefficient for sheet flow (use Table 5-3);

L = flow length (feet);

P_2 = 2-year, 24-hour rainfall (inches), (use Figure 5-1);

S_o = slope of hydraulic grade line (land slope, feet/foot).

The friction value (n_s) is used to calculate sheet flow. The friction value is Manning's effective roughness coefficient modified to take into consideration the effect of raindrop impact, drag over the plane surface, obstacles such as litter, depressions, crop ridges and rocks, and erosion and transportation of sediment. The n_s values are for very shallow flow depths of about 0.1 foot and are only used for travel lengths up to 100 feet. Table 5-3 gives Manning's n_s values for sheet flow for various surface conditions.

<u>Shallow Concentrated Flow:</u> After 100 feet, sheet flow is assumed to have developed into shallow concentrated flow. The travel time (T_t) for the shallow concentrated flow segment can be computed using Equation 5-4. The average velocity for shallow concentrated flow is calculated using the following equation:

$$V = k\sqrt{S_o} \tag{5-6}$$

Where: V = velocity (feet/second);

k = k_s or k_c, time of concentration velocity factor (feet/second); and,

S_o = slope of flow path (feet/foot).

Table 5-3 provides "k" for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = \frac{1.49R^{2/3}}{n} \tag{5-7}$$

Where: R = hydraulic radius; and,

n = Manning's roughness coefficient for open channel flow (Table 5-3 or 5-4).

TABLE 5-3
FRICTION VALUES (*n* and *k*) FOR USE
IN COMPUTING TIME OF CONCENTRATION

Sheet Flow[1]	n_S
Bare sand	0.010
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Asphalt and gravel	0.012
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 feet/foot)	0.06
Cultivated soil with crop residue (slope > 0.20 feet/foot)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
Shallow, Concentrated Flow	k_S
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n =0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.030)	11
Newly-bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
Channel Flow (Intermittent, R = 0.2)	k_C
Forested swale with heavy ground litter (n=0.10)	5
Forested drainage course/ravine with defined channel bed (n=0.050)	10
Rock-lined waterway (n=0.035)	15
Grassed waterway (n=0.030)	17
Earth-lined waterway (n=0.025)	20
Corrugated metal pipe (n=0.024)	21
Concrete pipe (n=0.012)	42
Other waterways and pipes	0.508/n
Channel Flow (Continuous Stream, R =0.4)	k_C
Meandering stream with some pools (n=0.040)	20
Rock-lined stream (n=0.035)	23
Grassed stream (n=0.030)	27
Other streams, man-made channels and pipe	0.807/n

[1] These values were determined specifically for sheet flow conditions and are not appropriate for conventional open channel flow calculations.

Source: WSDOT Highway Runoff Manual (2004) Table 4B-5; Engman (1983); and the Florida Department of Transportation Drainage Manual (1986).

TABLE 5-4
SUGGESTED VALUES OF MANNING'S ROUGHNESS COEFFICIENT "*n*" FOR CHANNEL FLOW

Type of Channel and Description	"*n*"[1]
A. CONSTRUCTED CHANNELS	
a. Earth, straight and uniform	
1. Clean, recently completed	0.018
2. Gravel, uniform selection, clean	0.025
3. With short grass, few weeds	0.027
b. Earth, winding and sluggish	
1. No vegetation	0.025
2. Grass, some weeds	0.030
3. Dense weeds or aquatic plants in deep channels	0.035
4. Earth bottom and rubble sides	0.030
5. Stony bottom and weedy banks	0.035
6. Cobble bottom and clean sides	0.040
c. Rock lined	
1. Smooth and uniform	0.035
2. Jagged and irregular	0.040
d. Channels not maintained, weeds and brush uncut	
1. Dense weeds, high as flow depth	0.080
2. Clean bottom, brush on sides	0.050
3. Same, highest stage of flow	0.070
4. Dense brush, high stage	0.100
B. NATURAL STREAMS	
B-1 Minor streams (top width at flood stage < 100	
a. Streams on plain	
1. Clean, straight, full stage, no rifts or deep pools	0.030
2. Same as No. 1, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as No. 3, but some weeds	0.045
5. Same as No. 4, but more stones	0.050
6. Sluggish reaches, weedy deep pools	0.070
7. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.100
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	
1. Bottom: gravel, cobbles and few boulders	0.040
2. Bottom: cobbles with large boulders	0.050
B-2 Floodplains	
a. Pasture, no brush	
1. Short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees	0.060
3. Medium to dense brush	0.070
4. Heavy, dense brush	0.100
d. Trees	
1. Dense willows, straight	0.150
2. Cleared land with tree stumps, no sprouts	0.040
3. Same as No. 2, but with heavy growth of sprouts	0.060
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as above, but with flood stage reaching branches	0.120

[1] The "n" values presented in this table are the "Normal" values as presented in Chow (1959). For an extensive range and for additional values refer to Chow (1959)

Source: WSDOT Hyway Runoff Manual (2004) Table 4B-6; Engman (1983) and the Florida Department of Transportation Drainage Manual (1986).

Open Channel Flow: Open channels are assumed to exist where channels are visible on aerial photographs, where streams appear on United States Geological Survey (USGS) quadrangle sheets, or where topographic information indicates the presence of a channel. The k_c values from Table 5-3 used in Equation 5-6 or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full conditions. After average velocity is computed the travel time (T_t) for the channel segment can be computed using Equation 5-4.

Precipitation Maps

The following isopluvial maps for the Spokane Region were generated with computer software by Spokane County from rain data collected from National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Volume IX, 1973. The numbers shown on the isopluvial curves represent inches of precipitation.

Design Storm Distributions

These methods require the selection of, or the input of, a rainfall distribution and the precipitation associated with a design storm. The following storm distributions shall be used:

- The NRCS Type II 24-hour storm for sizing water quality treatment facilities; or,
- The NRCS Type IA 24-hour storm for sizing flow control facilities.

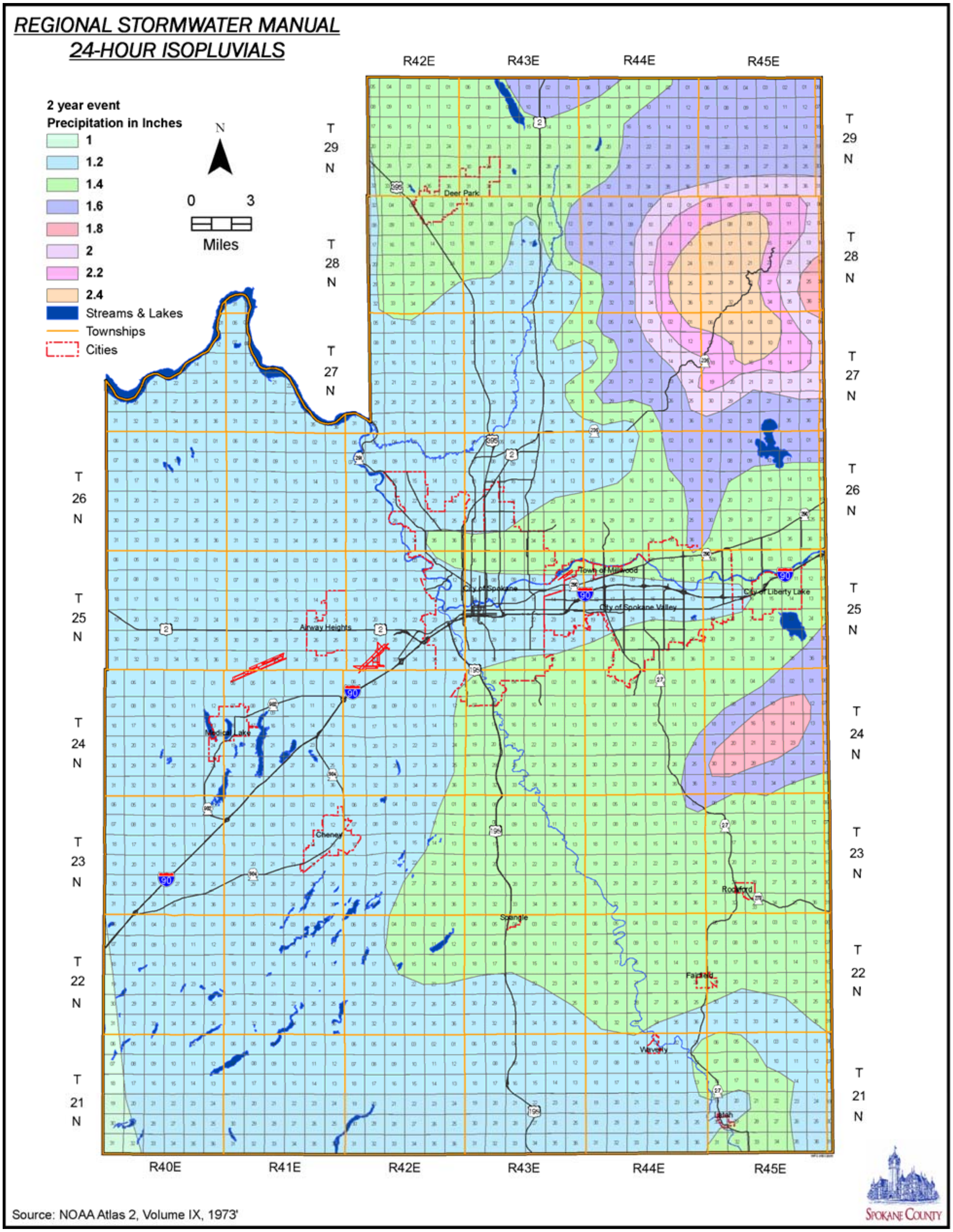

Figure 5-1 – 2-Year, 24-Hour Isopluvial Map

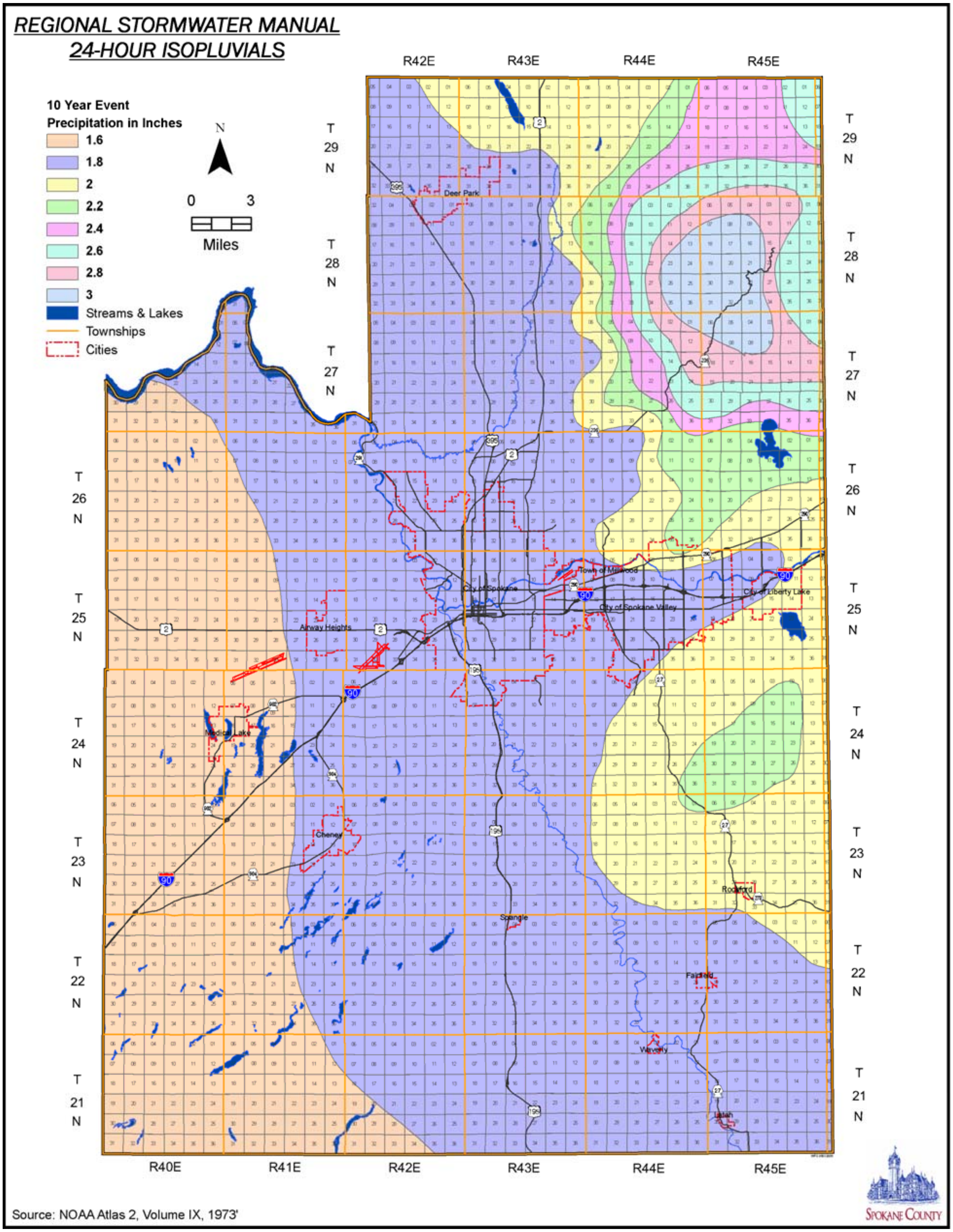

Figure 5-2 – 10-Year, 24-Hour Isopluvial Map

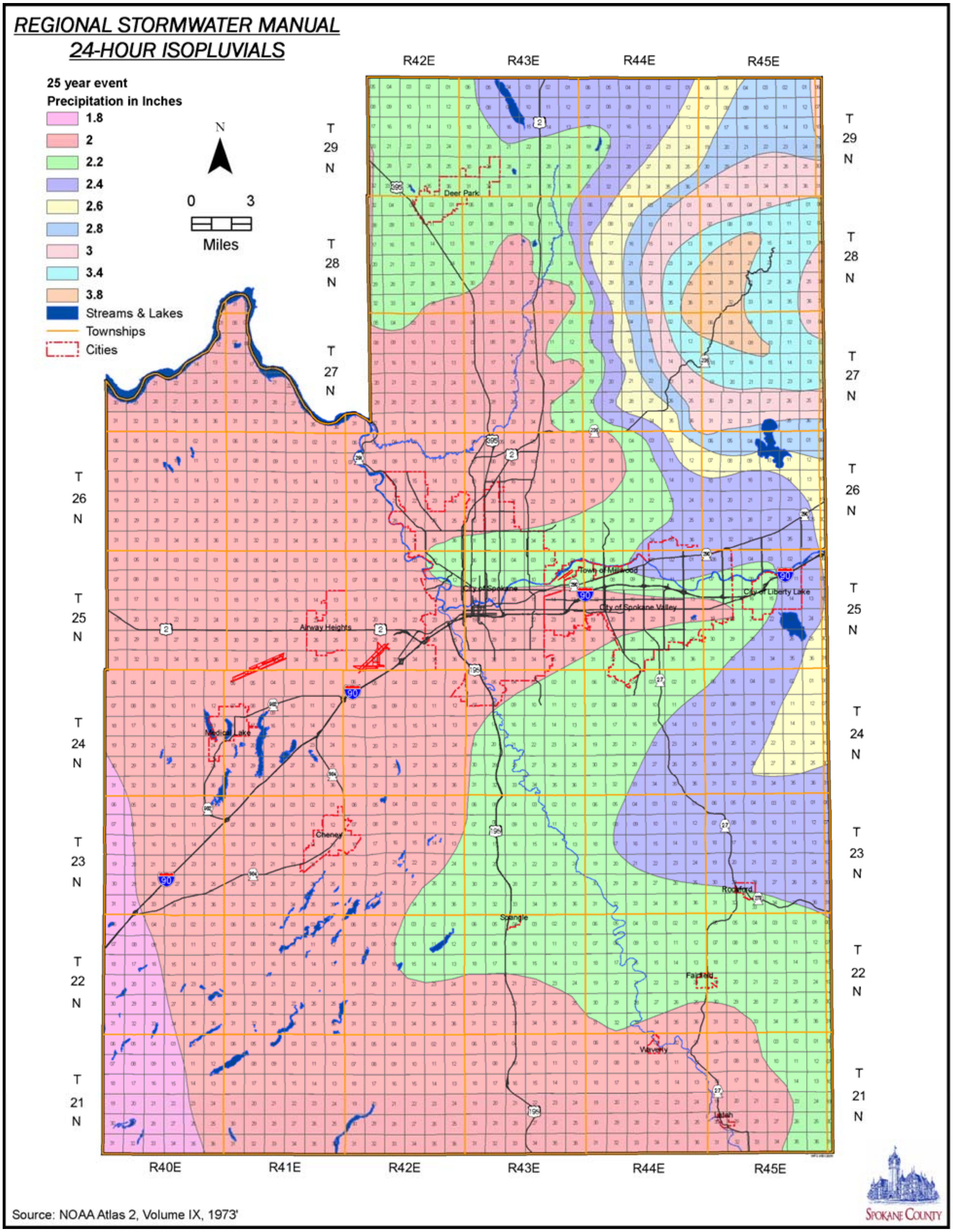

Figure 5-3 – 25-Year, 24-Hour Isopluvial Map

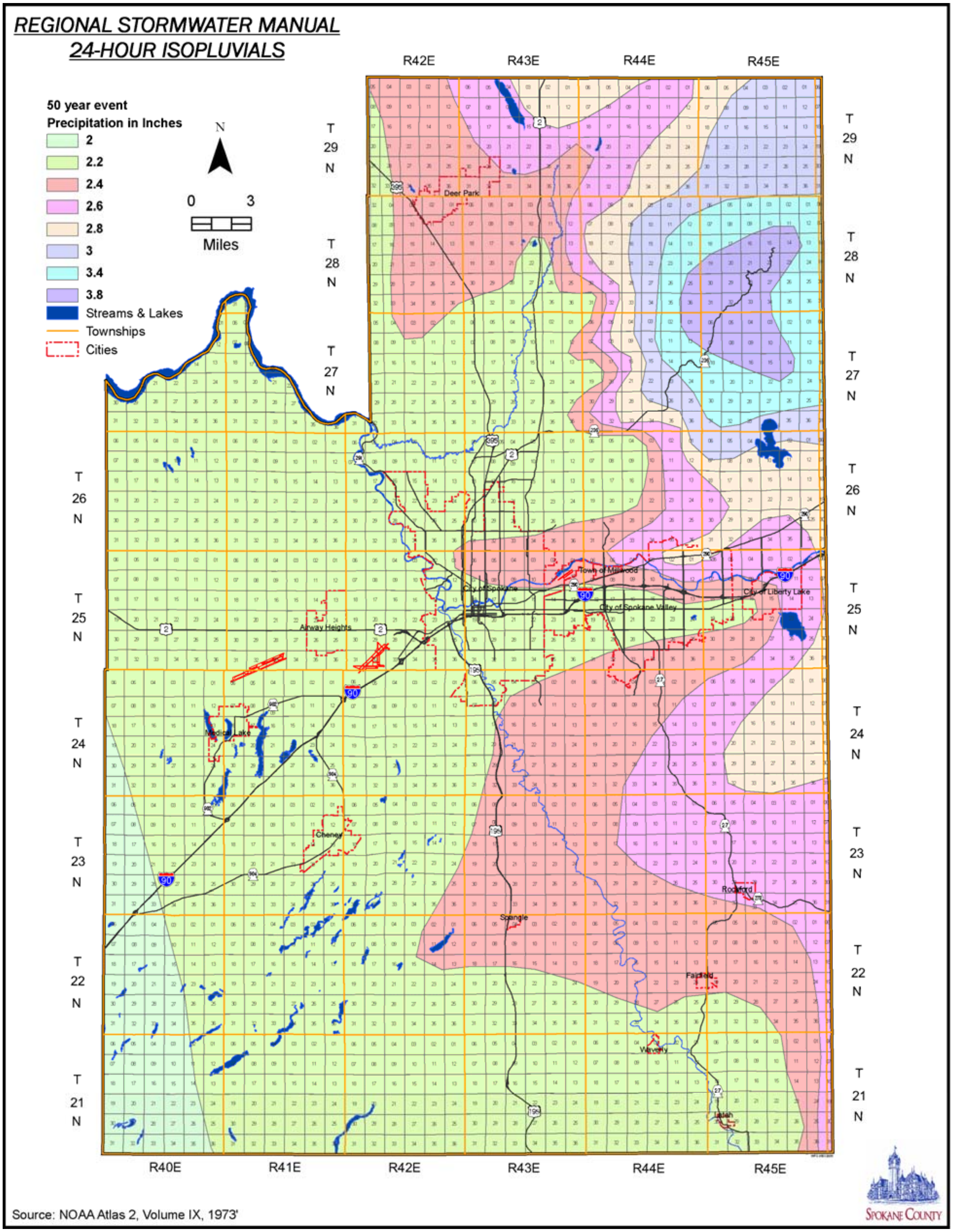

Figure 5-4 – 50-Year, 24-Hour Isopluvial Map

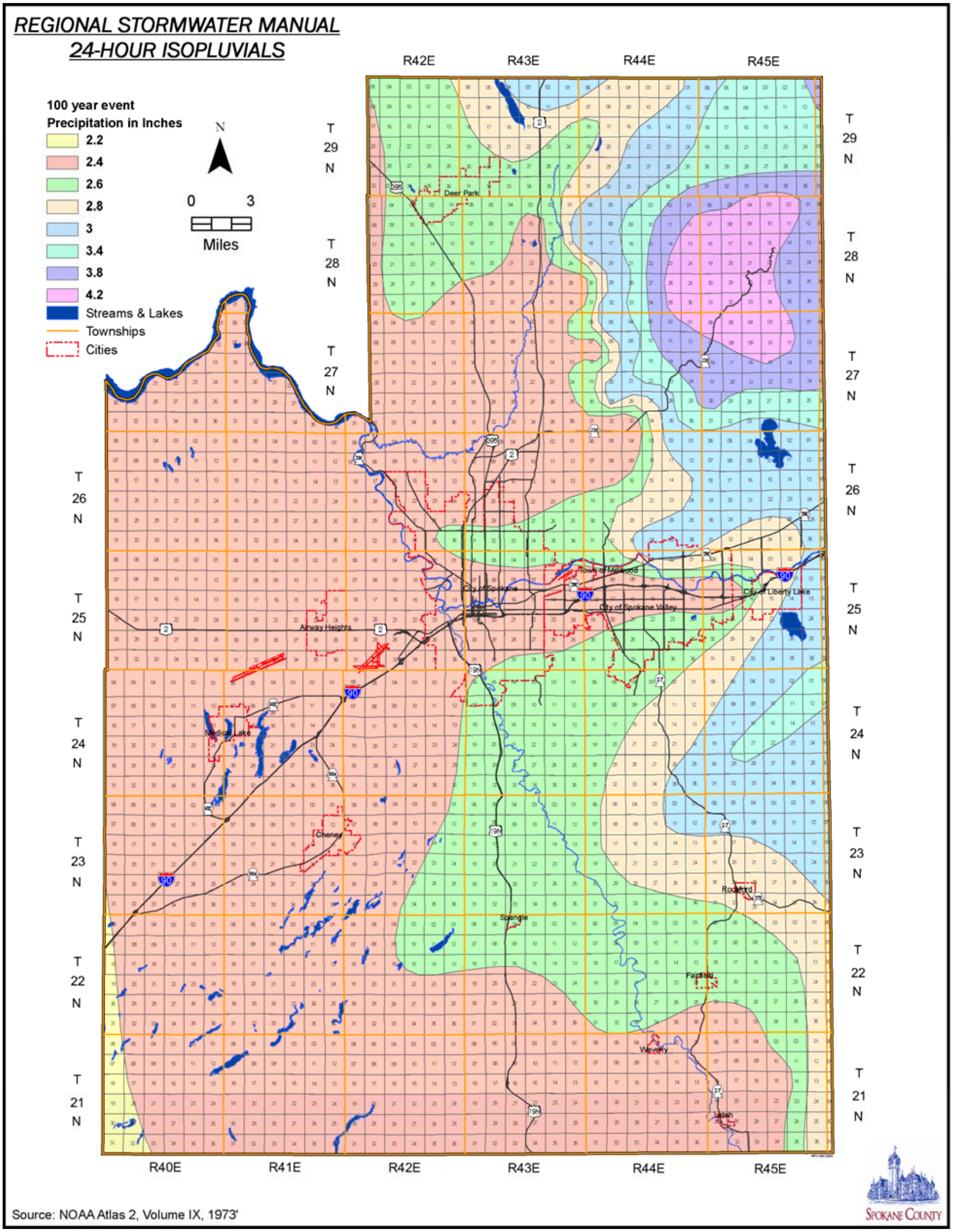

Figure 5-5 – 100-Year, 24-Hour Isopluvial Map

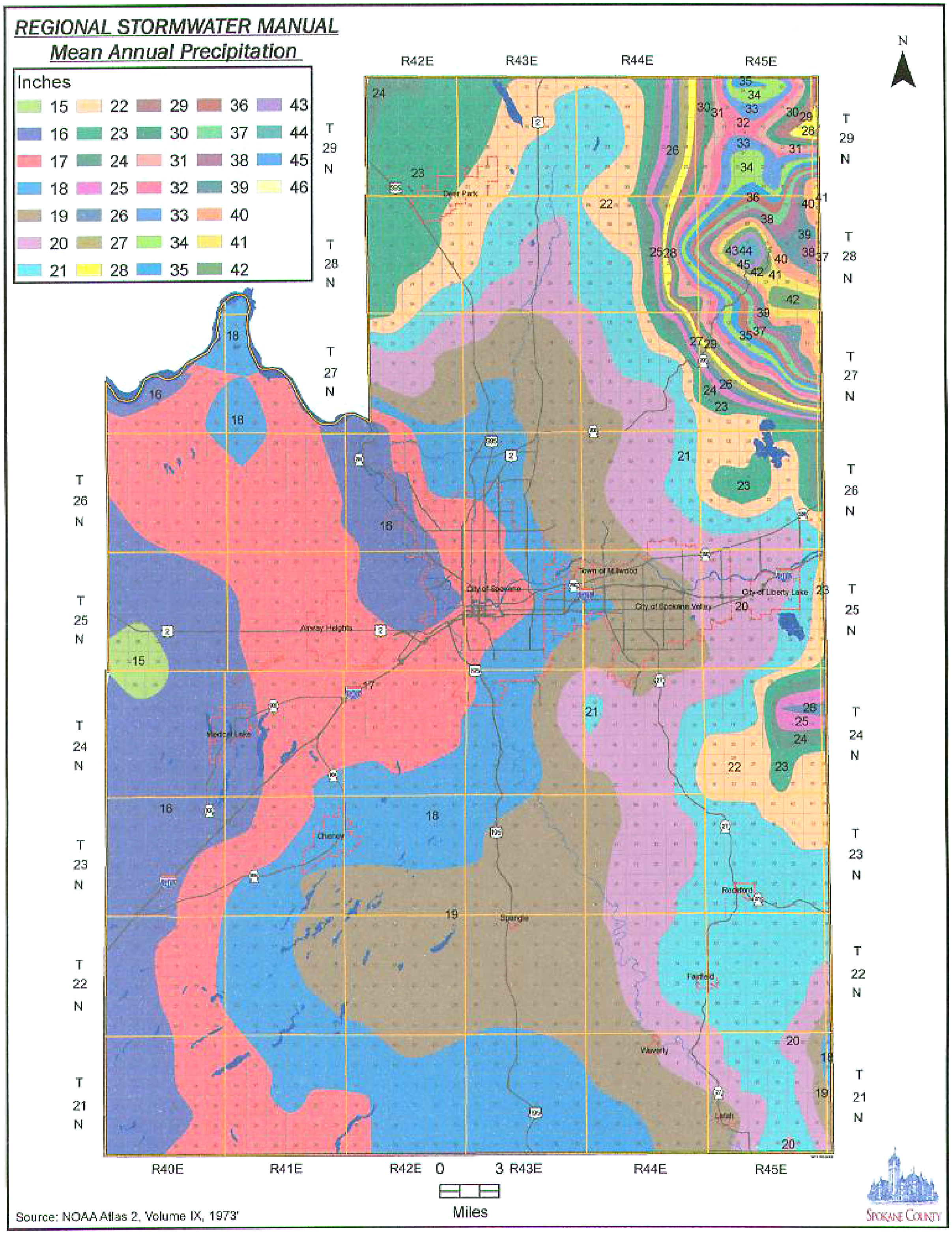

Figure 5-6 – Mean Annual Precipitation

5.4 LEVEL POOL ROUTING METHOD

This section presents a general description of the methodology for routing a hydrograph through an existing retention/detention facility or closed depression, and for sizing a new retention/detention facility using hydrograph analysis. The "level pool routing" technique presented here is one of the simplest and most commonly used hydrograph routing methods. This method is described in *Handbook of Applied Hydrology* (Chow, Ven Te, 1964) and elsewhere, and is based upon the continuity equation:

Inflow - Outflow = Change in storage

$$\left[\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2}\right] = \frac{\Delta S}{\Delta t} = S_2 - S_1 \qquad (5\text{-}8)$$

Where:
- I = inflow at time 1 and time 2;
- O = outflow at time 1 and time 2;
- S = storage at time 1 and time 2; and,
- Δt = time interval, time 2 – time 1.

The time interval, Δt, must be consistent with the time interval used in developing the inflow hydrograph. The Δt variable can be eliminated by dividing it into the storage variables to obtain the following rearranged equation:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2 \qquad (5\text{-}9)$$

If the time interval, Δt, is in minutes, the units of storage (S) are in cubic feet per minute, which can be converted to cubic feet per second by multiplying by 1 minute/60 seconds. The terms on the left-hand side of the equation are known from the inflow hydrograph and from the storage and outflow values of the previous time step. The unknowns O2 and S2 can be solved interactively from the given stage-storage and stage-discharge curves.

5.5 RATIONAL METHOD

The rational method is used to predict peak flows for small drainage areas. The rational method can be used for the design of conveyance, flow control, and subsurface infiltration facilities. The greatest accuracy is obtained for areas smaller than 100 acres and for developed conditions with large impervious areas. The peak flow rate is calculated using the following equation:

$$Q_P = CIA \qquad (5\text{-}10)$$

Where:
- Q_P = peak flow rate (cfs);
- C = runoff coefficient (dimensionless units);

I = rainfall intensity (inches/hour) (refer to Section 5.5.3); and,

A = drainage area (acres).

5.5.1 RUNOFF COEFFICIENTS

Table 5-5 provides runoff coefficients for the 10-year storm frequency. Steeply sloped areas and less frequent, higher intensity storms require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff. Generally, runoff coefficients should be increased by 10% when designing for a 25-year frequency; by 20% for a 50-year frequency; and by 25% for a 100-year frequency. Runoff coefficients should not be increased above 0.95.

TABLE 5-5
RUNOFF COEFFICIENTS FOR THE RATIONAL METHOD
(10-YEAR RETURN FREQUENCY)

	Runoff Coefficient (C)		
Type of Cover	**Flat (<2%)**	**Rolling (2% - 10%)**	**Hilly (>10%)**
Pavement and Roofs	0.90	0.90	0.90
Earth Shoulders	0.50	0.50	0.50
Drives and Walks	0.90	0.90	0.90
Gravel Pavement	0.50	0.55	0.60
Lawns, Sandy Soil	0.10	0.15	0.20
Lawns, Heavy Soil	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay and Loam	0.50	0.55	0.60
Cultivated Land, Sand and Gravel	0.25	0.30	0.35
Woodland and Forest	0.10	0.15	0.20
Meadow and Pasture Land	0.25	0.30	0.35

Source: WSDOT Hydraulics Manual, March 2004

5.5.2 TIME OF CONCENTRATION

The travel time, the time required for flow to move through a flow segment, shall be computed for each flow segment. The time of concentration is equal to the sum of the travel times for all flow segments. The procedure described below was developed by the NRCS. It is sensitive to slope, type of ground cover, and the size of channel. The time of concentration can be calculated as follows:

$$T_t = \frac{L}{K\sqrt{S}} \qquad (5\text{-}11)$$

$$T_c = T_{t1} + T_{t2} + \ldots + T_{tn} \qquad (5\text{-}12)$$

Where:

Where:	T_t	=	travel time of flow segment (minutes);
	T_c	=	time of concentration (minutes);
	L	=	length of segment (feet);
	K	=	ground cover coefficient, Table 5-6 (feet/minute);
	S	=	slope of segment (feet/foot); and,
	n	=	number of flow segments.

The time of concentration shall not be less than 5 minutes. For a few drainage areas, the time of concentration that produces the largest amount of runoff is less than the time of concentration for the entire basin. This can occur when two or more basins have dramatically different types of cover. The most common case would be a large paved area together with a long narrow strip of natural area. In this case, the engineer shall check the runoff produced by the paved area alone to determine if this scenario would cause a greater peak runoff rate than the peak runoff rate produced when both land segments are contributing flow. The scenario that produces the greatest runoff shall be used, even if the entire basin is not contributing flow to this runoff.

5.5.3 INTENSITY

The equation for calculating rainfall intensity is:

$$I = \frac{m}{T_C^n} \qquad (5\text{-}13)$$

Where:	m	=	coefficient of rainfall intensity, Table 5-7;

n = coefficient of rainfall intensity, Table 5-7;

I = rainfall intensity (inches/hour); and,

T_c = time of concentration (minutes).

TABLE 5-6
GROUND COVER COEFFICIENTS

Type of Cover	K (feet/minute)
Forest with heavy ground cover	150
Minimum tillage cultivation	280
Short pasture grass or lawn	420
Nearly bare ground	600
Small roadside ditch w/grass	900
Paved area	1,200
Gutter flow:	
4 inches deep	1,500
6 inches deep	2,400
8 inches deep	3,100
Storm Sewers:	
12 inch diameter	3,000
18 inch diameter	3,900
24 inch diameter	4,700
Open Channel Flow (n = .040):	
12 inches deep	1,100
Narrow Channel (w/d =1):	
2 feet deep	1,800
4 feet deep	2,800
Open Channel Flow (n = .040):	
1 foot deep	2,000
Wide Channel (w/d =9):	
2 feet deep	3,100
4 feet deep	5,000

Source: WSDOT Hydraulics Manual, March 2004

TABLE 5-7
INDEX TO RAINFALL COEFFICIENTS

2-year Event		10-year Event		25-year Event		50-year Event		100-year Event	
m	n	m	n	m	n	m	n	m	n
3.47	0.556	6.98	0.609	9.09	0.626	10.68	0.635	12.33	0.643

Source: WSDOT Hydraulics Manual, March 2004

The rainfall intensity (I) coefficients (m and n) have been determined for Spokane for the 2-, 10-, 25-, 50-, and 100-year storm events. These coefficients were developed from NOAA Atlas 2 and are shown in Table 5-7.

5.6 BOWSTRING METHOD (MODIFIED RATIONAL METHOD)

This method is used to estimate storage requirements for a given design storm using a series of hydrographs for different storm durations (t).

Depending on the relative magnitude of the time of concentration (T_c) and the storm duration, the shape of the hydrograph generated with this method varies from triangular to trapezoidal (see Figure 5-7).

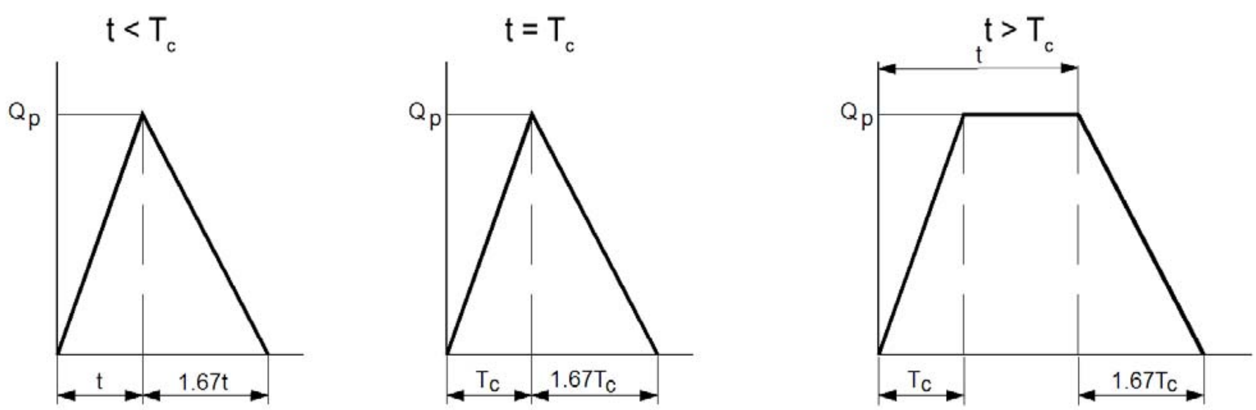

Figure 5-7 – Bowstring Method Hydrographs

The recession period (T_R) of the hydrograph is given by Equation 5-14.

$$T_R = 1.67T_P \qquad (5\text{-}14)$$

Where: $T_P = T_c$, when $t \geq T_c$; or,

$T_P = t$, when $t < T_c$.

The volume (V) under the hydrograph at a given time (t) is given by:

$$V(t) = 1.34Q_P t \text{ for } t \leq T_c \text{ (triangular hydrograph)} \qquad (5\text{-}15)$$

$$V(t) = Q_P t + 0.34Q_P T_C \text{ for } t > T_c \text{ (trapezoidal hydrograph)} \qquad (5\text{-}16)$$

With these equations, the base of the triangular hydrograph is equal to 2.67t. For the trapezoidal hydrograph, the time base is $t + 1.67T_c$. The top width of the trapezoid is equal to $t – T_c$. With this method, the hydrograph for each storm duration is overlaid with the outflow hydrograph. The outflow hydrograph is given by the following equation:

$$V_{OUT}(t) = Q_{OUT} t \qquad (5\text{-}17)$$

The critical storm duration is the storm duration that results in the maximum required detention storage.

5.6.1 DESIGN STEPS

Under certain circumstances as allowed by the local jurisdiction the Bowstring Method can be used for detention design with following procedure:

1. Compute the peak flow rate (Q_P) for $t = T_c$ using Equation 5-10 for the pre-developed condition. If the project proposes to release runoff off site, this is the maximum peak flow rate that shall be released.
2. Compute Q_P for $t = T_c$ using Equation 5-10 for the post-developed condition.
3. Compute intensities (I), peak flow rates (Q_P), and volumes (V) for various times (e.g., t = 5, 10, 25…minutes) using Equations 5-10, 5-13, 5-15, and 5-16.
4. Determine the allowable release rate (Q_{OUT}), which is limited to either the pre-developed peak flow rate or the allowable infiltration rate through drywells as determined by Section 4.3.1.
5. Calculate the outflow volume (V_{OUT}) using Equation 5-17.
6. The required storage is obtained as the maximum difference between inflow and outflow volumes by the tabular methods. The tabular method is illustrated in the example given in Appendix 5B.

Although credit is not given for infiltration through the pond bottom for ponds and swales, they shall comply with the criteria in Section 7.8.3.

5.7 WATER BUDGET METHOD

5.7.1 INTRODUCTION

A water budget analysis is required for the design of an evaporative pond. The analysis utilizes average monthly precipitation and pan evaporation values to estimate the net stormwater runoff volume increase during a two year cycle. The precipitation values are adjusted to account for the changes in precipitation over the Spokane Region. The water budget analysis is conducted for a two-year cycle to account for seasonal variations in precipitation, pan evaporation and antecedent runoff conditions and to verify that equilibrium is reached.

Equilibrium is reached when the analysis confirms that the required pond size does not increase in the second year of the cycle.

5.7.2 METHODOLOGY

The water budget analysis is performed utilizing the following relationships:

$$V_{STORAGE}(x) = V_{IN}(x) - V_{OUT}(x) + V_{STORAGE}(x-1) \tag{5-18}$$

$$V_{POND} = \max[V_{STORAGE}(x)] \tag{5-19}$$

Where:

x = any given month;

V_{IN} = water volume entering the evaporative pond in a given month. Stormwater runoff volume is calculated using the NRCS runoff Equations 5-1 and 5-2;

V_{OUT} = stormwater volume leaving the evaporative pond in a given month (i.e. pan evaporation, surface release);

$V_{STORAGE}$ = storage volume necessary for a given month; and,

V_{POND} = storage volume necessary to reach equilibrium in a 2-year cycle.

The analysis is repeated until the maximum storage volume in the second year is equal to or less than the maximum storage volume in the first year.

The cycle shall start in October, the month that yields the greatest net storage volume for the year.

Water loss through evaporation from overland surface areas is not considered in the water budget due to the wide variation in evaporation rates that occur over these types of surfaces. Depressional storage is the only reduction that can be considered in this analysis. This reduction may be considered if closed depressions are present on site in the pre-developed condition and are proposed to remain as an existing topographical feature, set aside for drainage purposes. Vegetal and minor topographical abstraction and interception are already accounted for in the NRCS curve numbers.

Depending on the site conditions, evaporative systems shall be designed using the Preferred or Alternative method design criteria described below.

The Preferred Method

The Preferred Method is used to size evaporation facilities that store the increase in stormwater runoff volume (after evaporation losses). Refer to Figures 7-7 and 7-8 for schematics of how this design is implemented.

The water budget analysis must demonstrate that the volume of runoff leaving the site over a 2-year cycle is less than or equal to the pre-developed volume for the cycle. If the facility has a surface release, the rate of release from the facility shall meet the detention design criteria (Section 7.3.2). If site conditions permit, the pre-developed volume could be infiltrated when a defined release point is not present on site.

If the evaporative system is designed in combination with a surface discharge, then Equations 5-18 through 5-21 shall be used:

$$V_{ALL} \leq V_{PRE} \tag{5-20}$$

$$Q_{ALL} \leq Q_{PRE} \tag{5-21}$$

Where: V_{ALL} = the total volume released from the site in two year cycle (not including pan evaporation or infiltration);

V_{PRE} = the total pre-developed volume of runoff for two year cycle;

Q_{PRE} = the pre-developed rate for the contributing basin; and,

Q_{ALL} = the release rate from the facility.

The Alternative Method

The Alternative Method is used to size evaporation facilities that store the total post-developed runoff volume (less evaporative losses) or full containment evaporative systems. The Alternative Method is used when the project site does not have a defined discharge point or when site conditions are not conducive to infiltration of the pre-developed volume.

The facility shall be sized to store the volume per Equations 5-18, 5-19, and 5-22:

$$V_{STORAGE}(o) = V_{IN}(o) - V_{OUT}(o) \qquad (5\text{-}22)$$

Where: o = first month of the two year cycle.

The facility shall include a factor of safety on the maximum depth of 1.2. The extra capacity provides emergency storage in the event that above average total annual precipitation is experienced. A full containment evaporative pond is required when there is no discharge point or site conditions prohibit the use of infiltration. These conditions may include little infiltrative capacity in the soil, existing high groundwater, or potential for adverse impacts on adjacent or down-gradient properties from additional stormwater being injected into the subsurface.

5.7.3 DESIGN STEPS

The following steps outline how to use the spreadsheets that have been developed for this method (check with the local jurisdiction for the most current spreadsheets for a proposed project). Example calculations are presented in Appendices 5C and 5D.

1. Determine the drainage basin boundaries that contribute to the evaporative pond and the land surface characteristics (i.e. grass, pavement, roof area, sidewalk, woods, etc.) for the post-developed conditions. These parameters also need to be determined for the pre-developed conditions when using the Preferred Method;
2. Determine the ARC II CN values for the pervious and impervious surfaces using Table 5-1 and weight the CN values per Section 5.3.4.
3. Determine the associated ARC III CN values per Table 5-2. Input the ARC II and ARC III CN values;
4. Input the impervious basin and total basin size, in acres;
5. Input the mean annual precipitation, in inches, per Figure 5-6;
6. Input the proposed pond side slopes;
7. Input an assumed pond depth, for the Preferred Method only, based upon depth to limiting layer or desired depth. Pond depth is calculated automatically for the Alternative Method based upon the necessary surface area (projected from pond bottom area) and the required volume necessary to store/evaporate;
8. Assume a value for the pond bottom area and input that value, in square feet, into the pond bottom area cell of the spreadsheet;
9. The pond bottom perimeter is calculated as a square for simplicity; should the actual perimeter be known (or general shape), this can be inserted in place of the calculated field; however, each time the pond bottom is changed during the iterative process, the pond bottom perimeter needs to be adjusted; and,
10. Vary the pond bottom area (up or down) until:
    - The “Amount Spilled” is less than or equal to the “Total Annual Pre-Developed Volume” for the Preferred Method; or,

- The month in which the "Total Volume Stored" in Pond (STORAGE column) shows a decrease from year one to year two for the Alternative Method.

11. Note that for the Preferred Method, these steps only satisfy the requirement to control volume to the pre-developed condition. In order to satisfy the requirement to control flow rates to the pre-developed condition, Section 7.3 must be utilized to design the detention portion of the drainage facility.

5.7.4 CURVE NUMBER ADJUSTMENT

The antecedent runoff condition (ARC) needs to be considered during the months of the year when the ground may be saturated or frozen. The CNs shall be adjusted as indicated in Table 5-8 and Table 5-2.

TABLE 5-8
CURVE NUMBER ADJUSTMENT FOR
ANTECEDENT RUNOFF CONDITION (ARC)

Month	Antecedent Runoff Condition (ARC)	Curve Number
April through October	Normal (ARC = II)	See Table 5-2
November and March	Wet (ARC = III)	See Table 5-2
December, January & February	n/a	95

The following should be noted when choosing CN values:

- For impervious surfaces such as roads, sidewalks and driveways, the ARC II CN is typically 98, and the correlating ARC III CN is 99. From December through February, the assumption is that if the CN of 98 goes up to 99 during the wet months, it will not revert to 98 during frozen ground conditions; and,
- During December through February, the CN for pervious surfaces is 95 regardless of the ARC II or III CNs; this is meant to approximate runoff from pervious surfaces during snowpack buildup and snowmelt.

5.7.5 CLIMATOLOGICAL DATA

Average monthly precipitation rates were obtained from the Western Regional Climate Center (WRCC), based on records from January 1, 1890 to December 31, 2005. This information is found in Table 5-9 and is updated quarterly at the following website:

- http://www.wrcc.dri.edu/cgi-bin/cliRECtM.pl?waspok.

The monthly pan evaporation values were also obtained from the WRCC and are current for the period from 1889 through 2002. In Washington State many pan evaporation stations do not take readings during winter. A “0.00” total indicates that no measurement was taken. Some totals are computed from meteorological measurements using a form of the Penman equation. The rates in this table were obtained using this method according to the WRCC website: http:wrcc.dri.edu/htmlfiles/westevap.final.html.

TABLE 5-9
AVERAGE MONTHLY PRECIPITATION AND PAN EVAPORATION VALUES

Month / Data	Precipitation (in)	Pan Evaporation (in)
January	1.97	0.61
February	1.54	1.11
March	1.39	2.28
April	1.11	4.45
May	1.42	6.69
June	1.20	8.14
July	0.55	10.70
August	0.63	9.42
September	0.80	5.90
October	1.17	2.58
November	2.08	0.92
December	2.20	0.51

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APPENDIX 5A – EXAMPLE CALCULATION: WEIGHTING CURVE NUMBERS

GIVEN

- The existing site is approximately 10-acres, consisting of Type B soils. Existing surface vegetative conditions include short grass and weeds.
- Post-developed site conditions consist of:
  - 38 – 10,000 square foot lots;
  - 1,500-square-foot homes with 500-square-foot driveways;
  - 1.30 acres of road impervious areas; and,
  - No sidewalks are proposed.

CALCULATIONS

1. Use Table 5-1 to find the CNs for the lawn areas and the roofs, driveways, and streets:

   CN = 61 for lawns (good condition) – Type B soils

   CN = 98 for streets, driveways, and roofs (impervious areas)

2. Compute the CN for the impervious basin. The connected impervious areas are driveways and streets. No weighting is required because the CNs values for the impervious areas are the same.

   Total driveway area = (38 driveways)(500 square feet/driveway)

   = 19,000 square feet = 0.44 acres

   Total connected impervious area = 0.44 +1.30 = 1.74 acres

   CN FOR THE IMPERVIOUS BASIN = 98

3. Compute the CN for the pervious basin. Although the roof area is impervious, it can be weighted with the lawn area because the two are considered homogeneous; i.e. the roofs are not hydraulically connected to the roads or driveways.

   Total roof area = (38 houses)(1500 square feet/house)

   = 57,000 square feet = 1.31 acres

   Total lawn area = Total site – total impervious area

   $= 10 - 1.74 - 1.31 = 6.95 \cdot acres$

   Total pervious basin = $1.31 + 6.95 = 8.26 \cdot acres$

Weighted CN for pervious basin: $$\frac{6.95(61)+1.31(98)}{8.26}=66.87\approx 67$$

CN FOR THE PERVIOUS BASIN = 67

APPENDIX 5B – EXAMPLE CALCULATION: BOWSTRING METHOD

GIVEN

- The existing site is approximately 5-acres, consisting of sandy soils. Existing surface vegetative conditions include short grass and weeds.
- Post-developed site conditions consist of:
  - o 20 – 10,000 square foot lots;
  - o 1,500-square-foot homes with 500-square-foot driveways;
  - o 0.50 acres of road impervious area; and,
  - o Topographic relief ranges 2 to 5%.
- When the site is developed, the longest time of concentration will consist of:
  - o 100 feet of overland flow @ 1%;
  - o 300 feet of gutter flow @ 1%; and,
  - o 300 feet of pipe flow @ 2%.
- The proponent proposes a pond with drywells for stormwater runoff disposal.
- Field samples were collected at the proposed location of the drywells. Using the Spokane County 200 Method, it was estimated that the drywell outflow rate is 1 cfs.

CALCULATIONS

1. Determine the weighted Runoff Coefficient (C) for the post-developed condition:

From Table 5-5:

C = 0.15 pervious areas – lawns (sandy soils, rolling terrain)

C = 0.90 impervious areas – streets, driveways, and sidewalks

Total roof area	=	20(1,500 square feet)
	=	30,000 square feet.
	=	0.69 acres
Total driveway area	=	20(500 square feet)
	=	10,000 square feet
	=	0.23 acres
Total impervious area	=	0.69 + 0.23 + 0.5 = 1.42 acres
Total permeable area:		5 – 1.42 acres = 3.58 acres

Weighted C: $= \dfrac{3.58(0.15)+1.42(0.90)}{5} = 0.36$

2. Determine the time of concentration (T_C).

Ground Cover Coefficient (K): (use Table 5-6)

Flow Segment Travel Time (T_t): $T_t = \dfrac{L}{K\sqrt{S}}$ (Equation 5-11)

FLOW SEGMENT	**LENGTH (feet)**	**SLOPE (feet/foot)**	**K (feet/minute)**	***T_t* (minutes)**
Overland Flow	100	0.01	420	2.38
Gutter Flow	300	0.01	1500	2.00
Pipe Flow	300	0.02	3000	0.71
Total Time of Concentration				5.09 min

3. Determine the intensity using Equation 5-13.

$$I = \frac{m}{T_C^n}$$

From Table 5-7; m and n are 6.98 and 0.609, respectively, for the 10-year storm.

$$I = \frac{6.98}{5.09^{0.609}} = 2.59 \text{ inches/hour}$$

4. Determine the peak flow rate t = T_c using Equation 5-10.

$$Q_P = CIA = 0.36(2.59 \text{ inches/hour})(5 \text{ acres}) = 4.66 \text{ cfs}$$

5. Compute the volume for t = T_c using Equation 5-15.

$$V(\text{t}) = 1.34 Q_P \text{t} = 1.34(4.66\,\text{cfs})(5.09\,\text{min})(60\,\text{sec/min}) = 1{,}907 \text{ cubic feet}$$

6. Determine the allowable release rate (Q_{OUT}).

Q_{OUT} = 1.0 cfs (Given)

7. Compute the outflow volume (V_{OUT}) for t = T_c using Equation 5-17.

$$V_{OUT} = Q_{OUT}\,\text{t} = (1.0\text{ cfs})(5.09\text{ min})(60\text{ sec/min}) = 305\text{ cubic feet}$$

8. Compute intensities (I), peak flow rates (Q_P), and inflow and outflow volumes (V, V_{OUT}) for various times (i.e. t = 5, 10, 25… minutes) using Equations 5-10, 5-13, 5-15, 5-16 and 5-17. This is simply done in a spreadsheet program, as shown in the sample spreadsheet on Figure 5B-1

9. The required storage is obtained as the maximum difference between inflow and outflow volumes (see spreadsheet, Figure 5B-1).

BOWSTRING METHOD (TEN YEAR STORM DESIGN)

PROJECT: PROJECT NAME
PROJECT NO: PROJECT NUMBER
BASIN: **BASIN NAME**
DESIGNER: DESIGNER NAME
DATE: 03/14/06

NUMBER OF DRYWELLS PROPOSED
0 Single (type A) 1 Double (type B)

Time of Conc. (min)	5.09		
Area (Acres)	5.00		
Weighted "C"	0.36		
Volume Provided	1650	storm:	1603
Outflow (cfs)	1.0	Drywell	
Area * C	1.80		

#1 Time (min.)	#2 Time (sec.) (#1*60)	#3 Intensity (in./hr.)	#4 Q dev. (cfs) (A*C*#3)	#5 V in (cu. ft.)	#6 V out (cu. ft.) (Outf.*#2)	#7 Storage (cu. ft.) (#5-#6)
5.09	305.40	2.59	4.66	1909	305.40	1603
5	300	2.62	4.71	1895	300	1595
10	600	1.72	3.09	2176	600	1576
15	900	1.34	2.41	2424	900	1524
20	1200	1.13	2.03	2643	1200	1443
25	1500	0.98	1.77	2838	1500	1338
30	1800	0.88	1.58	3014	1800	1214
35	2100	0.80	1.44	3177	2100	1077
40	2400	0.74	1.33	3327	2400	927
45	2700	0.69	1.24	3468	2700	768
50	3000	0.64	1.16	3600	3000	600
55	3300	0.61	1.09	3726	3300	426
60	3600	0.58	1.04	3845	3600	245
65	3900	0.55	0.99	3959	3900	59
70	4200	0.53	0.95	4067	4200	-133
75	4500	0.50	0.91	4172	4500	-328
80	4800	0.48	0.87	4272	4800	-528
85	5100	0.47	0.84	4370	5100	-730
90	5400	0.45	0.81	4463	5400	-937
95	5700	0.44	0.78	4554	5700	-1146
100	6000	0.42	0.76	4642	6000	-1358

DRYWELL REQUIREMENTS - 10 YEAR DESIGN STORM

Maximum storage by Bowstring = required: 1603 cu. ft.
provided: 1650 cu. ft. **OK!**

Number and type of drywells required = 0 SINGLE
1 DOUBLE

Figure 5B-1 – Bowstring Method Spreadsheet Example

APPENDIX 5C – EXAMPLE CALCULATION: WATER BUDGET (PREFERRED METHOD)

GIVEN

- The project is located in Section 31, Township 26 N, Range 42 E
- Pre-developed Site Conditions
    - Woods and grass combination, good condition CN = 58
- Post-developed Site Conditions
    - Total basin = 14 acres
    - Impervious basin CN = 98, 1.75 acres
    - Pervious basin CN = 67 (includes roofs and lawns), 8.00 acres
    - Remaining open area = to be used as open space or drainage
    - Open Space CN = 61
    - Pond Area CN = 98

CALCULATIONS

Spreadsheets referred to in these calculations are available from the local jurisdiction for a given project. Figure 5C-1 shows a sample spreadsheet.

1. Determine the ARC II CN values for the pervious and impervious surfaces. Refer to Appendix 5A for an example.
2. Determine the associated ARC III CN values per Table 5-2. Input the ARC II and ARC III CN values into the spreadsheet.

ARC II CN	ARC III CN
58	76
61	78
67	83
98	99

3. Input the impervious basin and total basin size, in acres, into the spreadsheet:

    Total impervious area = 1.75 acres

    Total pervious area = 8.0 acres

    Total basin area = 14.0 ac (includes pond areas & open areas)

4. Input the mean annual precipitation, in inches:

Mean annual precipitation = 17.0 inches (Figure 5-6)

5. Input the proposed pond side slopes into the spreadsheet:

   Assume: 3:1 for side slopes

6. Input the proposed pond depth into the spreadsheet pond depth:

   Assume: 1.5 feet for maximum surface water elevation

7. Input the pond bottom area in square feet:

   Assume: 10% of the total developed area

   Pond bottom area= $0.10 * (9.75 acres) * (43{,}560 squarefeet / acre)$

   = 42,471 square feet

8. Adjust the pond bottom area up and down until the "Amount Spilled" is less than or equal to the "Total Annual Pre-developed Volume" for the Preferred method.

   RESULTS OF THE EVAPORATIVE CELL

   The pond bottom area required is 35,700 square feet

   The depth of the evaporative cell is 1.5 feet *1.2 = 1.8 feet
   (1.2 is the factor of safety; refer to Section 7.7.2)

   This is the size of the first cell of a separated (two-cell) system, or the lower portion of a stacked (one-cell) system.

9. Begin sizing the detention cell facility by determining the peak flow rates for the pre-developed basin and post-developed basins using the design steps outlined in Section 5.3.4 for the 2 and 25-year, 24 hour storm.
   - If sizing a separated system (two separate cells), the detention cell is sized per the steps outlined in Section 5.3.4 and placed downstream of the evaporative cell. The overflow from the evaporative cell is placed at or above the required evaporative depth of 1.8 feet.
   - If sizing a stacked system (one cell), the detention portion of the cell is placed on top of the evaporative portion. Thus, the detention cell "bottom" and outflow structure has to be placed at or above the maximum surface water elevation of the evaporative system (including the factor of safety). The detention portion is designed per the criteria specified in Section 7.3 and shall have a 1 foot freeboard above the maximum water surface elevation.

Project :	Name of Project
Job No.:	number
Date:	12/5/07
Designer:	designer
Pond Bottom Area:	35,700 sq. ft.
Pond Bottom Perimeter:	756 ft
Pond Side Slopes:	3 : 1
Assumed Pond Depth:	1.5 ft
Assumed Pond Volume:	53,550 c.ft.

Evaporative / Detention
Combination Pond

Preferred Method

	AMC II Normal	AMC III Nov., Mar	- - Dec.-Feb.
Pre-Dev. (Impervious) CN:	98	99	99
Pre-Dev. (Permeable) CN:	58	76	95
Post-Dev. (Impervious) CN:	98	99	99
Post-Dev. (Permeable) CN:	67	83	95
Pre-Dev.(Impervious) S:	0.20	0.10	0.10
Pre-Dev.(Permeable) S:	7.24	3.16	0.53
Post-Dev.(Impervious) S:	0.20	0.10	0.10
Post-Dev.(Permeable) S:	4.93	2.05	0.53

Mean Annual Precipitation

Airport	16.11
Project Site	17.00
Multiplier	1.06

	Pre-dev	Post-dev	
Impervious Basin Size:	0.00	1.74 acres	
Impervious Pond Size:	0.00	0.82 acres	
Pervious Basin Size:	14.00	11.44 acres	
	14.00	14.00 acres	14.00

Month	Precip. "P" (in.)	Adj. "P" (in)	Imp pre-dev (P-0.2S)	Perm. pre-dev (P-0.2S)	Imp post-dev (P-0.2S)	Perm post-dev (P-0.2S)	Imp pre-dev Runoff Depth (in)	Perm pre-dev Runoff Depth (in)	Imp post-dev Runoff Depth (in)	Perm post-dev Runoff Depth (in)	Imp pre-dev runoff volume (cft)	Perm pre-dev runoff volume (cft)	TOTAL PRE VOL (cft)	Imp post-dev runoff volume (cft)	Perm post-dev runoff volume (cft)	TOTAL POST VOL (cft)	NET Increase in Volume (cft)	Pan Evap. (in.)	Evap Volume Out (cft) 28% Adj.	Total Volume to Handle (cft)	Current Volume in Pond (cft)	Spill Volume to Detention < PRE (cft)
Oct.	1.22	1.29	1.25	0.00	1.25	0.30	1.07	0.00	1.07	0.02	0	0	0	9,953	726	10,679	10,679	2.58	5,526	5,153	5,153	0
Nov.	2.02	2.13	2.11	1.50	2.11	1.72	2.01	0.48	2.01	0.79	0	24,549	24,549	18,722	32,661	51,383	26,834	0.92	1,971	54,565	53,550	1,015
Dec.	2.22	2.34	2.32	2.24	2.32	2.24	2.23	1.81	2.23	1.81	0	92,050	92,050	20,679	75,221	95,900	3,850	0.51	1,092	148,357	53,550	94,807
Jan.	2.05	2.16	2.14	2.06	2.14	2.06	2.05	1.64	2.05	1.64	0	83,287	83,287	19,015	68,060	87,075	3,788	0.61	1,307	139,319	53,550	85,769
Feb.	1.57	1.66	1.64	1.55	1.64	1.55	1.54	1.16	1.54	1.16	0	58,874	58,874	14,321	48,110	62,431	3,558	1.11	2,378	113,604	53,550	60,054
Mar.	1.38	1.46	1.44	0.82	1.44	1.05	1.34	0.17	1.34	0.35	0	8,678	8,678	12,466	14,699	27,164	18,486	2.28	4,884	75,831	53,550	22,281
Apr.	1.11	1.17	1.13	0.00	1.13	0.19	0.96	0.00	0.96	0.01	0	0	0	8,898	282	9,179	9,179	4.45	9,532	53,197	53,197	0
May	1.37	1.45	1.40	0.00	1.40	0.46	1.23	0.00	1.23	0.04	0	0	0	11,397	1,636	13,033	13,033	6.69	14,330	51,901	51,901	0
June	1.27	1.34	1.30	0.00	1.30	0.36	1.12	0.00	1.12	0.02	0	0	0	10,434	992	11,425	11,425	8.14	17,436	45,890	45,890	0
July	0.50	0.53	0.49	0.00	0.49	0.00	0.34	0.00	0.34	0.00	0	0	0	3,187	0	3,187	3,187	10.7	22,919	26,158	26,158	0
Aug.	0.60	0.63	0.59	0.00	0.59	0.00	0.44	0.00	0.44	0.00	0	0	0	4,093	0	4,093	4,093	9.42	20,178	10,073	10,073	0
Sept.	0.80	0.84	0.80	0.00	0.80	0.00	0.64	0.00	0.64	0.00	0	0	0	5,952	0	5,952	5,952	5.9	12,638	3,388	3,388	0
Oct.	1.22	1.29	1.25	0.00	1.25	0.30	1.07	0.00	1.07	0.02	0	0	0	9,953	726	10,679	10,679	2.58	5,526	8,540	8,540	0
Nov.	2.02	2.13	2.11	1.50	2.11	1.72	2.01	0.48	2.01	0.79	0	24,549	24,549	18,722	32,661	51,383	26,834	0.92	1,971	57,953	53,550	4,403
Dec.	2.22	2.34	2.32	2.24	2.32	2.24	2.23	1.81	2.23	1.81	0	92,050	92,050	20,679	75,221	95,900	3,850	0.51	1,092	148,357	53,550	94,807
Jan.	2.05	2.16	2.14	2.06	2.14	2.06	2.05	1.64	2.05	1.64	0	83,287	83,287	19,015	68,060	87,075	3,788	0.61	1,307	139,319	53,550	85,769
Feb.	1.57	1.66	1.64	1.55	1.64	1.55	1.54	1.16	1.54	1.16	0	58,874	58,874	14,321	48,110	62,431	3,558	1.11	2,378	113,604	53,550	60,054
Mar.	1.38	1.46	1.44	0.82	1.44	1.05	1.34	0.17	1.34	0.35	0	8,678	8,678	12,466	14,699	27,164	18,486	2.28	4,884	75,831	53,550	22,281
Apr.	1.11	1.17	1.13	0.00	1.13	0.19	0.96	0.00	0.96	0.01	0	0	0	8,898	282	9,179	9,179	4.45	9,532	53,197	53,197	0
May	1.37	1.45	1.40	0.00	1.40	0.46	1.23	0.00	1.23	0.04	0	0	0	11,397	1,636	13,033	13,033	6.69	14,330	51,901	51,901	0
June	1.27	1.34	1.30	0.00	1.30	0.36	1.12	0.00	1.12	0.02	0	0	0	10,434	992	11,425	11,425	8.14	17,436	45,890	45,890	0
July	0.50	0.53	0.49	0.00	0.49	0.00	0.34	0.00	0.34	0.00	0	0	0	3,187	0	3,187	3,187	10.7	22,919	26,158	26,158	0
Aug.	0.60	0.63	0.59	0.00	0.59	0.00	0.44	0.00	0.44	0.00	0	0	0	4,093	0	4,093	4,093	9.42	20,178	10,073	10,073	0
Sept.	0.80	0.84	0.80	0.00	0.80	0.00	0.64	0.00	0.64	0.00	0	0	0	5,952	0	5,952	5,952	5.9	12,638	3,388	3,388	0
Oct.	1.22	1.29	1.25	0.00	1.25	0.30	1.07	0.00	1.07	0.02	0	0	0	9,953	726	10,679	10,679	2.58	5,526	8,540	8,540	0
																			114190.02			

Total Annual Pre 267,438 Total Annual Post 381,503 114,065 Net Increase Amount Spilled 267,313

16.11 17.00 Mean Annual Precipitation for Project Site

Figure 5C-1 – Evaporative Pond Spreadsheet Example (Preferred Method)

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APPENDIX 5D – EXAMPLE CALCULATION: WATER BUDGET (ALTERNATIVE METHOD)

GIVEN

- The project is located in Section 31, Township 26 N, Range 42 E
- Pre-Developed Site Conditions
  - Woods and grass combination, good condition CN = 58
- Post Developed Site Conditions
  - Total basin = 14 acres
  - Impervious basin CN = 98, 1.75 acres
  - Pervious basin CN = 67 (includes roofs and lawns), 8.00 acres
  - Remaining open area = to be used as open space or drainage
  - Open Space CN = 61
  - Pond Area CN = 98

CALCULATIONS

Spreadsheets referred to in these calculations are available from the local jurisdiction for a given project. Figure 5D-1 shows a sample spreadsheet.

1. Determine the ARC II CN values for the pervious and impervious surfaces. Refer to Appendix 5A for an example.

2. Determine the associated ARC III CN values per Table 5-2. Input the ARC II and ARC III CN values into the spreadsheet.

ARC II CN	ARC III CN
61	78
67	83
98	99

3. Input the impervious basin and total basin size, in acres, into the spreadsheet;

   Total impervious area = 1.75 ac

   Total pervious area = 8.0 ac

   Total basin area = 14.0 ac (includes pond areas & open areas)

4. Input the mean annual precipitation, in inches.

   Mean annual precipitation = 17.0 inches (Figure 5-6)

5. Input the proposed pond side slopes into the spreadsheet.

   Use: 3:1 for side slopes

6. Input the pond bottom area in square feet

   Assume 30% of the total area developed.

   Pond bottom area $= 0.30 * (9.75 acres) * (43{,}560 squarefeet / acre)$

   = 127,413 square feet

   The pond bottom perimeter is calculated as a square for simplicity; should the actual perimeter be known (or general shape), this can be inserted in place of the calculated field. Note that each time the pond bottom is changed during the iterative process, the pond bottom perimeter needs to be adjusted.

7. Adjust the pond bottom area up and down until the month in which the "Total Volume Stored" in the pond (STORAGE column) is the largest and shows a decrease from Year 1 to Year 2 of the water budget cycle.

   - The month with the largest volume requirements is March in this example
   - The pond bottom area required is 137,000 square feet
   - The depth of the evaporative cell is 2.21 feet
   - Apply the factor of safety to the depth:
     2.21 feet x 1.2 = 2.66 feet
   - Add the freeboard to determine total pond depth:
     2.66 feet + 1.0 foot = 3.66 feet

Project : Name of Project			
Plat / BSP / Proj No:	number	Engineer:	designer
Date:	3/24/2008		
Pond Bottom Area:	138,000 sq. ft.		
Pond Bottom Perimeter:	1,486 ft		
Pond Side Slopes:	3 : 1		
Impervious Basin Size (Constant):	1.75 acres		
Impervious Basin Size (Pond Area):	3.17 acres		
Permeable Basin Size:	8.00 acres		
Off-Site Upstream Basin:	1.10 acres		
Total Basin Size:	14.02 acres		
Mean Annual Prec. - Airport:	16.11 in		
Mean Annual Prec. - Site:	17.00 in		
Multiplier:	1.06		
100-Year, 24 Hour, Prec.:	2.50 in		

Evaporative Pond to Accommodate All Post-Developed Volume

(no infiltration allowed)

Alternate Method

	AMC II Norm (Apr-Oct	AMC III Nov and Mar	--- Dec-Feb
Impervious CN:	98	99	99
Permeable CN:	67	83	95
Off-Site CN:	61	79	95
Impervious S:	0.20	0.10	0.10
Permeable S:	4.93	2.05	0.53
Off-Site S:	6.39	2.66	0.53

						INFLOW				OUTFLOW		STORAGE	POND DATA	
Month	Precipitation (in)	Adjusted Precipitation (in)	Impervious Runoff from Precipitation (in)	Permeable Runoff from Precipitation (in)	Off-Site Runoff from Precipitation (in)	Impervious Total Runoff Volume (cu ft)	Permeable Total Runoff Volume (cu ft)	Off-Site Total Runoff Volume (cu ft)	NET Total Volume (Imp+Perm+OS) (cu ft)	Pan Evap. (in)	Total Evap. Volume Out (cft) 72% Adj.	Total Volume Stored In Pond (cu ft)	Pond Depth (ft)	Pond Capacity (%)
													0.00	0
Oct.	1.22	1.29	1.07	0.02	0.00	19,124	508	0	19,632	2.58	21,362	0	0.00	0
Nov.	2.02	2.13	2.01	0.79	0.60	35,973	22,839	2,400	61,212	0.92	7,618	53,595	0.39	17
Dec.	2.22	2.34	2.23	1.81	1.81	39,733	52,600	7,233	99,566	0.51	4,276	148,885	1.08	47
Jan.	2.05	2.16	2.05	1.64	1.64	36,537	47,593	6,544	90,673	0.61	5,227	234,331	1.70	74
Feb.	1.57	1.66	1.54	1.16	1.16	27,518	33,642	4,626	65,786	1.11	9,695	290,422	2.10	92
Mar.	**1.38**	**1.46**	**1.34**	**0.35**	**0.24**	**23,952**	**10,278**	**953**	**35,183**	**2.28**	**20,162**	**305,443**	**2.21**	**97**
Apr.	1.11	1.17	0.96	0.01	0.00	17,096	197	0	17,293	4.45	39,480	283,256	2.05	90
May	1.37	1.45	1.23	0.04	0.00	21,899	1,144	17	23,060	6.69	59,066	247,250	1.79	78
June	1.27	1.34	1.12	0.02	0.00	20,048	693	2	20,744	8.14	71,300	196,694	1.43	62
July	0.50	0.53	0.34	0.00	0.00	6,124	0	0	6,124	10.70	92,675	110,142	0.80	35
Aug.	0.60	0.63	0.44	0.00	0.00	7,865	0	0	7,865	9.42	80,009	37,999	0.28	12
Sept.	0.80	0.84	0.64	0.00	0.00	11,437	0	0	11,437	5.90	49,287	149	0.00	0
Oct.	1.22	1.29	1.07	0.02	0.00	19,124	508	0	19,632	2.58	21,363	0	0.00	0
Nov.	2.02	2.13	2.01	0.79	0.60	35,973	22,839	2,400	61,212	0.92	7,618	53,595	0.39	17
Dec.	2.22	2.34	2.23	1.81	1.81	39,733	52,600	7,233	99,566	0.51	4,276	148,885	1.08	47
Jan.	2.05	2.16	2.05	1.64	1.64	36,537	47,593	6,544	90,673	0.61	5,227	234,331	1.70	74
Feb.	1.57	1.66	1.54	1.16	1.16	27,518	33,642	4,626	65,786	1.11	9,695	290,422	2.10	92
Mar.	**1.38**	**1.46**	**1.34**	**0.35**	**0.24**	**23,952**	**10,278**	**953**	**35,183**	**2.28**	**20,162**	**305,443**	**2.21**	**97**
Apr.	1.11	1.17	0.96	0.01	0.00	17,096	197	0	17,293	4.45	39,480	283,256	2.05	90
May	1.37	1.45	1.23	0.04	0.00	21,899	1,144	17	23,060	6.69	59,066	247,250	1.79	78
June	1.27	1.34	1.12	0.02	0.00	20,048	693	2	20,744	8.14	71,300	196,694	1.43	62
July	0.50	0.53	0.34	0.00	0.00	6,124	0	0	6,124	10.70	92,675	110,142	0.80	35
Aug.	0.60	0.63	0.44	0.00	0.00	7,865	0	0	7,865	9.42	80,009	37,999	0.28	12
Sept.	0.80	0.84	0.64	0.00	0.00	11,437	0	0	11,437	5.90	49,287	149	0.00	0

Resulting Pond Volume:	305,443 cu ft
Resulting Pond Depth:	2.21 ft
Factor of Safety to Depth:	2.66
Including 1' freeboard:	3.66 ft
Total Pond Capacity without freeboard:	316,363 cu ft

Figure 5D-1 – Evaporative Pond Spreadsheet Example (Alternate Method)

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APPENDIX 5E - HYDROLOGIC SOIL SERIES FOR WASHINGTON STATE

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Agnew	C	Dimal	D
Ahl	B	Dragoon	C
Aits	C	Dupont	D
Alderwood	C	Earlmont	C
Arents, Alderwood	B	Edgewick	C
Arents, Everett	B	Eld	B
Ashoe	B	Eloika	B
Athena	B	Elwell	B
Baldhill	B	Emdent	D
Barneston	C	Esquatzel	B
Baumgard	B	Everett	A
Beausite	B	Everson	D
Belfast	C	Freeman	C
Bellingham	D	Galvin	D
Bellingham variant	C	Garfield	C
Bernhill	B	Garrison	B
Boistfort	B	Getchell	A
Bong	A	Giles	B
Bonner	B	Glenrose	B
Bow	D	Godfrey	D
Brickel	C	Green Bluff	B
Bridgeson	D	Greenwater	A
Briscot	D	Grove	C
Buckley	C	Hagen	B
Bunker	B	Hardesty	B
Cagey	C	Harstine	C
Caldwell	C	Hartnit	C
Carlsborg	A	Hesseltine	B
Casey	D	Hoh	B
Cassolary	C	Hoko	C
Cathcart	B	Hoodsport	C
Cedonia	B	Hoogdal	C
Centralia	B	Hoypus	A
Chehalis	B	Huel	A
Cheney	B	Indianola	A
Chesaw	A	Jonas	B
Cinebar	B	Jumpe	B
Clallam	C	Kalaloch	C
Clayton	B	Kapowsin	C/D
Coastal beaches	variable	Katula	C
Cocolalla	D	Kilchis	C
Colter	C	Kitsap	C
Custer	D	Klaus	C
Custer, Drained	C	Klone	B
Dabob	C	Konner	D

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Dearyton	C	Lakesol	B
Delphi	D	Laketon	C
Dick	A	Lance	B
Larkin	B	Poulsbo	C
Latah	D	Prather	C
Lates	C	Puget	D
Lebam	B	Puyallup	B
Lummi	D	Queets	B
Lynnwood	A	Quilcene	C
Lystair	B	Ragnar	B
Mal	C	Rainier	C
Manley	B	Raught	B
Marble	A	Reardan	C
Mashel	B	Reed	D
Maytown	C	Reed, Drained or Protected	C
McKenna	D	Renton	D
McMurray	D	Republic	B
Melbourne	B	Riverwash	variable
Menzel	B	Rober	C
Mixed Alluvial	variable	Salal	C
Molson	B	Salkum	B
Mondovi	B	Sammamish	D
Moscow	C	San Juan	A
Mukilteo	C/D	Scamman	D
Naff	B	Schneider	B
Narcisse	C	Schumacher	B
Nargar	A	Seattle	D
National	B	Sekiu	D
Neilton	A	Semiahmoo	D
Newberg	B	Shalcar	D
Nez Perce	C	Shano	B
Nisqually	B	Shelton	C
Nooksack	C	Si	C
Norma	C/D	Sinclair	C
Ogarty	C	Skipopa	D
Olete	C	Skykomish	B
Olomount	C	Snahopish	B
Olympic	B	Snohomish	D
Orcas	D	Snow	B
Oridia	D	Solduc	B
Orting	D	Solleks	C
Oso	C	Spana	D
Ovall	C	Spanaway	A/B
Palouse	B	Speigle	B
Pastik	C	Spokane	C
Peone	D	Springdale	A
Pheeney	C	Sulsavar	B
Phelan	D	Sultan	C
Phoebe	B	Sultan variant	B
Pilchuck	C	Sumas	C
Potchub	C	Swantown	D
Tacoma	D	Vailton	B

Soil Type	Hydrologic Soil Group	Soil Type	Hydrologic Soil Group
Tanwax	D	Vassar	B
Tanwax, Drained	C	Verlot	C
Tealwhit	D	Wapato	D
Tekoa	C	Warden	B
Tenino	C	Wethey	C
Tisch	D	Whidbey	C
Tokul	C	Wilkeson	B
Townsend	C	Winston	A
Triton	D	Wolfeson	C
Tukwila	D	Woodinville	B
Tukey	C	Yelm	C
Uhlig	B	Zynbar	B
Urbana	C		

Notes:

Hydrologic Soil Group Classifications, as defined by the Soil Conservation Service:

A = (Low runoff potential) Soils having low runoff potential and high infiltration rates, even when thoroughly wetted. They consist chiefly of deep, well- to excessively drained sands or gravels, and have a high rate of water transmission (greater than 0.30 in/hr).

B = (Moderately low runoff potential) Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well- to well-drained soils, with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15–0.3 in/hr).

C = (Moderately high runoff potential) Soils having low infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine textures. These soils have a low rate of water transmission (0.05–0.15 in/hr).

D = (High runoff potential) Soils having high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential; soils with a permanent high water table; soils with a hardpan or clay layer at or near the surface; and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0–0.05 in/hr).

* = From SCS, TR-55, Second Edition, June 1986, Exhibit A-1. Revisions made from SCS, Soil Interpretation Record, Form #5, September 1988 and various county soil surveys.

This information can also be found online at: websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

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CHAPTER 6 – WATER QUALITY TREATMENT DESIGN

Chapter Organization

6.1 INTRODUCTION

Water quality treatment facilities are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead and zinc; nutrients such as nitrogen and phosphorus; certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and organic and inorganic decomposition. Floatable pollutants such as oil and debris can be removed with separator structures.

Many treatment facilities, if designed correctly, can function as both a water quality treatment facility and a flow control facility. This chapter describes design criteria for water quality treatment and Chapter 7 provides design criteria for flow control.

All engineering work for water quality treatment facilities shall be performed by, or under the direction of, a professional engineer currently licensed in the State of Washington.

6.2 PROTECTION OF AQUIFER WATER QUALITY

The Spokane Valley-Rathdrum Prairie aquifer extends across an area of about 325 square miles and provides drinking water for more than 500,000 people. Most of the developed areas in the Spokane region and in North Idaho lie directly over the aquifer. The aquifer is designated by the U.S. EPA as a “sole source aquifer” because it is the only feasible source of drinking water available to the local community. The following sections describe state and local measures adopted to protect the quality of water in the aquifer.

6.2.1 AQUIFER SENSITIVE AREA

Groundwater recharge areas have critical impacts on aquifers used for potable water, as defined by WAC 365-190-030 (2). The City of Spokane is subject to regulations governing the Aquifer Sensitive Area (ASA), delineated in Figure 6-1. Under these regulations, any project within the City of Spokane is required to provide treatment for all stormwater runoff from pollution generating impervious surfaces. In urban areas, bio-infiltration swales are the expected BMP for providing basic treatment.

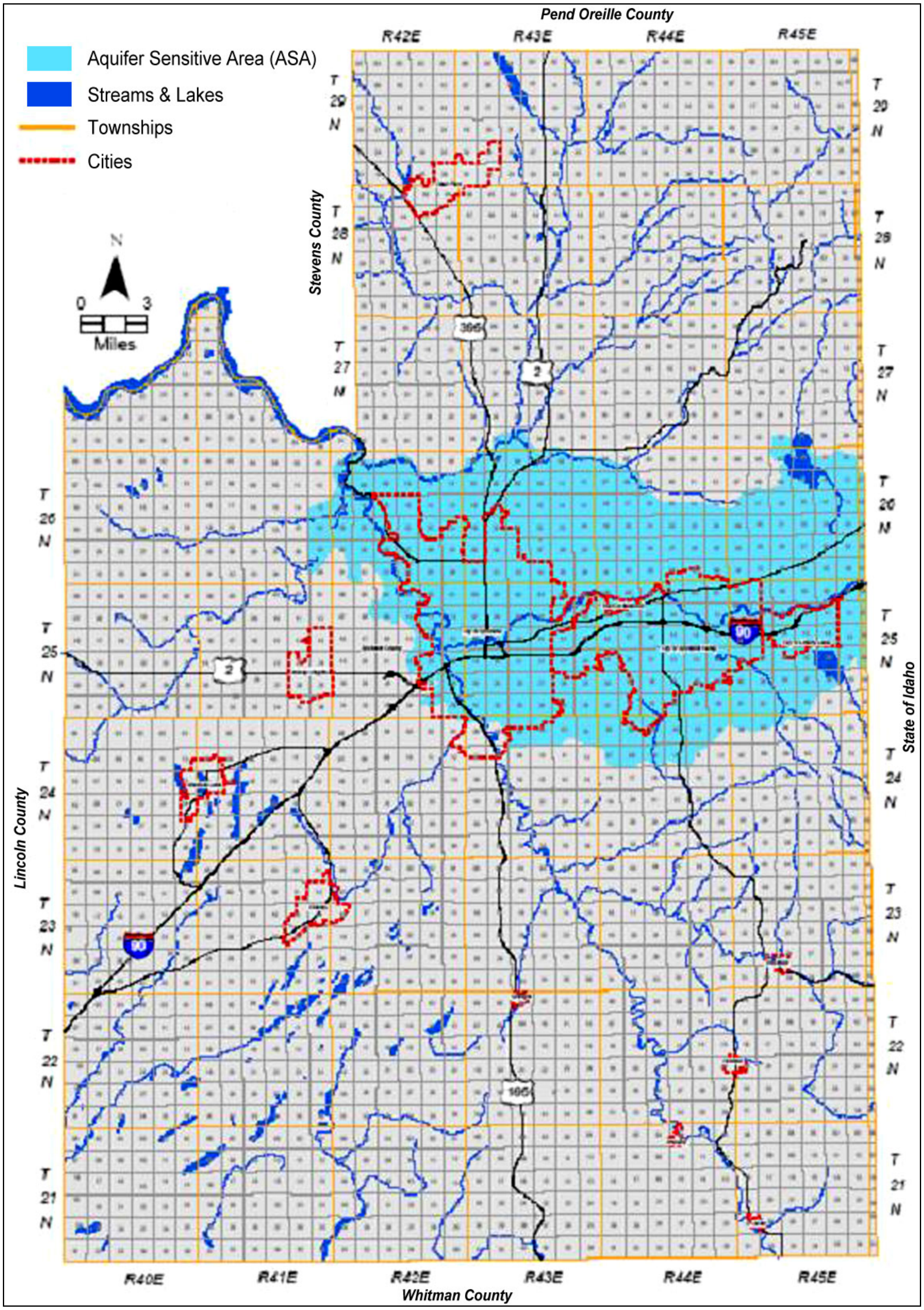


Figure 6-1 – Aquifer Sensitive Area (ASA)

6.2.2 CRITICAL AQUIFER RECHARGE AREAS

Spokane County and the City of Spokane Valley have designated the Critical Aquifer Recharge Areas (CARA) shown in Figure 6-2; this figure is also available on the Spokane County website:

- http://www.spokanecounty.org/BP/GISmaps/CARA/cara17.pdf

CARAs have prevailing geologic conditions associated with infiltration rates that create a high potential for contamination of groundwater resources, and they contribute significantly to the replenishment of groundwater.

The CARA resolution adopted by Spokane County requires that special consideration be given to stormwater runoff from areas with commercial and industrial development where chemical spills are more likely to occur. Specific potential problem areas include outdoor loading docks, fueling stations, and those activities involving toxic and hazardous materials handling.

For all land development in unincorporated areas of Spokane County and the City of Spokane Valley, the requirements of this regulation supersede those that govern the ASA. The incorporated areas of Spokane County, including the City of Spokane, are still subject to the requirements of the ASA. In addition, the entire Spokane region is subject to the Department of Ecology's Underground Injection Control (UIC) regulations (refer to Section 1.4.1).

Aquifer recharge areas are rated as having a high, moderate, or low susceptibility for contamination based on a scientific analysis of soils, hydraulic conductivity, annual rainfall, depth to the aquifer, vadose zone, and wellhead protection information. Wellhead protection areas approved by the Department of Health (DOH) and areas within a 1,000-foot radius of Group A and B wells without reported plans are treated as high susceptibility areas. Due to the numerous well-head capture zones found in Township 26 North, Range 43 East, and the difficulty associated with determining the exact "on-the-ground" locations of these protected zones on the CARA map, projects located within T26N, R43E are also subject to the requirements of high susceptibility areas (with the exception of the low susceptibility area located in the northeast corner of T26N, R43E).

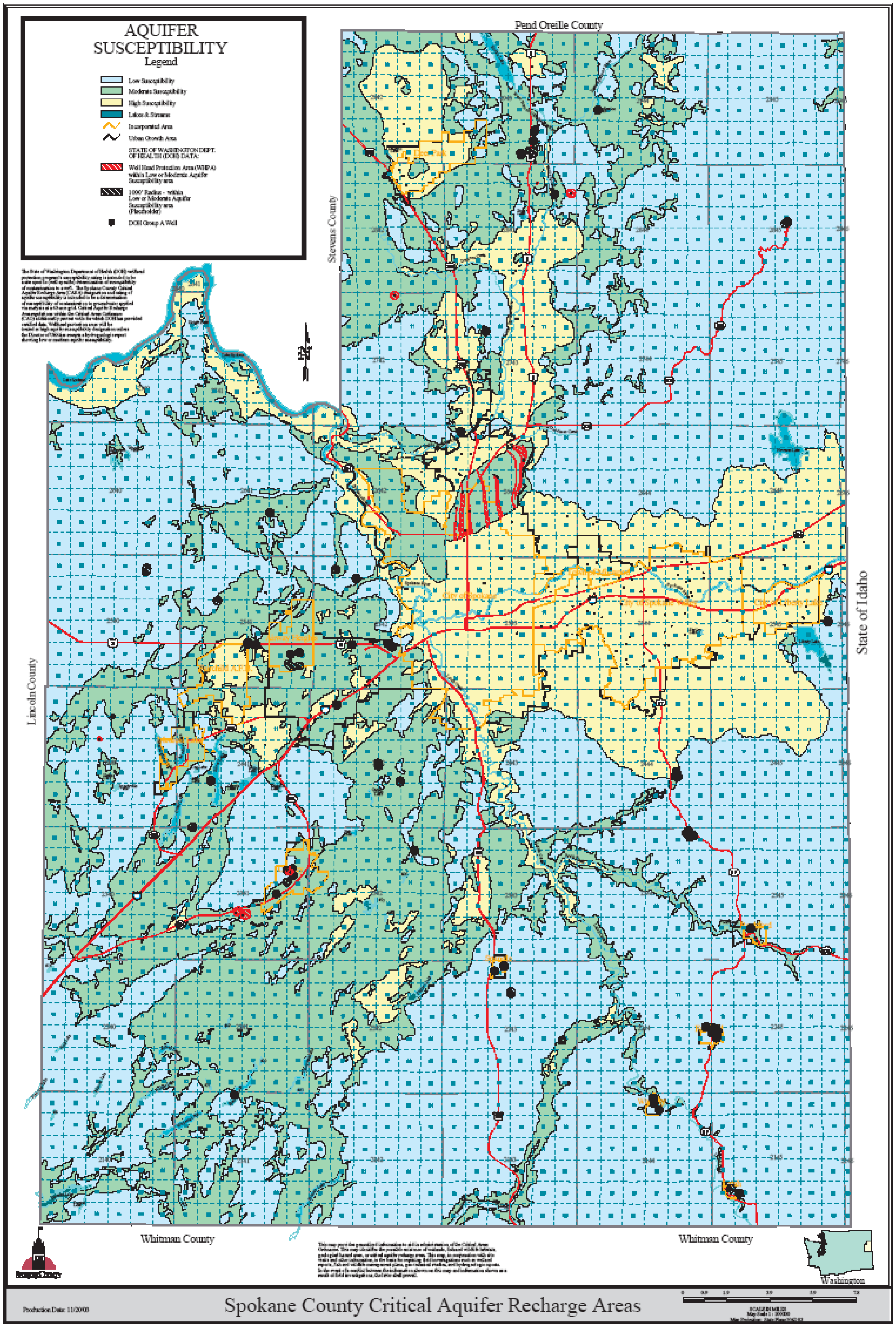


Figure 6-2 – Spokane County Critical Aquifer Recharge Areas

6.3 UIC FACILITIES

A UIC facility is a constructed subsurface infiltration system consisting of an assemblage of perforated pipes, drain tiles, or similar mechanisms intended to infiltrate fluids into the ground or a dug hole that is deeper than the largest surface dimension (WAC 173-218-030). Subsurface infiltration systems include drywells, pipe or French drains, drain fields, and similar devices that are designed to discharge stormwater directly into the ground. The following are not UIC facilities:

- Storm drain pipe systems that collect stormwater runoff and convey it to a disposal or treatment facility;
- Surface infiltration basins and flow dispersion stormwater infiltration facilities;
- Infiltration trenches designed without perforated pipe or a similar mechanism; or
- Storm drain components that contain perforated pipes, drain tiles, or other similar mechanism designed and intended to convey water directly or indirectly to a surface water body.

For discharge to UIC facilities, site BMPs must be chosen that will remove or reduce target pollutants to levels that comply with state groundwater quality standards when the discharge reaches the water table or first comes into contact with an aquifer (see WAC 173-200). Discharges to surface waters shall comply with WAC 173-201A, Water Quality Standards for Surface Waters of the State of Washington. Ecology's *Guidance for UIC Wells that Manage Stormwater* provides additional information.

6.3.1 LIMITATIONS ON THE USE OF UIC FACILITIES

Some water quality treatment BMPs presented in this chapter are not considered protective of groundwater for certain land uses. Because of the potential to contaminate groundwater, stormwater runoff shall not be discharged directly to UIC facilities from areas used for any of the following activities:

- Vehicle maintenance, repair and servicing;
- Commercial or fleet vehicle washing;
- Airport de-icing;
- Storage of treated lumber;
- Storage or handling of hazardous materials;
- Generation, storage, transfer, treatment or disposal of hazardous wastes;
- Handling of radioactive materials;
- Recycling (unless limited to glass products); and,

- Industrial or commercial areas without management plans for proper storage and spill prevention, control, and containment appropriate to the types of materials handled at the facility (refer to Ecology's *Stormwater Management Manual for Eastern Washington* for more information on stormwater pollution prevention plans and source control).

Stormwater runoff from these areas shall be handled on site with a closed-loop system or discharged to the sanitary sewer if allowed by the local jurisdiction. Stormwater from any portions of a site that do not contact the areas listed, such as roofs and parking areas, may be discharged to drywells, assuming that pre-treatment has been provided in accordance with the requirements presented in this chapter.

6.3.2 DRYWELL REGISTRATION

Drywells shall be registered with Ecology. The registration provides Ecology information to determine if a drywell is rule-authorized. Chapter 173-218 WAC lists the submittal requirements. Registration forms can be found on Ecology's UIC Program website.

A UIC facility may be rule-authorized when both of the following requirements are met:

- A registration form is submitted to Ecology; and,
- Discharge from the UIC facility does not contaminate groundwater.

Residential UIC facilities used for roof runoff or basement flood control automatically meet the non-endangerment standard and are considered rule-authorized; they are thus exempt from registering.

The project proponent should begin the registration process during the design phase and submit the completed paperwork prior to first use of the UIC facility.

6.4 POLLUTANT GENERATING IMPERVIOUS SURFACE AREAS

Pollutant generating impervious surface (PGIS) areas are significant sources of pollutants in stormwater runoff. These areas include surfaces subject to vehicular use, industrial activities, or storage of erodible or leachable materials that receive direct rainfall. A surface, whether paved or not, shall be considered a PGIS area if it is regularly used by motor vehicles. The following are considered PGIS areas: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, hydraulically connected sidewalks, parking lots, some roofs, fire lanes, vehicular equipment storage yards and airport runways.

Commercial roof runoff shall be pre-treated prior discharge to a UIC facility unless the project proponent, or his authorized agent, demonstrates that the runoff from the roof is not a waste fluid under WAC 173-218. Stormwater runoff is considered a waste fluid when discharged from the following:

- Metal roofs, unless coated with an inert, non-leachable material; or,
- Roofs subject to venting or manufacturing, commercial or other indoor pollutants (such as restaurants where oils or other solid particles are expelled due to cooking, processing, etc.); or,
- Asphalt-based roofs; or,
- Any roof area having electrical or mechanical equipment that is not hydraulically isolated from the remainder of the roof.

Some PGIS areas have additional requirements, as described in the following sections.

6.4.1 HIGH-USE SITES

High-use sites generate high concentrations of oil due to high traffic or the frequent transfer of petroleum products. High-use sites are land uses where sufficient quantities of free oil are likely to be present.

The following high-use sites require oil separator technology:

- A commercial or industrial site storing or transferring petroleum, not including locations where heating fuel is routinely delivered to end users;
- A commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more vehicles that are over 10 tons gross weight;
- Fueling stations and facilities;
- Maintenance and repair facilities for vehicles, aircraft, construction equipment, railroad equipment or industrial machinery and equipment;
- Railroad yards, and,
- High-density road intersections with expected ADT count equal to or greater than 25,000 on the main roadway and equal to or greater than 15,000 on any intersecting roadway.

For the above sites, oil separator technology is defined as removing the oil from the stormwater inflow in a step separate from any other pollutant removal via BMPs such as a coalescing plate or baffle-type oil control mechanism. This typically involves a “treatment train” of two BMPs in series in order to meet the treatment goals of pollutants other than oil.

The following high-use sites are subject to oil control, but are only required to employ sorptive technologies (such as swales) that physically or chemically bind the pollutants to sediment organic particles:

- A commercial or industrial site with an expected trip end count equal to or greater than 100 vehicles per 1,000 square feet of gross building area;
- A parking lot with an expected trip end count equal to or greater than 300 vehicles;
- Commercial on-street parking areas located on streets with an expected total ADT count equal or greater than 7,500; and,
- Outdoor storage yards and other sites subject to frequent use or storage of forklifts or other hydraulic equipment.

6.4.2 HIGH-ADT SITES

The following are high-ADT sites and require oil separator technology:

- Non-employee parking areas of commercial or industrial sites with trip end counts greater than 100 vehicles per 1,000 square feet gross building area or greater than 300 total trip ends, and,
- Any road or parking area with an expected ADT count equal to or greater than 30,000 (assumes a straight stretch of road, where intersecting ADTs are low).

For the above sites, oil separator technology is defined as removing the oil from the stormwater inflow in a step separate from any other pollutant removal via BMPs such as a coalescing plate or baffle-type oil control mechanism. This typically involves a “treatment train” of two BMPs in series in order to meet the treatment goals of pollutants other than oil.

6.4.3 MODERATE-USE SITES

Moderate-use sites are defined as moderate-ADT roadways and parking areas; primary access points for high-density residential apartments; most intersections controlled by traffic signals; and transit center stops. The following land uses are moderate-use sites:

- Urban roads with expected ADT between 7,500 and 30,000;
- Rural roads or freeways with expected ADT between 15,000 and 30,000; and,
- Parking areas with 40 to 100 trip ends per 1,000 square feet of gross building area, or between 100 and 300 trip ends.

6.5 TREATMENT GOALS

The goal for water quality treatment facilities is to treat approximately 90% of the annual runoff volume generated at a project site. Facilities that are designed according to the criteria set forth in this chapter should also capture and treat nearly all of the runoff from first flush events (heavy rainfall after a dry period). In urban areas, bio-infiltration swales are the expected BMP for providing basic treatment. The following subsections describe the key pollutants of concern.

6.5.1 TOTAL SUSPENDED SOLIDS (TSS)

Basic treatment facilities presented in this chapter are intended to achieve 80% removal of suspended solids, including solid components of metals, for flows with TSS concentrations ranging from 100 mg/L to 200 mg/L. The following BMPs have been found to provide a significant removal process for TSS:

- Bio-infiltration swales;
- Biofiltration channels;
- Vegetated buffer strips;
- Evaporation ponds.

6.5.2 TOTAL PETROLEUM HYDROCARBONS (TPH)

The oil control facilities presented in this chapter are intended to achieve the goal of removing any visible sheen and reducing the TPH concentration to a maximum of 10 mg/L for a 24-hour average and a maximum of 15 mg/L for a discrete sample. The following BMPs provide removal of TPH:

- Significant removal for high-use and high-ADT sites:
    - Bio-infiltration swales;
    - Oil/water separators (coalescing plate and baffle type);
    - Vegetated buffer strips (for High-ADT sites only); and,
    - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)
- Significant removal for all sites except high-ADT sites:
    - Oil/water separators (spill control type).
- Lesser removal (this BMP shall not be used for high-use or high-ADT sites unless preceded by an oil/water separator):
    - Biofiltration channels.

6.5.3 METALS TREATMENT

Metals treatment facilities presented in this chapter are intended to achieve approximately 50% removal of dissolved metals. The following BMPs have been found to provide removal for metals:

- Significant removal:
    - Bio-infiltration swales; and,
    - Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)
- Lesser removal (this BMP shall not be used for high-use or high-ADT sites without being preceded by another treatment BMP)
    - Biofiltration channels.

6.5.4 PHOSPHOROUS TREATMENT

The phosphorus treatment facilities are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations from 0.1 to 0.5 mg/L of total phosphorus. Bio-infiltration swales are the only BMP presented here that have been found to meet this removal goal for phosphorus. The following BMPs have been found to provide a lesser removal of phosphorus and shall only be used for phosphorus removal in combination with some other basic treatment BMP:

- Biofiltration channels;
- Vegetated buffer strips; and,
- Evaporation ponds designed using the Alternative Method (refer to Section 5.7.2)

6.6 APPLICABILITY

The exemptions listed in the sections below are superseded by requirements set forth in any applicable Total Maximum Daily Load (TMDL) or other water cleanup plan. At the time of the writing of this Manual, no TMDLs exist for water bodies in Spokane County. Contact the local jurisdiction for current information on whether any TMDLs have been issued.

6.6.1 BASIC TREATMENT

Applicability

Basic treatment provides removal of total suspended solids (TSS) and is required for all projects proposing UIC facilities that are:

- Located within the moderate or high susceptibility areas of the CARA;
- Located within Township 26 North Range 43 East (excluding the delineated low susceptibility areas isolated in the northeast corner of this Township and Range);
- Located within a 1,000-foot radius of Group A and Group B wells without reported plans;
- Located within a DOH-approved wellhead protection area;
- Proposing a moderate-use, high-use or high ADT site and located in the low or moderate susceptible areas of the CARA;
- Located within the ASA boundaries; or
- Located within the City of Spokane.

Basic treatment is also required for all projects:

- Meeting the regulatory threshold and discharging to waters of the state, including perennial and seasonal streams, lakes and wetlands;
- Requiring a 401 Water Quality Certification; or,
- Regulated to provide water quality treatment under other rules outside of Phase II jurisdictions.

Exemptions

Basic treatment is not required for:

- Non-pollutant generating impervious surface (NPGIS) areas unless the runoff from these areas is hydraulically connected to PGIS areas;
- Projects that discharge to the subsurface and are located within the low susceptibility areas of the CARA and are not proposing moderate-use, high-use, or high-ADT sites; or,
- Projects discharging non-waste fluids from roofs (WAC 173-218) directly to drywells.

6.6.2 OIL CONTROL

Applicability

All projects that meet the regulatory threshold and are high-use or high-ADT areas are required to provide oil control. High-use sites generate high concentrations of petroleum hydrocarbons due to high traffic turnover or the frequent transfer of oil and/or other petroleum products.

High-use sites and high-ADT roadways and parking areas shall treat runoff from the high-use portion of the site prior to discharge or infiltration. For high-use sites located within a larger project area, only the impervious area associated with the high-use site is subject to oil control treatment, as long as the flow from that area is separated; otherwise the treatment controls shall be sized for the entire area.

Refer to Section 6.7.4 for information used to determine the appropriate oil control technology.

Exemptions

Non-high-use sites and non-high ADT sites are exempt from oil treatment requirements.

6.6.3 METALS TREATMENT

Applicability

Metals treatment is required for all projects that are moderate- or high-use sites, and for sites that discharge to a surface water or UIC facility and meet any of the following definitions:

- Industrial sites as defined by the EPA (40 CFR 122.26(b)(14)) with benchmark monitoring requirements for metals;
- Industrial sites that handle, store, produce, or dispose of metallic products or other materials, particularly those containing arsenic, cadmium, chromium, copper, lead, mercury, nickel or zinc;
- High-use or high-ADT roadways or parking areas;
- Urban roads with expected ADT greater than 7,500;
- Rural roads or freeways with expected ADT greater than 15,000;
- Commercial or industrial sites with an equivalent trip end (ETE) count equal to or greater than 40 vehicles per 1,000 square feet of gross building area;

- Parking lots with 100 ETE or more;
- Public on-street parking areas in commercial and industrial zones;
- Highway rest areas;
- Runoff from metal roofs not coated with an inert, non-leachable material; or,
- Discharge to a surface water of the state that has been identified through a TMDL or other water clean-up plan as requiring metals removal.

Exemptions

Stormwater runoff is exempt from metals treatment requirements in the following situations, unless a specific water quality problem has been identified:

- Discharges to non-fish bearing streams;
- Subsurface discharges, unless identified as hydraulically connected to surface waters of the State. The Spokane Valley – Rathdrum Prairie Aquifer is hydraulically connected to a surface water of the state;
- Restricted residential and employee-only parking areas, unless subject to through traffic;
- Preservation/maintenance projects and some improvement or safety enhancement projects that do not increase motorized vehicular capacities; and,
- Discharges to some Category 4 wetlands; contact the Washington Department of Ecology for additional information.

6.6.4 PHOSPHORUS TREATMENT

Applicability

Phosphorus treatment is required where it has been determined by the federal, state, or local government that a water body is sensitive to phosphorus and that a reduction in phosphorus from new development and redevelopment is necessary to achieve the water quality standard to protect its beneficial uses. Where it is deemed necessary, a strategy will be adopted to achieve the reduction in phosphorus. The strategy will be based on knowledge of the sources of phosphorus and the effectiveness of the proposed methods of removing phosphorus. At the time of the writing of this manual, no TMDLs exist for any water body in Spokane County. Contact the local jurisdiction to determine if any have been issued that may affect a project design with regard to phosphorus treatment.

Phosphorus treatment may be required for water bodies reported under Section 305(b) of the Clean Water Act, and for those listed in Washington State's Nonpoint Source Assessment required under Section 319(a) of the Clean Water Act.

The Spokane River has been designated as not supporting beneficial uses due to phosphorus, and phosphorus treatment may be required.

Exemptions

Projects that do not propose to discharge to a water body sensitive to phosphorus are exempt from phosphorus treatment requirements.

6.7 TREATMENT BMPS

Infiltration-based swales and ponds, filtration-based vegetated buffer strips and channels, and evaporative ponds can all be effective in treating stormwater runoff. In most cases, soil properties must be appropriate to achieve effective treatment without adversely impacting groundwater resources. The location and depth to bedrock, water table, or impermeable layers, and the proximity to wells, foundations, septic system drain-fields, and unstable slopes can preclude the use of infiltration. If a lined treatment facility is proposed, the soil properties are less important, as the treatment is meant to occur via containment, plant uptake, and evaporation of the pollutants within the area of the facility that does not drain.

Oil/water separators (OWS) can be used to physically separate petroleum products from stormwater. An OWS does not, however, meet the other treatment goals set forth in this Manual, so it may have to be used in combination with another water quality treatment BMP, depending upon the expected pollutants.

This section provides design information and minimum requirements for all treatment BMPs identified in this Manual except evaporation ponds; evaporation ponds are addressed in Chapter 7. Inspection and maintenance standards for treatment BMPs and information about tracts and easements are found in Chapter 11. Selection, establishment and maintenance criteria for treatment facility vegetated cover are discussed in Chapter 7.

6.7.1 BIO-INFILTRATION SWALES

Bio-infiltration swales (formerly referred to as grassed percolation areas (GPAs) or '208' swales) combine plant material and soil to remove stormwater pollutants by both physical and chemical (ionic bonding, decomposition, plant root uptake, etc.) means via filtration and percolation into the ground. Bio-infiltration swales are sized to treat the volume equivalent of the 6-month NRCS Type II 24-hour water quality design storm. If the bio-infiltration facility is designed to function as a flow control facility as well as a water quality treatment facility, it shall also accommodate the flow control design storm event (refer to Section 2.2.4). If a bio-infiltration facility will also be used as a detention facility, refer to Section 7.3.2 for additional information.

Bio-Infiltration Swale Design

Bio-infiltration swales shall be sized using either Equation 6-1a or 6-1b. These equations estimate the volume required to treat stormwater runoff and were developed using the Alternate Hydrograph Method found in the *Stormwater Management Manual for Eastern Washington*.

$$V = 1133AP^{1.53} \qquad (6\text{-}1a)$$

$$V = 1815AP^{1.53} \qquad (6\text{-}1b)$$

Where: V = volume of bio-infiltration swale (cubic feet);

A = hydraulically connected impervious area to be treated (acres); and,

P = precipitation amount for the 6-month NRCS Type II 24 hour water quality design storm.

P shall be 1 inch for the all of the Spokane region, therefore the above equations can be simplified as follows:

$$V = 1133A \qquad (6\text{-}1c)$$

$$V = 1815A \qquad (6\text{-}1d)$$

Equations 6-1a and 6-1c can only be used when the following requirements are met, otherwise, Equations 6-1b and 6-1d shall be used:

- The subgrade soils have less than 12% fines; and,
- The subgrade soils have an infiltration rate greater than 0.15 in/hr.

Appendix 6A provides an example calculation for bioinfiltration swales.

Bio-Infiltration Swale Minimum Requirements

Bio-infiltration facilities shall meet the minimum requirements for limiting layers, setbacks, slopes, embankments, planting, and general requirements specified in Sections 7.5.2 and 7.8. In addition, the design of bio-infiltration swales shall conform to the requirements described below.

<u>Treatment Design Depth and Soil Criteria:</u> Bio-infiltration swales shall fully contain the design treatment volume with a maximum treatment design depth (from the swale

bottom to the elevation of the drywell grate or the first overflow or outflow mechanism) of 6 inches.

Organic matter content or cation exchange capacity (CEC) testing must be completed in order to substantiate the treatment soil composition. The tests shall be performed on composite samples taken from the treatment soil layer from the constructed pond bottom. A composite sample consists of well-mixed soil obtained from at least four cores, to a depth of at least 6 inches, randomly distributed over the pond bottom test area. A minimum of one test shall be performed for each bio-infiltration swale of 1,500 square feet or less, with one additional test for each additional 2,000 square feet of swale bottom or fraction thereof. “One test” is equal to four core samples taken uniformly over the percolation area. The soils will be considered suitable if the minimum criteria for CEC or soil organic matter content are met. Testing results shall be submitted as part of the construction certification process prior to the release of surety posted on project (contact the local jurisdiction for specific requirements).

Unless recommended otherwise by a geotechnical engineer, bio-infiltration swales shall be constructed with a treatment zone of medium- to well-draining soil (tested for infiltrative and treatment criteria) at least 12 inches thick, underlain by a subgrade infiltrative layer at least 48 inches thick. All soils, including amended native soils, shall meet the infiltrative rate criteria indicated in Table 6-1.

TABLE 6-1
BIO-INFILTRATION SWALE DESIGN CRITERIA

Criteria	**Design Requirement**
Treatment Zone Infiltration Rate (vegetated cover and treatment layer)[1]	Between 0.25 and 0.50 inches/hour
Subgrade Infiltration Rate[2,3]	At least 0.15 inches/hour and facility must completely drain within 72 hours
Average Cation Exchange Capacity	At least 15 milliequivalents/100 grams
Organic Matter Content	At least 2% by weight

[1] Sand and coarser soils are not suitable to be used as top soils when treatment is required.

[2] An infiltration test (for example, a single-ring infiltrometer test) demonstrating the facility’s conformance to the infiltration rate criteria may be required prior to construction certification.

[3] The 48-inch layer of infiltrative subgrade soils must meet the geotechnical recommendations as per the requirements found in Chapter 4.

Unless otherwise approved by the local jurisdiction, the treatment zone shall be planted with sod or dryland grass. Trees and large shrubs may be planted in the treatment zone provided they do not inhibit the growth of the grass. Contact the local jurisdiction for additional information. In all cases the plant materials shall meet the requirements of Section 7.8.9.

Inlets and Overflow: Curb inlets discharging into bio-infiltration swales shall be per the criteria specified in Chapter 8. A minimum separation of 3 inches shall be maintained between the flow line in the gutter (at the curb drop) or swale inlet and the top of the drywell grate. In addition, a 2-inch drop to the finish grade (of the swale side slope or swale bottom) below the concrete apron shall be provided to inhibit vegetation overgrowth and ensure positive flow into the swale.

A bypass or overflow structure to a flow control facility must be provided unless the treatment facility is able to accommodate the flow control design storm event as well as the water quality design storm event. Swales shall not be designed to overflow to a street unless approved by the local jurisdiction.

Construction and Inspection: In order to reduce the potential for over-compaction of the swale bottom, construction equipment and vehicles shall be kept off the treatment facility. Unless waived by the local jurisdiction, an infiltration test (for example, a single-ring infiltrometer test) demonstrating the facility’s conformance to the infiltrative rate criteria is required prior to construction certification. The treatment facility must have vegetation established prior to passing final inspection. In addition, if during final inspection, it is found that the constructed bio-infiltration swale does not conform to the accepted design, the system shall be reconstructed so that it does comply.

6.7.2 BIOFILTRATION CHANNELS

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration channel is a sloped, vegetated channel or ditch that both conveys and treats stormwater runoff. It does not provide flow control but can convey runoff to facilities designed for that purpose.

Biofiltration Channel Design

The following procedure shall be followed when designing biofiltration channels:

1. Determine the peak flow rate using the 6-month NRCS Type II 24-hour storm. The methods for calculating peak flow rates are found in Chapter 5. The 6-month precipitation is equal to (0.69)(2-year precipitation);

2. Determine the bottom width of the ditch using equation 6-2 or 6-3.

$$Q = \frac{1.486 A R^{2/3} S^{1/2}}{n} \tag{6-2}$$

Where: Q = flow (cfs);

A = cross-sectional area (square feet);

R = hydraulic radius (feet); and,

S = longitudinal slope of strip (feet/foot); slope criteria are given in the minimum geometry requirements in the following subsection; and,

n = Manning's roughness coefficient; Use n = 0.30 for sod (or channels that will be mowed regularly) and higher values such as n = 0.20 for natural (less dense) vegetation such as meadow or pasture.

For a trapezoidal channel with shallow flow, the hydraulic radius can be approximated to the depth of flow. Using this assumption, the following can be used to solve for the required width:

$$B = \frac{\left(\frac{n}{1.486}\right) Q}{y^{5/3} S^{1/2}} - Zy \tag{6-3}$$

Where: B = bottom width of the strip (feet);

n = Manning's roughness coefficient

y = depth of flow (feet); (3 inches maximum for dryland grass and 4 inches maximum for sod);

S = longitudinal slope of strip (feet/foot); slope criteria are given in the minimum geometry requirements in the following subsection;

Z = side slope of the strip in the form Z:1; and,

Q = flow (cfs).

3. Calculate the cross-sectional area of flow for the given channel;

4. Calculate the flow velocity. If the velocity is less than 1 foot/second, proceed to Step 5. Otherwise, change the channel dimensions and/or slope and return to Step 3; and,

5. Calculate the length of the channel and verify that the residence time is at least 9 minutes. The minimum channel length is 200 feet unless the width is increased per the minimum geometry requirements in the following subsection.

Commercially available software is most commonly used to compute many of the parameters associated with the sizing of a biofiltration channel. Appendix 6B provides an example calculation for biofiltration channels.

Biofiltration Channel Minimum Requirements

Biofiltration channels shall meet the minimum requirements found in Section 7.8, as well as the following geometry requirements:

- The biofiltration channel shall have a length of 200 feet. If a length of 200 feet is not possible, the width of the biofiltration channel must be increased so that the treatment area is the same as or more than it would be if a 200 foot length had been used. The length shall not be reduced such that the minimum residence time and/or maximum flow depth criteria are violated. The length shall in no case be less than 100 feet.
- The maximum bottom width is 10 feet and the minimum width is 1 foot. If the calculated bottom width exceeds 10 feet, parallel biofiltration channels shall be used in conjunction with a device that splits the flow and directs an equal amount to each channel.
- The ideal cross-section is a trapezoid with side slopes no steeper than 3:1. However, a rectangular shape can be proposed if there are topographical constraints or other construction concerns.
- Typically, the depth of flow shall not exceed 4 inches during the design storm. The depth of flow is 4 inches for sod and 3 inches for dryland grasses.
- The channel slope shall be at least 1% and no greater than 5%. Slopes of 2% to 4% provide the best performance. When slopes less than 2% are used, an under-drain is required. A 6-inch-diameter perforated pipe shall be installed in a trench lined with filter fabric and filled with 5/8-inch-minus round rocks. The pipe shall be placed at least 12 inches below the biofiltration channel bed and the bed shall incorporate topsoil that has a proportionately high sand content.
- The flow velocity shall not exceed 1 foot/second and the design shall provide for a 9 minute residence time.

6.7.3 VEGETATED BUFFER STRIPS

A vegetated buffer strip is a facility that is designed to provide stormwater quality treatment of conventional pollutants, but generally does not provide stormwater flow control.

Vegetated buffer strips are primarily used in rural areas adjacent to and parallel to paved areas such as parking lots or driveways, and along rural roadways where sheet flow from the paved area will pass through the buffer strip before entering a conveyance system or a flow control facility or being dispersed into areas where it can be infiltrated or evaporated.

Vegetated buffer strips are used to intercept overland sheet flow runoff from adjacent impervious areas. They slow runoff velocities, filter out sediment and other pollutants, and provide infiltration into underlying soils. One challenge associated with vegetated buffer strips is the difficulty in maintaining sheet flow. Concentrated flows can short circuit the buffer strips which can then contribute to eroded rills or flow channels across the strips. This results in little or no treatment of stormwater runoff.

This BMP is acceptable for use on any rural project that meets the following general criteria:

- The flow from the roadway must enter the buffer strip as sheet flow. Thus, the vegetated buffer strips must not receive concentrated flow discharges.
- A maximum flow path (paved width) of 30 feet can contribute to a buffer strip designed via this method (vegetated buffer strips should typically not be proposed for super-elevated roads, unless the 30 foot width is adhered to);
- Buffer strips may be used where the roadway ADT is less than 30,000;
- The longitudinal slope of the contributing impervious drainage area (parallel to the edge of the buffer area) shall be 5% or less;
- The lateral slope of the contributing drainage area perpendicular to the pavement edge (typically referred to as the cross-slope of the road)shall be 2% or less.

Vegetated buffer strips shall be constructed after other portions of the project are completed.

Vegetated Buffer Strip Design

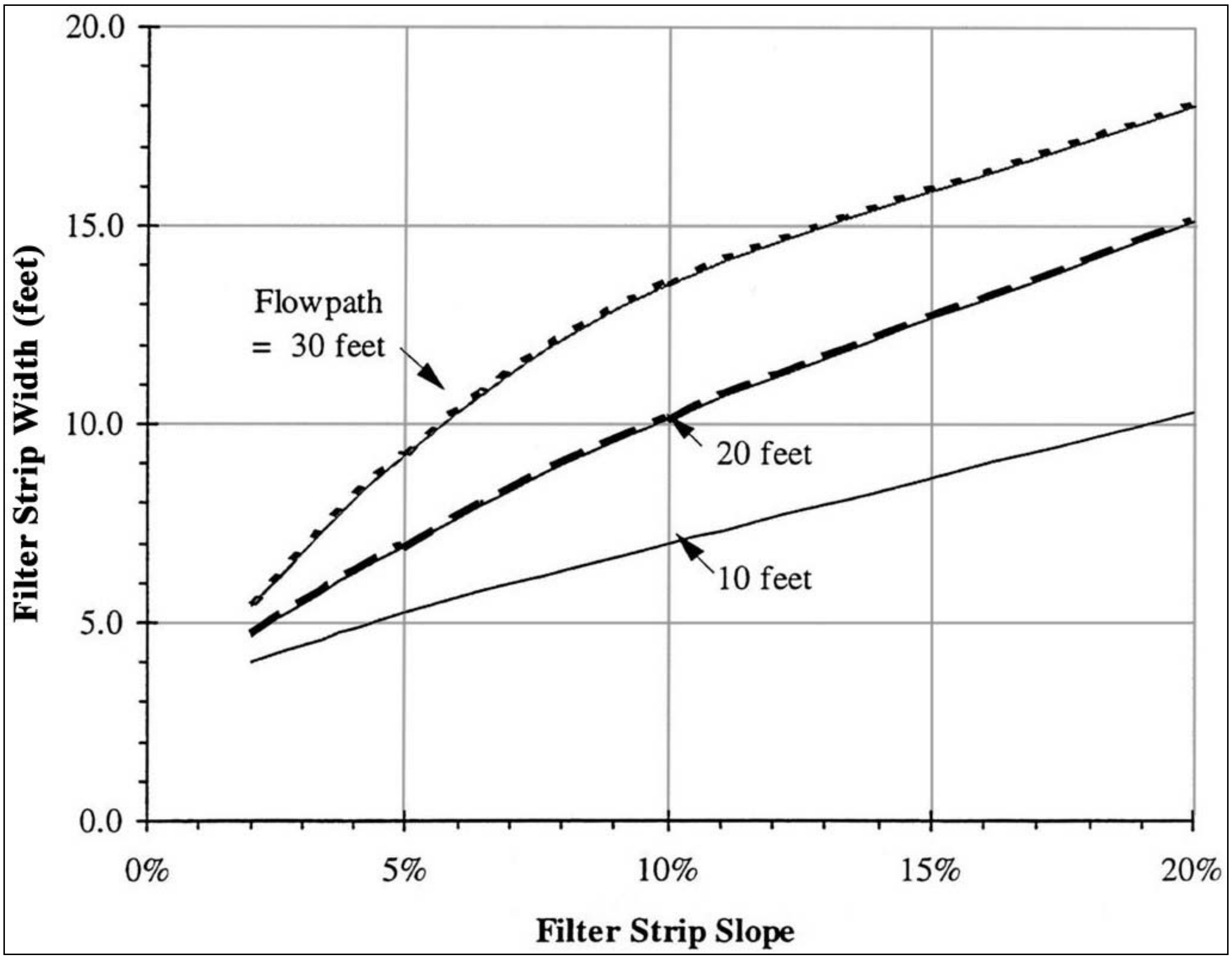
This procedure is based on the narrow area filter strips presented in the 1998 *King County Surface Water Design Manual*. The sizing of the buffer strip is based on the length of the flow path draining to the buffer strip and the longitudinal slope of the buffer strip itself (parallel to the flow path). The following design steps shall be followed:

1. Determine the flow path length draining to the buffer strip. Normally this is the width of the paved area draining to the strip, but if the site is sloped, the flow path may be longer. For crowned roads, the flow path is the distance from the crown to the edge of pavement;

2. Determine the average lateral or cross slope of the buffer strip: Calculate the cross slope of the buffer strip (parallel to the flow path), averaged over the total width of the buffer strip. If the slope is less than 2%, use 2% for sizing purposes. The maximum cross slope allowed is 6:1 horizontal to vertical or 17%; and,

3. Determine the required width of the buffer strip: Use Figure 6-3 to size the buffer strip. To use the figure, find the curve representing the appropriate width of the flow path (interpolate between curves as necessary). Find the point along the curve where the design longitudinal or cross slope of the buffer strip is directly below and read the buffer strip width to the left on the y-axis. The buffer strip must be designed to provide this minimum width (W) along the entire stretch of pavement draining to it.

Appendix 6C provides an example calculation for vegetated buffer strips.



Source: King County Surface Water Design Manual, 1998.

Figure 6-3 – Vegetated Buffer Strip

Vegetated Buffer Strip Minimum Requirements

Vegetated buffer strips shall meet the minimum requirements for planting, and general requirements specified in Sections 7.5.2 and 7.8. In addition, the design of buffer strips shall conform to the following requirements (see Figure 6-4):

- Geometry:
    - The minimum required buffer strip width is: 4 feet for a 10-foot flow path; 4.5 feet for a 25 foot flow path; and 5.5 feet for a 30-foot flow path. Flow path is the width of the paved surface discharging to the buffer strip.
    - The cross-slope of the buffer strip shall be no steeper than 6:1.
    - Along roadways, buffer strips shall be placed at least 1 foot, and preferably 3 to 4 feet, from the edge of pavement, to accommodate a vegetation free zone.
- Energy Dissipation:
    - A gravel-filled trench shall be installed between the pavement surface and the buffer strip to maintain sheet flow. This area serves as a flow spreader and shall consist of a trench filled with crushed aggregate (WSDOT Crushed Aggregate Base Course or WSDOT Crushed Aggregate Top Course).
    - The gravel filled trench shall be a minimum of 12 inches deep and 18 inches wide.

6.7.4 OIL/WATER SEPARATORS

Three types of OWS are included in this Manual:

- Coalescing plate types (gravity mechanism for separation),
- Baffle types,
- Spill control separators, such as T's or elbows located inside a catch basin.

OWSs are only effective in achieving oil and TPH removal at the required levels when regular maintenance is provided. Without proper sludge, oil and sediment removal, there is a high potential for clogging which can impair the long-term efficiency of the separator.

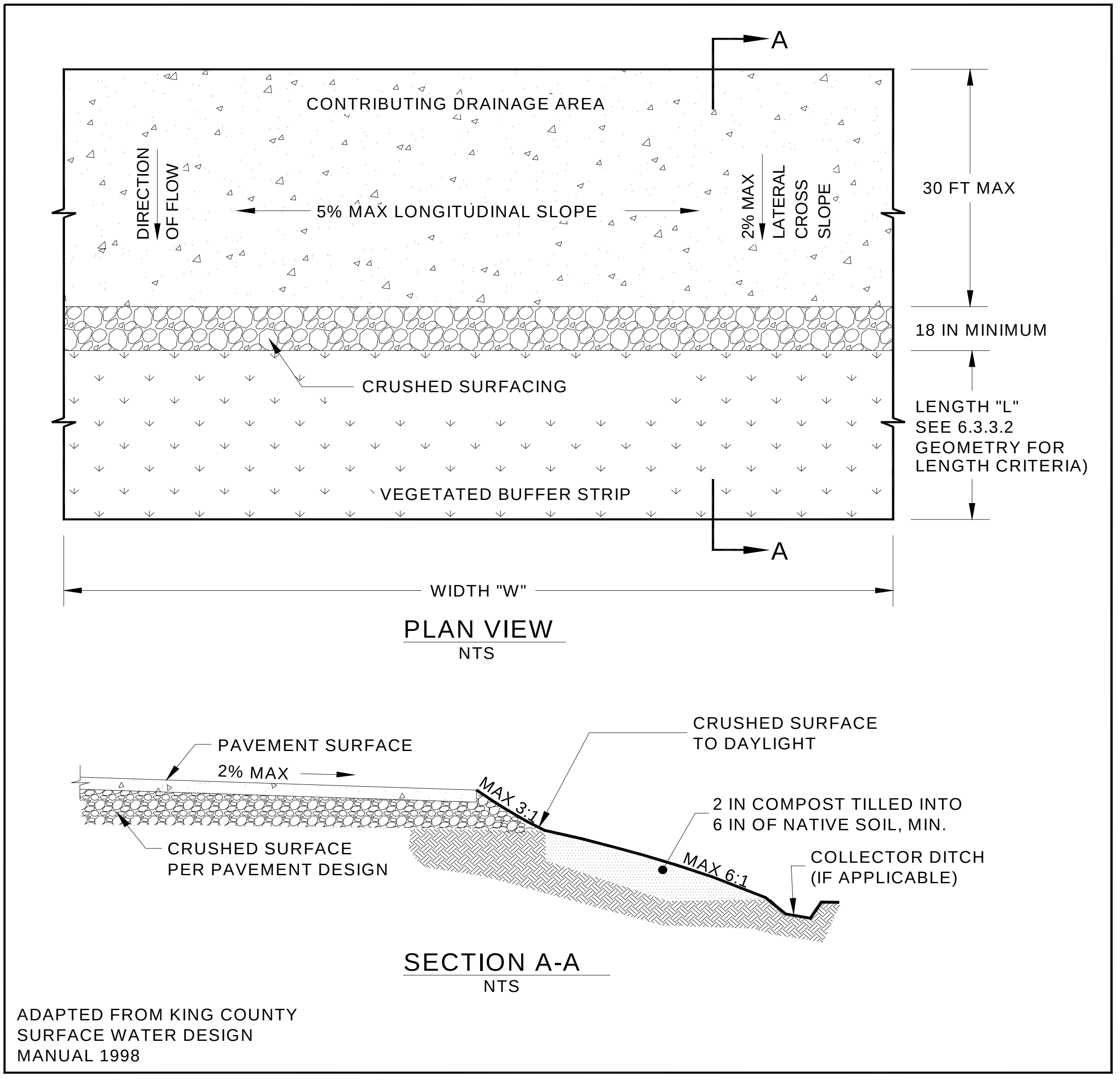


Figure 6-4 – Typical Vegetated Buffer Strip (details)

Oil/Water Separator Design

Detailed design information for coalescing plate and baffle type OWS can be found in Section 5.10.7 of the *Stormwater Management Manual for Eastern Washington*. Design information for spill control separators is presented in the minimum requirements subsection below.

Oil/Water Separator Minimum Requirements

The following design criteria are applicable to all types of oil control BMPS:

- Only impervious conveyances shall be used for oil-contaminated stormwater; and,
- Oil/water separators shall not be used for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.

The following are design criteria applicable to spill control separators:

- “T” or elbow separators in a catch basin are not allowed as an oil control device for high-ADT sites unless used in series with another water quality treatment facility;
- Oil control shall occur prior to dispersal into or through a water quality treatment facility;
- If an oil/water separator is applicable, it shall comply with the local jurisdiction’s standard plan.

The following design criteria are applicable to both coalescing plate and baffle type oil/water separators:

- If practical, determine expected oil/grease (or TPH) and TSS concentrations, lowest temperature, pH, empirical oil rise rates in the runoff, oil viscosity and specific gravity of the oil;
- Locate the separator off-line and bypass flows in excess of the water quality design flow rate;
- Follow industry standards such that the separator has a forebay, separator section, and afterbay;
- Design the surface area of the forebay at 20 square feet per 10,000 square feet of area draining to the separator;
- The length of the forebay shall be one-third to one-half the length of the entire separator;
- Include roughing screens for the forebay to remove debris (screen openings should be about ¾ inch);
- Include a submerged inlet pipe with a turned-down elbow in the forebay at least two feet from the bottom; the outlet pipe shall be a “T” sized to pass the design peak flow and placed at least 12 inches below the water surface;
- Size the separator bay for the water quality design flow rate;
- Include a shutoff mechanism at the separator outlet pipe; and,
- Use absorbents and/or skimmers in the afterbay as needed.

The following are additional design criteria applicable to baffle type oil/water separators:

- Oil retaining baffles (top baffles) shall be located at least a quarter of the total separator length from the outlet and shall extend down at least 50% of the water height and at least 1 foot from the separator bottom; and,
- Baffle height to water depth ratios shall be 0.85 for top baffles and 0.15 for bottom baffles.

6.7.5 WETLANDS

Some wetlands can be considered for use in stormwater treatment, if approved by Ecology. The following criteria are applicable for wetlands that discharge to surface waters of the State, which are generally defined as wetlands with a defined outlet.

Typically, a wetland must meet one of the following criteria in order to be considered for use as a stormwater treatment facility:

- It is a Category 4 wetland according to the Eastern Washington Wetland Rating System; or,
- It is a Category 3 wetland according to the Eastern Washington Wetland Rating System and the wetland has been previously disturbed by human activity such as agriculture, fill areas, ditches or the wetland is dominated by introduced or invasive weedy plant species as identified in the rating analysis.

In addition, the wetland must meet the criteria for hydrologic modification of a wetland. Hydrologic modification of a wetland for the purpose of stormwater management means that the wetland will receive a greater total volume of surface runoff following development than it receives in the current condition. A Category 3 or 4 wetland can only be considered for hydrologic modification if both of the following are demonstrated:

- There is good evidence that the natural hydrologic regime of the wetland can be restored by augmenting its water supply with excess stormwater runoff; or the wetland is under imminent threat exclusive of stormwater management and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership; and,
- The runoff is from the same natural drainage basin; the wetland lies in the natural routing of the runoff; and the site plan allows runoff discharge at the natural location. Exceptions may be made for regional facilities planned by a local jurisdiction, but the wetland should receive water from sites in the same watershed.

Hydrologic modification is not allowed for wetlands classified as Category 1 or 2 under the Eastern Washington Wetland Rating System unless the project proponent demonstrates to Ecology that the stormwater disposal methods outlined in this Manual are not possible at the site, and that other options would result in more damage to the wetland by limiting base flow.

Basic treatment (TSS removal) is not required prior to discharge to a Category 4 wetland, but it is required prior to discharge to a Category 3 wetland. A Category 3 wetland that meets the above requirements may be used to meet metals treatment requirements. Oil control is required for all high-use sites discharging to a wetland. Contact Ecology for specific treatment requirements with regard to any other wetland category or pollutant of concern.

Mitigation is usually required for the impact of hydrologic modification on a wetland. Appropriate measures include expansion, enhancement and/or preservation of a buffer around the wetland.

For wetlands that are isolated (i.e. are not hydraulically connected to a surface water of the State via an outlet from the wetland), the project proponent shall contact Ecology for further information with regard to using such a wetland for stormwater management.

6.8 EMERGING TECHNOLOGIES

Emerging technologies are new technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal.

6.8.1 BACKGROUND

During recent years, new technologies have been under development to meet the needs of urban stormwater pollutant control. However, because no standardized statewide procedure for evaluating these technologies was available, local jurisdictions and commercial entities have had to decide individually as to the appropriateness of their use. This has resulted in a wide range of differences in the criteria for accepting new technologies.

Some emerging technologies have already been installed in Washington state as parts of treatment trains or as stand-alone systems for specific applications. In some instances, emerging technologies can be used for retrofits and/or where land is unavailable for larger treatment systems.

6.8.2 ECOLOGY'S ROLE IN EVALUATING EMERGING TECHNOLOGIES

Ecology has developed a new technology evaluation program, which is described briefly in this section. The program is based on reviewing engineering reports on the performance of new technologies and reporting the results at Ecology's website. The program includes:

- A Technical Review Committee (TRC) including representatives from local governments in eastern and western Washington that acts in an advisory capacity to provide recommendations to Ecology on the level of development of each technology.
- A website with brief descriptions of each new technology, TRC recommendations, and Ecology's determinations of the levels of development of each technology. Ecology's main website address can be accessed at http://www.ecy.wa.gov/.

6.8.3 LOCAL JURISDICTION'S ROLE IN EVALUATING EMERGING TECHNOLOGIES

Local jurisdictions reserve the right to deny the use of any emerging technology even if it has been approved by Ecology. Local jurisdictions shall consider the following as they make decisions regarding the use of new stormwater technologies in their jurisdictions:

- <u>Remember the goal:</u> The goal of any stormwater management program or BMP is to treat and release stormwater in a manner that does not harm beneficial uses. Compliance with other water quality standards is one measure of determining whether beneficial uses will be harmed. Emerging technologies proposed for use in the Spokane area shall be compatible with use over a sole-source aquifer.
- <u>Exercise reasonable caution:</u> An emerging technology shall not be considered for use for new development sites unless there are strong supporting data indicating that its performance is expected to be reasonably equivalent to the BMPs already approved by Ecology. Local jurisdictions can refer to Ecology's website to obtain the latest performance verification of an emerging technology.
- <u>Conduct a monitoring program:</u> Identify an acceptable monitoring protocol to apply to those emerging technologies that have not yet been verified for limited or full-scale use at Ecology's website.
- <u>Review Treatment Goals:</u> Refer to Section 6.5 for acceptable performance objectives.

- Maintenance: Some emerging technologies may not be approved for use in public roads due to maintenance concerns. Use of emerging technologies in private roads and tracts may require the formation of a Homeowners' Association to provide perpetual maintenance of the drainage facilities. Contact the local jurisdiction for additional information.

To achieve the goals of the Clean Water Act and the Endangered Species Act, local jurisdictions may find it necessary to retrofit existing stormwater systems. In these situations, the use of any BMPs that make substantial progress toward these goals is a step forward and is encouraged by Ecology.

6.8.4 TESTING PROTOCOL

To properly evaluate new technologies, performance data must be obtained using an industry accepted protocol. A test protocol has been developed which serves to standardize the test conditions. Sampling criteria, site and technology information, QA/QC, target pollutants, and evaluation report content are specified in the protocol.

6.8.5 ASSESSING LEVELS OF DEVELOPMENT OF EMERGING TECHNOLOGIES

Ecology has received several submittals from vendors to approve their technologies for statewide applications. Moreover, it is evident that some technologies have been under development for many years and have improved considerably during that time.

To assess and classify levels of developments, Ecology is proposing to use the criteria below. These criteria can also be found on Ecology's website. Emerging technologies shall be used only within the application criteria and performance limits listed at Ecology's website.

Pilot Use Level Designation: For emerging technologies with limited performance data, the pilot use level designation (PULD) allows limited use to enable field testing. PULDs may be given based solely on laboratory performance data. Ecology will limit the number of installations to five during the pilot use level period.

Local governments may allow PULD technologies to be installed provided the proponent agree(s) to conduct additional field testing based on the TAPE at all installations to obtain a general use level designation (GULD). Proponents must conduct field testing at a minimum of one site in the Pacific Northwest to obtain a GULD.

Local governments covered by a municipal stormwater NPDES permit must notify Ecology in writing when a PULD technology is proposed. Ecology encourages other jurisdictions to notify Ecology headquarters when a PULD technology is proposed. Ecology also encourages all local governments to require proponents to provide a performance guarantee stating that PULD facilities will be upgraded as necessary, to the maximum extent practical, to meet Ecology performance goals.

General Use Level Designation: The general use level designation (GULD) confers a general acceptance for treatment device. Technologies with a GULD may be used anywhere in Washington, subject to Ecology conditions. Ecology plans to include GULD technologies in future stormwater manual updates.

Conditional Use Level Designation: The TRC established the conditional use level designation (CULD) for emerging technologies that have a considerable amount of performance data but the data were not collected per the TAPE protocol. The TRC may recommend a CULD based on field data collected by a protocol that is reasonably consistent but does not necessarily fully meet the TAPE protocol. The field data must meet the statistical goals set out in the TAPE guidelines (Appendix D). Laboratory data may be used to supplement field data. Conditional use level designations apply for a specified time period only. During this time period, the vendor must complete all field testing and submit a TER to Ecology and the TRC. Proponents must complete field testing at a minimum of one site in the Pacific Northwest to obtain a general use level designation.

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APPENDIX 6A – EXAMPLE CALCULATION: BIO-INFILTRATION SWALE

GIVEN

- The existing site is approximately 5 acres, consisting of sandy soils. Existing surface vegetative conditions include short grass and weeds.
- The subgrade soil has 10% fines and an infiltration rate of 0.10 inches per hour.
- Post developed site conditions consist of:
  - 20 – 10,000-square foot lots
  - 1,500-square-foot homes with 500-square-foot driveways
  - 0.50 acres of road impervious areas

CALCULATIONS

1. Determine the total PGIS for the site.

   Road PGIS: (0.50 acres)(43,560 square feet/acre) = 21,780 square feet

   Driveway PGIS: (500 square feet)(20 driveways) = 10,000 square feet

   Total PGIS: 10,000 square feet + 21,780 square feet = **31,780 square feet**

   = 0.73 acres

2. Determine the required treatment volume, using Equation 6-1.

   $$V = 1815A \qquad \text{(Equation 6-1d)}$$

   $$V = (1815)(0.73) = 1{,}325 \text{ cubic feet}$$

3. Determine the geometry of the bio-infiltration facility

   Use a treatment depth of 6 inches

   Pond Bottom Area Required* = $\frac{1{,}325 \cdot cf}{6 \cdot in} * \frac{12 \cdot in}{1 ft} = 2{,}648 \cdot sq.ft.$

   * For this example, there are no space constraints and side slope volume has been ignored.

Provide an infiltrative facility with a 2,650 square foot pond bottom area

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APPENDIX 6B – EXAMPLE CALCULATION: BIOFILTRATION CHANNEL

GIVEN

- Weighted pervious CN = 67
- Pervious area = 4.25 acres
- Impervious CN = 98
- Impervious area = 0.75 acres
- PGIS = 31,720 square feet
- 2-year, 24 hour storm precipitation = 1.2 inches
- Time of concentration = 6 minutes
- n = 0.2

CALCULATIONS

1. Determine the peak flow rate using the 6-month NRCS Type II 24-hour storm and the methods described in Chapter 5.

   6-month precipitation = (0.69)(2-year precipitation)

   = (0.69)(1.2 inches) = 0.83 inches

   Using a computer program, the peak flow rate is estimated to be 0.70 cfs.

2. Determine the bottom width of the ditch using Equation 6-3.

   Assume: A trapezoidal channel with 3:1 side slopes;

   3 inches for flow depth; and,

   3% longitudinal slope for biofiltration channel.

$$B = \frac{\left(\frac{n}{1.486}\right)Q}{y^{5/3}S^{1/2}} - Zy$$

$$B = \left[\frac{\left(\frac{0.2}{1.486}\right)(0.70cfs)}{\left(\frac{3in}{12\,{}^{in}\!/\!_{ft}}\right)^{5/3}\left(0.03\frac{ft}{ft}\right)^{1/2}} \right] - \left[(3)\left(\frac{3in}{12\,{}^{in}\!/\!_{ft}}\right) \right] = 4.75\,ft$$

3. Calculate the cross-sectional area of flow for the given channel and verify that the flow velocity is less than or equal to 1 foot/second;

$$\text{Area = y (B+ Zy) = } \left(\frac{3 \cdot in}{12\,{}^{in}\!/\!_{ft}}\right)\left(4.75 \cdot\ ft + 3 \cdot\ ft\left(\frac{3 \cdot in}{12\,{}^{in}\!/\!_{ft}}\right)\right) = 1.4 \cdot sq.ft.$$

$$\text{Velocity = } \frac{Q}{A} = \frac{0.70 \cdot cfs}{1.4 \cdot sq.ft} = 0.5 \cdot\ ft/\sec \leq 1$$ **OK**

4. Calculate the length of the channel to meet the 9 minute residence time. The minimum channel length is 200 feet unless the width is increased as described in the minimum requirements in Section 6.7.2.

$$L = (V)(t) = (0.50\ {}^{ft}\!/\!_{\sec})(9\min)(\frac{60 \cdot \sec}{1\min}) = 270\,ft$$

If the site cannot accommodate the required channel length, the width can be increased. Steps 3 and 4 should be repeated until the channel geometry best fits the existing site conditions.

The proposed channel geometry design is as follows:

- Trapezoidal shape with 3:1 side slopes
- 3% longitudinal slope
- Channel bottom width is 4.75 feet
- Minimum channel length is 270 feet

APPENDIX 6C – EXAMPLE CALCULATION: VEGETATED BUFFER STRIP

GIVEN

- A typical crowned road with a 30-foot-wide half road
- Average lateral road cross slope = 2%
- Average longitudinal slope = 4%
- The land adjacent to the road (where the buffer strip will be located) slopes away at an average slope = 5%

CALCULATIONS

1. Determine the flow path length draining to the buffer strip.

   Flow path is 30 feet

2. Determine the average lateral or cross slope of the buffer strip:

   Calculate the cross slope of the buffer strip (parallel to the flow path), averaged over the total width of the buffer strip.

   Use 5%

3. Determine required width of the buffer strip using Figure 6-3 to size the buffer strip.

   From Figure 6-3: buffer strip width = 9 feet

   9 feet > 5.5 feet (the minimum width for buffer strips with a 30-foot flow path) **OK**

   Provide an 18-inch-wide, 1-foot-deep gravel filled trench

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CHAPTER 7 – FLOW CONTROL

Chapter Organization

7.1 INTRODUCTION

This chapter outlines the minimum requirements for sizing flow control facilities. Standard flow control facilities are detention/retention ponds, drywells, and evaporation ponds. Any other facility is considered a non-standard system, and shall be evaluated individually by the local jurisdiction. Flow control facilities are necessary to mitigate potential adverse impacts on down-gradient properties due to the increase in stormwater runoff caused by land development.

Unless specifically approved by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required (refer to Section 3.4.5 for down-gradient analysis criteria). Exceptions with regard to rate and volume control can be made for regional facilities planned by the local jurisdiction.

All engineering work for flow control facilities shall be performed by, or under the direction of, a professional engineer currently licensed in the State of Washington.

Refer to Chapter 11 for maintenance requirements.

7.2 APPLICABILITY AND EXEMPTIONS

7.2.1 APPLICABILITY

All projects that meet the regulatory threshold shall comply with this Basic Requirement.

7.2.2 EXEMPTIONS

Projects are exempt from flow control if they discharge to any of the following:

- The Spokane River or other exempt water bodies, which are defined in the *Stormwater Management Manual for Eastern Washington* as fifth-order or greater stream channels, as determined from a 1:150,000 scale map;
- A river or stream that is fifth-order or greater as determined from a 1:24,000 scale map;
- A river or stream that is fourth-order or greater as determined from a 1:100,000 scale map;

- A stream that flows only during runoff-producing events. These streams are defined as those that do not discharge via surface flow to a non-exempt surface water following receipt of the 2-year, NRCS Type 1A, 24 hour rainfall event. In addition, for the stream to be exempt, it shall be able to carry the runoff from an average snowmelt event, but shall not have a period of base flow during a year of normal precipitation;
- A lake or reservoir with a contributing watershed areas greater than 100 square miles;
- A reservoir with outlet controls that are operated for varying discharges to the down-gradient reaches as for hydropower, flood control, irrigation or drinking water supplies (discharges to uncontrolled flow-through impoundments are not exempt).

In order to be exempted the discharge shall meet all of the following requirements:

- The project area must be drained by a conveyance system that consists entirely of manmade conveyance elements (i.e. pipes, ditches, outfall protection); and,
- The conveyance system must extend to the ordinary high water mark line of the receiving water, or (in order to avoid construction activities in sensitive areas) flows are properly dispersed before reaching the buffer zone of the sensitive or critical area; and,
- Any erodible elements of the conveyance system for the project area must be adequately stabilized to prevent erosion; and,
- Surface water from the project area must not be diverted from or increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact. Adverse impacts are expected from uncontrolled flows causing a significant increase or decrease in the 1.5- to 2-year peak flow rate.

Maps shall be standard U.S. Geological Survey (USGS) maps or geographic information system (GIS) data sets derived from USGS base maps.

7.3 DETENTION FACILITIES

7.3.1 INTRODUCTION

A detention system is a storage facility that has a surface discharge. Detention ponds, vaults and underground storage tanks are all considered to be detention facilities. Refer to the *Stormwater Management Manual for Eastern Washington* for design criteria for vaults and underground storage tanks.

A detention facility is intended to control peak stormwater runoff rates, and if designed per the criteria in this chapter, does not control volume. If the subgrade soils meet the drawdown criteria specified in Section 7.8.3, the engineer may choose to propose a system that uses infiltration in conjunction with a detention pond as a means to control volume. Otherwise, the engineer can use evaporation to control volume, in conjunction with a detention pond (refer to Section 7.7.2).

7.3.2 MINIMUM REQUIREMENTS

The following minimum requirements shall be met. Additional requirements are specified in Section 7.8.

Design Criteria

Detention facilities shall be designed such that the release rate does not exceed the pre-developed conditions for multiple storm events. The analysis of multiple design storms is needed to control and attenuate both low and high flow storm events.

The total post-developed discharge rate leaving the site (including bypass flow) shall be limited to the pre-development rates outlined in Table 7-1. Bypass flow is the runoff that leaves the site without being conveyed through the drainage system.

TABLE 7-1
ALLOWABLE DISCHARGE RATES

Design Frequency (24 hr storm)	Post-Developed Discharge Rate[1]
2-year	≤ 2-year pre-developed
25-year	≤ 25-year pre-developed
100-year[2] (Emergency Overflow)	Overflow route only

[1] Post-developed flow is equal to the release from detention facility plus the bypass flow.

[2] The emergency overflow shall direct the 100-year post-developed flow safely towards the downstream conveyance system

Detention systems that store any stormwater below the first overflow shall adhere to the subgrade infiltrative criteria specified in Table 6-1. Unless waived by the local jurisdiction, the subgrade infiltration rate shall be verified through testing.

If the detention facility is also proposed to function as a water quality treatment facility, the following criteria must be met:

- The first orifice or outlet from the facility must be placed 6 inches above the pond bottom; and,

- The treatment zone shall meet the requirements specified in Table 6-1 and be verified through testing, unless waived by the local jurisdiction.

The NRCS Type 1A 24 hour storm event is the design storm to be used for all flow control facilities that use a surface discharge; for flow control facilities that involve infiltration into the subsurface, the NRCS Type II 24 hour storm event can be used for design.

A wetland may also be considered for use as a flow control facility, if approved by Ecology. Refer to Section 7.9.3 for additional information.

Setbacks

When a detention facility is proposed upslope of developed property or at the top of a slope inclined 10% or greater, down-gradient impacts shall be evaluated and the minimum setback from the slope must be greater than or equal to the height of the slope. The distance between the outlet structure and the inlet into the detention facility shall be maximized.

Release Point

Stormwater runoff from a developed site shall leave the site in the same manner and location as it did in the pre-developed condition. Therefore, a detention system may be used only when a well-defined natural drainage course is present prior to development.

7.4 OUTFLOW CONTROL STRUCTURES

7.4.1 INTRODUCTION

Control structures are weirs, orifices, culverts, or manholes with a restrictor device that is used for controlling outflow from a facility to meet a desired standard. This section presents a general overview of flow control structures. For additional information, the engineer should consult a hydraulics reference.

7.4.2 OUTFLOW CONTROL STRUCTURE TYPES

Weirs and Orifices

Weirs and orifices are partial obstructions in an open channel or in a detention facility at the point of discharge, typically used to limit and measure flow rates. Weirs have openings with no top, referred to as a notch, through which the water flows when its surface elevation is above the bottom of the opening (the weir invert). An orifice is typically a circular opening cut into the structure obstructing the stream. The following are common features of weirs:

- Weir Length: The weir length is the length of the notch in the direction perpendicular to the flow:
    - Contracted weirs (see Figure 7-1) have weir lengths less than the channel width or pond wall, and the falling liquid sheet (called the nappe) decreases in width as it falls.
    - Suppressed weirs (see Figure 7-2) extend the full channel width.

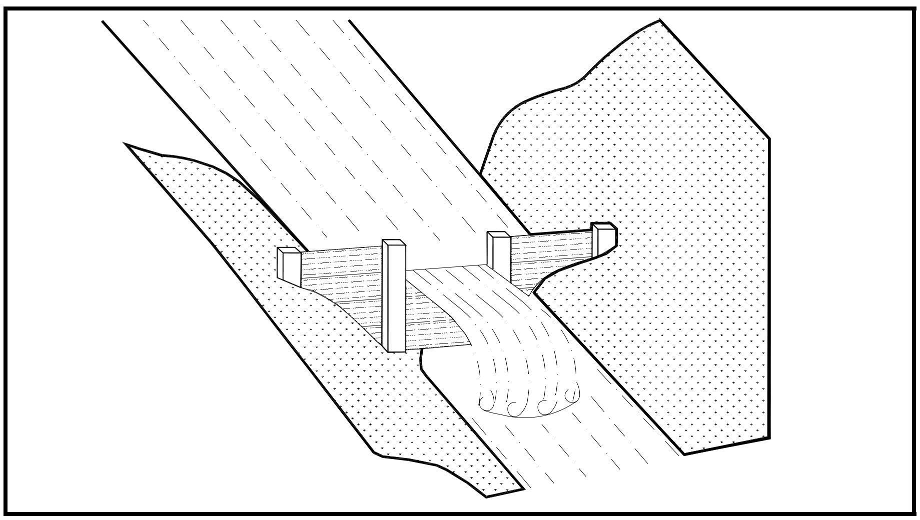


Figure 7-1 – Contracted Weir

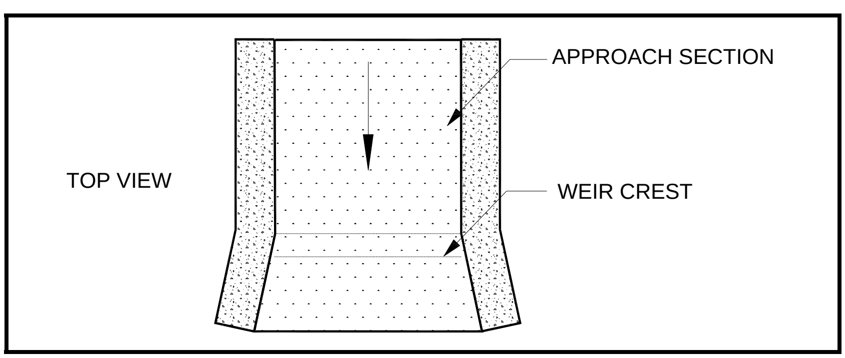


Figure 7-2 – Suppressed Weir

- Weir Crest: The weir crest is the surface of the weir invert in the direction of the flow:
    - Broad-crested weirs (see Figure 7-3) have a crest that extends horizontally in the direction of flow far enough that the flow leaves the weir in essentially a horizontal direction. A weir is broad-crested if the length of the crest in the direction of flow is greater than half of the head (H).
    - Sharp-crested weirs (see Figure 7-4) have a narrow crest with a sharp upstream edge so that water flows clear of the crest. The weir invert or top of the crest should be set above the pond bottom a height of at least twice the maximum head, preferably more.

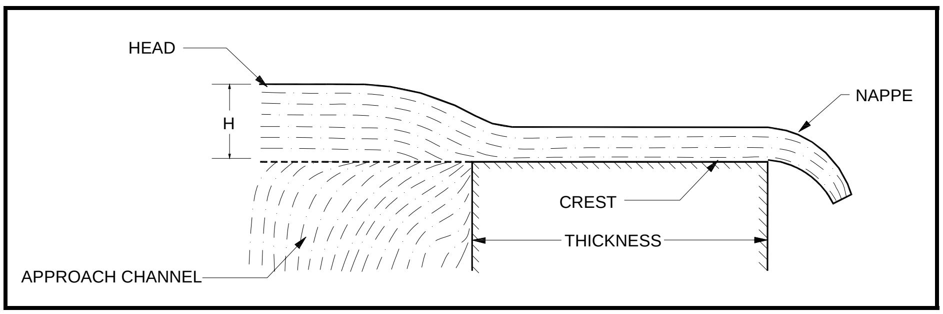


Figure 7-3 – Broad-Crested Weir

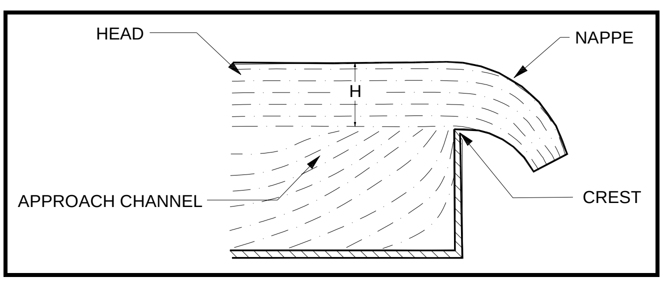


Figure 7-4 – Sharp-Crested Weir

- Weir Notch Shape: The following are the common shapes of weir openings, as viewed looking in the direction of the flow:
    - V-notch: The opening has two sloped sides coming together at a point at the bottom.
    - Rectangular: The opening has two vertical sides and a horizontal invert.

- o Trapezoidal (Cipoletti): The opening has a horizontal invert and two sloped sides.

Table 7-2 provides equations and coefficients for calculating flow through the most common types of weirs and orifices used for flow control.

TABLE 7-2
FLOW EQUATIONS FOR VARIOUS WEIR AND ORIFICE TYPES

Weir/Orifice Type	**Equation**	***C***
Sharp Crested V-notch weir[1]	$Q = C\left(Tan\,\theta/2\right)H^{5/2}$	0.60
Broad Crested Suppressed Rectangular weir	$Q = CLH^{3/2}$	0.33
Rectangular Sharp Crested Weirs[1]: Contracted; Suppressed	$Q = C\left(L - 0.2H\right)H^{3/2}$; $Q = CLH^{3/2}$	$3.27 + 0.40\frac{H}{Y}$
Sharp Crested Cipoletti (Trapezoidal)[1] Side slopes are 1:4	$Q = CLH^{3/2}$	3.367
Broad Crested Trapezoidal Weir	$Q = C(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}\left(Tan\,\vartheta\right)H^{5/2}\right]$	0.60
Orifice	$Q = CA\sqrt{2gH}$	0.62

[1] The weir inverts should be set above the pond bottom a height of at least twice the maximum head.

Q = flow (cfs); C = coefficient of discharge; A = area of orifice (square feet); H = hydraulic head (feet); g = gravity (32.2 feet/second^2); θ = angle of side slopes (degrees); Y = storage depth (feet); L = weir length or opening (feet)

Risers

A riser typically consists of a circular pipe or box inlet with its opening oriented parallel to the water surface. A riser operates under three hydraulic flow regimes in this order as the water surface elevation rises: weir, orifice, and full barrel. Full barrel flow occurs when the downstream conduit is undersized with respect to the riser capacity and when the water surface elevation rises high enough.

Figure 7-5 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions). For additional information, consult a hydraulics reference.

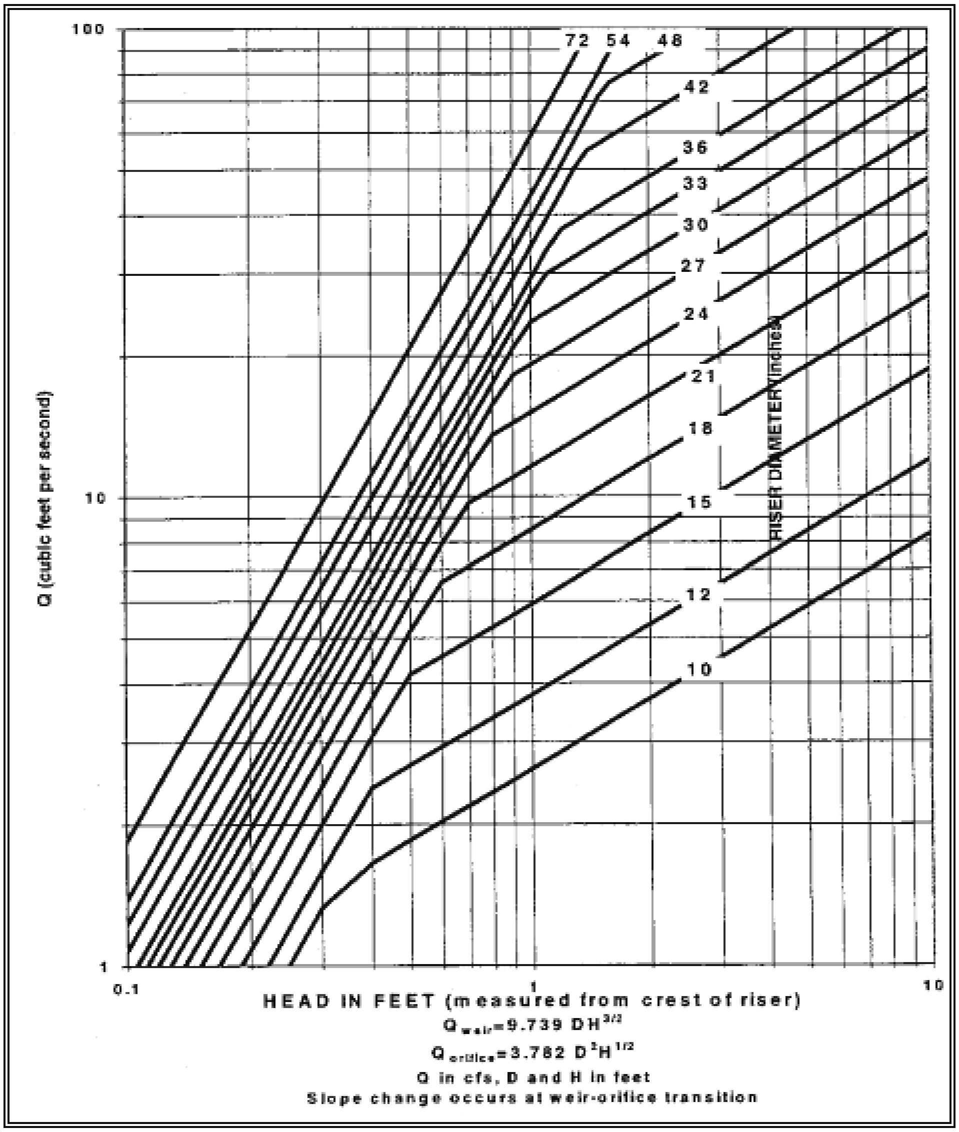


Figure 7-5 – Flow Rates vs. Head (riser)

7.4.3 MINIMUM REQUIREMENTS

Outflow control structures shall meet the following requirements:

- A weir used as a flow control structure shall be made of non-erosive material that is resistant to alteration or vandalism, such as reinforced concrete or metal with a non-corrosive surface. An emergency overflow weir can be made of soil with revetment;

- The inverts for sharp-crested weirs should be set above the pond bottom a height of at least twice the maximum head;
- The crest length for broad-crested weirs should be at least 3 times the maximum head and preferably 4 times the maximum head, or more;
- Runoff shall enter the detention facility through a conveyance system separate from the control and outflow conveyance system. The distance between the inlet and outlet shall be maximized to reduce sediment from accumulating in the outflow structure;
- Flow control structures discharging from a high use site to a drainage facility shall include an oil control BMP that meets the requirements outlined in Chapter 6;
- Control structures shall be selected taking into consideration the expected hydraulic heads. Table 7-3 presents typical control structures and their applicability.

TABLE 7-3
OPTIMAL APPLICATION OF CONTROL STRUCTURES

Control Structure	Pond Head
Outlet Pipe	Very Low
V-Notch Weir	Low
Slotted Weir	Moderate
Multi-Stage Orifice	High

- Circular orifices shall be 3 inches in diameter or greater. Slotted weirs can be used in lieu of smaller orifices to reduce the occurrence of plugging;
- The top of manhole/catch basin grates used for control structures shall be placed 2 inches above the finish grade when located in earth or gravel locations.

Figure 7-6 shows a typical flow control structure.

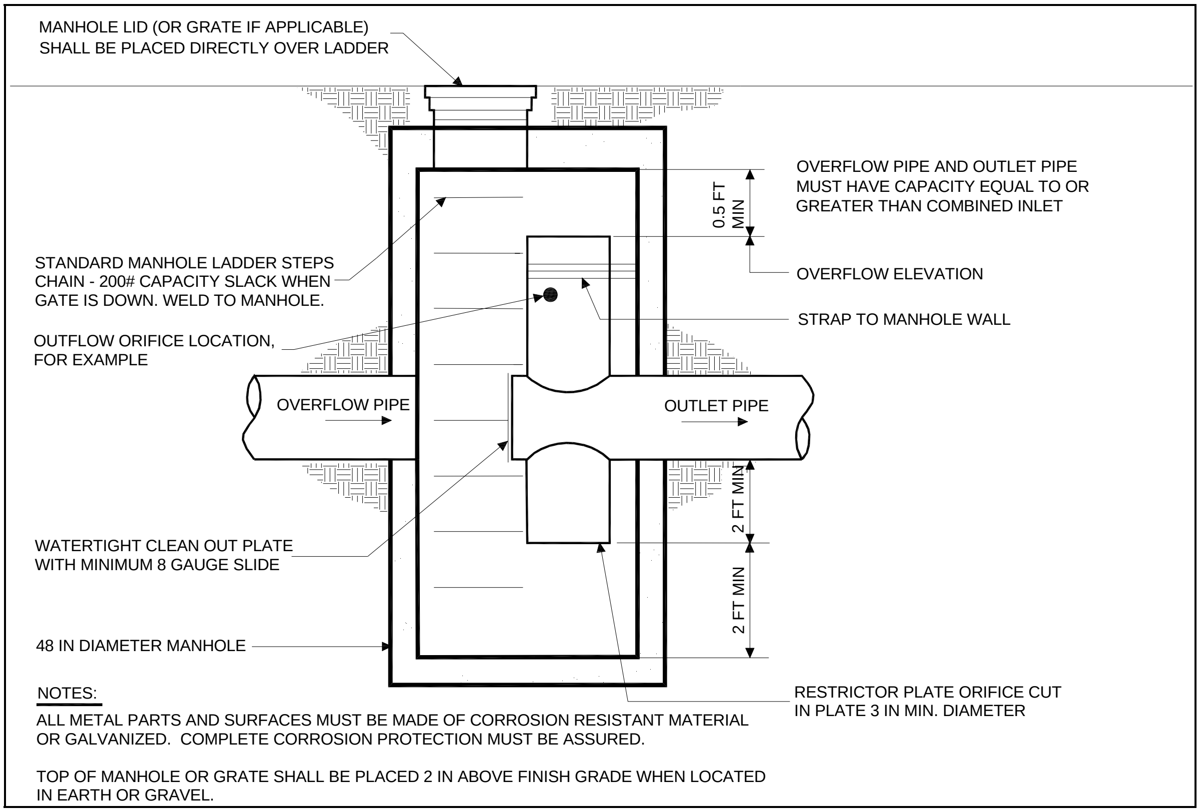


Figure 7-6 – Flow Control Structure Example

7.5 INFILTRATION FACILITIES

7.5.1 INTRODUCTION

An infiltration facility is used for disposing of stormwater runoff into the subsurface and can be used for flow control provided that:

- The discharge is uncontaminated or properly treated so that it does not violate water quality criteria per Chapter 6. For additional information regarding discharges to drywells, refer to Ecology's *Guidance for UIC Wells that Manage Stormwater*;
- The Geotechnical Site Characterization demonstrates the suitability of the soil for subsurface disposal;
- The down-gradient analysis indicates that adverse impacts are not anticipated; and,
- The discharge does not violate UIC regulations.

Drywells are considered standard infiltration facilities. The engineer shall consider the impact of infiltration on groundwater elevations both on site and on down-gradient properties.

For discharges to UIC facilities, the best management practices chosen for the site must remove or reduce the target pollutants to levels that will comply with state groundwater quality standards when the discharge reaches the water table or first comes into contact with an aquifer (see WAC 173-200). Pre-treatment is required prior to discharging to a UIC facility (refer to Chapter 6 for additional information). Discharges to surface waters shall comply with WAC 173-201A, Water Quality Standards for Surface Waters of the State of Washington. Refer to Chapter 6 for BMP selection.

7.5.2 MINIMUM REQUIREMENTS

In addition to the requirements specified in Section 7.8, infiltration facilities shall meet the minimum requirements described below.

Swale Sizing

The methodology for sizing swales is in Section 5.6.

Location

Drywells shall be spaced at least 30 feet center-to-center or twice the depth of the drywell, whichever is greater.

If the site has the potential for contaminated or unstable soil, then these conditions shall be investigated and appropriate mitigating measures taken before designing infiltration facilities in theses areas.

Infiltration facilities shall not be placed on or above a landslide hazard area or slopes greater than 15 percent without evaluation by a geotechnical engineer and jurisdictional approval.

Outflow Rates

Outflow rates shall be determined using the field methods presented in Section 4.3.1.

The active barrel of the drywell shall be installed within the target soil layer. Target soils with more than 12% fines (percent passing the No. 200 sieve) are not suitable for drywells.

The proponent may assume a maximum outflow rate of 0.3 cfs and 1.0 cfs for Type A and Type B drywells, respectively, if all of the following conditions are met:

- The drywells are located within the NRCS Garrison or Springdale soil groups. A full-scale drywell test may still be required;
- The soils are verified by a qualified professional. Field verification should include classifying the target layer soils, obtaining soil gradation data and confirming that the site soils are consistent with the design outflow rates.
- There is no history of drainage problems in the vicinity of the drywell location;
- The anticipated rise in the elevation of the local groundwater table resulting from the disposal facility will not significantly impact adjacent properties or structures; and,
- The local jurisdiction does not have concerns regarding the soil's ability to drain.

Limiting Layer

The optimal separation between the bottom of the drywell and the limiting layer (bedrock, groundwater, clay lens, etc.) shall equal the maximum drywell head, which is 6 feet for single-depth drywells and 10 feet for double-depth drywells. The limiting layer separation can be reduced to 4 feet when the factors of safety specified in Appendix 4A are applied.

For a pond or swale with no infiltrative structure, the separation shall be a minimum of 4.5 feet below the pond bottom, to account for the 6-inch treatment zone and 48 inches of subgrade infiltrative soil.

The local jurisdiction reserves the authority to increase the required depth to the limiting layer should there be evidence that the functionality of the facility will be negatively impacted.

Setback

Drywells shall be placed with the following setback distances:

- At least 100 feet from water wells;
- At least 200 feet from springs used for drinking water supplies,
- At least 100 feet from septic tanks or drainfields;
- At least 100 feet up-slope and 20 feet down-slope from building foundations, unless a reduction is geotechnically justified;
- At least 20 feet from a Native Growth Protection Easement; and,
- Per the geotechnical engineer's recommendations when located up-slope from a structure or behind the top of a slope inclined in excess of 15 percent.

7.6 NATURAL DISPERSION

7.6.1 INTRODUCTION

Natural dispersion attempts to minimize the hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow and infiltration. There are three types of natural dispersion:

- Concentrated Flow Dispersion: Used for steep driveways or other small pavement areas, concentrated flow dispersion uses berms or drains to direct runoff from the paved area to a vegetated pervious area (the "dispersal area") that slows entry of the runoff into a conveyance system, allows for some infiltration and provides some water quality enhancement.
- Sheet Flow Dispersion: Used for flat or moderately sloped paved or cleared areas, sheet flow dispersion consists of a vegetated buffer zone through which sheet flow from the pavement passes, providing flow attenuation and treatment.
- Full Dispersion: Use for larger areas of new residential or commercial development, full dispersion is the preservation of native vegetation on some portion of the site to allow dispersion of runoff from roofs, driveways and roads within the site.

Natural dispersion can be used for impervious or pervious surfaces that are graded to avoid concentrating flows. This flow control method shall only be considered for use on rural projects, including linear roadway projects, large lot subdivision, short plat roads, driveways, sport courts, parking lots and roofs that are not guttered. This flow control method is not intended for use prior to discharge to a lake, stream or water body.

7.6.2 MINIMUM REQUIREMENTS

This section describes a sheet-flow dispersion technique; concentrated flow dispersion is not allowed in the Spokane Region at this time.

In addition to the requirements specified in Section 7.8, as applicable, the following minimum requirements shall be met:

- The dispersal area shall be well-vegetated;
- A vegetated dispersal width of 10 feet must be provided for every 20 feet of width of impervious surface that drains to the dispersal area, with 10 feet the minimum width in all cases. An additional 0.25 feet of vegetated dispersal width shall be provided for each additional foot of impervious surface;

- A vegetated dispersal width of 1 foot must be provided for every 6 feet of disturbed pervious area (i.e. bare soil and non-native landscaping);
- Natural dispersion areas (perpendicular to the impervious area) shall have a slope no steeper than 14% (7H:1V). If this criterion cannot be met due to site constraints, the dispersal width must be increased 1.5 feet for each percent increase in slope above 14%, and in no case shall the slope exceed 20%;
- The average longitudinal slope (roughly parallel to the road or diagonally away from the road) of the dispersal area shall be no more than 15%;
- The longitudinal slope of the contributing impervious or pervious drainage area (parallel to the edge of the dispersal area) shall be 5% or less;
- The lateral slope of the contributing impervious or pervious drainage area (perpendicular to the dispersal area, typically the road cross-slope) shall be 4.5% or less;
- The sheet flow path leading to the natural dispersal area shall not be longer than 75 feet for impervious areas or 150 feet for pervious areas;
- The longitudinal length of the dispersal area shall be equivalent to or greater than the longitudinal length of impervious area that is contributing the sheet flow;
- A 2-foot-wide transition zone (to discourage channeling) shall be provided between the edge of the impervious surface and the vegetated dispersal area, or under the eaves of a roof that has not been guttered. This may be an extension of the sub-grade material (crushed rock), modular pavement, or drain rock;
- The dispersal area shall have a minimum infiltration rate of 4 inches per hour;
- Clearing and grubbing of native dispersal area shall be minimized in order to help maintain the existing root systems that are vital to the success of natural dispersion;
- The area around the dispersal zones shall not be compacted;
- For sites with septic systems, the dispersal area must be downgradient of the drain field primary and reserve areas. This requirement may be waived by the local jurisdiction if the site topography clearly indicates that flow is prohibited from intersecting the drain field;
- The dispersal area shall be located down-gradient from building sites;
- The dispersal area shall be clearly identified on all construction plans, including grading plans, so that the area is not cleared, grubbed or compacted, and shall be clearly delineated on the site;

- Native vegetation and existing trees should not be removed from the natural growth retention areas except where required to meet sight distance, clear-zone or other traffic-related requirements, or if the vegetation is diseased;
- Dispersal is not allowed across, over or toward a landslide or geohazardous area; and,
- The dispersal area shall be preserved within the road right of way, a separate dedicated tract or an easement in order to ensure that treatment and flow control are not interrupted.

7.7 EVAPORATION FACILITIES

7.7.1 INTRODUCTION

Evaporation systems are used to collect and dispose of stormwater runoff when soils are not conducive to infiltration, shallow groundwater is present, or there is the potential for negative impacts due to post-developed stormwater runoff being injected into the subsurface.

The locally developed spreadsheet described in Section 5.7.3 is the most common tool used to perform evaporative pond capacity calculations.

7.7.2 MINIMUM REQUIREMENTS

Liner

Geosynthetic or natural liners may be required to limit infiltration in areas where there is the potential for down-gradient impacts or where the water table may adversely impact the pond via seepage or mounding. The liner shall be a product suitable for stormwater storage and installed per the geotechnical engineer's or manufacturer's recommendation.

When an evaporative pond is proposed, a geotechnical engineer shall provide evaluation of the following:

- Liner materials and installation;
- The potential for groundwater seepage into the pond from the surrounding area;
- The potential for any down-gradient adverse impacts due to the injection of developed stormwater volume into the subsurface; and,
- The potential for groundwater mounding or uplift for a lined pond.

Based upon the information in these evaluations, the geotechnical engineer shall make recommendations regarding the following, if applicable:

- Liner materials and installation; and,
- Any proposed mitigation measures.

Pond Geometry

Evaporative systems designed with the Preferred Method (refer to Section 5.7.2) shall have an evaporation volume separate from the detention volume that provides attenuation of peak flows. Depending on the site conditions and limitations, the proponent can provide separated cells or stacked cells to satisfy this requirement.

<u>Separated system:</u> This type of facility has one evaporation cell (upstream cell) followed by a detention or infiltration cell (downstream cell). The storage volume and design depth of the evaporation cell is determined by a water budget analysis as described in Section 5.7. A factor of safety of at least 1.2 is applied to the required evaporative volume or design depth. The invert of the overflow to the detention or infiltration facility is placed at or above the maximum surface water elevation of the evaporative system (including the factor of safety).

The downstream cell is designed per the criteria for detention facilities (refer to Section 7.3) or infiltration facilities (refer to Section 7.5). In order to allow a point discharge from a detention facility, it must be established that there is an existing, well-defined natural drainage course. A 1-foot freeboard above the maximum surface elevation of the detention or infiltration cell is required. Figure 7-7 shows a typical cross-section of a separated system.

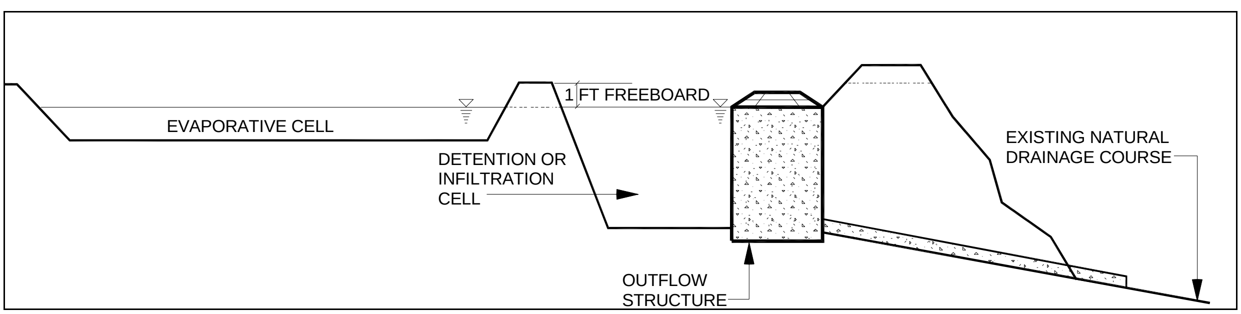


Figure 7-7 – Separated Evaporative/Detention Facility Cross-Section

<u>A stacked system:</u> This type of facility has the evaporative cell (lower cell) below the detention cell (upper cell). The storage volume and design depth of the evaporation cell are determined by a water budget analysis as described in Section 5.7. A factor of safety of at least 1.2 is applied to the required evaporative volume or design depth. Once the dimensions of the lower cell are determined, the upper cell is placed on top of the lower cell. Thus, the detention cell "bottom" and outflow structure must be

placed at or above the maximum surface water elevation of the evaporative system (including the factor of safety).

The detention cell is designed per the criteria specified in Section 7.3. In order to allow a point discharge from a detention facility, it must be established that there is an existing, well-defined natural drainage course. A 1-foot freeboard above the maximum surface elevation of the detention or infiltration cell is required. Figure 7-8 shows a typical cross-section of a stacked system.

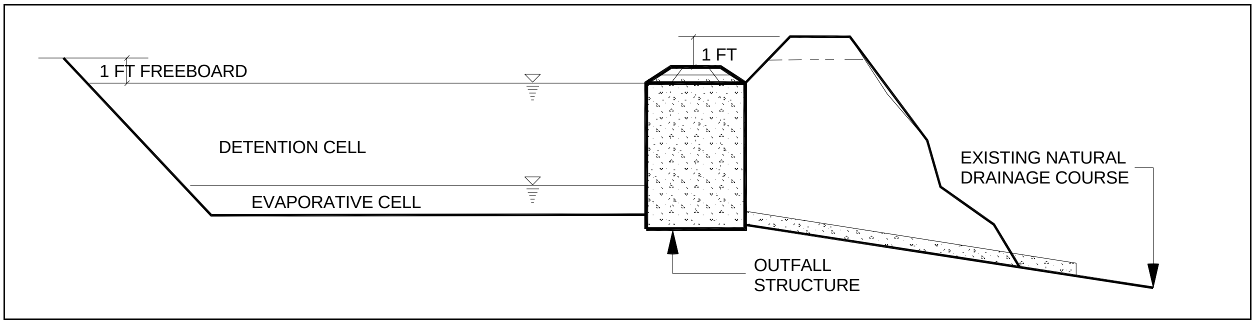


Figure 7-8 – Stacked Evaporative/Detention System Cross-Section

Treatment

Evaporative systems designed with the Alternative Method are not subject to water quality treatment requirements. Evaporative systems designed with the Preferred Method are required to provide water quality treatment per the goals, applicability and criteria specified in Chapter 6.

7.8 ADDITIONAL REQUIREMENTS FOR ALL FACILITIES

The following minimum requirements shall be met for all flow control facilities:

7.8.1 GENERAL

The design of flow control facilities shall adhere to the following:

- Pond bottoms shall be located a minimum of 0.5 feet below the outlet to provide sediment storage; and,
- In general, all pond bottoms shall be flat. Roadside swales are considered flat if the swale bottom slope is 1% or less. When calculating treatment volume, the designer can assume a flat bottom for swale/pond bottom slopes up to 1%. Note that if treatment volume versus area is the methodology used, the volume may be calculated assuming a flat bottom even if the roadside swale bottom has a slope (maximum of 1%).

However, for the calculation of stormwater disposal volume, the grade of the roadside swale bottom shall factor into the geometry used to size the facility. The drainage facility bottom shall slope away from the pond inlet and toward the control structure at 1% for a maximum distance of 20 feet.

- Drainage facilities shall be located within the right of way, within a border easement parallel to the road or within a drainage tract. In unincorporated Spokane County, drainage facilities may also be located in a drainage easement on private property (refer to Chapter 11 for specific information).

7.8.2 SETBACKS

Setbacks for any pond, swale or ditch (measured from the maximum design operating depth) shall be at least 30 feet when located up-gradient or 10 feet when located down-gradient from septic tanks or drainfields.

Pond overflow structures shall be located a minimum of 10 feet from any structure or property line. The toe of the berm or top of bank shall be a minimum of 5 feet from any structure or property line.

7.8.3 DRAWDOWN TIME

Detention and infiltration facilities shall have a minimum subgrade infiltration rate of 0.15 inches/hour and drain completely within 72 hours after a storm event.

7.8.4 SIDE SLOPES

Pond side slopes shall meet one of the following requirements:

- Interior side slopes shall not be steeper than 3:1 (horizontal to vertical);
- Interior side slopes may be increased to a maximum of 2:1 (horizontal to vertical) if the surrounding grade creates a cut or fill with no greater depth than 1.0 foot;
- Exterior side slopes shall not be steeper than 2:1 (horizontal to vertical) unless analyzed for stability by a geotechnical engineer.
- Pond walls may be vertical retaining walls, provided that:
    - A fence is provided along the top of the wall for walls 2.5 feet or taller;
    - A 4-foot-wide access ramp to the pond bottom is provided, with slopes less than 4:1 (horizontal to vertical); and,

  - The design is stamped by an engineer with structural expertise if the wall is surcharged or if it is 4 feet or more in height. A separate building permit may be required by the local jurisdiction if the wall height exceeds 4 feet.

7.8.5 EMERGENCY OVERFLOW SPILLWAY

An emergency overflow spillway shall be provided, whenever reasonable, to bypass the 100-year developed peak flow toward the downstream conveyance system in the event of plugged orifices or high flows that exceed the design storm.

Emergency overflow spillways shall be provided for detention ponds with constructed berms 2 feet or more in height and for ponds located on grades in excess of 5%.

Emergency overflow spillways shall be analyzed as broad crested trapezoidal weirs and comply with the following requirements:

- The spillway shall have the capacity to pass the 100 year-developed peak flow with a 30% freeboard;
- The full width of the spillway shall be armored with riprap and extend downstream to where emergency overflows enter the conveyance system;
- If the detention facility is located on an embankment, the overflow spillway shall be armored to a minimum of 10 feet beyond the toe of the embankment; and;
- The overflow path shall be identified on the construction plans and easements shall be provided as necessary.

Engineers may choose to design the detention pond multi-stage outflow structure with an emergency bypass that can route the 100-year storm through the structure and out of the pond directly into the conveyance channel. However, due to the high potential for sedimentation and plugged orifices within these structures, an emergency overflow spillway shall still be provided in order to reduce the potential for a pond berm breach for detention ponds that require an emergency overflow spillway.

7.8.6 EMBANKMENTS

The height of an embankment is measured from the top of the berm to the catch point of the native soil at the lowest elevation. Embankments shall meet the following minimum requirements:

- Embankments 4 feet or more in height shall be constructed as recommended by a geotechnical engineer. Depending upon the site, geotechnical recommendations may be necessary for lesser embankment heights;

- Embankments shall be constructed on native consolidated soil, free of loose surface soil materials, fill, roots, and other organic debris or as recommended by the geotechnical engineer;
- Energy dissipation and erosion control shall be provided to stabilize the berm and its overflow;
- The embankment compaction shall produce a dense, low permeability engineered fill that can tolerate post-construction settlements with minimal cracking. The embankment fill shall be placed on a stable subgrade and compacted to a minimum of 95% of the Modified Proctor Density (ASTM Procedure D1557);
- Anti-seepage filter-drain diaphragms shall be considered on all outflow pipes and are required on outflow pipes when design water depths are 8 feet or greater;
- Embankments must be constructed by excavating a key. The key width shall equal 50 percent of the berm base width, and the key depth shall equal 50 percent of the berm height; and,
- The berm top width shall be a minimum of 4 feet.

7.8.7 FENCING

Fencing or other barriers may be required to protect the health, welfare and safety of the public. In general, fencing is required for the following:

- Drainage facilities with the first overflow at 2 or more feet above the pond bottom;
- Drainage facilities with retaining walls 2.5 feet high or taller;
- Drainage facilities located at, or adjacent to, schools, nursing homes, day-cares, or similar facilities; and,
- Evaporation Ponds.

Fencing is not required for a typical bio-infiltration swale. However, the local jurisdiction reserves the authority to require a fence along any swale or pond should there be a concern for safety.

At the discretion of the local jurisdiction, if a pond is proposed as an amenity (i.e. enhancements to the disposal facility are proposed, such as rocks, boulders, waterfalls, fountains, creative landscaping or plant materials), the design will be reviewed on a case-by-case basis, such that the fencing requirements may be reduced or waived.

At the discretion of the local jurisdiction, marking fences, terraces, shallower side-slopes, egress bars, etc. may be allowed instead of fencing.

The minimum fencing requirements are as follows:

- The fencing shall be at least 4 feet tall unless otherwise specified by the local jurisdiction, and provide visual access; and,
- Gates are to be provided where drainage facilities are fenced. The gates shall be a minimum of 12 feet wide and have locks.

The City of Spokane Valley reserves the authority to waive any and all fencing in commercial areas, as reviewed and accepted on a case-by-case basis by City staff.

7.8.8 PLANTING REQUIREMENTS

Exposed earth on the pond bottom and interior side slopes shall be sodded, seeded or vegetated in a timely manner, taking into account the current season. Unless a dryland grass or other drought tolerant plant material is proposed, irrigation shall be provided. All remaining areas of the tract or easement shall be sodded or planted with dryland grass or landscaped.

7.8.9 LANDSCAPING

Where space and circumstances allow, the landscaping scheme and common use areas should be integrated with the open drainage features and into the overall stormwater plan. Plants other than turf grass have characteristics that can provide additional stormwater management benefits such as enhanced evapotranspiration and improved soil-holding capabilities.

However, in all cases the landscaping and other uses must be subservient to the primary stormwater needs and functions. Landscaping that does not conflict with the collection, conveyance, treatment, storage, and disposal of stormwater is encouraged. The following general principles should guide the landscaping and selection of plants in conjunction with stormwater facilities:

- Supplemental landscaping areas should be grouped into irregular islands and borders outside of the immediate stormwater facilities and not uniformly dispersed throughout them. The constructed stormwater features should be irregular and curved in shape to look more natural. Avoid straight lines and regular shapes where and when possible;
- Trees and shrubs shall not be planted on pond liners due to potential leakage from root penetration;
- Trees and shrubs shall not be planted near drainage appurtenances such as outlet control structures, manholes, catch basins, inlets, storm drain lines, and underground disposal structures such as drywells or drain-fields. The minimum spacing between the tree or shrub and the drainage structure shall be equal to the crown diameter of the mature plant;

- Trees and shrubs shall not be planted within the treatment, storage, and conveyance zones of swales, ponds, and open channels, unless treatment and storage calculations take into account the mature tree size and allow runoff to reach the drainage facilities;
- Self-limiting plants shall be used, not spreading or self-seeding types.
- Full-size forest trees and trees with aggressive root systems should not be used except where space and circumstances allow. Deciduous trees with heavy shade and leaf-fall should also be avoided to allow the survival of the surrounding grass areas and not plug drainage facilities. Evergreens and smaller ornamental trees are normally better suited to urban conditions;
- Shrubs should be upright in form and groundcovers should have neat growth patterns to assist in their maintenance and that of the surrounding grass areas; and,
- The plant selection needs to consider the native soil conditions and altered moisture conditions created by the stormwater facilities. The plants need to be adaptable to the changes in site conditions. Plants that are self-sufficient and self-limiting, do not require year-round irrigation and require minimal care are encouraged.

7.8.10 MAINTENANCE

Maintenance is of primary importance for drainage facilities to operate as designed. The requirements of Chapter 11 shall be met as applicable.

7.8.11 DAM SAFETY

Detention facilities that can impound 10 acre-feet (435,600 cubic feet) or more with the water level at the embankment crest are subject to the state's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled stormwater release. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate.

Dam safety considerations generally apply only to the volume of water stored above natural ground level. Per the definition of dam height in WAC 173-175-030, natural ground elevation is measured from the downstream toe of the dam. If a trench is cut through natural ground to install an outlet pipe for a spillway or low-level drain, the natural ground elevation is measured from the base of the trench where the natural ground remains undisturbed.

Ecology's Dam Safety Office is available to provide written guidance documents and technical assistance for owners and engineers to address dam safety requirements. If the pond exceeds the volume criteria for dam safety, Ecology shall be contacted early in the facilities planning process.

7.9 SPECIAL REQUIREMENTS

7.9.1 SPECIAL DRAINAGE AREAS

Special Drainage Areas (SDAs) are designated areas with shallow soils, bedrock near the surface of the land, and soils or geological features that may make long-term infiltration of stormwater difficult or areas where infiltration may pose potential problems for on-site or adjacent properties. These areas may also contain steep slopes where infiltration of water and dispersion of water into the soils may be difficult or delayed, creating drainage problems such as erosion. Known areas of flooding or areas that historically have had drainage or high groundwater problems (mapped or unmapped) are also SDAs.

SDAs in the City of Spokane are described in SMC 17D.060 "Stormwater Facilities." Additional requirements for development in these areas are included in this ordinance.

Spokane County has mapped several SDAs. Among the mapped SDAs are portions of the Glenrose/Central Park Watershed, the North Spokane Stormwater Planning Area and the West Plains Stormwater Planning Areas. The Spokane County Stormwater Utility Section maintains and updates these maps. At the discretion of the local jurisdiction, an area can be designated as an SDA if it is determined that development may have adverse impacts on existing or future down-gradient or adjacent properties.

Unless specifically approved by the local jurisdiction, the peak rate and volume of stormwater runoff from any proposed land development to any natural or constructed point of discharge downstream shall not exceed the pre-development peak rate or volume of runoff. A down-gradient analysis demonstrating that there will be no expected adverse impacts on downgradient properties will be required. Exceptions with regard to rate and volume control can be made for regional facilities planned by the local jurisdiction.

7.9.2 FLOODPLAINS

In the City of Spokane and the City of Spokane Valley, floodplain requirements are administered by the planning department. Check with the local jurisdiction for more information and specific requirements.

When any property is developed in and around identified Areas of Special Flood Hazard (100-year floodplains) all work must conform to the requirements of the National Flood Insurance Program and the flood ordinance of the local jurisdiction. This section summarizes the general requirements for projects located within a floodplain. Specific requirements and additional information can be obtained from the local jurisdiction.

Land-actions located within a floodplain (A and B Flood Zones only) shall conform with the following requirements:

- A Floodplain Development permit shall be obtained from the local jurisdiction before any development (including structures, manufactured homes, bridges, culverts, grading, excavation or fill) is undertaken, constructed, located, extended, connected or altered on any property that is partly or entirely located in a floodplain;
- The 100-year Base Flood Elevation (BFE) shall not increase at any point by more than 1.0 foot within Unnumbered A Zones and B Zones; increase in other designated flood hazard areas (numbered A zones and floodways) may be further restricted.
- Projects proposing any increases in BFEs or in the way floodwaters enter and exit the property may require approval from the impacted property owners.
- Disposal of increases in stormwater runoff may not be allowed in an identified 100-year floodplain.
- The lowest floor (including basement floor) shall be elevated to a minimum of 1.0 foot above the BFE. Flood Insurance Rate Maps (FIRMs) provide the BFEs for some flood zones. Development in areas without established BFEs may be inspected by the local jurisdiction. When it is not evident that the proposed building will be outside the flood zone or if a subdivision is proposed, a flood study may be required to establish the 100-year BFE and delineate the 100-year floodplain;
- Commercial, industrial, or other nonresidential buildings may be floodproofed to 1 foot above the BFE in lieu of elevating the lowest floor elevation to a minimum of 1.0 foot above the BFE. Floodproofing techniques shall be certified by an engineer or architect licensed in the State of Washington;
- Residential emergency access and egress shall be provided for the 100-year event;
- The plat dedication of all subdivision proposals associated with floodplains shall contain language prescribed by the local jurisdiction.

A floodplain study is required when development impacts floodplains or may impact floodplains in an unnumbered A Flood Zone or when BFEs have not been established. Disturbance to the floodplain may include filling, excavating, etc. The floodplain study shall meet the following requirements:

- The 100-year peak flows and volumes shall be determined for each basin. The engineer shall review FEMA studies, previously accepted floodplain studies, USGS studies and gage data, or watershed plans for already established 100-year flows. If 100-year flows are not available from other sources acceptable to the local jurisdiction, the engineer shall calculate the required flow by comparison with similar watersheds where flows have been determined or the use of regression equations (see USGS Water Resources Investigations Report 97-4277, *Magnitude and Frequency of Floods in Washington* or the most current version), or by running a hydraulic model per the requirements of this Manual. Contact the local jurisdiction for guidance on the appropriate storm type and duration to use.
- The study shall include all relevant calculations for determining the 100-year flow. The study shall be presented in a rational format so as to allow a reviewer to reproduce the same results; a basin map showing the site boundary and the limits of the watershed contributing to the floodplain shall be included. Topographic contours shall extend beyond the floodplain's watershed boundary, as needed, to confirm the basin limits. The basin map shall meet the requirements of Section 3.4.3;
- In determining the BFE, the study shall use field-surveyed cross-sections of the floodplain in the project area. The cross-sections shall extend offsite, as necessary, to delineate the floodplain in the area of the proposal. FEMA-generated cross-sections may be available for use, but these shall be supplemented with field-surveyed cross-sections for the specific site;
- The BFE shall be determined and the floodplain shall be delineated for the pre-developed and post-developed conditions. The BFE shall be tabulated by station in order to estimate any change to the BFE and delineate modifications to the floodplain. The analysis shall calculate the pre-developed and post-developed BFEs as follows:
  - To the nearest 1/10 of a foot in unnumbered A and B zones;
  - To the nearest 1/100 of a foot in numbered A zones; and,
  - To the nearest 1/1,000 of a foot (as required by FEMA) in floodway areas.
- Floodplain analysis maps shall be prepared for the pre-developed and post-developed conditions and shall meet the following requirements:
  - The maps shall show the BFEs on-site to the nearest 1/10th of a foot and clearly delineate the 100-year floodplain;
  - Topographic contours shall be clearly marked, a bench mark shall be identified for the topographic work and the details of the bench mark shall be discussed;

  - Maps shall clearly show no violations to the requirements of the local jurisdiction's Flood Ordinance;
  - All lots and development, a north arrow, and a scale bar shall be shown on the map; and,
  - The map must be stamped and signed by an engineer.

In unincorporated Spokane County, plats, short plats and commercial project floodplain requirements shall be coordinated during the pre-design meeting and submitted with the Drainage Submittal. For single-family residential projects, the engineer shall work directly with the Environmental Programs section of the Engineering Department as soon as possible in the planning process.

7.9.3 WETLANDS AND CLASSIFIED STREAMS

Wetlands and classified streams are regulated by the Department of Ecology, the Department of Fish and Wildlife and the local jurisdiction's critical areas ordinance. Classified streams are those identified and classified under the Washington Department of Natural Resources' water typing system. This section provides criteria for using a wetland for stormwater treatment or disposal. The engineer shall coordinate with the local building and planning department for further requirements.

The term wetland encompasses a variety of aquatic habitats including swamps, marshes, bogs or floodplains. Wetlands have a natural supply of water, from flooding rivers, streams, natural drainage channels, connections to groundwater, or a perched shallow groundwater table, and are typically inundated with water for a portion of the year. Wetlands are often vegetated with aspen, cattails, cottonwoods, willows, reed grasses and other aquatic plants.

Sites with a wetland or a classified stream often feature other Natural Location of Drainage Systems as well. In addition to the requirements in Section 8.3, the following are required for sites with a wetland or classified stream:

- A qualified wetland biologist shall categorize the wetland, according to the local jurisdiction's critical areas ordinance and Ecology's Wetland Rating System for Eastern Washington, and delineate the wetland boundaries and buffer areas. More information can be found at: http://www.ecy.wa.gov/programs/sea/wetlan.html;
- The proponent shall submit to the local jurisdiction a Mitigation Plan, accepted by the Department of Ecology, if the wetland is to be disturbed due to construction activity or if any natural source of recharge to the wetland will be eliminated or altered;
- A Hydraulic Permit shall be obtained when work is proposed within the normal high-water level of classified streams. Site alterations within the buffers of regulated streams are generally limited to essential access and

utility needs or restoration plans as reviewed and accepted by the State Department of Fish and Wildlife and under the local jurisdiction's critical areas ordinance; and,

- The local planning department and state and federal agencies shall be contacted for permitting and buffer requirements, etc.

Requirements for hydrologic modification of a wetland for stormwater treatment or disposal are presented in Section 6.7.5.

7.9.4 CLOSED DEPRESSIONS

Closed depressions are natural low areas that hold a fixed volume of surface water. Depending upon soil characteristics, a closed depression may or may not accumulate surface water during wet periods of the year. Some closed depressions may be classified as wetlands. If so, the engineer shall comply with the wetland criteria specified in this chapter and in Chapter 6. Analysis of closed depressions shall include the following at a minimum:

- Identification of the location of the closed depression on the pre-developed basin map;
- A routing analysis of the drainage basins contributing to the closed depression to estimate the peak flow rates and volumes leaving the site in the pre-developed condition;
- An estimation of the storage capacity of the closed depression for the 100-year storm event;

If the closed depression will be filled in, a facility shall be provided that has the capacity to store the 100-year volume that was historically intercepted by the closed depression. This is in addition to the drainage facilities required for flow control and treatment due to the increase in stormwater runoff. The construction plans shall include a grading plan of any closed depression areas to be filled in. The grading plan shall show both existing and finish grade contours. The plans shall also specify compaction and fill material requirements.

7.10 REGIONAL STORMWATER FACILITIES

Regional stormwater facilities are grass-lined ditches, natural drainageways, ponds, pipes and various other means of conveying, treating and disposing of stormwater runoff that serve as the "backbone" of a system to which smaller drainage elements can be connected. Most regional facilities serve more than a single development within a given contributing drainage basin. Regional facilities have the potential to lessen flooding in existing drainage problem areas and to provide new development with an alternative to on-site stormwater disposal.

If regional facilities consist of pipes or other non-infiltrative conveyance facilities, they have the potential to significantly increase stormwater runoff and contaminants going into selected discharge areas. The location of such discharges, and pretreatment levels, must be carefully considered to avoid adverse impacts on water resources.

Regional facilities may reduce a community's long term costs for stormwater management because they can free up buildable land for development and can be less expensive to build, operate, and maintain than multiple individual facilities. The local jurisdiction may assume responsibility, or form a partnership, for the design, construction, operation and maintenance of regional facilities.

Studies are currently being performed and completed for several planned regional facilities in the Spokane region. In addition, local jurisdictions have begun mapping natural stormwater features that will need to be incorporated into future regional stormwater systems. Due to this recent progress, developments in the near future may be allowed to discharge stormwater into regional systems. As regional facilities come "on-line," the requirements for on-site treatment and detention may vary from the basic requirements in this manual. Close coordination with the local jurisdiction will be required in order to determine the location and timing of any planned regional system, and to learn the specific design criteria for on-site stormwater facilities that may discharge into the system.

All projects shall be reviewed for the presence of natural drainageways, and a determination will be made as to their significance with regard to preservation of natural conveyance and potential use as part of a regional system.

When a local jurisdiction assumes the responsibility for any or all portions of the design, construction, operation, and maintenance of the drainage facilities, project proponents shall be required to contribute a pro-rated share of the cost (via system development charges or other related fees) based on the estimated cost of improvements the project proponent would otherwise have been required to install. The proponent shall supply the information to justify the estimated costs of the foregone individual improvements.

While opportunities may be available for private developments to use public regional stormwater facilities to accommodate runoff, local jurisdictions reserve the authority to limit or restrict discharge to public facilities.

Spokane County has completed Stormwater Management Plans for Chester Creek and the Glenrose, Central Park, North Spokane and West Plains Stormwater Planning Areas. The City of Spokane has completed a City Stormwater Management Plan and the City of Spokane Valley may also identify needed regional stormwater facilities in the near future. Project proponents shall coordinate with the appropriate local jurisdiction early in the project proposal process if the project is in an area for which natural drainage features with potential regional significance have been identified where regional facilities have been proposed, or where capital improvement plans have been adopted.

CHAPTER 8 – CONVEYANCE

Chapter Organization

8.1 INTRODUCTION

A conveyance system includes all natural or constructed components of a storm drain system that collect stormwater runoff and convey it away from structures, minimizing the potential for flooding and erosion.

Conveyance facilities consist of curbs and gutters, inlets, storm drains, catch basins, channels, ditches, pipes and culverts. The placement and hydraulic capacities of storm drain structures and conveyance systems shall consider the potential for damage to adjacent properties and minimize flooding within traveled roadways. The conveyance system shall also provide discharge capacity sufficient to convey the design flow at velocities that are self-cleaning without being destructive to the conveyance facilities. These objectives are achieved by designing all conveyance facilities using the design storm event specified for the given facility and by adhering to requirements such as minimum velocity, freeboard, cover, etc.

A properly designed conveyance system maximizes hydraulic efficiency by using the proper material, slope and size. Constructed conveyance systems should emulate natural, pre-developed conditions to the maximum extent feasible. Field-verified defined natural drainageways must be preserved and protected; filling them in and building on top of them is not an acceptable practice. In addition, some drainageways may be required for regional use (refer to Section 8.3.4 for criteria).

Inflow and discharge from the system shall occur at the natural drainage points in the same manner as the pre-developed condition as determined by topography and existing drainage patterns.

8.2 APPLICABILITY

All projects shall comply with this Basic Requirement regardless of whether the project they meet the regulatory threshold.

8.3 NATURAL AND CONSTRUCTED CHANNELS

8.3.1 CHANNEL ANALYSIS

A channel analysis shall be performed for all constructed channels proposed for a project and for all field-verified existing natural drainageways/channels present on-site (refer to Section 8.3.4 for details). The following requirements apply to the Drainage Report and the road and drainage plans, when applicable:

- Complete channel calculations shall be provided, indicating the design peak flow rates and assumptions, such as channel shape, slope and Manning's coefficient (see Table 5-4);
- Calculations, including the velocity, capacity, and Froude number shall be provided for each distinct channel segment whenever the geometry of the channel changes (i.e. if the slope, shape or roughness changes significantly);
- The centerline and direction of flow for all constructed drainage ditches or natural channels within the project limits are to be clearly shown on the construction plans and basin map. For all proposed channels, locating information shall be provided at all angle points;
- Calculations shall support the riprap area, thickness, riprap size and gradation, and filter blanket reinforcement for all channel protection, which shall be provided when permissible velocities are exceeded (see Table 8-1). This information shall be included in the plans;

TABLE 8-1
PERMISSIBLE VELOCITIES FOR CHANNELS WITH ERODIBLE LININGS, BASED ON UNIFORM FLOW IN CONTINUOUSLY WET, AGED CHANNELS

Soil Type Of Lining (Earth; No Vegetation)	Maximum Permissible Velocities (feet/second)		
	Clear Water	Water Carrying Fine Silts	Water Carrying Sand & Gravel
Fine sand (non-colloidal)	1.5	2.5	1.5
Sandy loam (non-colloidal)	1.7	2.5	2.0
Silt loam (non-colloidal)	2.0	3.0	2.0
Ordinary firm loam	2.5	3.5	2.2
Volcanic ash	2.5	3.5	2.0
Fine gravel	2.5	5.0	3.7
Stiff clay (very colloidal)	3.7	5.0	3.0
Graded, loam to cobbles (non-colloidal)	3.7	5.0	5.0
Graded, silt to cobbles (colloidal)	4.0	5.5	5.0
Alluvial silts (non-colloidal)	2.0	3.5	2.0
Alluvial silts (colloidal)	3.7	5.0	3.0
Coarse gravel (non-colloidal)	4.0	6.0	6.5
Cobbles and shingles	5.0	5.5	6.5
Shales and hard pans	6.0	6.0	5.0

Source: Special Committee on Irrigation Research, American Society of Civil Engineers, 1926.

- The Froude number shall be checked near the beginning and near the end of a channel that has significant grade changes to determine if a hydraulic jump occurs (as indicated by the Froude number changing from <1 to >1, or vice versa). Since it is difficult to correlate the location of a hydraulic jump to the actual location in the field, the engineer shall propose evenly spaced riprap berms, check dams, or other protective measures to ensure that the jump does not erode the conveyance facility;
- When geosynthetics are used for channel protection, the plans shall clearly specify fabric type, placement, and anchoring requirements. Installation shall be per the manufacturer's recommendation; and,
- Plans for grass-lined channels shall specify seed mixture and irrigation requirements, as applicable.

8.3.2 MINIMUM REQUIREMENTS

Slope

Minimum grades for constructed channels shall be as follows:

- 1.0% for asphalt concrete; and,
- 0.5% for cement concrete, graded earth or close-cropped grass.

Side Slopes

Ditch cross-sections may be V-shaped or trapezoidal. However, V-ditches are not recommended in easily erodible soils or where problems establishing vegetation are anticipated.

The side slope of roadside ditches shall conform to the requirements for clear zone of the local jurisdiction and WSDOT design standards.

No ditches or channels shall have side slopes that exceed the natural angle of repose for a given material or per Table 8-2.

Location

Constructed channels shall not be placed within or between residential lots. Ditches and channels shall be located within a drainage tract or within a border easement. Ditches or channels may be allowed to traverse through lots in large-lot subdivisions (lots of 1 acre or more) and consideration may be given to placement within an easement versus a tract. The local jurisdiction will review these proposals on a case-by-case basis.

TABLE 8-2
MAXIMUM DITCH OR CHANNEL SIDE SLOPES

Type of Channel	**Side Slope (Horizontal: Vertical)**
Firm rock	¼:1 to Vertical
Concrete-lined stiff clay	½:1
Fissured rock	½:1
Firm earth with stone lining	1½:1
Firm earth, large channels	1½:1
Firm earth, small channels	2:1
Loose, sandy earth	2:1
Sandy, porous loam	3:1

Source: Civil Engineering Reference Manual, 8th Edition

Depth

The minimum depth of open channels shall be 1.3 times the flow depth or 1 foot; whichever is greater.

Velocity

Table 8-1 lists the maximum permissible mean channel velocities for various types of soil and ground cover. If mean channel velocities exceed these values, channel protection is required (refer to Section 8.3.3). In addition, the following criteria shall apply:

- Where only sparse vegetative cover can be established or maintained, velocities should not exceed 3 feet/second;
- Where the vegetation is established by seeding, velocities in the range of 3 to 4 feet/second are permitted;
- Where dense sod can be developed quickly or where the normal flow in the channel can be diverted until a vegetative cover is established, velocities of 4 to 5 feet/second are permitted; and,
- On well established sod of good quality, velocities in the range of 5 to 6 feet/second are permitted.

8.3.3 CHANNEL DESIGN

Channel Capacity

Open channels shall be sized using the following variation of Manning's formula.

$$Q = VA = \frac{1.486\ A\ R^{2/3}\ \ S^{1/2}}{n} \tag{8-1}$$

Where:

Q	=	rate of flow (cfs);
V	=	mean velocity in channel (feet/second);
A	=	cross-sectional area of flow in the channel (square feet);
R	=	hydraulic radius (feet); where R = A/P, and P = wetted perimeter (feet)
S	=	channel slope (feet/foot);
n	=	Manning's roughness coefficient (Table 5-4); and,

Note: Manning's equation will give a reliable estimate of velocity only if the discharge, channel cross-section, roughness, and slope are constant over a sufficient distance to establish uniform flow conditions. Uniform flow conditions seldom, if ever, occur in nature because channel sections change from point to point. For practical purposes, however, Manning's equation can be applied to most open channel flow problems by making judicious assumptions.

Energy Dissipation Design

An energy dissipater is useful in reducing excess velocity, as a means of preventing erosion below an outfall or spillway. Common types of energy dissipaters for small hydraulic works are: hydraulic jumps, stilling wells, riprap outfall pads, and gabion weirs.

Channel Protection

Channel velocities shall be analyzed at the following locations, and if they are found to be erosive, channel protection shall be provided:

- At the top of a watershed, at the point where the stormwater runoff becomes concentrated into a natural or constructed channel;
- At all changes in channel configuration (grade, side slopes, depth, shape, etc.), if an erosive velocity is determined at a change in channel

configuration, the velocity shall be evaluated up the channel until the point at which the velocity is determined not to be erosive; and,

- At periodic locations along the entire channelized route.

A material shall be selected that has revetment and armoring capabilities, and the channel shall be analyzed using the Manning's "n" value for that material to determine if the material will reduce the velocity in the channel. In some cases, vegetative cover (natural grasses, etc.) may provide excellent protection without changing the flow characteristics and should be evaluated. If the calculations reveal that common materials such as riprap are not adequate, stronger protection such as gabions and/or stilling pools may be necessary.

Riprap Protection at Outlets

If the velocity at a channel or culvert outlet exceeds the maximum permissible velocity for the soil or channel lining, channel protection is required. The protection usually consists of a reach between the outlet and the stable downstream channel lined with an erosion-resistant material such as riprap.

The ability of riprap revetment to resist erosion is related to the size, shape and weight of the stones. Most riprap-lined channels require either a gravel filter blanket or filter fabric under the riprap.

Riprap material shall be blocky in shape rather than elongated. The riprap stone shall have sharp, angular, clean edges. Riprap stone shall be reasonably well-graded.

<u>Apron Dimensions:</u> The length of an apron (L_a) is determined using the following empirical relationships that were developed for the U.S. Environmental Protection Agency (ASCE, 1992):

$$L_a = \left(\frac{1.8Q}{D_O^{3/2}}\right) + \left(7D_O\right) \text{ for } \quad TW < \frac{D_O}{2} \tag{8-2}$$

Or

$$L_a = \left(\frac{3Q}{D_O^{3/2}}\right) + \left(7D_O\right) \text{ for } \quad TW \geq \frac{D_O}{2} \tag{8-3}$$

Where: D_o = maximum inside culvert width (feet);

Q = pipe discharge (cfs); and,

TW = tailwater depth (feet).

When there is no well-defined channel downstream of the apron, the width, W, of the apron outlet as shown in Figure 8-1, shall be calculated using Equation 8-4 or 8-5:

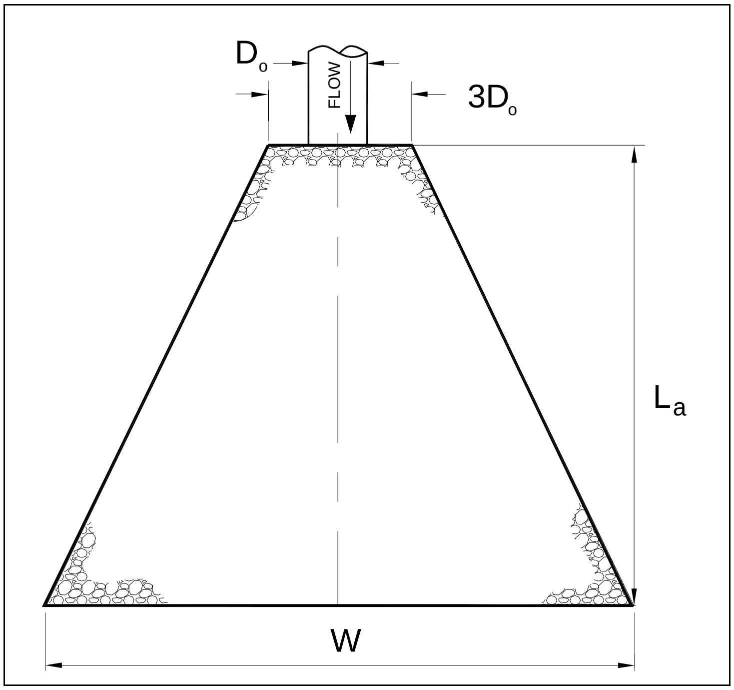


Figure 8-1 – Riprap Revetment at Outfall Schematic

$$W = 3D_O + 0.4L_a \text{ for } \qquad TW \geq \frac{D_O}{2} \tag{8-4}$$

$$W = 3D_O + L_a \text{ for } \qquad TW < \frac{D_O}{2} \tag{8-5}$$

When there is a well-defined channel downstream of the apron, the bottom width of the apron should be at least equal to the bottom width of the channel and the lining should extend at least 1 foot above the tailwater elevation.

The width of the apron at a culvert outlet should be at least 3 times the culvert width.

Apron Materials: The median stone diameter, D_{50} is determined from the following equation:

$$D_{50} = \frac{0.02Q^{4/3}}{TW(D_O)} \tag{8-6}$$

Where: D_{50} = the diameter of rock, for which 50% of the particles are finer.

The riprap should be reasonably well graded, within the following gradation parameters:

$$1.25 \leq \frac{D_{max}}{D_{50}} \leq 1.50 \text{ and } \frac{D_{15}}{D_{50}} = 0.50 \text{ and } \frac{D_{min}}{D_{50}} = 0.25$$

Where: D_{max} = the maximum particle size;

D_{min} = the minimum particle size; and,

D_{15} = the diameter of rock, for which 15% of the particles are finer.

Minimum Thickness: The minimum thickness of the riprap layer shall be 12 inches, D_{max} or $1.5D_{50}$, whichever is greater.

Filter Blanket: A filter fabric blanket under the riprap is normally needed. If a gravel or sand filter blanket is used, then it shall conform to the gradation parameters listed in Table 8-3.

TABLE 8-3
CRITERIA FOR GRAVEL OR
SAND FILTER BLANKET GRADATION

Primary Criterion	$D_{15} < 5d_{85}$
Recommended Secondary Criteria	$5d_{15} < D_{15} < 40d_{15}$ $D_{50}/d_{50} < 50$

Guidelines for Stormwater Management, Spokane County, February 1998

The size of the filter blanket material is designated d_{xx}, the size of the riprap is designated D_{xx}, and the size of the subgrade is designated d'_{xx}. The thickness of each filter blanket should be one-half that of the riprap layer. If it is found that $D_{15}/d'_{85} < 2$ then no filter blanket is needed. Where very large riprap is used, it is sometimes necessary to use two filter blanket layers between the sub-grade and the riprap.

8.3.4 PRESERVATION OF NATURAL LOCATION OF DRAINAGE SYSTEMS (NLDS)

New development shall be designed to protect certain natural drainage features that convey or store water or allow it to infiltrate into the ground in its natural location, including drainageways, floodplains (Section 7.9.2), wetlands and streams (including classified streams) (Section 7.9.3), and natural closed depressions (Section 7.9.4). These features are collectively referred to as the Natural Location of Drainage Systems (NLDS). Preserving the NLDS will help ensure that stormwater runoff can continue to be conveyed and disposed of at its natural location. Preservation will also increase the ability to use the predominant systems as regional stormwater facilities. A regional stormwater facility is typically defined as a system designed and built by a local jurisdiction to receive an agreed-upon rate and volume of stormwater from a defined contributing drainage area, but it can also refer to a private system that serves multiple developments.

Projects located within the City of Spokane shall refer to the City of Spokane's Stormwater Ordinance for specific requirements with regard to the Natural Location of Drainage Systems that may differ from the information found in this section.

Definitions

Some of the drainageways that need to be evaluated for preservation purposes or for potential use as part of a regional facility have been mapped. These drainageways are generally defined as Type A and Type B:

- Type A drainageways are predominant systems that are considered a significant part of a larger existing natural conveyance system.
- Type B drainageways are systems that are generally less prominent, but are deemed to perform important functions in the existing management of stormwater runoff and may be necessary for managing stormwater as part of a larger regional or natural system.

Because every site is unique, the local jurisdiction shall make interpretations, as necessary, based on site visits and technical information as to the exact location and type of drainageways or any NLDS on a project site. The local jurisdiction may also require the project proponent to provide engineering information to assist in this determination.

The maps denoting these drainageways are not definitive; a computer program was used to generate the contours and identify the drainageways. The Type A/B designations are not concrete labels nor are they all inclusive. The maps are only one tool that may be used to identify existing natural drainageways; field verification will typically be required to fully identify the existence of a drainageway and its significance with regard to a natural conveyance system. The Spokane County Stormwater Utility Section maintains maps of drainageways identified within the Spokane County Stormwater Service Areas. The criteria for analysis and preservation of all other NLDS (floodplains, wetlands, closed depressions and wetlands/streams) are covered in Chapter 7.

Protection

No cuts or fills shall be allowed in predominant drainageways except for perpendicular driveway or road crossings with engineering plans showing appropriately sized culverts or bridges. Predominant drainageways shall be preserved for stormwater conveyance in their existing location and state, and shall also be considered for use as regional facilities.

Less prominent drainageways in a non-residential development and in a residential development containing lots 1 acre or smaller may be realigned within the development provided that the drainageway will enter and exit the site at the pre-developed location and that discharge will occur in the same manner as prior to development.

Realignment of a less prominent drainageway shall be defined as still following the “basic” flow path of the original drainageway. An acceptable example would be if the drainageway is proposed to be realigned such that it will follow a new road within the proposed development, and will be left in its existing state or utilized as part of the project’s on-site stormwater system.

Stormwater leaving the site in the same manner shall be defined as replicating the way the stormwater left the site in its existing condition. If the drainageway is preserved in its existing location and is left undisturbed, this goal should be met. If the local jurisdiction accepts the proposal to allow a less predominant drainageway to be routed through the site via a pipe, the following additional criteria shall be met:

- Where the less prominent drainageway enters the site, the design shall ensure that the entire drainageway is “captured” as it enters the site; i.e. the surrounding property shall not be regraded to “neck-down” the drainageway so that it fits into a drainage easement or tract or structure intended to capture and reroute the off-site stormwater runoff.
- Where the less prominent drainageway exits the site, the design shall ensure that the stormwater leaves the pipe, pond or structure a significant distance from the edge of the adjacent property so that by the time the stormwater reaches the property boundary, its dispersal shall mimic that of the pre-developed condition.

Since some of the less prominent drainageways may also be useful for managing regional stormwater, if identified as a significant drainageway (i.e. necessary conveyance for flood control, or being considered as a connection to a planned regional facility or conveyance route), then the drainageway may be subject to the same limitations and criteria as a predominant drainageway.

The size of the tract or easement containing the drainageway shall be determined based on an analysis of the existing and proposed stormwater flows directed to these drainage systems and any access and maintenance requirements found in this Manual. This analysis shall be performed as per the criteria found in Basic Requirement No. 5, Section 2.2.5.

All new development containing lots that are 1 acre or smaller shall be required to set aside the drainageway as open space in a separate tract. For new development containing lots that are greater than 1 acre, the drainageway may be set aside in either a tract or an easement.

All projects shall be reviewed for the presence of any NLDS and a determination will be made as to their significance with respect to preservation for continued natural conveyance and for potential use as part of a regional system.

8.4 CULVERTS

A culvert is a short pipe used to convey flow under a roadway or embankment. A culvert shall convey flow without causing damaging backwater flow constriction, or excessive outlet velocities. Factors to be taken into consideration in culvert design include design flows, the culvert's hydraulic performance, the economy of alternative pipe materials and sizes, horizontal and vertical alignment, and environmental concerns.

8.4.1 CULVERT ANALYSIS

When applicable, the following items shall be included in the Drainage Report, or on road and drainage plans:

- Complete culvert calculations that state the design peak flow rates, velocities at the inlet and outlet, flow control type, and design information for the culvert such as size, slope, length, material type, and Manning's coefficient (refer to Table 8-4);
- Headwater depths and water surface elevations for the design flow rate;
- Roadway cross-section and roadway profile;
- Location information for each of the culvert inverts and invert elevations;
- Type of end treatment (wingwall, flared end sections, etc); and,
- Wall thickness.

8.4.2 MINIMUM REQUIREMENTS FOR CULVERTS

Peak Flow Rate

Culverts shall be sized to handle the design peak flow rates calculated using the methods described in Chapter 5 and the design criteria specified in Chapter 2.

To avoid saturation of the road base, culverts shall be designed such that the water surface elevation for the design storm event does not exceed the elevation of the base course of the roadway.

Culverts shall be designed to withstand the 100-year storm event without damage.

TABLE 8-4
MANNING'S ROUGHNESS COEFFICIENT (n)
FOR CULVERTS

Material Type	n
Concrete pipe	0.013
Ductile iron	0.013
HDPE (only allowed in private roads)	0.013
CMP	0.024

HDPE = high-density polyethylene; CMP = corrugated metal pipe; PVC = polyvinyl chloride

Allowable Headwater Elevation

Headwater is the depth of water at the culvert entrance at a given design flow. Headwater depth is measured from the invert of the culvert to the water surface.

Culverts shall be designed to carry the design runoff with a headwater depth less than 2 times the culvert diameter for culverts 18 inches or less in diameter, and less than 1.5 times the culvert diameter for culverts more than 18 inches in diameter.

Velocity and Slope

To avoid silting, the minimum velocity of flow through culverts shall be 4 feet/second and the minimum slope shall be 0.5%.

Diameter

Table 8-5 lists required minimum culvert diameters.

TABLE 8-5
MINIMUM CULVERT SIZES

Culvert Location	Minimum Size (inches)
Under public roads	18
Under private roads	12
Under driveways/approaches	12

Material and Anchoring

Corrugated metal pipe, ductile iron, or concrete boxes can be used for all culverts. High-density polyethylene (HDPE) is only allowed in private roads. For grades greater than or equal to 20%, anchors are required unless calculations or the manufacturer's recommendations show that they are not necessary.

Placement/Alignment

Generally, culverts shall be placed on the same alignment and grade as the drainageway. Consideration should also be given to changes of conditions over time by using design measures such as:

- Cambering or crowning under high tapered fill zones;
- Raising intakes slightly above the flow line to allow for sedimentation;
- Using cantilevered outfalls away from road banks to allow for toe erosion; and,
- Using drop inlets or manholes to reduce exit velocities on steep terrain.

Angle Points

The slope of a culvert shall remain constant throughout the entire length of the culvert. However, in situations where existing roadways are to be widened, it may be necessary to extend an existing culvert at a different slope; the location where the slope changes is referred to as the angle point. The change in slope tends to create a location in the culvert that catches debris and sediment. If an extension of a culvert is to be placed at a different grade than the existing culvert, a manhole shall be provided at the angle point to facilitate culvert maintenance.

Outfalls

Outfalls shall conform to the requirements of all federal, state, and local regulations. Erosion control shall be provided at the culvert outfall. Refer to Section 8.3.3 for additional information regarding outfall protection.

Culvert Debris and Safety

The engineer shall evaluate the site to determine whether debris protection shall be provided for culverts. Debris protection shall be provided in areas where heavy debris flow is a concern, for example, in densely wooded areas. Methods for protecting culverts from debris problems include: upsizing the culvert and installing debris deflectors, trash racks or debris basins. Section 3.4.8 of the *WSDOT Hydraulic Manual* has additional information on debris protection.

Safety bars to prevent unauthorized individuals from entering the culvert shall be provided for culverts with a diameter greater than 36 inch (see WSDOT standard drawings).

When a trash rack is proposed, the effects of plugging shall be evaluated. Consideration should be given to the potential degree of damage to the roadway and adjacent property, potential hazard and inconvenience to the public, and the number of users of the roadway.

Structural Design

The *WSDOT Hydraulics Manual*, Tables 8-11.1 through 8-11.18, shows the maximum cover for different pipe materials and sizes.

For culverts under roadways, the amount of cover over the culvert is defined as the distance from the top of the pipe to the bottom of the pavement. It does not include asphalt or concrete paving above the base. The minimum amount of cover is 2 feet for culverts, unless proposing ductile iron pipe. The minimum cover for ductile iron pipe is 1 foot.

The minimum cover for culverts under private driveways is 1 foot from the top of the pipe to the finish grade of the drivable surface. Driveway culverts shall be a minimum of 12” CMP or ductile iron pipe.

If the depth of cover is shallow (less than 1 foot) and truck wheel loads are present, it will be necessary to propose a design to prevent structural damage to the pipe or to implement the manufacturer’s recommendations. Also, extreme fill heights (20 feet or greater) may cause structural damage to pipes and will require a special design or adherence to the manufacturer’s recommendations.

End Treatments

The type of end treatment used on a culvert depends on many interrelated and often conflicting considerations:

- <u>Projecting Ends</u> is a treatment in which the culvert is simply allowed to protrude out of the embankment. This is the simplest and most economical. There are several disadvantages such as susceptibility to flotation and erosion, safety when projecting into a roadway clear zone (an area beyond the traveled roadway provided for recovery of errant vehicles), and aesthetic concerns;
- <u>Beveled End Sections</u> consist of cutting the end of the culvert at an angle to match the embankment slope surrounding the culvert. Beveled ends should be considered for culverts 6 feet in diameter or less. Structural problems may be encountered for larger culverts not reinforced with a headwall or slope collar;

- <u>Flared End Sections</u> are manufactured culvert ends that provide a simple transition from culvert to a drainage way. Flared end sections are typically only used on circular pipe or pipe arches. This end treatment is typically the most feasible option in pipes up to 48 inches in diameter. Safety concerns generally prohibit their use in the clear zone for all but the smallest diameters;
- <u>Headwalls</u> are concrete frames poured around a beveled or projecting culvert. They provide structural support and eliminate the tendency for buoyancy. They are considered feasible for metal culverts that range from 6 to 10 feet in diameter. For larger diameters, a slope collar is recommended. A slope collar is a reinforced concrete ring that surrounds the exposed culvert end; or,
- <u>Wingwalls and Aprons</u> are intended for use on reinforced concrete box culverts. Their purpose is to retain and protect the embankment, and provide a smooth transition between the culvert and the channel.

8.4.3 CULVERT DESIGN

Culvert analysis is typically performed using commercially available computer software. If hand calculations are proposed, example calculations can be found in several technical publications and open channel hydraulics manuals.

8.5 STORM DRAIN SYSTEMS

A storm drain system is a network of pipes that convey surface drainage from catch basins or other surface inlets, through manholes, to an outfall.

The design of storm drain systems shall take into consideration runoff rates, pipe flow capacity, hydraulic grade line, soil characteristics, pipe strength, potential construction problems, and potential impacts on down-gradient properties.

8.5.1 PIPE ANALYSIS

The following items shall be included in the Drainage Report, or on road and drainage plans:

- A basin map showing on-site and off-site basins contributing runoff to each inlet, which includes a plan view of the location of the conveyance system;
- Complete pipe calculations that state the design peak flow rates and design information for each pipe run, such as size, slope, length, material type, and Manning's coefficient (see Table 8-6);

- Velocities at design flow for each pipe run;
- The hydraulic grade line at each inlet, angle point, and outlet; and,

TABLE 8-6
MANNING'S ROUGHNESS COEFFICIENTS (n)
FOR CLOSED SYSTEMS

Material Type	n
Concrete pipe	0.013
Ductile iron	0.013
HDPE[1]	0.013
PVC (only allowed in closed system)	0.013

[1] Contact the local jurisdiction for additional requirements when using HDPE pipe.

For lateral pipe connections to storm drain lines in existing rights-of-way (i.e. from a catch basin to a drywell, a main line stormwater system, a pond or a swale), fixed invert elevations are preferred but not required. The minimum depth from finish grade to pipe invert and the minimum pipe slope necessary to satisfy the freeboard and self-cleaning velocity requirements shall be provided. If necessary, invert elevations may be adjusted during construction to avoid potential conflicts with existing utilities in the right of way.

8.5.2 MINIMUM REQUIREMENTS

Peak Flow Rate

Closed pipe systems shall be sized to handle the design peak flow rates. These peak rates can be calculated using the methods described in Chapter 5 and the design criteria specified in Chapter 2.

Hydraulic Grade Line

The hydraulic grade line (HGL) represents the free water surface elevation of the flow traveling through a storm drain system. Pipes in closed systems will be sized by calculating the HGL in each catch basin or manhole. A minimum of 0.5 feet of freeboard shall be provided between the HGL in a catch basin or manhole and the top of grate or cover.

Pipe Velocities and Slope

In Spokane County and the City of Spokane Valley pipe systems shall be designed to have a self-cleaning velocity of 2.5 feet/second at design flow. In the City of Spokane, pipe systems shall be designed to have a self-cleaning velocity of 3 feet/second or greater calculated under full flow conditions even if the pipe is only flowing partially full during the design storm.

Pipe velocities should not be excessively high since high flow velocities (approaching and above 10 feet/second) cause abrasion of the pipes. When the design velocities are 10 feet/second or greater, manufacturer's recommendations demonstrating that the pipe material can sustain the proposed velocities shall be provided.

When the grade of a storm pipe is greater than or equal to 20%, then pipe anchors are required at the joints, at a minimum, unless calculations and manufacturer's recommendations demonstrate that pipe anchors are not needed. Pipe anchor locations are to be defined on the plans, and a pipe anchor detail shall be referenced or provided.

Pipe material shall meet the WSDOT standards for storm sewer pipe. All pipe segments shall be pressure tested, according to WSDOT testing procedures and standards

Pipe Diameter and Length

The minimum pipe diameter shall be 12 inches, except that single pipe segments less than 50 feet long may be 8 inches in diameter. The maximum length of pipe between junctions shall be no greater than 300 feet. No pipe segment shall have a diameter smaller than the upstream segments.

Placement and Alignment

No storm drain pipe in a drainage easement shall have its centerline closer than 5 feet to a private rear or side property line. A storm drain located under a road shall be placed in accordance with the local jurisdiction's requirements or standard plans.

If it is anticipated that a storm drain system may be expanded in the future, provisions for the expansion shall be incorporated into the current design.

Outfalls

Pipe outfalls shall be placed on the same alignment and grade as the drainage way. Outfalls shall conform to the requirements of all federal, state, and local regulations. Erosion control is required at the storm system outfalls. Refer to Section 8.3.3 for additional information regarding outfall protection.

Storm Drain Debris and Safety

The engineer shall evaluate the site to determine whether debris protection shall be provided for storm drain systems. Debris protection shall be provided in areas where heavy debris flow is a concern, for example, in densely wooded areas. Methods for protecting storm drain systems from debris problems include debris deflectors, trash racks and debris basins. The WSDOT Hydraulic Manual has additional information on debris protection.

For enclosed storm drain systems in urban locations, safety bars shall be provided for outfalls with a diameter 18 inches or greater, in order to prevent unauthorized individuals from entering the storm drain system. Outfalls within a fenced area are not required to have safety bars. The clear space between bars shall be 4 inches maximum.

Structural Design

The *WSDOT Hydraulics Manual*, Tables 8-11.1 through 8-11.18, shows the maximum cover for different pipe materials and sizes.

In unincorporated Spokane County and the City of Spokane Valley, the amount of cover over the pipe is defined as the distance from the top of the pipe to the bottom of the pavement. It does not include asphalt or concrete paving above the base. The minimum amount of cover is 2 feet, unless proposing ductile iron. The minimum cover for ductile iron pipe is 1 foot.

In the City of Spokane, cover is measured from the top of pipe to the top of the pavement. The minimum amount of cover is 3 feet, unless proposing ductile iron. The minimum cover for ductile iron pipe is 1 foot.

If the depth of cover is shallow (less than 1 foot) and truck wheel loads are present, it will be necessary to propose a design to prevent structural damage to the pipe or to implement manufacturer's recommendations. Extreme fill heights (20 feet or greater) may also cause structural damage to pipes and will thus require a special design or adherence to the manufacturer's recommendations.

Inverts at Junctions

Whenever two pipes of the same size meet at a junction, the downstream pipe shall be placed with its invert 0.1 feet below the upstream pipe invert. When two different sizes of pipes are joined, pipe crowns shall be placed at the same elevation. The exception to this rule is at drop manholes. Exceptions may be allowed by the local jurisdiction when topographic conditions will significantly impact the depth of the disposal location.

Combined Systems

Combined sanitary and stormwater sewer systems are prohibited.

8.5.3 PIPE DESIGN

To analyze the conveyance capacity of a closed pipe system, the following general steps may be followed when steady flow conditions exist, or conditions can be accurately approximated assuming steady flow conditions:

1. Estimate the size of the pipes assuming a uniform flow condition, using Equation 8-1. Refer to Table 8-6 for Manning's coefficient values.
2. For the pipe sizes chosen, determine uniform and critical flow depth;
3. Determine if upstream (accelerated) flow conditions or downstream (retarded) flow conditions exist. Subcritical flow occurs when downstream conditions control, supercritical flow occurs when upstream conditions control. Determine what flow regime will occur by comparing uniform flow depth, critical flow depth, and initial flow depth. Identify hydraulic jump locations, and where any other discontinuity of flow depth will occur.
4. Conduct a more detailed analysis by computing the hydraulic grade line. The direct step method or standard step method is often used to calculate the hydraulic grade line. For supercritical flow, begin at the upstream end and compute flow sections in consecutive order heading downstream. For sub-critical flow, begin at the downstream end and compute flow sections in consecutive order heading upstream.

The analysis of closed pipe systems is typically done using commercially available computer software packages. If hand calculations are proposed, example calculations can be found in several technical publications on open channel hydraulics, such as: "Handbook of Hydraulics", by Brater and King; and "Open-Channel Hydraulics" by French.

8.6 GUTTERS

A gutter is a section of pavement adjacent to a roadway that conveys water during a storm runoff event. Gutter flow calculations are necessary to establish the spread of water onto the shoulder, parking lane, or travel lane. Roadways shall have an adequate non-flooded width to allow for the passing of vehicular traffic during the design storm event. The non-flooded width (L) is shown in Figure 8-2 and the minimum non-flooded widths for various road classifications are outlined in Table 8-7.

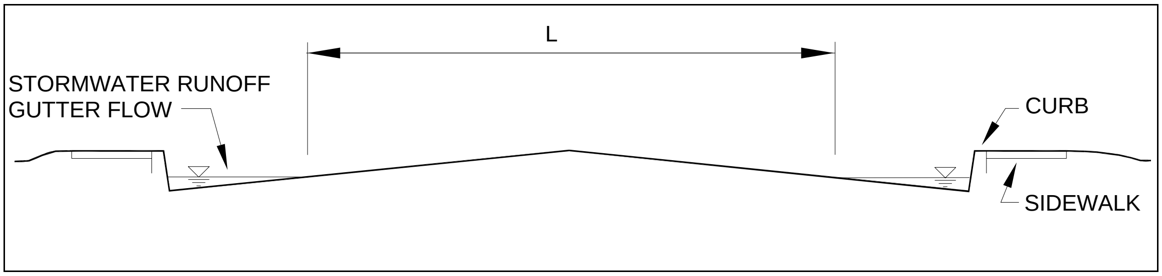


Figure 8-2 – Non-Flooded Road Width (L)

TABLE 8-7
NON-FLOODED ROAD WIDTH REQUIREMENTS

Road Classification	Non-Flooded Width (L)
Private Road	12 feet
Local Access	12 feet
Collector Arterial, 2 Lane	16 feet
Minor Arterial, 2 Lane	24 feet
Other road types	Per local jurisdiction

The non-flooded width shall be evaluated at low points and at proposed inlet locations. The non-flooded width shall also be evaluated at intersections. Bypass flow shall be limited to 0.1 cfs at intersections and at the project boundary.

Non-flooded width and flow depth at the curb are often used as criteria for spacing pavement drainage inlets (curb or grate inlets). Drainage inlets shall be spaced so that the non-flooded width requirements are met and stormwater does not flow over the back of the curb. Spacing shall not exceed 300 feet regardless of flooded width and flow depth compliance.

Generally, inlets shall be placed in the uphill side of the curb return. Additionally, the first inlet shall not be located more 500 feet from the point where the gutter flow path originates.

8.6.1 GUTTER ANALYSIS

When applicable, the drainage report shall include complete gutter calculations that state the design peak flow rates, design flow depth, road cross slope, road grade, and non-flooded width.

The equation for calculating gutter flow is a modified version of Manning’s equation.

$$Q = \frac{0.56\ S_x^{1.67} S_L^{0.5} T^{2.67}}{n} \quad (8\text{-}7)$$

Where:
- Q = flow rate (cfs);
- n = Manning's coefficient (from Table 8-8);
- S_L = longitudinal slope of the gutter (feet/foot);
- S_x = cross slope (feet/foot); and,
- T = spread (feet)

TABLE 8-8
MANNING'S ROUGHNESS COEFFICIENTS (*N*)
FOR STREET & PAVEMENT GUTTERS

Type of Gutter or pavement	**n**
Concrete gutter, troweled finish	0.012
Asphalt Pavement	
Smooth Texture	0.013
Rough Texture	0.016
Concrete pavement	
Float finish	0.014
Broom finish	0.016
Source: Federal Highway Administration (FHWA), Hydraulic Engineering Circular No. 22, Second Edition	

8.6.2 GUTTER DESIGN

Uniform Gutter Section

Uniform gutter sections have a cross slope that is equal to the cross slope of the shoulder or travel lane adjacent to the gutter (see Figure 8-3). The spread (T) in a uniform gutter section can be calculated using Equation 8-7 and solving for T (spread) as follows:

$$T = \left(\frac{Q\ n}{0.56\ S_x^{1.67} S_L^{0.5}} \right)^{0.375} \quad (8\text{-}8)$$

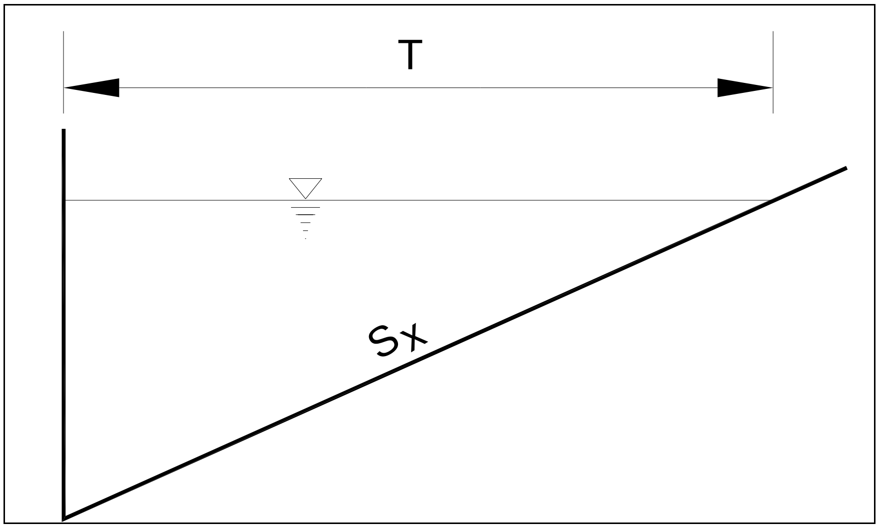


Figure 8-3 – Uniform Gutter Section

An example calculation for determining the non-flooded width and the depth of flow for a uniform gutter section is provided in Appendix 8A.

Composite Gutter Section

Gutters with composite sections have has a cross slope that is steeper than that of the adjacent pavement (see Figure 8-4). The design of composite gutters requires consideration of flow in the depressed segment of the gutter.

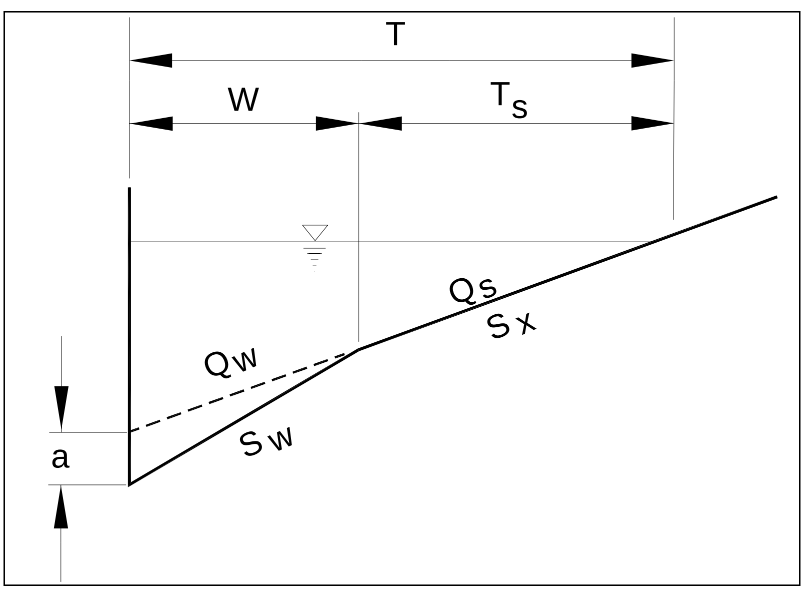


Figure 8-4 – Composite Gutter Section

The spread (T) in composite gutter sections cannot be determined by a direct solution; an iterative approach following the procedure outlined below must be used. An example calculation for determining the spread for a composite gutter section is included in Appendix 8B.

1. Assume a flow rate above the depressed gutter section, Q_S.
2. Compute Q_W using the following:

$$Q_w = Q - Q_s \tag{8-9}$$

Where: Q_W = flow rate in the depressed section of the gutter (cfs);
Q = design flow rate (cfs);
Q_S = flow rate in the gutter section beyond the depressed section (cfs);

3. Compute the gutter cross slope (if it is not given), S_W, using following equation:

$$S_w = S_x + a/W \tag{8-10}$$

Where: S_W = cross slope of the depressed gutter (feet/foot);
S_X = road cross slope (feet/foot);
W = gutter width (feet); and,
a = gutter depression (feet).

4. Compute E_o using the following equation:

$$E_o = \frac{Q - Q_s}{Q} = \frac{Q_w}{Q} \tag{8-11}$$

Where: E_o = ratio of flow in a chosen width (the width of a depressed gutter or grate) to the total gutter flow.

5. Solve for T using following equation:

$$T = W\left\{1 + \left(\frac{\dfrac{S_w}{S_x}}{\left[\dfrac{S_w}{S_x}\left(\dfrac{E_o}{1-E_o}\right)+1\right]^{3/8} - 1}\right)\right\} \tag{8-12}$$

6. Compute T_S using following equation:

$$T_S = T - W \qquad (8\text{-}13)$$

Where: T_S = the width of the spread from the junction of the gutter with the edge of pavement to the edge of the spread (feet).

7. Use Equation 8-7 to determine Q_s for T_S and compare to estimated Q_s from Step 1. Steps 1 through 6 shall be repeated until the estimated and computed Q_s are approximately the same.

8.7 DRAINAGE INLETS

Drainage inlets are used to collect runoff and discharge it to a storm drainage system. They are typically located in gutter sections, paved medians, and roadside and median ditches. Inlets most commonly used in the Spokane Region are as follows:

- Grate Inlets consist of an opening in the gutter or ditch covered by a grate. They perform satisfactorily over a wide range of longitudinal slopes. Grate inlets generally lose capacity as the grade of the road, gutter or ditch increases.
- Curb Inlets are vertical openings in the curb. They are most effective on flat grades, in sumps, and where flows are found to carry significant amounts of floating debris. Curb inlets lose interception capacity as the gutter grade increases; therefore, the use of curb inlets is recommended in sumps and on grades less than 3%.
- Combination Inlets consist of both a curb-opening and a grate inlet. They offer the advantages of both grate and curb inlets, resulting in a high capacity inlet.

There are many variables involved in designing the number and placement of inlets, and in determining the hydraulic capacity of an inlet. The hydraulic capacity of a storm drain inlet depends upon its geometry as well as the characteristics of the gutter flow. Inlet capacity governs both the rate of water removal from the gutter and the amount of water that can enter the storm drainage system. Inadequate inlet capacity or poor inlet location may cause flooding on the roadway resulting in a hazard to the traveling public.

8.7.1 MINIMUM REQUIREMENTS

Peak Flow Rate

The capacity of drainage inlets shall be determined using the design peak flow rates. These rates can be calculated using the methods described in Chapter 5 and the design storm criteria specified in Chapter 2.

Bypass flow shall be limited to 0.1 cfs at intersections and at the project boundary.

Structures

Catch basins, inlets and storm manholes shall conform to the standard plans of the local jurisdiction, or the standard plans jointly published by WSDOT and APWA (M21-01).

Catch basins shall be used in all public and private roads unless utility conflicts prohibit their use.

WSDOT/County Type 1 Catch Basins shall not be used where invert elevation depths are more than 5 feet below lid elevations. Manholes shall be used in these situations.

Catch basins, inlets, and storm manholes shall be placed at all breaks in grade and horizontal alignments. Pipe runs shall not exceed 300 feet for all pipe sizes.

Horizontal and vertical angle points shall not be allowed in a storm system unless a manhole is provided for cleaning.

Grates

Herringbone grates are no longer accepted in roadway applications.

All grate inlets constructed at low points shall be combination inlets. The most commonly used combination inlet is a vaned grate with a hooded curb cut area.

Grate inlets on grade shall have a minimum spacing of 20 feet to enable the bypass water to reestablish its flow against the face of curb. Drainage inlets shall not be located on the curved portion of a curb return.

Grates shall be depressed to ensure satisfactory operation; the maximum depression is 2 inches.

Inlets with larger openings may be used for additional capacity, such as WSDOT Grate Inlet Type 2 (WSDOT Standard Plan B-40.35-00) with frame and vaned grate (WSDOT Standard Plan B-40.40-00). WSDOT Grate Inlet Type 1 and Grates A and B shall not be used in areas of pedestrian or vehicular traffic. Refer to WSDOT Manual and Standard Plans if any of the WSDOT inlets are proposed.

Curb Inlets

Concrete curb inlets (i.e. aprons) shall be used at the entrances to all stormwater facilities to aid stormwater conveyance into the facility and to suppress grass growth at the inlet.

The curb inlet shall have a 2-inch depression at the curb line and a maximum length of 6 feet.

At a minimum (where space constraints allow), curb inlets shall be placed at the most upstream and downstream point along the road adjacent to the treatment or disposal facility, regardless of the flow directed to the curb inlet. In many cases, when a long drainage facility is proposed, and the engineering calculations support it, additional intermediate curb inlets may be required.

Overflow structures, such as drywells or catch basins, shall be located away from the point or points where runoff flows into the facility. When the overflow structure is located within the facility, slopes around the structure shall be no greater than 4:1 (horizontal to vertical).

8.7.2 DRAINAGE INLET DESIGN

Grate Inlets, Continuous Grade

The capacity of an inlet on a continuous grade can be found by determining the portion of the gutter discharge directly over the width of the inlet. On continuous grades (assuming that the grate has the capacity to intercept the entire flow rate directed toward it), the amount of stormwater intercepted by a grate is equal to the amount of stormwater runoff flowing directly over the grate plus the amount that flows in over the side of the grate through the slats/bars. The analysis shall include a 35% clogging factor. The use of formulas for side flow interception for grate inlets found in *FHWA Hydraulic Engineering Circular No. 22* (HEC-22) will be accepted.

The following procedure is most accurate when velocities are in the range of 3 to 5 feet/second at a 2% or 3% longitudinal slope. For instances where the velocity is found to exceed 5 feet/second, additional intermediate inlets can be added, contributing basins redefined, and the associated velocities recalculated. While adding inlets is one solution to reducing the velocity, more information may be found regarding the affect of side flow by consulting the HEC-22 Circular, Section 4.4 Drainage Inlet Design. Note that commercially available software may be used to determine grate inlet capacity.

The capacity of a grate inlet on a continuous grade may be calculated using the procedure outlined below. Figure 8-5 identifies key parameters. Example calculations for grate inlets on a continuous grade for a uniform gutter section and a composite gutter section are provided in Appendices 8C and 8D.

1. Determine the runoff from the contributing basin at the high point to the first inlet. This is the amount of runoff that could be intercepted by the first inlet.
2. Select an inlet and note the grate width (GW) in the calculations (refer to Table 8-9).

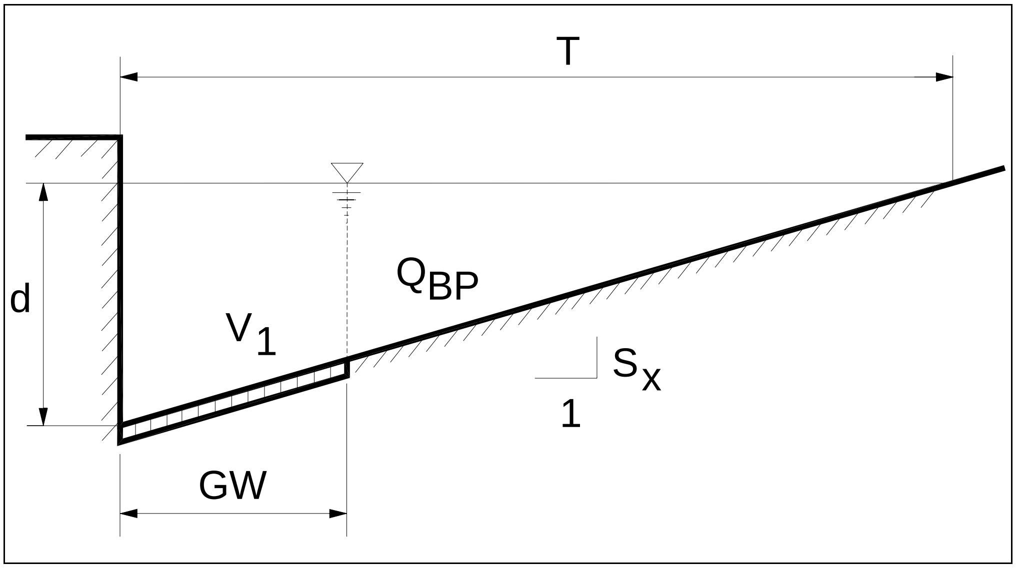


Figure 8-5 – Typical Grate Inlet Cross-Section

TABLE 8-9
ALLOWABLE WIDTH AND PERIMETER
FOR GRATE CAPACITY ANALYSIS

Structure Type	**Allowable Width on a Continuous Grade (feet)**	**Allowable Perimeter in a Sump Condition (feet)**
Vaned Grate for Catch Basin and Inlet	1.67	—
Metal Frame and Grate for Catch Basin and Inlet (Herringbone Pattern)[1]	1.67	—
Metal Frame with Hood and Bi-Directional Vaned Grate	1.67	3.13[4,5]
Frame and Vaned Grates for Grate Inlet Type 2 (WSDOT B-40.40-00)	1.75[2] 3.50[3]	2.96[4,5]

[1] Not recommended for new construction. Values are presented for evaluation of existing conditions.
[2] Normal Installation – see Figure 5-5.5 of WSDOT Hydraulics Manual
[3] Rotated Installation – see Figure 5-5.5 of WSDOT Hydraulics Manual
[4] This perimeter value has already been reduced by 50% for clogging.
[5] This perimeter value has also been reduced for bar area.

Note: Readers should review the most current versions of the local jurisdiction's standard plans for any revisions that may have been made to values provided in this table.

3. Analyze the most upstream inlet. The width of flow (T) is calculated using the procedure described in Section 8.6.2. Verify that T is within the allowable limit (see Table 8-7), then determine the amount of flow intercepted by the grate (basin flow – bypass flow).
4. The inlet bypass flow on a continuous grade is computed as follows:

$$Q_{BP} = Q\left[\frac{(T - GW)}{(T)}\right]^{\frac{8}{3}} \tag{8-14}$$

Where:	Q_{BP}	=	portion of flow outside the grate width (cfs);
	Q	=	total flow of gutter approaching the inlet (cfs);
	T	=	spread, calculated from the gutter section upstream of the inlet (feet); and
	GW	=	grate inlet width perpendicular to the direction of flow (feet), see Table 8-9.

5. The velocity shall not exceed 5 feet/second. The velocity of flow directly over the inlet is calculated as follows:

$$V_1 = \frac{Q - Q_{BP}}{(GW)\left[d - 0.5(GW)(S_x)\right]} \tag{8-15}$$

Where:	V_1	=	velocity over the inlet (feet/second);
	S_x	=	cross slope (feet/foot); and,
	d	=	depth of flow at the face of the curb (feet), given by:

$$d = (T)(S_x) \tag{8-16}$$

If the non-flooded road width does not meet the minimum criteria, an additional inlet should be placed at an intermediate location and the procedure repeated. If the velocity exceeds 5 feet/second then side flow shall be considered using the method outlined in HEC-22.

6. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (to the inlet at the station being analyzed.
7. The last inlet may require an adjustment of spacing (usually smaller spacing) in order to prevent a bypass flow to the project boundaries.

Curb Inlets, Continuous Grade

The capacity of a curb inlet on a continuous grade depends upon the length of opening and the depth of flow at the opening. This depth in turn depends upon the amount of depression of the flow line at the inlet, the cross slope, the longitudinal slope, and the roughness of the gutter. The analysis shall include a 35% clogging factor.

The capacity of a curb inlet on a continuous grade may be calculated using the procedure outlined below. Example calculations for curb inlets on a continuous grade for a uniform gutter section and a composite gutter section are provided in Appendices 8E and 8F.

1. Determine the runoff from the contributing basin at the high point to the first curb inlet. This is the amount of runoff that could be intercepted by the first curb inlet.
2. Analyze the most upstream inlet. The width of flow (T) is calculated using the procedure described in Section 8.6.2. Verify that T is within the allowable limit (Table 8-7).
3. The length of the curb-opening inlet required for total interception of gutter flow is calculated as follows:

$$L_T = 0.6Q^{0.42}S_L^{0.3}\left(\frac{1}{nS_e}\right)^{0.6} \quad (8\text{-}17)$$

Where: L_T = curb opening length required to intercept 100% of the flow (feet);

S_e = equivalent cross slope (feet/foot);

for uniform gutter sections: $S_e = S_x$; and,

for composite gutter sections:

$$S_e = S_x + E_o\left(S_w - S_x\right) = S_x + \left(\frac{E_o a}{12W}\right) \quad (8\text{-}18)$$

where: a = gutter depression (inches);

E_o = ratio of flow in the depressed section to total gutter flow, calculated in the gutter configuration upstream of the inlet; and,

W = gutter width (feet).

4. When the actual curb inlet is shorter than the length required for total interception, calculate the efficiency of the curb inlet using Equation 8-19.

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8} \quad (8\text{-}19)$$

Where: E = efficiency; and,

L = actual curb opening length (feet).

5. Compute the interception capacity of the curb inlet using the following relationship:

$$Q_i = (E)(Q) \tag{8-20}$$

Where: Q_i = curb inlet capacity (cfs),

6. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the inlet at the station being analyzed.

$$Q_{BP} = Q - Q_i \tag{8-21}$$

7. The last inlet may require an adjustment of spacing (usually smaller spacing) in order to prevent a bypass flow to the project boundaries.

Combination Inlets, Sump Condition

Inlets in sump locations perform differently than inlets on a continuous grade. Inlets in sump locations operate in one of two ways: 1) as a weir, at low ponding depths; or 2) as an orifice, at high ponding depths (1.4 times the grate opening length). It is very rare that ponding on a roadway will become deep enough to force the inlet to operate as an orifice; therefore, this section will focus on the inlet operating as a weir.

The interception capacity of a combination inlet in a sump is equal to that of a grate inlet alone in weir flow. Design procedures presented here are a conservative approach to estimating the capacity of inlets in sump locations. All inlets in a sump condition shall be evaluated using a 50% clogging factor.

The analysis shall include an evaluation of the inlet and the surrounding street, gutter, curb and adjacent properties for storm events exceeding the required level of service. An emergency overflow path shall be provided.

The capacity of a combination inlet operating in a sump as a weir may be estimated using the following procedure. There are also commercially available software programs that will analyze combination inlets in a sump location. An example calculation for a combination inlet in a sump location is provided in Appendix 8G.

1. Determine the runoff contributing to the combination inlet. This is the sum of the bypassed flows from all upstream inlets and the runoff generated from the basin contributing directly to the combination inlet.
2. Determine the allowable spread (T_{all}) based on the non-flooded width requirements in Table 8-7.
3. Calculate the depth of flow at the curb (d) using Equation 8-16.

4. Determine the average depth of flow over the grate using one of the following relationships:

   For uniform gutter sections:

$$d_{ave} = d - S_x\left(\frac{W}{2}\right) + y \tag{8-22}$$

   For composite gutter sections:

$$d_{ave} = d + \frac{W}{2}\left(S_w - 2S_x\right) + y \tag{8-23}$$

   Where: y = local depression (feet), Spokane County Standard Plans B-7 and B-18 show a 1-inch local depression at the grate.

5. Calculate the allowable flow (Q_{all}) using the following relationship:

$$Q_{all} = CPd^{3/2} \tag{8-24}$$

   Where: Q_{all} = allowable flow based upon the maximum allowable spread (cfs);

   P = perimeter of the grate inlet (refer to Table 8-9 for projects in Spokane County and the City of Spokane Valley);

   d = average depth of water across the grate (feet); and,

   C = may be taken as 3.0.

6. Compare the allowable flow to the actual flow. If the actual flow is less than the allowable flow then the combination inlet capacity is adequate. Otherwise, changes shall be made to the design and steps 1 through 5 repeated.

Curb Inlets, Sump Condition

The procedure below assumes that the curb inlet is operating as a weir and the depth of flow is less than the height of the curb opening.

The capacity of a concrete curb inlet (no grate) in a sump condition may be calculated by the method described below. An example calculation for a curb inlet in a sump location is provided in Appendix 8H.

1. Determine the runoff contributing to the curb inlet. This is the sum of the bypassed flows from all upstream inlets and the runoff generated from the basin contributing directly to the combination inlet.

2. Determine the allowable spread (T_{all}) based upon the non-flooded width requirements found in Table 8-7.
3. Calculate the depth of flow at the curb (d).
4. Calculate the allowable flow (Q_{all}) using one of the following relationships:

   For a depressed curb opening inlet:

$$Q_{all} = 2.3(L + 1.8W)d^{3/2} \tag{8-25}$$

   Where:
   - Q_{all} = allowable flow based upon the maximum allowable spread (cfs);
   - W = lateral width of depression (feet);
   - L = length of curb opening (feet); and,
   - d = depth of flow at the curb (feet).

   For a curb opening inlet without a depression:

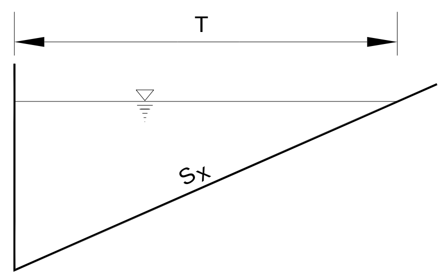
$$Q_{all} = 3.0Ld^{3/2} \tag{8-26}$$

5. Compare the allowable flow to the actual flow. If the actual flow is less than the allowable flow then the curb inlet capacity is adequate. Otherwise, changes shall be made to the design and steps 1 through 4 repeated.

APPENDIX 8A – EXAMPLE CALCULATION: NON-FLOODED WIDTH (UNIFORM GUTTER SECTION)

GIVEN

- A crowned private road with a uniform gutter section (as illustrated), assuming an equal flow rate on each side of the road.
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Road/Gutter cross slope (S_X) = 0.02 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/ft
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Calculate the spread (T) for half of the roadway using Equation 8-8.

$$T = \left(\frac{Q\ n}{0.56\ S_x^{1.67} S_L^{0.5}} \right)^{0.375} = \left(\frac{(4.2)(0.016)}{0.56\ (0.02)^{1.67} (0.01)^{0.5}} \right)^{0.375} = 12.4 \text{ feet}$$

2. Calculate the non-flooded width using the following relationship for crowned roadways, and then verify that the non-flooded width is within the allowable limit (refer to Table 8-7):

Non-flooded width = 2[(½)(RW) + W – T)]
= 2[(½)(30) + 1.5 – 12.4)]
= 8.2 feet < 12 feet **FAIL***

* Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, the design fails to meet the required non-flooded road width criteria. The design will need to be altered (i.e. try an additional inlet placed at an intermediate location, contributing basins redefined, new flow rates calculated, and the above steps repeated).

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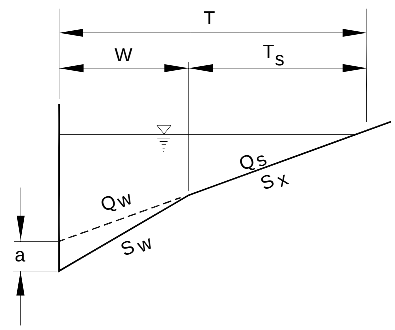
APPENDIX 8B – EXAMPLE CALCULATION: NON-FLOODED WIDTH (COMPOSITE GUTTER SECTION)

GIVEN

- A super-elevated local access road with a composite gutter section (as illustrated).
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Road cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = .081 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Assume a flow rate (Q_s) for that portion of the flow above the depressed gutter section.

   Assume Q_s = 1.4 cfs

2. Calculate Q_w using Equation 8-9.

$$Q_w = Q - Q_s = 4.2 - 1.4 = 2.8\text{cfs}$$

3. Calculate E_o using Equation 8-11.

$$E_o = \frac{Q - Q_s}{Q} = \frac{Q_w}{Q} = \frac{2.8}{4.2} = 0.67$$

4. Calculate the spread (T) using Equation 8-12.

$$T = W\left\{1 + \left(\frac{\frac{S_w}{S_x}}{\left(\left[\frac{S_w}{S_x}\left(\frac{E_o}{1-E_o}\right)+1\right]^{3/8} - 1\right)}\right)\right\} = 1.5\left\{1 + \left(\frac{\frac{0.081}{0.02}}{\left(\left[\left(\frac{0.081}{0.02}\right)\left(\frac{0.67}{1-0.67}\right)+1\right]^{3/8} - 1\right)}\right)\right\} = 6.17 \text{ ft}$$

5. Calculate T_S using Equation 8-13.

$$T_S = T - W = 6.17 - 1.5 = 4.67\text{ft}$$

6. Use Equation 8-7 to compute Q_s for the calculated Ts, then compare to the estimated Q_s from Step 1.

$$Q_S\,(\text{computed}) = \frac{0.56\ S_x^{1.67} S_L^{0.5} T_S^{2.67}}{n} = \frac{0.56\ (0.020)^{1.67}(0.01)^{0.5}(4.67)^{2.67}}{0.016} = 0.31\ \text{cfs} < 1.4\ \text{cfs}$$

Since Q_s (estimated) and Q_s (computed) are not approximately equal, repeat Steps 1 through 6 until the estimated and computed Q_s are numerically closer in value.

7. Assume a new Q_s and repeat steps 2 through 6. The following parameters are calculated using Q_s = 2.6 cfs.

Q_W = 1.6 cfs

E_o = 0.38

T = 11.68 feet

T_S = 10.18 feet

Q_s = 2.5 cfs (computed)

Q_s (estimated) ≈ Q_s (computed)

Note that a spreadsheet can be set up to perform the above calculations, and commercially available software can calculate spread in composite gutters.

8. Now that T has been found for the relationship: Qs (estimated) ≈ Qs (calculated), calculate the non-flooded width using the following relationship for super-elevated roadways, and then verify that the non-flooded width is within the allowable limit (refer to Table 8-7):

Non-flooded width = RW + 2W - T

= 30 + 2(1.5) - 11.68

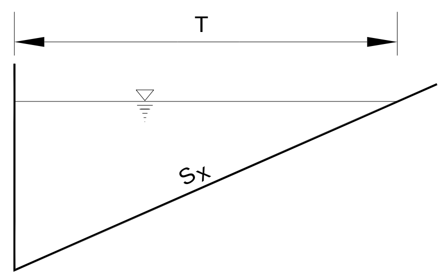
= 21.3 feet > 12 feet **OK***

* Table 8-7 indicates that the minimum non-flooded width is 12 feet for local access roads. Therefore, the design has met the required non-flooded road width criteria.

APPENDIX 8C – EXAMPLE CALCULATION: GRATE INLET CAPACITY (UNIFORM GUTTER SECTION)

GIVEN

- A crowned private road with a uniform gutter section (as illustrated), assuming an equal flow rate on each side of the road.
  - Flow rate (Q) = 2.5 cfs
  - Gutter width (W) = 1.5 ft
  - Spokane County Type 1 Grate (Standard Plan B-12) Grate width (GW) = 1.67 feet
  - Road/Gutter cross slope (S_X) = 0.02 feet/foot
  - Longitudinal slope (S_L) = 0.03 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate (Q) is given as 2.5 cfs

2. Select an inlet and note the grate width.

   For this example, the grate width (GW) is given as 1.67 ft

3. Calculate the spread (T) for half of the roadway using Equation 8-8.

$$T = \left(\frac{Q\ n}{0.56\ S_x^{1.67} S_L^{0.5}} \right)^{0.375} = \left(\frac{(2.5)(0.016)}{0.56\ (0.02)^{1.67}(0.03)^{0.5}} \right)^{0.375} = 8.31\text{feet}$$

4. Calculate the non-flooded width using the following relationship, and then verify that the non-flooded width is within the allowable limit (refer to Table 8-7):

   Non-flooded width = 2[(½)(RW) + W – T)]
   = 2[(½)(30) + 1.5 – 8.31)]
   = 16.38 feet > 12 feet **OK***

   * Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

5. Calculate the inlet bypass flow using Equation 8-14:

   With 35% clogging factor, grate width (GW) = 1.67(1 - 0.35) = 1.09'

$$Q_{BP} = Q\left[\frac{(T)-(GW)}{(T)}\right]^{\frac{8}{3}} = 2.5\left[\frac{8.31-1.09}{8.31}\right]^{\frac{8}{3}} = 1.72\text{cfs}$$

   Therefore the capacity of the inlet = 2.5 – 1.72 = 0.78 cfs

6. Verify that the velocity does not exceed 5 feet/second. The velocity of flow directly over the inlet is calculated using Equation 8-15 (where d = T S_x):

$$V_1 = \frac{Q-Q_{BP}}{(GW)\left[d-0.5(GW)(S_x)\right]} = \frac{2.5-1.72}{1.09\left[(8.31)(0.02)-0.5(1.09)(.02)\right]} = 4.61\text{ft/s} < 5 \text{ feet/second } \textbf{OK**}$$

   **Refer to Section 8.7.2 for guidance when the velocity exceeds 5 feet/second.

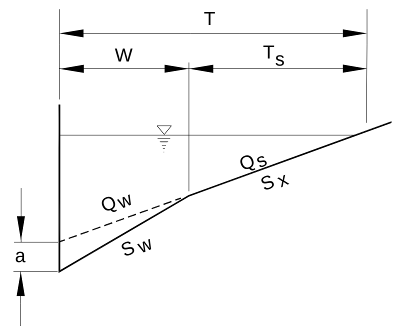
7. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the inlet at the station being analyzed.

Note that the City of Spokane requires the analysis to include a 50% clogging factor.

APPENDIX 8D – EXAMPLE CALCULATION: GRATE INLET CAPACITY, CONTINUOUS GRADE (COMPOSITE GUTTER SECTION)

GIVEN

- A super-elevated local access road with a composite gutter section (as illustrated)
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Spokane County Type 1 Grate (Standard Plan B-12) Grate Width (GW) = 1.67 feet
  - Road cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = .081 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate is given as 4.2 cfs

2. Select an inlet and note the grate width.

   For this example, the grate width (GW) is given as 1.67 feet

3. Calculate the spread (T) for half of the roadway using the method outlined in Appendix 8B and verify that the non-flooded width is within the allowable limit (Table 8-7).

   T = 11.68 feet
   (Solution from Appendix 8B)

   Non-flooded width = 21.3 feet > 12 feet **OK***
   (Solution from Appendix 8B)

   * Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

4. Calculate the inlet bypass flow using Equation 8-14:

   With 35% clogging factor, grate width (GW) = 1.67(1 - 0.35) = 1.09'

$$Q_{BP} = Q\left[\frac{(T)-(GW)}{(T)}\right]^{\frac{8}{3}} = 4.2\left[\frac{11.68-1.09}{11.68}\right]^{\frac{8}{3}} = 3.23\text{cfs}$$

Therefore the capacity of the inlet = 4.2 – 3.23 = 0.97 cfs

5. Verify that the velocity does not exceed 5 feet/second. The velocity of flow directly over the inlet is calculated using Equation 8-15:

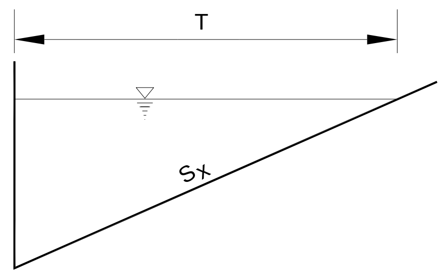
$$V_1 = \frac{Q - Q_{BP}}{(GW)\left[d - 0.5(GW)(S_x)\right]} = \frac{4.2-3.23}{1.09\left[(11.68)(0.02) - 0.5(1.09)(0.02)\right]} = 4.00\text{ft/s} < 5\text{ feet/second } \textbf{OK}$$

6. The analysis is then repeated with the next inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the inlet at the station being analyzed.

APPENDIX 8E – EXAMPLE CALCULATION: CURB INLET CAPACITY, CONTINUOUS GRADE (UNIFORM GUTTER SECTION)

GIVEN

- A crowned private road with a uniform gutter section (as illustrated), assuming an equal flow rate on each side of the road.
  - Flow rate (Q) = 1.5 cfs
  - Gutter width (W) = 1.5 feet
  - Curb Inlet Length (L) = 3 feet
  - Road/Gutter cross slope (S_x) = 0.02 feet/foot
  - Longitudinal slope (S_L) = 0.03 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate is given as 1.5 cfs

2. Calculate the spread (T) for half of the roadway using Equation 8-8 and verify that the non-flooded width is within the allowable limit (Table 8-7).

$$T = \left(\frac{Q \ n}{0.56 \ S_x^{1.67} S_L^{0.5}} \right)^{0.375} = \left(\frac{(1.5)(0.016)}{0.56 \ (0.02)^{1.67} (0.03)^{0.5}} \right)^{0.375} = 6.86\text{feet}$$

   Non-flooded width = 2[(½)(RW) + W – T)]

   = 2[(½)(30) + 1.5 – 6.86)]

   = 19.3 feet > 12 feet **OK***

   * Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

3. Calculate the length of curb inlet required for total interception of gutter flow using Equation 8-17:

$$L_T = 0.6Q^{0.42}S_L^{0.3}\left(\frac{1}{nS_e}\right)^{0.6} = (0.6)(1.5^{0.42})(0.03^{0.3})\left(\frac{1}{0.016 * 0.02}\right)^{0.6} = 31.1\text{feet}$$

4. Calculate the efficiency of the curb inlet using Equation 8-19.

$$E = 1-\left(1-\frac{L}{L_T}\right)^{1.8} = 1-\left(1-\frac{3.0}{31.1}\right)^{1.8} = 0.167$$

5. Compute the interception capacity and the bypass flow of the curb inlet using Equations 8-20 and 8-21.

$$Q_i = (E)(Q) = (0.167)(1.5) = 0.25\text{cfs}$$

$$Q_{BP} = Q - Q_i = 1.5 - 0.25 = 1.25\text{cfs}$$

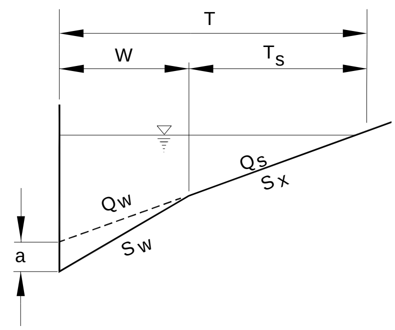
6. The analysis is then repeated with the next curb inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the next inlet.

Note that the City of Spokane requires the analysis to include a 50% clogging factor.

APPENDIX 8F – EXAMPLE CALCULATION: CURB INLET CAPACITY, CONTINUOUS GRADE (COMPOSITE GUTTER SECTION)

GIVEN

- A super-elevated local access road with a composite gutter section (as illustrated)
  - Flow rate (Q) = 4.2 cfs
  - Gutter width (W) = 1.5 feet
  - Curb Inlet Width (GW) = 3 feet
  - Road cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = .081 feet/foot
  - Longitudinal slope (S_L) = 0.01 feet/foot
  - Manning's friction coefficient, n = 0.016
  - Road width (RW) = 30 feet



CALCULATIONS

1. Determine the runoff from the contributing basin at the high point to the first inlet;

   For this example, the design flow rate is given as 4.2 cfs

2. Calculate the spread (T) for half of the roadway using the method outlined in Appendix 8B and verify that the non-flooded width is within the allowable limit (Table 8-7).

   T = 11.68 feet
   (Solution from Appendix 8B)

   Non-flooded width = 21.3 feet > 12 feet **OK***
   (Solution from Appendix 8B)

   * Table 8-7 indicates that the minimum non-flooded width is 12 feet for private roads. Therefore, design has met the required non-flooded road width criteria.

3. Calculate the equivalent cross slope (S_e) using Equation 8-18 and the length of curb inlet required for total interception of gutter flow (L_T) using Equation 8-17.

$$S_e = S_x + E_o\left(S_w - S_x\right) = 0.02 + 0.38(0.081 - 0.02) = 0.043$$

   Where, E_o = 0.38 (Solution from Appendix 8B)

$$L_T = 0.6Q^{0.42} S_L^{0.3} \left(\frac{1}{nS_e} \right)^{0.6} = (0.6)(4.2^{0.42})(0.01^{0.3}) \left(\frac{1}{(0.016)(0.043)} \right)^{0.6} = 21.8 \text{feet}$$

4. Calculate the efficiency of the curb inlet using Equation 8-19.

$$E = 1 - \left(1 - \frac{L}{L_T} \right)^{1.8} = 1 - \left(1 - \frac{3.0}{21.8} \right)^{1.8} = 0.23$$

5. Compute the interception capacity and the bypass flow of the curb inlet using Equations 8-20 and 8-21.

$$Q_i = (E)(Q) = (0.23)(4.2) = 0.97 \text{cfs}$$

$$Q_{BP} = Q - Q_i = 4.2 - 0.97 = 3.23 \text{cfs}$$

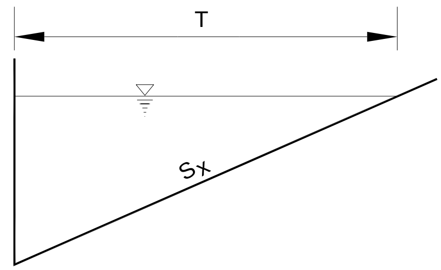
6. The analysis is then repeated with the next curb inlet. The bypass flow (Q_{BP}) from the previous inlet shall be added to the flow from the contributing basin to determine the total flow (Q) to the next inlet.

Note that the City of Spokane requires the analysis to include a 50% clogging factor.

APPENDIX 8G – EXAMPLE CALCULATION: COMBINATION INLET CAPACITY, SUMP

GIVEN

- A crowned private road with a uniform gutter section (as illustrated).
  - Inlet: Metal Frame with Hood, Type 2 and Bi-Directional Vaned Grate, Type 3 – Spokane County Standard Plans B-11 and B-14
  - Gutter Width (W) = 1.5 feet
  - Local depression = 1 inch
  - Cross slope (S_x) = 0.02 feet/foot
  - Road width (RW) = 30 feet
  - Q_{BP} = 0.68 cfs = Upstream inlets total bypass flow rate
  - Q_{BASIN} = 0.82 cfs = Contributing drainage basin direct flow rate



CALCULATIONS

1. Determine the total runoff contributing and bypassed to the combination inlet.

$$Q_{TOTAL} = Q_{BP} + Q_{BASIN} = 0.68\text{cfs} + 0.82\text{cfs} = 1.5\text{cfs}$$

2. From Table 8-7, the non-flooded width for a private road is 12 feet minimum. Determine the allowable spread (T) for the roadway using the following relationship for a crowned roadway:

$$T_{all} = \frac{\text{R}W + 2W - \text{Non - flooded Width}}{2} = \frac{30 + (2)(1.5) - 12}{2} = 10.5 \text{ feet}$$

3. Calculate the depth of flow at the curb (d) using Equation 8-16.

$$d = (T)(S_x) = (10.5)(0.02) = 0.21 \text{ feet}$$

4. Determine the average depth of flow over the grate using Equation 8-22.

$$d_{ave} = d - S_x\left(\frac{W}{2}\right) + y = 0.21 - 0.02\left(\frac{1.5}{2}\right) + \frac{1}{12} = 0.28 \text{ feet}$$

5. Calculate the allowable flow (Q_{all}) using Equation 8-24.

$$Q_{all} = CPd^{3/2} = (3.0)(3.13)(0.28)^{3/2} = 1.38 \text{ cfs}$$

6. Compare the allowable flow to the actual flow.

$$1.38 \text{ cfs}(Q_{all}) \prec 1.5 \text{ cfs}(Q) \qquad \textbf{FAIL*}$$

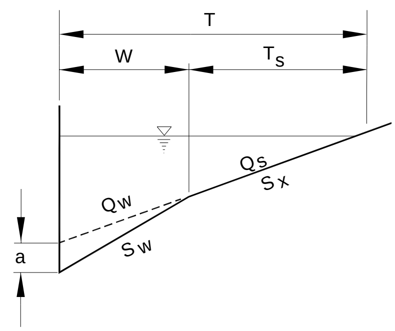
 * The actual flow rate directed at the given metal frame and grate inlet combination exceeds the calculated allowable flow capacity of the structure. The design will need to be altered (i.e. try an additional inlet placed at an intermediate location, contributing basins redefined, new flow rates calculated, and the above steps repeated).

Note that grate perimeter used in this example includes a 50% clogging factor (refer to Table 8-9).

APPENDIX 8H – EXAMPLE CALCULATION: CURB INLET CAPACITY, SUMP

GIVEN

- A crowned private road with a composite gutter section (as illustrated).
  - Curb opening length (L) = 3.0 feet (reduce by half – clogging safety factor)
  - Local depression = 1 inch
  - Cross slope (S_X) = 0.02 feet/foot
  - Gutter cross slope (S_W) = 0.081 feet/foot
  - Gutter Width = 1.5 feet
  - Road width (RW) = 30 feet
  - Q_{BP} = 0.68 cfs = Upstream inlets total bypass
  - Q_{BASIN} = 0.82 cfs = Contributing drainage basin direct flow rate



CALCULATIONS

1. Determine the total runoff contributing and bypassed to the curb inlet.

$$Q_{TOTAL} = Q_{BP} + Q_{BASIN} = 0.68\text{cfs} + 0.82\text{cfs} = 1.5\text{cfs}$$

2. From Table 8-7, the non-flooded width for a private road is 12 feet minimum. Determine the allowable spread (T) for the roadway using the following relationship for crowned roadways:

$$T_{all} = \frac{\text{R}W + 2W - \text{Non-flooded Width}}{2} = \frac{30 + (2)(1.5) - 12}{2} = 10.5 \text{ feet}$$

3. Calculate the depth of flow at the curb (d).

$$d = (1.5)(0.081) + (10.5 - 1.5)(0.02) = 0.30 \text{ feet}$$

4. Calculate the allowable flow (Q_{all}) using Equation 8-25.

$$Q_{all} = 2.3(L + 1.8W)d^{3/2} = 2.3[(1.5 + (1.8)(1.5)](0.30)^{3/2} = 1.59 \text{ cfs}$$

5. Compare the allowable flow to the actual flow.

$$1.59\text{cfs}\left(Q_{all}\right) > 1.5\,\text{cfs}\left(Q\right) \qquad \textbf{OK*}$$

* The actual flow rate directed at the curb inlet is less than the calculated allowable flow capacity of the structure. The design is adequate.

CHAPTER 9 – EROSION AND SEDIMENT CONTROL DESIGN

Chapter Organization

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9.1 INTRODUCTION

This chapter lists the steps for developing a Erosion and Sediment Control (ESC) plan, which is a required component of a Drainage Submittal or permit. Controlling erosion and preventing sediment and other pollutants from leaving the project site during construction can be achieved by implementing the best management practices (BMPs) identified in this chapter. The ESC plan shall outline specific construction BMPs for a project site to avoid adverse stormwater impacts from construction activities on water resources, roads, drainage facilities, surrounding properties and other improvements. Potential impacts due to erosion and sedimentation include:

- Sediment accumulation in culverts, storm drains and open channels, resulting in decreased capacities and the potential for increased flooding and increased maintenance frequency;
- Sedimentation of storage ponds and swales, resulting in decreased infiltrative and storage capacity, and the potential for increased flooding and failure;
- Clogging and failure of Underground Injection Control (UIC) facilities;
- Destruction of vegetation, topsoil and seeds, making re-establishment of vegetation difficult;
- Increased turbidity, reducing water quality in water bodies; and,
- Air pollution due to fugitive dust.

Implementation of an effective ESC plan may help to reduce these potential impacts as well as other unforeseen environmental impacts and associated costs.

Although the construction phase of a project is usually considered a temporary condition, construction work may take place over several seasons. All BMPs used in the course of construction should be of sufficient size, strength, and durability to readily outlast the expected construction schedule and operate properly during the design storm rainfall conditions (see Basic Requirement No. 6 in Chapter 2 for design storm criteria).

9.2 APPLICABILITY

Land-disturbing activities are activities that result in a change in existing soil cover (vegetative or non-vegetative) or site topography. Land-disturbing activities include, but are not limited to, demolition, construction, clearing and grubbing, grading and logging. The following land-disturbing activities require an ESC plan:

- Major land-disturbing activities involving 1 acre or more of disturbed area; or,
- Minor land-disturbing activities, such as grading, involving less than 1 acre of disturbed area but requiring a permit by the local jurisdiction.

An ESC plan, when required, shall be submitted with either the road and drainage plans or the permit application, prior to any land-disturbing activity. Clearing and grading activities for developments will be permitted only if conducted pursuant to an accepted site development plan that establishes permitted areas of clearing, grading, cutting, and filling. When establishing these permitted clearing and grading areas, consideration shall be given to minimizing removal of existing trees and minimizing disturbance and compaction of native soils except as needed for building purposes. These permitted clearing and grading areas and any other areas with a preservation requirement, such as critical or sensitive areas, buffers, native growth protection easement areas or tree retention areas, shall be delineated on the site plans and development site plan. ESC plans are only required to address the area of land that is subject to the land-disturbing activity for which a permit is being requested and the area of land that will serve as the stockpile or staging area for materials.

9.3 EXEMPTIONS

An ESC plan is typically not required for the following activities:

- Commercial agriculture as regulated under RCW Chapter 84.34.020;
- Forest practices regulated under WAC Title 222, except for Class IV General Forest Practices that are conversions from timberland to other uses;
- Actions by a public utility or any other governmental agency to remove or alleviate an emergency condition, restore utility service, or reopen a public thoroughfare to traffic;
- Land divisions, interior improvements to an existing structure, and other activities requiring permits or approvals for which there is no physical disturbance to the surface of the land; and,
- Minor land-disturbing activities that do not require a permit.

Although an ESC plan may not be required for the situations noted above, that does not relieve the proponent from the responsibility of controlling erosion and sediment during construction nor the liability of damage claims associated with adverse impacts on off-site properties.

9.4 EROSION AND SEDIMENT CONTROL (ESC) PLAN

9.4.1 INTRODUCTION

The ESC plan must be prepared by a professional engineer currently licensed in the State of Washington with a good working knowledge of hydrology and ESC practices, or a Certified Erosion and Sedimentation Control Technician. A copy of the

ESC plan must be located on the construction site or within reasonable access to the site. As site construction progresses, the ESC plan may require modification to reflect changes in site conditions.

The ESC plan must accompany the road and drainage plans, grading plan, or permit request and should be integrated into the grading plan whenever possible. It must contain sufficient information to demonstrate to the local jurisdiction that potential problems associated with erosion, sediment, and pollution have been adequately addressed for the proposed project. The drawings and notes should be clear and concise and describe when and where each BMP is to be implemented.

9.4.2 MINIMUM REQUIREMENTS FOR ESC PLANS

At a minimum, all ESC plans must be legible, reproducible and on good quality 24” x 36” bond paper, and must contain the following information:

- Title block, north arrow, scale and plan preparation date;
- Name of property owner, permit applicant, anticipated contact person on-site, and the stamp and signature of the engineer who prepared the plan (note that for municipal projects, this information will be not be available until the pre-construction conference);
- Vicinity map, section, township and range, project address, project boundaries and dimensions;
- Description of project, list of on-site soils and existing vegetation, location of any existing water bodies and/or critical areas;
- Summary description of ESC BMPs utilized (see Section 9.4.3);
- ESC Standard Plan Notes (see Appendix 9A);
- Construction Sequence (see Section 9.4.3)

9.4.3 BEST MANAGEMENT PRACTICES FOR ESC PLANS

BMPs must be used to comply with the requirements of this chapter. It is not the intent of this chapter to limit innovative or creative efforts to effectively control erosion and sedimentation. Experimental ESC management practices to improve erosion control technology and meet the purpose and intent of this chapter are encouraged as a means of solving erosion and sedimentation problems. Minor modifications to standard BMPs are considered experimental ESC management practices and, as with any proposed BMP, must be reviewed and accepted by the local jurisdiction. It is important to note that not only do new facilities and off-site properties need to be protected from erosion and sedimentation, but existing facilities on-site or downstream also need to be evaluated and protected if there is potential for damage due to lack of erosion control.

As the season and subsequent site conditions dictate, alterations to existing ESC BMPs may be warranted or additional ESC measures may be required. Note that items below that are shown in *italics* are considered *General Erosion and Sedimentation Control Notes* (see Appendix 9A for complete list). These notes shall be shown on the ESC plan, when applicable to the given project site.

BMPs are referenced in this chapter by their identification code in the September 2004 *Stormwater Management Manual for Eastern Washington* (e.g., BMP C101, BMP C102). Detailed examples and descriptions of these BMPs are included in Chapter 7 of the Eastern Washington manual. At a minimum, the following items shall be addressed in the ESC plan:

1. Construction Sequence

- *The following construction sequence shall be followed in order to best minimize the potential for erosion and sedimentation control problems:*
    - *a) Clear and grub sufficiently for installation of temporary ESC BMPs;*
    - *b) Install temporary ESC BMPs; constructing sediment trapping BMPs as one of the first steps prior to grading;*
    - *c) Clear, grub and rough grade for roads, temporary access points and utility locations;*
    - *d) Stabilize roadway approaches and temporary access points with the appropriate construction entry BMP;*
    - *e) Clear, grub and grade individual lots or groups of lots;*
    - *f) Temporarily stabilize, through re-vegetation or other appropriate BMPS, lots or groups of lots in situations where substantial cut or fill slopes are a result of the site grading;*
    - *g) Construct roads, buildings, permanent stormwater facilities (i.e. inlets, ponds, UIC facilities, etc.);*
    - *h) Protect all permanent stormwater facilities utilizing the appropriate BMPs;*
    - *i) Install permanent ESC controls, when applicable; and,*
    - *j) Remove temporary ESC controls when:*
        - ♦ *Permanent ESC controls, when applicable, have been completely installed;*
        - ♦ *All land-disturbing activities that have the potential to cause erosion or sedimentation problems have ceased; and,*
        - ♦ *Vegetation had been established in the areas noted as requiring vegetation on the accepted ESC plan on file with the local jurisdiction.*

2. *Clearing Limits*

- Distinctly mark all clearing limits, both on the plans and in the field—taking precaution to visibly mark separately any sensitive or critical areas, and their buffers, and trees that are to be preserved—prior to beginning any land-disturbing activities, including clearing and grubbing; and,
- If clearing and grubbing has occurred, there is a window of 15 days in which construction activity must begin, otherwise the cleared area must be stabilized.
- Suggested BMPs:
  - BMP C101: Preserving Natural Vegetation
  - BMP C102: Buffer Zones
  - BMP C103: High Visibility Plastic or Metal Fence
  - BMP C104: Stake and Wire Fence

3. *Construction Access Route*

- Limit access for construction vehicles to one route whenever possible;
- Stabilize the construction access route with quarry spalls or crushed rock to minimize the tracking of sediment onto roadways;
- *Inspect all roadways, at the end of each day, adjacent to the construction access route. If it is evident that sediment has been tracked offsite and/or beyond the roadway approach, removal and cleaning is required.*
- *If sediment removal is necessary prior to street washing, it shall be removed by shoveling or pickup sweeping and transported to a controlled sediment disposal area.*
- *If street washing is required to clean sediment tracked offsite, once sediment has been removed, street wash wastewater shall be controlled by pumping back on-site or otherwise prevented from discharging into systems tributary to waters of the state;*
- Locate wheel washes or tire baths, if applicable to ESC plan, on site. Dispose of wastewater into a separate temporary on-site treatment facility in a location other than where a permanent stormwater facility is proposed; and,
- *Restore construction access route equal to or better than the pre-construction condition.*
- Suggested BMPs:
  - BMP C105: Stabilized Construction Entrance
  - BMP C106: Wheel Wash

- BMP C107: Construction Road/Parking Area Stabilization

4. ***Install Sediment Controls***

- *Retain the duff layer, native topsoil, and natural vegetation in an undisturbed state to the maximum extent practical;*
- Pass stormwater runoff from disturbed areas through a sediment pond prior to leaving a construction site or discharging to an infiltration facility;
- Keep sediment on the project site, to the maximum extent practical, in order to protect adjacent properties, water bodies, and roadways;
- Stabilize earthen structures such as dams, dikes, and diversions with either quarry spalls, seed or mulch, or a combination thereof;
- Locate sediment facilities such that they will not interfere with natural drainage channels or streams; and,
- *Inspect sediment control BMPs weekly at a minimum, daily during a storm event, and after any discharge from the site (stormwater or non-stormwater). The inspection frequency may be reduced to once a month if the site is stabilized and inactive.*
- Suggested BMPs:
  - BMP C230: Straw Bale Barrier
  - BMP C231: Brush Barrier
  - BMP C232: Gravel Filter Berm
  - BMP C233: Silt Fence
  - BMP C234: Vegetated Strip
  - BMP C235: Straw Wattles
  - BMP C240: Sediment Trap
  - BMP C241: Temporary Sediment Pond

5. ***Soil Stabilization***

- Select appropriate BMPs to protect the soil from the erosive forces of raindrop impact, flowing water and wind, taking into account the expected construction season, site conditions and estimated duration of use;
- *Control fugitive dust from construction activity in accordance with state and local air quality control authorities with jurisdiction over the project area;*
- *Stabilize exposed unworked soils (including stockpiles), whether at final grade or not, within 10 days during the regional dry season (July 1 through September 30) and within 5 days during the regional wet season*

(October 1 through June 30). Soils must be stabilized at the end of a shift before a holiday weekend if needed based on the weather forecast. This time limit may only be adjusted by a local jurisdiction with a "Qualified Local Program," if it can be demonstrated that the recent precipitation justifies a different standard and meets the requirements set fourth in the Construction Stormwater General Permit; and,

- Stabilization practices include, but are not limited to, temporary and permanent seeding, sodding, mulching, plastic covering, erosion control fabric and mats, soil application of polyacrylamide (PAM) and the early application of gravel base on areas to be paved, and dust control.
- Suggested BMPs:
    - BMP C120: Temporary and Permanent Seeding
    - BMP C121: Mulching
    - BMP C122: Nets and Blankets
    - BMP C123: Plastic Covering
    - BMP C124: Sodding
    - BMP C125: Topsoiling
    - BMP C126: Polyacrylamide (PAM) for Soil Erosion Protection
    - BMP C130: Surface Roughening
    - BMP C131: Gradient Terraces
    - BMP C140: Dust Control

6. *Protection of Inlets*

- *Protect inlets, drywells, catch basins and other stormwater management facilities from sediment, whether or not facilities are operable,* so that stormwater runoff does not enter the conveyance system (both on and off site) without being treated or filtered to remove sediment;
- *Keep roads adjacent to inlets clean;* sediment and street wash water shall not be allowed to enter the conveyance system (both on and offsite) without prior treatment;
- *Inspect inlets weekly at a minimum and daily during storm events.* Inlet protection devices shall be cleaned or removed and replaced before 6 inches of sediment can accumulate.
- Suggested BMP:
    - BMP C220: Storm Drain Inlet Protection

7. Runoff from Construction Sites

- Protect down-gradient properties, waterways, and stormwater facilities from possible impacts due to increased flow rates, volumes, and velocities of stormwater runoff from the project site that may temporarily occur during construction;
- *Construct stormwater control facilities (detention/retention storage pond or swales) before grading begins. These facilities shall be operational before the construction of impervious site improvements; and,*
- Protect permanent infiltration ponds that are used for flow control during construction.
- Suggested BMPs:
    - BMP C240: Sediment Trap
    - BMP C241: Temporary Sediment Pond

8. Washout Site for Concrete Trucks and Equipment

- Designate the location of a slurry pit where concrete trucks and equipment can be washed out. Slurry pits are not to be located in or upstream of a swale, drainage area, stormwater facility or water body, or in an area where a stormwater facility is existing or proposed.
- Suggested BMP:
    - BMP C151: Concrete Handling

9. Material Storage/Stockpile

- Identify locations for storage/stockpile areas, within the proposed ESC plan boundaries, for any soil, earthen and landscape material that is used or will be used on-site;
- *Stockpile materials (such as topsoil) on-site, keeping off roadway and sidewalks; and,*
- Maintain on-site, as feasible, items such as gravel and a roll of plastic, for emergency soil stabilization during a heavy rain event, or for emergency berm construction.
- Suggested BMP:
    - BMP C150: Materials On Hand

10. Cut and Fill Slopes

- Consider soil type and its erosive properties;

- Divert any off-site stormwater run-on or groundwater away from slopes and disturbed areas with interceptor dikes, pipes or temporary swales. Off-site stormwater shall be managed separately from stormwater generated on-site;
- Reduce slope runoff velocities by reducing the continuous length of slope with terracing and diversion, and roughening the slope surface;
- Place check dams at regular intervals within ditches and trenches that are cut into a slope; and,
- Stabilize soils on slopes, where appropriate.
- Suggested BMPs:
  - BMP C120: Temporary and Permanent Seeding
  - BMP C130: Surface Roughening
  - BMP C131: Gradient Terraces
  - BMP C200: Interceptor Dike and Swale
  - BMP C201: Grass-Lined Channels
  - BMP C204: Pipe Slope Drains
  - BMP C205: Subsurface Drains
  - BMP C206: Level Spreader
  - BMP C207: Check Dams
  - BMP C208: Triangular Silt Dike (Geotextile-Encased Check Dam)

11. Stabilization of Temporary Conveyance Channels and Outlets

- Design, construct and stabilize all temporary on-site conveyance channels to prevent erosion from the expected flow velocity of a 2-year, NRCS Type II, 24-hour frequency storm or 2-year Rational Method event, in the post-developed condition; and,
- Stabilize outlets of all conveyance systems adequately to prevent erosion of outlets, adjacent streambanks, slopes and downstream reaches.
- Suggested BMPs:
  - BMP C202: Channel Lining
  - BMP C209: Outlet Protection

12. Dewatering Construction Site

- Discharge any effluent of dewatering operations that has similar characteristics to stormwater runoff at the site, such as foundation, vault, and trench dewatering, into a controlled system prior to discharge into a sediment trap or sediment pond; and,

- Handle highly turbid or otherwise contaminated dewatering effluent, such as from a concrete pour, construction equipment operation, or work inside a coffer dam, separately from stormwater disposed of on-site.
- Consider other disposal options such as:
  - infiltration;
  - transportation off site for legal disposal in a way that does not pollute;
  - treatment and disposal on-site with chemicals or other technologies; and,

13. Control of Pollutants Other Than Sediment on Construction Sites

- Control on-site pollutants, such as waste materials and demolition debris, in a way that does not cause contamination of stormwater or groundwater. Woody debris may be chopped or mulched and spread on-site;
- *Cover, contain and protect all chemicals, liquid products, petroleum products, and non-inert wastes present on-site from vandalism (see Chapter 173-304 WAC for the definition of inert waste), use secondary containment for on-site fueling tanks;*
- *Conduct maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system repairs, solvent and de-greasing operations, fuel tank drain down and removal, and other activities that may result in discharge or spillage of pollutants to the ground or into stormwater runoff using spill prevention measures, such as drip pans. Clean all contaminated surfaces immediately following any discharge or spill incident. If raining, perform on-site emergency repairs on vehicles or equipment using temporary plastic over and beneath the vehicle;*
- *Conduct application of agricultural chemicals, including fertilizers and pesticides, in such a manner, and at application rates, that inhibits the loss of chemicals into stormwater runoff facilities. Amend manufacturer's recommended application rates and procedures to meet this requirement, if necessary; and,*
- Locate pH-modifying sources, such as bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and cutting, exposed aggregate processes, and concrete pumping and mixer washout waters, downstream and away from any stormwater facilities or location of proposed stormwater facilities. Adjust pH if necessary to prevent violations of water quality standards. Obtain approval from Ecology for using chemicals other than liquid CO_2 or dry ice to adjust pH.

- Suggested BMPs:
    - See also Chapter 10 – Source Control
    - BMP C151: Concrete Handling
    - BMP C152: Sawcutting and Surfacing Pollution Prevention

14. Permanent BMPs

- Include permanent BMPs, if necessary, in the ESC plan to ensure the successful transition from temporary BMPs to permanent BMPs; and,
- Restore and rehabilitate temporary BMPs that are proposed to remain in place after construction as permanent BMPs.

15. Maintenance of BMPs

- *Inspect on a regular basis (at a minimum weekly, and daily during/after a runoff producing storm event) and maintain all ESC BMPs to ensure successful performance of the BMPs. Conduct maintenance and repair in accordance with individual ESC BMPs outlined in this section; and,*
- *Remove temporary ESC BMPs within 30 days after they are no longer needed. Permanently stabilize areas that are disturbed during the removal process.*

9.4.4 MODIFICATION TO ESC PLANS

ESC plans may be modified after submittal to the reviewing agency. An amended plan shall be submitted to illustrate any modifications to the methods used to prevent and control erosion and sedimentation.

9.5 ADDITIONAL INFORMATION REGARDING ESC PLANS

9.5.1 PERFORMANCE STANDARDS

The following performance standards represent a minimum threshold for controlling soil erosion and sedimentation caused by land-disturbing activities and will be used to determine if the requirements of this chapter have been met:

1. Minimize Tracking onto Roadways

This performance standard has not been met if soil, dirt, mud or debris is visibly tracked onto the road area and a reasonable attempt to control it through the use of ESC BMPs is not evident.

2. Protection of Roadways, Properties and Stormwater Facilities

This performance standard has not been met if there is visible downstream deposition of soil, dirt, mud or debris, originating from the project site, on adjacent or down-gradient roads, properties or stormwater systems.

3. Proper Washout of Concrete Trucks and Equipment

This performance standard has not been met if there is observation or evidence of concrete washout outside the area designated for concrete washout on the accepted ESC plan.

4. Protection of Water Bodies, Streams and Wetlands

This performance standard has not been met if there is obvious turbidity or deposition of soil, dirt, mud, or debris from the project site into adjacent water bodies or into sensitive or critical areas and their buffers. In addition, the performance standard requires that no construction activity, material or equipment encroach into sensitive or critical areas.

9.5.2 MAINTENANCE RESPONSIBILITY

The proponent is responsible to ensure that BMPs are used, maintained, and repaired so that the performance standards continue to be met. After all land-disturbing activity is complete and the site has been permanently stabilized, maintenance and the prevention of erosion and sedimentation is the responsibility of the property owner. Special criteria regarding the degradation of water resources are found in the Washington Administrative Code of various state agencies such as the Departments of Ecology, Natural Resources, and Fish and Wildlife.

9.5.3 ENFORCEMENT AND APPEALS PROCESS

Review the local jurisdiction’s code to determine the enforcement and appeal processes for violation of the above performance standards.

APPENDIX 9A – ESC STANDARD PLAN NOTES

The following ESC Standard Plan Notes originate from Section 9.4.3. These notes are an overall set; use only what applies to the given project.

1. The following construction sequence shall be followed in order to best minimize the potential for erosion and sedimentation control problems:
   (a) Clear and grub sufficiently for installation of temporary ESC BMPs;
   (b) Install temporary ESC BMPs, constructing sediment trapping BMPs as one of the first steps prior to grading;
   (c) Clear, grub and rough grade for roads, temporary access points and utility locations;
   (d) Stabilize roadway approaches and temporary access points with the appropriate construction entry BMP;
   (e) Clear, grub and grade individual lots or groups of lots;
   (f) Temporarily stabilize, through re-vegetation or other appropriate BMPS, lots or groups of lots in situations where substantial cut or fill slopes are a result of the site grading;
   (g) Construct roads, buildings, permanent stormwater facilities (i.e. inlets, ponds, UIC facilities, etc.);
   (h) Protect all permanent stormwater facilities utilizing the appropriate BMPs;
   (i) Install permanent ESC controls, when applicable; and,
   (j) Remove temporary ESC controls when:
2. Permanent ESC controls, when applicable, have been completely installed;
3. All land-disturbing activities that have the potential to cause erosion or sedimentation problems have ceased; and,
4. Vegetation had been established in the areas noted as requiring vegetation on the accepted ESC plan on file with the local jurisdiction.
5. Inspect all roadways, at the end of each day, adjacent to the construction access route. If it is evident that sediment has been tracked off site and/or beyond the roadway approach, cleaning is required.
6. If sediment removal is necessary prior to street washing, it shall be removed by shoveling or pickup sweeping and transported to a controlled sediment disposal area.
7. If street washing is required to clean sediment tracked off site, once sediment has been removed, street wash wastewater shall be controlled by pumping back on-site or otherwise prevented from discharging into systems tributary to waters of the state.
8. Restore construction access route equal to or better than the pre-construction condition.

9. Retain the duff layer, native topsoil, and natural vegetation in an undisturbed state to the maximum extent practical.
10. Inspect sediment control BMPs weekly at a minimum, daily during a storm event, and after any discharge from the site (stormwater or non-stormwater). The inspection frequency may be reduced to once a month if the site is stabilized and inactive.
11. Control fugitive dust from construction activity in accordance with the state and/or local air quality control authorities with jurisdiction over the project area.
12. Stabilize exposed unworked soils (including stockpiles), whether at final grade or not, within 10 days during the regional dry season (July 1 through September 30) and within 5 days during the regional wet season (October 1 through June 30). Soils must be stabilized at the end of a shift before a holiday weekend if needed based on the weather forecast. This time limit may only be adjusted by a local jurisdiction with a "Qualified Local Program," if it can be demonstrated that the recent precipitation justifies a different standard and meets the requirements set fourth in the Construction Stormwater General Permit.
13. Protect inlets, drywells, catch basins and other stormwater management facilities from sediment, whether or not facilities are operable.
14. Keep roads adjacent to inlets clean.
15. Inspect inlets weekly at a minimum and daily during storm events.
16. Construct stormwater control facilities (detention/retention storage pond or swales) before grading begins. These facilities shall be operational before the construction of impervious site improvements.
17. Stockpile materials (such as topsoil) on site, keeping off of roadway and sidewalks.
18. Cover, contain and protect all chemicals, liquid products, petroleum product, and non-inert wastes present on site from vandalism (see Chapter 173-304 WAC for the definition of inert waste), use secondary containment for on-site fueling tanks.
19. Conduct maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system repairs, solvent and de-greasing operations, fuel tank drain down and removal, and other activities that may result in discharge or spillage of pollutants to the ground or into stormwater runoff using spill prevention measures, such as drip pans. Clean all contaminated surfaces immediately following any discharge or spill incident. If raining over equipment or vehicle, perform emergency repairs on site using temporary plastic beneath the vehicle.
20. Conduct application of agricultural chemicals, including fertilizers and pesticides, in such a manner, and at application rates, that inhibits the loss of chemicals into stormwater runoff facilities. Amend manufacturer's recommended application rates and procedures to meet this requirement, if necessary.
21. Inspect on a regular basis (at a minimum weekly, and daily during/after a runoff producing storm event) and maintain all erosion and sediment control BMPs to ensure successful performance of the BMPs. Note that inlet protection devices shall be cleaned or removed and replace before six inches of sediment can accumulate.

22. Remove temporary ESC BMPs within 30 days after the temporary BMPs are no longer needed. Permanently stabilize areas that are disturbed during the removal process.

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CHAPTER 10 – SOURCE CONTROL

Chapter Organization

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10.1 INTRODUCTION

Source control consists of measures taken to prevent pollutants from entering stormwater and thus affecting the water quality of surface water and groundwater. Source control measures are typically in the form of best management practices (BMPs) to keep the common pollutants generated in an urban environment from contacting stormwater, either through physical separation of areas or through careful management of activities that generate pollutants. Water pollutants are generally defined as hazardous or toxic solids that are water soluble or transportable, or substances that are liquids at ambient temperatures and pressures. Insoluble gases and vapors are not considered water pollutants.

The main purpose of source control BMPs is to prevent pollutants from coming into contact with stormwater through physical separation and/or management of activities that produce pollutants. Guidance for selecting BMPs to satisfy this basic requirement is presented in Chapter 8 of the *Stormwater Management Manual for Eastern Washington*. For more information regarding source control and the recommended BMPs, visit the Washington State Department of Ecology website at the following address:

- http://www.ecy.wa.gov/programs/wq/stormwater/index.html.

10.2 APPLICABILITY

All projects, unless exempted in Section 2.1.4, shall comply with this Basic Requirement. Project proponents are required to implement applicable source controls through the use of BMPs as specified in Chapter 8 of the *Stormwater Management Manual for Eastern Washington*.

A project proponent is not relieved from the responsibility of preventing pollutant release from coming in contact with stormwater, whether or not the project triggers the regulatory threshold.

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CHAPTER 11 – MAINTENANCE, TRACTS AND EASEMENTS

Chapter Organization

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11.1 MAINTENANCE

11.1.1 INTRODUCTION

Insufficient maintenance of stormwater control facilities can lead to poor performance, shortened life, increased maintenance and replacement costs, and property damage.

The local jurisdiction maintains the stormwater system structures located within the public road right of way and structures located within border easements that serve public road runoff, unless a separate agreement exists whereby the homeowner, property owner or other independent entity is responsible for the maintenance. Drainage tracts created by public projects will be maintained by the local jurisdiction. The project proponent is to provide for the perpetual maintenance of all elements of the stormwater system located outside the public right of way. The high-frequency maintenance of vegetated cover, turf grass and other landscaping within the public right of way and within border easements that accommodate public road runoff is the responsibility of the adjacent property owner. When applicable, the following maintenance-related items shall be submitted with the Drainage Submittal (refer to Chapter 3) for all projects:

- A copy of the conditions, covenants and restrictions (CC&Rs) for the homeowners' association (HOA) in charge of operating and maintaining all elements of the stormwater system;
- A Financial Plan outlining the funding mechanism for the operation, maintenance, repair, and replacement of the private stormwater system, including contingencies; and,
- An Operations and Maintenance (O&M) Manual.

Appendix 5A and 6A of the *Stormwater Management Manual for Eastern Washington* outline facility maintenance recommendations and frequencies.

11.1.2 APPLICABILITY

All projects that meet the regulatory threshold and that propose drainage facilities or structures shall comply with the Basic Requirement for operation and maintenance. All projects that propose UIC facilities also must comply with the operation and maintenance requirements, regardless of whether they meet the regulatory threshold.

11.1.3 HOMEOWNERS' AND PROPERTY OWNERS' ASSOCIATIONS

For privately maintained stormwater systems in residential neighborhoods, a homeowner's association, or alternate entity acceptable to the local jurisdiction, shall be formed to maintain the facilities located outside of the public right of way.

A draft copy of the CC&Rs for the HOA in charge of operating and maintaining the facilities associated with the stormwater system shall be submitted as part of the Drainage Submittal review package. The CC&Rs shall summarize the maintenance and fiscal responsibilities of the HOA, reference the O&M Manual (Section 11.1.4), and include a copy of the sinking fund calculations and Financial Plan (Section 11.1.5). Annual HOA dues shall provide funding for the annual operation and maintenance of all facilities associated with the stormwater system and for the eventual replacement of these facilities.

For commercial/industrial and multi-family residential developments with joint stormwater systems and multiple owners, a property owners' association (POA) or similar entity such as a business shall be formed, or a reciprocal-use agreement executed.

Homeowners' associations and property owners' associations are to be non-profit organizations accepted by the Washington Secretary of State. A standard business license is not acceptable for this purpose.

11.1.4 OPERATION AND MAINTENANCE MANUAL

For stormwater systems operated and maintained by a HOA or POA, an O&M Manual is required. The O&M Manual summarizes the tasks required to ensure the proper operation of all facilities associated with the stormwater system and must include, as a minimum:

- Description of the entity responsible for the perpetual maintenance of all facilities associated with the stormwater system, including legal means of successorship;
- Description of maintenance tasks to be performed and their frequency;
- A list of the expected design life and replacement schedule of each component of the stormwater system;
- A general site plan (drawn to scale) showing the overall layout of the site and all the facilities associated with the stormwater system; and,
- A description of the source control BMPs.

11.1.5 FINANCIAL PLAN

A Financial Plan is required in order to provide the entity responsible for maintenance with guidance with regard to financial planning for maintenance and replacement costs. The Financial Plan shall include the following items:

- A list of all stormwater-related facilities and their expected date of replacement and associated costs;
- Sinking fund calculations that take into consideration probable inflation over the life of the infrastructure and estimates the funds that need to be set aside annually (an example is provided in Appendix 11A); and,
- A mechanism for initiating and sustaining the sinking fund account demonstrating that perpetual maintenance of all facilities associated with the stormwater system will be sustained.

11.1.6 MAINTENANCE ACCESS REQUIREMENTS

An access road is required when the stormwater system facilities/structures are located 8 feet or more from an all weather drivable surface and are maintained by the local jurisdiction. Privately maintained facilities located 15 feet or more from an all weather drivable surface are also required to have an access road. When required, maintenance access roads shall meet the following minimum requirements:

- The horizontal alignment of all access roads shall be designed and constructed to accommodate the turning movements of a Single-Unit Truck (as defined by *AASHTO Geometric Design of Highways and Streets*, Exhibit 2-4, 2004 Edition). The minimum outside turning radius shall be 50 feet. The minimum width shall be 12 feet on straight sections and 15 feet on curves;
- Access roads shall consist of an all weather, drivable surface;
- Access roads shall be located within a 20-foot-minimum-width (or as required by the horizontal alignment requirements) tract or easement, extending from a public or private road;
- Access roads shall have a maximum grade of 10 percent;
- A paved apron must be provided where access roads connect to paved public roads; and,
- Gravel access roads shall have a minimum of 6 inches of crushed surfacing top course, in accordance with WSDOT Standard Specifications and shall be designed to support the heaviest anticipated maintenance vehicle year round.

The following access road requirements apply only when the local jurisdiction has assumed the responsibility of the maintenance and operation of the facilities, though it is recommended that access roads for privately maintained facilities also be designed to meet these criteria:

- If the maintenance access road is longer than 150 feet, a turn-around is required at or near the terminus of the access road. Turn-arounds are required for long, winding, or steep conditions, regardless of the length of the drive, where backing up would otherwise be difficult; and,
- Turn-arounds shall conform to the jurisdiction’s standard plan.

11.2 TRACTS AND EASEMENTS

Flow control and treatment facilities must be located within the right of way, within a border easement parallel to the road or within an individual tract. For lots larger than 1 acre, the drainage facility may be located within a drainage easement if the facility does not occupy more than 10% of the lot and does not straddle private property lines. Stormwater facilities serving commercial projects do not generally require separate tracts or easements unless they serve more than one parcel.

A stormwater facility, as defined for this section, is a swale or pond. It is acceptable for other types of facilities, such as a pipe, to be in a drainage easement.

11.2.1 TRACTS

A drainage tract for access, maintenance, operation, inspection and repair shall be dedicated to the entity in charge of the maintenance and operation of the stormwater system. Unless otherwise approved by the local jurisdiction, a tract will be dedicated when any of the following situations are present:

- Facilities associated with a stormwater system serving a residential development are located outside of the public right of way;
- Drainage ditches are located in residential neighborhoods. The limits of the tract may have to be delineated with a permanent fence when the ditch is located near property lines; or,
- A drainageway is present on a lot of 1 acre or smaller (refer to Section 8.3.4).

Tracts shall be of sufficient width to provide access to, and maintain, repair or replace elements of, the stormwater system without risking damage to adjacent structures, utilities and normal property improvements, and without incurring additional costs for shoring or specialized equipment.

11.2.2 EASEMENTS

A drainage easement for access, maintenance, operation, inspection and repair shall be granted to the entity in charge of the maintenance and operation of the stormwater system. The easement shall grant to the local jurisdiction the right to ingress/egress over the easement for purposes of inspection or emergency repair. If not in a tract, the following infrastructure shall be placed within drainage easements:

- Elements of a stormwater system, such as a pipe, located outside the public right of way. Easements for stormwater conveyance pipes shall be of sufficient width to allow construction of all improvements, including any associated site disturbances, and access to maintain, repair or replace the pipe and appurtenances without risking damage to adjacent structures or incurring additional costs for shoring or special equipment. No storm pipe in a drainage easement shall have its centerline closer than 5 feet to a private rear or side property line. The storm drain shall be centered in the easement. The minimum drainage easement shall be 20 feet;
- For drainage ditches and natural drainageways, the easement width shall be wide enough to contain the runoff from a 50-year storm event for the contributing stormwater basin, plus a 30% freeboard or 1 foot, whichever is greater. Constructed drainage ditches will not typically be allowed to straddle lot lines. Natural drainageways (refer to Section 8.3.4) located on lots larger than 1 acre may be placed in an easement; and,
- Easements for access roads and turnarounds shall be at least 20 feet wide.

Easement documents shall be drafted by the project proponent for review by the local jurisdiction and recorded by the project proponent.

Off-Site Easements

When a land action proposes infrastructure outside the property boundaries, an off-site easement shall be recorded separately from plat documents, with the auditor's recording number placed on the face of the plat. The easement document shall include language prescribed by the local jurisdiction. The easement language shall grant the local jurisdiction the right to ingress and egress for purposes of routine or emergency inspection and maintenance. The following will be submitted to the local jurisdiction for review:

- A legal description of the site stamped and signed by a surveyor;
- An exhibit showing the entire easement limits and easement bearings, stamped and signed by a surveyor;
- Proof of ownership for the affected parcel and a list of signatories; and,
- Copy of the draft easement.

The legal exhibit and description shall have 1-inch margins for all four sides of the page. All text shall be legible and at least 8 point.

For plats and binding site plans, the off-site drainage facility must be clearly identified on the plans and operation and maintenance responsibilities must be clearly defined prior to acceptance of the project.

APPENDIX 11A – EXAMPLE CALCULATION: SINKING FUND

LIST OF QUANTITIES

Description	Units	Quantity	Unit Price		Total
24" Pipe	LF	175	$40.00	$	7,000.00
21" Pipe	LF	50	$40.00	$	2,000.00
18" Pipe	LF	700	$26.00	$	18,200.00
15" Pipe	LF	650	$24.00	$	15,600.00
12" Pipe	LF	1600	$22.00	$	35,200.00
10" Pipe	LF	50	$20.00	$	1,000.00
			Pipe Total	**$**	**79,000.00**
Inlets	EA	22	$500.00	$	11,000.00
Type B Drywells	EA	4	$2,500.00	$	10,000.00
			Structure Total	**$**	**21,000.00**

ANNUAL MAINTENANCE AND OPERATION COSTS

Description	Units	Quantity	Unit Price		Total
Inspect Structures	DAY	4	$50.00	$	200.00
Flush/Clean Inlets	EA	26	$100.00	$	2,600.00
Flush Pipes				$	-
Inspect Ponds and Clean Outlets	LS	1	$500.00	$	500.00
Mowing & Irrigation of Ponds	DAY	34	$250.00	$	8,500.00
			Annual Maintenance Cost	**$**	**11,800.00**

REPLACEMENT COST & ANNUAL COST PER LOT

Description		Total
Assume 50% of Pipe is Replaced in 20 years (=Pipe Total*0.5)	$	39,500.00
Assume 25% of Structures are Replaced in 20 years (=Structure Total*0.25)	$	5,250.00
Total Present Value (PV) of Replaced Pipe and Structures	**$**	**44,750.00**
Future Value of Pipe and Structures (FV), assume inflation=4%, n=20		
FV = PV(F/P, 4%, n=20)	$	98,052.76
Annual Set-Aside for Future Replacement (A), assume interest=6%, n=20		
A = FV(A/F, 6%, n=20)	$	2,665.52
Annual Maintenance and Operation Costs (from subtotal above)	$	11,800.00
Total Annual Costs	**$**	**14,465.52**
Total Charge per Lot, assume 100 Lots		
Charge per Lot = Total Annual Costs / # of Lots		
Charge per Lot	**$**	**144.66**

NOTE: F/P, A/F factors are from interest tables

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