

# 4.8 Sand Filters BMP Summary Fact Sheets



**Description:** Multi-chamber structure designed to treat storm water runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system. It can be configured as either a surface or subsurface facility. In sand filter systems, storm water pollutants are removed primarily through filtration with some additional treatment from gravitational settling and adsorption.

#### **IMPORTANT CONSIDERATIONS**

#### **DESIGN CRITERIA:**

- A sediment chamber that contains 20 percent of the water quality volume is required as a pretreatment device.
- The underdrain system must be designed so that runoff exits the facility within design duration assuming 50 percent of the underdrain capacity is lost due to clogging.
- Maximum contributing drainage area is 10 acres.
- No runoff should enter the filter's sand bed until the upstream drainage area is completely stabilized.
- The filtration media surface must be sized using Darcy's equation with an average filtration rate of 1.75 inches/hour.
- Maximum ponding depth for water quality storm is 24 inches with an additional 36 inches for more severe storm events.
- The filter media must be designed to drain and re-aerate between storm events.
- The top of the filter media must be flat.

#### ADVANTAGES/BENEFITS:

- Normally used in highly impervious areas.
- Good retrofit capability.
- Can be located underground with limited surface space.
- Larger units can be used to partially attenuate runoff peaks.

#### **DISADVANTAGES/LIMITATIONS:**

- High maintenance burden.
- Typically needs to be combined with other controls to provide water quantity control.
- Not recommended for areas with high sediment content in storm water or clay/silt runoff areas.
- Relatively costly.
- Possible odor problems.
- Infiltration and internal water storage techniques are allowed.

#### MAINTENANCE CONSIDERATIONS:

- Inspect for clogging rake debris screen and first inch of sand.
- Remove sediment from forebay/chamber when more than 1 foot of storage is lost.
- Sediment, topsoil, and 3 inches of filter material must be removed after the allowable drawdown time is exceeded by 25 percent.
- Entire filter material and underdrain system must be replaced if removal of 3 inches of media does not restore filtration rate.

#### STORMWATER MANAGEMENT SUITABILITY

L = Low M = Moderate H = High

H 1-inch, 6-hr Water Quality Protection

M 1-yr, 24-hr Channel Protection Volume

M Peak Attenuation Control for 10-yr, 6-hr Storm

M Peak Attenuation Control for 25-yr, 6-hr storm

Sand filter facilities are highly effective in controlling pollution removal for the 1-inch, 6-hour storm and can be designed to control the volume of the 1-yr, 24-hr storm and a portion of peak attenuation for larger storm events.

#### **IMPLEMENTATION CONSIDERATIONS**

L Land Requirements

H Capital Cost

H Maintenance Cost

H Maintenance Considerations

#### PRIMARY POLLUTANT REMOVAL PROCESSES

Filtration

#### POLLUTANT REMOVAL RATES

Effectiveness	Detention	Media	Max.	Pollutant
	Time	Depth	PIndex	Removal
		-		Rates
Optimal	2.0 days	2.5	50	85% TSS
Efficiency		feet	ppm	70% TP
Standard	1.0 days	2.0	50	70% TSS
Efficiency	-	feet	ppm	35% TP
TSS-only	2.0 days	2.5	N/A	85% TSS
Efficiency	-	feet		



# 4.8 Sand Filters

# 4.8.1 General Description

Sand filters are structural storm water controls that capture and temporarily store storm water runoff and pass it through a filter bed of sand. Most sand filter systems consist of two-chambers. The first chamber, the sediment forebay, removes floatables and heavy sediments. The second chamber, the filtration chamber, removes additional pollutants and finer sediments by filtering the runoff through a sand bed. The filtered runoff is collected by an underdrain and discharged. Sand filters can be used on development sites where the use of other controls may be precluded.

There are two primary sand filter types, the surface sand filter and the underground sand filter:

**Surface Sand Filter** – The surface sand filter is a ground level open air facility that consists of a sediment forebay and a filter bed chamber. Surface sand filters can be designed as an excavation, with earthen embankments, or as a concrete or block structure. A surface sand filter facility consists of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment chamber while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing through the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 4.8.1 and 4.8.2 illustrate a typical surface sand filter.

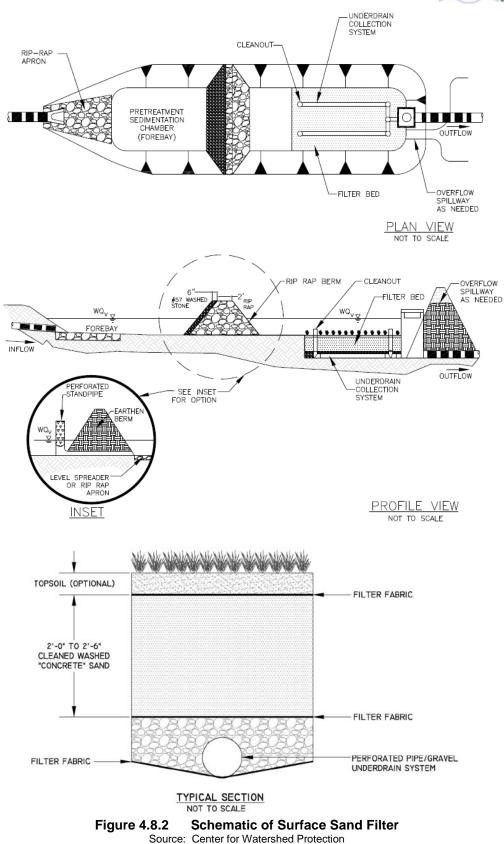
**Underground Sand Filter** – The underground sand filter is located in a vault, and is intended primarily for extremely space limited and high density areas. The underground sand filter is a two-chamber system with an optional third chamber for peak or volume attenuation and to collect and combine the filtered runoff with overflow runoff. The initial chamber is a sedimentation chamber that temporarily stores runoff and utilizes the storage area to capture sediment. The sedimentation chamber is separated from the sand filter chamber by a submerged wall that protects the filter bed from oil, trash, and large particle sediment. The filter bed should be a minimum of 2.0 feet or 2.5 feet deep depending upon design selected, and may have a protective screen of gravel or permeable geotextile to limit clogging. The sand filter chamber also includes an underdrain system with inspection and clean out wells. Perforated drain pipes under the sand filter bed extend into the downstream system or the optional third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir.

Underground sand filters are typically constructed on-line, but can be constructed off-line. For off-line construction, the overflow between the second and third chambers may not be required. The underground vault must be tested for water tightness prior to placement of filter layers. Figure 4.8.5 illustrates a typical underground sand filter.

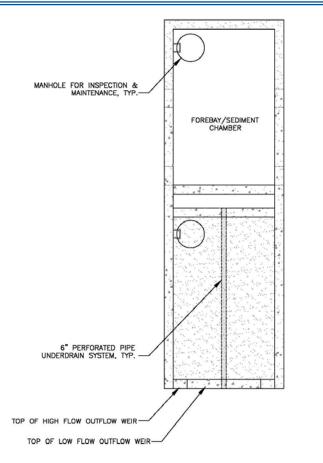


Figure 4.8.1 Surface Sand Filter











# 4.8.2 Storm Water Management Suitability

Sand filter systems are designed primarily for storm water quality and will typically need to be used in conjunction with another structural control to provide downstream channel protection and peak discharge control. Under certain circumstances, filters can provide runoff quantity control, particularly for smaller storm events and large filters. It is important to ensure that a sand filter facility is designed to safely bypass high flows by either preventing the high flows from entering the facility or by ensuring that the high flows do not create erosive conditions if they enter the facility.

### Water Quality Control (WQ<sub>v</sub>)

In sand filter systems, storm water pollutants are removed through a combination of gravitational settling, filtration, and adsorption. The filtration process removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients.

### Channel Protection (CP<sub>v</sub>)

For smaller sites, a sand filter may be designed to capture the entire channel protection volume  $CP_v$  in either an off- or on-line configuration. Given that a sand filter system is typically designed to completely



drain over 1 to 2 days, the requirement of controlling the 1-year, 24-hour storm runoff volume could be met. For larger sites or where only the  $WQ_v$  is diverted to the sand filter facility, another structural control must be used to provide  $CP_v$  volume control.

#### Peak Attenuation Control (Q<sub>p</sub>)

In most cases, another structural control must be used in conjunction with a sand filter system to reduce the post-development peak flow to pre-development levels (detention) if needed. However, if designed with sufficient volume (stage), the peak attenuation control for the 10- and/or 25-year, 6-hour storms may be controlled by the sand filter facility.

Sand filter facilities must provide flow diversion or be designed to safely pass extreme storm flows and protect the filter bed and facility. A maximum ponding depth of 5 feet above the filter media must be maintained during all storm events greater than the 1-inch, 6-hour storm event, up to the 50-year, 6-hour storm.

# 4.8.3 Pollutant Removal Capabilities

Three sand filter designs have been developed for application in the Mecklenburg County area. The <u>optimal efficiency design</u> has the capability to remove 85% of the total suspended solids and 70% of the total phosphorus load. The <u>standard efficiency design</u> has the capability to remove 70% of the total suspended solids and 35% of the total phosphorus load. The <u>TSS-only design</u> has the capability to remove 85% of the total suspended solids and 0% of the total phosphorus loads. All of these designs assume urban post-development runoff conditions that has been observed in the Mecklenburg County area and that the facilities are sized, designed, constructed, and maintained in accordance with the appropriate recommended specifications contained in this manual. The design pollutant removal rates are derived from sampling data and computations completed for the development of this manual. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or treatment train approach. See section 4.8.4 for a discussion of design variables and appropriate pollutant removal rates for specific designs.

# 4.8.4 Planning and Design Criteria

The following criteria are to be considered minimum standards for the design of sand filters. Items listed in Section 4.1.4.A through 4.1.4.H. are requirements and must be addressed in the design. Items listed in Section 4.1.4.I. are recommendations and are optional.

### A. Design Requirements

Following is a list of design requirements that must be followed in the design of sand filters.

• Following are the design values that are required for the three sand filter designs that are available for application in Mecklenburg County. The appropriate minimum design values and associated pollutant removal rates for each of the design are given in Table 4.8.1.

	Table 4.6.1 Design			1
Threshold	Minimum	Minimum	Maximum	Pollution Removal
	Detention Time	Media Depth	PIndex	Rate
Optimal				85% TSS
Efficiency	2.0 days	2.5 feet	50 ppm	70% TP
Standard				70% TSS
Efficiency	1.0 days	2 feet	50 ppm	35% TP
TSS-only				85% TSS
Efficiency	2.0 days	2.5 feet	N/A	

 Table 4.8.1 Design Values and Pollution Removal Rates



- A sediment chamber is required as a pretreatment device for all sand filters. The sedimentation chamber storage area must be sized to hold 20 percent of the water quality volume.
- For above ground sand filters, the sedimentation chamber bottom elevation must be above the top of the filter media elevation.
- Sand filters require a sand filter media with a gravel and perforated pipe underdrain system. The underdrain system must not limit outflow more than the filter media and must be designed so that runoff exits the facility within the design duration. The underdrain system (pipe capacity and orifice capacity) must be designed assuming that 50 percent of the capacity is lost due to clogging.
- The underdrain collection system should be equipped with 6-inch minimum perforated Schedule 40 or stronger PVC pipe or double wall HDPE pipe. Perforations shall be per AASHTO M278 for PVC pipe, AASHTO M252 for double wall HDPE pipe, or be 3/8-inch in diameter spaced 3 inches on center along 4 longitudinal rows that are spaced 90° apart. The pipes shall have a minimum slope of 0.5% and a maximum spacing of 10 feet on center.
- An internal water storage (IWS) system is allowed, provided that the filter media and underdrain system are designed per requirements, specifications and calculations for infiltration provided in Chapter 18 of the NCDENR Stormwater BMP Manual. If IWS is used, the WQv should infiltrate the soil within 48 hours.
- Cleanouts of 6-inch solid PVC must be provided for every 50 linear feet of underdrain, at all bends, and ends of the system for maintenance purposes. The top of the cleanouts should extend 6 inches above the top of filter and have a watertight, vandal proof cap. At least one cleanout shall be installed as an emergency drain that is flush with the top of filter and have a 6-inch threaded extension pipe. The furthest cleanout from the outlet must have the minimum required filter media depth.
- Underdrain pipes must be placed in the bottom of a 12-inch minimum gravel layer. The gravel shall be #57 washed stone and must provide a minimum of 4 inches of cover over the pipe(s).
- The top of the sand filter media must be protected. Washed sod, filter fabric with number 2 stone on top, or a 1-inch thick debris screen should be used to prevent large floatables from clogging the system.
- The maximum contributing drainage area for a surface sand filter is 10 acres. The maximum drainage area for a perimeter sand filter is 2 acres. The maximum drainage area for an underground sand filter is 5 acres.
- Sand filter systems are designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They must not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.
- No runoff should enter the filter's sand bed until the upstream drainage area is completely stabilized and site construction if completed. Any disturbed areas within the drainage area must be identified and stabilized. Filtration controls must only be constructed after the construction site is stabilized.
- The filtration media surface area should be sized using Darcy's equation using an average filtration rate of 1.75 inches/hour.

# $A_{f} = (WQ_{v})(d_{f}) / [(k)(h_{f} + d_{f})(t_{f})]$

where:

 $A_f$  = surface area of sand filter media (ft<sup>2</sup>)



- WQ<sub>v</sub> = water quality control volume ( $ft^3$ )
  - = filter bed depth (2.0' or 2.5' per design)
- = coefficient of permeability of filter media (3.5 ft/dav)k h
  - = average height of water above filter bed (1.0' maximum)
- = design filter bed drain time (days) tf
- Maximum ponding depth for the water quality storm event is 24 inches with an additional 36 inches for more severe storm events.
- All embankments shall be designed per the North Carolina Dam Safety Law of 1967, if applicable, and designed according to the requirements in Section 4.0.6 of this manual
- The top of a sand filter must be flat. .

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For underground sand filters, the minimum distance from the top of sand to the inside top of the structure is 5 feet.

#### **Physical Specifications/Geometry** Β.

Figure 4.8.4 illustrates the various components of a sand filter.

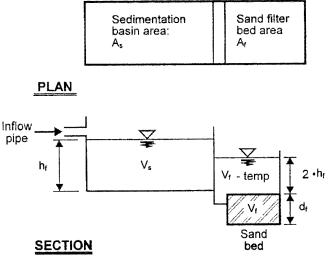


Figure 4.8.4 Surface Sand Filter Volumes Source: Claytor and Schueler, 1996

The filter media consists of a 2.0 to 2.5 feet layer of clean washed medium sand (meeting ASTM C33 concrete sand specifications) on top of the gravel and underdrain system. A 1-inch thick debris screen must be placed on top of the sand filter media to prevent large floatables from clogging the system. Permeable filter fabric is placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system. A proper fabric selection with equal pore-openings is critical. Figure 4.8.5 illustrates a typical media cross section.

The structure of the surface sand filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric should be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.



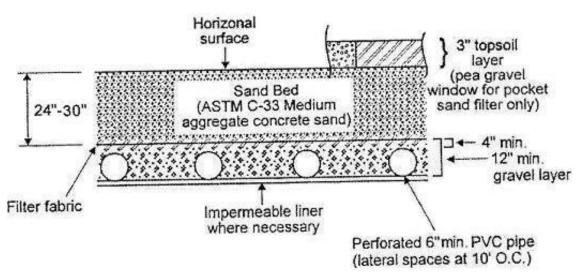


Figure 4.8.5 Typical Sand Filter Media Cross Sections Source: Claytor and Schueler, 1996

### C: Pretreatment/Inlets

- Pretreatment of runoff in a sand filter system is provided by the sedimentation chamber.
- Inlets to surface sand filters must be provided with energy dissipators. Exit velocities from the sedimentation chamber must be sheet flow to prevent filter media erosion.
- Figure 4.8.9 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter.

### D. Outlet Structures

Outlet pipe must be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways). If all storms are being routed through the outlet, outlet protection may be required.

### E. Emergency Spillway

An emergency or bypass spillway must be included in the sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the internal baffle walls or embankments in a manner that can cause structural damage to the filter media or other surrounding features.

# F. Maintenance Access

Adequate access must be provided for all sand filter systems for inspection and maintenance, including the appropriate equipment and vehicles. Access grates to the filter bed must be included in a perimeter and underground sand filter design. The access location must be spaced so that all underground locations are within 25 feet from surface access. Facility designs must enable maintenance personnel to easily replace upper layers of the filter media. See appropriate jurisdiction's land development standards manual for the width of the required easement (PCCE or SDE).



# G. Safety Features

Surface sand filter facilities can be fenced to restrict access from non-approved personnel.

# H. Landscaping

Surface filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass must be capable of withstanding frequent periods of inundation and drought.

### I. Design Recommendations

In addition to the design requirements and variables, following are some design recommendations that should be considered for sand filter design.

- Sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with less than 50% imperviousness or high clay/silt sediment loads must not use a sand filter unless additional pretreatment is considered to reduce the potential clogging and failure of the filter bed.
- Surface sand filters are generally used in an off-line configuration where the water quality volume (WQ<sub>v</sub>) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. In many cases, storm water flows greater than the WQ<sub>v</sub> are diverted to other controls or downstream using a diversion structure or flow splitter.
- Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
- For a surface sand filter, a 2-foot separation is recommended between the bottom of the sand filter and the elevation of the seasonally high water table.

# 4.8.5 Design Procedures

Following are the design procedures to be used for the design of sand filters.

- Step 1 Using the BMP Selection Matrix presented at the beginning of Chapter 4 determine if the development site and conditions are appropriate for the use of a sand filter facility.
- Step 2 Consider any special site-specific design conditions and check to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
- Step 3 Compute water quality volume (WQ<sub>v</sub>) using equations 3.2 and  $3.3 WQ_v = 1.0R_vA/12$ .
- Step 4 Compute site hydrologic parameters using the SCS procedures and/or computer models that use the SCS procedures.
- Step 5 Compute water quality peak flow (WQ<sub>p</sub>) using equation 3.4 for a modified curve number and the SCS hydrograph procedures with a 1-inch, 6-hr, balanced storm event.
- Step 6 Compute channel protection volume (CP<sub>v</sub>) using the SCS method and a 1-yr, 24-hr storm event. Estimate approximate storage volume for channel protection.

Charlotte-Mecklenburg BMP Design Manual



- Step 7 Size flow diversion structure, if needed, to divert the water quality volume to the sand filter.
- Step 8 Compute the release rates for the water quality control and channel protection volume control.
- Step 9 Compute pretreatment volume (if included in the design). The sedimentation chamber should be sized to contain 20 percent of the WQ<sub>v</sub>.
- Step 10 Size filtration basin chamber

The filter area is sized using the following equation (based on Darcy's Law):

$$A_{r} = (WQ_{v}) (d_{f}) / [(k) (h_{r} + d_{f}) (t_{f})]$$

where:

- $A_r$  = surface area of filter bed (ft<sup>2</sup>)
- WQ<sub>v</sub> = Water Quality Protection Volume (or total Volume to be infiltrated)
- $d_f$  = filter bed depth (designer selects either 24 inches or 30 inches)
- k = coefficient of permeability of filter media (ft/day) (use 3.5 ft/day for sand)
- $h_f$  = average height of water above filter bed (ft) (1/2  $h_{max}$ , which varies based on site but  $h_{max}$  is typically < 1 foot)
- t<sub>f</sub> = design filter bed drain time (days) (designer selects either 27 or 51 hours, which is 24 or 48 hours beyond the center of the water quality storm event, 3 hours)

Set preliminary dimensions of filtration basin chamber and sedimentation chamber.

- Step 11 Derive stage-discharge and stage-storage relations for the sand filter. Assume that discharge occurs for headwater depths at the elevation of the top of the filter media and higher. A zero discharge should be assumed at the elevation of the top of filter media.
- Step 12 Route flows through sand filter facility and adjust design of facility to meet all design criteria.
- Step 13 Design inlets, pretreatment facilities, underdrain system, and outlet structures
- Step 14 Compute overflow weir sizes

#### 4.8.6 Inspection and Maintenance Requirements

Specific maintenance inspections and requirements are contained in Chapter 7 of the Administrative Manual.



# 4.8.7 Design Form

Design Procedure Form: Sand Filters	
	NOTES:
SAND FILTER FEASIBILITY	
1. Is the use of a sand filter appropriate?	
2. Confirm local design criteria and applicability.	
PRELIMINARY HYDROLOGIC CALCULATIONS	
<ol> <li>Compute, WQ<sub>v</sub> water quality volume requirements Compute Runoff Coefficient, R<sub>v</sub> Compute WQ<sub>v</sub> volume requirements</li> </ol>	Rv = WQ <sub>v</sub> = acre-ft
<ol> <li>Compute site hydrologic input parameters Development Conditions Area CN (SCS curve number) Adjusted CN (SCS curve number adjusted for 1-inch storm event) Time of concentration</li> </ol>	Pre-developed Post-developed acresacres  hourshours
5. Compute $WQ_p$ peak flow	WQ <sub>p</sub> = cfs
6. Compute $CP_v$ (channel protection volume) Compute S (maximum retention) Compute 1-yr, 24-hr total rainfall depth Compute $q_d$ (runoff volume for 1-year, 24-hour storm event) Compute $CP_v$	S = Rainfall Depth = inches $q_d = $ inches $CP_v = $ acre-ft
7. Size flow diversion structure	
8. Compute release rates Compute $WQ_v$ release rate Compute $CP_v$ release rate	Release Rate = cfs Release Rate = cfs
SAND FILTER DESIGN	
9. Compute sedimentation chamber volume $Vol_{pre} = (0.20)(WQ_v)$	$Vol_{pre} = $ acre-ft A <sub>v</sub> = ft <sup>2</sup>
10. Size filtration bed chamber Compute area from Darcy's Law	$\begin{array}{l} A_r = \underline{\qquad \qquad ft^2} \\ L = \underline{\qquad \qquad ft} \\ W = \underline{\qquad \qquad ft} \end{array}$
11. Develop stage-storage and stage-discharge relationships	Elev         Area. (ft <sup>2</sup> )         Volume. (ft <sup>3</sup> )         Acc. Vol. (ft <sup>3</sup> )         Q (cfs)
12. Route Flows through sand filter	
13. Design inlets and underdrain system,	
<ol> <li>Compute overflow weir sizes Compute overflow – Orifice equation Weir from sedimentation chamber – Weir equation Weir from filtration chamber – Weir equation</li> </ol>	Q =cfs Length =ft Length =ft
15. Assess Maintenance Access and Safety Features	
Notes	



# 4.8.8 Sand Filter Design Example #1

The following design example is for a sand filter facility designed to control the 1-inch, 6-hour for water quality purposes, 1-year, 24-hour for channel protection purposes, and 10-year 6-hour for flood control purposes following the design procedures given in section 4.8. In this design example, the channel protection volume ( $CP_v$ ) is required to be held for a minimum of 24 hours from the center of the rainfall event (as is the requirement for projects within Mecklenburg County and the six Towns); however, the user should note that within the City of Charlotte, the channel protection volume ( $CP_v$ ) is required to be held for a minimum of 24 hours from the six Towns); however, the user should note that within the City of Charlotte, the channel protection volume ( $CP_v$ ) is required to be held for a minimum of 48 hours from the center of the rainfall event. Figure 4.8.6 shows the site plan for the development and base hydrologic data that will be used in the design example.

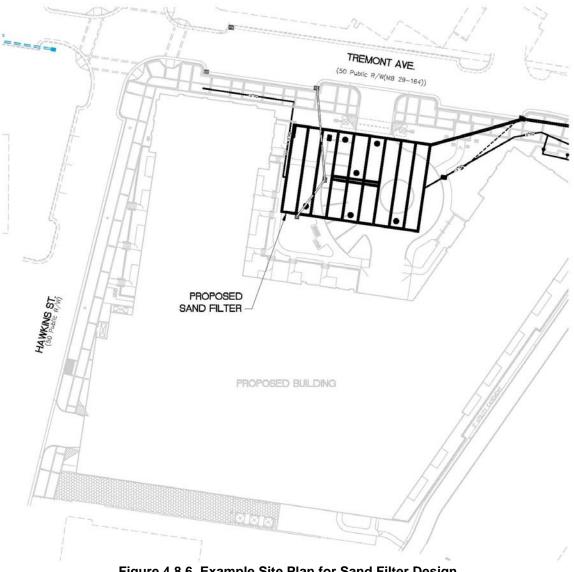


Figure 4.8.6 Example Site Plan for Sand Filter Design

The following steps illustrate how to use the design procedures given in section 4.8 to design a sand filter facility that will be acceptable for the design criteria given in this manual.



# Step 1 BMP Feasibility

For the purposes of this design example, assume that a sand filter design is feasible.

#### Step 2 Confirm Design Criteria

The design criteria contained in Section 4.1 of the manual apply to this design.

#### Step 3 Compute Water Quality Volume (WQ<sub>v</sub>)

• Compute Runoff Coefficient, R<sub>v</sub>, using (Schueler's Method) Equation 3.1

 $R_v = 0.05 + 0.009(I) = 0.05 + (79.2)(0.009) = 0.76$ 

• Compute Water Quality Volume, WQ<sub>v</sub>, using Equation 3.2

WQ<sub>v</sub> = 1.0R<sub>v</sub>A/12 = (1.0 inches)(0.76)(2.93 acre)(1foot/12 inches) = 0.19 ac-ft

• Convert Water Quality Volume, WQv to inches of runoff using Equation 3.3

 $WQ_v = 1.0(R_v) = 1.0(0.76) = 0.76$  inches

#### Step 4 Compute Site Hydrologic Input Parameters

The site contains 2.93 acres and is proposed to be re-developed to 79.2 percent imperviousness. Using SCS hydrologic procedures, the following data can be determined for the example development site. For pre-developed conditions, an assumption that the site was 50% forest in good hydrologic condition and 50% pasture in good hydrologic condition is required. The site consists of 15% hydrologic type B soils and 85% hydrologic type C soils. The pre-developed topography drains in two directions and includes two sub-basins. The post-developed topography drains in one direction.

The pre-developed weighted curve number is:

 $CN_{weighted} = (0.5)(0.15)(61) + (0.5)(0.85)(74) + (0.5)(0.15)(55) + (0.5)(0.85)(70) \\= 69.9 \\Use 70$ 

The post-developed weighted curve number is (based on 79 percent impervious from site plan):

 $CN_{weighted} = (0.21)(0.15)(61) + (0.21)(0.85)(74) + (0.79)(98)$ = 92.6 Use 93

The modified post-developed curve number for application with the 1-inch, 6-hour storm event, using Equation 3.4 is:

 $\begin{array}{ll} \text{CN}_{\text{weighted}} &= 1000/[10+5\text{P}+10\text{WQ}_{v}-10(\text{WQ}_{v}^{2}+1.25\text{ WQ}_{v}\text{P})^{0.5}] \\ \text{CN}_{\text{weighted}} &= 1000/[10+5(1.0)+10(0.76)-10\{(0.76^{2}+(1.25)(0.76)(1.0)\}^{0.5}] \\ &= 97.7 \\ \text{Use } 98 \end{array}$ 



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Condition	Area (acres)	CN	CN (adjusted) for 1-inch storm	t <sub>c</sub> (hours) <sup>1</sup>
Pre-developed (WS1)	1.1	70	N/A	0.532
Pre-developed (WS2)	1.8	70	N/A	0.532
Post-developed	2.9	93	98	0.083

#### Table 4.8.2 Hydrologic Input Data

<sup>1</sup>Based on methods described in the Charlotte-Mecklenburg Storm Water Design Manual

#### Table 4.8.3 Results of Preliminary Hydrologic Calculations (From Computer Model Results Using SCS Hydrologic Procedures)

			••••	10000000000	
Condition	Q <sub>1-inch</sub>	Q <sub>1-year</sub>	Q <sub>10-year</sub>	Q <sub>25-year</sub>	Q <sub>50-year</sub>
Runoff	cfs	cfs	cfs	cfs	cfs
Pre-developed (WS1)	0.00	0.38	1.36	1.92	2.39
Pre-developed (WS2)	0.00	0.59	2.12	2.99	3.71
Post-developed	4.61	8.20	17.5	20.70	23.25

#### Step 5 Compute Water Quality Peak Flow (WQ<sub>p</sub>)

• Compute WQ<sub>p</sub> using SCS the hydrograph procedure documented in the Charlotte-Mecklenburg Storm Water Design Manual and the HEC-1 model or equivalent hydrologic model as approved by the review engineer. A 1-inch, 6-hour balanced storm event is required.

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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KN	OWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.
THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE C THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH R NEW OPTIONS: DAMBERAK OUTFLOW SUBMERGENCE , SINCLE EVEN DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM	T DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
HEC-1 INPUT	PAGE 1
LINE ID1234	5678910
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13		008 .007	.007	.007	.006	.005	.005	.005	.005	.005		
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\*\*\* NORMAL END OF HEC-1 \*\*\*

Note that the previous HEC-1 model output using the SCS method indicates that the runoff volume is 0.79 inches which is within an acceptable range (0.03 inches deviation from 0.76 inches) of the Schueler method runoff volume results using Equation 3-2.

### Step 6 Compute Channel Protection Volume (CP<sub>v</sub>)

• Compute maximum soil retention using SCS methods shown in the Charlotte-Mecklenburg Storm Water Design Manual. Note that the CN value used is the original site CN value, not the adjusted CN value used during the water quality runoff volume computation.

S = 1000/CN-10 = 1000/93.0 - 10 = 0.75 inches



Compute total runoff for the 1-year, 24-hour storm event. Total rainfall depth is 2.58 inches.

 $\begin{array}{lll} \mathsf{Q}_{\mathsf{d}} &= (\mathsf{P}\text{-}0.2\mathsf{S})^2/(\mathsf{P}\text{+}0.8\mathsf{S}) \\ &= [2.58-(0.2)(0.75)]^2/[2.58+(0.8)(0.75)] \\ &= 1.86 \text{ inches} \end{array}$ 

Compute watershed runoff

 $CS_v = (1.86 \text{ inches})(2.93 \text{ acres})(1 \text{ foot/12 inches}) = 0.45 \text{ acre-feet}$ 

#### • Estimate Approximate Storage Volume

The designer has elected to direct all storm events into the sand filter facility. The maximum ponding depth for the 1-inch, 6-hour storm event must be less than 24 inches. The maximum ponding depth for the 1-year, 24-hour and 10-year, 6-hour storm event must be less than 5 feet. In order to achieve the pollutant removal goals of the Post Construction Ordinance, the sand filter must hold the Water Quality Volume for a minimum of 2.0 days above and within the filter media. The design requirements include a filter media thickness of 2.5 feet and an underdrain system thickness of 1.0 feet.

The Channel Protection Volume is required to be held within the sand filter for a minimum of 24 hours beyond the center of the design storm event rainfall. The center of rainfall is at hour twelve, therefore, the time of interest for assessing the Channel Protection Volume is hour thirty-six (24 hours plus 12 hours). The "Static Method" can be used as an initial estimate which sets the storage volume equal to the runoff volume, assumes that the storage volume fills instantaneously and empties through the outlet structures including the filter media, orifices, and weirs. In the case of the sand filter facility, the outlet structure for the Water Quality Volume is based on the filter media. The outlet structure for the Channel Protection Volume may be based on a combination of the filter media and an overflow weir and/or orifice structure.

Using the Static Method that sets the storage volume equal to the runoff volume, the sand filter facility requires 0.19 acre-ft storage to hold the Water Quality Volume. The sand filter facility requires 0.45 acre feet storage to hold the total Channel Protection Volume. These values can be used as estimates to develop approximate storage volumes and grading plans, but routing computations must be performed to complete the design.

#### Step 7 Size Flow Diversion Structure

This design example does not include a flow diversion structure (refer to Section 4.8.9 for example of flow diversion structure design.

#### Step 8 Compute Release Rates for Water Quality Control and Channel Protection Volume

The following outlet hydraulic computations are performed using the Static Method. Routing computations must be performed to refine the design. The routing computations must show that a minimum of 5 percent of the runoff volume is held within the storage volume after the design duration time beyond the center of rainfall.

• Compute the release rate for water quality control.

The water quality control volume ( $WQ_v$ ) is to be released over a 2.0 day period beyond the center of rainfall (48 hours plus 3 hours).

Release rate =  $(0.19 \text{ ac-ft x } 43560 \text{ ft}^2/\text{acre})/(51.0 \text{ hrs x } 3,600 \text{ sec/hr}) = 0.045 \text{ cfs}$ 



• Compute the release rate for channel protection volume.

The channel protection volume ( $CP_v$ ) is to be released over a 24-hour period beyond the center of rainfall (24 hours plus 12 hours).

Release rate =  $(0.45 \text{ ac-ft x } 43560 \text{ ft}^2/\text{acre})/(36 \text{ hrs x } 3,600 \text{ sec/hr}) = 0.151 \text{ cfs}$ 

#### Step 9 Compute Sedimentation Chamber Volume

The sedimentation chamber storage area above the filter media must be sized to hold 20 percent of the water quality volume in order to remove trash and large sediment particles.

Sediment Chamber<sub>vol</sub> =  $(0.19 \text{ acre-feet})(43,560 \text{ sq ft/acre})(0.20) = 1,655 \text{ ft}^3$ 

For the underground configuration, a six foot depth is effective in providing storage volume for the sedimentation chamber (five feet of headwater storage above the top of sand filter plus one foot below the top of sand filter for sediment and trash storage). A sedimentation chamber 331  $\text{ft}^2$  (1,655  $\text{ft}^3$ /5 feet) in area will meet the requirements for pre-treatment. Later routing computations indicate that additional storage is necessary to control the 1-year, 24-hour storm event, so the sedimentation chamber size is increased.

#### Step 10 Compute Sand Filter Area to Treat Water Quality Volume

Size the sand filter ponding/filter area based on Darcy's equation. Assume that all of the filter media capacity is effective and that no surface area is ineffective due to clogging. A design value of 1.75 inch/hour (3.5 foot/day) for the coefficient of permeability of the filter media is required. The detention time is 2 days beyond the center of rainfall for the 6-hour storm (48 hours plus 3 hours is 51 hours).

$$A_f = (WQ_v)(d_f)/[(k)(h_f+d_f)(t_f)]$$

where:

- $A_f$  = surface area of filter bed (ft<sup>2</sup>)
- $d_f$  = filter bed depth (ft)
- k = coefficient of permeability of filter media (ft/day)
- h<sub>f</sub> = average height of water above filter bed (ft)
- t<sub>f</sub> = design filter bed drain time (days)

$$\begin{array}{rcl} \mathsf{Af} &=& \underbrace{(0.19 \ \mathrm{acre-ft})(43560 \ \mathrm{sf/ac})(2.5 \ \mathrm{ft}))}_{(3.5 \ \mathrm{ft/day})(0.5 \ \mathrm{ft}+2.5 \ \mathrm{ft})(2.125 \ \mathrm{days})} \\ &=& 927.3 \ \mathrm{sg} \ \mathrm{ft} \end{array}$$

Use 30 foot by 30 foot sand filter

### Step 11a Develop Sand Filter Storage-Elevation Table

Figure 4.8.6 shows the sand filter location on site, Figure 4.8.7 shows cross-sections and the plan view of the sand filter and Table 4.8.4 shows the storage-elevation data that was developed for this example. Note that the storage volumes presented result from an iterative process of routing three design storm events through the facility; the 1-inch, 6-hour, 1-year, 24-hour, and 10-year, 6-hour storm events. The 50-year storm event is routed through the facility to ensure that the facility and surrounding buildings area not impacted. Also, note that storage volume below the top of the sand filter in the sedimentation chamber is ignored in the routing computations. Runoff does not leave that storage volume with a positive outflow.

Charlotte-Mecklenburg BMP Design Manual



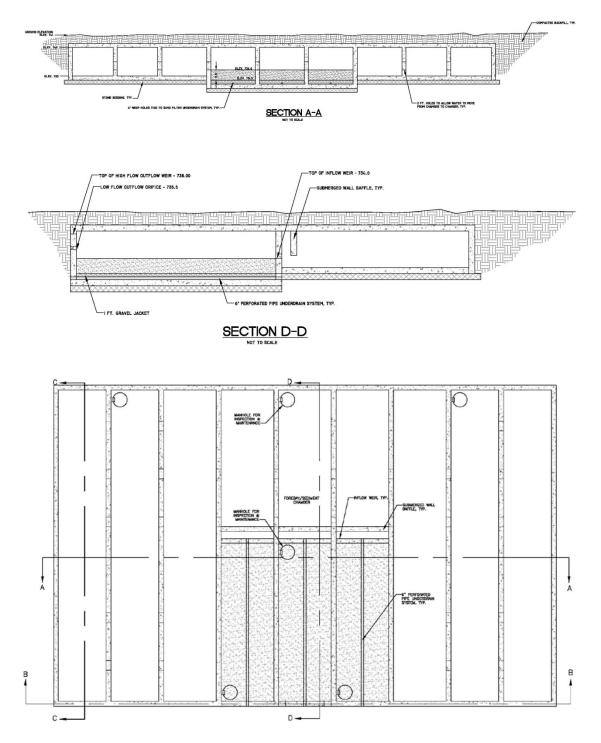


Figure 4.8.7 Plan View of Sand Filter



		Table 4.0.4	ballu Filler Sid	Jiage-Lievali	JII Dala	
Elevation	Area (sf)	Area (ac)	Avg. Area	Height (ft)	Inc vol (ac-	Acc vol (ac-
			(ac)		ft)	ft)
734	5,826	0.134				0.000
735	5,826	0.134	0.134	1.0	0.134	0.134
736	5,826	0.134	0.134	1.0	0.134	0.268
737	5,826	0.134	0.134	1.0	0.134	0.402
738	5,826	0.134	0.134	1.0	0.134	0.536
739	5,826	0.134	0.134	1.0	0.134	0.670

### Table 4.8.4 Sand Filter Storage-Elevation Data

# Step 11b Develop Stage-Discharge for Sand Filter Media

The 1-inch, 6-hour storm event and portions of the more severe storm events will flow through the filter media. The outflow conditions for the filter media must be assessed in order to derive the relation for the stage-discharge and in order to perform routing computations. The routing must be performed for the storage area above the filter media, and not the area within the filter media. Therefore, all of the computations are based on elevation above the top of the filter media. Outflow when runoff is below the top of the filter media is ignored and assumed to be zero when the depth of flow is equal to the top of media. The percentage of the filter media that is assumed to be clogged during the surface area computation procedure (0 percent) should be considered when computing the outflow conditions.

 $A_f = (WQ_v)(d_f)/[(k)(h_f+d_f)(t_f)]$ 

 $WQ_v/t_f = Q_o = A_f(k)(h_f+d_f)/(d_f))$ 

where:

- $A_f$  = surface area of filter bed (ft<sup>2</sup>)
- $d_f$  = filter bed depth (ft)
- k = coefficient of permeability of filter media (ft/day)
- $h_f$  = average height of water above filter bed (ft)

At elevation 739, five feet above the top of filter media

- $Q_o = (900 \text{ft}^2)[(3.5 \text{ft}/\text{day})(5 \text{ft}+2.5 \text{ft})]/(2.5 \text{ft})]$ 
  - = 9,450 cf/day
  - = 0.109 cfs

At elevation 738, four feet above the top of filter media

- $Q_o = (900ft^2)[(3.5ft/day)(4ft+2.5ft)]/(2.5 ft)$ 
  - = 8,190 cf/day
  - = 0.095 cfs

At elevation 737, three feet above the top of filter media

- $Q_o = (900ft^2)[(3.5ft/day)(3ft+2.5ft)]/(2.5ft)]$ 
  - = 6,930 cf/day
  - = 0.080 cfs

At elevation 736, two feet above the top of filter media

- $Q_o = (900ft^2)[(3.5ft/day)(2ft+2.5ft)]/(2.5 ft)$ 
  - = 5,670 cf/day
  - = 0.066 cfs

At elevation 735, one foot above the top of filter media

- $Q_o = (900ft^2)[(3.5ft/day)(1ft+2.5ft)]/(2.5 ft)$ 
  - = 4,410 cf/day
  - = 0.051 cfs



At elevation 734, top of filter media Qo = 0.00 cfs

#### Step 12a Route Runoff Hydrographs through Sand Filter

Route all of the appropriate runoff hydrographs through the sand filter facility with the following goals:

- 1-inch, 6-hour storm event through the filter media with less than 24 inches of ponding depth.
- 1-year, 24-hour; 10-year, 6-hour, and 50-year, 6-hour storm event through the filter media and over flow structure with maximum 5 feet of ponding depth.
- Hold 5 percent of the 1-year, 24-hour storm event within the sand filter storage volume 24 hours after the center of rainfall (48 hours within the City of Charlotte and its ETJ).
- Attenuate the 10-year, 6-hour storm events to pre-development levels. Note that a portion of the site is being diverted, therefore the pre-developed target discharge is based on only the amount of watershed that was flowing in that direction in pre-developed conditions, and additional attenuation and detention storage are required.

The following HEC-1 file provides the results of the 1-inch, 6-hour storm event routing. The peak water surface elevation is shown to by 735.29 with the entire 1-inch storm event flowing through the filter media. The peak flow is attenuated from 4.61 cfs to 0.06 cfs. More than five percent (12.8%) of the 1-inch, 6-hour storm event is shown to remain within the sand filter storage volume at 51 hours (2 days after the center of rainfall). An outlet orifice to control the 1-year, 24-hour storm event will be placed above the peak water surface elevation of the 1-inch, 6-hour storm event, 735.29 and is discussed in the next design step.

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FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO	PACKAGE (HI 1998 4.1 8 TIME 10:1 AI DI DI STI * *	* * 04:14 * * **********	ENGINEERIN . 2006 *** *** **	1G ** *** ***	UCTION DESIGN	I MANUAL		* U.S. * HYDR( * * D. *	ARMY CORPS DLOGIC ENGIN 609 SECONI AVIS, CALIFO (916) 756	VEERING CENTER D STREET DRNIA 95616 5-1104
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:: AI DI CI AI DI STI * * ******	HARLOTTE-MEC HARLOTTE-MEC ATE: OCTOBER	ENGINEERIN . 2006 *** *** ** 0N POST	4G ** *** *** F1	*** *** *** *	I MANUAL		* U.S. * HYDR( * * D. *	ARMY CORPS DLOGIC ENGIN 609 SECONI AVIS, CALIFO (916) 756	VEERING CENTER D STREET DRNIA 95616 5-1104
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO	PACKAGE (HI 1998 4.1 8 TIME 10:: AI DI CI AI DI STI * * ******	HARLOTTE-MEC HARLOTTE-MEC ATE: OCTOBER	ENGINEERIN . 2006 *** *** ** 0N POST	1G ** *** ***	*** *** *** *	I MANUAL		* U.S. * HYDR( * * D. *	ARMY CORPS DLOGIC ENGIN 609 SECONI AVIS, CALIFO (916) 756	VEERING CENTER D STREET DRNIA 95616 5-1104
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO	PACKAGE (HI 1998 4.1 8 TIME 10:: AI DI CI AI DI STI * * ******	HARLOTTE-MEC HARLOTTE-MEC ATE: OCTOBER	ENGINEERIN . 2006 *** *** ** 0N POST	NG ** *** *** F1 YTAL EXCESS	= .76	I MANUAL		* U.S. * HYDR( * * D. *	ARMY CORPS DLOGIC ENGIN 609 SECONI AVIS, CALIFO (916) 756	VEERING CENTER D STREET DRNIA 95616 5-1104
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO	PACKAGE (HI 1998 4.1 8 TIME 10:: AI DI CI AI DI STI * * ******	HARLOTTE-MEC HARLOTTE-MEC ATE: OCTOBER	ENGINEERIN 2006 *** *** ** ON POSI .24, TC FLOW	NG ** *** *** F1 DTAL EXCESS RUNOFF N IN CUBIC	= .76 SUMMARY FEET PER SECC	*** *** ** ND		* U.S. * HYDR( * * D. *	ARMY CORPS DLOGIC ENGIN 609 SECONI AVIS, CALIFO (916) 756	VEERING CENTER D STREET DRNIA 95616 5-1104
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO	PACKAGE (HI 1998 4.1 8 TIME 10:: AI DI CI AI DI STI * * ******	HARLOTTE-MECC VALYZED ABC ATE: OCTOBER	ENGINEERIN 2006 *** *** ** ON POSI .24, TC FLOW	NG F1 DTAL EXCESS N IN CUBIC N HOURS, A	= .76 SUMMARY	NND : MILES		* U.S. * HYDR * D. * *	ARMY CORPS DLOGIC ENGIN 609 SECONN VIS, CALIFC (916) 750	HEERING CENTER D STREET JRNTA 95616 5-1104
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:: AI DI CI AI DI STI * * ******	HARLOTTE-MEC MALVZED ABC ATE: OCTOBER ATE: OCTOBER ATE: ADE ATE ADE ATE STATI TAL LOSS = PEAK	ENGINEERIN 2006 *** *** ** ON POST .24, TC FLOW TIME IN	NG F1 YTAL EXCESS RUNOFF V IN CUBIC V HOURS, A AVERAGE	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX	ND MILES LIMUM PER:		* U.S. * HYDR * D. * *	ARMY CORPS DLOGIC ENGIN 609 SECONI AVIS, CALIFO (916) 756	HEERING CENTER ) STREET )RNIA 95616 -1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:1 	HARLOTTE-MEC WALVZED ABC ATE: OCTOBER ADH AT STATI TAL LOSS = PEAK	ENGINEERIN 2006 	NG F1 DTAL EXCESS N IN CUBIC N HOURS, A	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX	ND MILES LIMUM PER:		* U.S. * HYDR( * D. * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:1 AI DI CI AI DI STATION	HARLOTTE-MEC WALVZED ABC ATE: OCTOBER ADH AT STATI TAL LOSS = PEAK	ENGINEERIN 2006 	NG F1 YTAL EXCESS RUNOFF V IN CUBIC V HOURS, A AVERAGE	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX	ND MILES LIMUM PER:		* U.S. * HYDR( * D. * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO ************************************	PACKAGE (HI 1998 4.1 8 TIME 10:4 	HARLOTTE-MEC VALVZED ABC ATE: OCTOBER ATE: OCTOBER ATE: ACTOBER TAL LOSS = PEAK FLOW	ENGINEERIN 2006  ON POST .24, TC FLOW TIME IN TIME OF PEAK	rl T1 DTAL EXCESS W HOURS, A AVERAGE 6-HOUR	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR	NND : MILES XIMUM PER: 72-H(	eod Jur	* U.S. * HYDR( * D. * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:1 AI DI CI AI DI STATION	HARLOTTE-MEC VALVZED ABC ATE: OCTOBER ATE: OCTOBER ATE: ACTOBER TAL LOSS = PEAK FLOW	ENGINEERIN 2006 	NG F1 YTAL EXCESS RUNOFF V IN CUBIC V HOURS, A AVERAGE	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR	NND : MILES XIMUM PER: 72-H(		* U.S. * HYDR( * D. * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:1 	HARLOTTE-MEC VALVZED ABC ATE: OCTOBER ATE: OCTOBER ATE: ACTOBER TAL LOSS = PEAK FLOW	ENGINEERIN 2006  ON POST .24, TC FLOW TIME IN TIME OF PEAK	rl T1 DTAL EXCESS W HOURS, A AVERAGE 6-HOUR	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR	NND : MILES XIMUM PER: 72-H(	eod Jur	* U.S. * HYDR( * D. * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:1 	ARLOTTE-MEC WALVZED ABC ATE: OCTOBER APH AT STATI TAL LOSS = PEAK FLOW 0.	ENGINEERIN 2006 	rl T1 DTAL EXCESS W HOURS, A AVERAGE 6-HOUR	= .76 SUMMARY FEET PER SECC FLOW FOR MAX 24-HOUR 0.	NND : MILES (IMUM PER: 72-H(	eod Jur	* U.S. * HYDR( * D. * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 30 KK + PO + TOTAL RAINFALL = OPERATION HYDROGRAPH -	PACKAGE (HI 1998 4.1 8 TIME 10:1 2 2 2 2 3 2 3 3 3 3 3 3 3 3 3 3 3 3 3	ARLOTTE-MEC WALVZED ABC ATE: OCTOBER APH AT STATI TAL LOSS = PEAK FLOW 0.	ENGINEERIN 2006  ON POST .24, TC FLOW TIME IN TIME OF PEAK	NG F1 DTAL EXCESS V IN CUBIC V HOURS, A AVERAGE 6-HOUR 0.	= .76 SUMMARY FEET PER SECC FLOW FOR MAX 24-HOUR 0.	NND : MILES (IMUM PER: 72-H(	cod JUR 0.	* U.S. HYDR( * D. * * * * * * * * * * * * * * * * * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:1 AI DI CI AI DI DI DI DI DI DI DI DI DI DI DI DI DI	ARLOTTE-MEC VALYZED ABC ATE: OCTOBER ATE: OCTOBER TE: OCTOBER TAL LOSS = PEAK FLOW 0. 0.	ENGINEERIN 2006 	NG F1 DTAL EXCESS N HOURS, A AVERAGE 6-HOUR 0.	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR 0. 0.	NND : MILES (IMUM PER: 72-H(	COD DUR 0. 0.	* U.S. * HYDR( * D. * * * * * * * * * * * * * * * * * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 30 KK + PO ******** 30 KK + PO ******* TOTAL RAINFALL = OPERATION HYDROGRAPH -	PACKAGE (HI 1998 4.1 8 TIME 10:1 2 2 2 2 3 2 3 3 3 3 3 3 3 3 3 3 3 3 3	ARLOTTE-MEC VALYZED ABC ATE: OCTOBER ATE: OCTOBER TE: OCTOBER TAL LOSS = PEAK FLOW 0. 0.	ENGINEERIN 2006 	NG F1 DTAL EXCESS V IN CUBIC V HOURS, A AVERAGE 6-HOUR 0.	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR 0. 0.	NND : MILES (IMUM PER: 72-H(	cod JUR 0.	* U.S. HYDR( * D. * * * * * * * * * * * * * * * * * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 30 KK • PO • • • • • • • • • • • • • • • • • • •	PACKAGE (HI 1998 4.1 8 TIME 10:1 AI DI CI AI DI DI DI DI DI DI DI DI DI DI DI DI DI	ARLOTTE-MEC VALYZED ABC ATE: OCTOBER ATE: OCTOBER TE: OCTOBER TAL LOSS = PEAK FLOW 0. 0.	ENGINEERIN 2006 	NG F1 DTAL EXCESS N HOURS, A AVERAGE 6-HOUR 0.	= .76 SUMMARY FEET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR 0. 0.	NND : MILES (IMUM PER: 72-H(	COD DUR 0. 0.	* U.S. * HYDR( * D. * * * * * * * * * * * * * * * * * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 30 KK • PO • TOTAL RAINFALL = OPERATION HYDROGRAPH •	PACKAGE (HI 1998 4.1 8 TIME 10:1 AI DI CI AI DI DI DI DI DI DI DI DI DI DI DI DI DI	HARLOTTE-MEC NALVZED ABC ATE: OCTOBER ATE: OCTOBER ATE: OCTOBER ADH AT STATI TAL LOSS = PEAK FLOW 0. 0. 0.	ENGINEERIN 2006 	NG F1 DTAL EXCESS N HOURS, A AVERAGE 6-HOUR 0.	= .76 SUMMARY FFET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR 0. 0.	NND : MILES (IMUM PER: 72-H(	COD DUR 0. 0.	* U.S. * HYDR( * D. * * * * * * * * * * * * * * * * * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 30 KK PO 	PACKAGE (HI 1998 4.1 8 TIME 10:4 	HARLOTTE-MEC WALVZED ABC ATE: OCTOBER ATE: OCTOBER ATE: OCTOBER ADH AT STATI TAL LOSS = PEAK FLOW 0. 0. 0.	ENGINEERIN 2006 	NG T1 DTAL EXCESS RUNOFF N HOURS, A AVERAGE 6-HOUR 0. 0.	= .76 SUMMARY FFET PER SECC REA IN SQUARE FLOW FOR MAX 24-HOUR 0. 0.	NND : MILES (IMUM PER: 72-H(	toD DUR 0. 0.	* U.S. * HYDR( * D. * * * * * * * * * * * * * * * * * * *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
FLOOD HYDROGRAPH JUN VERSION RUN DATE 10APRO 	PACKAGE (HI 1998 4.1 8 TIME 10:: Al CI Al DI STATION STATION AT PRE1 AT PRE2 AT COMB1 AT POST1	APH AT STATI TAL LOSS = PEAK FLOW 0. 0. 0. 5.	ENGINEERIN 2006 	NG F1 DTAL EXCESS V IN CUBIC V HOURS, A AVERAGE 6-HOUR 0. 0. 0.	= .76 SUMMARY FEET PER SECC FLOW FOR MAX 24-HOUR 0. 0. 0. 0.	NND : MILES IMUM PER: 72-HO	cod DUR 0. 0. 0. 0.	* U.S. * HYDR( * D. *	ARMY CORPS DLOGIC ENGIN 609 SECONI (916) 750	HEERING CENTER ) STREET )RNIA 95616 :-1104 
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\*\*\* NORMAL END OF HEC-1 \*\*\*

The following HEC-1 file provides the results of an iterative process to control the 1-year, 24-hour storm event routing. The iterative process included increasing the storage volume above the sand filter and



decreasing the outlet orifice until more than 5 percent of the 1-year, 24-hour storm event runoff is held within the sand filter after 36 hours (24 hours past the center of the rainfall – 12 hours). The iterative process requires the designer to export the hydrograph to a spreadsheet and compute the hydrograph volume before and after the time of interest or setting the total HEC-1 model time to the time of interest and comparing the routed hydrograph volume with the total runoff hydrograph volume.

1******	******
* *	* *
* FLOOD HYDROGRAPH PACKAGE (HEC-1) *	* U.S. ARMY CORPS OF ENGINEERS *
* JUN 1998 *	* HYDROLOGIC ENGINEERING CENTER *
* VERSION 4.1 *	* 609 SECOND STREET *
* *	* DAVIS, CALIFORNIA 95616 *
* RUN DATE 10APR08 TIME 10:46:38 *	* (916) 756-1104 *
* *	* *
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ THE SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

					HEC-1	INPUT						PAGE	1
LINE	ID.	1	2.		4.	5	6.		8.	9.	10		
1	ID	CHA	ARLOTTE-	ECKLENBI	JRG POST	CONSTRUC	TION DES	SIGN MAN	JAL				
2	ID				GINEERING								
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	*	DIAGRAM											
	*	TIME 1	INTERVAL	CARD									
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5	IN	6	0	0									
	*												
	*	OUTPUT	CONTROL	CARD									
6	IO	5	0	0									
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7	KK	PRE1											
8	PB	2.58					*******				****		
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9	PT	.0000	.0010	.0010	.0010	.0011	.0010	.0011	.0010	.0011	.0011		
10	PI				.0010	.0011	.0010		.0010	.0011	.0011		
11	PI				.0011	.0012	.0011		.0011	.0012	.0012		
12	PI		.0012		.0013	.0012	.0012			.0013	.0013		
13	PI	.0013	.0013	.0013	.0015	.0014	.0015		.0014	.0015	.0014		
13	PI	.0014	.0014		.0015	.0015	.0015		.0015	.0015	.0018		
15	PI	.0018		.0018	.0019	.0019	.0018		.0019	.0019	.0020		
15	PI	.0020		.0020	.0021	.0021	.0021		.0021	.0021	.0022		
10	PI	.0022	.0022	.0024	.0021	.0021	.0021		.0021	.0021	.0030		
18	PI	.0032	.0032		.0032	.0032	.0032		.0034	.0036	.0038		
19	PI	.0032	.0041	.0044	.0046	.0048	.0051		.0058	.0062	.0066		
20	PI	.0070	.0077	.0086	.0096	.0106	.0115		.0476	.0764	.1371		
21	PI	.0951	.0190	.0166	.0144	.0122	.0098		.0080	.0074	.0068		
22	PI	.0064	.0060	.0056	.0054	.0052	.0048	.0046	.0044	.0042	.0040		
23	PI	.0038	.0037	.0036	.0035	.0034	.0034		.0033	.0032	.0031		
24	PI	.0030	.0030	.0029	.0028	.0027	.0027		.0026	.0025	.0024		
25	PI	.0023	.0023	.0022	.0023	.0022	.0022		.0021	.0021	.0021		
26	PI	.0021	.0020	.0020	.0020	.0019	.0020	.0019	.0019	.0018	.0018		
27	PI	.0018	.0018	.0017	.0018	.0017	.0017		.0017	.0016	.0016		
28	PI	.0015	.0016	.0015	.0015	.0015	.0014		.0014	.0013	.0014		
29	PI	.0013	.0013	.0013	.0013	.0013	.0012		.0013	.0012	.0013		
30	PI	.0012	.0013	.0012	.0013	.0012	.0012		.0012	.0012	.0012		
31	PI	.0012	.0012	.0012	.0012	.0012		.0012	.0012	.0011	.0012		
32	PI	.0011	.0012	.0011	.0012	.0011		.0012	.0011	.0011	.0011		
33	PI	.0011											
34	KM	EAST PF	RE-DEVELO		DITIONS								
35	KO	5	0	0	0	21							
36	BA	.0018											
37	LS	0	69.9	0									
38	UD	0.319											
					HEC-1	INPUT						PAGE	2
LINE	ID.	1	2.		4.	5	6.	7.	8.	9.	10		
39	KK	PRE2											
40	KM		RE-DEVELO	PED CONI	DITIONS								
41	KO	5	0	0	0	21							

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	42	BA										
		D۵										
			.0028									
	43	LS	0	69.9	0							
	44	UD	0.319									
	••	02	0.515									
	45	KK	COMB1									
	46	KO	5	0	0	0	21					
	47	HC	2									
	40		D0.00									
	48	KK	POST									
	49	KM	POST-DF		CONDITI	ONS - EN	TIRE DRA	INAGE AREA				
	50	KO	3	0	0	0	21					
	51	BA	.0046									
	52	LS	0	92.6	0							
	53	UD	0.050									
	54	KK	WQRTE									
	55		5 Ngit15	0	0	0	21					
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	56	KM						ER CHAMBER				
	57	KM	TWO ELF	EVATIONS	- 734 F	OR SEDIM	ENTATION	CHAMBER, 7	730.5 FOR BO	TTOM OF SAN	D FILT	
	58	KM	THEREF	ORE GETT	ING ALL	OF SEDIM	ENTATION	CHAMBER EF	FFECTIVE FOR	ATTENUATIO	N	
	59	KM	WITMII MI	UR BYORD	DIAN OF	1 0000 0	OD ODDIM	ENT STORAGE				
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	60	KM	5-INCH	ORIFICE	AT 735.	5, 8 FOO	r WEIR A'	т 738				
	61	RS	1	ELEV	734							
	62	SV	0	.134 735 .044	167	.201	.268	.401	.535 .66	9		
				. 1 3 4	.10/		736			-		
	63	SE	734	/35	/35.25	735.5	/36	737	738 73			
	64	SQ	0	.044	.051	.055	.050		.826 1.08	B 37.300		
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FLOOD H	HYDROGRAPH P	ACKAGE	(HEC-1)	) *						* U.S.	ARMY CORPS	OF ENGINEERS
	JUN			*								EERING CENTER
	UDD CTON .	1		-						* niDR		
	VERSION 4	i.1		*						•	609 SECONE	
				*						* D	AVIS, CALIFO	RNIA 95616
RUN DATE	E 10APR08	TIME	10:46:3/	8 *						*	(916) 756	-1104
				*						*	(220) / 30	
	********											
				ZED BY AN OCTOBER								
* *** ***	* *** *** **	* *** *	DATE:	OCTOBER	2006		*** ***	*** *** ***	* *** *** **	* *** *** *	** *** *** *	** *** *** ***
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8 KK	********** * POST * *********	**** * * *	DATE:	OCTOBER	2006		*** *** :	*** *** ***	* *** *** **	* *** *** *	** *** *** *	** *** *** ***
* *** *** 18 KK 50 KO	********** * POST * *********	**** * * *	DATE:	OCTOBER	2006		*** ***	*** *** ***	* *** *** **	* *** *** *	** *** *** *	** *** *** ***
18 KK 50 KO	********** * Post * **********	**** * * *	DATE:	OCTOBER	2006		*** ***	*** *** ***				** *** *** ***
8 KK 0 KO	********** * Post * **********	**** * * * * * * * * * * * * * * * * *	DATE: *** *** * ROL VARI <i>I</i>	OCTOBER *** *** ;	2006	*** ***		*** *** ***		* *** *** *		
8 KK 0 KO	********** * POST * *********** OUTPU SCS L	***** * * VT CONTF OSS RAT STRTL	DATE:	OCTOBER *** *** ABLES .16 IN:	2006 *** *** ITIAL AB	*** *** STRACTIO		*** *** ***			** *** *** *	** *** *** ***
8 KK 0 KO	********** * POST * *********** OUTPU SCS L	***** * ***** OT CONTF OSS RAT STRTL CRVNBR	DATE: ROL VARIA FE 92	OCTOBER *** *** ABLES .16 IN: 2.60 CU	2006 *** *** UTIAL AB EVE NUMB	*** *** STRACTIO	N	*** *** ***		* *** *** *	** *** *** *	
8 KK 0 KO	********** * POST * *********** OUTPU SCS L	***** * * VT CONTF OSS RAT STRTL	DATE: ROL VARIA FE 92	OCTOBER *** *** ABLES .16 IN: 2.60 CU	2006 *** *** UTIAL AB EVE NUMB	*** *** STRACTIO	N	*** *** ***		* *** *** *	** *** *** *	
8 KK 0 KO	********** * POST * *********** OUTPU SCS L	**** * * T CONTF OSS RAT STRTL CRVNBR RTIMP	DATE: **** **** * ROL VARIA FE 92	OCTOBER *** *** ABLES .16 IN: 2.60 CU	2006 *** *** TTIAL AB VVE NUMB RCENT IM	*** *** STRACTIO ER PERVIOUS	N	*** *** ***		* *** *** *		
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 **** *** ITIAL AB RVE NUMB RCENT IM DN PO	*** *** STRACTIO ER PERVIOUS ST	N AREA					
18 KK 50 KO 52 LS	********** * POST * *********** OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 **** *** ITIAL AB RVE NUMB RCENT IM DN PO	*** *** STRACTIO ER PERVIOUS ST	N AREA					
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 **** *** ITIAL AB RVE NUMB RCENT IM DN PO	*** *** STRACTIO ER PERVIOUS ST TOTAL EX	N AREA CESS =	1.82				
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 *** *** TITAL AB RVE NUMB CCENT IM CON PO .76,	*** *** STRACTIO ER PERVIOUS ST TOTAL EX RU	N AREA CESS =	1.82 MARY				
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 *** *** TITAL AB RVE NUMB CCENT IM CON PO .76,	*** *** STRACTIO ER PERVIOUS ST TOTAL EX RU	N AREA CESS =	1.82 MARY			** *** *** *	
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 *** *** TIAL AB VVE NUMB RCENT IM DN FO .76, FL	STRACTIO ER PERVIOUS ST TOTAL EX RU OW IN CU	N AREA CESS = NOFF SUM BIC FEET	1.82 MARY PER SECONI	D			
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	OCTOBER **** **** * ABLES .16 IN: 2.60 CU .00 PEI AT STATI(	2006 *** *** TIAL AB VVE NUMB RCENT IM DN FO .76, FL	STRACTIO ER PERVIOUS ST TOTAL EX RU OW IN CU	N AREA CESS = NOFF SUM BIC FEET	1.82 MARY	D			
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	ABLES .16 IN: .00 PEI AT STATIC LOSS =	2006 TTIAL AB RVE NUMB RCENT IM ON PO .76, FL TIME	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS	N AREA CESS = NOFF SUM BLC FEET , AREA :	1.82 MARY PER SECONI IN SQUARE N	D MILES			
8 KK 0 KO 2 LS	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: COL VARIA ROL VARIA FE 92 ROGRAPH 2	ABLES .16 IN: .00 PEI AT STATIC LOSS =	2006 *** *** TIAL AB VVE NUMB RCENT IM DN FO .76, FL	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS	N AREA CESS = NOFF SUM BLC FEET , AREA :	1.82 MARY PER SECONI	D MILES	BASIN	MAXIMUM	TIME OF
3 KK ) KO 2 LS TOTAL F	* POST * OUTPU SCS L	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF	DATE: ROL VARIA FE 92 ROGRAPH 2 , TOTAL I	OCTOBER ABLES .16 IN: 2.60 CU AT STATIC LOSS = PEAK	2006 TTIAL AB RVE NUMB RCENT IM ON PO .76, FL TIME	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS	N AREA CESS = NOFF SUM BLC FEET , AREA :	1.82 MARY PER SECONI IN SQUARE N	D MILES			TIME OF
3 KK ) KO 2 LS TOTAL F	* POST * OUTPU SCS I RAINFALL =	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF 2.58,	DATE: ROL VARIA FE 92 ROGRAPH 2 , TOTAL I	ABLES .16 IN: .00 PEI AT STATIC LOSS =	2006 *** *** ETIAL AB EVE NUMB RCENT IM DN PO .76, FL TIME TIME OF	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUM BIC FEET , AREA : RAGE FLOI	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN	D MILES MUM PERIOD	BASIN	MAXIMUM	
3 KK ) KO 2 LS TOTAL F	* POST * OUTPU SCS I RAINFALL =	***** * ***** OSS RAI STRTL CRVNBR RTIMP HYDF 2.58,	DATE: ROL VARIA FE 92 ROGRAPH 2 , TOTAL I	OCTOBER ABLES .16 IN: 2.60 CU AT STATIC LOSS = PEAK	2006 *** *** ETIAL AB EVE NUMB RCENT IM DN PO .76, FL TIME TIME OF	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUM BIC FEET , AREA : RAGE FLOI	1.82 MARY PER SECONI IN SQUARE N	D MILES	BASIN	MAXIMUM	TIME OF
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8 KK 0 KO 2 LS TOTAL F	* POST * OUTPU SCS I RAINFALL =	T CONTR STRTL CRVNBR RTIMP HYDF 2.58, STAT	DATE: ROL VARIA FE 92 ROGRAPH 2 , TOTAL I	OCTOBER ABLES .16 IN: 2.60 CU AT STATIC LOSS = PEAK	2006 *** *** ETIAL AB EVE NUMB RCENT IM DN PO .76, FL TIME TIME OF	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUM BIC FEET , AREA : RAGE FLOI	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN	D MILES MUM PERIOD	BASIN	MAXIMUM	TIME OF
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8 KK 0 KO 2 LS TOTAL F	* POST * OUTPU SCS I RAINFALL =	T CONTR STRTL CRVNBR RTIMP HYDF 2.58, STA1	DATE: ROL VARIA FE 92 ROGRAPH 2 , TOTAL I	OCTOBER ABLES .16 IN: 2.60 CU AT STATIC LOSS = PEAK	2006 *** *** ETIAL AB EVE NUMB RCENT IM DN PO .76, FL TIME TIME OF	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUM BIC FEET , AREA : RAGE FLOI	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN	D MILES MUM PERIOD	BASIN	MAXIMUM	TIME OF
8 KK 0 KO 2 LS TOTAL F OF	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT	ATT CONTR OSS RAI STRTL CRVNBR RTIMP HYDF 2.58, STAI	DATE: ROL VARIA ROL VARIA ROGRAPH A , TOTAL I FION	OCTOBER ABLES .16 INI 2.60 CUI .00 PEL AT STATIC LOSS = PEAK FLOW	2006 TTIAL AB RVE NUMB CCENT IM ON PO .76, FL TIME TIME OF PEAK	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUM BIC FEET BIC FEET , AREA : RAGE FLOI HOUR	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR	D MILES MUM PERIOD 72-HOUR	BASIN AREA	MAXIMUM	TIME OF
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8 KK 0 KO 2 LS TOTAL F OF HY	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT	TT CONTF JOSS RATI CRVNBR RTIMP HYDF 2.58, STAT	DATE: ROL VARIA TE 92 ROGRAPH A , TOTAL I FION PRE1	ABLES .16 IN: 2.60 CU .00 PE AT STATIC LOSS = PEAK FLOW 0.	2006 TIAL AB VVE NUMB SCENT IM NN PO .76, FL TIME OF PEAK 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUM BLC FFET , AREA : , AREA : , AREA : HOUR HOUR 0.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0.	D MILES MUM PERIOD 72-HOUR 0.	BASIN AREA .00	MAXIMUM	TIME OF
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8 KK 0 KO 2 LS TOTAL F OF HY	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT	T CONTR CRVNER RTIMP HYDF 2.58, STAI	DATE: ROL VARIA TE 92 ROGRAPH 2 , TOTAL 1 CION PRE1 PRE2	ABLES .16 IN: 2.60 CUI .00 PEI AT STATIC LOSS = PEAK FLOW 0. 1.	2006 TIAL AB RVE NUMB RCENT IM DN PO .76, TIME TIME 12.35 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUMI BIC FEET , AREA : RAGE FLOU HOUR 0. 0.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0. 0.	D MILES MUM PERIOD 72-HOUR 0. 0.	BASIN AREA .00 .00	MAXIMUM	TIME OF
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8 KK 0 KO 2 LS TOTAL F OF HY HY 2	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT	STAT	DATE: ROL VARIA TE 92 ROGRAPH 2 , TOTAL 1 CION PRE1 PRE2	ABLES .16 IN: 2.60 CUI .00 PEI AT STATIC LOSS = PEAK FLOW 0. 1.	2006 TIAL AB RVE NUMB RCENT IM DN PO .76, TIME TIME 12.35 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUMI BIC FEET , AREA : RAGE FLOU HOUR 0. 0.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0. 0.	D MILES MUM PERIOD 72-HOUR 0. 0.	BASIN AREA .00 .00	MAXIMUM	TIME OF
8 KK 0 KO 2 LS TOTAL F OF HY HY 2	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT COMBINED AT	TT CONTR STRTL CRVNBR RTIND 2.58, STAI	DATE: ACL VARIA TE 92 ROGRAPH A , TOTAL I CION PRE1 PRE2 DMB1	ABLES .16 INI 2.60 CU AT STATIC LOSS = PEAK FLOW 0. 1.	2006 TTIAL AB EVE NUMB EVE NUMB CCENT IM ON PO .76, TIME TIME OF PEAK 12.35 12.35 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUMM BIC FEET , AREA : RAGE FLOO HOUR 0. 0. 0.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0. 0. 0.	D MILES MUM PERIOD 72-HOUR 0. 0.	BASIN AREA .00 .00	MAXIMUM	TIME OF
8 KK 0 KO 2 LS TOTAL F OF HY HY 2	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT COMBINED AT	TT CONTR STRTL CRVNBR RTIND 2.58, STAI	DATE: ROL VARIA TE 92 ROGRAPH 2 , TOTAL 1 CION PRE1 PRE2	ABLES .16 INI 2.60 CU AT STATIC LOSS = PEAK FLOW 0. 1.	2006 TIAL AB RVE NUMB RCENT IM DN PO .76, TIME TIME 12.35 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUMI BIC FEET , AREA : RAGE FLOU HOUR 0. 0.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0. 0.	D MILES MUM PERIOD 72-HOUR 0. 0.	BASIN AREA .00 .00	MAXIMUM	TIME OF
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8 KK 0 KO 2 LS TOTAL F OF HY 2 HY	* POST * OUTPU SCS I RAINFALL = PERATION YDROGRAPH AT COMBINED AT	TT CONTR OSS RAI STATL CRVNBR RTIMP HYDF 2.58, STAT CC CC CC CC CC CC CC CC CC C	DATE: ACL VARIA TE 92 ROGRAPH A , TOTAL I FION PRE1 PRE2 DMB1 DST	OCTOBER ABLES .16 IN: 2.60 CUI .00 PEI AT STATIC LOSS = PEAK FLOW 0. 1. 1. 8.	2006 TIAL AB ETIAL AB EVE NUMB SCENT IM PO .76, IL .76, IL .76, IL .25 12.35 12.35 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUMI BIC FFET , AREA : RAGE FLOI HOUR 0. 0. 0. 1.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0. 0. 0. 0.	D MILES MUM PERIOD 72-HOUR 0. 0. 0. 0.	BASIN AREA .00 .00 .00	MAXIMUM	TIME OF
8 KK 0 KO 2 LS TOTAL F OF HY 2 HY	* POST * OUTPU SCS L RAINFALL = PERATION YDROGRAPH AT COMBINED AT YDROGRAPH AT	TT CONTR OSS RAI STATL CRVNBR RTIMP HYDF 2.58, STAT CC CC CC CC CC CC CC CC CC C	DATE: ACL VARIA TE 92 ROGRAPH A , TOTAL I CION PRE1 PRE2 DMB1	OCTOBER ABLES .16 IN: 2.60 CUI .00 PEI AT STATIC LOSS = PEAK FLOW 0. 1. 1. 8.	2006 TTIAL AB EVE NUMB EVE NUMB EVE NUMB ON PO .76, TIME TIME OF PEAK 12.35 12.35 12.35	STRACTIO ER PERVIOUS ST TOTAL EX OW IN CU IN HOURS AVE	N AREA CESS = NOFF SUMM BIC FEET , AREA : RAGE FLOO HOUR 0. 0. 0.	1.82 MARY PER SECONI IN SQUARE N W FOR MAXIN 24-HOUR 0. 0. 0.	D MILES MUM PERIOD 72-HOUR 0. 0.	BASIN AREA .00 .00	MAXIMUM	TIME OF

\*\*\* NORMAL END OF HEC-1 \*\*\*

First, note that the runoff volume is computed to be 1.82 inches which is the same runoff volume computed using the standard SCS formulas presented in step 4 of this example. Second, note that the more than 5 percent of the runoff volume is held within the BMP storage volume at 36 hours. A spreadsheet summary indicates that the total runoff volume held within the BMP is 36.6 percent. The peak water surface elevation in the BMP is 736.04. The additional amount held is due to the additional storage volume that is needed to provide peak flow attenuation that is determined in Step 12b.

Charlotte-Mecklenburg BMP Design Manual



#### Step 12b Calculate Q<sub>10</sub> Release Rate and Water Surface Elevation(s)

The next step of the design process is to design the sand filter to be used to achieve the peak attenuation goals for the 10-year, 6-hour storm event. This process is similar to previous examples in that the design is iterative. A stage-storage-discharge relations is developed assuming an outflow orifice and/or weir and storage area. The storm event is routed through the storage volume, and the outflow peak discharge is compared to the pre-development peak discharge for the 10-year, 6-hour storm event; 1.3 cfs. In addition, the peak stage for the 10-year, 6-hour storm events must be less than 5 feet above the top of the filter media.

The following HEC-1 output files illustrate the results of the iterative process for the 10-year storm event. A 5-inch orifice and an 8-foot weir that are installed at elevations 735.5 and 738.0, respectively attenuate the post-developed discharge to the appropriate value for the 10-year, 6-hour storm event. The TAPE21 file indicates that the peak discharge for the 10-year, 6-hour storm event is 1.08 cfs with a peak stage of 737.98 which is less than the pre-developed target release rate of 1.36 cfs. Note that the peak stage is 3.98 feet above the top of the sand filter media. The 3.98 feet ponding depth is less than the allowable 5 feet depth. Intermediate steps are not presented.

1*1	*************************************	* * *							* * *	*************	* * * *
*		*							*		*
*	FLOOD HYDROGRAPH PACKAGE (HEC-1)	*							*	U.S. ARMY CORPS OF ENGINEERS	*
*	JUN 1998	*							*	HYDROLOGIC ENGINEERING CENTER	*
*	VERSION 4.1	*							*	609 SECOND STREET	*
*		*							*	DAVIS, CALIFORNIA 95616	*
*	RUN DATE 10APR08 TIME 10:57:28	*							*	(916) 756-1104	*
*		*							*		*
**	***************************************	* * *							* * *	******	* * * *
			х	х	XXXXXXX	XXXX	х	х			
			x	v	X	X	x	XX			

Х	Х	XXXXXXX	XX	XXX		Х
х	х	Х	х	Х		XX
х	х	Х	х			Х
XXXX	XXXX	XXXX	х		XXXXX	Х
х	х	Х	х			Х
х	х	Х	х	Х		Х
Х	Х	XXXXXXX	XX	XXX		XXX

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINCLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ THE SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

					HEC-1							PAG
LINE	ID.	1	2		4	5	6	7	8	9	10	
1	ID	CHA	RLOTTE-M	ECKLENBU	RG POST	CONSTRUC	TION DES	IGN MANU	JAL			
2	ID	ANA	LYZED BY	ABC ENG	INEERING	3						
3	ID	DAT	E: OCTOB	ER 2006								
	*	*******	******	* * * * * * * *	******	******	* * * * * * * *	* * * * * * * *	******	******	* * *	
	*											
	*	TIME S	PECIFICA	TION CAR	D							
	*	COMPUT	ATION DU	RATION S	ET TO 6	HOURS						
4	IT	1	0	0	360							
	*	DIAGRAM										
	*	TIME I	NTERVAL	CARD								
5	IN	5	0	0								
	*											
	*	OUTPUI	CONTROL	CARD								
6	IO	5	0	0								
	*											
7	KK	PRE1										
	* *	* * * * * * * * *	******	* * * * * * * *	******	******	* * * * * * * *	******	******	******	* * *	
	* *					STORM EV						
	* *	*******	******	******	******	*******	******	******	******	*******	***	
8	PI	.000	.011	.011	.012	.012	.012	.012	.013	.013	.013	
9	PI		.014		.015	.016	.016	.017	.018	.018	.023	
10	PI		.025		.027	.029	.036	.039	.042	.045	.049	
11	PI	.054	.079	.089	.103	.161	.201	.395	.590	.275	.177	
12	PI		.095		.057	.051	.047	.043	.040	.038	.030	
13	PI		.027		.024	.023	.019	.018				
14	PI	.016	.015	.015	.014	.014	.013	.013	.013	.012	.012	
15	PI	.012	.011	.011	.000							
16	KM		E-DEVELO		ITIONS							
17	KO	5	0	0	0	21						
18	BA	.0018										
19	LS	0	69.9	0								
20	UD	0.319										
	KK	PRE2										
21	R.R.											
21 22	KM	WEST PF	E-DEVELO	PED COND	ITIONS							

1



	24 25	LS	.0028 0 69.9	0							
	26	UD	0.319								
		KK			0	01					
	28 29	KO HC	5 0 2	0	0	21					
	30	KK									
			POST-DEVELOPEI 3 0				EA				
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#### Step 13 Design Inlets and Underdrain System

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Inlet conveyance system design is not included in this design example. Standards for conveyance system design are covered in the Charlotte-Mecklenburg Storm Water Design Manual.

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The underdrain system must be designed to meet two design goals; the underdrain capacity must be greater than the filter media capacity, and the capacity must drain the runoff volume from the system within design duration (2.125 days for this example). The design must assume that 50 percent of the underdrain system (perforations and pipe system capacity) is lost due to clogging.

Design specifications require the underdrain system to be a 6-inch perforated PVC pipe with 3/8-inch perforations spaced 3 inches on center, along 4 longitudinal rows spaced 90° apart. Minimum underdrain slope is 0.5 percent.

Charlotte-Mecklenburg BMP Design Manual



The length, slope, number of pipes, spacing, etc. is configured per design requirements. Based upon the required area for the sand filter BMP (927  $\text{ft}^2$ ) the approximate dimensions of the sand filter area is selected to be 30 feet wide by 30 feet in length (approximately 927  $\text{ft}^2$ ).

The design process uses a trial and error process. The capacity of the perforations and pipe (assuming 50 percent of the system is clogged) are computed. The computed underdrain capacity is checked relative to the filter media capacity to ensure that the filter media is the controlling outflow condition. The computed underdrain capacity if compared to the static outflow discharge that ensures the runoff within the system leaves within 51 hours.

#### Compute minimum drawdown discharge

Water quality volume	=	(0.19 ac-ft)(43,560ft <sup>3</sup> /ac ft)	$= 8,276 \text{ ft}^3$
Drawdown	=	8,276 ft <sup>3</sup> /[(51 hours)(3,600sec/	hour)]
	=	0.045 cfs	

#### Compute perforation capacity

Since the maximum underdrain spacing is 10 feet on center and the sand filter area is 30 feet wide by 30 feet in length, three parallel underdrain pipes (6-inch diameter PVC) 30 feet in length were selected. For the calculations below, the length of pipe containing holes was reduced by 1 foot per cleanout to account for fittings.

Number of perforations	=	(3  pipes)(4  rows/ft)(30 - 2)  ft/pipe)(4  holes/row) = 1,344  holes
50 percent of perforations	=	672 holes
Capacity of one hole	=	CA(2gh) <sup>0.5</sup>
	=	$(0.6)(3.1416)[(3/8in)(1/24)]^{2}[(64.4)(5.0ft)]^{0.5}$
	=	0.0083 cfs
Total capacity	=	(0.0083  cfs)(672) = 5.58  cfs

The perforations capacity (5.58 cfs) is greater than the filter media capacity (0.051 cfs, computed in step 11b) and the minimum drawdown capacity requirement (0.045 cfs computed in this step). Therefore the design is acceptable.

Note that the headwater depth used to determine the filter media capacity is 1.0 feet, the average headwater depth above the filter media for the water quality storm event. The drawdown computation is also based on the water quality volume. The headwater depth for the perforations is also based on the same average headwater elevations, 1 feet above the filter media, or 5.0 feet above the perforations.

#### Compute underdrain pipe capacity

For 6-inch PVC underdrain pipe		
Capacity of pipe	=	(1.49/n)(A)(A/P) <sup>0.67</sup> (S) <sup>0.5</sup>
	=	$(1.49/0.013)(0.1963 \text{ ft}^2)(0.125 \text{ ft})^{0.67}(0.005)^{0.5}$
	=	0.40 cfs
Fifty percent assuming clogging	=	0.20 cfs

The underdrain pipe capacity (0.20 cfs) is greater than the filter media capacity (0.051 cfs, computed in step 11b) and the minimum drawdown capacity requirement (0.045 cfs computed in this step). Therefore the design is acceptable.

#### Step 14 Design Overflow Weir

The final step is to route the 50-year, 6-hour storm event through the sand filter facility to ensure that a minimum of 6-inches of freeboard is provided and that a maximum of 5 feet of depth is over the sand filter media. An eight (8) foot weir at 738.0 is proposed as the emergency overflow. The peak stage is 738.25 which is 4.25 feet above the filter media (less than 5 feet) and therefore meets design standards. The following HEC-1 output file illustrates the results.



PAGE 1

1**	*****	**	***	******	* *
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*	FLOOD HYDROGRAPH PACKAGE (HEC-1)	*	*	U.S. ARMY CORPS OF ENGINEERS	*
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*	VERSION 4.1	*	*	609 SECOND STREET	*
*		*	*	DAVIS, CALIFORNIA 95616	*
*	RUN DATE 10APR08 TIME 11:10:20	*	*	(916) 756-1104	*
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

HEC-1 INPUT

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINCLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ THE SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

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10	PI	.032	.033	.035	.037	.039	.049	.053	.056	.061	.066		
11	PI	.073	.103	.116	.133	.209	.260	.513	.749	.356	.231		
12	PI	.145	.124	.109	.077	.069	.063	.058	.054				
13	PI			.034		.031	.026						
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46	SQ	0	.044	.051	.055	.058	.420			37.300			
47	SE	734	734.5		735.25	735.5	736	737	738	739			
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*	609 SECOND STREET	,
*	DAVIS, CALIFORNIA 95616	1
*	(916) 756-1104	1
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		**

CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL ANALYZED BY ABC ENGINEERING DATE: OCTOBER 2006

			) MILES							
	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FL	OW FOR MAXIM	NUM PERIOD	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+					6-HOUR	24-HOUR	72-HOUR			
+	HYDROGRAPH AT	PRE1	2.	3.50	0.	0.	0.	.00		
+	HYDROGRAPH AT	PRE2	4.	3.50	1.	1.	1.	.00		
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+	HYDROGRAPH AT	POST	23.	3.18	2.	2.	2.	.00		
+ +	ROUTED TO	WQRTE	10.	3.32	1.	1.	1.	.00	738.25	3.32

\*\*\* NORMAL END OF HEC-1 \*\*\*

#### Table 4.8.5 Summary of Controls Provided

Control Element	Type/Size of Control	Stor. (ac-ft)	Peak Elev. (MSL)	Disc. (cfs)	Remarks
Water Quality Extended Detention (WQ <sub>v-ed</sub> )	Sand filter media at 734.0	0.176	735.29	0.05	Entire 1-inch, 6-hour storm event is routed through sand filter media
Channel Protection (CP <sub>v</sub> )	Sand filter media at 734.0 and 5-inch orifice at 735.5	0.281	736.04	0.43	Portion of the 1-year, 24-hour storm event is routed through the sand filter and a portion is routed through the 5-inch orifice outlet
Flood Protection (Q <sub>10</sub> )	Sand filter media at 734.0 and 5-inch orifice at 735.5	0.542	737.98	1.08	Same orifice control was designed for the 1-year, 24- hour and the 10-year, 6-hour storm events
Emergency Overflow (Q <sub>50</sub> )	Sand filter media at 734.0, 5-inch orifice at 735.5, and 8-foot weir at 738.0	0.717	738.25	10.16	Less than 5 feet of headwater depth on sand filter media.

#### Step 15 Assess Maintenance Access and Safety Features

The filter media and sedimentation chamber must be accessible from the surface in order to provide regular maintenance without significant access challenges. All areas of both chambers must be within 25 feet of an access location from the surface that is large enough for personnel to enter in order to remove trash, debris, sediment, etc. In addition, the sand filter media must be accessible in order to facilitate complete replacement when the sand filter ponds runoff without filtration.



# 4.8.9 Sand Filter Design Example #2

The following design example presents a different design approach for the same site presented in Section 4.8.8. Instead of implementing a stand-alone sand filter facility, the different design approach implements a combination of a sand filter facility and above ground extended dry detention basin designed to control the 1-inch, 6-hour for water quality purposes, 1-year, 24-hour for channel protection purposes, and 10-year 6-hour for flood control purposes following the design procedures given in section 4.8. The 1-inch, 6-hour storm event and portions of the 1-year, 24-hour and 10-year, 6-hour storm events are diverted to the sand filter. The additional flow that is not directed to the sand filter of the 1-year, 24-hour and 10-year, 6-hour storm events is diverted to an above-ground extended dry detention basin. In this design example, the channel protection volume ( $CP_V$ ) is required to be held for a minimum of 24 hours from the center of the rainfall event (as is the requirement for projects within Mecklenburg County and the six Towns); however, the user should note that within the City of Charlotte, the channel protection volume ( $CP_V$ ) is required to be held for a minimum of 24 hours from the

The combination of these two BMP's do not meet the goals of the post-construction ordinance; 85% TSS and 70% TP removal, so they are being presented for illustrative purposes only. For an actual site design case, additional BMPs within the treatment train would be added so that the post-construction goals are met. A grassed swale combined with a bioretention facility would supplement the two BMP presented in the example to meet the post-construction ordinance goals. Methods to compute the pollutant removal of BMPs in series are presented in Section 4.0. Figure 4.8.9 shows the site plan for the development and base hydrologic data that will be used in the design example.

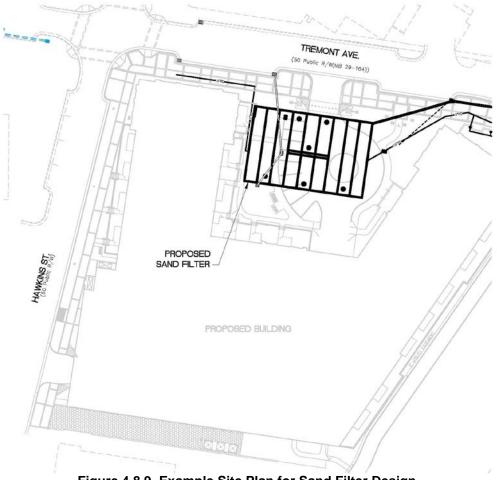


Figure 4.8.9 Example Site Plan for Sand Filter Design



The following steps illustrate how to use the design procedures given in section 4.8 to design a sand filter facility that is acceptable for the design criteria given in this manual.

# Step 1 BMP Feasibility

For the purposes of this design example, assume that a sand filter design is feasible.

# Step 2 Confirm Design Criteria

The design criteria contained in Section 4.1 of the manual apply to this design.

### Step 3 Compute Water Quality Volume (WQ<sub>v</sub>)

• Compute Runoff Coefficient, R<sub>v</sub>, using (Schueler's Method) Equation 3.1

 $R_v = 0.05 + 0.009(I) = 0.05 + (79.2)(0.009) = 0.76$ 

• Compute Water Quality Volume, WQ<sub>v</sub>, using Equation 3.2

 $WQ_v = 1.0R_vA/12 = (1.0 \text{ inches})(0.76)(2.93 \text{ acre})(1foot/12 \text{ inches}) = 0.19 \text{ ac-ft}$ 

• Convert Water Quality Volume, WQv to inches of runoff using Equation 3.3

 $WQ_v = 1.0(R_v) = 1.0(0.76) = 0.76$  inches

### Step 4 Compute Site Hydrologic Input Parameters

The site contains 2.93 acres and is proposed to be re-developed to 79.2 percent imperviousness. Using SCS hydrologic procedures, the following data can be determined for the example development site. For pre-developed conditions, an assumption that the site was 50% forest in good hydrologic condition and 50% pasture in good hydrologic condition is required. The site consists of 15% hydrologic type B soils and 85% hydrologic type C soils. The pre-developed topography drains in two directions and includes two sub-basins. The post-developed topography drains in one direction.

The pre-developed weighted curve number is:

$$CN_{weighted} = (0.5)(0.15)(61) + (0.5)(0.85)(74) + (0.5)(0.15)(55) + (0.5)(0.85)(70) = 69.9$$
  
Use 70

The post-developed weighted curve number is (based on 79 percent impervious from site plan):

 $CN_{weighted} = (0.21)(0.15)(61) + (0.21)(0.85)(74) + (0.79)(98) = 92.6$ 

Use 93

The modified post-developed curve number for application with the 1-inch, 6-hour storm event, using Equation 3.4 is:

$$\begin{array}{ll} \text{CN}_{\text{weighted}} &= 1000 / [10 + 5\text{P} + 10\text{WQ}_{\text{v}} - 10(\text{WQ}_{\text{v}}^2 + 1.25 \text{ WQ}_{\text{v}}\text{P})^{0.5}] \\ \text{CN}_{\text{weighted}} &= 1000 / [10 + 5(1.0) + 10(0.76) - 10\{(0.76^2 + (1.25)(0.76)(1.0)\}^{0.5}] \\ &= 97.7 \\ \text{Use } 98 \end{array}$$



Condition	Area (acres)	CN	CN (adjusted)	t <sub>c</sub> (hours) <sup>1</sup>						
			for 1-inch storm							
Pre-developed (WS1)	1.1	70	N/A	0.532						
Pre-developed (WS2)	1.8	70	N/A	0.532						
Post-developed	2.9	93	98	0.083						

#### Table 4.8.6 Hydrologic Input Data

<sup>1</sup>Based on methods described in the Charlotte-Mecklenburg Storm Water Design Manual

#### Table 4.8.7 Results of Preliminary Hydrologic Calculations (From Computer Model Results Using SCS Hydrologic Procedures)

Condition	Q <sub>1-inch</sub>	Q <sub>1-year</sub>	Q <sub>10-year</sub>	Q <sub>25-year</sub>	Q <sub>50-year</sub>
Runoff	cfs	cfs	cfs	cfs	cfs
Pre-developed (WS1)	0.00	0.38	1.36	1.92	2.39
Pre-developed (WS2)	0.00	0.59	2.12	2.99	3.71
Post-developed	5.38	8.20	17.50	20.70	23.25

#### Step 5 Compute Water Quality Peak Flow (WQ<sub>p</sub>)

 Compute WQ<sub>p</sub> using SCS the hydrograph procedure documented in the Charlotte-Mecklenburg Storm Water Design Manual and the HEC-1 model. A 1-inch, 6-hour balanced storm event is required.

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*	JUN 1998	*	*	HYDROLOGIC ENGINEERING CENTER	*
*	VERSION 4.1	*	*	609 SECOND STREET	*
*		*	*	DAVIS, CALIFORNIA 95616	*
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

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10	PT		.007	.007	.008	.008	.009	.009	.010	.011	.012		
11	PT		.019	.022	.025	.039	.050	.108	.188	.075	.043		

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15			3 .003					*****			
16		EAST PRE-DEV									
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\*\*\* NORMAL END OF HEC-1 \*\*\*

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Note that the previous HEC-1 model output using the SCS method indicates that the runoff volume is 0.76 inches which agrees with the Schueler method runoff volume results using Equation 3-2.

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#### Step 6 Compute Channel Protection Volume (CP<sub>v</sub>)

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3.20

• Compute maximum soil retention using SCS methods shown in the Charlotte-Mecklenburg Storm Water Design Manual. Note that the CN value used is the original site CN value, not the adjusted CN value used during the water quality runoff volume computation.

S = 1000/CN-10 = 1000/93.0 - 10 = 0.75 inches

Compute total runoff for the 1-year, 24-hour storm event. Total rainfall depth is 2.58 inches.



 $\begin{aligned} \mathsf{Q}_{\mathsf{d}} &= (\mathsf{P}\text{-}0.2\mathsf{S})^2 / (\mathsf{P}\text{+}0.8\mathsf{S}) \\ &= (2.58 - 0.2^* 0.75)^2 / (2.58 + 0.8^* 0.75) \\ &= 1.86 \text{ inches} \end{aligned}$ 

Compute watershed runoff

 $CP_v = (1.86 \text{ inches})(2.93 \text{ acres})(1 \text{ foot/12 inches}) = 0.45 \text{ acre-feet}$ 

### <u>Estimate Approximate Storage Volume</u>

The designer has elected to direct the entire Water Quality Volume ( $WQ_v$ ) into the sand filter. A portion of the channel protection volume ( $CP_v$ ) and the flood control event; 1-year, 24-hour and 10-year, 6-hour storm events; respectively, will be diverted into the sand filter. The remainder of the channel protection volume and flood control event will be diverted to a downstream extended dry detention basin. For the sand filter, the maximum ponding depth for the 1-inch, 6-hour storm event must be less than 24 inches. For the sand filter, the maximum ponding depth for the 1-year, 24-hour and 10-year, 6-hour storm event must be less than 5 feet. In order to limit the cost of constructing an underground chamber for the sand filter, the standard efficiency sand filter design requires the Water Quality Volume ( $WQ_v$ ) to be held for a minimum of 1.0 day above and within the filter media beyond the center of the rainfall design storm event (24 hours plus 3 hours = 27 hours). The design requirements include a filter media thickness of 2.0 feet and an underdrain system thickness of 1.0 feet.

The Channel Protection Volume ( $CP_v$ ) is required to be held within the combination of the sand filter and extended dry detention for a minimum of 24 hours beyond the center of the design storm event rainfall. The center of rainfall is at hour twelve, therefore, the time of interest for assessing the Channel Protection Volume ( $CP_v$ ) is hour thirty-six (24 hours plus 12 hours). The "Static Method" can be used as an initial estimate which sets the storage volume equal to the runoff volume, assumes that the storage volume fills instantaneously and empties through the outlet structures including the filter media, orifices, and weirs. In the case of the sand filter facility, the outlet structure for the Water Quality Volume ( $WQ_v$ ) is based on the filter media. The outlet structure for the Channel Protection Volume ( $CP_v$ ) may be based on a combination of the filter media and an overflow weir and/or orifice structure.

Using the Static Method, the sand filter facility requires 0.19 acre-feet to hold the Water Quality Volume ( $WQ_v$ ). The extended dry detention facility requires approximately 0.26 acre-feet (0.45 – 0.19; Channel Protection Volume ( $CP_v$ ) less the Water Quality Volume diverted to the sand filter) to meet the goals of controlling the Channel Protection Volume ( $CP_v$ ). These values can be used as estimates to develop approximate storage volumes and grading plans, but routing computations must be performed to complete the design.

#### Step 7 Compute Diversion Structure Geometry

All flows less than the peak flow computed for the 1-inch, 6-hour storm event are desired to be diverted into the sand filter facility. Storm events most intense or larger than the 1-inch, 6-hour storm event are desired to be directed away from the sand filter area into the downstream extended dry detention basin. For the development site, the watershed is almost entirely impervious and is drained by closed pipe systems. Therefore, the diversion facility will intercept the contributing watershed in a pipe system structure and divert the low flows into the sand filter through a low flow orifice. A weir wall which overtops for more intense or larger storm events based on the low flow orifice headwater depth directs the additional discharge to the downstream extended dry detention facility. Figure 4.8.10 illustrates the diversion structure geometry.



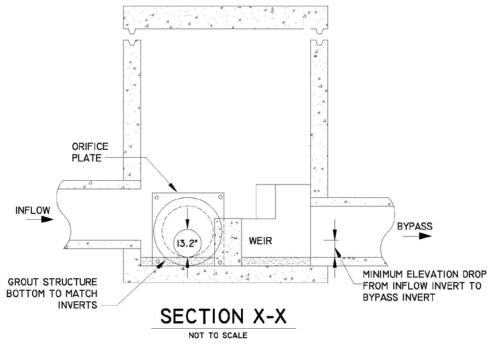


Figure 4.8.10 Diversion Structure Geometry

Based on an assumed weir height of 2 foot and a length of 4 feet, a low flow orifice is sized to direct the peak discharge for the 1-inch, 6-hour storm event with a headwater less than the weir height to the sand filter. Flow that overtops the weir will not enter the sand filter and flow directly to the downstream extended dry detention basin.

- Use orifice equation to compute cross-sectional area and diameter of orifice to divert flow to sand filter.
  - Q = CA(2gh)<sup>0.5</sup>, for Q = 5.38 cfs, h = 2.0 ft  $\frac{1}{2}$  diameter of orifice, and C = discharge coefficient = 0.6
  - Try 13.2 inch orifice
  - Solve for A: A = 5.38 cfs /  $[0.6((2)(32.2 \text{ ft/s}^2)(2.0-(13.2/24)))^{0.5}] = 0.93 \text{ ft}^2$
  - With A =  $\pi d^2/4$ , d = 1.09 = 13.0 inches, say OK
  - Use 13.2 inch orifice

Develop stage-discharge relations for a 13.2 inch orifice combined with a 2 foot high weir, 4 feet in length. Invert of the 13.2 inch orifice is 735.0 in a manhole structure upstream from the sand filter with top of filter media elevation of 734.0. Table 4.8.8 illustrates the results of hydraulic computations for the diversion structure

Elevation	Discharge into sand filter (cfs)	Discharge into extended detention (cfs)	Total flow (cfs)								
735.00	0.00	0.00	0.00								
735.50	1.54	0.00	1.54								
736.00	3.07	0.00	3.07								
736.50	4.46	0.00	4.46								
737.00	5.51	0.00	5.51								

4.8.33

# Table 4.8.8 Diversion Structure Hydraulic Results



737.50	6.39	3.68	10.07
738.00	7.16	10.40	17.56
738.50	7.86	19.11	26.97
739.00	8.50	29.42	37.92
739.50	9.09	41.11	50.20
740.00	9.65	54.04	63.69

Check the design of the diversion structure with the HEC-1 model using the diversion computation process or by using level pool routings. An iterative process may be necessary to ensure that all of the 1-inch, 6-hour storm event is being diverted to the sand filter and that an appropriate amount of the 1-year, 24-hour; 10- and 50-year, 6-hour storm events are being bypassed. For this site, the peak rate and runoff volume for the 1-year, 24-hour storm event is similar to the peak rate and runoff volume for the 1-inch, 6-hour storm event. Therefore, the sand filter will treat all of the 1-inch, 6-hour storm event and the majority of the 1-year, 24-hour storm event, and must provide a safe overflow system for a portion of the larger storm events such as the 10- and 50-year, 6 hour storm events. Table 4.8.9 presents the results of the diversion design which were developed from a detailed HEC-1 output and TAPE21 files. The following HEC-1 output file presents the results of the analysis for the 1-year, 24-hour storm event.

Storm Event	Peak discharge (cfs)	Runoff volume (acre- feet)	Peak discharge into sand filter (cfs)	Runoff volume into sand filter (acre-feet)	Bypassed peak discharge (cfs)	Bypassed runoff volume (acre-feet)					
1-inch, 6-hour	5.51	0.19	5.51	0.19	0.00	0.00					
1-year, 24-hour	8.33	0.45	6.05	0.43	2.28	0.02					
10-year, 6-hour	17.66	0.72	7.17	0.58	10.49	0.14					
50-year, 6-hour	23.25	1.01	7.58	0.76	15.66	0.25					

Table 4.8.9 Diversion HEC-1 Model Results

The diversion design was based on peak flow and ignored the benefit/impact of storage that could be associated with a diversion structure. A storage routing may be more appropriate, if significant storage is present within the diversion structure.

Note that the even though the larger peak flows are bypassing the sand filter for the more severe storm events (10- and 50-year, 6-hour), a high percentage of the runoff volume for those storm events is entering the sand filter. The design of the sand filter must account for the impact of these high runoff volumes.

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*	VERSION 4.1 *	*	609 SECOND STREET	*				
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THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRANT7 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION



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11 12	PI	.0013	.0012	.0012	.0013	.0012	.0012	.0013	.0012		.0013	
13 14	PI PI		.0014 .0016	.0014 .0016	.0015 .0017	.0015	.0015 .0016	.0015 .0018	.0015		.0016	
15	PI	.0018	.0018	.0018	.0019	.0019	.0018	.0020	.0019	.0019	.0020	
16 17	PI	.0022	.0020			.0021 .0026	.0021 .0026	.0021 .0028	.0021 .0029			
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23 24	PI PI		.0037 .0030	.0036	.0035	.0034	.0034	.0033	.0033		.0031	
25 26	PI PI	.0023	.0023	.0022	.0023	.0022	.0022	.0022	.0021	.0021	.0021	
27	PI	.0018	.0018	.0017	.0018	.0017	.0017	.0016	.0017	.0016	.0016	
28 29	PI PI		.0016 .0013	.0015	.0015	.0015	.0014	.0014	.0014	.0013	.0014	
30 31	PI PI	.0012	.0013 .0012	.0012	.0013	.0012	.0012	.0013	.0012	.0012	.0012	
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	HYDROGRAPH AT	DIV	2.	12.02	0.	0.	0.	.00		
	HYDROGRAPH AT	SF	6.	12.02	1.	0.	0.	.00		

\*\*\* NORMAL END OF HEC-1 \*\*\*

### Step 8 Compute Release Rates for Water Quality Control and Channel Protection Volume

The following outlet hydraulic computations are performed using the Static Method. Routing computations must be performed to refine the design. The routing computations must show that a minimum of 5 percent of the runoff volume is held within the storage volume after the design duration time beyond the center of rainfall.

• Compute the release rate for water quality control.

The Water Quality Volume ( $WQ_v$ ) is to be released over a 1.0 day period beyond the center of rainfall (24 hours plus 3 hours).

Release rate =  $(0.19 \text{ ac-ft x } 43560 \text{ ft}^2/\text{acre})/(27.0 \text{ hrs x } 3,600 \text{ sec/hr}) = 0.085 \text{ cfs}$ 

• Compute the release rate for Channel Protection Volume (CP<sub>v</sub>).

The Channel Protection Volume ( $CP_v$ ) is to be released over a 24-hour period beyond the center of rainfall (24 hours plus 12 hours).

Release rate =  $(0.26 \text{ ac-ft x } 43560 \text{ ft}^2/\text{acre})/(36 \text{ hrs x } 3,600 \text{ sec/hr}) = 0.087 \text{ cfs}$ 

### Step 9 Compute Sedimentation Chamber Volume

The sedimentation chamber storage area above the filter media must be sized to hold 20 percent of the Water Quality Volume ( $WQ_v$ ) in order to remove trash and large sediment particles.

Sediment Chamber<sub>vol</sub> =  $(0.19 \text{ acre-feet})(43,560 \text{ sq ft/acre})(0.20) = 1,655 \text{ ft}^3$ 

For the underground configuration, a three foot depth is effective in providing storage volume for the sedimentation chamber (two feet of headwater storage above the top of sand filter plus one foot below the top of sand filter for sediment and trash storage). A sedimentation chamber 828 ft<sup>2</sup> (1,655 ft<sup>3</sup>/2 feet) in area will meet the requirements for pre-treatment. Note that in the previous sand filter example shown in Section 4.8.8. the sedimentation chamber was increased in size in order to control the Channel Protection



Volume  $(CP_v)$  and provide attenuation for the 10-year, 6-hour storm event. For this example, the combination of the sand filter and above-ground detention will allow the underground sedimentation chamber size to not be increased as much because the 1-year, 24-hour storm event is controlled with the above-ground extended dry detention facility.

### Step 10 Compute Sand Filter Area to Treat Water Quality Volume

Size the sand filter ponding/filter area based on Darcy's equation. Assume that all of the filter media capacity is effective and that no surface area is ineffective due to clogging. A value of 1.75 inch/hour (3.5 ft/day) for the coefficient of permeability of the filter media is required. The detention time is one day beyond the center of rainfall for the 6-hour storm (24 hours plus 3 hours is 27 hours)

$$A_f = (WQ_v)(d_f)/[(k)(h_f+d_f)(t_f)]$$

Where:

- $A_f$  = surface area of filter bed (ft<sup>2</sup>)
- $d_f$  = filter bed depth (ft)
- k = coefficient of permeability of filter media (ft/day)
- $h_f$  = average height of water above filter bed (ft)
- $t_f$  = design filter bed drain time (days)

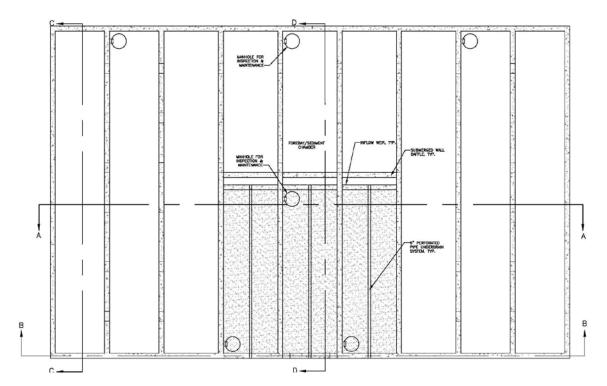
= 1,395.1 sq ft

Use 38 foot by 38 foot sand filter

## Step 11a Develop Sand Filter Storage-Elevation Table

Figure 4.8.9 shows the sand filter and extended dry detention location on site, Figure 4.8.11 shows the plan view of the sand filter, Figure 4.8.12 shows the plan view of the extended dry detention. Table 4.8.10 shows the storage-elevation data for the sand filter. Table 4.8.11 shows the storage-elevation data for the sand filter. Table 4.8.11 shows the storage-elevation data for the extended dry detention. Note that the storage volumes presented for the sand filter do <u>not</u> result from an iterative process of routing three design storm events through the facility; the 1-inch, 6-hour, 1-year, 24-hour, and 10-year, 6-hour storm events. The sand filter storage volumes presented are direct results of sedimentation chamber size and filter media foot print size computations because the other design requirements; 10-year, 6-hour storm event peak attenuation is provided by diverting to a downstream BMP facility. A portion of the 50-year storm event is routed through the facility to ensure that the facility and surrounding buildings area not impacted. Also, note that storage volume below the top of the sand filter in the sedimentation chamber is ignored in the routing computations. Storm water runoff does not discharge from that storage volume with a positive outflow.







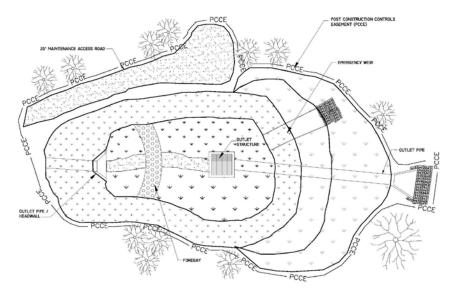


Figure 4.8.12 Plan View of Extended Dry Detention



				olugo Eloval	Ull Bulu	
Elevation	Area (sf)	Area (ac)	Avg. Area (ac)	Height (ft)	Inc vol (ac- ft)	Acc vol (ac- ft)
734	2,272	0.052				0.000
734.5	2,272	0.052	0.052	0.5	0.026	0.026
735	2,272	0.052	0.052	0.5	0.026	0.052
735.5	2,272	0.052	0.052	0.5	0.026	0.078
736	2,272	0.052	0.052	0.5	0.026	0.104
736.5	2,272	0.052	0.052	0.5	0.026	0.130
737	2,272	0.052	0.052	0.5	0.026	0.156

### Table 4.8.10 Sand Filter Storage-Elevation Data

## Table 4.8.11 Extended Dry Detention Storage-Elevation Data

				V		
Elevation	Area (sf)	Area (ac)	Avg. Area (ac)	Height (ft)	Inc vol (ac- ft)	Acc vol (ac- ft)
734	3,500	0.080				0.000
735	3,500	0.080	0.080	1.0	0.080	0.080
736	3,500	0.080	0.080	1.0	0.080	0.160
737	3,500	0.080	0.080	1.0	0.080	0.240
738	3,500	0.080	0.080	1.0	0.080	0.320
739	3,500	0.080	0.080	1.0	0.080	0.400

### Step 11b Develop Stage-Discharge for Sand Filter Media

The 1-inch, 6-hour storm event and portions of the more severe storm events will flow through the filter media. The filter media flow conditions must be assessed in order to derive the relation for the stagedischarge and in order to perform routing computations. The routing must be performed for the storage area above the filter media, and not the area within the filter media. Therefore, all of the computations are based on elevation above the top of the filter media. Outflow when runoff is below the top of the filter media is ignored and assumed to be zero when the depth of flow is equal to the top of media. The percentage of the filter media that is assumed to be clogged during the surface area computation procedure (0 percent) should be considered when computing the outflow conditions.

 $A_f = (WQ_v)(d_f)/[(k)(h_f+d_f)(t_f)]$ 

 $WQ_v/t_f = Q_o = A_f(k)(h_f+d_f)/(d_f))$ 

where:

- $A_f$  = surface area of filter bed (ft<sup>2</sup>)
- $d_{f}$  = filter bed depth (ft)
- k = coefficient of permeability of filter media (ft/day)
- h<sub>f</sub> = average height of water above filter bed (ft)

At elevation 737, three feet above the top of filter media

- $Q_o = (1,444ft^2)[(3.5ft/day)(3.0ft+2.0ft)]/(2.0 ft)$ 
  - = 12,635.0 cf/day
  - = 0.146 cfs

At elevation 736, two feet above the top of filter media

- $Q_o = (1,444ft^2)[(3.5ft/day)(2.0ft+2.0ft)]/(2.0 ft)$ 
  - = 10.108.0 cf/day
  - = 0.117 cfs



At elevation 735, one foot above the top of filter media

- $Q_0 = [(1,444ft^2)]((3.5ft/day)(1.0ft+2.0ft)]/(2.0 ft)$ 
  - = 7,581 cf/day
  - = 0.088 cfs

At elevation 734, top of filter media Qo = 0.00 cfs

### Step 12a Route Runoff Hydrographs through Sand Filter

Route all of the appropriate runoff hydrographs through the sand filter facility with the following goals:

- 1-inch, 6-hour storm event through the filter media with less than 24 inches of ponding depth. Ensure that the 1 day detention time design requirement is being met by holding 5 percent of the 1-inch, 6-hour runoff volume within the storage volume.
- 1-year, 24-hour; 10-year, 6-hour, and 50-year, 6-hour storm event through the filter media and over flow structure with maximum 5 feet of ponding depth.
- Hold 5 percent of the 1-year, 24-hour storm event within the sand filter and/or extended dry detention storage volume 24 hours after the center of rainfall.
- Attenuate the 10-year, 6-hour storm events to pre-development levels. Note that a portion of the site is being diverted, therefore the pre-developed target discharge is based on only the amount of watershed that was flowing in that direction in pre-developed conditions, and additional attenuation and detention storage are required.

The following HEC-1 file provides the results of the first iteration of the 1-inch, 6-hour storm event routing. The peak water surface elevation is shown to by 736.90 with the entire 1-inch storm event flowing through the filter media. The routed peak water surface elevation is 2.90 feet which is greater than the allowable 2.0 feet. The peak flow is attenuated from 5.51 cfs to 0.14 cfs. Three (3.1%) percent of the 1-inch, 6-hour storm event is shown to remain within the sand filter storage volume at 27 hours (1day after the center of rainfall). Therefore, additional iterations are necessary to reduce the peak stage while increasing the attenuation benefits so that the design goal of holding 5% of the runoff volume at 27 hours is met. The revisions that are implemented during the iterations are to increase the storage area by increasing the sedimentation chamber while leaving the outflow through the sand filter at the same value.



х	х	XXXXXXX	XX	XXX		х
Х	х	Х	х	Х		XX
Х	х	Х	х			х
XXXX	XXXX	XXXX	х		XXXXX	х
Х	х	Х	х			х
Х	х	х	х	Х		х
Х	х	XXXXXXX	XX	XXX		XXX

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HECIGS, HECIDB, AND HECIKW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILIRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1	HEC-1 INPUT	PAGE 1
LINE	ID12345678910	
1 2 3	ID CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL ID ANNLYZED BY ARC ENGINEERING ID DATE: COTOBER 2006 * * * * * * * * * * * * * * * * * * *	



4	IT 1 * DIAGRAM		0	1620								
5	* TIME	INTERVAL										
-	*	PUT CONTRO										
6	IO 5	5 0	0									
7	KK PRE]		********	******	******	* * * * * * * * *	******	******	*******	* * * *		
	* *******	*******	********	*******	******	* * * * * * * * *	******	******				
8 9	PI .000 PI .004	0 .003 4 .004 7 .007	.003	.003	.003	.003	.003	.004	.005	.004		
10 11	PI .007 PI .013	7 .007 3 .019	.007	.008	.008	.009	.009	.010	.011	.012		
12	PI .028 PI .008	.023	.020	.014	.012	.011	.010	.009	.009	.008		
14 15	PI .004 PI .003	.004	.004	.004	.004	.004	.004	.004	.003	.003		
16	* ******** KM EAST	*******	********	*******			******	******	******	* * * *		
17	ко 5	5 0			21	5						
18 19	BA .0018 LS (	69.9	0									
20	UD 0.319											
21 22	KK PRE2 KM WEST	SUB-BASIN	I PRE-DEVE	ELOPED CC	NDITIONS	s						
23 24	BA .0028			0	21							
25 26	LS ( UD 0.319	) 69.9	0									
27	KK COMBI	L										
28 29	KO 5 HC 2	5 0	0	0	21							
30	KK POSTI											
31 32	KM POST-	- DEVELOPED 3 0		ONS - ENT 0		INAGE ARE	A					
33 34	BA .0046	5		0	21							
34 35	LS ( UD 0.050	) 97.7 )	U								-	
LINE	ID1	2.		HEC-1			7	8			PAGE 2	
36	KK DIV	7										
36 37 38	ко 5	5 0	0	0	21							
39	DI 0.00	1.54		4.46					37.92			
40	DQ 0.00		3.07	4.46	5.51	6.39	7.16	7.86	8.50	9.09		
41 42	KK SI KM RECAI	L HYDROGR	арн тнат			SAND FIL	TER					
43 44	KO SI	5 0	0	0	21							
45	KK SFROU	J										
46 47	KO S KM ROUTE		0 HYDROGR#	0 APH THROU	21 JGH THE S	SAND FILT	ER FACII	LITY				
48 49	KM NO OV RS I	VERFLOW ST L ELEV ) .026	RUCTURE 1 734	INCLUDED	IN STAG			FLOW TI	HROUGH FI	LTER ME		
50 51	SV 0 SE 734	0.026 734.5	.052 735	.078	.104	.130 736.5	.156 737					
52 53	SQ 0.00	0.073	0.088	0.102	0.117		0.146					
54	ZZ		,55	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	,50	,5015	, , , ,		*******	*******	*****	* * * *
FLOOD HYDROGRAPH PI		*							*		S OF ENGINEER	
JUN	1998	*							* HYDI	ROLOGIC ENG	INEERING CENT	
VERSION 4		*								609 SECC DAVIS, CALI	FORNIA 95616	
RUN DATE 10APR08		*							*		56-1104	
******	***********	*****							******	* * * * * * * * * * * *	******	****
		LOTTE-MEC			ISTRUCTIO	ON DESIGN	I MANUAL					
		YZED BY A C: OCTOBER		SERING								
	HYDROGRAPH	I AT STATI	ION POS	ST1								
TOTAL RAINFALL =	1.00, TOTAI	LOSS =	.24, 1	FOTAL EXC	ESS =	.76						
				OW IN CUE		MARY PER SECC IN SQUARE						
0000	000		TIME OF					RIOD	BASIN	MAXIMUM	1 TIME OF	
OPERATION	STATION	FLOW	PEAK	6-Н	IOUR	24-HOUR	72-1	IOUR	AREA	STAGE	MAX STAGE	
HYDROGRAPH AT						-						
	PRE1	0.	4.87		0.	0.		0.	.00			
HYDROGRAPH AT	PRE2	0.	5.78		0.	0.		0.	.00			
2 COMBINED AT												
		0.	5.52		0.	0.		0.	.00			
HYDROGRAPH AT												



+		POST1	5.	3.18	0.	0.	0.	.00		
+	DIVERSION TO	SF	5.	.00	0.	0.	0.	.00		
+	HYDROGRAPH AT	DIV	0.	.00	0.	0.	0.	.00		
+	HYDROGRAPH AT	SF	5.	3.18	0.	0.	0.	.00		
+ +	ROUTED TO	SFROU	0.	4.72	0.	0.	0.	.00	736.90	5.10

\*\*\* NORMAL END OF HEC-1 \*\*\*

1

The following HEC-1 file provides the results of the additional iterations of the 1-inch, 6-hour storm event routing to result in a peak water surface elevation less than 2 feet and to hold more than 5% of the runoff in the BMP at 27 hours. The peak water surface elevation is shown to by 735.94 with the entire 1-inch storm event flowing through the filter media. The peak flow is attenuated from 5.51 cfs to 0.14 cfs. Approximately ten (9.6%) percent of the 1-inch, 6-hour storm event is shown to remain within the sand filter storage volume at 27 hours (1 day after the center of rainfall). The sand filter footprint cannot be reduced because the size must meet the footprint requirements derived by the Darcy equation. Therefore, the sand filter footprint remains as 38 feet by 38 feet. The sedimentation chamber is increased from a footprint area of 828 square feet to 2,070 square feet, an increase of 150 percent. The resulting sedimentation chamber holds 4,140 cubic feet which is 50 percent of the Water Quality Volume (WQ<sub>v</sub>), not 20 percent that is required by the design specifications.

1*********	***************************************
* *	* *
* FLOOD HYDROGRAPH PACKAGE (HEC-1) *	* U.S. ARMY CORPS OF ENGINEERS *
* JUN 1998 *	* HYDROLOGIC ENGINEERING CENTER *
* VERSION 4.1 *	* 609 SECOND STREET *
* *	* DAVIS, CALIFORNIA 95616 *
* RUN DATE 10APR08 TIME 16:26:12 *	* (916) 756-1104 *
* *	* *
********	***********

Х	Х	XXXXXXX	XXX	XXX		х
Х	Х	Х	Х	Х		XX
Х	Х	х	х			х
XXXX	XXXX	XXXX	х		XXXXX	х
Х	Х	х	х			х
Х	Х	х	х	Х		х
Х	х	XXXXXXX	XXX	XXX		XXX

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ THE SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

					HEC-1	INPUT						PAGE	1
LINE	ID	1	2	3	4	5	б	7	8	9	10		
1	ID	CHA	RLOTTE-M	ECKLENBU	RG POST	CONSTRUC	TION DES	IGN MANU	AL				
2	ID	ANA	LYZED BY	ABC ENG	INEERING								
3	ID	DAT	E: OCTOB	ER 2006									
	* *	******	* * * * * * * *	* * * * * * * *	* * * * * * * *	******	* * * * * * * *	* * * * * * * *	* * * * * * * *	* * * * * * * *	* * *		
	*												
	*	TIME S	PECIFICA	TION CAR	D								
	*	TOTAL	MODEL DU	RATION -	27 HOUR	S							
	*	24 HOU	RS AFTER	CENTER	OF 6 HOU	R RAINFA	LL						
4	IT	1	0	0	1620								
	* E	IAGRAM											
	*	TIME I	NTERVAL	CARD									
5	IN	5	0	0									
	*												
	*	OUTPUT	CONTROL	CARD									
6	IO	5	0	0									
	*												
7	KK	PRE1											
	* **	******	* * * * * * * *	* * * * * * * *	* * * * * * * *	******	* * * * * * * *	* * * * * * * *	* * * * * * * *	* * * * * * * *	* * *		
	* **	*******	***** 1	-INCH, 6	HOUR ST	ORM EVEN	T *****	* * * * * * * *	******	* * * * * * * *	* * *		
	* **	******	*******	******	******	******	******	* * * * * * * *	******	* * * * * * * *	* * *		
8	PI	.000	.003	.003	.003	.003	.003	.003	.004	.004	.004		
9	PI	.004	.004	.004	.004	.004	.005	.005	.005	.005	.006		
10	PI	.007	.007	.007	.008	.008	.009	.009	.010	.011	.012		
11	PI	.013	.019	.022	.025	.039	.050	.108	.188	.075	.043		
12	PI	.028	.023	.020	.014	.012	.011	.010	.009	.009	.008		
13	PI	.008	.007	.007	.007	.006	.005	.005	.005	.005	.005		
14	PI	.004	.004	.004	.004	.004	.004	.004	.004	.003	.003		
15	PI	.003	.003	.003	.000								
	* **	******	******	******	******	******	******	******	******	******	* * *		



												· · · · · · · · · · · · · · · · · · ·	
16	KM	EAST SU	B-BASIN	PRE-DEV	ELOPED C	ONDITION	s						
17	KO	5	0	0	0	21							
18	BA	.0018											
19	LS	0	69.9	0									
20		0.319	05.5	0									
20	02	0.515											
21	KK	PRE2											
21		WEST SU	D DACTN	DDE DEU	FLODED C		~						
22		WEST 50			0		3						
			U	U	U	21							
24		.0028											
25			69.9	0									
26	UD	0.319											
27	KK	COMB1											
28	KO	5	0	0	0	21							
29	HC	2											
30	KK	POST1											
31	KM	POST-DE	VELOPED	CONDITI	ONS - EN	TIRE DRA	INAGE AR	EA					
32	KO	3	0	0	0	21							
33	BA	.0046											
34	LS	0	97.7	0									
35		0.050											
					HEC-1	INPUT						PAGE 2	
					inde 1	1111-01						11101 1	
LINE	TD	1	2	3	4	5	6	7	8	9	1.0		
21112	10												
36	KK	DIV											
37	KO	5	0	0	0	21							
38	DT	SF	0	0	0	21							
39	DI	0.00	1.54	3.07	4.46	E E1	10 07	17 56	26.97	27 02	E0 20		
40	DI	0.00		3.07	4.40	5.51			26.97				
40	DQ	0.00	1.54	3.07	4.40	5.51	0.39	/.10	/.00	8.50	9.09		
43													
41	KK	SF											
42	KM				WAS DIV		SAND FI	LTER					
43	KO		0	0	0	21							
44	DR	SF											
45	KK	SFROU											
46	KO	3	0	0	0	21							
47		ROUTE D											
48					INCLUDED	IN STAG	E-DISCHA	RGE; ALL	FLOW THE	ROUGH FI	LTER ME		
49	RS	1	ELEV	734									
50	SV	0	.041	.083	.123	.162	.201	.240					
51	SE	734	734.5		735.5								
52		0.00											
53		734											
54	ZZ												
* * * * * * * * * * * * * * * * * * * *	******	*******	****						,	******	*******	*****	******
*			*							* · · · · · ·			*
* FLOOD HYDROGRAPH P	NOVNOR	(UEC 1)	*								ADMV O	ORPS OF ENGINEED	RS *
1 DOOD HIDROORHH I		(HEC-1)	-							0.5			
* JUN * VERSION 4												ENGINEERING CEN	TER *
* VERSION 4	.1		*						,			ECOND STREET	
·	min	1	*						,			ALIFORNIA 95616	*
* RUN DATE 10APR08	TIME	10:20:12	*						1		(916)	) 756-1104	*

* *	*
* FLOOD HYDROGRAPH PACKAGE (HEC-1) *	* U.S. ARMY CORPS OF ENGINEERS
* JUN 1998 *	* HYDROLOGIC ENGINEERING CENTER
* VERSION 4.1 *	* 609 SECOND STREET
* *	<ul> <li>* DAVIS, CALIFORNIA 95616</li> </ul>
* RUN DATE 10APR08 TIME 16:26:12 *	* (916) 756-1104
* *	*

CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL ANALYZED BY ABC ENGINEERING DATE: OCTOBER 2006

### 1 RUNOFF SUMMARY FLOW IN CUBIC FEET PER SECOND TIME IN HOURS, AREA IN SQUARE MILES PEAK FLOW TIME OF PEAK AVERAGE FLOW FOR MAXIMUM PERIOD BASIN AREA MAXIMUM STAGE TIME OF MAX STAGE OPERATION STATION 24-HOUR 6-HOUR 72-HOUR HYDROGRAPH AT PRE1 Ο. 4.87 Ο. Ο. 0. .00 HYDROGRAPH AT PRE2 5.78 Ο. Ο. .00 0. 0. 2 COMBINED AT COMB1 Ο. ο. Ο. 5.52 Ο. .00 HYDROGRAPH AT POST1 5. 3.18 Ο. Ο. Ο. .00 DIVERSION TO SF .00 0. Ο. Ο. .00 5. HYDROGRAPH AT DIV 0. .00 0. 0. Ο. .00 HYDROGRAPH AT SF 5. 3.18 0. 0. 0. .00 ROUTED TO + SFROU Ο. 5.42 0. Ο. 0. .00 735.94 5.73

\*\*\* NORMAL END OF HEC-1 \*\*\*

1

The following HEC-1 file provides the results of an iterative process to control the 1-year, 24-hour storm event routing. The design process is iterative and is performed in concert with the design process for



peak flow attenuation for the 10-year, 6-hour storm event. The initial goal is to minimize the storage within the sand filter and maximize the storage within the extended dry detention basin because the relative cost of the underground sand filter is expected to be much greater than the above ground extended dry detention basin. However, some of the first iterations resulted in a conclusion that the flood control attenuation benefits of the extended dry detention basin could be maximized but the overall site flood controls were still not met. In other words, reducing the extended dry detention outflow to near zero would still not meet the pre-development target rates because the sand filter outflow was higher than pre-developed rates. Therefore, additional flood control must be provided by the storage volume above the sand filter to supplement the flood control benefits of the extended dry detention basin.

The iterative process included increasing the storage volume above the sand filter and decreasing the outlet orifice until more than 5 percent of the 1-year, 24-hour storm event runoff is held within the sand filter after 36 hours (24 hours past the center of the rainfall – 12 hours). The iterative process requires the designer to export the hydrograph to a spreadsheet and compute the hydrograph volume before and after the time of interest or setting the total HEC-1 model time to the time of interest and comparing the routed hydrograph volume with the total runoff hydrograph volume.

The design goal to control the 1-year, 24-hour storm event for 24 hours past the center of rainfall is complex because of the two BMPs that are designed to perform as parallel facilities. To assess if the design goal is met, several different checks must be performed. The first design check is straight-forward and is focused on the sand filter facility. The majority of runoff volume for the 1-year, 24-hour storm event is diverted to the sand filter. The diverted hydrograph includes most of the smaller peak flows because higher flows are diverted to the extended dry detention basin. Determining if the 1-year, 24-hour storm event is controlled for the design duration is assessed by comparing the sand filter inflow hydrograph (diverted hydrograph) to the sand filter outflow hydrograph. The entire site 1-year, 24-hour hydrograph should not be used in the comparison. The second check is more complex and requires checking of the combined outflows for the sand filter and extended dry detention basin with the entire site post-development hydrograph.

1***********	***************************************
* *	*
* FLOOD HYDROGRAPH PACKAGE (HEC-1) *	* U.S. ARMY CORPS OF ENGINEERS
* JUN 1998 *	* HYDROLOGIC ENGINEERING CENTER
* VERSION 4.1 *	* 609 SECOND STREET
* *	<ul> <li>* DAVIS, CALIFORNIA 95616</li> </ul>
* RUN DATE 11APR08 TIME 10:00:52 *	* (916) 756-1104
* *	*
*******	*********

Х	х	XXXXXXX	XX	XXX		X
Х	Х	х	х	Х		XX
Х	Х	х	х			х
XXXX	XXX	XXXX	х		XXXXX	х
Х	Х	х	х			х
Х	Х	х	х	Х		х
Х	Х	XXXXXXX	XX	XXX		XXX

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

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1		HEC-1 INPUT	PAGE	1
I	INE	ID1		
	1	ID CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL		
	2	ID ANALYZED BY ABC ENGINEERING		
	3	ID DATE: OCTOBER 2006		
		* ******************************		
		*		
		* TIME SPECIFICATION CARD		
		* TOTAL MODEL DURATION - 27 HOURS		
		* 24 HOURS AFTER CENTER OF 6 HOUR RAINFALL		
	4	IT 1 0 0 1620		
		* DIAGRAM		
		* NOTE INPUT INTERVAL SET TO 6 MINUTES FOR 1-YEAR STORM DISTRIBUTION		
	5			
	5	*		
		* OUTPUT CONTROL CARD		
	6			
	0	10 2 0 0		



						STORM EV							
2	* **	******	* * * * * * * * *	******	* * * * * * * *	* * * * * * * * *	******	* * * * * * * *	*******	******	* * * *		
9 10	PI PI	.0000	.0010 .0011 .0012	.0010	.0010	.0011	0011	.0011	.0010	.0011	.0012		
11	PI	.0012	.0012	.0012	.0011 .0013	.0012	.0012	.0012	.0012	.0013	.0013		
12 13	PI	.0013	.0013	.0013	.0013	.0014	.0013			.0013	.0014		
14			.0014		.0015			.0013		.0015			
15	PI	.0018	.0018	.0018	.0019	.0019	.0018	.0020	.0019	.0019	.0020		
16 17	PI	.0020	.0020	.0020	.0021			.0021		.0021			
18	PI	.0022	.0022	.0024	.0024	.0026	.0026	.0028	.0029	.0029	.0030		
19	PI	.0039	.0041	.0044	.0046	.0048	.0051	.0054	.0058	.0062	.0066		
20 21	PI	.0070	.0077	.0086 .0166	.0096	.0106	.0115	.0238 .0084	.0476	.0764	.1371		
21		.0951			.0144	.0122	.0098	.0084	.0080	.0074	.0068		
23	PI	.0038	.0037	.0036	.0035	.0034	.0034	.0033	.0033	.0032	.0031		
24 25						.0027				.0025			
25	PI	.0021	.0020	0020	.0023	.0019		.0019	.0019	.0018			
27	PI	.0018	.0018	.0017	.0018	.0017	.0017	.0016	.0017	.0016	.0016		
28 29	PI PI	.0015	.0016	.0015	.0015	.0015	.0014	.0014 .0013	.0014	.0013	.0014		
30	PI	.0013	.0013	.0012	.0013	.0013	.0012	.0013		.0012	.0013		
31	PI	.0012	.0012	.0012	.0012	.0012	.0011	.0012	.0012	.0011	.0012		
32			.0012	.0011	.0012	.0011	.0011	.0012	.0011	.0011	.0011		
33 34	KM	.0011 EAST S	UB-BASIN	PRE-DEVI	ELOPED C	ONDITIONS	3						
35	KO	5	0		0								
36 37	BA	.0018 0	60.0	0									
37	LS UD	0.319	69.9	U									
					HEC-1	INPUT						PAGE 2	
LINE	TD	,	2	2	4	5	~	7	0	0	1.0		
LINE	10				4 .			/ .	0		10		
39 40	KK KM	PRE2	ID DACTN	DDE DEVI	PLODED O	ONDITIONS							
40	KO	WE31 3		PRE-DEVI			>						
42	BA	.0028											
43 44	LS UD	0 0.319	69.9	0									
44	UU	0.319											
45	KK	COMB1											
46 47	KO HC	5 2	0	0	0	21							
4 /	HC	2											
48	KK	POST1											
49	KM	POST-D				TIRE DRAI	INAGE ARI	EA					
50 51	KO BA	3 .0046	0	0	0	21							
52	LS	0	92.6	0									
53	UD	0.050											
54	KK	DIV											
55	KO	5	0	0	0	21							
56	DT	SF	1 54	2 05		5 51	10.07	10.56	06.07	27 00	50.00		
57 58	DI DI	0.00	1.54	3.07	4.46	5.51	10.07	17.56	20.97	37.92	50.20		
59	DQ	0.00	1.54	3.07	4.46	5.51	6.39	7.16	7.86	8.50	9.09		
60	DQ	9.65											
61	KK	EDROU											
62	KO	3		0	0	21							
63	KM					UGH THE I							
64 65	KM KM					NED SAND OF THE F		AND EXTE	DRY CHEU	DETENTIO	UUTF		
66	RS	1	ELEV	730									
67	SV	0	.080	.160	.240	.320							
68 69	SE SQ	730	730.5 0.24	731 0.38	731.5 9.68	732 26.57							
70	SE		730.5		731.5								
71 72	KK KM	SF RECALL	HADBUGB	орн тилт	WAS DIT	ERTED TO	SAND FT	UTER					
72	KO	5	0 O				SAND FI	BR					
74	DR	SF											
75	KK	SFROU											
75	KO	3		0	0								
77	KM	ROUTE	DIVERTED			UGH THE S							
78					INCLUDED	IN STAGE	-DISCHAI	RGE; ALL	FLOW THE	ROUGH FII	LTER ME		
79 80	RS SV	1	ELEV .041	734	.123	.162	. 201	.240	.282	.323	.364		
81	SV	.391	0.404										
82	SE	734	734.5	735	735.5	736	736.5	737	737.5	738	738.5		
83 84		738.85	739 0.073	0 080	0 100	0.117	0 1 2 2	0 1/4	0 386	0 626	1.107		
85			6.706	0.000	0.102			0.140	0.000	0.020	1.10/		
86	SE		734.5	735	735.5		736.5	737	737.5	738	738.5		
					HEC-1	INPUT						PAGE 3	
LINE	TD		2		4	5		7	8	9	10		
	SE	738.85	739										
87	кк	COMBO											
		3	0	0	0	21							
88 89	KO					FLOW AND	EXTENDED	D DRY DE	CENTION (	UTFLOW			
88 89 90	KO KM	COMBIN	ATION OF	SAND FII	LTER OUT	FIOW AND							
88 89	KO		ATION OF	SAND FII	LTER OUT	FLOW AND							

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*	FLOOD	HYDROGRAPH	PACKAGE	(HEC-1)	*
*		JUN	1998		*
*		VERSION	4.1		*
*					*
*	RUN DAI	TE 11APRO	8 TIME	10:00:52	*
*					*
**	******	*******	******	******	* * *

*	U.S. ARMY CORPS OF ENGINEERS	*
*	HYDROLOGIC ENGINEERING CENTER	*
*	609 SECOND STREET	*
*	DAVIS, CALIFORNIA 95616	*
*	(916) 756-1104	*
*		*
****	***************************************	* * *

CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL ANALYZED BY ABC ENGINEERING DATE: OCTOBER 2006

1					RUNOFF SU IN CUBIC FEE HOURS, AREA	T PER SECOND				
+	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FL	OW FOR MAXIM	UM PERIOD	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	PRE1	0.	12.35			0.	.00		
+	HYDROGRAPH AT	PRE2	1.	12.35	0.	0.	0.	.00		
+	2 COMBINED AT	COMB1	1.	12.35	0.	0.	0.	.00		
+	HYDROGRAPH AT	POST1	8.	12.02	1.	0.	0.	.00		
+	DIVERSION TO	SF	б.	12.02	1.	0.	0.	.00		
+	HYDROGRAPH AT	DIV	2.	12.02	0.	0.	0.	.00		
+ +	ROUTED TO	EDROU	0.	12.13	0.	0.	0.	.00	730.13	12.13
+	HYDROGRAPH AT	SF	б.	12.02	1.	0.	0.	.00		
+ +	ROUTED TO	SFROU	0.	13.85	0.	0.	0.	.00	737.31	13.92
+	2 COMBINED AT	COMBO	0.	13.65	0.	0.	0.	.00		

\*\*\* NORMAL END OF HEC-1 \*\*\*

### Step 12b Calculate Q<sub>10</sub> Release Rate and Water Surface Elevation(s)

The next step of the design process is to design the sand filter and extended dry detention to be used to achieve the peak attenuation goals for the 10-year, 6-hour storm event. This process is similar to previous examples in that the design is iterative. A stage-storage-discharge relations is developed assuming an outflow orifice and/or weir and storage area. The storm event is routed through the storage volume, and the outflow peak discharge is compared to the pre-development peak discharge for the 10-year, 6-hour storm event; 3.48 cfs. In addition, the peak stage for the 10-year, 6-hour storm events must be less than 5 feet above the top of the filter media.

The following HEC-1 output files illustrate the results of the iterative process for the 10-year storm event where both the sand filter and extended dry detention basin attenuation benefits are maximize. The sand filter uses a 0.15 foot weir that is installed at elevation 737.0, 3 feet above the sand filter media to attenuate the post-developed discharge to the appropriate value for the 10-year, 6-hour storm event. The extended dry detention basin uses a 4-inch diameter orifice at the invert of the basin. The TAPE21 file indicates that the peak discharge for the 10-year, 6-hour storm event is 1.62 cfs with a peak stage of 738.83 for the sand filter and 730.83 for the extended dry detention basin. Note that the peak stage is 4.83 feet above the top of the sand filter media. The 4.83 feet ponding depth is less than the allowable 5 feet depth. Also note that the peak stage in the extended dry detention basin is only 0.83 feet because of the minimal opportunity for benefit for flood attenuation from the extended dry detention basin because the majority of the hydrograph is diverted into the sand filter. Intermediate steps are not presented.

1 \* FLOOD HYDROGRAPH PACKAGE (HEC-1) \* \* JUN 1998 \* \* \* \* \* \* \* \* \* \* \* \* \* \* U.S. ARMY CORPS OF ENGINEERS \* HYDROLOGIC ENGINEERING CENTER \*



*		VERSION 4.1	*
*			*
*	RUN DATE	11APR08 TIM	E 10:07:46 *
*			*
* *	* * * * * * * * * * *	********	******

1

1

*	609 SECOND STREET	
*	DAVIS, CALIFORNIA 95616	
*	(916) 756-1104	
*		
* * * *	*****	*



THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAW77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

					HEC-1	INPUT						PAGE	1
LINE	ID.	1.	2					7	8 .	9 .	10		-
1 2	ID ID		ARLOTTE-M				CTION DES	SIGN MANU	JAL				
3	ID	DA	TE: OCTOR	BER 2006									
	*	******	******	******	*******	******	******	******	******	******	* * * *		
	*	TTME	SPECIFICA	TTON ON	סנ								
	*	TOTAL	MODEL DU	RATION ·	- 27 HOUF	۱S							
	*	24 HO	URS AFTER	CENTER	OF 6 HOU	JR RAINFA	ALL						
4	IT	1	0	0	1620								
	* 1	DIAGRAM	INTERVAL	CARD									
5	IN		0										
	*												
6	* IO		T CONTROL 0										
0	*	5	0	0									
7	KK	PRE1											
,			******	******	*******	******	******	******	******	******	* * * *		
			******										
			*******										
8 9	PI PI	.000	.011	.011	.012	.012	.012	.012	.013	.013	.013		
10	PI	.024	.014	.015	.027	.029	.036	.039	.042	.045	.049		
11	PI	.054	.079	.089	.103	.161	.201	.395	.590	.275	.177		
12 13	PI PI	.112	.095	.084	.057	.051	.047	.043	.040	.038	.030		
14	PI		.027			.023	.013	.013	.017	.017	.010		
15	PI		.015	.011	.000								
16	KM	EAST S	UB-BASIN	PRE-DEVI	ELOPED CC	NDITION:	S						
17 18	KO BA	5 .0018	0	0	0	21							
19	LS	0	69.9	0									
20	UD	0.319											
21	KK	PRE2											
22	KM		UB-BASIN				S						
23 24	KO BA	5	0	0	0	21							
24	LS	.0028 0	69.9	0									
26	UD	0.319		-									
27	кк	COMB1											
28	ко	5	0	0	0	21							
29	HC	2											
30	KK	POST1											
31	KM		EVELOPED	CONDITIC	ONS - ENT	TIRE DRA	INAGE ARI	EA					
32	KO	3	0	0	0	21							
33 34	BA LS	.0046	92.6	0									
35	UD	0.050	52.0	0									
					HEC-1	INPUT						PAGE	2
LINE	ID.	1 .	2		4	5.		7	8 .	9 .	10		
36	KK	DIV											
37	KO	5	0	0	0	21							
38	DT	SF	1 64	2 07	4 40	F F 7	10.07	17.54	26.07	27 00	F0 00		
39 40	DI	0.00	1.54	3.07	4.46	5.51	10.07	17.56	26.97	37.92	50.20		
41	DQ	0.00	1.54	3.07	4.46	5.51	6.39	7.16	7.86	8.50	9.09		
42	DQ	9.65											
43	KK	EDROU											
44	KO	3	0	0	0	21							
45	KM	ROUTE	BYPASSED TARGET I	HYDROGRA	APH THROU	JGH THE I	DOWNSTREA	AM EXTENI	DED DRY	DETENTIO	N OUTER		
46 47	KM KM		HOURS BE						NDED DRY	DETENTI	UN OUTF		
48	RS		ELEV	730									
49	SV	0	.080	.160	.240	.320 732							
50 51	SE SQ	730	730.5 0.24	731 0.38	731.5 9.68	732 26.57							
52	SQ	730	730.5	731	731.5	732							
53 54	KK KM	SF RECALL	HYDROGRA	DH TUNT	WAS DIT	RTED TO	SAND ET	TER					
51	1014	VECHIN	DROGRA		MAG DIVE		STAD FI						



55	KO	5	0	0	0	21					
56	DR	SF									
57	KK	SFROU									
58	KO	3	0	0	0	21					
59	KM	ROUTE	DIVERTED	HYDROGH	RAPH THRO	UGH THE	SAND FILT	ER FACI	LITY		
60	KM	NO OVE	ERFLOW ST	RUCTURE	INCLUDED	IN STAG	E-DISCHAR	GE; ALL	FLOW TH	HROUGH FI	LTER ME
61	RS	1	ELEV	734							
62	SV	0	.041	.083	.123	.162	.201	.240	.282	.323	.364
63	SV	.391	0.404								
64	SE	734	734.5	735	735.5	736	736.5	737	737.5	738	738.5
65	SE	738.85	739								
66	SO	0.00	0.073	0.088	0.102	0.117	0.132	0.146	0.386	0.626	1.107
67	SO	1.333	6.706								
68	SE	734	734.5	735	735.5	736	736.5	737	737.5	738	738.5
69	SE	738.85	739								
70	KK	COMBO									
71	KO	3	0	0	0	21					
72	KM	COMBIN	NATION OF	SAND FI	LTER OUT	FLOW AND	EXTENDED	DRY DE	TENTION	OUTFLOW	
73	HC	2									
74	ZZ										

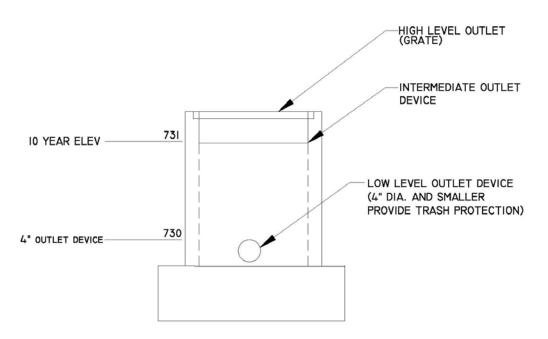
* *	* *
* FLOOD HYDROGRAPH PACKAGE (HEC-1) *	* U.S. ARMY CORPS OF ENGINEERS *
* JUN 1998 *	* HYDROLOGIC ENGINEERING CENTER *
* VERSION 4.1 *	* 609 SECOND STREET *
* *	* DAVIS, CALIFORNIA 95616 *
* RUN DATE 11APR08 TIME 10:07:46 *	* (916) 756-1104 *
* *	* *

### CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL ANALYZED BY ABC ENGINEERING DATE: OCTOBER 2006

1					RUNOFF SU IN CUBIC FEE HOURS, AREA	T PER SECOND				
	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FL	OW FOR MAXIM	UM PERIOD	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+					6-HOUR	24-HOUR	72-HOUR			
+	HYDROGRAPH AT	PRE1	1.	3.52	0.	0.	0.	.00		
+	HYDROGRAPH AT	PRE2	2.	3.52	0.	0.	0.	.00		
+	2 COMBINED AT	COMB1	3.	3.52	1.	0.	0.	.00		
+	HYDROGRAPH AT	POST1	17.	3.18	1.	0.	0.	.00		
+	DIVERSION TO	SF	7.	3.18	1.	0.	0.	.00		
+	HYDROGRAPH AT	DIV	10.	3.18	0.	0.	0.	.00		
+ +	ROUTED TO	EDROU	0.	3.35	0.	0.	0.	.00	730.83	3.37
+	HYDROGRAPH AT	SF	7.	3.18	1.	0.	0.	.00		
+ +	ROUTED TO	SFROU	1.	4.03	1.	0.	0.	.00	738.83	4.08
+	2 COMBINED AT	COMBO	2.	3.98	1.	0.	0.	.00		

\*\*\* NORMAL END OF HEC-1 \*\*\*





# OUTLET STRUCTURE DETAIL

### NOT TO SCALE

### Figure 4.8.13 Schematic of Extended Detention Basin Outlet Structure

Comparison of this example with the previous stand-alone sand filter example indicates that the storage volume required is less for three of the design storm events; 1-inch, 6-hour, 10-year, 6-hour, and 50-year, 6-hour storm events. The storage volume required is slightly larger for this example for the 1-year, 24-hour control requirement. However, some of the storage volume is provided in an above-ground extended dry detention facility which may be more cost-effective to construct relative to an under-ground sand filter.

### Step 13 Design Inlets and Underdrain System

Inlet conveyance system design is not included in this design example. Standards for conveyance system design are covered in the Charlotte-Mecklenburg Storm Water Design Manual.

The underdrain system must be designed to meet two design goals; the underdrain capacity must be greater than the filter media capacity, and the capacity must drain the runoff volume from the system within design duration (1.13 days for this example). The design must assume that 50 percent of the underdrain system (perforations and pipe system capacity) is lost due to clogging.

Design specifications require the underdrain system to be a 6-inch perforated PVC pipe with 3/8-inch perforations spaced 3 inches on center, along 4 longitudinal rows spaced 90° apart. Minimum underdrain slope is 0.5 percent.

The length, slope, number of pipes, spacing, etc. is configured per design requirements. Based upon the required area for the sand filter BMP  $(1,395 \text{ ft}^2)$  the approximate dimensions of the sand filter area is selected to be 38 feet wide by 38 feet in length (approximately 1,444 ft<sup>2</sup>).

Charlotte-Mecklenburg BMP Design Manual



The design process uses a trial and error process. The capacity of the perforations and pipe (assuming 50 percent of the system is clogged) are computed. The computed underdrain capacity is checked relative to the filter media capacity to ensure that the filter media is the controlling outflow condition. The computed underdrain capacity if compared to the static outflow discharge that ensures the runoff within the system leaves within 27 hours.

### Compute minimum drawdown discharge

Water quality volume	=	(0.19 ac-ft)(43,560ft <sup>3</sup> /ac ft)	= 8,276 ft <sup>3</sup>
Drawdown	=	8,276 ft <sup>3</sup> /[(27 hours)(3,600sec/	hour)]
	=	0.085 cfs	

### Compute perforation capacity

Since the maximum underdrain spacing is 10 feet on center and the sand filter area is 38 feet wide by 38 feet in length, three parallel underdrain pipes (6-inch diameter PVC) 38 feet in length were selected. For the calculations below, the length of pipe containing holes was reduced by 1 foot per cleanout to account for fittings.

Number of perforations	=	(3 pipes)(4 rows/ft)(38-2) ft/pipe)(4 holes/	row) = 1,728 holes
50 percent of perforations	=	864 holes	
Capacity of one hole	=	CA(2gh) <sup>0.5</sup>	
	=	(0.6)(3.1416)[(3/8in)(1/24)] <sup>2</sup> [(64.4)(3.0ft)] <sup>0</sup>	).5
	=	0.0064 cfs/hole	
Total capacity	=	(0.0064 cfs/hole)(864 holes) =	= 5.53 cfs

The perforations capacity (5.53 cfs) is greater than the filter media capacity (0.088 cfs, computed in step 11b) and the minimum drawdown capacity requirement (0.085 cfs computed in this step). Therefore the design is acceptable.

Note that the headwater depth used to determine the filter media capacity is 1.0 feet, the average headwater depth above the filter media for the water quality storm event. The drawdown computation is also based on the water quality volume. The headwater depth for the perforations is also based on the same average headwater elevations, 1 feet above the filter media, or 3.0 feet above the perforations.

### Compute underdrain pipe capacity

For 6-inch PVC underdrain pipe at 0.005 ft/ft slope:							
Capacity of pipe	=	(1.49/n)(A)(A/P) <sup>0.67</sup> (S) <sup>0.5</sup>					
	=	$(1.49/0.013)(0.1963 \text{ ft}^2)(0.125 \text{ ft})^{0.67}(0.005)^{0.5}$					
	=	0.40 cfs					
Fifty percent assuming clogging :	=	0.20 cfs					

The pipe capacity (0.20 cfs) is greater than the filter media capacity (0.088 cfs, computed in step 11b) and the minimum drawdown capacity requirement (0.085 cfs computed in this step). Therefore the design is acceptable.

### Step 14 Design Overflow Weir

The final step is to route the 50-year, 6-hour storm event through the sand filter and extended dry detention basin facilities to ensure that a minimum of 6-inches of freeboard is provided and that a maximum of 5 feet of depth is over the sand filter media. A thirty (30) foot weir at 738.85 is proposed as the emergency overflow for the sand filter. A ten (10) foot weir at 731.00 is proposed as the emergency overflow for the extended dry detention. The following HEC-1 output file illustrates the results.

1**	*****	*****	***********************
*		*	*
*	FLOOD HYDROGRAPH PACKAGE	(HEC-1) *	* U.S. ARMY CORPS OF ENGINEERS
*	JUN 1998	*	* HYDROLOGIC ENGINEERING CENTER
*	VERSION 4.1	*	* 609 SECOND STREET
*		*	* DAVIS, CALIFORNIA 95616



\* RUN DATE 11APR08 TIME 10:50:36 \* \* \*

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\* (916) 756-1104 \* \* \*

х	х	XXXXXXX	XX	XXX		Х
Х	х	х	х	Х		XX
Х	х	х	х			Х
XXXX	XXX	XXXX	х		XXXXX	Х
Х	х	х	х			Х
Х	Х	х	х	Х		Х
Х	Х	XXXXXXX	XX	XXX		XXX

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE. THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE, SINCLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY, DSS:READ THE SERIES AT DESIRED CALCULATION INTERVAL LOSS RATE:GREEN AND AMPT INFILTRATION KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

					HEC-1	INPUT						PAGE	1
LINE	ID.	1.	2					7 .	8 .	9 .	10		-
			ARLOTTE-M										
1 2	ID ID		ARLOTTE-M ALYZED BY				CTION DES	SIGN MAN	JAL				
3	ID	DAT	TE: OCTOR	BER 2006									
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	*		MODEL DU			RS							
	*		JRS AFTER				ALL						
4	IT	1	0	0	1620								
	* 1	DIAGRAM	INTERVAL	CARD									
5	IN		0										
5	*	2	0	0									
	*		r controi										
6	IO	5	0	0									
	-												
7	KK	PRE1											
			*******										
	* *	********	* * * * * * * * * * * * * * * * * * *	50-YEAR	, 6-HOUR	STORM E	VENT ****	********	********	********	****		
8	PT	000	.016	016	016	017	017	018	018	.019	.019		
9	PI			.021					.025	.026	.031		
10	PI	.032	.033	.035	.037	.039	.049			.061	.066		
11	PI	.073	.103	.116		.209			.749	.356	.231		
12 13	PI PI	.145	.124	.109	.077	.069	.063	.058	.054	.051	.040		
14	PI	.022	.036 .021 .016	.021	.020	.019	.026	.018	.054 .024 .018	.023	.017		
15	PI	.017	.016	.016	.000								
16	KM		JB-BASIN				S						
17 18	KO BA	.0018	0	0	0	21							
19	LS	0	69.9	0									
20	UD	0.319											
21 22	KK KM	PRE2	JB-BASIN	DDE DEV	PLODED CO		~						
23	KO				0		5						
24	BA	.0028											
25	LS	0	69.9	0									
26	UD	0.319											
27	KK	COMB1											
28	KO	5	0	0	0	21							
29	HC	2											
30	кк	POST1											
31	KM		EVELOPED	CONDITI	ONS - ENT	TIRE DRA	INAGE ARE	EA					
32	KO		0										
33	BA	.0046											
34 35	LS UD	0.050	92.6	0									
35	UD	0.050			HEC-1	INPUT						PAGE	2
LINE	ID.	1.	2	3.	4	5 .	6.	7.	8 .	9 .	10		
36	KK	DIV											
37	KO	5	0	0	0	21							
38 39	DT DI	SF 0.00	1.54	3.07	4.46	E E1	10.07	17 56	26.97	27 02	E0 20		
40		63.69	1.54	3.07	4.40	0.01	10.07	17.50	20.97	57.92	50.20		
41	DQ	0.00	1.54	3.07	4.46	5.51	6.39	7.16	7.86	8.50	9.09		
42	DQ	9.65											
43	KK	EDROU											
43	KO	3	0	0	0	21							
45	KM		BYPASSED										
46	KM		TARGET I						NDED DRY	DETENTI	ON OUTF		
47 48	KM RS	FOR 24	HOURS BE ELEV	YOND TH 730	e centér	OF THE 1	KAINFALL						
48	SV	1 0	.080	.160	.240	.320							
50	SE	730	730.5	731	731.5	.320 732							
51	SQ	0.00	0.24	0.38	9.68	26.57							
52	SE	730	730.5	731	731.5	732							
53	KK	SF											
54	KM	RECALL	HYDROGRA				SAND FI	LTER					
55	KO	5	0	0	0	21							
56	DR	SF											



SFROU 57 58 59 61 62 63 65 66 65 66 67 68 69KK KO KM RS SV SV SE SQ SQ SE SE 3 0 0 0 21 
 3
 0
 0
 0
 21

 ROUTE DIVERTED HYDROGRAPH THROUGH THE SAND FILTER FACILITY

 NO OVERFLOW STRUCTURE INCLUDED IN STAGE-DISCHARGE; ALL FLOW THROUGH FILTER ME

 1
 ELEV
 734

 0
 0.401
 .083
 .123
 .162
 .201
 .240
 .282
 .323
 .364

 .331
 0.404
 .083
 .123
 .162
 .201
 .240
 .282
 .323
 .364
 0.404 734.5 739 0.073 6.706 734.5 739 735 736 735.5 736.5 737 737.5 738 738.5 734 734 738.85 0.00 1.333 734 738.85 0.088 0.102 0.117 0.132 0.146 0.386 0.626 1.107 735 735.5 736 736.5 737 737.5 738 738.5 
 70
 KK
 COMBO

 71
 KO
 3

 72
 KM
 COMBINATION

 73
 HC
 2

 74
 ZZ
 2
 3 0 0 0 21 COMBINATION OF SAND FILTER OUTFLOW AND EXTENDED DRY DETENTION OUTFLOW \*\*\*\*\* U.S. ARMY CORPS OF ENGINEERS HYDROLOGIC ENGINEERING CENTER 609 SECOND STREET DAVIS, CALIFORNIA 95616 (916) 756-1104 FLOOD HYDROGRAPH PACKAGE (HEC-1) JUN 1998 VERSION 4.1 RUN DATE 11APR08 TIME 10:50:36 

> CHARLOTTE-MECKLENBURG POST CONSTRUCTION DESIGN MANUAL ANALYZED BY ABC ENGINEERING DATE: OCTOBER 2006

1					RUNOFF SU IN CUBIC FEE HOURS, AREA	T PER SECOND				
	OPERATION	STATION	PEAK FLOW	TIME OF PEAK				BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+					6-HOUR	24-HOUR	72-HOUR			
+	HYDROGRAPH AT	PRE1	2.	3.50	0.	0.	0.	.00		
+	HYDROGRAPH AT	PRE2	4.	3.50	1.	0.	0.	.00		
+	2 COMBINED AT	COMB1	б.	3.50	1.	0.	0.	.00		
+	HYDROGRAPH AT	POST1	23.	3.18	2.	1.	0.	.00		
+	DIVERSION TO	SF	8.	3.18	2.	0.	0.	.00		
+	HYDROGRAPH AT	DIV	16.	3.18	1.	0.	0.	.00		
+ +	ROUTED TO	EDROU	5.	3.30	0.	0.	0.	.00	731.23	3.30
+	HYDROGRAPH AT	SF	8.	3.18	2.	0.	0.	.00		
+ +	ROUTED TO	SFROU	5.	3.45	1.	0.	0.	.00	738.96	3.45
+	2 COMBINED AT	COMBO	8.	3.42	1.	0.	0.	.00		

\*\*\* NORMAL END OF HEC-1 \*\*\*

Table 4.8.12 presents the results of the design. In addition, the table includes the results (*highlighted with italics*) of the previous design example discussed in section 4.8.8. The previous design example used only a sand filter to meet the design goals of the same site.



	Table 4.8.12 Summary of Controls Provided									
Control Element	Type/Size of Control	Stor. (ac-ft)	Peak Elev. (MSL)	Disc. (cfs)	Remarks					
Water Quality Extended Detention (WQ <sub>v-ed</sub> )	Sand filter media at 734.0	0.154	735.90	0.14 cfs	Entire 1-inch, 6-hour storm event is routed through sand filter media					
Water Quality Extended Detention (WQ <sub>v-ed</sub> )	Sand filter media at 734.0	0.176	735.29	0.05 cfs	Entire 1-inch, 6-hour storm event is routed through sand filter media					
Channel Protection (CP <sub>v</sub> )	Sand filter media at 734.0 and 0.15 foot weir at 737.0/extended dry detention 4-inch orifice at 730.0	0.266 + 0.021 = 0.287	737.31 730.13	0.29 0.06	Portion of the 1-year, 24-hour storm event is routed through the sand filter and a portion is routed through the extended dry detention 4-inch orifice outlet					
Channel Protection (CP <sub>v</sub> )	Sand filter media at 734.0 and 5-inch orifice at 735.5	0.281	736.04	0.43 cfs	Portion of the 1-year, 24-hour storm event is routed through the sand filter and a portion is routed through the 5-inch orifice outlet					
Flood Protection (Q <sub>10</sub> )	Sand filter media at 734.0 and 0.15 foot weir at 737.0/extended dry detention 4-inch orifice at 730.0	0.391 + 0.133 = 0.524	738.83 730.83	1.32 0.33	Same orifice control was designed for the 1-year, 24- hour and the 10-year, 6-hour storm events					
Flood Protection $(Q_{10})$	Sand filter media at 734.0 and 5-inch orifice at 735.5	0.542	737.98	1.08 cfs	Same orifice control was designed for the 1-year, 24- hour and the 10-year, 6-hour storm events					
Emergency Overflow (Q <sub>50</sub> )	Sand filter media at 734.0,0.15 foot weir at 737.0, and 30 foot weir at 738/extended dry detention 4-inch orifice at 730.0 and 10 foot weir at 731.0	0.403 + 0.197 = 0.600	738.96 731.23	5.23 4.75	Less than 5 feet of headwater depth on sand filter media.					
Emergency Overflow (Q <sub>50</sub> )	Sand filter media at 734.0, 5-inch orifice at 735.5, and 8-foot weir at 738.0	0.717	738.25	10.16 cfs	Less than 5 feet of headwater depth on sand filter media.					

## Table 4.8.12 Summary of Controls Provided

<u>Step 15</u> Assess Maintenance Access and Safety Features The filter media and sedimentation chamber must be accessible from the surface in order to provide regular maintenance without significant access challenges. All areas of both chambers must be within 25 feet of an access location from the surface that is large enough for personnel to enter in order to remove trash, debris, sediment, etc. In addition, the sand filter media must be accessible in order to facilitate complete replacement when the sand filter ponds runoff without filtration.