Chapter 7 Detention Facilities for Stormwater Flow Control

This section presents the methods, criteria, and details for design and analysis of detention facilities. These facilities provide for the temporary storage of increased stormwater runoff resulting from development pursuant to the performance standards set forth in Minimum Requirement #7 for flow control (Volume 1).

There are three primary types of detention facilities described in this section: detention ponds, tanks, and vaults.

7.1 Detention Facility Design Criteria

7.1.1 Detention Facility Setbacks

Setback requirements are generally required by the City, uniform building code requirements, the Tacoma Pierce County Health Department, or other state regulations. Where a conflict between setbacks occurs, the City shall require compliance with the most stringent of the setback requirements from the various codes/regulations. The following are the minimum setbacks required per this manual.

- At least 100 feet from drinking water wells, and springs used for public water supplies. Infiltration facilities upgradient of drinking water wells and within 1, 5, and 10-year time of travel zones must comply with Health Department requirements (Washington Wellhead Protection Program, DOH, Publication #331-018).
- All systems shall be at least 10 feet from any building structure and at least 5 feet from any other structure or property line unless approved in writing by Environmental Services. If necessary, setbacks shall be increased from the minimum 10 feet in order to maintain a 1H:1V side slope for future excavation and maintenance. Vertical pond walls may necessitate an increase in setbacks.
- The discharge point shall not be placed on slopes steeper than 20 percent. A geotechnical analysis and report shall be required on slopes over 15% or if located within 200 feet of the top of steep slopes (40% or greater) or a landslide hazard area. More stringent setbacks may be required based upon the Tacoma Municipal Code.
- At least 10 feet from septic tanks and septic drainfields. Additional setbacks from DOH Publication 333-117 Onsite Sewage Systems, Chapter 246-272A WAC may apply. Shall not be located upstream of residential septic systems unless topography or a hydrology analysis clearly indicates that subsurface flows will not impact the drainfield.
- Environmental Services may require additional setbacks or analysis for facilities proposed to be sited within the influence of known contaminated sites or abandoned landfills.

7.1.2 Detention Facility Access

- The detention facility shall be easily accessible in order to perform necessary inspections and maintain the facility.
- Maintenance access road(s) shall be provided to the control structure and other drainage structures associated with the facility.

- Access roads/ramps must meet the following requirements:
    - Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement.
    - Maximum grade shall be 15 percent.
    - Outside turning radius shall be a minimum of 40 feet.
    - Fence gates shall be located only on straight sections of road.
    - Access roads shall be 15 feet in width on curves and 12 feet on straight sections.
    - A driveway meeting City design standards must be provided where access roads connect to paved public roadways.
- If a fence is required, access shall be limited by a double-posted gate. If a fence is not required, access shall be limited by two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.
- Additional easements or modifications to proposed lot boundaries may be required to provide adequate access to detention facilities. Right-of-way may be needed for detention pond maintenance. Any tract not abutting public right-of-way shall have a 15-foot wide extension of the tract to an acceptable access location.

7.1.3 Detention Facility Overflow

In all ponds, tanks, and vaults, a primary overflow (usually a riser pipe within the control structure; see Section 7.5) shall be provided to bypass the 100-year developed peak flow over or around the restrictor system. The design must provide controlled discharge directly into the downstream conveyance system.

7.1.4 Detention Facility Seeps and Springs

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm driven. However, more continuous seeps and springs, which extend through longer dry periods, are likely from a deeper groundwater source. When continuous flows are intercepted and directed through flow control facilities, adjustments to the facility design shall be made to account for the additional base flow. Flow monitoring of intercepted flow may be required for design purposes.

7.1.5 Detention Facility Maintenance

Per Minimum Requirement #10, an operation and maintenance plan shall be prepared for all stormwater management facilities. See Volume 1, Appendix C for specific maintenance requirements. Maintenance shall be a basic consideration in design and cost-determination of the stormwater management facility.

Any standing water removed during the maintenance operation must be disposed of in a City approved manner. See the dewatering requirements in Volume 4 of this manual. Pretreatment may be necessary. Solids must be disposed in accordance with state and local waste regulations.

Facilities shall be constructed such that the facility can be easily inspected by one person. This may require construction of additional inspection ports or access manholes to allow inspection access to be opened by one person.

7.1.6 Detention Facility Easements

See Chapter 13 for information concerning easements.

7.2 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (Chapter 6 and Volume 5), and water quality wetponds and combined detention/wetponds (Volume 5).

7.2.1 Dam Safety for Detention Ponds

Stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more above normal, surrounding grade with the water level at the embankment crest are subject to Ecology's dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate. The Applicant shall contact Ecology's Dam Safety Engineers at Ecology Headquarters if any of these conditions are met.

7.2.2 Design Criteria Specific for Detention Ponds

Standard details for detention ponds are provided in Figure 3 - 13 through Figure 3 - 16 and Table 3 - 10. Control structure discussion and details are provided in Section 7.5.

7.2.2.1 General

- Ponds must be designed as flow-through systems (however, parking lot storage may utilize a back-up system; see Chapter 8). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.
- Pond bottoms shall be level and be located a minimum of 0.5 feet below the inlet and outlet to provide sediment storage.
- Design criteria for outflow control structures are specified in Section 7.5.
- A geotechnical analysis and report must be prepared for slopes 20% or greater, or if located within 200 feet of the top of a slope 20% or greater or landslide hazard area. The scope of the geotechnical report shall include the assessment of impoundment seepage on the stability of the natural slope where the facility will be located within the setback limits set forth in this section.

7.2.2.2 Setbacks

The following setback requirements shall be met, along with those stipulated in Section 7.1.1.

- The 100-year water surface elevation shall be at least 10 feet from any building structure and at least 5 feet from any other structure or property line unless approved in writing by Environmental Services. If necessary, setbacks shall be increased from the minimum 10 feet in order to maintain a 1H:1V side slope for future excavation and maintenance. Vertical pond walls may necessitate an increase in setbacks.

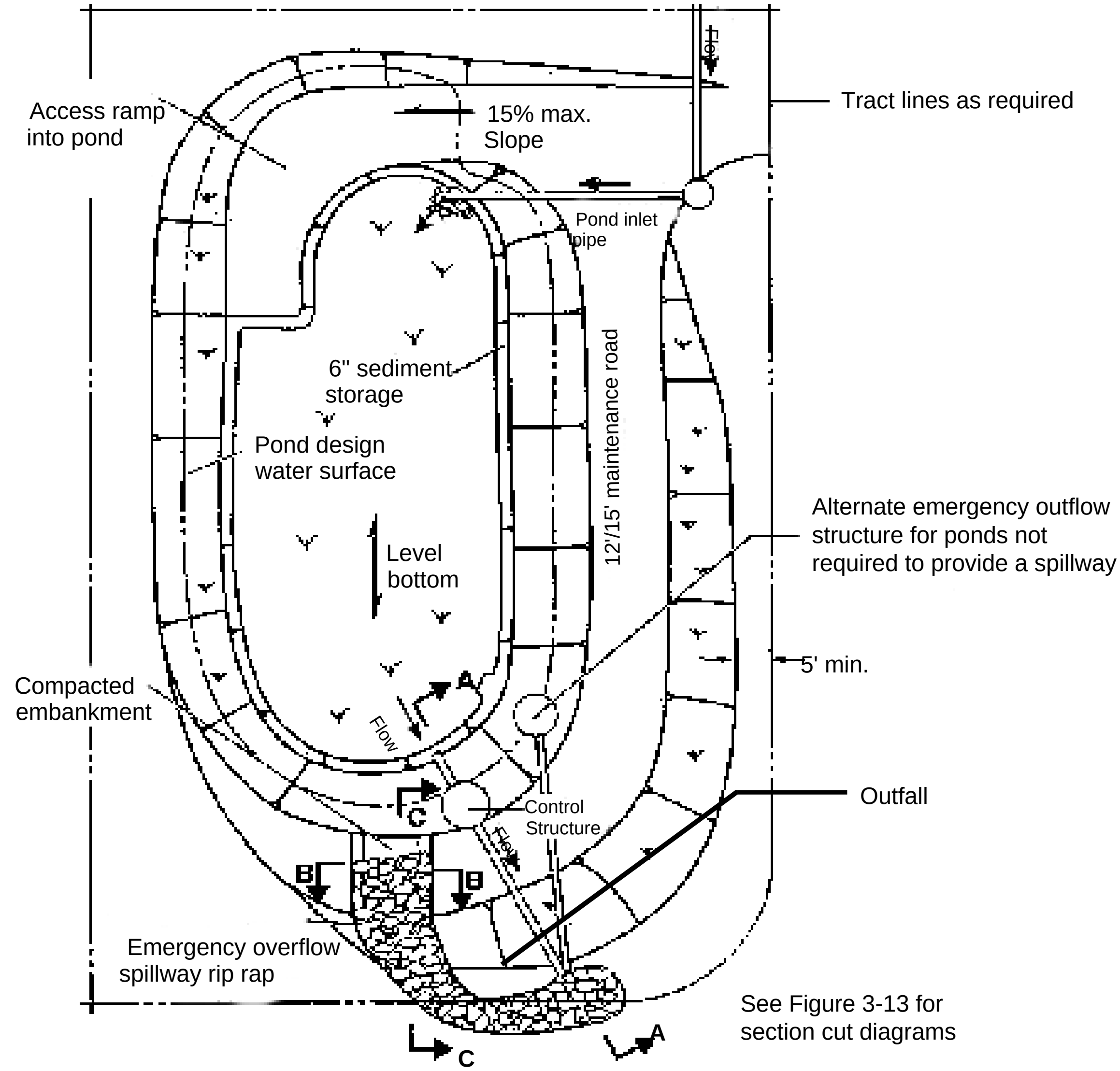
7.2.2.3 Side Slopes

- Interior side slopes up to the emergency overflow water surface shall not be steeper than 3H:1V unless a fence is provided (see Section 7.2.2.8).
- Exterior side slopes must not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.
- Pond walls may be vertical retaining walls, provided:
  - They are constructed of minimum 3,000 psi structural reinforced concrete.
  - A fence is provided along the top of the wall.
  - At least 25% of the pond perimeter shall be a vegetated soil slope not steeper than 3H:1V.
  - Access for maintenance per this section shall be provided.
  - The design is stamped by a licensed structural engineer or civil engineer with structural expertise.
  - Ladders shall be provided on the walls for safety reasons as required by Environmental Services.

  Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type walls may be used if designed by a geotechnical engineer, structural engineer, or civil engineer with structural expertise.

7.2.2.4 Embankments

- Pond berm embankments higher than 6 feet must be designed by a professional engineer with geotechnical expertise.
- For berm embankments 6 feet or less in height, the minimum top width shall be 6 feet or as recommended by a geotechnical engineer.
- Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.
- Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width unless specified otherwise by a geotechnical engineer. Embankment compaction should be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. The embankment fill shall be placed on a stable subgrade and compacted to a minimum of 95% of the Standard Proctor Maximum Density, ASTM Procedure D698. Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content.
- The berm embankment shall be constructed of soils with the following minimum characteristics per the United States Department of Agriculture's Textural Triangle: a minimum of 20% silt and clay, a maximum of 60% sand, a maximum of 60% silt, with nominal gravel and cobble content.
- Anti-seepage filter-drain diaphragms must be placed on all pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Dam Safety Guidelines, Part IV, Section 3.3.B. An electronic version of Dam Safety Guidelines is available in PDF format at www.ecy.wa.gov/programs/wr/dams/dss.html



Note:
This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 3 - 13. Typical Detention Pond

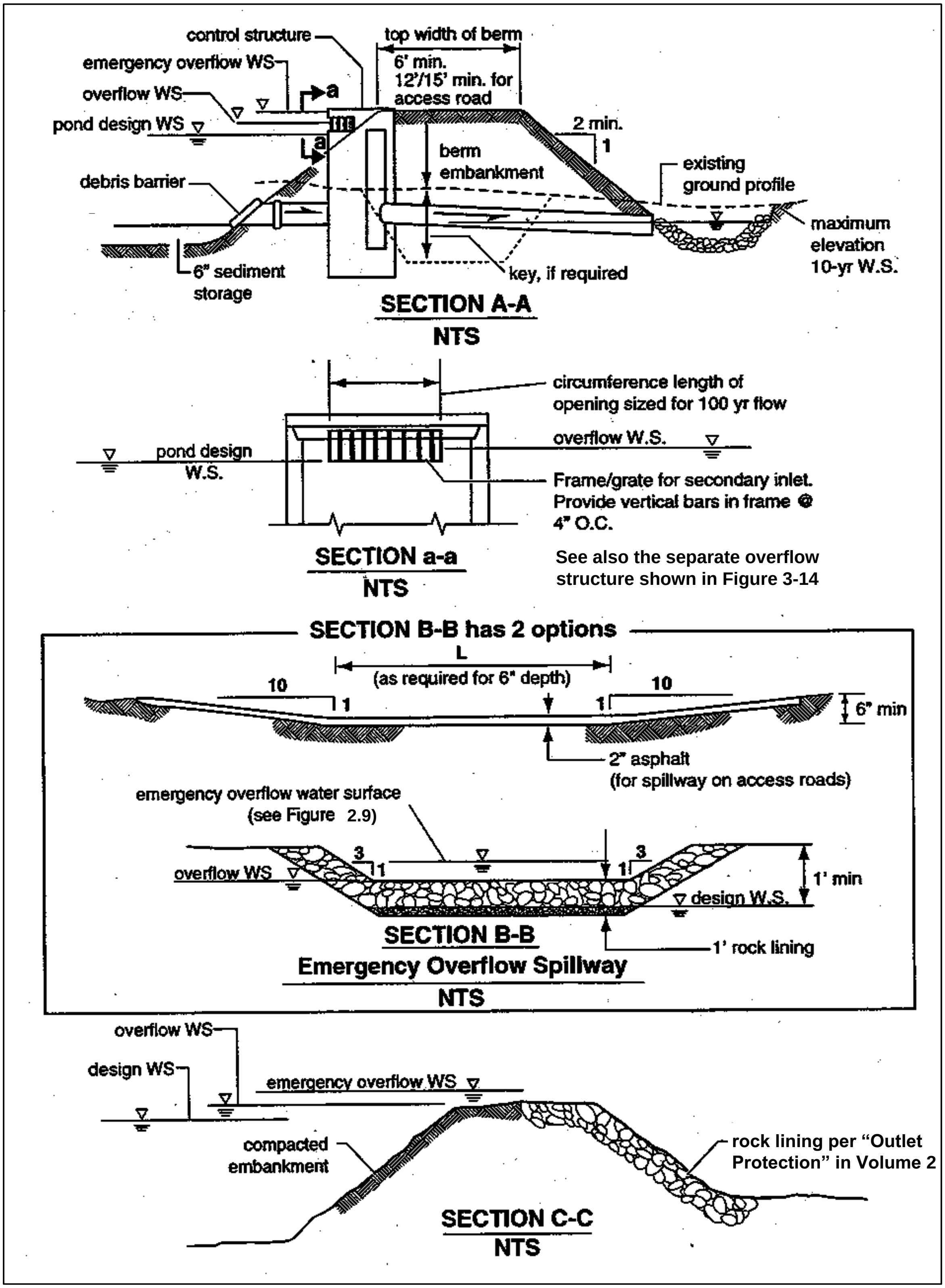
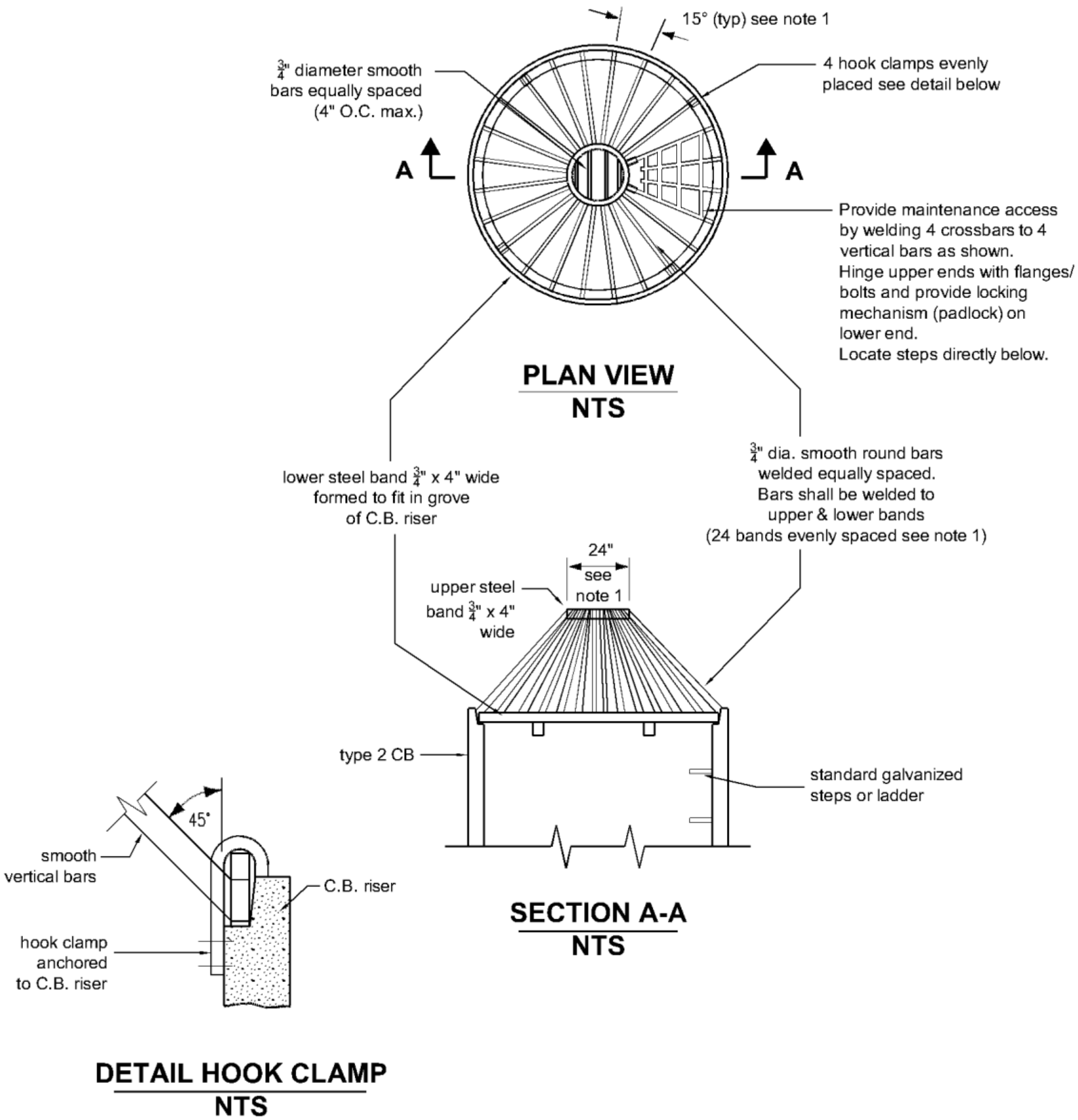


Figure 3 - 14. Typical Detention Pond Sections



NOTES:

1. Dimensions are for illustration on 54" diameter CB. For different diameter CB's adjust to maintain 45° angle on "vertical" bars and 7" o.c. maximum spacing of bars around lower steel band.
2. Metal parts must be corrosion resistant; steel bars must be galvanized.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection (except on type 2 streams)
4. This debris barrier is for use outside of road right-of-way only. For debris cages within road right-of-way.

Figure 3 - 15. Overflow Structure

7.2.2.5 Overflow

The following overflow requirements shall be met along with those stipulated in Section 7.1.3.

- A secondary inlet to the control structure shall be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening ("jailhouse window") in the control structure manhole functions as a weir (see Figure 3 - 14) when used as a secondary inlet.
- The maximum circumferential length of this opening must not exceed one-half the control structure circumference.
- The "birdcage" overflow structure as shown in Figure 3 - 15 may also be used as a secondary inlet.

7.2.2.6 Emergency Overflow Spillway

- In addition to the above overflow provisions, ponds shall have an emergency overflow spillway. For impoundments of 10 acre-feet or greater, the emergency overflow spillway must meet the state's dam safety requirements (see above). For impoundments less than 10 acre-feet, ponds must have an emergency overflow spillway that is sized to pass the 100-year developed peak flow. Emergency overflow spillways shall control the location of pond overtopping such that flow is directed into the downstream conveyance system or public right of way.
- As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a Type II manhole fitted with a birdcage as shown in Figure 3 - 15. The emergency overflow structure must be designed to pass the 100-year developed peak flow, with a minimum of 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point.
- The emergency overflow spillway shall be armored with riprap in conformance with the "Outlet Protection" BMP in Volume 2 (BMP C209). The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system (See Figure 3 - 14).
- Emergency overflow spillway designs must be analyzed as broad-crested trapezoidal weirs as described in Methods of Analysis at the end of this section. Either one of the weir sections shown in Figure 3 - 14 may be used.

7.2.2.7 Access

The following access requirements shall be met along with those stipulated in Section 7.1.2:

- An access ramp is required for pond cleaning and maintenance. The ramp must extend to the pond bottom with a maximum slope of 15 percent (see access road criteria in Section 7.1.2).
- The internal berm of a wetpond or combined detention and wetpond may be used for access if it is designed to support a loaded truck, considering the berm is normally submerged and saturated.

7.2.2.8 Fencing

- A fence is required when a pond interior side slope is steeper than 3H:1V, or when the impoundment is a wall greater than 24 inches in height. Fencing is required for all vertical walls. Fencing is required if more than 10 percent of slopes are steeper 3H:1V.

  Also note that detention ponds on school sites shall comply with safety standards developed by the Department of Health (DOH) and the Superintendent for Public Instruction (SPI). These standards include what is called a ‘non-climbable fence.’

- Fences shall be 6 feet in height (see WSDOT Standard Plan L-2, Type 1 or Type 3 chain link fence). The fence may be a minimum of 4 feet in height if the depth of the impoundment is 5 feet or less (see WSDOT Standard Plan L-2, Type 4 or Type 6 chain link fence).
- Access gates shall be 16 feet in width consisting of two swinging sections 8 feet in width.
- Vertical metal balusters or 9 gauge galvanized steel fabric with bonded vinyl coating shall be used as fence material with the following aesthetic features:
  - Vinyl coating shall be compatible with the surrounding environment (e.g., green in open grassy areas and black or brown in wooded areas). All posts, cross bars, and gates shall be painted or coated the same color as the vinyl clad fence fabric.
  - Fence posts and rails shall conform to WSDOT Standard Plan L-2 for Types 1, 3, or 4 chain link fence.
- For metal baluster fences, Uniform Building Code standards apply.
- Wood fences may be used in residential areas where the fence will be maintained by homeowners associations or adjacent lot owners.
- Wood fences shall have pressure treated posts (ground contact rated) either set in 24-inch deep concrete footings or attached to footings by galvanized brackets. Rails and fence boards may be cedar, pressure-treated fir, or hemlock.

7.2.2.9 Signage

Detention ponds, infiltration ponds, wetponds, and combined ponds shall have a sign placed for maximum visibility from adjacent streets, sidewalks, and paths. An example and specifications for a permanent stormwater control pond are provided in Figure 3 - 16 and Table 3 - 10.

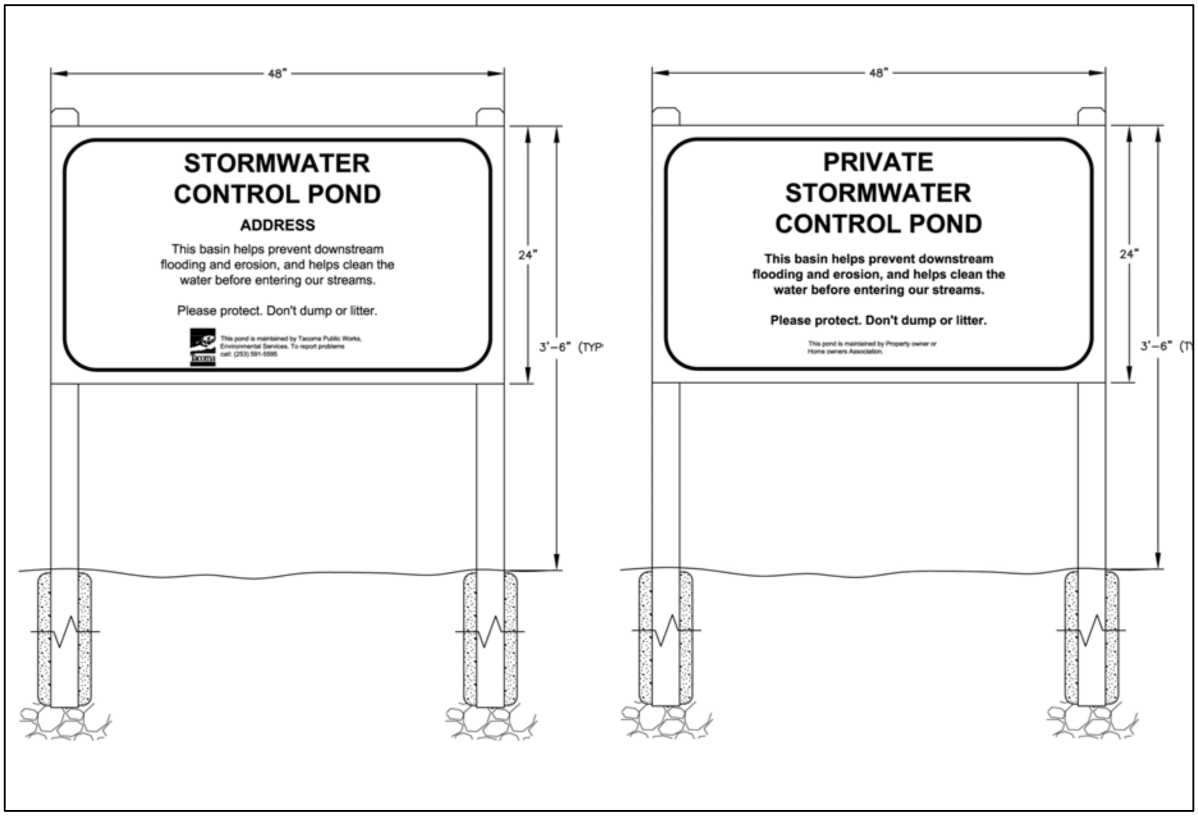


Figure 3 - 16. Examples of Permanent Stormwater Control Pond Sign

Table 3 - 10: Permanent Stormwater Control Pond Sign Specifications

Size	48 inches by 24 inches
Material	0.125 gauge aluminum
Face	Non-reflective vinyl or 3 coats outdoor enamel (sprayed)
Lettering	Silk-screen enamel where possible, or vinyl letters
Colors	Per City specifications where required
Type Face	Helvetica condensed. Title: 3 inch; Sub-Title: 1-1/2 inch; Text: 1 inch;
Border	Outer 1/8-inch border distance from edge: 1/4 inch All text shall be at least 1-3/4 inches from border.
Installation	Secure to chain link fence if available. Otherwise install on two posts as described below. Top of sign no higher than 42 inches from ground surface.
Posts	Pressure-treated 4” x 4”; beveled tops 1-1/2 inches higher than the top of the sign; mounted atop gravel bed, installed in 30-inch concrete-filled post holes (8-inch minimum diameter)
Placement	Face sign in direction of primary visual or physical access. Do not block any access road. Do not place within 6 feet of structural facilities (e.g. manholes, spillways, pipe inlets).
Special Notes	This facility is lined.

7.2.2.10 Planting Requirements

Exposed earth on the pond bottom and interior side slopes shall be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract shall be planted with grass or be landscaped and mulched with a 4-inch cover of hog fuel or shredded wood mulch. Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site. The mulch should be free of garbage and weeds and should not contain excessive resin, tannin, or other material detrimental to plant growth. Multiple plantings and mulching may be required until vegetation has established itself. A bond may be required to guarantee vegetation stabilization for detention facilities.

7.2.2.11 Landscaping

Landscaping is encouraged for most stormwater tract areas (see below for areas not to be landscaped). However, if provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, "naturalistic" stormwater facilities may be placed in open space tracts.

The following guidelines shall be followed if landscaping is proposed for facilities.

- No trees or shrubs shall be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders.
- Species of trees with roots that seek water shall be avoided within 50 feet of pipes or manmade structures.
- Planting shall be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.
    - Trees or shrubs may not be planted on portions of water-impounding berms taller than four feet high. Only grasses may be planted on berms taller than four feet.
    - Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and must have a fibrous root system. Table 3 - 11 gives some examples of trees with these characteristics developed for the Central Puget Sound.

NOTE: The internal berm in a wetpond is not subject to this planting restriction since the failure of an internal berm would be unlikely to create a safety problem.

- All landscape material, including grass, shall be planted in topsoil. Native underlying soils may be made suitable for planting if amended with 4 inches of compost tilled into the subgrade. Compost used should meet specifications for Grade A compost quality. See http://www.ecy.wa.gov/programs/swfa/compost/
- For a naturalistic effect as well as ease of maintenance, trees or shrubs shall be planted in clumps to form "*landscape islands*" rather than planting evenly spaced.
    - The landscaped islands shall be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the 6 feet setback should be counted from the outer drip line of the trees (estimated at maturity).
    - This setback allows a 6-foot wide mower to pass around and between clumps.
- Evergreen trees and trees which produce relatively little leaf-fall (such as Oregon ash, mimosa, or locust) are preferred in areas draining to the pond.

- Trees should be set back so that branches do not extend over the pond (to prevent deposition of leaves into the pond).
- Drought tolerant species are recommended.

Table 3 - 11: Small Trees and Shrubs with Fibrous Roots

Small Trees/High Shrubs	Low Shrubs
Red twig dogwood (*Cornus stolonifera*)*	Snowberry (*Symporicarpus albus*)*
Serviceberry (*Amelanchier alnifolia*)*	Salmonberry (*Rubus spetabilis*)*
Filbert (*Corylus cornuta*, others)*	Rosa rugosa (avoid spreading varieties)
Highbush cranberry (*Vaccinium opulus*)	Rock rose (*Cistus spp., Ceanothus spp.*, choose hardier varieties)
Blueberry (*Vaccinium spp.*)	New Zealand flax (*Phormium penax*)
Fruit trees on dwarf rootstock	Ornamental grasses (e.g. *Miscanthis, Pennisetum*)
Rhododendron (native and ornamental varieties)	

* Native Species

7.2.3 Methods of Analysis

7.2.3.1 Detention Volume and Outflow

The volume and outflow design for detention ponds must be in accordance with Minimum Requirements # 7 in Volume 1 and the hydrologic analysis and design methods in Chapter 1 of Volume 3. Design guidelines for restrictor orifice structures are given in Section 7.5.

The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.

7.2.3.2 Detention Ponds in Infiltrative Soils

Detention ponds may occasionally be sited on soils that are sufficiently permeable for a properly functioning infiltration system (see Chapter 6). These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Chapter 6 for infiltration ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

7.2.3.3 Emergency Overflow Spillway Capacity

For impoundments under 10-acre-feet, or ponds not subject to dam safety requirements, the emergency overflow spillway weir section must be designed to pass the 100-year runoff event for developed conditions assuming a broad-crested weir. The **broad-crested weir equation** for the spillway section in Figure 3 - 17, for example, would be:

$$Q_{100} = C(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\tan\theta)H^{5/2}\right] \quad \text{(equation 1)}$$

Where Q_{100} = peak flow for the 100-year runoff event (cfs)

C = discharge coefficient (0.6)

g = gravity (32.2 ft/sec^2)
L = length of weir (ft)
H = height of water over weir (ft)
θ = angle of side slopes (degrees)

NOTE: Q_{100} is either the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year, 1-hour flow, indicated by an approved continuous runoff model, multiplied by a factor of 1.6

Assuming C = 0.6 and Tan θ = 3 (for 3:1 slopes), the equation becomes:

$$Q_{l00} = 3.21[LH^{3/2} + 2.4\ H^{5/2}] \quad \text{(equation 2)}$$

To find width L for the weir section, the equation is rearranged to use the computed Q_{l00} and trial values of H (0.2 feet minimum):

$$L = [Q_{l00}/(3.21H^{3/2})] - 2.4\ H \text{ or 6 feet minimum} \quad \text{(equation 3)}$$

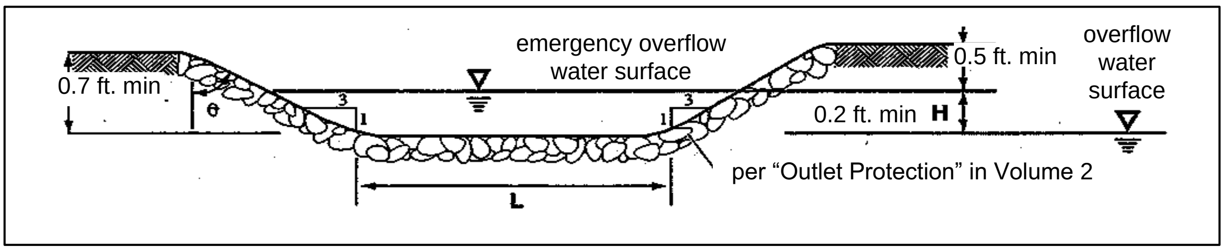


Figure 3 - 17. Weir Section for Emergency Overflow Spillway

7.3 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter pipe. Standard detention tank details are shown in Figure 3 - 18 and Figure 3 - 19. Control structure details are shown in Section 7.5.

Certain of these requirements and design criteria shall also apply to other types of detention facilities, for example arch pipe detention facilities. Environmental Services shall determine which requirements and design criteria are appropriate for various types of detention facilities.

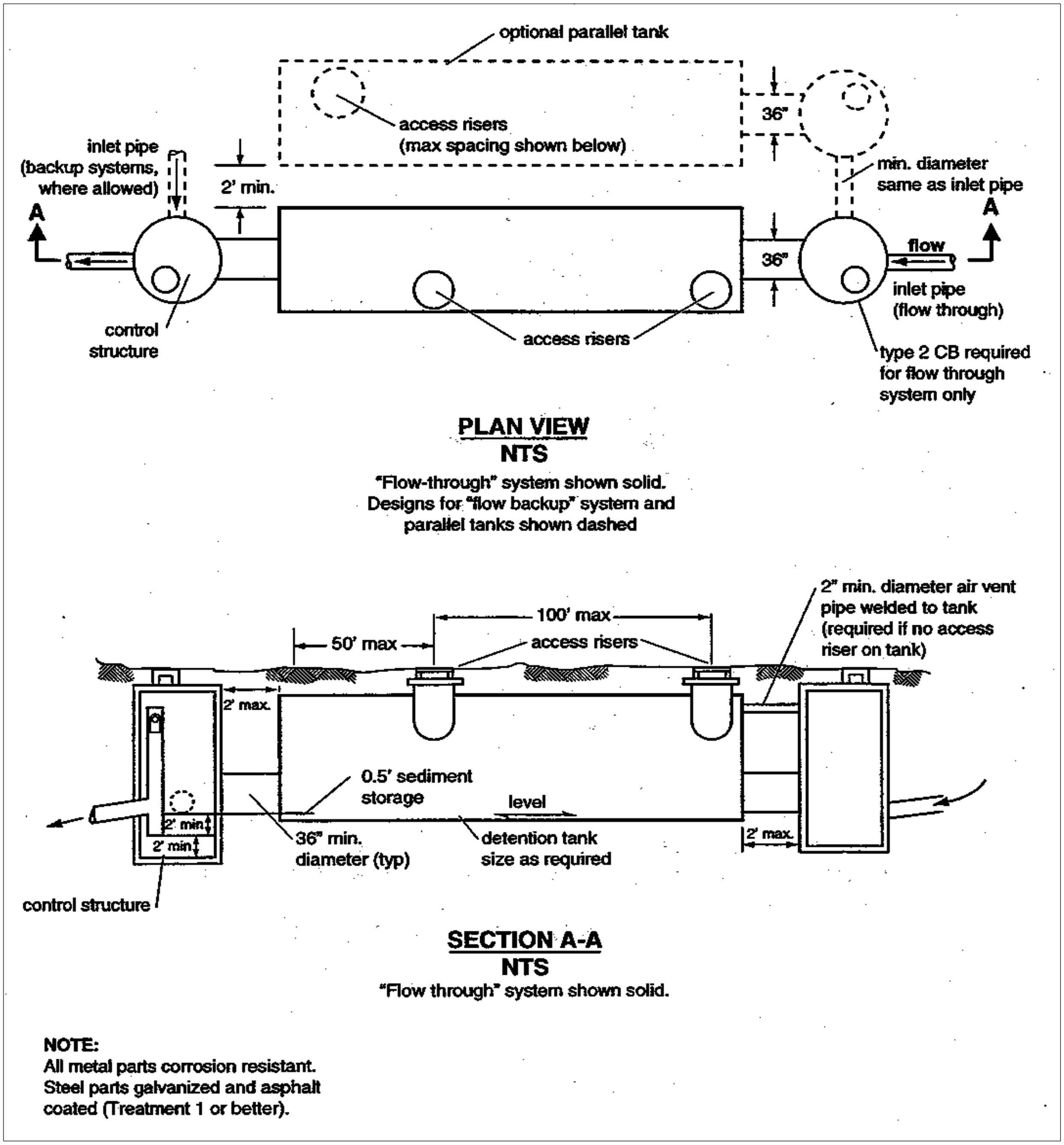
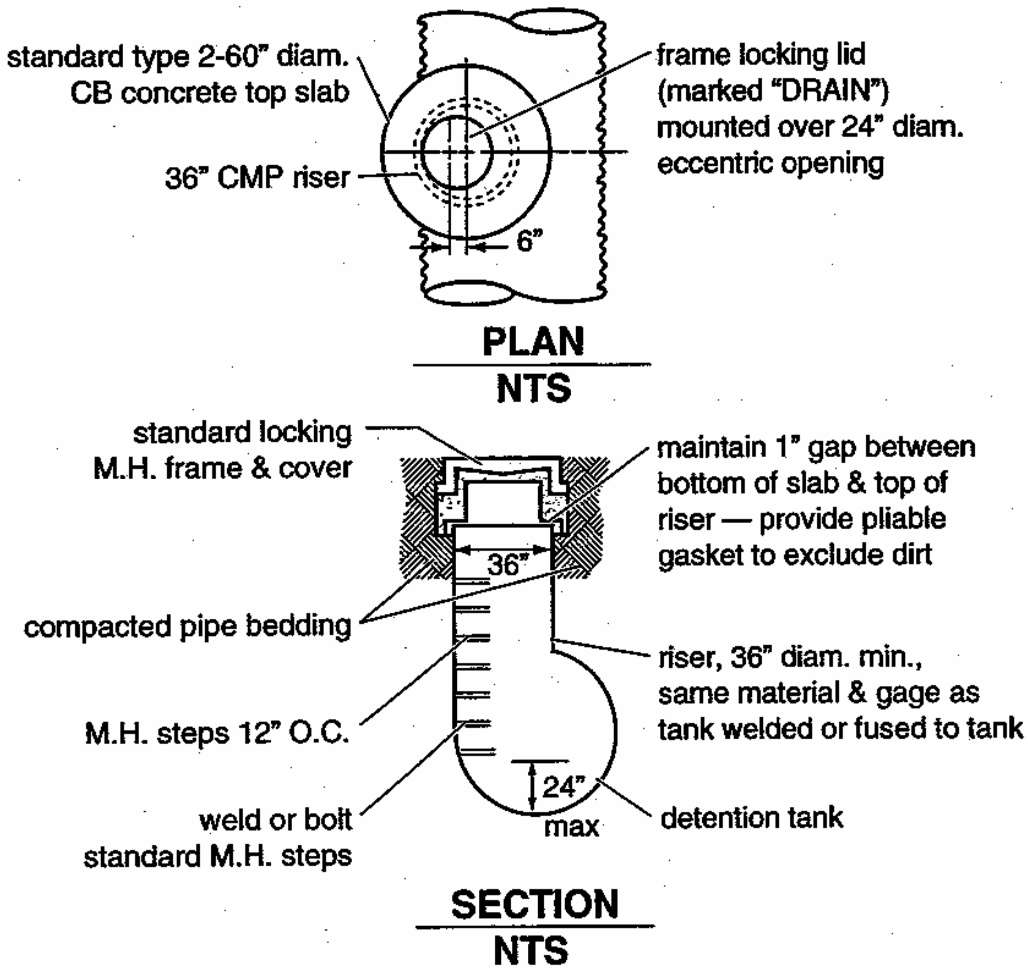


Figure 3 - 18. Typical Detention Tank



Notes:

1. Use adjusting blocks as required to bring frame to grade.
2. All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
3. Must be located for access by maintenance vehicles.
4. May substitute WSDOT special Type IV manhole (RCP only).

Figure 3 - 19. Detention Tank Access Detail

7.3.1 Design Criteria

7.3.1.1 General

- Tanks shall be designed as flow-through systems with manholes in line (see Figure 3 - 18) to promote sediment removal and facilitate maintenance.
- The detention tank bottom shall be located 6 inches below the inlet and outlet to provide dead storage for sediment. If arch pipe is used, the minimum dead storage is 0.5 feet.
- The minimum pipe diameter for a detention tank is 36 inches.
- The minimum thickness for CMP shall be 12-gauge.
- Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe. These sections shall not be considered as access when determining required access points.
- Details of outflow control structures are given in Section 7.5.
- Parallel tanks shall be placed a minimum of two feet from each other measured from the edge of tank or pipe.

7.3.1.2 Materials

Acceptable materials for stormwater facilities include plastics, iron, aluminum, stainless steel, and concrete. Zinc galvanized materials are prohibited. Galvanized metal pipes may only be used it they employ a protective asphalt coating. Pipe material, joints, and protective treatment for tanks shall be in accordance with Section 9.05 of the *WSDOT/APWA Standard Specification*.

7.3.1.3 Structural Stability

Tanks must meet structural requirements for overburden support and traffic loading if appropriate. Tanks must be designed for H-20 live loads when located in areas subject to vehicular traffic. Metal tank end plates shall be designed for structural stability at maximum hydrostatic loading conditions. Tanks shall not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

7.3.1.4 Buoyancy

Buoyancy calculations shall be required where groundwater may induce flotation. Engineers are required to address this issue in project design documentation.

7.3.1.5 Access

The following requirements for access shall be met along with those stipulated in Section 7.1.2.

- The maximum depth from finished grade to tank invert shall be 20 feet.
- Access openings shall be positioned a maximum of 50 feet from any location within the tank. A minimum of one access opening per tank shall be provided.
- The maximum distance between access risers shall be 100 feet.
- All tank access openings shall have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).
- Thirty-six inch minimum diameter CMP riser-type manholes (see Figure 3 - 19) of the same gauge as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.

- All tank access openings must be readily accessible to maintenance vehicles.
- Tanks must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s) just under the access lid.

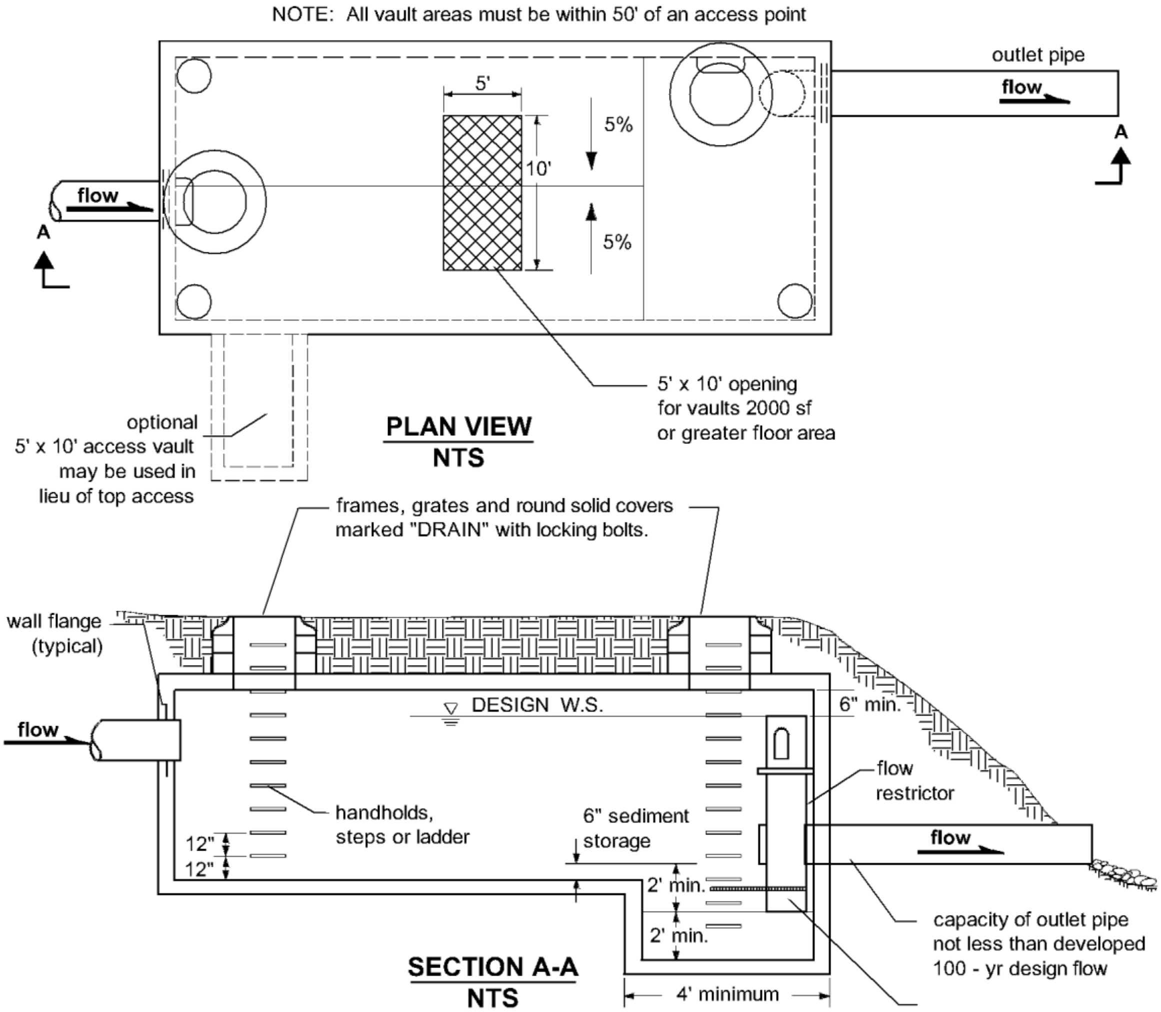
7.3.1.6 Methods of Analysis

Detention Volume and Outflow

The volume and outflow design for detention tanks must be in accordance with Minimum Requirement # 7 in Volume 1 and the hydrologic analysis and design methods in Chapter 1. Restrictor and orifice design are given in Section 7.5.

7.4 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 3 - 20. Control structure details are shown in Section 7.5.



NOTES:

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment 1 or better).
2. Provide water stop at all cast-in-place construction joints. Preceast vaults shall have approved rubber gasket system.
3. Vaults ≤10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

Figure 3 - 20. Typical Detention Vault

7.4.1 Design Criteria

7.4.1.1 General

- Detention vaults shall be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized (as feasible).
- The detention vault bottom shall slope at least 5 percent from each side towards the center, forming a broad “v” to facilitate sediment removal. More than one “v” may be used to minimize vault depth. The vault bottom may be flat with 0.5 – 1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.
- The invert elevation of the outlet shall be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet shall also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.
- Details of outflow control structures are given in Section 7.5.

7.4.1.2 Materials

Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. All construction joints must be provided with water stops. Acceptable materials for stormwater facilities include plastics, iron, aluminum, stainless steel and concrete. Zinc galvanized materials are prohibited. Galvanized metal pipes may only be used if they employ a protective asphalt coating or other Environmental Services approved coating.

7.4.1.3 Structural Stability

All vaults must meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, 1998 Interim Revisions, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet live load requirements of the City. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

7.4.1.4 Access

The following requirements for access shall be met along with those stipulated in Section 7.1.2.

- Access must be provided over the inlet pipe and outlet structure.
- Access openings shall be positioned a maximum of 50 feet from any location within the vault. Additional access points may be needed on large vaults.
- An access opening shall be provided directly above the lowest point of each “v” in the vault floor.
- An access opening shall be provided directly above each connection to the vault.
- For vaults with greater than 1,250 square feet of floor area, a 5’ x 10’ removable panel should be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided, as shown in Figure 3 - 20.
- For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided.

- Ladders and hand-holds shall be provided at all access openings, and as needed to meet OSHA confined space requirements.
- All access openings, except those covered by removable panels, may have round, solid locking lids, or 3-foot square, locking diamond plate covers.
- Vaults with widths 10 feet or less must have removable lids.
- The maximum depth from finished grade to the vault invert shall be 20 feet.
- Internal structural walls of large vaults should be provided with openings sufficient for maintenance access between cells. The openings should be sized and situated to allow access to the maintenance “v” in the vault floor.
- A minimum of two access openings shall be provided into each cell.
- The minimum internal height shall be 7 feet from the highest point of the vault floor (not sump), and the minimum width shall be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as a tank with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.
- Vaults must comply with the OSHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
- Ventilation pipes (minimum 12-inch diameter or equivalent) shall be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively, removable panels over the entire vault, or manhole access at 12-foot spacing, may be provided.

7.4.2 Methods of Analysis

7.4.2.1 Detention Volume and Outflow

The volume and outflow design for detention vaults must be in accordance with Minimum Requirement # 7 in Volume 1 and the hydrologic analysis and design methods in Chapter 1. Restrictor and orifice design are given in Section 7.5.

7.5 Control Structures

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a facility to meet the desired performance.

The restrictor device usually consists of two or more orifices and/or a weir section sized to meet performance requirements. Standard control structure details are shown in Figure 3 - 21 through Figure 3 - 23.

7.5.1 Design Criteria

7.5.1.1 Multiple Orifice Restrictor

In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

- Minimum orifice diameter is 0.5 inches. In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, do not reduce the live storage depth to less than 3 feet in an attempt to meet the performance standards. Under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.

- Orifices may be constructed on a tee section as shown in Figure 3 - 21 or on a baffle as shown in Figure 3 - 22.
- In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g. a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements (see Figure 3 - 23).
- Backwater effects from water surface elevations in the conveyance system shall be evaluated. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes. Backwater effects shall also be analyzed for areas that are influenced by tides.

7.5.1.2 Riser and Weir Restrictor

- Properly designed weirs may be used as flow restrictors (see Figure 3 - 23 and Figure 3 - 25 through Figure 3 - 27). However, they must be designed to provide for primary overflow of the developed 100-year peak flow discharging to the detention facility.
- The combined orifice and riser (or weir) overflow may be used to meet performance requirements. However, the design must still provide for primary overflow of the developed 100-year peak flow assuming all orifices are plugged. Figure 3 - 28 can be used to calculate the head in feet above a riser of given diameter and flow.

7.5.1.3 Access

The following guidelines for access may be used.

- An access road to the control structure is needed for inspection and maintenance, and must be designed and constructed as specified in Section 7.1.2.
- Manhole and catch basin lids for control structures must be locking, and rim elevations must match proposed finish grade.
- Manholes and catch basins must meet the OSHA confined space requirements, which include clearly marking entrances to confined space areas.

7.5.1.4 Materials

Acceptable materials for stormwater facilities include plastics, iron, aluminum, stainless steel and concrete. Zinc galvanized materials are prohibited. Galvanized metal pipes may only be used if they employ an approved protective coating.

7.5.1.5 Maintenance

Per Minimum Requirement #10, an operation and maintenance plan shall be prepared for all stormwater management facilities. See Volume 1, Appendix C for specific maintenance requirements. Maintenance shall be a basic consideration in design and cost-determination of the stormwater management facility.

Any standing water removed during the maintenance operation must be disposed of in a City approved manner. See the dewatering requirements in Volume 4 of this manual. Pretreatment may be necessary. Solids must be disposed in accordance with state and local waste regulations.

Facilities shall be constructed such that the facility can be easily inspected by one person. This may require construction of additional inspection ports or access manholes to allow inspection access to be opened by one person.

7.5.2 Methods of Analysis

This section presents the methods and equations for design of **control structure restrictor devices.** Included are details for the design of orifices, rectangular sharp-crested weirs, v-notch weirs, sutro weirs, and overflow risers.

7.5.2.1 Orifices

Flow-through orifice plates in the standard tee section or turn-down elbow may be approximated by the general equation:

$$Q = C\,A\sqrt{2gh} \qquad \text{(equation 4)}$$

where Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = gravity (32.2 ft/sec^2)

Figure 3 - 24 illustrates this simplified application of the orifice equation.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(equation 5)}$$

where *d* = orifice diameter (inches)
Q = flow (cfs)
h = hydraulic head (ft)

7.5.2.2 Rectangular Sharp-Crested Weir

The rectangular sharp-crested weir design shown in Figure 3 - 25 may be analyzed using standard weir equations for the fully contracted condition.

$$Q = C\,(L - 0.2H)H^{3/2} \qquad \text{(equation 6)}$$

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P = as shown in Figure 3 - 25
L = length (ft) of the portion of the riser circumference as necessary not to exceed 50 percent of the circumference
D = inside riser diameter (ft)

NOTE: This equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.

7.5.2.3 V-Notch Sharp - Crested Weir

V-notch weirs as shown in Figure 3 - 26 may be analyzed using standard equations for the fully contracted condition.

7.5.2.4 Proportional or Sutro Weir

Sutro weirs are designed so that the discharge is proportional to the total head. This design may be useful in some cases to meet performance requirements.

The sutro weir consists of a rectangular section joined to a curved portion that provides proportionality for all heads above the line A-B (see Figure 3 - 27). The weir may be symmetrical or non-symmetrical.

For this type of weir, the curved portion is defined by the following equation (calculated in radians):

$$\frac{x}{b} = 1 - \frac{2}{\pi} Tan^{-1} \sqrt{\frac{Z}{a}} \qquad \text{(equation 7)}$$

Where a, b, x and Z are as shown in Figure 3 - 27.

The head-discharge relationship is:

$$Q = C_d \, b \sqrt{2ga} \left(h_1 - \frac{a}{3} \right) \qquad \text{(equation 8)}$$

where Q = flow (cfs)
g = gravity

Values of C_d for both symmetrical and non-symmetrical sutro weirs are summarized in Table 3 - 12; *h1* is shown in Figure 3 - 27.

When b > 1.50 or a > 0.30, use C_d*=0.6.*

7.5.2.5 Riser Overflow

The nomograph in Figure 3 - 28 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).

NOTE: Q_{100} is either the peak 10-minute flow computed from the 100-year, 24-hour storm and a Type 1A distribution, or the 100-year, 1-hour flow, indicated by an approved continuous runoff model, multiplied by a factor of 1.6

Table 3 - 12: Values of C_d for Sutro Weirs

C_d Values, Symmetrical					
a (ft)	**b (ft)**				
	0.50	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608
Cd Values, Non-Symmetrical					
a (ft)	**b (ft)**				
	0.50	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612	0.6135	0.614

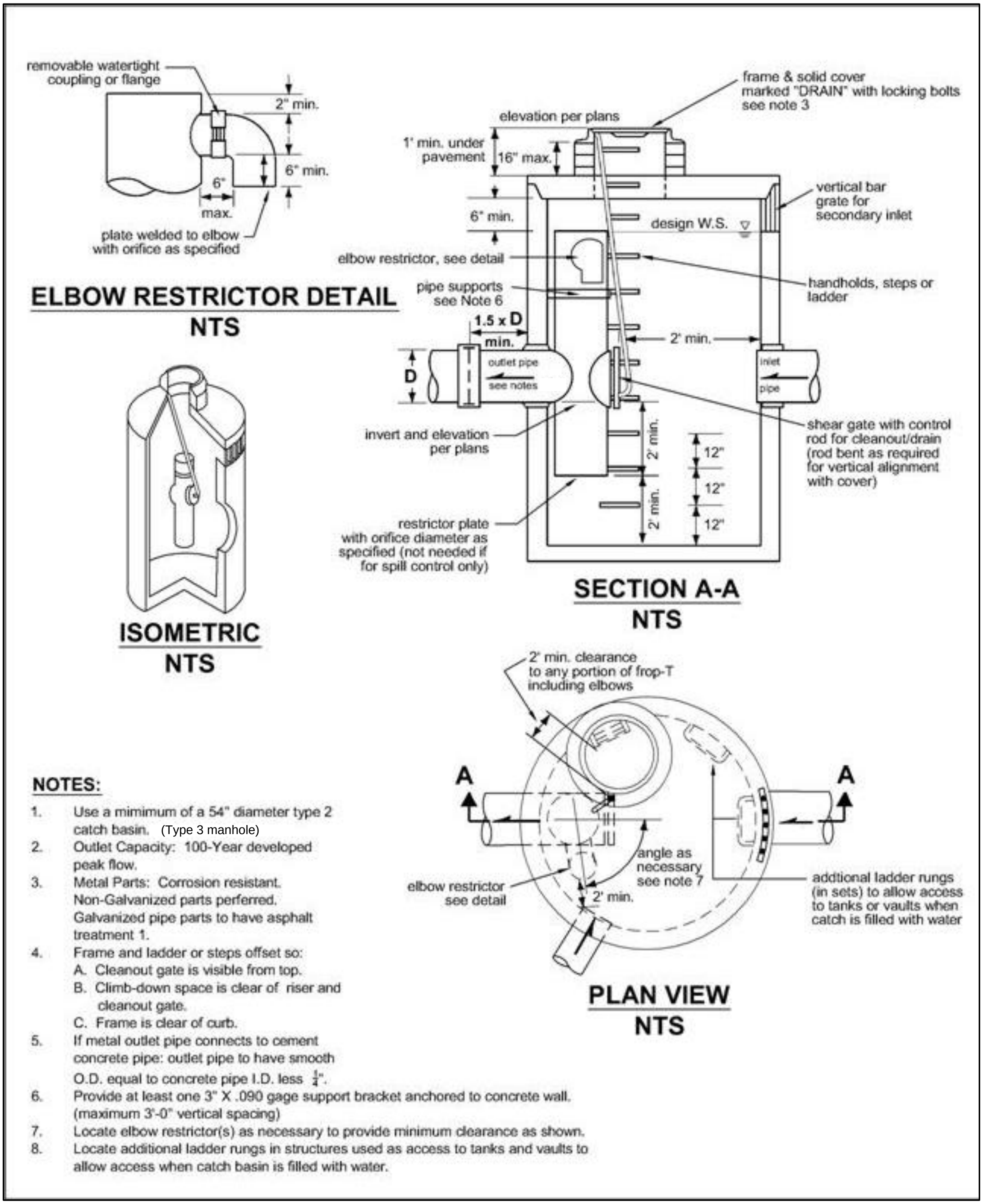


Figure 3 - 21. Flow Restrictor (TEE)

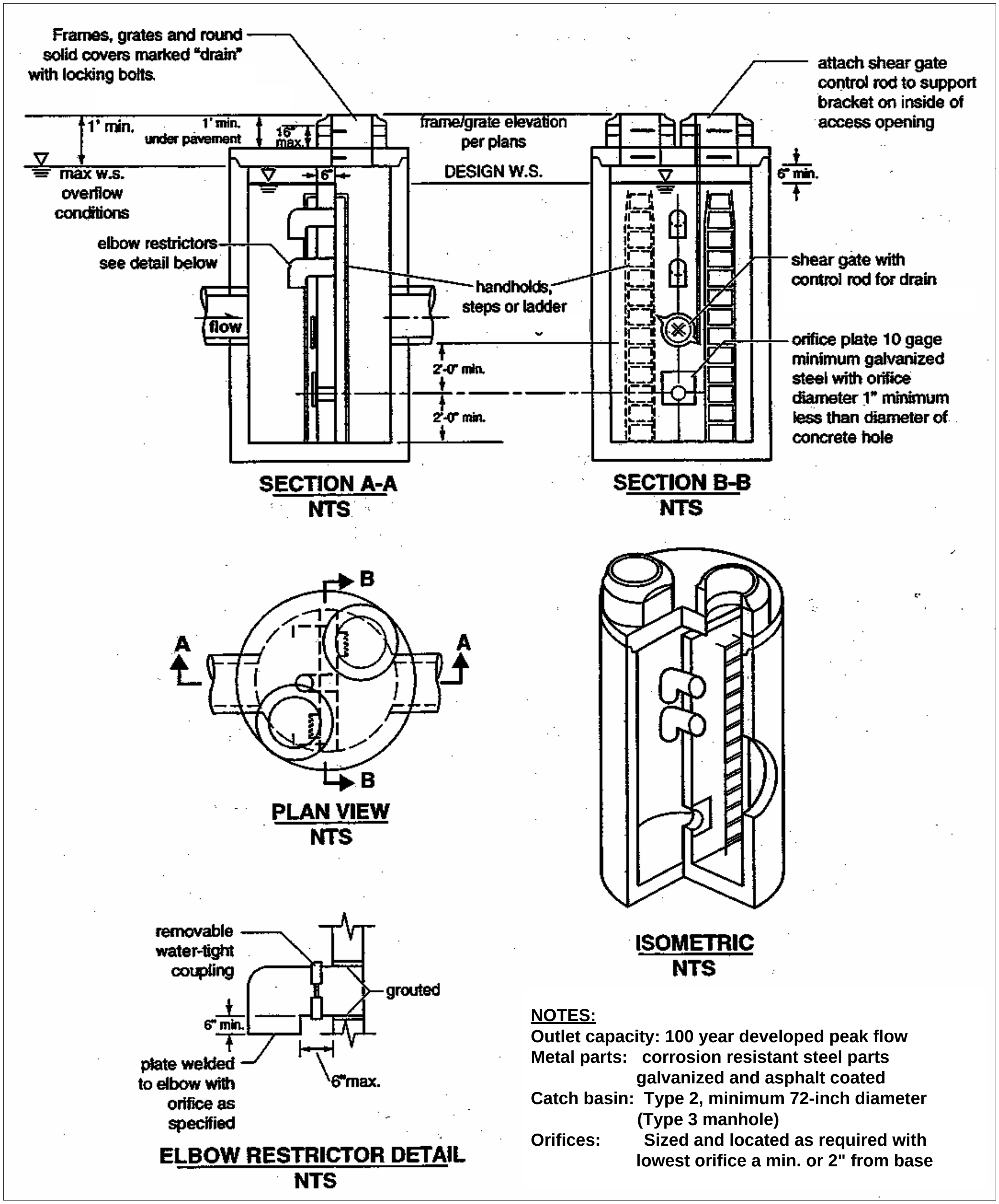
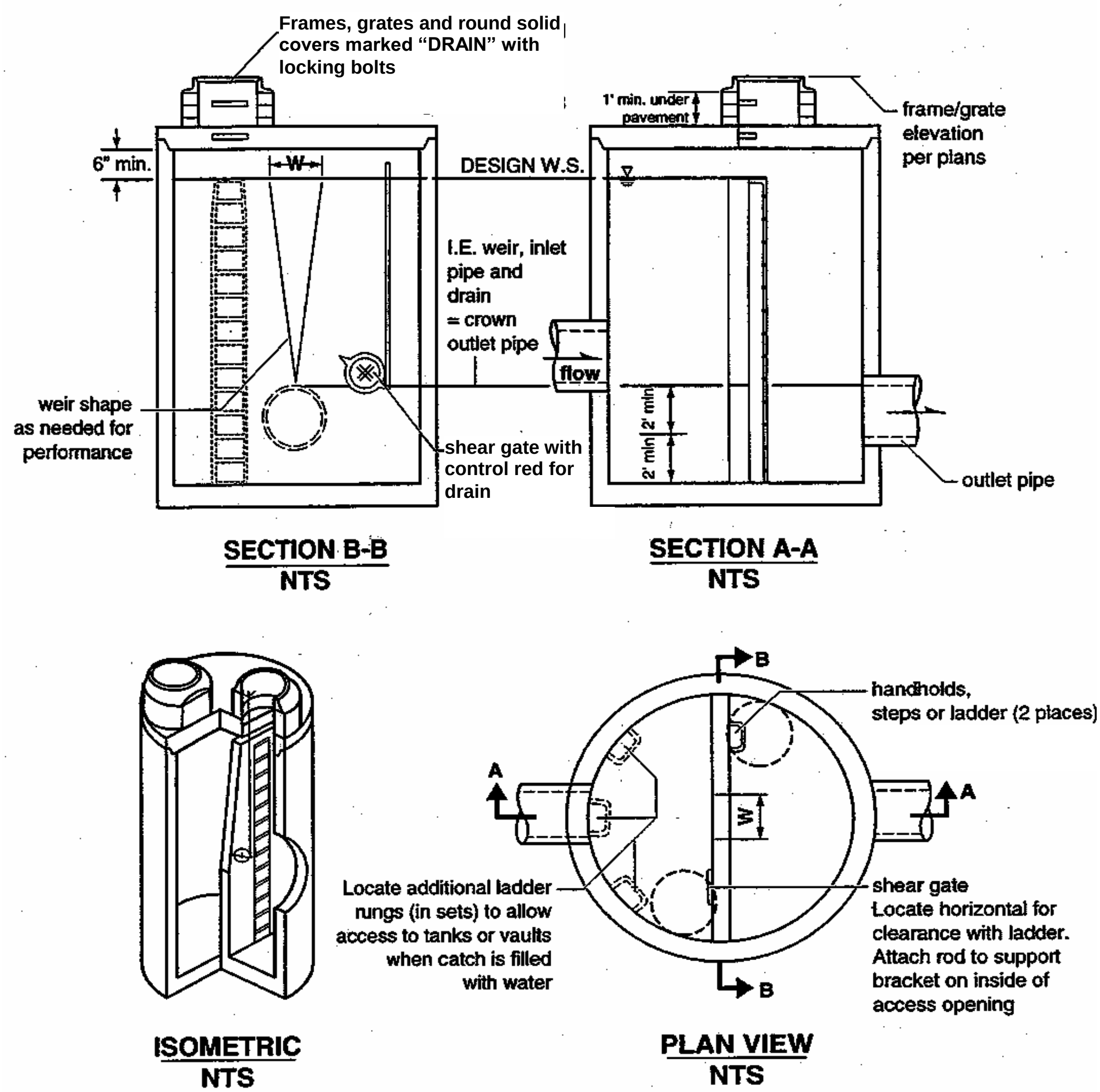


Figure 3 - 22. Flow Restrictor (Baffle)



NOTES:

Outlet Capacity: 100-year developed peak flow.
Metal Parts: Corrosion-resistant steel parts galvanized and asphalt coated.
Catch Basin: Type 2, Min. 72" diameter (Type 3 manhole)
Baffle Wall: To be designed with concrete reinforcing as required.
Spill Containment: Must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Figure 3 - 23. Flow Restrictor (Weir)

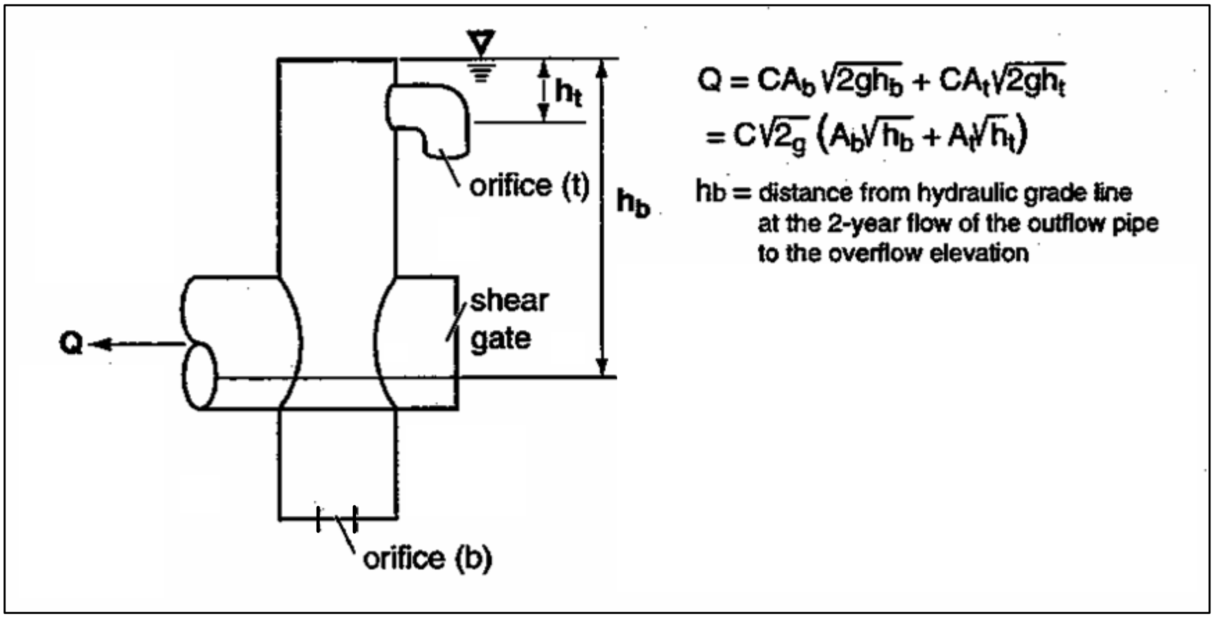


Figure 3 - 24. Simple Orifice

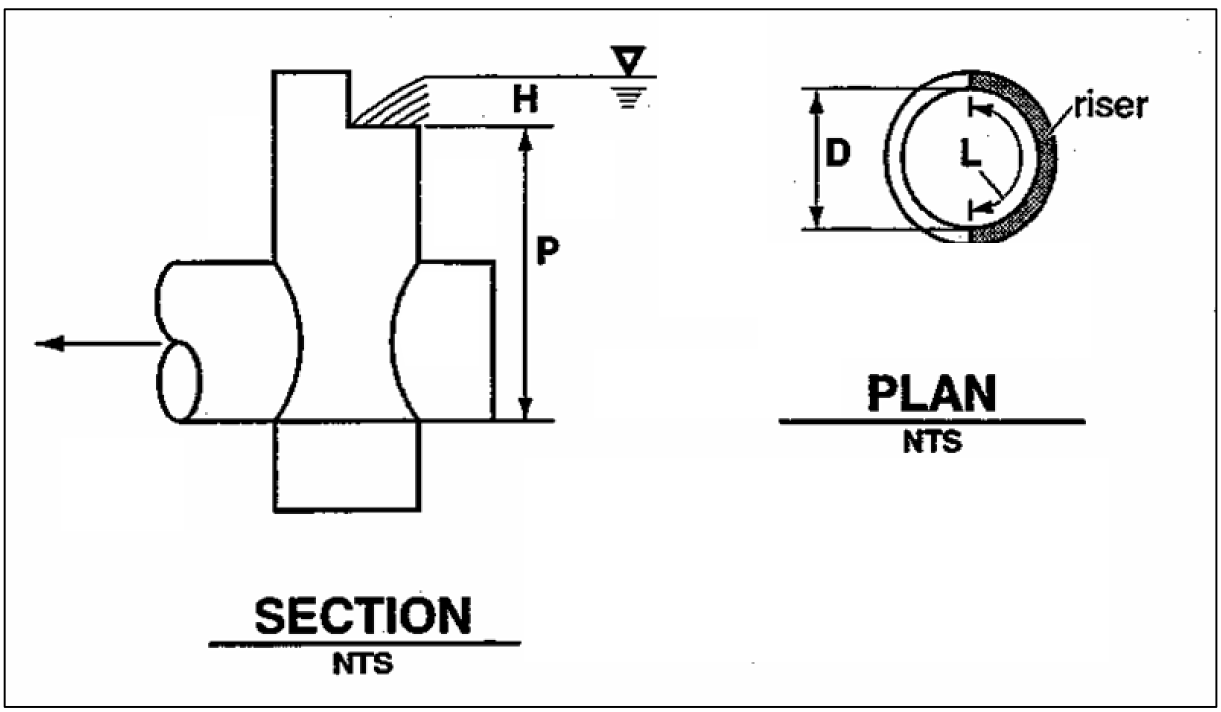
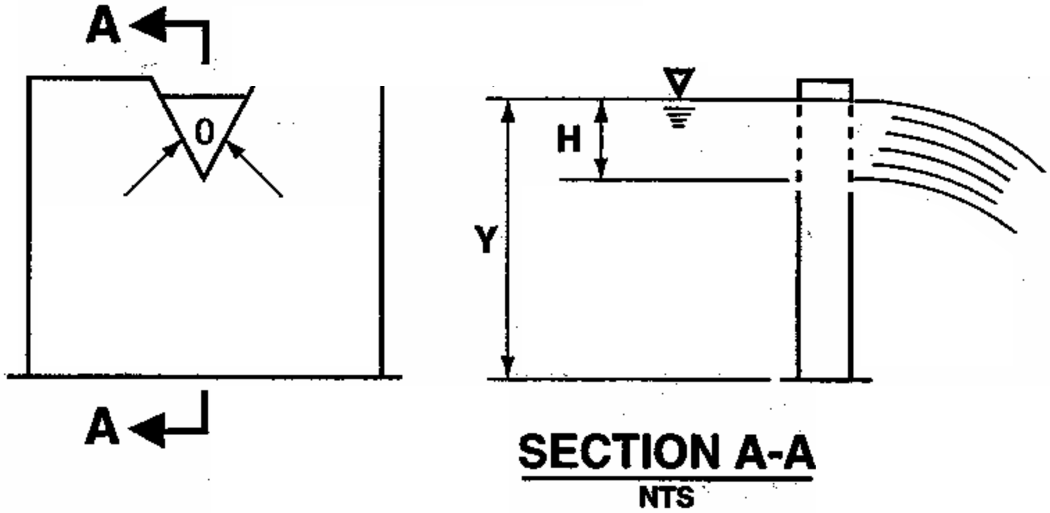


Figure 3 - 25. Rectangular, Sharp-Crested Weir



$$Q = C_d(\tan \theta/2)Y^{5/2}, \text{ in cfs}$$

Where values of C_d may be taken from the following chart:

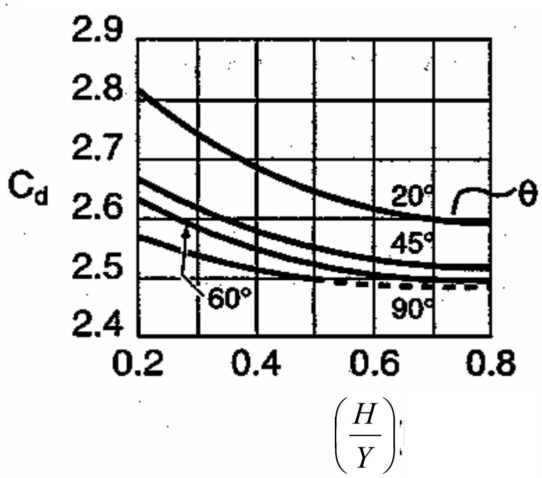


Figure 3 - 26. V-Notch, Sharp-Crested Weir

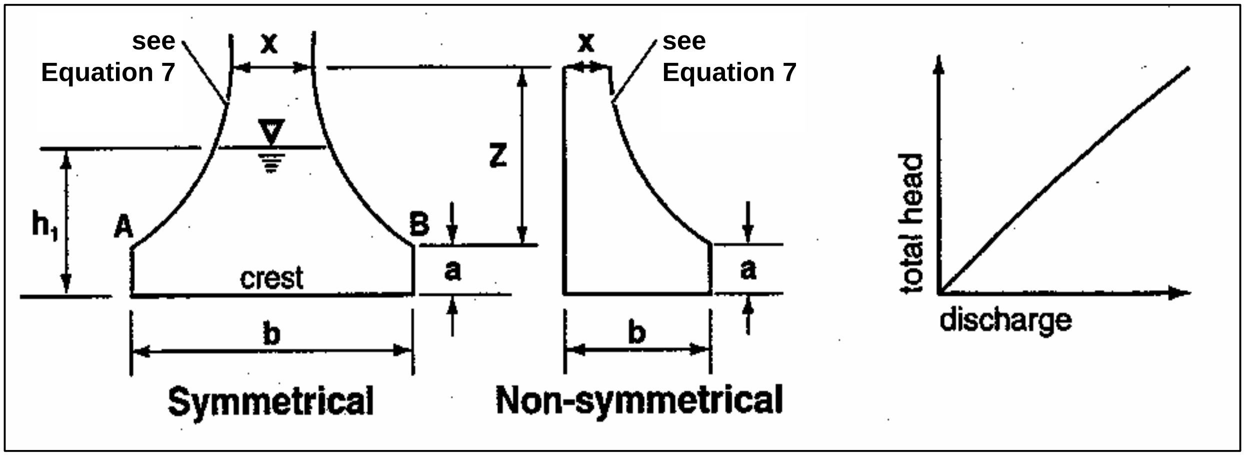


Figure 3 - 27. Sutro Weir

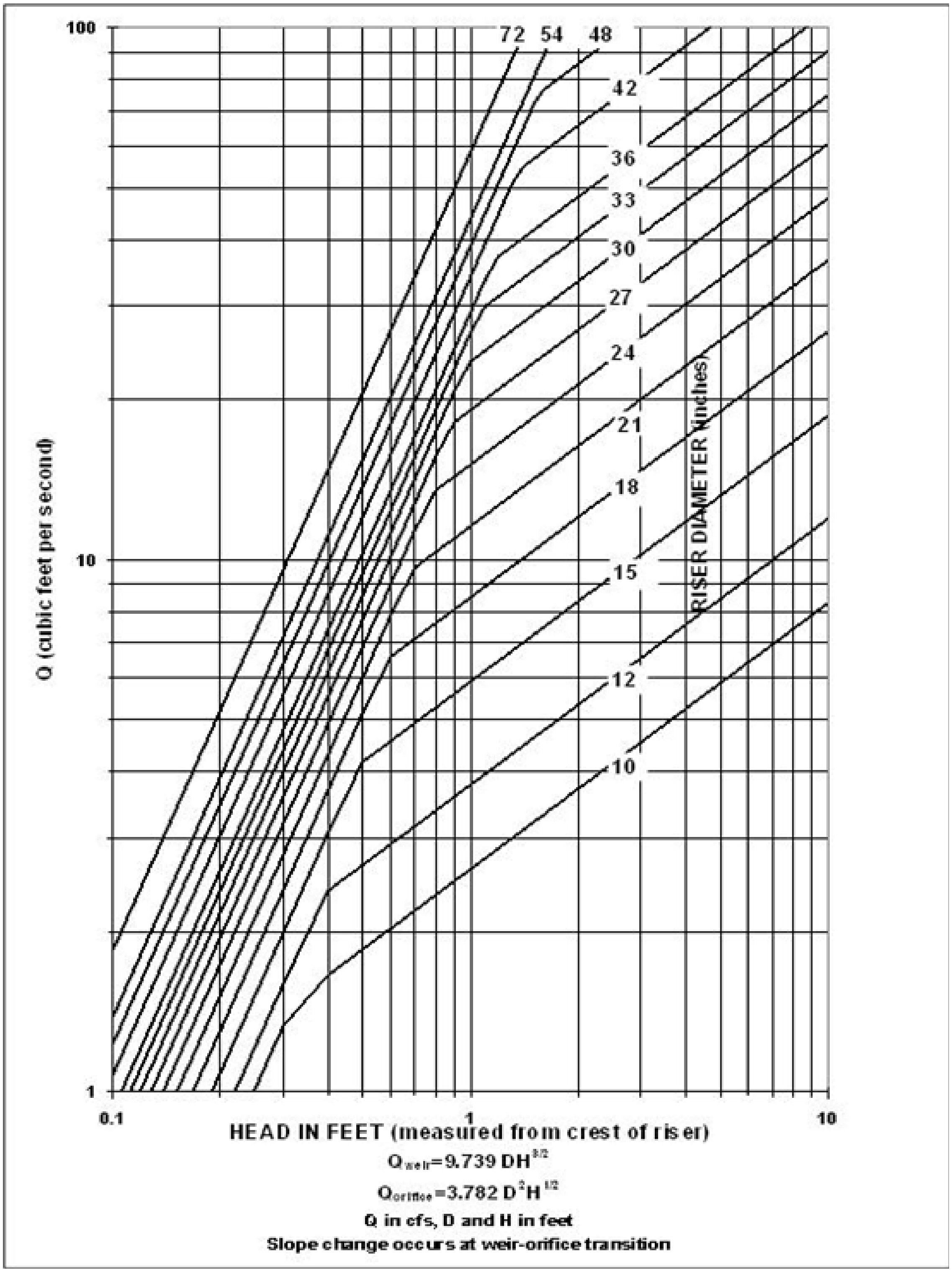


Figure 3 - 28. Riser Inflow Curves