

# USER MANUAL – PCM-FSD FINAL DESIGN

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## LIST OF ABBREVIATIONS

City	City of Colorado Springs
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
C.R.S.	Colorado Revised Statutes
DCM	Drainage Criteria Manual
EPA	Environmental Protection Agency
EDB	Extended Detention Basin
EURV	Excess Urban Runoff Volume
FSD	Full Spectrum Detention
GB	Grass Buffer
GS	Grass Swale
MS4	Municipal Separate Storm Sewer System
PCM	Permanent Control Measure
PPS	Permeable Pavement Systems
RG	Rain Garden
RP	Retention Pond
SWMM	Storm Water Management Model
WB	Wetland Basin
WQCD	Water Quality Control Division
WQCV	Water Quality Capture Volume

# CHAPTER 1

## INTRODUCTION

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## 1.0 INTRODUCTION

Protecting the quality of stormwater runoff is important to the City of Colorado Springs (City), and is required by the Colorado Discharge Permit System (CDPS) Regulations. The policies and guidance described in this user manual is pursuant to the **Municipal Code of the City, Colorado, Chapter 7, Article 7, Part 15.** The Colorado Department of Public Health and Environment (CDPHE), Water Quality Control Division (WQCD), through the Municipal Separate Storm Sewer System (MS4) permit issued to the City, requires the City to control and reduce the discharge of pollutants to protect stormwater quality and to satisfy the appropriate water quality requirements of the Colorado Water Quality Control Act (§ 25-8-101 et seq., C.R.S.) and the Colorado Discharge Permit Regulations (Colorado Regulation No. 61). The City's MS4 permit requires the City to implement a program to reduce the discharge of pollutants from public and private **construction sites, and the process described herein is a part of the approved construction program.**

## 2.0 PURPOSE OF MANUAL

This manual, entitled *User Manual - PCM-FSD Final Design*, provides the workbook user with instructions for user input requirements and a description of calculated results. Results in the workbook are calculated based on user inputs and are compared to City DCM requirements and recommendations. If the differences are significant enough and the user input values are outside of City requirements or recommendations the results will be flagged. Orange flagged messages are used when the user input value is not within City DCM recommended guidance. Red flagged messages are used when the user input value does not meet City DCM requirements.

This document contains both requirements and recommended guidance. Requirements are denoted by verbs such as "shall" and "must," while guidance is denoted by the use of "should" or is specifically called out as guidance or recommendations.

Revisions to this document may be incorporated as necessary. The policies and procedures herein may be subject to change if they are found to no longer be effective or compliant with the City's MS4 requirements. It is the responsibility of applicants to obtain the latest revision to this document.

City staff will review project submittals for compliance with this manual and with the ultimate goal of reducing the pollution of state surface waters. The provisions in this manual shall be regarded as the minimum requirements for Permanent Control Measures and Detention Facilities. The City does not and will not assume liability for design and construction deficiencies by others.

### 3.0 RELATIONSHIP OF THIS USER MANUAL TO OTHER PUBLISHED CRITERIA AND REGULATIONS

In the event of a direct and irreconcilable conflict between this user manual, the PCM-FSD Final Design Workbook and other published City criteria, the City Drainage Criteria Manual shall prevail.

Compliance with this manual does not affect a Permittee's obligations to comply with other applicable local, state, and federal criteria and regulations.

### 4.0 REQUEST FOR VARIANCE

Permittees may request variances from the requirements outlined in the PCM-FSD Final Design Workbook and this User Manual. The procedure for requesting variances is described in the City Drainage Criteria Manual. A variance cannot be granted which would create a condition of non-compliance with the City's MS4 permit. Any variance approved by the City will be documented, including a description of the reasons for the approval and a finding that the variance does not create a condition of non-compliance with the City's MS4 Permit.

### 5.0 DEFINITION OF TERMS

Commonly used terms in this manual have been defined as follows for convenience, but this is not intended to be an exhaustive list.

## CHAPTER 2

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The **Final Design Form worksheet** allows the user to perform a check of the final storage routing for the design submitted to the City for a new development, redevelopment, or retrofit project. A copy of this Final Design Form needs to accompany the final drainage report, final design drawings and specifications being submitted to the City for review and approval. The following instructions are organized to be consistent with the same Section numbering seen on the Final Design Form worksheet.

## 1. SELECT INPUT PREFERENCES

This section allows the user to select how they want to enter user inputs based on the final design information that should be readily accessible to the designer. Depending on the options selected, some sections of the workbook will be locked and greyed out because they do not apply. The sections that do apply will have unlocked blue input cells and black text for descriptions. The option button selections include:

Stage vs. Elevation – Do you prefer to evaluate the storage facility, outlet structure inverts and water surface elevations relative to a defined stage set equal to zero (e.g. permanent pool surface or sand filter media surface set equal to zero) or do you prefer to evaluate the facility with respect to actual design elevations (e.g. 5,280 feet). The selection chosen will impact the remainder of the worksheet inputs along with the calculated results.

Stage-Area vs. Stage-Volume – Do you prefer to enter storage data as a Stage-Area relationship or as a Stage-Volume relationship in Section 2 of the form. The Stage-Area relationship is preferred when available because this relationship can be used to calculate the Stage-Volume relationship using the conic volume equation. If the Stage-Volume relationship is selected, there is no way to back-calculate the Stage-Area method and some results can't be generated in the summary table and charts.

Outlet Stages and Dimensions vs. Stage-Discharge Relationship – This option allows the user to either enter all the specific WQCV/EURV and FSD outlet structure details in Sections 4 through 8 (e.g. invert elevations, orifice areas, weir/grate and spillway dimensions, and restrictor plate geometry) or to instead simply enter a Stage-Discharge relationship in Section 2. Use of the Stage-Discharge Relationship input preference does not provide the user or reviewer the ability to check the Final Design performance and it is recommended that this preference should only be used when the outlet structure input options can't adequately represent the final design outlet structure configuration.

Area (sq.ft.) & Volume (cu.ft.) vs. Area (ac) & Volume (ac-ft) – Allows the user to select the preferred units of measurement based on the available design data. The selection chosen will impact the remainder of the worksheet inputs along with the calculated results



## 2. PROVIDE STAGE-AREA-VOLUME-DISCHARGE RELATIONSHIPS

Based on your preferences in Section 1, provide final design inputs in the blue colored cells for the stage-area relationship or stage-volume relationship and the stage-discharge relationship (if selected). Enter as many rows as you need to adequately describe how the basins water surface area/volume/discharge varies with stage. All rows do not need to be filled out; however, do not leave blank rows between entries. It is very important that if "Stage" is selected in Section 1 that Stage Zero be the entry in the first row and that Stage Zero represent the filter media surface (RG or SF), micropool surface (EDB), or permanent pool surface (RP or WB). Similarly, if "Elevation" is entered in Section 1, the elevation in the first row must represent the filter media surface (RG or SF), micropool surface (EDB), or permanent pool surface (RP or WB).

Data may be copied and pasted into the table if they are available on another spreadsheet or table. Description entries in any row of the Description column is optional. Entries for Stage, Volume, and Discharge (if selected) must be greater than or equal to the previous entry in the row above. If the user enters a decreasing value the program will alert the user and delete the entry. However, Area entries may decrease to represent closed conduit pipe storage (e.g. upper section of a circular pipe). All volumes are calculated from user input areas using the Conic Equation and not the average-end method.

After all entries are provided, click on the "Interpolate Table for Routing Calculations" button. This creates an expanded table (hidden down and to the right of the user input sections) that interpolates values at 0.1 feet increments between your entries. This expanded table is then used in the Puls Routing calculations. When the interpolation routine is completed, a message (blue text) below the button will notify the user that "Interpolated Table Complete". If at any time the user changes the input preferences in Section 1 or the data entries in the Section 2 table, the Interpolation button will need to be clicked again.

In special cases when there is no flood routing basin above the WQCV/EURV basin, the user still needs to extend the basin stage-area relationship or stage-volume relationship above the WQCV/EURV water surface to account for larger storm events. This represents the flooded area above the WQCV/EURV water surface as water spreads into adjacent terrain such as parking lots, streets, or vegetated areas.

## 3. TRIBUTARY WATERSHED HYDROLOGY

In this section you must provide tributary watershed information including area, effective imperviousness, and soil type percentages along with calculated tributary watershed hydrology including pre-development peak flows, post-development storm inflow hydrographs and the associated hydrograph time interval.

3.A) Tributary Watershed Area – Enter the tributary watershed area including the surface area of the PCM-Detention facility. The tributary watershed area is used in calculating the default WQCV and EURV per the City

DCM. The tributary watershed area is also used to calculate the default micropool surface area (for EDBs) per the City DCM.

3.B) Effective Imperviousness of Tributary Area (Ia) – Enter the effective imperviousness of the tributary watershed. The imperviousness is also used in calculating the default WQCV and EURV the default micropool surface area (for EDBs) per the City DCM.

3.C) NRCS Hydrologic Soil Groups of Tributary Watershed – Enter the percentage of each soil type within the tributary watershed. The sum of the three soil types percentages must equal 100%, otherwise the program will notify the user and clear the last entry. The soil type percentages are used to calculate the default EURV per the City DCM.

3.D) Provide Pre-Development Peak Flows from model runs – The user may enter the pre-development peak flows (cfs) in the blue input cells for the return periods to be routed through the storage facility. These peak flows are needed to show how close the post-developed peak flows match the pre-developed condition and how well the final design mitigates downstream flooding. The blue input cells provide options for the 2-, 5-, 10-, 25-, 50-, 100- and 500-year pre-development peak flows. The City requires that, at a minimum, you provide the 5- and 100-year values in order to evaluate the 5-year with respect to Colorado Statutes regarding drain times under 72 hours and the 100-year for flood hazard purposes. Providing other return period values is optional but provides a good way to evaluate if the final design is meeting the intent of the full-spectrum detention concept by limiting peak flows for intermediate storms (5-yr through 50-yr) to pre-development conditions and to ensure that the 500-year volume and peak flow can pass through the emergency spillway without overtopping the embankment. Keep in mind that this analysis only shows the comparison just downstream of the detention facility and that further downstream the combined outflow from multiple detention facilities may exceed pre-development conditions. Detailed analysis of larger urban catchments has shown that matching the peak 100-year pre-developed flow at each site results in increased flooding along major waterways downstream. Therefore, it is a good idea to slightly over detain the 100-year runoff volume and release it at 90% of the pre-development peak flow to account for the downstream effects of multiple facilities.

3.E) Adjust "Time Interval" to match Post-Development Inflow Hydrographs – Enter the time interval that your post-development storm inflow hydrographs are based on. Up to 72 rows may be filled out, sufficient for 2-, 3- and 6-hour storms at 5-minute increments. If you need to use a 12-hour storm, change the "Time Interval" from 5-minutes to 10-minutes and use appropriate hydrograph values.

3.F) Provide Post-Development Inflow Hydrographs from model runs – Enter the post-development storm inflow hydrographs for each of the return periods that you entered for pre-developed peak flows. The City requires that, at a minimum, you provide the 5-year and 100-year hydrograph values for the reasons discussed above. The hydrographs can be copied and pasted from another Excel worksheet to speed up and simplify data entry.

## 4. WQCV/EURV PCM TYPE AND OUTLET DETAILS

Section 4 allows the user to specify the type of PCM being designed, the target WQCV and EURV (optional), and the PCM outlet structure details. The entry fields include:

4.A) Select WQCV/EURV PCM Type – The pulldown list allows the user to identify which type of PCM is included in the final design. The options include RG, SF, EDB, RP, and WB. The selected PCM Type has implications on the rest of the inputs in Section 4 (some rows are greyed out and locked if not applicable). The selected PCM Type also impacts which rows are visible on the fifth page of the worksheet. The fifth page includes sections on growth media/vegetation, micropools, trickle channels, permanent pools, baseflow, inlet energy dissipation, forebays, trash racks, embankment protection, and maintenance access. Only the sections applicable to the selected PCM Type are visible, all other sections are hidden.

4.B) Water Quality Capture Volume (WQCV) – Enter the WQCV for the tributary watershed area. If the user has provided all of the required tributary watershed inputs in Section 3 and has selected the PCM Type, the required WQCV per the City DCM will be shown to the right of the user input cell for reference.

4.C) Excess Urban Runoff Volume (EURV) – Enter the EURV calculated for the tributary watershed area (not an available option for Rain Gardens/Bioretenion because the increased inundation time is detrimental to the vegetation). The EURV is an optional input parameter and is not required if not relevant to the final design. If the user has provided all of the required tributary watershed inputs in Section 3 and has selected the PCM Type, the required EURV per the City DCM will be shown to the right of the user input cell for reference.

4.D) Impermeable Geomembrane Liner – This option only applies when RG or SF are selected in 4.A. Select whether an impermeable geomembrane liner will be installed. An impermeable geomembrane liner is required when the PCM is in close proximity to a structure or building foundation, expansive soils are present under the basin, or if there is a potential for groundwater contamination due to the land uses in the tributary catchment. If an impermeable liner is provided, underdrains will be automatically selected in Section 4.E.

4.E) Underdrains – This option only applies when RG or SF are selected in 4.A. If an impermeable liner is provided in Section 4.D. then the underdrains are automatically selected. Underdrains are highly recommended/required on all installations when the underlying soil conductivity and soil mantle thickness will not adequately infiltrate the WQCV in 12-hours or less. If underdrains are provided then the user will need to provide the depth to the centroid of the underdrain outlet orifice, measured from the filter media surface (4.G.) and the Underdrain Outlet Orifice Area (4.H.) in order to determine the discharge through the underdrain system. However, if underdrains are not provided then the discharge through the bottom of the PCM (RG or SF) is determined based on the average infiltration rate (4.F.) calculated as described below.

4.F) Calculated Average Infiltration Rate of WQCV through bottom of PCM – The average infiltration rate is only calculated when either RG or SF are selected in 4.A. The average infiltration rate (in/hr) is calculated based on

the rate required to drain the WQCV (cu.ft.) through the bottom area of the PCM (sq.ft.) in 12 hours. When an underdrain is provided, the average infiltration rate is provided for informational purposes only but is not used in further calculations. However, if no underdrain is provided then the average infiltration rate is used to calculate the discharge rate through the bottom of PCM and is factored into the Puls Routing method when routing hydrographs through the detention basin.

4.G) Depth to Centroid of Underdrain Outlet Orifice from filter media surface – This input cell only applies when RG or SF are selected in 4.A and Underdrains are selected in 4.E. If “Stage” was selected in Section 1, the depth should represent the distance below stage zero and should be entered as a positive number. If “Elevation” was selected in Section 1, the input description for 4.G. will instead read “Elevation of Underdrain Outlet Orifice Centroid” and the user should enter the actual design elevation of the underdrain outlet orifice centroid which will be less than the filter media surface elevation entered in the first row of the table in Section 2.

4.H) Underdrain Outlet Orifice Area – This input cell only applies when RG or SF are selected in 4.A and Underdrains are selected in 4.E. This input value represents the orifice area of the underdrain outlet restrictor plate. The outlet orifice is used to control the emptying time of the RG or SF.

4.I) WQCV/EURV Orifice Plate – This section only applies when EDB, RP, or WB are selected in 4.A. Here the user can enter the stage (or elevation) or each orifice opening centroid along with the corresponding open area of each orifice. For EDBs, there will typically be multiple rows of orifice openings, whereas for RPs and WBs, there may be only a single orifice opening. The workbook is capable of evaluating up to 25 rows of orifice openings.

4.J) Discharge Coefficient for all WQCV/EURV Outlet Orifices – This input cell applies to either the underdrain outlet orifice (if an underdrain is provided for a RG or SF) or all of the orifice openings in the WQCV/EURV orifice plate (for an EDB, RP, or WB).

## 5. FLOOD CONTROL OUTLET STRUCTURE TYPE

Section 5 provides a pulldown list which allows the user to select the type of outlet structure being used to detain and release flood events. This section is greyed out if the user has selected to provide a stage-discharge relationship in Sections 1 and 2. If the user has opted to describe the outlet structure then the user is given two options in the pulldown list.

The first option is the traditional FSD outlet structure consisting of an overflow weir (dropdown) and grate that is drained by an outlet pipe with a flow restriction plate (horizontal plate over top half of pipe, circular orifice plate, or rectangular orifice plate). An emergency spillway is also included with this option. This design assumes that the flow restriction plate on the entrance to the outlet pipe controls the release rate of the 100-year design storm. The overflow weir is set at an elevation above the WQCV/EURV water surface elevation so that it is only utilized when the WQCV or EURV is exceeded (typically larger flood events greater than 5-year design storm).

The overflow grate serves as a trash rack to screen trash that may plug the outlet pipe's entrance and to provide a safety barrier to keep people out of the structure. The emergency spillway is designed to allow larger design storms (e.g. 500-year) to pass through the detention facility or to provide an overflow path if the outlet structure gets clogged. If this option is selected, Sections 6, 7, and 8 will need to be filled out in order to route the design storms.

The second option is to only provide an emergency spillway above the WQCV/EURV outlet structure and not have an overflow weir or outlet pipe. This option may be common in smaller PCM installations where flood control will be handled in downstream regional facilities. If this option is selected, Sections 6 and 7 will be locked and greyed out and the user only needs to provide inputs for the emergency spillway in Section 8.

## 6. OVERFLOW WEIR (DROPBOX) AND GRATE (FLAT OR SLOPED)

This section provides for the entry of final design parameters of the outlet control dropbox. The entry fields include:

6.A) Overflow Weir Front Edge Height (or Elevation) – Enter the height above Stage Zero or the elevation of the front edge of the overflow box. The program assumes that the top of the grate is flush with the top of the overflow outlet box (no gap between the concrete overflow box and the grate).

6.B) Overflow Weir Front Edge Length (inside edge of dropbox) – Enter the overflow Weir Front Edge Length (inside edge of overflow box). This is set equal to the horizontal distance between the inside walls of the dropbox behind the front wall or the distance between the inside edges of the grate frame, whichever is smaller.

6.C) Overflow Weir Grate Slope (H:V, enter zero for flat grate) – This entry defines if you have a flat or sloping grate. If flat, enter "zero". If sloping, enter the slope as horizontal vs. vertical.

6.D) Horizontal Length of Weir Sides (inside edge of dropbox) – Enter the horizontal distance (feet), between the front inside-wall and the back-inside wall of dropbox or the horizontal distance between the front and back inside edges of the grate frame, whichever is smaller.

6.E) Overflow Grate Open Area % (grate open area / total grate area) – Enter, in percent, the total area of the grate that is actually open, namely not blocked by trash rack bars.

6.F) Debris Clogging % – Based on engineer's best professional judgement, enter the percent of the grate that may be blocked by floating debris during larger storm events. Depending on the size of the tributary area, grate and its openings, for small catchments (e.g., 3 to 8 impervious acres) it could be as little as 25%. For large catchments (e.g., 50 impervious acres, it could be 50% or more. This also depends on land uses and waterway type upstream. Natural channels with woody debris are likely to deliver larger quantities of floating debris during large events.

6.G) Height of Grate Upper Edge (at back side of dropbox) – The calculated height at the top of a sloping grate. For flat grates (zero slope), the height will be the same as the weir front edge height entered in 6.A.

6.H) Overflow Grate Slope Length (inside edge of dropbox) – The calculated length of the sloping grate along the grate surface determined from the grate slope (6.C) and the horizontal length of the weir sides (6.D). For flat grates (zero slope), the slope length will be the same as the horizontal length entered in 6.D.

6.I) Overflow Grate Open Area (without debris) – The calculated open area of the grate based on the grate dimensions (6.B. and 6.H.) and the percent open area (6.E.).

6.J) Overflow Grate Open Area (with debris) – The calculated open area of the grate determined by adjusting the grate open area without debris (6.I) by the percent debris clogging entered in 6.F.

## 7. OUTLET PIPE WITH FLOW RESTRICTION PLATE

In this section the user enters the final design parameters for the outlet pipe and flow restriction plate used to control the release rate of the 100-year design storm when detaining flood events. The required input parameters will depend on the type of outlet restriction selected in 7.A.

7.A) Select Type of Outlet Restriction – The pulldown list includes three flow restriction plate options. The figure shown to the right of the Final Design Form worksheet inputs provides images depicting each outlet configuration. Once an option is selected from the pulldown list, the appropriate input cells descriptions below will be updated to reflect the required inputs for that outlet configuration. The three options include:

(1) Circular Outlet Pipe w/ Restrictor Plate which consists of a circular pipe with a horizontal restrictor plate covering up the top portion of the outlet pipe. The restrictor plate height above the invert of the outlet pipe controls the discharge rate into the outlet pipe during the 100-year event.

(2) Circular Orifice Plate which consists of a circular or rectangular outlet pipe with a restrictor plate fully covering the entrance. The restrictor plate has a circular orifice cutout which is smaller than the outlet pipe dimensions and controls the discharge rate into the outlet pipe during the 100-year event.

(3) Rectangular Orifice Plate which consists of a circular or rectangular outlet pipe with a restrictor plate fully covering the entrance. The restrictor plate has a rectangular orifice cutout which is smaller than the outlet pipe dimensions and controls the discharge rate into the outlet pipe during the 100-year event.

7.B) Depth (or Elevation) to Invert of Outlet Pipe (or Outlet Orifice) – This input cell description depends on the selection of Stage vs. Elevation in Section 1 and the Outlet Restriction Type selected in 7.A. If Stage was selected, you will be asked to provide the depth to invert of outlet pipe (or depth to invert of outlet orifice) relative to “Stage = 0”. This value should be a positive number and is the distance below the media filter,

micropool, or permanent pool. If Elevation was selected, you will be asked to provide the elevation of the outlet pipe invert (or elevation of outlet orifice invert).

7.C) Outlet Pipe Diameter, Circular Orifice Diameter or Rectangular Orifice Width – Depending on the Outlet Restriction Type selected in 7.A, the user must provide either the outlet pipe diameter, circular orifice diameter, or width of rectangular orifice, all in inches.

7.D) Restrictor Plate Height above Pipe Invert or Rectangular Orifice Height – If the user selected Circular Outlet Pipe with Restrictor Plate in 7.A, the height from the outlet pipe invert to the bottom edge of the restrictor plate (inches) must be provided. If the user selected Circular Orifice Plate in 7.A, this input cell is not needed and the cell will be greyed out. If the user selected Rectangular Orifice Plate in 7.A, the height of the rectangular orifice cutout (inches) must be provided.

7.E) Half Central Angle of Restrictor Plate on Pipe – This calculation is only performed when Circular Pipe with Restrictor Plate is selected in 7.A. The calculation is necessary to determine the orifice area and orifice centroid for the portion of the outlet pipe below the restrictor plate. If circular or rectangular orifice plates are selected this row is greyed out because the calculation is not necessary.

7.F) Outlet Orifice Area – This is the calculated orifice area based on the user inputs in 7.A through 7.D.

7.G) Height of Outlet Orifice Centroid above Outlet Pipe Invert (or Orifice Invert) – This is the calculated orifice centroid relative to the outlet pipe invert or orifice invert depending on the Outlet Restriction Type selected in 7.A.

7.H) Ratio of Grate Open Area / 100-yr Orifice Area – This is the calculated open area ratio of the Overflow Grate Open Area (6.I.) divided by the Outlet Orifice Area (7.F). It is recommended that this value be greater than or equal to 4 to ensure that the Outlet Restriction Plate is the controlling element of the outlet structure and that the grate is not controlling the actual release rate of the 100-year design storm.

## 8. EMERGENCY SPILLWAY (RECTANGULAR OR TRAPEZOIDAL)

In this section the user enters the geometry of the emergency spillway and the desired freeboard in order to check the adequacy of the emergency spillway/overflow capacity and depth.

8.A) Spillway Invert Stage (relative to Stage = 0 ft) or Spillway Invert Elevation – Depending on the option selected in Section 1, enter either the stage (relative to stage zero) or the elevation of the spillway crest. The minimum stage or elevation entered also depends on the outlet structure type selected in Section 5. When the dropdown with grate and outlet pipe are being utilized, the spillway stage or elevation should be above the 100-year ponding depth to ensure it does not interfere with the controlled release rate of the 100-year design storm through the outlet pipe restriction plate. For designs where only the emergency spillway is being used

(no dropbox or outlet pipe), the stage or elevation should be above the WQCV ponding depth, or EURV ponding depth when applicable, to ensure it does not interfere with the controlled release rate of the WQCV and EURV through the filter media or orifice plate.

8.B) Spillway Crest Length – Enter the length of the broad-crested spillway weir perpendicular to the flow direction. If you are not using a spillway and are using a reinforced embankment, enter the total length of the embankment crest. The user should be aware that mathematical instabilities can occur for large weir lengths since the discharge rate can increase very rapidly with depth, thus causing the Puls method to produce oscillating results in flow and depth. Should that happen, providing a shorter spillway crest length may stabilize the outflow, but may somewhat underestimate the actual flow rates overtopping the basin.

8.C) Spillway End Slopes (H:V) – Enter the average of the side slopes at the ends of the spillway (horizontal vs. vertical). Estimate these using either the formed slopes or the terrain slopes at the ends of the spillway. Enter “0” if the ends are vertical walls.

8.D) Freeboard above Maximum Water Surface – Enter the freeboard above the overflow water surface stage/elevation you provided for in your design.

8.E) Spillway Design Flow Depth – This is the calculated flow depth through the emergency spillway based on the un-detained post-development peak flow rate for the 100-year design storm entered in Section 3.

8.F) Stage (or Elevation) at Top of Freeboard – This is the calculated stage (or elevation) at the freeboard level (100-year overflow water surface plus freeboard depth).

8.G) Basin Area at Top of Freeboard – This is the calculated surface area of the detention facility at the stage (or elevation) corresponding to the stage (or elevation) at top of freeboard (8.F.). This provides the user with the surface area footprint of the detention facility assuming the outlet structure is clogged and the entire 100-year design storm inflow passes through the emergency spillway.

## 9. ROUTED HYDROGRAPH RESULTS

Once all of the required inputs have been entered in Sections 1 through 8, the program will automatically route the hydrographs through the detention facility and summarize the results in this section. Only results for the return periods containing hydrology data in Section 3 will be populated. Results that are outside of City recommended ranges will be highlighted in pink for further evaluation and possible changes in design. The summary results include:

Inflow hydrograph volume calculated based on the user input post-development storm inflow hydrographs. It is a good idea to double check the calculated volumes against the source of the inflow hydrographs to make sure the data was entered correctly.



Predevelopment Peak Flows are simply a copy of the user entered values in Section 3.

Peak Inflow is the largest value in the post-development storm inflow hydrographs entered by the user in Section 3.

Peak Outflow is calculated using the Puls Routing Method to route the storm inflow hydrographs through the user defined storage facility and outlet structure.

Ratio (Outflow/Predevelopment) is simply the ratio of the peak outflow from the detention facility divided by the user entered pre-development peak flow. This provides a quick comparison of the release rates against the pre-development condition to determine if the final design is functioning as intended.

Structure Controlling Flow identifies which component of the overall outlet configuration is controlling the release rate at that return periods maximum water surface elevation. For example, in an EDB, a good FSD design would result in the orifice plate controlling the WQCV, EURV, 2-yr and possibly 5-yr release rates. The overflow weir (dropbox) and grate would likely control the 10-year through 50-year storms. The outlet pipe restrictor plate would control the 100-year release rate (ideally to 90% of the pre-development peak flow), and the emergency spillway would be functioning during the 500-year storm.

Maximum Velocity through Grate represents the velocity through the grate open area at the maximum water surface elevation of each return period. Research has shown that the maximum velocity should not exceed 2 feet per second due to safety concerns regarding a person getting pinned to the rack during a large storm event. At velocities below 2 fps the average child should be strong enough to pull themselves safely off of the outlet structure. If no overflow weir (dropbox) with grate is provided this row is not applicable.

Time to Drain 97% of Volume shows the duration in hours it takes to drain a design storm from when the inflow hydrograph begins until only 3% of the design storm volume remains in the detention facility. The value of 97% is based on the Colorado Statute that 97% of the 5-year storm drain within 72 hours to avoid impacts on senior water rights.

Time to Drain 99% of Volume shows the duration in hours it takes to drain a design storm from when the inflow hydrograph begins until only 1% of the design storm volume remains in the detention facility. These results are used to determine the drain time of the WQCV (e.g. 40 hours for an EDB) and also to ensure that all design storms drain within 120 hours per the Colorado Statute. The value of 99% is used because the math used to calculate drain times results in a disproportionately long time to drain the last 1% due to the very small head on the outlet structure.

Maximum Ponding Depth is the calculated maximum depth of each return period based on the Puls Routing Method.

Area at Maximum Ponding Depth is the corresponding surface area at the maximum ponding depth based on the Stage-Area relationship. If the user entered a stage-volume relationship in Section 2 instead, this row will not be applicable.

Maximum Volume Stored is the corresponding storage volume at the maximum ponding depth based on the Stage-Volume relationship.

In addition to the summary results table, three graphs are provided showing inflow vs. outflow hydrographs, ponding depth over time, and the stage-area-volume-discharge relationships for the design.

**Sections 1 through 9 conclude the input/output information required for storage routing of design hydrographs through the detention facility using the Puls Routing Method. The sections that follow provide additional information about many of the design elements for the type of PCM used. The required inputs will vary with the type of PCM used and the sections are organized along those categories. Select the PCM type for the final design being evaluated.**

## Rain Garden (RG)

## Sand Filter (SF)

## Extended Detention Basin (EDB)

## Retention Pond (RP)

## Wetland Basin (WB)

## **Rain Garden (RG)**

### **10. (RG) - GROWTH MEDIA**

Select whether the growth media for the rain garden is at least 18 inches deep and meets the DCM specification. Explain when and why not.

### **11. (RG) - VEGETATION**

11.A) Will the Rain Garden be vegetated with seed or sod – Select whether the rain garden will be vegetated using seeding, sand-grown or other high infiltrations capable turf, or none. Explain any deviations from DCM requirements.

11.B) Will plantings be included in Rain Garden – Select whether there will be plantings of shrubs and/or trees on the side of the growth media. These are not permitted on the media itself because the deeper root structures can damage underdrain systems and overall maintenance becomes more difficult. Explain any deviations from DCM requirements.

### **12. (RG) - IRRIGATION**

12.A) Will the Rain Garden be irrigated – Select whether the rain garden will have temporary irrigation, permanent irrigation, or whether no irrigation will be provided. Explain why there will be no irrigation. If a permanent irrigation system is installed, it is important that the sprinkler heads be located outside of the infiltration surface because sediment accumulations will tend to bury the sprinkler heads and create a maintenance burden when trying to remove accumulated sediment.

### **13. (RG) - INLET ENERGY DISSIPATION (HIGHLY RECOMMENDED)**

13.A) Type of Inflow and Energy Dissipation – Select whether there is no energy dissipation at the inlet because water enters as sheet flow, or if a form of energy dissipation is provided because flow entering the rain garden is concentrated. Explain and describe what type of inlet energy dissipation is being provided.

**[Return to PCM Selection List](#)**

## **Sand Filter (SF)**

### 10. (SF) - INLET ENERGY DISSIPATION

10.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Provide a brief explanation for your selection and describe any specific characteristics.

### 11. (SF) - EMBANKMENT DESIGN AND PROTECTION

11.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

11.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

11.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical.

### 12. (SF) - MAINTENANCE ACCESS

12.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the PCM being used. Please note that there are some options that may not be applicable to the PCM being used. For sand filters, applicable options include Basin Bottom, Inlet, Outlet Works, and Cleanouts.

**[Return to PCM Selection List](#)**

## **Extended Detention Basin (EDB)**

### **10. (EDB) – MICROPOOL (SMALL PERMANENT POOL BELOW LOWEST OUTLET ORIFICE)**

10.A) Depth of Micropool – Enter the depth of the permanent pool. It is required that it be no less than 2.5 feet to mitigate mosquito breeding.

10.B) Initial Surcharge Depth above Micropool to the invert of Trickle Channel – Enter the depth between the water surface of the micropool and the invert of the trickle channel. A minimum of 4 inches is required to keep water from backing up into the main part of the EDB and to facilitate maintenance operations. A maximum of 12 inches is recommended. If outside of this range, explain why.

10.C) Surface Area of Micropool based on Tributary Impervious Area – Enter the micropool surface area in square feet. The surface area should be greater than 10 square feet and should not exceed 400 square feet per the City DCM. The calculated Initial Surcharge Volume (ISV) will be calculated based on the entries in 10.B and 10.C.

### **11. (EDB) – TRICKLE CHANNEL**

11.A) Type of Trickle Channel – Select whether a trickle channel is used, and if it is, whether it is concrete lined or uses some other type of bottom. Describe any specific characteristics of the trickle channel or why one is not needed.

11.B) Depth of Trickle Channel – Enter the depth of the trickle channel in inches. For concrete-lined trickle channels a depth of 6 inches is required. Explain any differences from the requirements (e.g. very small tributary catchment, trickle channel sized to carry peak flow from forebay outlet, etc.)

### **12. (EDB) – INLET ENERGY DISSIPATION (REQUIRED)**

12.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Provide a brief explanation for your selection and describe any specific characteristics.

### **13. (EDB) – FOREBAY**

13.A) Forebay Volume – Enter the forebay volume in cubic feet. If the forebay volume does not meet the DCM requirements of 1.0% of the WQCV, explain why.

## 14. (EDB) –WQCV/EURV TRASH RACK (NEEDED TO MINIMIZE CLOGGING POTENTIAL OF THE ORIFICE PLATE)

14.A) Type of Trash Rack – Select “recommended materials” if using the City recommended trash rack materials. If specifying an alternative to the recommended materials, choose "Other" and provide a description of the specified material. Also make sure that the width of the largest opening in the trash rack is smaller than the smallest orifice dimension in the orifice plate).

14.B Minimum Trash Rack Open Area – Calculated value based on the open area of the orifices in the water quality plate using the equation provided. This ensures that the orifice plate controls the discharge rate and not the trash rack.

14.C) Open Area / Gross Area Ratio of Trash Rack – This is the ratio of the trash rack open area to the total trash rack area. DCM recommends a minimum ratio of 0.6 for circular orifices and 0.71 for rectangular orifices.

14.D) Minimum Total Gross Trash Rack Area – Calculated value provides the minimum trash rack area (length x width) required to satisfy the minimum trash rack open area calculated in 14.B.

14.E) Height of the Trash Rack – Enter the total height of the trash rack. It is required that it be extended at least 2 feet below the permanent water surface of the micropool. The program will flag the height if it is not greater than or equal to the WQCV depth plus 2 feet.

14.F) Width of Opening in Concrete Wall for Mounting Trash Rack – Enter the width of opening in concrete wall for mounting trash rack, in inches. A minimum of 12 inches is recommended for a maintainable installation. The program will flag the width if less than the orifice plate width or if when multiplied by the height of the trash rack (14.E) the total area is less than the minimum total gross trash rack area (14.D).

14.G) Width of Opening in Concrete Wall for Mounting Orifice Plate – Enter the width in inches. The program will flag the width if it is less than the width of the orifice openings plus 12 inches.

14.H) Width of Orifice Plate to permit mounting to concrete wall – Enter orifice plate width in inches. The program will flag the width if less than 20 inches or less than the width of opening in concrete wall for mounting orifice plate (14.G) plus 8 inches (4-inch overlap on each side).

## 15. (EDB) – EMBANKMENT DESIGN AND PROTECTION

In addition to the following three inputs, the design engineer is required to file all appropriate paperwork with the Dam Safety Engineer whenever the embankment or the basin design falls within the filing requirements of the State.

15.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

15.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

15.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical.

## 16. (EDB) – VEGETATION TYPES, SOURCES AND INSTALLATION PROTOCOLS

Select whether the design uses irrigation or is non-irrigated vegetation. Briefly describe the vegetation type, sources, and installation protocols and reasons for it.

## 17. (EDB) – MAINTENANCE ACCESS

17.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the PCM being used. Please note that there are some options that may not be applicable to the PCM being used. For extended detention basins, applicable options include Basin Bottom, Inlet/Forebay, Trickle Channel, and Outlet Works.

[Return to PCM Selection List](#)

## Retention Pond (RP)

### 10. (RP) – PERMANENT POOL

10.A) Permanent Pool Volume – Enter the permanent pool volume, in cubic feet or acre-ft depending on the units of measurement selected in Section 1. It is recommended that the volume be no less than 120% of the WQCV to minimize algal growth.

10.B) Width of Wetland Safety Bench (Littoral Zone) – Enter the width of wetland safety bench, in feet. It is recommended that it be no less than 4 feet.

10.C) Maximum Depth of Wetland Safety Bench (Littoral Zone) at Inner Edge – Enter the maximum depth of wetland safety bench at the innermost edge, in feet. It is recommended that it be between 0.5 and 1.0 feet.

10.D) Maximum Depth of Pond – Enter the maximum depth of pond, namely the depth between the permanent pool's surface and the bottom of the pond. It is recommended that this be between 6 and 12 feet to enhance mixing and minimize chances for stratification.

### 11. (RP) – BASEFLOW

11.A) Is there sufficient baseflow to support the permanent pool – Determine whether there is sufficient baseflow to sustain the permanent pool or if the pool can be sustained by groundwater. Briefly describe the reason for your conclusion and reference any supporting documentation.

### 12. (RP) – INLET ENERGY DISSIPATION AND FLOATABLE CONTAINMENT (REQUIRED)

12.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Provide a brief explanation for your selection and describe any specific characteristics.

12.B) Is a flexible floating trash boom provided to trap floatables – Indicate if a floating trash boom is provided and provide specific details of the type and location. Explain reasoning if a boom is not provided.

### 13. (RP) – FOREBAY

13.A) Forebay Volume – Enter the forebay volume in cubic feet or acre-feet depending on the units of measurement selected in Section 1. A forebay in a retention pond is part of the total permanent pool, typically



separated by an underwater berm from the main body of the pond. Because of this, a larger forebay is recommended than is used for an EDB, namely around 3% of the WQCV. A concrete-lined bottom is also recommended to facilitate maintenance.

#### 14. (RP) –WQCV/EURV TRASH RACK (NEEDED TO MINIMIZE CLOGGING POTENTIAL OF THE ORIFICE PLATE)

14.A) Type of Trash Rack – Select “recommended materials” if using the City recommended trash rack materials. If specifying an alternative to the recommended materials, choose "Other" and provide a description of the specified material. Also make sure that the size of the largest opening in the trash rack relative is smaller than the smallest orifice dimension in the orifice plate).

14.B Minimum Trash Rack Open Area – Calculated based on the open area of the orifices in the water quality plate using the equation provided. This ensures that the orifice plate controls the discharge rate and not the trash rack.

14.C) Open Area / Gross Area Ratio of Trash Rack – This is the ratio of the trash rack open area to the total trash rack area. DCM recommends a minimum ratio of 0.6 for circular orifices and 0.71 for rectangular orifices.

14.D) Minimum Total Gross Trash Rack Area – provides the minimum trash rack area (length x width) required to satisfy the minimum trash rack open area calculated in 14.B.

14.E) Height of the Trash Rack – Enter the height of the trash rack. It is required that it be extended at least 2 feet below the permanent water surface of the micropool (or permanent pool depending on PCM type). The program will flag the height if it is not greater than or equal to the WQCV depth plus 2 feet.

14.F) Width of Opening in Concrete Wall for Mounting Trash Rack – Enter the width of opening in concrete wall for mounting trash rack, in inches. The program will flag the width if less than the orifice plate width or if when multiplied by the height of the trash rack (14.E) the total area is less than the minimum total gross trash rack area (14.D).

14.G) Width of Opening in Concrete Wall for Mounting Orifice Plate – Enter the width in inches. The program will flag the width if it is less than 12 inches or is less than the width of the orifice openings plus 12 inches.

14.H) Width of Orifice Plate to permit mounting to concrete wall – Enter orifice plate width in inches. The program will flag the width if less than 20 inches or less than the width of opening in concrete wall for mounting orifice plate (14.G) plus 8 inches (4-inch overlap on each side).

## 15. (RP) – EMBANKMENT DESIGN AND PROTECTION

In addition to the following three inputs, the design engineer is required to file all appropriate paperwork with the Dam Safety Engineer whenever the embankment or the basin design falls within the filing requirements of the State.

15.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

15.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

15.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical.

## 16. (RP) – VEGETATION TYPES, SOURCES AND INSTALLATION PROTOCOLS

Select whether the design uses irrigation or is non-irrigated vegetation. Briefly describe the vegetation type, sources, and installation protocols and reasons for it.

## 17. (RP) – MAINTENANCE ACCESS

17.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the PCM being used. Please note that there are some options that may not be applicable to the PCM being used. For retention ponds, applicable options include Permanent Pool, Safety Bench, Inlet/Forebay, and Outlet Works.

[Return to PCM Selection List](#)

## Wetland Basin (WB)

### 10. (WB) – PERMANENT POOL

10.A) Permanent Pool Volume – Enter the permanent pool volume, in cubic feet or acre-ft depending on the units of measurement selected in Section 1. It is recommended that the volume be no less than 75% of the WQCV to minimize algal growth.

10.B) Littoral Zone Area as a Percent of Permanent Pool Area – Enter the approximate littoral zone area as a percentage of total permanent pool surface area. It is recommended that the littoral zone occupy 50% to 70% of the wetland basin's surface area.

10.C) Width of Littoral Zone Safety Bench around perimeter – Enter the width of the littoral zone safety bench located around the entire perimeter of the basin. It is recommended that it be no less than 4 feet wide.

10.D) Average Depth of Littoral Zone – Enter the average depth of the littoral zone. It is recommended that it be between 0.5 and 1.0 feet to promote wetland vegetation growth.

10.E) Number of Open Water Areas in Permanent Pool – Enter the total number of open water areas in the permanent pool. It is recommended that there be at least 3, including the forebay and the outlet area to provide diverse habitat for predator species (i.e., species that mitigate mosquito problems).

10.F) Maximum Depth of Open Water Areas – Enter the maximum depth of all open water areas. It is recommended that the maximum depth in a wetland basin be between 2 and 4 feet.

### 11. (WB) – BASEFLOW

11.A) Is there sufficient baseflow to support the permanent pool – Determine whether there is sufficient baseflow to sustain the permanent pool or if the pool can be sustained by groundwater. Briefly describe the reason for your conclusion and reference any supporting documentation.

### 12. (WB) – INLET ENERGY DISSIPATION AND FLOATABLE CONTAINMENT (REQUIRED)

12.A) Select the Type of Energy Dissipation at Inlet – From the dropdown menu, select the type of energy dissipation provided at concentrated inflow locations. Provide a brief explanation for your selection and describe any specific characteristics.

12.B) Is a flexible floating trash boom provided to trap floatables – Indicate if a floating trash boom is provided and provide specific details of the type and location. Explain reasoning if a boom is not provided.

### 13. (WB) – FOREBAY

13.A) Forebay Volume – Enter the forebay volume in cubic feet or acre-feet depending on the units of measurement selected in Section 1. A forebay in a wetland basin is part of the total permanent pool, typically separated by a littoral zone/berm between it and the main body of the wetland. Because of this a large forebay is recommended, namely around 3% of the WQCV. A concrete-lined bottom is also recommended to facilitate maintenance.

### 14. (WB) –WQCV/EURV TRASH RACK (NEEDED TO MINIMIZE CLOGGING POTENTIAL OF THE ORIFICE PLATE)

14.A) Type of Trash Rack – Select “recommended materials” if using the City recommended trash rack materials. If specifying an alternative to the recommended materials, choose "Other" and provide a description of the specified material. Also make sure that the size of the largest opening in the trash rack relative is smaller than the smallest orifice dimension in the orifice plate).

14.B) Minimum Trash Rack Open Area – Calculated based on the open area of the orifices in the water quality plate using the equation provided. This ensures that the orifice plate controls the discharge rate and not the trash rack.

14.C) Open Area / Gross Area Ratio of Trash Rack – This is the ratio of the trash rack open area to the total trash rack area. DCM recommends a minimum ratio of 0.6 for circular orifices and 0.71 for rectangular orifices.

14.D) Minimum Total Gross Trash Rack Area – provides the minimum trash rack area (length x width) required to satisfy the minimum trash rack open area calculated in 14.B.

14.E) Height of the Trash Rack – Enter the height of the trash rack. It is required that it be extended at least 2 feet below the permanent water surface of the micropool (or permanent pool depending on PCM type). The program will flag the height if it is not greater than or equal to the WQCV depth plus 2 feet.

14.F) Width of Opening in Concrete Wall for Mounting Trash Rack – Enter the width of opening in concrete wall for mounting trash rack, in inches. The program will flag the width if less than the orifice plate width or if when multiplied by the height of the trash rack (14.E) the total area is less than the minimum total gross trash rack area (14.D).

14.G) Width of Opening in Concrete Wall for Mounting Orifice Plate – Enter the width in inches. The program will flag the width if it is less than 12 inches or is less than the width of the orifice openings plus 12 inches.

14.H) Width of Orifice Plate to permit mounting to concrete wall – Enter orifice plate width in inches. The program will flag the width if less than 20 inches or less than the width of opening in concrete wall for mounting orifice plate (14.G) plus 8 inches (4-inch overlap on each side).

## 15. (WB) – EMBANKMENT DESIGN AND PROTECTION

In addition to the following three inputs, the design engineer is required to file all appropriate paperwork with the Dam Safety Engineer whenever the embankment or the basin design falls within the filing requirements of the State.

15.A) Describe Embankment Protection – Select whether there is an emergency spillway or some other type of embankment protection. Describe embankment protection design and level of protection it provides, such as the 100-year or larger flood event.

15.B) Select Type of Material used for spillway or embankment hardening – From the dropdown menu, select whether the spillway or embankment hardening will use concrete lining, heavy riprap, heavy soil riprap, buried and vegetated turf reinforcement mats, geocell mats, or other type of erosion protection. For other, explain the type being used and the engineering behind its use.

15.C) Downstream Slope of Embankment – Enter the downstream slope of the embankment. DCM recommends no steeper than 4 feet horizontal for each 1 foot vertical.

## 16. (WB) – VEGETATION TYPES, SOURCES AND INSTALLATION PROTOCOLS

Select whether the design uses irrigation or is non-irrigated vegetation. Briefly describe the vegetation type, sources, and installation protocols and reasons for it.

## 17. (WB) – MAINTENANCE ACCESS

17.A) Describe Routine & Restorative Maintenance Access – Check each box that applies for providing maintenance access to each of the elements of the PCM being used. Please note that there are some options that may not be applicable to the PCM being used. For wetland basins, applicable options include Permanent Pool, Safety Bench, Inlet/Forebay, and Outlet Works.

[Return to PCM Selection List](#)