13.0 Introduction

This chapter summarizes evaluation methods and design criteria for flood control detention facilities, referencing the Storage Chapter of Volume 2 of the *UDFCD Manual* for much of the background information. Criteria presented in the Storage Chapter of Volume 2 of the *UDFCD Manual* shall govern except as modified or added to herein.

13.0.1 Stormwater Quality Considerations. Detention facilities are used both for attenuating peak flows during large flood events and for providing extended detention and sedimentation during small, frequent events to enhance stormwater quality. Extended detention facilities used for water quality management may be incorporated into flood control detention basins or kept separate. Extended detention and other water quality best management practices are discussed in Chapter 14, Stormwater Quality, and in Volume 3 of the *UDFCD Manual*.

13.1 General Requirements

13.1.1 Detention shall be Provided for all New Development, Redevelopment and Expansion. The County requires that Water Quality Capture Volume and flood control detention be provided for all new development, redevelopment, or expansion of a site**.** Storage volume and release rate criteria are based on three design events, as follows:

1. Water Quality Capture Volume (WQCV). This is defined in Volume 3 of the *UDFCD Manual*.

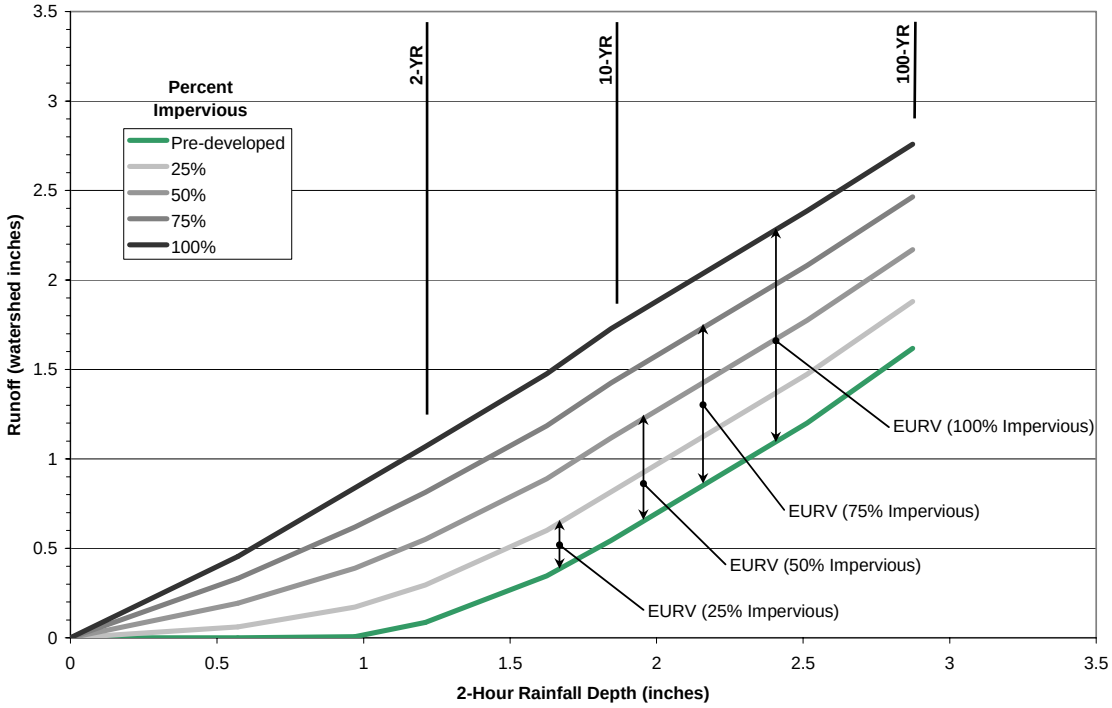
2. Excess Urban Runoff Volume (EURV). This is a volume that, for Type C or D soils, is about twice as large as the Water Quality Capture Volume, or slightly larger than the total 2-year runoff volume, and is similar to the 10-year detention volume using the UDFCD simplified equation. Excess Urban Runoff Volume is further explained in Section 13.1.2.

3. The 100-year event. Procedures for sizing detention facilities for these design events are discussed in Section 13.3 and the Storage Chapter of the *UDFCD Manual*. Facilities that combine the first two events or all three events generally do not require a separate design for Water Quality Capture Volume; the Water Quality Capture Volume and water quality release rate are “built in” to the Excess Urban Runoff Volume design.

13.1.2 Excess Urban Runoff Volume. Excess urban runoff volume is the difference between the developed and pre-developed runoff volume for the range of storms that produce runoff from pervious land surfaces (generally beyond the 2-year event). Excess urban runoff volume is illustrated in Figure 13-1 and is relatively constant for a given imperviousness over a wide range of storm events. Designing a detention basin to capture excess urban runoff volume and release it slowly (at a rate similar to water quality capture volume release) means that all the frequent storms smaller than approximately the 2-year event will be reduced down to flows that are as near to zero as possible and typically less than the threshold value for erosion in most drainageways. In addition, by incorporating an

outlet structure that limits 100-year runoff to the UDFCD allowable release rate, the larger storms greater than the 2-year event will be reduced down to discharges and hydrograph shapes that approximate pre-developed conditions. This reduces the likelihood that runoff hydrographs from multiple basins will combine to produce greater discharges than pre-developed conditions.

FIGURE 13-1
EXCESS URBAN RUNOFF VOLUME (EURV)
[TYPE C/D SOILS]



This detention approach, based on capturing the excess urban runoff volume and releasing it slowly, is termed "full-spectrum detention". Full spectrum detention will be implemented throughout the County with the intent of reducing the flooding and stream degradation impacts associated with urban development more effectively than the former detention criteria. However, full-spectrum detention will not do away with the need to implement effective stream stabilization as identified in Chapter 12, Open Channel Design, nor change the policy regarding consideration of detention benefits discussed in Section 6.8 of Chapter 6, Hydrology.

13.1.3 Compatibility of Full-spectrum Detention Policy with Former Water Quality Capture Volume/10-year/100-year Criteria. The water quality capture volume, excess urban runoff volume and 100-year detention volumes based on the current policy are similar in magnitude to the water quality capture volume, 10-year and 100-year volumes associated with the former criteria (as long as water quality capture volume is added to the UDFCD 100-year required volume). The main difference is that the excess urban runoff volume described in Section 13.3 is drained at a much slower rate than the 10-year detention volume was under the former criteria.

If master plans exist that recommend water quality capture volume/10-year/100-year detention facilities, the County generally intends that these will be implemented as full-spectrum facilities; however, the final determination of detention policy will be by the County.

There may be opportunities to convert existing 10-year/100-year detention facilities with or without water quality capture volume into full-spectrum facilities by reducing the capacity of the 10-year control orifice to a excess urban runoff volume release rate, and ensuring that the debris grate for the excess urban runoff volume orifices and the 100-year outlet and emergency spillway for the facility are adequate.

13.1.4 Definition of Redevelopment, Expansion and/or Improvement. Redevelopment of a site occurs when a change in the property use and/or function is desired, and produces physical changes to the site. The redevelopment of a site shall require that on-site detention be provided for the entire site, including those areas that previously had not provided detention due to the site being developed prior to County criteria and standards.

Expansion of a site occurs when additional area on the site is to be developed. The expansion of a site shall require that current County standards for detention for the **entire site** are met, where feasible. There are two conditions that may arise for site expansion, depending upon whether or not detention has been provided for the existing site prior to expansion.

- Detention has been provided for the existing developed area. The new expansion shall require that additional detention be provided to accommodate the expanded development.
- Detention has not been provided for the existing developed area. Detention will be required for the full expansion and to the extent possible, for the existing site area that has previously been un-detained. The County will require that a reasonable attempt be made to provide detention storage for the previously developed, un-detained portion of the site.

13.2 Regional, Sub-regional, and On-site Detention Facilities

There are three basic approaches for configuring detention facilities, as described below.

13.2.1 Regional Detention. Regional detention, as recognized by Douglas County, refers to online facilities located on a major drainageway, with an upstream watershed area generally ranging from about 130-acres to one-square mile. The definition of a major drainageway is discussed in Section 12.0.4. Figure 13-2 provides a generalized illustration of a regional detention approach.

Regional detention facilities may be constructed by a public entity such as a municipality or special district to serve several landowners in the upstream watershed. It may also be possible for a single landowner to construct a regional facility if the upstream watershed lies within the area controlled by the owner.

Even if the upper part of the watershed is owned by others, it may be possible for a single landowner to construct a regional facility if the conditions below are satisfied and the County approves the concept.

Compared to on-site facilities, regional detention facilities are typically more reliable, require less land area, and are more cost effective to construct and maintain. Regional facilities, being larger, can generally provide more favorable riparian habitat and offer greater opportunities for achieving multi-use objectives, such as combining with park and open space resources and connecting to trail systems. Because of these benefits, Douglas County requires that new development implement regional or sub-regional detention at a subdivision level in lieu of on-site detention at the time each lot is developed. For large subdivisions, the County requires that regional or sub-regional detention be implemented by the first sub-divider rather than passing on the responsibility for detention to owners of individual filings.

Regional detention facilities meeting the requirements below may be recognized and included in hydrologic modeling of downstream major drainageways. Sub-regional and on-site detention facilities may not be recognized in the determination of flow rates for downstream major drainageways.

The County reserves the right to approve any proposed regional detention facilities. Generally, the following conditions shall be met:

1. Regional detention facility shall be designed to accommodate the fully developed flows from the upstream watershed. Designing for upstream offsite areas is discussed in Section 13.3.2.

2. Regional detention facilities are required to be owned and maintained by a public entity, with ownership and maintenance responsibilities clearly defined to ensure the proper function of the facility in perpetuity.

3. Drainage easements for the facility, including access from a public street, shall be provided to the County.

4. An Operations and Maintenance Manual is required to be prepared for the regional facility and accepted by the County.

5. Regional facilities within the District must be designed, constructed and accepted for UDFCD maintenance assistance.

6. The creation of a jurisdictional dam shall be avoided.

7. The facility shall be permitted under applicable environmental permits and clearances.

8. Construction of the regional facility must be coordinated with development in the upstream watershed. If the regional facility has not been constructed, temporary on-site detention (and water quality) shall be required to be

provided with development projects until the regional facility is available.

9. The drainageways upstream of a regional facility shall be designed to convey fully-developed flows to the regional facility and stabilized in accordance with the criteria in Chapter 12, Open Channel Design, and in Section 14.1, Step 3.

10. If the regional facility includes water quality capture volume and if any portions of the drainageways upstream of the facility are determined to be jurisdictional with respect to 404 permitting (see Section 12.0.5), the development sites upstream of the jurisdictional drainageway shall implement reduced directly connected imperviousness to the levels identified in Section 14.2.2.

13.2.2 Sub-regional Detention. Sub-regional detention, as defined by Douglas County, refers to facilities located upstream of a major drainageway (having a drainage area less than 130 acres) and serving more than one lot. The definition of a major drainageway is discussed in Section 12.0.4. Figure 13-3 illustrates a typical sub-regional detention approach.

Like regional facilities, sub-regional detention facilities may be constructed by a public entity such as a municipality or special district to serve several landowners in the upstream watershed or by a single landowner. It may be possible for a single landowner to construct a sub-regional facility if the upper part of the watershed is owned by others if the conditions identified below are achieved and the County approves the placement. Unlike regional detention, sub-regional and onsite detention facilities may not be recognized in the determination of flow rates for downstream major drainageways.

Sub-regional detention offers many of the same benefits as regional facilities in comparison to on-site detention. As such, Douglas County requires that new development implement regional or sub-regional detention at a subdivision level in lieu of on-site detention at the time each lot is developed.

The County reserves the right to approve any sub-regional detention facilities. Generally, the conditions listed in Section 13.2.1 for regional facilities shall be adhered to for sub-regional facilities. Requirements for clearly defining ownership and maintenance responsibilities, preparing an O&M Manual, providing adequate easements, and the other conditions listed for regional facilities are required for sub-regional detention facilities. Requirements for reducing directly connected impervious area if jurisdictional streams exist upstream of sub-regional water quality facilities also apply. These requirements are identified in Section 14.2.2.

13.2.3 On-site Detention. On-site detention refers to facilities serving one lot, generally commercial or industrial sites draining areas less than 20-acres. Douglas County allows on-site detention only on infill lots, where regional or sub-regional facilities are not able to be implemented. Figure 13-4 illustrates a typical on-site detention approach.

On-site detention facilities may not be recognized in the determination of flow rates for downstream major drainageways. On-site detention facilities may receive runoff from upstream off-site areas. Section 6.8 and Section 13.3.2 describe criteria regarding off-site flows.

Integrating Detention and Site Landscaping Requirements. Locating detention basins in areas reserved to meet site landscaping requirements is generally encouraged. Incorporating detention into landscaped areas generally creates detention facilities which are easy to inspect, are relatively easy to maintain, and can enhance the overall aesthetics of a site. Further discussion regarding landscaping improvements in detention facilities is provided in Section 13.6.

Parking Lot Detention. Parking lot detention is acceptable on commercial and business sites and can offset some of the storage volume that needs to be provided on landscape areas. Parking lot detention shall meet the requirements of Section 13.4. The County will review parking lot detention on a case-by-case basis.

Underground Detention. Underground detention is prohibited in Douglas County.

Rooftop Detention. Rooftop detention is prohibited in Douglas County.

13.3 Detention Basin Design Criteria

13.3.1 Sizing Methodology. Three different procedures for sizing full-spectrum detention volumes are described in the Storage chapter of the *UDFCD Manual*. A set of simplified equations or a design spreadsheet may be used for drainage areas up to 160 acres and a hydrograph approach is outlined for watershed areas up to one square mile. The release rate for the excess urban runoff volume shall be based on a drain time of 72 hours, as specified in the *UDFCD Manual*. Control orifices shall be sized using procedures outlined in the Storage Chapter of the *UDFCD Manual*.

Douglas County requires that the 100-year volume provided for full-spectrum detention facilities be equal to the 100-year detention volume calculated using the UDFCD simplified equation plus 1.0 times the water quality capture volume. The UDFCD design spreadsheet provides an option to specify that the water quality capture volume be added to the 100-year simplified equation volume. When the term “100-year volume” is used in these criteria in association with full-spectrum detention, it refers to the sum of the water quality capture volume and the UDFCD 100-year simplified equation or the 100-year volume using the hydrograph methods described in the UDFCD Storage Chapter.

The water quality capture volume is typically part of the excess urban runoff volume and the excess urban runoff volume is normally configured within the 100-year volume in one combined facility with one outlet structure. However, any combination of the incremental volumes, as shown in Figure 13-5, is acceptable.

13.3.2 On-site Detention and Addressing Off-site Flows. Two approaches are generally acceptable for addressing off-site flows that must be conveyed through a site and the potential impacts to the on-site detention.

1. Separate Conveyance Systems. In this approach, off-site runoff is conveyed to a point downstream of the on-site detention pond outfall. The detention pond is sized based on the tributary area of the site. Off-site flows and the detained runoff can be conveyed in the same system downstream of the detention pond.

2. Design for Off-site Flows. An alternative method is to design the detention basin for the entire upstream watershed area, including the future development flows from off-site areas without giving any credit to off-site detention facilities. This method may be appropriate if the off-site tributary area is relatively small, but it becomes less feasible as the off-site tributary increases.

Further discussion regarding detention benefits in off-site flow analysis can be found in Section 6.8. Consideration of the benefits of detention provided in the off-site area may be considered in some cases, if there is sufficient justification. In those cases, the design engineer shall utilize detailed hydrograph methods to size the on-site detention to account for the additional volume from the off-site area and the differences in timing of the various hydrographs.

13.3.3 Multiple Small Detention Basins. Extended detention basins providing water quality capture volume, excess urban runoff volume, and 100-year detention typically function best if configured in one or a few large basins as opposed to multiple small basins with very small orifices. Therefore, the minimum number of detention installations is generally preferable. The same is not necessarily true for porous landscape and porous pavement detention, which may be configured in multiple small installations.

13.3.4 Detention Basins in Series. Locating two or more detention basins in series on an individual development site inherently leads to inefficiencies in the required storage volume of the downstream facilities and is generally discouraged, especially for the water quality capture volume and the excess urban runoff volume portion of a full-spectrum detention facility.

If site runoff is detained by two or more detention facilities in sequence before leaving the site, hydrograph approaches, as described in Section 3.4 of the Storage Chapter in Volume 2 of the *UDFCD Manual*, shall be used to determine the effect of sequential detention and to determine the detention capacity that is needed to reduce runoff peaks to the specified predevelopment flow rates at the end of the system.

13.3.5 Interconnected Ponds. When sequential detention ponds are located in close proximity, separated by a short culvert or pipe at a roadway crossing, or when sequential ponds have similar invert elevations, the ponds may have to be modeled as “interconnected ponds”. This situation could also occur if other downstream conditions cause variable backwater effects that influence the

discharge of the detention pond outlet pipe. In these scenarios, the water surface elevation in the downstream pond can reduce the discharge rate from the upper pond and in some cases reverse flow can occur from the downstream pond into the upstream pond. The routing analysis is much more complex because the ponds are hydraulically dependent and the water surface elevations continuously vary and change the discharge characteristics. It is the responsibility of the design engineer to ensure that the appropriate analyses are performed and submitted when ponds are "interconnected".

13.3.6 Outlets into Streets. Detention ponds that have an outlet pipe terminating in the gutter of a street, such as through a chase section, present potential ponding and icing problems in the gutter, and create hazards to the traveling public during periods in which the pond is emptying rapidly. Therefore, detention ponds shall be designed to outlet into a storm sewer, drainageway, or other designated drainage system that is reasonably available, as determined by the County. It must be shown that the storm sewer, drainageway, or other designated drainage system where the pond outlets have the capacity to convey the detention pond flows.

The County may allow an outlet to discharge into the gutter in cases where a storm sewer or other drainage system is not reasonably available when the minor storm (5-year) peak flow for the tributary area is less than 3.5-cubic feet per second, and it must be shown that the street has adequate capacity to convey the excess runoff within the allowable limits. A transition from the outlet pipe to a curb chase will normally be required and the chase section shall be designed to convey the discharge at a low velocity. The location of the outlet shall be designed to minimize potential problems or conflicts with other improvements, and shall be angled toward the downstream slope of the gutter to direct flows downstream instead of perpendicularly into the street. Discharge into the gutter will not be allowed on local streets.

13.3.7 Excavated or Embankment Slopes. All excavated or embankment slopes from the pond bottom to the 100-year water surface elevation shall be no steeper than 4 (horizontal) to 1 (vertical). Excavated slopes above the 100-year water surface elevation and the slope on the downstream side of embankments shall be 3 to 1 or flatter. Embankments shall be provided with a top width of at least 10-feet. An emergency overflow spillway shall be provided as described in Section 13.3.13. All earthen slopes shall be covered with a minimum of 6-inches of topsoil and revegetated.

It is the responsibility of the design engineer to ensure that the design of any earthen embankment is based on specific recommendations of a geotechnical engineer. In addition, the construction of large embankments or dams may fall under the jurisdiction of the Office of the State Engineer as discussed in Chapter 3, Stormwater Management and Development, Section 3.3.2.

13.3.8 Freeboard Requirements. The minimum required freeboard for detention facilities is 1.0-foot above the computed water surface elevation when the emergency spillway is conveying the maximum design flow. Section 13.3.13

provides design information for the emergency spillway and embankment protection.

13.3.9 Low Flow Channels. All grassed-bottom detention ponds shall include a low flow channel sized to convey a minimum of 1% of the 100-year peak inflow. The low flow channel shall be constructed of concrete; concrete with boulder edges, soil-riprap, or other materials accepted by the County and shall have a minimum depth of 0.5-feet. The minimum longitudinal slope shall be 0.5-percent and this longitudinal slope should ensure that non-erosive velocities are maintained adjacent to the low flow channel when the design capacity is exceeded.

If accepted by the County, an unlined low flow channel may be used. The unlined low flow channel shall be at least 1.5-feet deep below adjacent grassed benches and shall be vegetated with herbaceous wetland vegetation or riparian grasses, appropriate for the anticipated moisture conditions. The minimum longitudinal slope shall be 0.5-percent and the minimum width of the grassed bench adjacent to the low flow channel shall be 12-feet on one or both sides where equipment can access. The maximum side slope below the bench shall be 4 to 1 and the maximum bottom width of the channel shall be 12-feet if equipment can access one side of the channel and 24-feet if equipment can access both sides.

Typical cross-sections of low flow channels are shown in Figure 13-6.

13.3.10 Bottom Slope. For grassed detention facilities, the pond bottom shall be sloped at least 4-percent for the first 25-feet and at least 1- to 2-percent thereafter to drain toward the low flow channel or outlet, measured perpendicular to the low flow channel. The benches above unlined low flow channels, if approved, shall slope at least 1- to 2- percent toward the low flow channel.

13.3.11 Inlet Facilities. Unless otherwise accepted by the County, runoff shall enter a detention facility via a stabilized drainageway, a 100-year drop structure, or a storm sewer with energy dissipater. Riprap rundowns are generally not accepted due to a history of erosion problems. Figures 14-8 and 14-9 illustrate concepts for incorporating sediment forebays into storm sewer outfalls entering a detention facility.

13.3.12 Outlet Structure. Detention basin outlets shall be functional for controlling the design release rates, provided with oversized safety/debris grates to reduce the potential for debris plugging, easy to maintain, and designed with favorable aesthetics.

Four example concepts of a combined outlet for full-spectrum detention are shown in Figures 14-4 through 14-7. Two figures show integral micropools (one with parallel wingwalls with a flush bar grating and the other with flared wingwalls and handrails). The other figures show an external micropool. External micropools shall only be used if a constant baseflow exists, and only with the approval of the County.

Orifice spacing may be adjusted based on the discussion in the next section if approved by the County. A sealant must be specified behind the orifice plate to prevent leakage around the plate. All hydraulic sizing, concrete structure dimensions, reinforcing, and metalwork details for outlet structures shall be the responsibility of the design engineer.

13.3.13 Trash Racks. The minimum net open area of the trash rack protecting the Excess Urban Runoff Volume orifices and the flood control orifice shall comply with Figure 7 of Volume 3's Typical Structural Best Management Practice Details. The safety grate criteria discussed in the Culverts section of the Volume 1 of the *UDFCD Manual*, shall also apply. The trash rack protecting the orifices must extend to the bottom of the micropool so that flow can pass through the rack below the level of any floating debris and make its way through the orifices.

If the control orifices are 2.5-inches or greater in diameter or 2-inches square, standard fabricated bar grating (with nominal openings of 1- by 4-inches) may be used as a debris grate instead of well-screen. The larger grate may reduce the potential for clogging with debris. If approved by the County, the vertical spacing between orifices may be increased to 8-inches or 12-inches and the orifice areas increased by a factor of two (for 8-inch spacing) or three (for 12-inch spacing) to enable larger orifices and larger trash rack openings.

Bar grating may be used on parallel sloping wingwalls, either as the primary debris grate (if orifices are at least 2.5 inches in diameter) or as a course screen and safety grate in lieu of handrail. Sloping bar grating shall have a lockable hinged section at least 2-feet square to allow access to the orifice plate or well-screen. Manhole steps shall be provided on the side of the wingwall directly under the hinged opening. The bearing bars for steel bar grating shall be designed to withstand hydrostatic loading up to the spillway crest (assuming the grate is clogged and bears the full hydrostatic head), but generally not designed for larger loads (like vehicular loads) so that the hinged panels are not excessively heavy. Panels of bar grating shall be no more than 3-feet wide and all parts of the grating and support frames shall be hot-dipped galvanized. Bar grating shall be fastened down to the outlet structure.

The flood-flow orifice shall be sized to provide the allowable 100-year release rate when the 100-year detention volume is completely full. The weir crest at the top of the 2-year volume shall pass the allowable 100-year release rate at a head that is at least 0.5-feet below the completely-full 100-year full-spectrum volume, maintaining control at the 100-year orifice in the design event.

13.3.14 Emergency Spillway and Embankment Protection. Whenever a detention basin uses an embankment to contain water, the embankment shall be protected from catastrophic failure due to overtopping. Overtopping can occur when the pond outlet becomes obstructed or when a storm larger than a 100-year event occurs. Erosion protection for the embankment may be provided in the form of a buried riprap layer on the entire downstream face of the embankment or a separate emergency spillway constructed of buried riprap or concrete. In either case, the protection shall be constructed to convey the 100-year developed flow

from the upstream watershed without accounting for any flow reduction within the detention basin.

The invert of the emergency spillway shall be set at the 100-year water surface elevation. A concrete wall shall be constructed at the emergency spillway crest extending at least to the bottom of the riprap and bedding layers located immediately downstream. The crest wall shall be extended at the sides up to one foot above the emergency spillway design water surface.

Riprap embankment protection shall be sized based on methodologies developed specifically for overtopping embankments. Two such methods have been documented by Colorado State University (USNRC, 1988) and by the US Department of Agriculture (ASAE, 1998) and designers are referred to these publications for a complete description of sizing methodology and application information. Figure 13-7 illustrates typical rock sizing for small (under 10-feet high) embankments based on these procedures that may be used during preliminary design to get an approximate idea of rock size. Final design shall be based on the more complete procedures documented in the referenced publications. The thickness and bedding requirements shall be based on the criteria identified in the *UDFCD Manual*.

The emergency spillway is also needed to control the release point and direction of the overflow. The emergency spillway and the path of the emergency overflow downstream of the spillway and embankment shall be clearly depicted on the drainage plan. Structures shall not be permitted in the path of the emergency spillway or overflow. The emergency overflow water surface shall be shown on the detention facility construction drawings.

13.3.15 Retaining Walls. The use of retaining walls within detention basins is generally discouraged due to the potential increase in long-term maintenance costs and concerns regarding the safety of the general public and maintenance personnel. If retaining walls are proposed, footings shall be located above the Excess Urban Runoff Volume. Wall heights shall not exceeding 30-inches are preferred, and walls shall not be used on more than 50-percent of the pond circumference. If terracing of retaining walls is proposed, adequate horizontal separation shall be provided between adjacent walls. The horizontal separation shall ensure that each wall is loaded by the adjacent soil, based on conservative assumptions regarding the angle of repose. Separation shall consider the proposed anchoring system and equipment and space that would be needed to repair the wall in the event of a failure. The failure and repair of any wall shall not impact or affect loading on adjacent walls. In no case shall the separation be less than 2 times the adjacent wall height, such that a plane extended through the bottom of adjacent walls shall not be steeper than 2 (horizontal) to 1 (vertical). The maximum ground slope between adjacent walls shall be 4-percent.

Walls shall not be used where live loading or additional surcharge from maintenance equipment or vehicle traffic could occur. The horizontal distance between the top of a retaining wall and any adjacent sidewalk, roadway, or structure shall be at least three times the height of the wall. The horizontal distance to any maintenance access drive not used as a sidewalk or roadway

shall be at least 4-feet. Any future outfalls to the pond shall be designed and constructed with the detention basin out to a distance sufficient to avoid disturbing the retaining walls when the future pipeline is connected to the outfall.

Any wall exceeding a height of 30-inches requires perimeter fencing, safety railing, or guardrail depending on the location of the wall relative to roadways, parking areas, and pedestrian walkways. Any wall exceeding a height of 4-feet (measured from the bottom of the footing to the top of the wall) requires a Building Permit.

A Professional Engineer licensed in the State of Colorado shall perform a structural analysis and design the retaining wall for the various loading conditions the wall may encounter; including the differences in hydrostatic pressure between the front and back of the wall. A drain system should be considered behind the wall to ensure that hydrostatic pressures are equalized as the water level changes in the pond. The wall design and calculations shall be stamped by the professional engineer and submitted to the County. The structural design details and requirements for the retaining wall(s) shall be included in the construction drawings.

Retaining walls shall not be used within the limits of any impermeable lining of water quality basins or detention ponds.

13.3.16 Landscaping Guidelines. Integration of detention and site landscaping requirements is encouraged as outlined in Section 13.2.3. The landscaping guidelines described in Section 13.6 shall be followed to provide a detention facility that blends with the site, is attractive, and well-vegetated.

13.3.17 Signage. Two signs, each with a minimum area of 3-square feet shall be provided around the perimeter of all detention facilities. The signs shall be fabricated using red lettering on a white background with the following message:

WARNING
THIS AREA IS A STORMWATER
FACILITY AND IS SUBJECT TO
PERIODIC FLOODING

13.3.18 Easement Requirements. Drainage easements shall be provided to ensure for access to and for the maintenance of the detention basins and outlet facilities. Drainage easements shall be granted to the County for inspection and maintenance purposes, and shall be shown on the drainage plan, final plats and final development plan. The drainage easement shall state that the County has the right of access on the easements for inspection and maintenance purposes. Drainage easements shall be kept clear of obstructions to the flow and shall allow maintenance access. The minimum requirements for detention basins are as required to contain storage and water quality capture volume including freeboard, associated facilities, and adequate maintenance access around the perimeter based on the access road width criteria provided in Section 13.7. Access to the basin shall be provided in an easement.

13.3.19 Maintenance. The maintenance of detention facilities shall be performed by the property owner, or as otherwise designated by legal agreement. Maintenance operations shall be in accordance with the approved operations and maintenance manual (O&M Manual) for the project as described in Section 4.6. Routine maintenance of detention basins shall include sediment and debris removal. Non-routine maintenance may include the repair and/or replacement of outlet structures, trickle channel, outlet pipes, channel slopes, and other related facilities. When appropriate maintenance is not provided, the County may provide the necessary maintenance and shall assess the associated cost to the property owner. All detention basins, with or without retaining walls, shall be designed in accordance with the maintenance requirements identified in Section 13.7.

13.4 Design Standards for Parking Lot Detention

13.4.1 Easement Requirements. Easements for parking lot detention shall be provided in accordance with Chapter 3, Stormwater Management and Development. Easements shall include the area of the parking lot that is inundated by the 100-year water surface elevation, and the outlet structure and conveyance facilities.

13.4.2 Maintenance Requirements. Maintenance of parking lot detention ponds and facilities shall be provided in accordance with Chapter 3, Stormwater Management and Development. The property owner shall be required to ensure that the release structures are maintained.

13.4.3 Depth Limitation. The maximum allowable design depth above pavement surfaces for the excess urban runoff volume is 3-inches and for the 100-year flood is 9-inches. However, to account for future overlays or parking lot resurfacing, the design volumes shall be attained even with an assumed 2-inch overlay (translating to an allowable depth of 1-inch for the excess urban runoff volume and 7-inches for the 100-year event). The water quality capture volume shall be located entirely out of (below) the pavement area, possibly in one or more landscaped parking islands or adjacent landscaping. An emergency spillway sized for the 100-year inflow peak shall be provided with a crest set at the 100-year water surface elevation and a maximum flow depth over the emergency spillway of 6-inches. A minimum of 1.0-feet of freeboard is required above the 100-year emergency water surface to the first floor elevation of any adjacent structures (equivalent to 18-inches over the 100-year water surface).

13.4.4 Outlet Configuration. The outlet configuration shall be designed in accordance with criteria shown in Volume 3 of the *UDFCD Manual*, as modified by Chapter 14 Stormwater Quality for the type of water quality capture volume facility selected for the site. Outlets for the excess urban runoff volume and 100-year events shall limit peak flows to the maximum design release rates.

13.4.5 Flood Hazard Warning. All parking lot detention areas shall have a minimum of two signs posted identifying the detention pond area. The signs shall have a minimum area of 1.5-square feet and contain the following message:

WARNING
THIS AREA IS A DETENTION POND AND
IS SUBJECT TO PERIODIC FLOODING
TO A DEPTH OF 9-INCHES OR MORE

Any suitable materials and geometry of the sign are permissible, subject to approval by the County. The property owner shall be responsible to ensure that the sign is provided and maintained at all times.

13.5 Stormwater Retention

13.5.1 Stormwater Retention. Stormwater runoff retention has been used in areas where there exists no viable alternative for providing an outfall for a detention pond. However, problems with past retention basins including soil expansion, siltation, and lack of infiltration capacity have created a nuisance to the general public. Further, retention has the potential of depriving downstream water rights of their legal right to the retained water. Use of retention shall be minimized, except where significant environmental, recreational, or recharge benefits are apparent and water rights issues have been addressed with the State Engineer's Office.

13.5.2 Facility Requirement. Stormwater retention shall not be permitted, except as approved on a case-by-case basis and, as an interim measure in areas where an outlet collector storm sewer system has been planned, but has not been constructed. When allowed, retention shall be considered as interim solution, and shall be required to be converted to detention when the outlet system is available.

13.5.3 Minimum Sizing Requirements. When the County determines that stormwater retention is appropriate as an interim measure, the facility shall be sized using the following criteria:

1. The minimum retention volume shall equal the watershed area upstream of the retention basin (including off-site areas) times the unit runoff amount shown in Figure 13.8, based on the estimated future development percent imperviousness for the entire upstream watershed. Figure 13-8 is based on 1.5 times the estimated runoff from a 24-hour 100-year storm to account for storms larger than a 100-year event, storms of longer duration, or back-to-back storms. Additional considerations when implementing a retention facility are discussed in Section 3 of the Storage Chapter in Volume 2 of the *UDFCD Manual*.

13.6 Landscaping Guidelines

Integration of detention and site landscaping requirements is encouraged as outlined in Section 13.2.3. Consideration to the type and quantity of landscaping materials should be given, to ensure that the capacity of the pond is maintained, and that future maintenance activities can be performed with minimal disruption of vegetated areas. The following is a list of recommendations for pond grading and landscaping:

a. Wherever possible, involve a landscape architect in the design of detention facilities to provide input regarding layout, grading, and the vegetation plan.

b. Create a basin with a pleasing, natural shape that is characterized by variation in the top, toe, and slopes of banks. Avoid boxy, geometric patterns that are easy to draw using CAD. Better results are usually achieved by creating a grading plan by hand and then smoothly digitizing the proposed contours in to the design drawings. A "golf course look" is more attractive than straight lines and straight slopes.

c. Grass selection and plant materials are key in softening the appearance of a detention area and blend it in with the surrounding landscaping and natural features. Species are to be suitable for the particular hydrologic conditions in the basin; with wetland or riparian species selected for the bottom areas subject to frequent and prolonged inundation. Bluegrass rarely works well in the lowest, water quality portion of a basin. Guidelines for revegetation, along with recommended seed mixes, are provided in the *UDFCD Manual*.

d. Multipurpose detention facilities are encouraged with recreation activities such as passive open space areas, pedestrian paths, children's play areas, and active recreation areas. It is recommended that active recreation facilities be located above the 2-year water surface to avoid frequent inundation.

e. To reduce the potential for clogging of debris grates, no straw mulch shall be used within the Excess Urban Runoff Volume of a detention basin. Instead, erosion control blanket shall be installed for a width of at least 6-feet on either side of concrete low flow channels or up to a depth of 1-foot in soil riprap or benched low flow channels. The blanket shall comply with the materials and installation requirements for erosion control blankets (straw coconut or 100% coconut) shown in the County's Grading, Erosion, and Sediment Control (GESC) Manual. Additional blanket or other erosion control measures may be required by the County.

f. Trees shall not be planted within the excess urban runoff volume. Trees such as Cottonwood, Willow, and Aspen shall not be planted within the 100-year water surface of a detention basin to avoid nuisance spreading of root systems within the facility.

13.7 Designing for Maintenance

Detention facilities shall be designed to facilitate ongoing maintenance operations. The following provisions for maintenance shall be required:

13.7.1 Access for Sediment Removal. A stable access and working bench shall be provided so that equipment can remove accumulated sediment and debris from the detention basin and perform other necessary maintenance activities at all components of the facility. Unless otherwise approved by the County, the horizontal distance from the working bench to the furthest point of removal for the forebay, bottom of the detention basin, or outlet structure shall be no more than 24-feet. The working bench and access drive shall slope no more than 10-percent, and be at least 12-feet wide for a centerline radius greater than 80-feet and at least 14-feet wide for a centerline radius between 50- and 80-feet. The minimum centerline radius shall be 50-feet. Unless otherwise approved, the working bench and access drive shall be constructed of the following materials:

Below any permanent water surface: A reinforced concrete bottom slab at least 6-inches thick shall be provided as a working platform. The surface of the concrete shall be provided with a grooved finish to improve traction, with grooves oriented to drain water away to one or both sides. Concrete shall be placed on at least 6-inches of gravel base compacted subgrade.

Below the Excess Urban Runoff Volume water surface: The access ramp shall be reinforced concrete as specified above, or at least a 12-inch thick layer of aggregate base course or crushed gravel over compacted subgrade.

Above the Excess Urban Runoff Volume and below the 100-year water surface: An access ramp shall be reinforced concrete as specified above or at least an 8-inch thick layer of aggregate base course or crushed gravel over compacted subgrade.

The use of reinforced turfgrass meeting applicable UDFCD criteria, if proposed in this zone for an access drive, will be considered by the County on a site-specific basis. If used, a system of marking the edges is required so that its location is evident to maintenance crews. Also, shrubs, trees, sprinkler heads and valve boxes shall not be located in the reinforced turfgrass area.

As stated above, any retaining walls shall to be laid out in a manner that avoids access restrictions. Any handrails or fences, likewise, shall permit vehicular access. The entrance to an access drive from a roadway or parking lot shall be located so that traffic safety is not compromised.

13.7.2 Other Improvements to Facilitate Maintenance. Other improvements that could facilitate maintenance operations in the future are encouraged. These could include:

a. Providing adequate room for staging the equipment involved in clean-out operations.

b. Providing a power receptacle adjacent to the detention basin to enable dewatering operations using an electric pump. Electric pumps are quieter and require less attention in the event pumps need to operate overnight.

c. For larger, natural sites, it may be worthwhile to reserve a suitable location for disposing sediment that is cleaned out of the pond. This has to be carefully thought through, however, to make sure it is feasible to dump the material on-site, allow it to dry, then spread it and re-seed and much the area, without causing erosion problems.

d. Designing configuration and dimensions of grates to allow debris to be raked off using standard garden tools.

FIGURE 13-2
REGIONAL DETENTION APPROACH

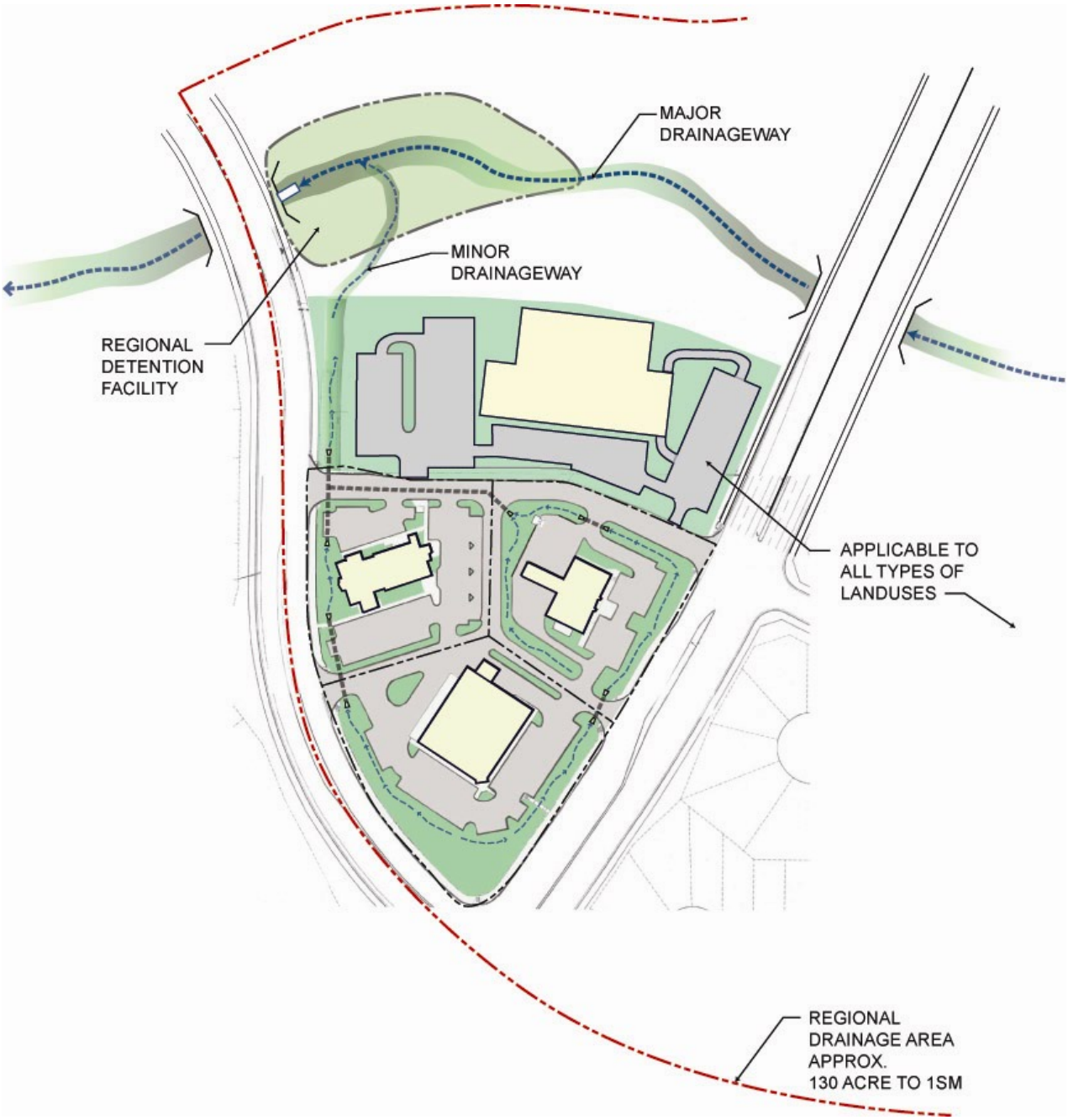


FIGURE 13-3
SUB-REGIONAL DETENTION APPROACH

FIGURE 13-4
ON-SITE DETENTION APPROACH

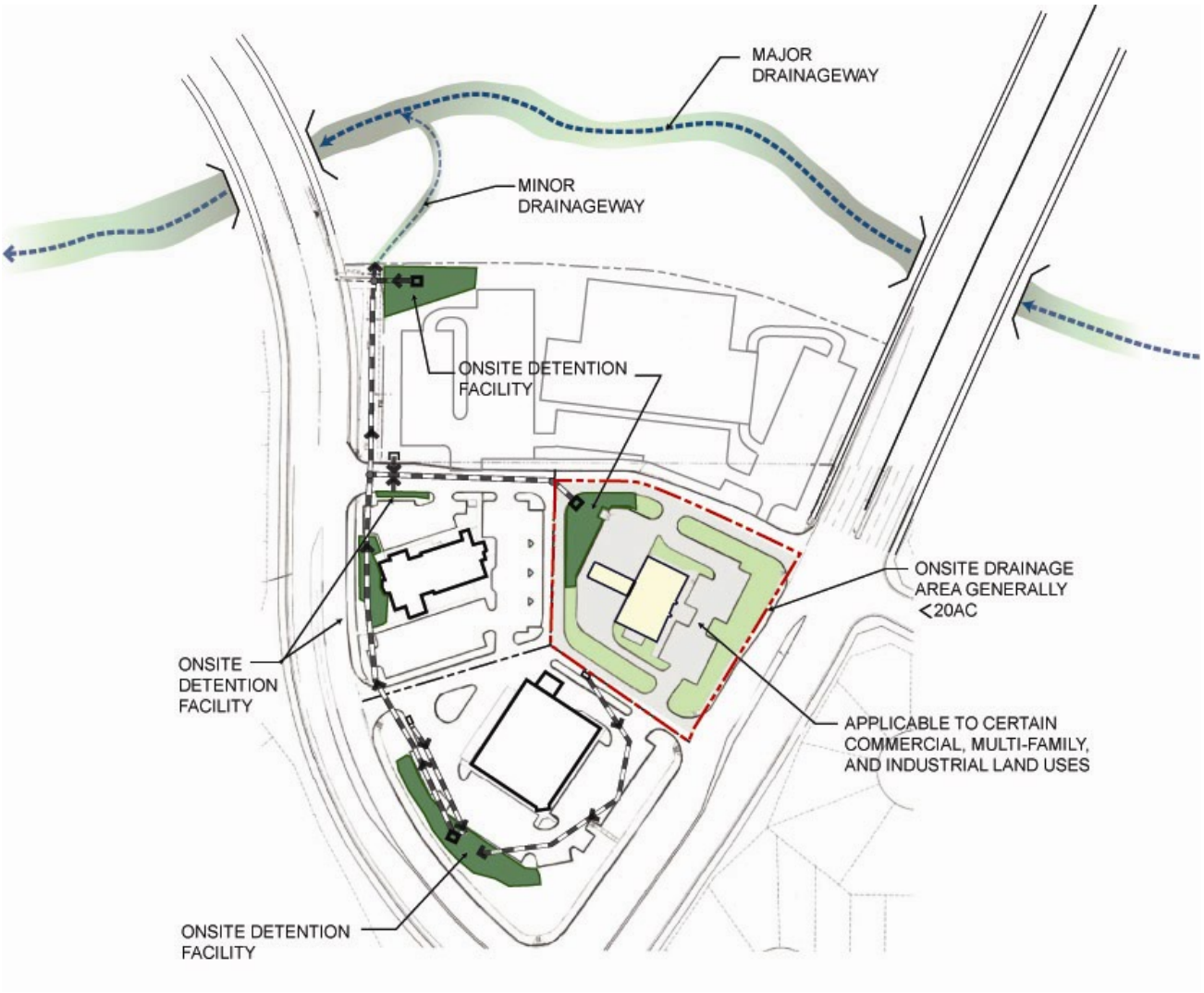


FIGURE 13-5
DESIGN OPTIONS FOR DETENTION BASINS

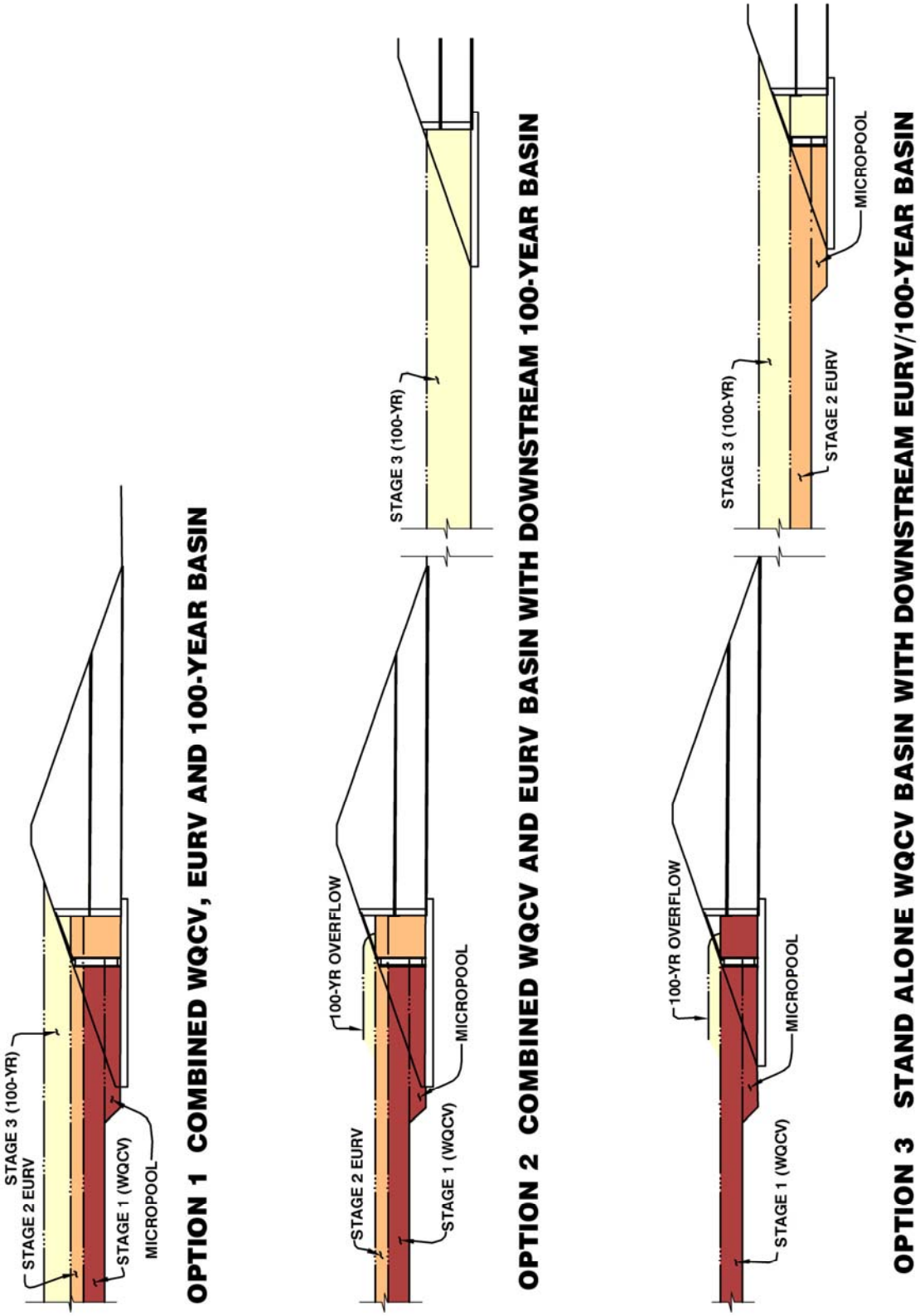
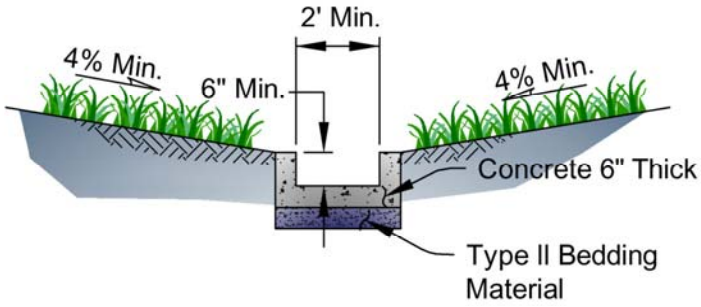
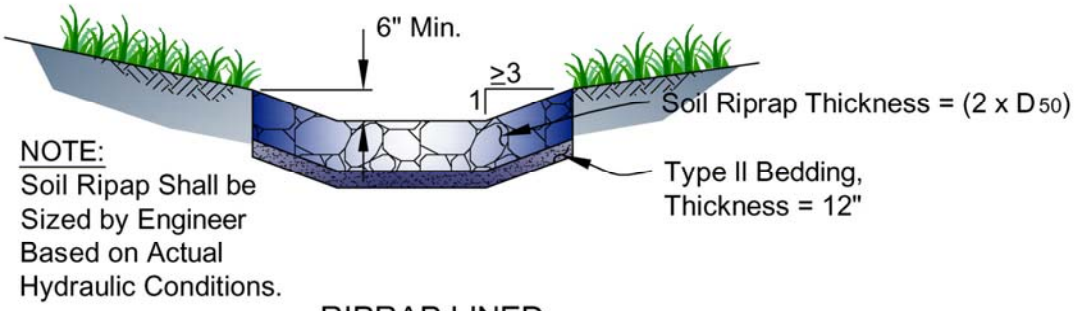


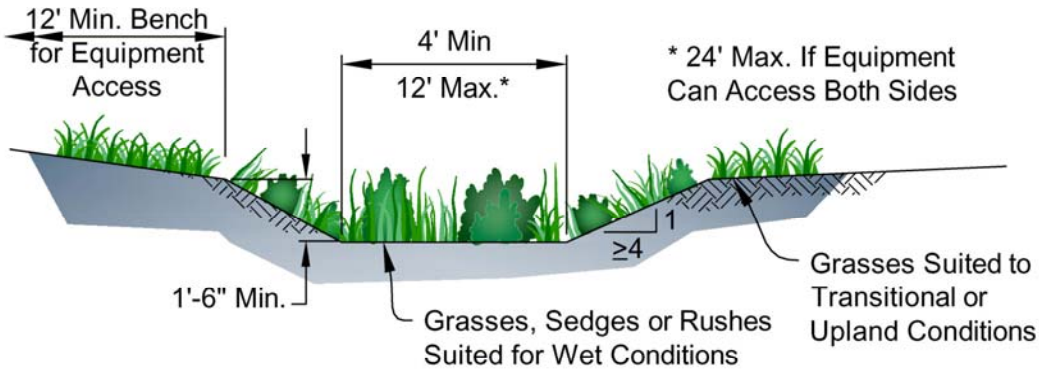
FIGURE 13-6
TYPICAL LOW FLOW CHANNEL DETAILS



CONCRETE LINED

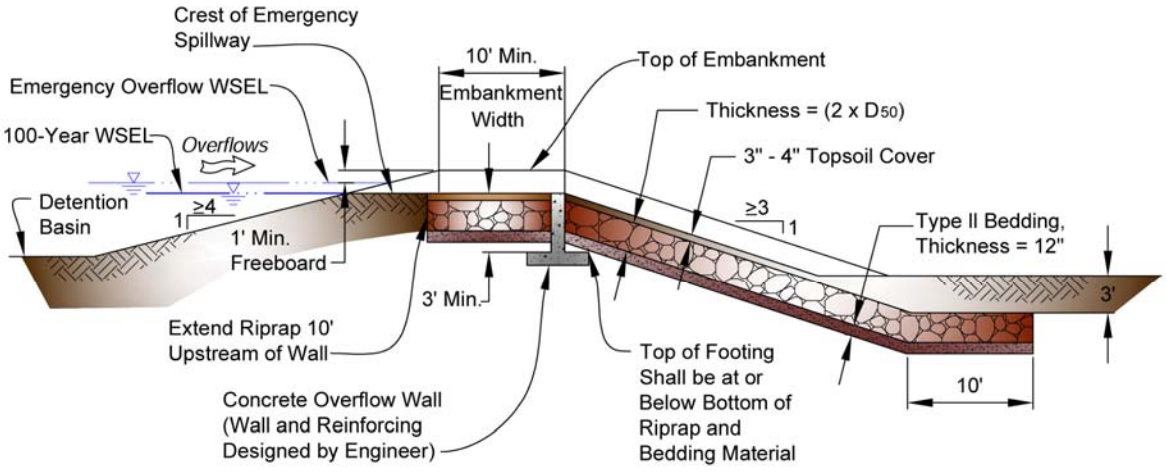


RIPRAP LINED
Must be Approved by County Prior to Use

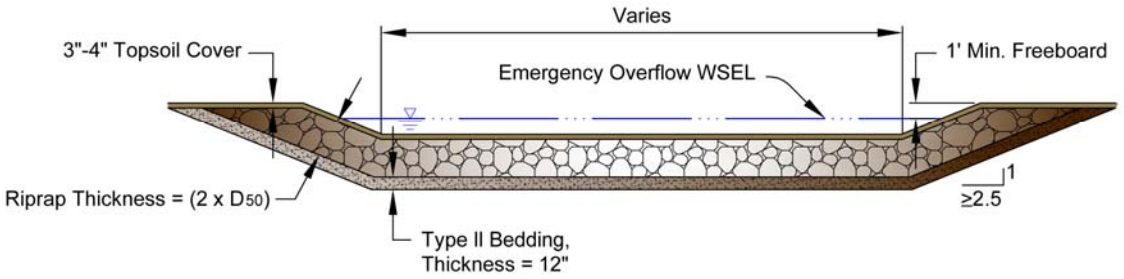


BENCHED SYSTEM (UNLINED)
Must be Approved by County Prior to Use

FIGURE 13-7
EMBANKMENT PROTECTION DETAILS AND ROCK SIZING CHART



EMERGENCY SPILLWAY PROFILE



SPILLWAY CHANNEL AT CREST AND DOWNSTREAM SIDE OF EMBANKMENT

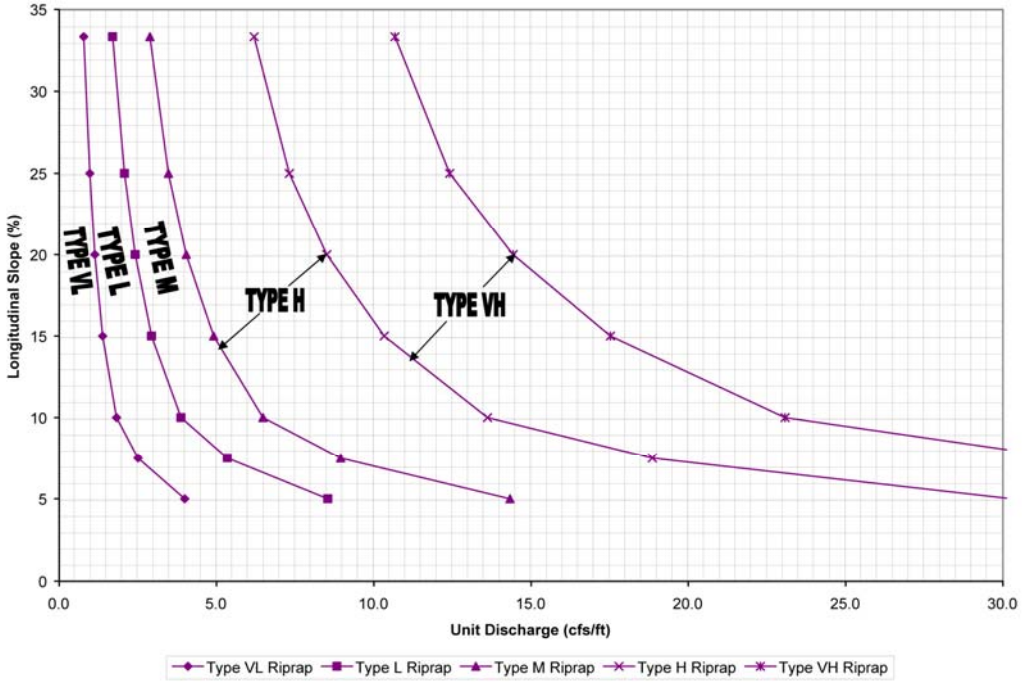


FIGURE 13-8
100-YEAR REQUIRED RETENTION VOLUME