



CHAPTER 13. STORAGE
Design Checklist for Storage Design

Yes	No	N/A	Design Requirements
I. GENERAL DESIGN GUIDELINES			
			A. Full-spectrum detention is provided for all new development, redevelopment or expansion of a site to provide for water quality and flood control detention.
			B. Detention facilities are designed in accordance with Section 13.3 and the Storage Chapter of the UDFCD Manual.
			C. A detention facility that is proposed in a Master Plan as a WQCV/10-year/100-year detention facility is designed and shall be constructed as a full-spectrum facility. This methodology was confirmed with the County prior to design.
			D. Detention Requirements for Redevelopment, Expansion and/or Improvement
			1. Onsite detention is required for the redevelopment of a site; detention is 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.
			2. Additional detention will be provided to accommodate the expanded development of a site where detention has been provided for the existing developed areas and the existing facilities will be converted to full-spectrum facilities as much as possible.
			3. Detention will be provided for the full expansion of a site where detention has not been provided for the existing developed area that has previously been un-detained to the maximum extent practical.
			E. Exemptions from Detention Requirements
			1. Detention requirements may be waived for additions to existing buildings and paved areas if the total impervious area of all additions is less than 2500 ft ² of impervious area and there are no adverse impacts to adjacent or downstream properties.
			2. Detention requirements may be waived for subdivisions with individual residential lots that are 19+ acres and there are no adverse impacts to adjacent or downstream properties.
			F. Unless already approved in a County Master Plan, onsite detention is provided for a site adjacent to a major drainageway (i.e. "beat-the-peak" analysis is not an acceptable detention exemption).
			G. Temporary detention is provided where permanent detention, such as a regional detention pond, is intended but has not been constructed.
II. REGIONAL, SUB-REGIONAL, AND ONSITE DETENTION FACILITIES			
			A. Regional Detention Requirements



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			1. Regional detention facility has been designed to accommodate fully developed flows from the upstream watershed.
			2. Regional detention facility is/will be owned and maintained by a public entity with ownership and maintenance responsibilities clearly defined.
			3. Regional detention facilities located within UDFCD boundaries are designed, constructed and accepted for UDFCD maintenance assistance.
			4. Drainage easements are provided to the County for regional detention facilities.
			5. An Operations and Maintenance (O&M) Manual is completed for all regional detention.
			6. A Stormwater Facilities Maintenance Agreement is provided for all regional detention.
			7. A State Engineer's Office jurisdictional dam will not be created at a regional detention facility.
			8. The facility has been permitted under all applicable environmental permits and clearances.
			9. Design and construction of the regional facility has been coordinated with development in the upstream watershed.
			10. Drainageways upstream of regional facility are stabilized per Chapter 12 and Step 3 of Section 14.1. Upstream development sites will reduce directly-connected impervious areas as described in Chapter 14, Section 14.2.
			11. The drainage system that conveys flow to the regional facility is designed for fully-developed flowrates.
			B. Sub-Regional Detention Requirements
			1. Sub-regional detention facility is designed to accommodate fully developed flows from the upstream watershed.
			2. Drainage easements are provided to the County for sub-regional detention facilities.
			3. An Operations and Maintenance (O&M) Manual has been completed for all sub-regional detention.
			4. A Stormwater Facilities Maintenance Agreement has been provided for all sub-regional detention.
			5. A State Engineer's Office jurisdictional dam will not be created at a sub-regional detention facility.
			6. The facility is permitted under all applicable environmental permits and clearances.
			7. Design and construction of sub-regional facility has been coordinated with development in the upstream watershed.
			8. The drainage system that conveys flow to the sub-regional facility is designed for fully-developed flowrates.



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			C. Onsite Detention Requirements
			1. Onsite detention is only allowed on infill lots (where regional or sub-regional facilities are not provided).
			2. Onsite detention cannot be recognized in the determination of flowrates for downstream major drainageways.
			3. An onsite facility is designed for runoff from the site and any offsite area that is routed to the pond.
III. DETENTION BASIN DESIGN CRITERIA			
			A. Sizing Methodology
			1. Volume calculations are in accordance with the Storage chapter of the UDFCD Manual.
			2. The 100-year volume for full-spectrum detention facilities is equal to the 100-year detention volume calculated using the UDFCD simplified equation plus 1.0 times the WQCV.
			B. Onsite Detention and No Pass-Through Offsite Flows
			1. Offsite runoff is routed around the detention pond and reconnected downstream of the pond.
			C. Onsite Detention Including Offsite Flows
			1. Detention basin is designed for the entire upstream watershed area, including the future development flows from offsite areas without providing credit to offsite detention facilities.
			D. Detention Basins in Series and Interconnected Ponds
			1. Sequential or interconnected detention basins are analyzed using the hydrograph approaches, as described in Section 3.4 of the Storage Chapter of the UDFCD Manual. It is the design engineer's responsibility to ensure that the appropriate analyses are performed for interconnected and sequential ponds.
			E. Outlets into Streets
			1. Outlets into streets are only used when drainage system is not reasonably available to use as an outlet.
			2. The 5-year peak flow for the pond's tributary area is less than 3.5 cfs.
			3. The street has adequate capacity to convey the excess runoff within the allowable limits (per Chapter 7).
			4. Details for a transition from the outlet pipe to a curb chase are included.
			5. The curb chase is angled pointing downstream and designed to reduce the velocity and spread of flow.
			F. Excavated and Embankment Slopes
			1. Excavated and embankment slopes from the bottom of a pond to the 100-year water surface are 4:1 or flatter.



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Yes	No	N/A	Design Requirements
			2. Excavated and embankment slopes above the 100-year water surface elevations are 3:1 or flatter.
			3. Slopes on the downstream side of an embankment are 3:1 or flatter.
			4. Embankments have a minimum top width of 10-feet.
			5. Earthen embankments are designed based on the recommendations of a geotechnical engineer.
			6. Earthen slopes are stabilized and revegetated per the County's GESC requirements.
			G. A minimum of 1-foot of freeboard is provided from the emergency spillway design storm water surface elevation to the top of the embankment.
			H. Hard-Lined Low Flow Channel and Pond Bottom Slope
			1. The low flow channel conveys a minimum of 1% of the 100-year storm.
			2. The low flow channel shall be constructed of concrete, concrete with boulder edges, or soil riprap.
			3. Private detention ponds have a low flow channel with a minimum width of 2-feet and depth of 0.5-feet.
			4. Regional detention ponds have a low flow channel with a minimum width of 4-feet and depth of 0.5-feet.
			5. The low flow channel has a minimum longitudinal slope of 0.5%.
			6. Non-erosive velocities are maintained adjacent to the low flow channel when the design capacity is exceeded.
			7. The pond bottom is sloped a minimum of 4% for the first 25-feet adjacent to the low flow channel.
			8. The pond bottom is sloped a minimum of 1-2% beyond the first 25-feet adjacent to the low flow channel.
			I. Unlined Low Flow Channel and Pond Bottom Slope
			1. The County approved an unlined low flow channel prior to design.
			2. The low flow channel is a minimum of 1.5-feet deep below adjacent grassed benches.
			3. The low flow channel is vegetated with herbaceous wetland vegetation or riparian grasses, as appropriate.
			4. The low flow channel has a minimum longitudinal slope of 0.5%.
			5. A grassed maintenance access bench is provided adjacent to the low flow channel (on one or both sides) with a minimum width of 12-feet.
			6. The maximum sideslope below the maintenance access bench is 4:1.
			7. If a maintenance access bench is provided on both sides of the low flow channel, then the maximum low flow channel width is 24-feet.
			8. If a maintenance access bench is provided on one side of the low



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			flow channel, then the maximum low flow channel width is 12-feet.
			9. The pond bottom is sloped a minimum of 1-2% toward the unlined low flow channel.
			J. Stormwater is conveyed into a detention facility through a stabilized drainageway, 100-year drop structure, or storm sewer with energy dissipater.
			K. Outlet Structure
			1. The design engineer is responsible for the hydraulic sizing, concrete dimensions and reinforcement, and all metalwork details for the outlet structure.
			2. The outlet structure is easy to maintain and designed with favorable aesthetics.
			3. A sealant behind the orifice plate to prevent leakage is specified.
			L. Trash Racks
			1. The minimum net open area of the trash rack protecting the EURV orifices and the flood control orifice is in accordance with Figure 7 of UDFCD's Volume 3, Typical Structural Best Management Practice Details.
			2. The trash rack safety grate is designed in accordance with the criteria discussed in the Culverts section of the UDFCD Manual.
			3. For control orifices 2.5-inches or greater in diameter (or 2-inches square), standard fabricated bar grating with nominal openings of 1-inch x 4-inches, may be used instead of a well-screen.
			4. If approved by the County, the vertical spacing between control orifices may be increased to 8-inches or 12-inches and the design orifice areas increased by a factor of 2 for 8-inch spacing or 3 for 12-inch spacing.
			5. Bar grating may be used on parallel sloping wingwalls as the primary debris screen (for orifices at least 2.5 inches in diameter) or as a course screen and safety grate in lieu of a handrail.
			6. Bar grating has a lockable hinged section at least 2-foot square for access to the orifice plate or well-screen. Manhole steps shall be provided on the side of the wingwall directly below the hinged opening.
			7. Bar grating is designed to withstand hydrostatic loading up to the spillway crest (assume the grate is clogged and bears the full hydrostatic head).
			8. Individual bar grating panels are no more than 3-feet wide unless otherwise approved.
			9. All parts of the bar grating and support frames are hot-dipped galvanized.
			10. Bar grating is fastened down to the outlet structure.
			11. The flood-flow orifice is sized to accommodate the allowable 100-



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			year release rate when the 100-year detention volume is completely full.
			12. The weir crest at the top of the EURV passes the allowable 100-year release rate at a head at least 0.5-feet below the full 100-year full-spectrum volume, maintaining control at the 100-year orifice in the design event.
			M. Emergency Spillway and Embankment Protection
			1. The emergency spillway is designed to convey the 100-year developed flow from the upstream watershed without accounting for any flow reduction within the detention basin.
			2. The invert of the emergency spillway is set at the 100-year water surface elevation.
			3. A concrete wall is constructed at the emergency spillway crest which extends to the bottom of the riprap and bedding layers and up the sides of the spillway to one foot above the emergency spillway design water surface elevation.
			4. Figure 13-7 was used to size riprap embankment protection during preliminary design for embankments under 10-feet high.
			5. For final design, riprap embankment protection is evaluated based on methodologies developed specifically for overtopping embankments. See Section 13.3.14 for specific methodologies.
			6. The path of flow over and downstream of the emergency spillway is determined and clearly depicted on the drainage plan. Structures are not located within the emergency overflow path.
			N. Retaining Walls
			1. Retaining wall footings are above the EURV water surface.
			2. Retaining walls are not greater than 30-inches in height.
			3. Retaining walls are not used on more than 50% of a pond's circumference.
			4. Terraced retaining walls have adequate separation to address wall structural design requirements, including anchoring system and maintenance requirements. A minimum separation of 5-feet between terraced walls is required.
			5. The maximum ground slope between terraced walls is 4%.
			6. A Building Permit shall be acquired for all retaining walls located in detention ponds.
			7. Retaining walls include handrails or guardrails which meet both the County's transportation safety criteria and IBC requirements.
			8. The distance from the top of a retaining wall to any adjacent sidewalk, roadway curb or structured feature is a minimum of 3 times the retaining wall height.
			9. The distance from the top of a retaining wall to any maintenance access drive (not used as a sidewalk or roadway) is a minimum of



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			4-feet.
			10. Include any Designated "future" outfalls into the detention basin include design and construction that eliminate future disturbance.
			11. If requested by the County perimeter fencing, safety railing and/or guardrail at County specified location(s) is included.
			12. Retaining wall structural analysis calculations have been completed and stamped by a Professional Engineer and submitted to the County's Building Division for review.
			13. Retaining walls are not located within the limits of any impermeable lining of the detention basin.
			O. Signage
			1. The pond design/construction includes an Outlet Modification Sign as described in Section 13.3.17.
			2. The pond design/construction includes two Flood Hazard Warning Signs as described in Section 13.3.17.
			P. Easements
			1. A drainage easement which includes the storage and WQCV (including freeboard), associated structures (inlet, outlet, etc.) and maintenance access around the perimeter of the pond is granted to the County.
			2. The drainage easement states that the County has the right of access on the easement for inspection and maintenance purposes.
			3. The drainage easement is clear of obstructions to the flow.
IV. DESIGN STANDARDS FOR PARKING LOT DETENTION			
			A. Easements
			1. A drainage easement which includes the area of the parking lot inundated by the 100-year water surface elevation, the outlet structure and conveyance facilities is granted to the County.
			2. The drainage easement states that the County has the right of access on the easement for inspection and maintenance purposes.
			B. Depth Limitations
			1. The WQCV is located entirely out of (below) the pavement area, in landscape parking island(s) or other adjacent landscaping.
			2. The EURV water surface is no more than 1-inch in depth.
			3. The 100-year water surface is no more than 7-inches in depth.
			4. The emergency spillway is sized for the 100-year peak inflow with a maximum flow depth over the spillway of 6-inches.
			5. A minimum of 1-foot freeboard is provided above the 100-year emergency spillway water surface elevation to the first floor elevation of any adjacent structures.
			C. Outlet Structure



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			1. The outlet structure is designed in accordance with Volume 3 of the UDFCD Manual and modified as necessary per Chapter 14 for a WQCV facility.
			2. The outlet is designed to limit the peak flows for the EURV and 100-year events to the maximum design release rates.
			D. Signage
			1. The pond design/construction includes an Outlet Modification Sign as described in Section 13.4.5.
			2. The pond design/construction includes two Flood Hazard Warning Signs as described in Section 13.4.5.

V. STORMWATER RETENTION

			A. General Guidelines and Sizing Requirements
			1. Stormwater retention (either permanent or as an interim measure) was approved by the County prior to design.
			2. The minimum retention volume is equal to the watershed area upstream of the retention basin (including offsite areas) times the unit runoff amount provided in Figure 13-8. Figure 13-8 was applied based on the estimated future imperviousness of the upstream watershed.
			B. Design Requirements for Interim Retention Ponds (when approved by the County)
			1. An overflow section that will protect embankments from the overflow that results from a 100-year storm when the pond is completely full and the tributary area is fully developed is provided.
			2. Pond sideslopes are 4:1 or flatter.
			3. A minimum of 1-foot of freeboard above the maximum retention volume water surface elevation is provided.
			4. The potential impacts to local groundwater levels and damage to nearby properties have been evaluated.
			5. A release of 0.25 cfs or less from the pond is allowed if it will be conveyed to a major drainageway and does not cause nuisance conditions.
			6. A drainage easement is granted to the County for inspection and maintenance access.
			7. The design engineer has determined how and where the retention pond will be drained for maintenance operations.

VI. LANDSCAPING GUIDELINES

			A. A landscape architect has been included in the design of the detention facility to provide assistance with layout, grading, and a vegetation plan.
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			B. The detention basin is designed with a pleasing, natural shape with variation in the top, toe and slopes of the banks.
			C. Grass and plant materials suitable for the various hydrologic conditions of the basin have been selected. The UDFCD Manual has been referenced for additional guidance.
			D. Active recreation areas located in multipurpose detention facilities are located above the EURV.
			E. No straw mulch is used for erosion control purposes within the EURV stage of a detention basin. See the County's GESC requirements for additional information.
			F. No trees are planted within the EURV.
			G. Cottonwoods, willows and aspens (trees with nuisance root systems) are not be planted within the 100-year water surface.

VII. DESIGNING FOR MAINTENANCE

			A. Access for Sediment Removal
			1. Stable access(s) and working bench(s) are provided within the detention basin such that the horizontal distance between the working bench to the furthest point of sediment removal from the forebay, outlet structure and bottom of the pond is not more than 24-feet.
			2. Access roads and working benches have a longitudinal slope no greater than 10%.
			3. The access road centerline radius is a minimum of 50-feet.
			4. The access road is at least 12-feet wide for a centerline radius greater than 80-feet.
			5. The access road is at least 14-feet wide for a centerline radius between 50- and 80-feet.
			6. Access roads/working benches located below any permanent water surface are designed to be constructed of a reinforced concrete slab a minimum of 6-inches thick placed on a 6-inch gravel base over compacted subgrade. The surface of the concrete shall have a grooved finish.
			7. Access roads/working benches located below the EURV water surface elevation meet the same requirements as below any permanent water surface elevation (see No. 6) OR will be constructed of an 12-inch thick layer of aggregate base course or crushed gravel over compacted subgrade.
			8. Access roads/working benches located above the EURV and below the 100-year water surface meet the same requirements as below any water surface elevation (see No. 6) OR will be onstructed of an 8-inch thick layer of aggregate base course or



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			crushed gravel over compacted subgrade.
			9. The use of reinforced turfgrass for access road surfacing has been approved by the County prior to design.
			10. If approved by the County, the reinforced turfgrass meets all applicable UDFCD criteria. Shrubs, trees, sprinkler heads and valve boxes are not located in the reinforced turfgrass area. Markings are provided to delineate the edges of the access.
			11. Entrances to access roads from roadways or parking lots are located such that traffic safety is not compromised.
			B. Other Guidelines to Facilitate Maintenance
			1. Adequate room for staging the equipment used in the clean-out operations is provided.
			2. A power receptacle adjacent to the detention basin for dewatering operations is provided.
			3. For large, natural sites, a suitable location for disposal of sediment that is cleaned out of the pond is reserved.
			4. The grates located on the inlet/outlet structure are designed in a configuration which allows debris to be raked off of the grate using standard gardening tools.



CHAPTER 13. STORAGE Construction Plans Checklist

Yes	No	N/A	Construction Plan Requirements
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I. DETENTION BASIN PLAN VIEW, the following information shall is shown:

			A. Title block with project information, including a list of sheet revisions and an approval block
			B. Boundaries of project and plan sheet layout (key map)
			C. Existing and proposed roadways, sidewalks, culverts, storm sewer structures/pipes, irrigation ditches and other surface features
			D. Summary table which includes tributary basin area, pond inflow flowrate, peak pond storage, peak pond discharge rate, and the peak stage for each of the pond design events.
			E. Existing and proposed utilities (overhead and underground)
			F. Existing and proposed contours
			G. Right-of-way and easement lines
			H. Proposed pond centerline (typically along trickle channel alignment) with horizontal control
			I. Proposed maintenance road(s) with horizontal control
			J. North arrow and scale bar
			K. Linework and labels indicating design water surface(s)
			L. Linework and labels for proposed pond structures (i.e. inlet, forebay, trickle channel, micropool, outlet structure, emergency spillway, etc.)
			M. Limits of cut and fill
			N. Location(s) of geotechnical test holes
			O. Flow arrows indicating direction of flow through pond

II. DETENTION BASIN PROFILE VIEW (typically located along trickle channel alignment), the following information is shown:

			A. Title block with project information, including a list of sheet revisions and an approval block
			B. Horizontal and vertical scale bars
			C. Existing and proposed ground along profile centerline
			D. Existing and proposed utilities along profile centerline
			E. Design water surface elevation(s) (i.e. Micropool, WQCV, EURV, 100-year)
			F. Proposed structures along profile centerline, including specific reference (control) stations and elevations (i.e. drop structures, inlet, forebay, trickle channel, micropool, outlet structure)
			G. Flow arrows with proposed longitudinal grades along profile centerline

III. DETENTION BASIN DETAILS, the following details and information is provided:

			A. Maintenance road and access ramp cross sections and details
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Yes	No	N/A	Construction Plan Requirements
			B. Trickle channel cross sections and details
			C. Forebay cross sections and details
			D. Forebay outlet structure cross section and details
			E. Micropool cross sections and details
			F. Outlet structure cross sections and details
			G. Emergency spillway cross sections and details
			H. Cross sections and details for erosion protection at pond outfall
			I. Include any additional structure details or special connections that are not included in the Arapahoe County Standard Details or Colorado Department of Transportation M & S Standard Plans