REVISED FINAL DESIGN

CALCULATION PACKAGE

ON-SITE DISPOSAL FACILITY
PHASE V
PROJECT NUMBER 20105

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

REVISION 0
VOLUME VII of VII
JANUARY 2002

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CALCULATION PACKAGE
ON-SITE DISPOSAL FACILITY
PHASE V
PROJECT NUMBER 20105

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by

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under

Fluor Fernald, Inc.
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Volume VII

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Revision 0

United States Department of Energy

Fernald Environmental Management Project
Fernald, Ohio

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Under

Fernald Environmental Restoration Management Corporation
Subcontract 95PS005028

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REVISED FINAL DESIGN PACKAGE
LIST OF CALCULATIONS
On-Site Disposal Facility
Fernald Environmental Management Project

VOLUME I

1. INTRODUCTION

1.1 Design Parameter Summary
1.2 Computer Program Validation

1.2.1 Autodesk® and SOFTDESK®
1.2.2 HydroCAD™
1.2.3 USDA-SCS TR-55
1.2.4 USEPA HELP Model
1.2.5 XSTABL – Version 5
1.2.6 SHAKE91
1.2.7 YSLIP_C
1.2.8 Landfill Air Emissions Estimation Model
1.2.9 RAECOM

1.3 Select Technical Preferences
1.4 Geotechnical Data Points

2. ODSF LAYOUT

2.1 Required Volume
2.2 Capacity Verification
2.3 Earthwork Required Volume

3. GEOTECHNICAL – STATIC SLOPE STABILITY

3.1 OSDF Foundation
3.2 Liner System
3.3 Impacted Material Configurations

- Interim
- Final

3.4 Intercell Berm
3.5 Final Cover System
3.6 Access Corridor
3.7 Borrow Area Cut Slopes

LIST OF CALCULATIONS (continued)

4. GEOTECHNICAL – SEISMIC SLOPE STABILITY

4.1 Seismic Hazard Assessment
4.2 Seismic Site Response Analysis
4.3 Seismic Performance Evaluation

- Pseudo-Static Stability
- Deformation Analysis

5. GEOTECHNICAL – SETTLEMENT

5.1 Foundation Settlement
5.2 Localized Impacted Material Settlement
5.3 Overall Impacted Material Settlement

VOLUME II

6. LINER SYSTEM

6.1 Hydrostatic Uplift
6.2 Liner Geosynthetics Selection

- Geosynthetic Clay Liner
- Geomembrane Liner
- Geotextile Cushion
- Geosynthetic Selection to Preclude Tension

6.3 Liner Frost Protection

7. LEACHATE MANAGEMENT – LEACHATE GENERATION

7.1 Leachate Generation Rates

- During Filling
- After Closure

7.2 Required Cell Leachate Storage

7.3 Cell 7 Impacted Runoff Catchment Area Requirements (See Volume VII)

LIST OF CALCULTIONS (continued)

8. LEACHATE MANAGEMENT – LEACHATE COLLECTION SYSTEM

8.1 Maximum Head in LCS

- Maximum Head in LCS Drainage Layer
- Maximum Head in LCS Drainage Corridor

8.2 Geotextile Filter Design

- Geotextile Filtration
- Geotextile Biological Clogging Potential

8.3 LCS Pipe Design

- LCS Pipe Flow Capacity
- LCS Pipe Perforation Sizing
- LCS Pipe Structural Stability

9. LEACHAGE MANAGEMENT – LEAK DETECTION SYSTEM

9.1 Migration through Primary Liner
9.2 Maximum Head in LDS

- Maximum Head in LDS Drainage Layer
- Maximum Head in LDS Drainage Corridor

9.3 Time of Travel in LDS
9.4 LDS Pipe Design

- LDS Pipe Flow Capacity
- LDS Pipe Perforation Sizing
- LDS Pipe Structural Stability

9.5 Action Leakage Rate

10. LEACHATE MANAGEMENT – LEACHATE TRANSMISSION SYSTEM

10.1 LTS Gravity Line Design

- LTS Gravity Line Flow Capacity
- LTS Gravity Line Structural Stability
- LTS Gravity Line Frost Protection

LIST OF CALCULATIONS (continued)

10.2 LTS Temporary Gravity Line Design

- LTS Temporary Gravity Line Hydraulic Pressure
- LTS Temporary Gravity Line Structural Stability
- LTS Temporary Gravity Line Frost Protection

10.3 LDS and LCS Manhole Design

- LCS and LCS Manhole Hydrostatic Uplift
- LCS and LCS Manhole Structural Design
- Structural Concrete Design for the Cover and Floatation Anchor

10.4 LTS Permanent Lift Station Design

- LTS Permanent Lift Station Storage Volume
- LTS Permanent Lift Station Manhole Uplift
- LTS Permanent Lift Station Structural Design

10.5 LTS Pipe Hydrograph

VOLUME III

11. FINAL COVER SYSTEM

11.1 Final Cover System Temporary Erosion Mat Design
11.2 Final Cover System Vegetation Design
11.3 Final Cover System Erosion Resistance
11.4 Final Cover System Frost Penetration Depth
11.5 Final Cover System Granular Filter Layer Design
11.6 Final Cover System Biointrusion Barrier Design
11.7 Final Cover System Drainage Layer Design

- Cover System Water Balance
- Cover Drainage Layer Maximum Head

11.8 Final Cover System Geosynthetics Selection

- Geotextile Cushion
- Geomembrane Cap
- Geosynthetic Clay Cap

LIST OF CALCULATIONS (continued)

12. SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

12.1 Stormwater Runon/Runoff and Drainage Control Structures
12.2 OSDF Sediment Basins
12.3 OSDF-Phase III Surface-Water Management System Design (See Volume V)
12.4 OSDF – Phase IV Surface-Water Management System Design (See Volume VI)
12.5 OSDF Phase V, Surface-Water Management System Design and Post-Closure Hydrology (See Volume VII)

13. SURFACE-WATER MANAGEMENT AFTER OSDF CLOSURE

13.1 Stormwater Runon/Runoff and Drainage Control Structures

- Northern Area Calculations
- Eastern Area Calculations
- Southern Area Calculations
- Western Area Calculations
- Addendum to Southern Area Calculations of 13.1

VOLUME IV

13.2 Drainage Control Structure Erosion Resistance

13.3 OSDF Phase V, East 2000-Year Drainage Channel Evaluation (See Volume VII)

13.4 Sedimentation Evaluation of Permanent Drainage Channels for High-Frequency Design Storms (See Volume VII)

14. SUPPORT FACILITIES

14.1 Electrical Power Demand
14.2 Potable Water Demand
14.3 Sanitary Wastewater Discharge
14.4 Construction Water Demand
14.5 Decontamination Facility Water Demand
14.6 Decontamination Facility Pavement
14.7 Construction Administration Area Surfacing
14.8 Construction Haul Road
14.9 Leachate Transmission System Access Corridor

LIST OF CALCULATIONS (continued)

15. BORROW AREA

15.1 Borrow Area Required Volume
15.2 Borrow Area Capacity Verification
15.3 Borrow Area Water Demand
15.4 Stormwater Runoff Routing
15.5 Borrow Area Sediment Basin
15.6 Surface-Water Management During Development (See Volume V)
15.7 OSDF-Phase III Borrow Area Development Subarea Volume Verification (See Volume V)
15.8 OSDF-Phase III Borrow Area Stockpile Area Capacity Calculation (See Volume V)

16. IMPACTED MATERIALS MANAGEMENT

16.1 Impacted Material Haul Road
16.2 Impacted Runoff from Haul Road
16.3 OSDF Methane Generation
16.4 OSDF Radon 222 Release

17. HORIZONTAL MONITORING WELL

17.1 Differential Settlement and Tensile Strain
17.2 Structural Stability

Section 7.3

4664

7.3 CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS

4664

COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS

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Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	SUBMIT AC TO FF/DUE EPA	29 JAN 01	CDC	MAO	DGP

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ADDENDUM TO SECTION 7.2
(ADDED TO REVISION 1 PACKAGE)

The calculation package presented in Section 7.2 was prepared to establish minimum cell storage requirements for containment of impacted runoff during the filling of cells. The analyses shown are for the case where the maximum containment volume of an impacted runoff catchment area (IRCA) is limited by the minimum elevation of a rain flap installed along the intercell berm at the south edge of the IRCA. This case applies to the northernmost and interior on-site disposal facility (OSDF) cells (i.e., Cells 1 to 6). The southernmost OSDF cell (i.e., Cell 7) differs from the other cells in that the maximum containment volume of the IRCA is limited by the minimum elevation of a rain flap installed along the Cell 7 perimeter.

This addendum to Section 7.2 was prepared to establish minimum IRCA storage requirements for Cell 7, and additionally, to estimate the decreasing Cell 7 IRCA storage requirements as Cell 6 and 7 are progressively capped. Similar methods and input data to that used in Section 7.2 were used herein. This addendum is presented as Section 7.3 of the OSDF Final Design Calculation Package, and is entitled "Cell 7 Impacted Runoff Catchment Area Requirements." Section 7.3 is presented in Volume VII of the OSDF Final Design Calculation Package.

CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS

EXECUTIVE SUMMARY

PURPOSE OF ANALYSES

The purpose of this calculation package is to demonstrate the adequacy of the Cell 7 impacted runoff catchment area (IRCA) design in providing the necessary impacted runoff storage capacity during staged closure of the final cells (i.e. Cells 6 and 7) for the on-site disposal facility (OSDF). Furthermore, the package provides requirements for sizing the IRCA during final closure construction activities through use of a design chart to interpolate for cases where the capped cell area is between that of the stages of closure evaluated in this package. Additionally, the flow capacity of channels discharging to the IRCA and the expected time for drawdown of impacted runoff within the IRCA are calculated to demonstrate that the design meets the required design criteria.

METHODS OF ANALYSES

The cases modeled in this package represent conditions expected to exist during the staged closure of the final two cells (i.e. Cells 6 and 7). Analyses are separated into three groups:

i.) evaluation of IRCA storage capacity,

ii.) evaluation of IRCA inlet channel capacity, and

iii.) evaluation of impacted runoff drawdown time.

It is important to note that non-impacted runoff is being defined as runoff from cap areas over which two lifts of compacted clay cap have been placed as a part of the final cover system. Non-impacted runoff will be diverted to the OSDF surface water management system and thus will not enter the IRCA. The term "capped" will be used to describe areas of the landfill that have received at least two lifts of compacted clay cap and where runoff has been diverted to the OSDF surface water management system, and "uncapped" will refer to areas of the landfill that discharge runoff to the IRCA.

IRCA Storage Capacity

Three stages of IRCA filling are considered for evaluation. These stages and the runoff areas associated with these stages are shown in Figures 1 through 3. Figure 1 shows the IRCA geometry designed to contain the runoff for Stage I, when both Cells 6 and 7 are uncapped. This geometry provides a smaller IRCA plan area than those of Cells 1 through 6 as presented in an earlier calculation package (Section 7.2, Required Cell Leachate Storage); however, it will be shown to provide adequate volume. The geometry of Stage I was chosen to provide a remaining

impacted material placement capacity of approximately 40,000 cubic yards. Calculations showing the total impacted material, select impacted material and non-select impacted material remaining to be placed for Stages I and II are presented in Attachment A-4. Figure 2 shows an IRCA geometry designed to contain the runoff for Stage II, which exists when Cell 6 is capped and Cell 7 remains uncapped. Figure 3 shows the case when Cell 6 is completely capped and the majority of Cell 7 is capped (i.e., Stage III). The IRCA in this case will consist of a "V-shaped" channel along the west and south perimeter of the uncapped portion of Cell 7. Figure 4 shows a cross-section of the V-shaped channel. The uncapped area for this stage consists of ~~the~~ uncapped area ~~at~~ from the previous stage (i.e., the IRCA and 3.5:1 slopes from Stage II) plus a 67 ft wide strip at the perimeters of this area where a temporary construction access road will be constructed.

The IRCA is considered adequate if it complies with the design criteria used to evaluate the IRCAs for Cells 1 through 6 in Section 7.2, which requires the IRCA to provide storage capacity to handle the 25-year, 24-hour storm event with 0.5 ft of freeboard. Hydrologic and basin routing analyses are performed using methodologies presented in TR-20 [USDA-SCS, 1982] and TR-55 [USDA-SCS, 1986], as coded into the computer program HydroCAD™.

This calculation will provide requirements for sizing the IRCA during final closure construction activities through use of a design chart to interpolate for cases where the capped area is between that of the stages analyzed in this package.

Channel Capacity

The required depths for channels discharging to the IRCA are evaluated for the "worst-case" scenario (i.e., Stage I). Stage I represents the worst-case scenario in regards to the channel depth because it has the largest uncovered area, resulting in the largest impacted runoff peak flow rate being routed through the channels. The channels are designed to convey peak flow rates from the 25-year, 24-hour storm event with minimum freeboard of 0.5 ft as established in the DCP [GeoSyntec, 2000]. Hydraulic analyses for channels are performed using Manning's equation as coded into a computer spreadsheet. Peak flow rates for the channels were taken from the HydroCAD™ output performed for the IRCA capacity calculations.

Additionally, the adequacy of a culvert will be evaluated using the computer program CulvertMaster®. The culvert is designed to convey the runoff being conveyed by Channel C beneath a temporary access road at the inlet to the IRCA. The culvert capacity calculation is presented in Attachment A-5.

Drawdown Time

The amount of time expected for impacted runoff to drain from the IRCA after the completion of the 25-year, 24-hour storm event into the Cell 7 LCS is referred to; herein, as the drawdown time. An estimation of the drawdown time is made for the three stages described earlier in this calculation package. The estimation for Stage I is controlled by the fact that the flow rate will be limited by the capacity of the enhanced permanent leachate transmission system

(EPLTS) permanent lift station pumps. A simplified calculation was performed for this stage where the volume of the IRCA is discharged at the maximum allowable flow rate of the EPLTS permanent lift station pumps (i.e., 200 gpm). The estimation of the drawdown time and flow rate for Stage II and Stage III are calculated using Darcy's Law. The flow rates for these stages do not exceed that of the EPLTS permanent lift station pumps; therefore, the drawdown time is independent of the permanent lift station pump capacity.

RESULTS

Phase V IRCAs and channels are designed for the 25-year, 24-hour storm event. The results are as follows:

IRCA Storage Capacity

- The calculated peak water elevation for the 25-year, 24-hour storm event allows more than 0.5 ft of freeboard from the minimum embankment crest elevation for the three cases analyzed.
- The results of the HydroCAD™ analysis of the IRCA storage capacity for the three stages analyzed are summarized in Table 8. The results show that the required IRCA storage capacity for each of the three stages analyzed for the staged closure are:

  Stage I = 195,400 ft^3

  Stage II = 113,000 ft^3

  Stage III = 51,200 ft^3

Channel Capacity

- Calculated freeboards corresponding to the peak flow rate for the inlet channels are 3.3 ft for Channel C and 3.4 ft for Channel E; therefore, the calculated freeboards exceed the minimum required freeboard of 0.5 ft. The locations for channels C and E are shown on Figure 1.
- Calculated peak flow velocities for the unlined channels are 7.01 ft/s for Channel C and 5.47 ft/s for Channel E. Appropriate erosion control practices should be used by the contractor to minimize the potential for erosion.
- The 36 in. diameter CMP culvert designed to convey the runoff from Channel C beneath the temporary access road and into the IRCA has a computed headwater elevation of 601.1 ft for Stage I and 600.7 ft for Stage II. Both values are less than the allowable headwater elevation of 603.0 ft; therefore, the culvert has adequate capacity to convey the runoff for both Stage I and Stage II. THIS CULVERT WILL NOT BE IN USE FOR STAGE III. DCD 01/30/02

Drawdown Time

- Considering only the flow into the LCS drainage corridor, Stage I would experience a rapid drawdown of the impacted runoff (i.e., less than one day) given the high gradient of the flow; however, the actual drawdown time for the IRCA in this case will be limited by the capacity of the EPLTS. The EPLTS permanent lift station pumps provide a maximum flow rate of 200 gpm, which results in a drawdown time of approximately 5 days for Stage I. ALLOWABLE DCP 01/30/02

- The estimated drawdown time for Stage II was calculated to be 7.7 days with a maximum flow rate of 149.4 gpm.

- The estimated drawdown time for Stage III was calculated to be 5.2 days with a maximum flow rate of 79.8 gpm.

CONCLUSIONS

The purpose of this calculation package was to demonstrate the adequacy of the design in providing the necessary impacted runoff storage capacity during staged closure of the final cells (i.e. Cells 6 and 7) in the OSDF. Additionally, IRCA inlet channel capacity and IRCA drawdown time were calculated to show that the design meets the required design criteria. The following conclusions are made based on the calculations performed in this package:

- The IRCAs for the three stages evaluated provide adequate storage volume to contain the runoff for the 25-year, 24-hour storm event.

- A design chart has been prepared (Figure 5) to provide requirements for sizing the IRCA based on the uncapped area of the OSDF remaining at any time during the staged closure.

- The temporary channels carrying the runoff into the IRCA provide adequate capacity; however, due to high flow ~~rates~~ VELOCITIES DCP 01/30/02, appropriate erosion control practices should be implemented by the contractor.

- The 36 in. diameter CMP culvert designed to convey the runoff from Channel C beneath the temporary access road and into the IRCA has adequate capacity for flow for Stage I and Stage II. THIS CULVERT WILL NOT BE USED FOR STAGE III. DCP 01/30/02

- Calculation results show that the design meets the applicable design criteria; therefore, the design is considered acceptable.

CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS

EXECUTIVE SUMMARY

TABLE OF CONTENTS

CALCULATION PROCEDURES

INTRODUCTION AND PURPOSE 7

DESIGN SCENARIOS 7

METHODS OF ANALYSIS 9

DESIGN CRITERIA 11

REFERENCES 12

DATA VERIFICATION

INTRODUCTION 13

INPUT PARAMETERS 13

REFERENCES 16

CALCULATIONS

INTRODUCTION 17

CALCULATIONS AND RESULTS 17

CONCLUSIONS 19

REFERENCES 20

TABLES, FIGURES AND ATTACHMENTS

TABLES 21

FIGURES 27

ATTACHMENT A-1 41

ATTACHMENT A-2 79

ATTACHMENT A-3 85

ATTACHMENT A-4 96

ATTACHMENT A-5 105

CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS

4664

CALCULATION PROCEDURES

INTRODUCTION AND PURPOSE

The purpose of this calculation package is to demonstrate the adequacy of the Cell 7 impacted runoff catchment area (IRCA) design in providing the necessary impacted runoff storage capacity during staged closure of the final cells (i.e. Cells 6 and 7) for the on-site disposal facility (OSDF). Furthermore, the package provides requirements for sizing the IRCA during the final closure construction through use of a design chart to interpolate for cases where the capped cell area is between that of the stages of closure evaluated in this package. Additionally, the flow capacity of channels discharging to the IRCA and the expected time for drawdown of impacted runoff within the IRCA are calculated to demonstrate that the design meets the required design criteria.

DESIGN SCENARIOS

The cases modeled in this package represent conditions expected to exist during the staged closure of the final two cells (i.e. Cells 6 and 7). Analyses are separated into three groups:

i.) evaluation of IRCA storage capacity,

ii.) evaluation of IRCA inlet channel capacity, and

iii.) evaluation of impacted runoff drawdown time.

It is important to note that the criteria defining non-impacted runoff has been established as runoff from cap areas over which two lifts of compacted clay cap have been placed as a part of the final cover system. Non-impacted runoff will be diverted to the OSDF surface water management system and thus will not enter the IRCA. The term "capped" will be used to describe areas of the landfill that have received at least two lifts of compacted clay cap and where runoff has been diverted to the OSDF surface water management system, and "uncapped" will refer to areas of the landfill that discharge runoff to the IRCA.

Three stages of IRCA filling are defined for evaluation. These stages and the runoff areas associated with these stages are shown in Figures 1 through 3. Figure 1 shows the IRCA geometry designed to contain the runoff for Stage I, when both Cells 6 and 7 are uncapped. This geometry provides a smaller IRCA plan area than those of Cells 1 through 6 as presented in an earlier calculation package (Section 7.2, Required Cell Leachate Storage); however, it will be shown to provide adequate volume. The geometry of Stage I was chosen to provide a remaining impacted material placement capacity of approximately 40,000 cy in Cell 7. Calculations showing the total impacted material, select impacted material and non-select impacted material

remaining to be placed for Stages I and II are presented in Attachment A-4. Figure 2 shows an IRCA geometry designed to contain the runoff for Stage II, which exists when Cell 6 is capped and Cell 7 remains uncapped. Figure 3 shows the case when Cell 6 is completely capped and the majority of Cell 7 is capped (i.e., Stage III). The IRCA in this case will consist of a "V-shaped" channel along the west and south perimeter of the uncapped portion of Cell 7. Figure 4 shows a cross-section of the V-shaped channel. The uncapped area for this stage consists of the uncapped area from the previous stage (i.e., the IRCA and 3.5:1 slopes from Stage II) plus a 67 ft wide strip at the perimeters of this area where a temporary construction access road will be constructed.

IRCA Storage Capacity

The required IRCA storage capacity will be calculated for the three stages as discussed above. A comparison will be made to the actual IRCA storage capacity to show that adequate storage is provided for the IRCA geometries shown in Figures 1 through 3.

Channel Capacity

Channel capacity calculations will be performed for the most critical channels (i.e., Channel C and Channel E) identified in Figure 1. These channels are the most downstream channels for the two groups of catchment areas contributing runoff to the IRCA; therefore, these channels will receive more flow than the upstream channels. The calculations will be performed for the geometry in Stage I, as this represents the stage with the largest uncapped area and consequently the greatest volume of runoff.

Additionally, the capacity of a culvert will be calculated using the computer program CulvertMaster®. The culvert is designed to convey the runoff being carried by Channel C beneath a temporary access road at the inlet to the IRCA. The culvert capacity calculation can be found in Attachment A-5.

Drawdown Time

The amount of time expected for impacted runoff to drain from the IRCA after the completion of the 25-year, 24-hour storm event into the Cell 7 LCS is referred to herein as the drawdown time. An estimation of the drawdown time is made for Stage I, Stage II and Stage III. three stages represented in this calculation package. The estimation for Stage I is controlled by the fact that the flow rate will be limited by the allowable capacity of the enhanced permanent leachate transmission system (EPLTS) permanent lift station pumps. A simplified calculation was performed for this stage where the volume of the IRCA is discharged at the maximum flowrate of the EPLTS permanent lift station pumps (i.e., 200 gpm). The estimation of the drawdown time and flow rate for Stage II and Stage III are calculated using Darcy's Law. The flow rates for these stages do not exceed that of the EPLTS permanent lift station pumps; therefore, the drawdown time is independent of the permanent lift station pump capacity.

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METHODS OF ANALYSIS

4664

IRCA Storage Capacity

Required IRCA storage capacity calculations are performed using methodologies presented in TR-20 [USDA-SCS, 1982] and TR-55 [USDA-SCS, 1986], as coded into the computer program HydroCAD™ [HydroCAD™, 1993]. HydroCAD™ breaks the units influencing the runoff into three types: (i) Subcatchments, (ii) Reaches, and (iii) Ponds. Different input parameters are required for each.

Certain input parameters are required for the overall analysis; these parameters include: (i) design storm event, and (ii) rainfall distribution.

The main input parameters needed for the Subcatchment subroutines include: (i) subcatchment runoff curve numbers, (ii) subcatchment areas, (iii) flow length and geometry, (iv) 2-year, 24-hour storm event, and (iv) Manning's coefficient.

The main input parameters required for the Reach subroutines include: (i) channel geometry, and (viii) Manning's coefficient.

The main input parameters for the Pond subroutines include: (i) pond areas at various elevations, and (ii) properties of the outflow structures.

The values for these parameters used herein are presented in the Data Verification Section of this calculation package. Further discussion of the significance of these input parameters can be found in Section 12.4 of the Revised Final Design Calculation Package On-Site Disposal Facility entitled "OSDF-Phase IV-Surface Water Management Design".

Once the required storage capacity has been calculated for the three stages shown in the closure drawing, requirements will be provided for sizing the IRCA during the final closure construction through use of a design chart (Figure 5) to interpolate for cases where the capped area is between that of the stages analyzed in this package.

Channel Capacity

The adequacy for the hydraulic capacity of the inlet channels is evaluated in terms of an available freeboard for peak flow rates. The available freeboard is calculated as the difference between the available flow depth in the channel and the calculated peak flow depth. The peak flow depth is calculated based on Manning's equation as coded into a computer spreadsheet. Manning's equation is as follows:

$$Q_{max} = \frac{1.49}{n} A R^{2/3} S_o^{1/2}$$

4664

Where: Q_{max} = peak flow rate (cfs)

n = Manning's roughness coefficient (dimensionless)

A = cross-sectional area of flow (ft^2)

R = hydraulic radius (ft) defined as R = A/P where P is wetted perimeter (ft)

S_o = longitudinal slope (rise/run)

Both A and P are functions of the peak flow depth; therefore, the equation can be used to solve for the peak flow depth.

The values for these parameters used herein are presented in the Data Verification Section of this calculation package. Peak flow rates for the Channel C and Channel E were used as inputs and were taken from the HydroCAD™ output performed for the IRCA storage capacity calculations. The minimum available flow depth is obtained directly from the Construction Drawings at the point that the channels flow into the IRCA.

As mentioned earlier, the capacity of the culvert at the inlet of Channel C will be calculated using the computer program CulvertMaster®. The detailed culvert capacity calculation and procedures can be found in Attachment A-5.

Drawdown Time

As mentioned earlier, the drawdown time is the amount of time expected for impacted runoff associated with a 25-year, 24-hour storm event to drain from the IRCA into the Cell 7 LCS. The drawdown time for the three stages will be calculated using Darcy's Law as shown below:

$$\Delta t = \frac{\Delta V}{kiA}$$

Where: Δt = incremental drawdown time (seconds)

ΔV = incremental volume change (ft^3)

k = permeability of the LCS drainage layer (ft/day)

i = hydraulic gradient (ft/ft)

A = area perpendicular to flow (ft^2)

A spreadsheet was used to perform the computations incrementally between various storage elevations of the IRCA. The volume between these incremental storage elevations will be established using HydroCAD™ output for the IRCAs in Stage II and III. A more detailed discussion of the calculation is presented in Attachment A-3.

The estimation for Stage I is controlled by the fact that the flow rate will be limited by the allowable capacity of the enhanced permanent leachate transmission system (EPLTS) permanent lift station pumps. A simplified calculation was performed for this stage where the volume of the IRCA is discharged at the maximum flowrate of the EPLTS permanent lift station pumps (i.e., 200 gpm). The equation below shows the formula used to calculate the drawdown time for Stage I:

ALLOWABLE

$$t = \frac{V}{Q}$$

Where: t = drawdown time (days)

V = required IRCA storage capacity for a given stage (ft^3)

Q = flow rate (gpm)

DESIGN CRITERIA

The calculations included in this package have been performed for the 25-year, 24-hour storm event as required by the Design Criteria Package (DCP) [GeoSyntec, 2000]. For the Fernald Environmental Management Project (FEMP) property, this event has a rainfall intensity of 4.7 in. [Parsons, 1995].

IRCA Storage Capacity

The storage capacity will be calculated for the IRCA for each of the three stages shown for the closure sequencing and shall provide at least 0.5 ft of freeboard from the minimum embankment crest elevation.

Channel Capacity

The calculated freeboard of the channels must equal or exceed the minimum required freeboard of 0.5 ft as stated in the DCP [GeoSyntec, 2000]. The velocity of the flow within each channel will be calculated based on the assumption that the channels will be unlined. This velocity will be checked against a maximum suggested flow rate of 2.0 ft/sec for unlined channels as established in Section 7.2. If the computed flow velocity is larger than this criterion, appropriate erosion control practices will be required in the field.

The culvert must contain adequate capacity to convey flow such that the computed headwater elevation is less than the allowable headwater elevation. The allowable headwater elevation shall contain a minimum freeboard of 0.5 ft as required for the channels.

Drawdown Time

The drawdown time will be calculated and the results will be reported.

REFERENCES

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CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS - 4664

DATA VERIFICATION

INTRODUCTION

This section presents the selection of parameters used to perform analyses in the Calculation Results section of this calculation package. Many of these parameters have been established in earlier calculation packages; however, some are unique to this package and will be discussed in detail herein. The input parameters will be discussed in terms of the three main types of calculations being performed as part of this package.

INPUT PARAMETERS

IRCA Storage Capacity

As discussed in the Calculation Procedures section, the computer program HydroCAD™ was used to compute the required IRCA storage capacity. HydroCAD™ breaks the units influencing the runoff into three types: (i) Subcatchments, (ii) Reaches, and (iii) Ponds. Different input parameters are required for each.

Some of the input parameters are required for the overall analysis; these parameters include: (i) design storm event and (ii) rainfall distribution. The design storm event in this analysis is the 25-year, 24-hour storm event, which has a rainfall intensity of 4.7 in. [Parsons, 1995]. The rainfall distribution for the Fernald Environmental Management Project (FEMP) property is Type II, and was established based on a chart that shows the rainfall distribution for different regions of the United States. The calculation package in Section 7.2 shows this chart.

The main input parameters needed for the Subcatchment subroutines include: (i) subcatchment runoff curve numbers, (ii) subcatchment areas, (iii) flow lengths and slopes, (iv) magnitude of precipitation from the 2-year, 24-hour storm event, and (iv) Manning's coefficient. The runoff curve number for the entire OSDF was set as CN = 91 as established in Section 7.2 for a newly graded area of the soil type found at the OSDF. The subcatchment areas, flow lengths, and slopes of the flow paths were established from the construction drawings. The 2-year, 24-hour storm event has a rainfall magnitude of 2.55 in. [Parsons, 1995]. Manning's coefficient of roughness was set at 0.011 for all of the subcatchment areas as established in Section 7.2 for a smooth rolled surface. Tables 1 through 3 show the remaining inputs used by HydroCAD™ for the Subcatchment calculations for Stages I, II and III.

The main input parameters required for the Reach subroutines include: (i) channel geometry and (ii) Manning's coefficient. The channel geometry (i.e., channel side slopes, longitudinal slope, channel length and inlet and outlet elevations) was established from the construction

-- 4664

drawings. Manning's coefficient was set as 0.018 as established in Section 7.2 for a straight unlined channel. Tables 4 and 5 show the geometric inputs used in HydroCAD™ for the Reach calculations for Stage I and Stage II. The HydroCAD™ analysis performed for Stage III is fairly simplistic and does not require the use of Reaches.

The main input parameters for the Pond subroutines include: (i) pond areas for given elevations and (ii) properties of the outflow structures. The pond areas were measured for various elevations using AutoCAD. Table 6 shows the areas measured and the corresponding elevations for the IRCA in each of the three stages of the staged closure. No outflow structures were modeled in this analysis, which provides a conservative estimate of the storage capacity, since no outflow was allowed.

Additional discussion of the selection of the parameters can be found in the notes below Tables 1 through 6. The results of the analyses will be presented in the Calculation Results section of this package.

Channel Capacity

As discussed in the Calculation Procedures section of this package, the peak depth of flow required to carry the maximum flow ~~capacity~~ was computed using Manning's equation and was compared to the available flow depth.

RATES OF PEAK DCP 01/30/02

The minimum available flow depth was obtained directly from the construction drawings at the point that the channels flow into the IRCA. The minimum available flow depths used in the analyses are 5 ft for both Channel C and Channel E.

The parameters needed to compute the channel capacity using Manning's equation are as follows: (i) the peak flow rate, Q_{max} (cfs); (ii) Manning's coefficient, n (dimensionless); (iii) the cross-sectional area of flow, A (ft^2); the hydraulic radius, R (ft); and the longitudinal slope of the channel, S_o (rise/run).

The peak flow rates for the Channel C and Channel E were obtained from the HydroCAD™ output performed for the IRCA storage capacity calculation for Stage I. The peak flow rates used in the analyses are 46.3 cfs for Channel C and 31.9 cfs for Channel E.

The value used for the Manning's coefficient is 0.018. This is the same value that was used for the channels in the HydroCAD™ analysis discussed above.

The parameters A, R, and S_o are functions of the geometry of the channel and are established directly from the construction drawings. The values of the geometrical input parameters used for this calculation are shown in Table 7. The results of the analyses are presented in the Calculation Results section of this package.

The input parameters needed for the culvert calculation will be presented in Attachment A-5 along with the detailed calculation.

Drawdown Time 4664

As discussed in the Calculation Procedures section of this package, the drawdown time for Stage III was computed using Darcy's Law for incremental IRCA elevations. The parameters needed for this analysis include: (i) incremental volume change, ΔV (ft); the permeability of the LCS drainage layer, k (ft/s); the hydraulic gradient, i (ft/ft); and the area perpendicular to flow, A (ft). The input values used for the drawdown analysis are shown below:

Where: ΔV = varies (corresponds to the storage elevation the IRCA according to HydroCAD™ output)

k = 0.0033 ft/s (minimum permeability of the LCS drainage layer as required by the specifications)

i = varies (related to the storage elevation of the IRCA)

A = 84 ft^2 for Stage I; varies for Stage III (the area will change depending on the storage elevation of the IRCA)

The values for incremental volume change, hydraulic gradient and area (for Stage III only) will vary depending on the storage elevation of the IRCA and can be found in the spreadsheet output in Attachment A-3.

The simplified calculation performed to provide an estimate of the drawdown time controlled by the allowable capacity of the EPLTS permanent lift station pumps for Stage I will require the following input parameters: (i) volume of required IRCA storage capacity, V (ft^3); and (ii) the flow rate of the leachate, Q (gpm). The volume of required IRCA storage capacity was computed as a part of the IRCA storage capacity calculations in this calculation package. The volume of required IRCA storage capacity is approximately 195,400 ft^3 for Stage I. The flow rate of the leachate is that of the EPLTS permanent lift station pumps, which has been established as 200 gpm.

REFERENCES

- 4664

Parsons, *2,000-Year Flood and Probable Maximum Flood Sitewide Flood Plain Determination*, CERCLA/RCRA Unit 2, Project Order 148, Fernald Environmental Management Project, Rev. A, Fairfield, OH, August 1995.

CELL 7 IMPACTED RUNOFF CATCHMENT AREA REQUIREMENTS -- 4664

CALCULATIONS

INTRODUCTION

This section presents calculations and results based on procedures and data presented in the Calculation Procedures and Data Verification sections of this calculation package. The calculations and results will be discussed for the three types of analyses performed as part of this package.

CALCULATIONS AND RESULTS

IRCA Storage Capacity

The IRCA is considered adequate if it complies with the design criteria used to evaluate the IRCAs for Cells 1 through 6 in Section 7.2, which requires the IRCA to provide storage capacity to handle the 25-year, 24-hour storm event with 0.5 ft of freeboard. Hydrologic and basin routing analyses are performed using methodologies presented in TR-20 [USDA-SCS, 1982] and TR-55 [USDA-SCS, 1986], as coded into the computer program HydroCAD™. The output from HydroCAD™ for the three stages of the staged closure can be found in Attachment A-1.

This calculation provides requirements for sizing the IRCA during the final closure construction through use of a design chart (Figure 5) to interpolate for cases where the capped area is between that of the stages analyzed in this package.

The results of the IRCA Storage Capacity calculations are as follows:

- The calculated peak water elevation for the 25-year, 24-hour storm event allows more than 0.5 ft of freeboard from the minimum embankment crest elevation for the three cases analyzed.

- The results HydroCAD™ analysis of the IRCA storage capacity for the three stages analyzed are summarized in Table 8. The results show that the required IRCA storage capacity for each of the three stages analyzed for the staged closure are as follows:

  Stage I = 195,400 ft^3

  Stage II = 113,000 ft^3

  Stage III = 51,200 ft^3

Additionally, estimates of the volume of impacted material were made for Stage I and Stage II. Calculations showing the total impacted material, select impacted material and non-select

impacted material remaining to be placed for Stages I and II are presented in Attachment A-4. The results of these estimates are included in Table 8.

Channel Capacity

The channels are designed to safely convey peak flow rates from the 25-year, 24-hour storm event. Hydraulic analyses for channels are performed using Manning's equation as coded into a computer spreadsheet. Attachment A-2 shows the detailed calculations for the channels. The results for the channel capacity are as follows:

- Calculated freeboards for channels are 3.3 ft for Channel C and 3.4 ft for Channel E; therefore, the calculated freeboards exceed the minimum required freeboard of 0.5 ft.
- Calculated peak flow velocities for the unlined channels are 7.01 ft/s for Channel C and 5.47 ft/s for Channel E. Appropriate erosion control practices should be used by the contractor.

The 36 in. diameter CMP culvert designed to convey the runoff from Channel C beneath the temporary access road and into the IRCA has a computed headwater elevation of 601.1 ft for Stage I and 600.7 ft for Stage II. Both values are less than the allowable headwater elevation of 603.0 ft; therefore, the culvert has adequate capacity to convey the runoff for both Stage I and Stage II.

Drawdown Time

The amount of time expected for impacted runoff to drain from the IRCA after the completion of the 25-year, 24-hour storm event into the Cell 7 LCS is referred to herein as the drawdown time. An estimation of the drawdown time is made for the three stages represented in this calculation package.

The detailed calculation of the drawdown of Stages II and III and the simplified calculation of the drawdown for Stage I are included in Attachment A-3. The results of the drawdown calculation are as follows:

- Considering only the flow into the LCS drainage corridor, Stage I would experience a rapid drawdown of the impacted runoff (i.e., less than one day) given the high gradient of the flow; however, the actual drawdown time for the IRCA in this case will be limited by the capacity of the EPLTS. The EPLTS permanent lift station pumps provide a maximum flow rate of 200 gpm, which results in a drawdown time of approximately 5 days for Stage I.

  allowable per oil/gloc

- The estimated drawdown time for Stage II was calculated to be 7.7 days with a maximum flow rate of 149.4 gpm.

4664

- The estimated drawdown time for Stage III was calculated to be 5.2 days with a maximum flow rate of 79.8 gpm.

CONCLUSIONS

The purpose of this calculation package is to demonstrate the adequacy of the design in providing the necessary impacted runoff storage capacity during staged closure of the final cells (i.e. Cells 6 and 7) in the OSDF. Additionally, IRCA inlet channel capacity and IRCA drawdown time are calculated to show that the design meets the required design criteria. The following conclusions are made based on the calculations performed in this package:

- The IRCAs for the three stages provide adequate storage volume to contain the runoff for the 25-year, 24-hour storm event.
- A design chart has been created (Figure 5) to offer guidance in sizing the IRCA based on the uncapped area of the OSDF remaining at any time during the staged closure.
- The temporary channels carrying the runoff into the IRCA provide adequate capacity; however, due to high flow ~~rates~~ velocities, appropriate erosion control practices should be used by the contractor. DCP 01/30/02
- The 36 in. diameter CMP culvert designed to convey the runoff from Channel C beneath the temporary access road and into the IRCA has adequate capacity for flow for Stage I and Stage II. THIS CULVERT WILL NOT BE USED FOR STAGE III. DCP 01/30/02
- Calculation results show that the design meets the applicable design criteria; therefore, the design is considered acceptable.

REFERENCES

- 4664

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U.S. Department of Agriculture (USDA-SCS). *Technical Release Number 20 (TR-20),* Soil Conservation Service, 1982.

Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAB Date: 24 Jan 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

Table 1 - Input parameters describing the geometry used in the HydroCAD Subcatchment calculations for Stage I

		Sheet Flow 1[1]		Sheet Flow 2[1]		Shallow Concentrated Flow 1		Shallow Concentrated Flow 2		Channel Flow				
Subcatchment Label	Area (ft^2)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Long. Slope (ft/ft)	Flow Depth (ft)	Left Slope (H:V)	Right Slope (H:V)
A	3.07	89	0.05	11	0.1	47	0.1	163	0.167	400	0.0075	1.5	1.5:1	3:1
B	2.59	89	0.05	11	0.1	47	0.1	163	0.167	498	0.006	1.5	1.5:1	3:1
C	2.21	98	0.05	2	0.1	59	0.1	191	0.167	420	0.01	1.5	1.5:1	3:1
D	3.47	89	0.05	11	0.1	47	0.1	205	0.167	400	0.0075	1.5	3:1	1.5:1
E	1.33	89	0.05	11	0.1	47	0.1	205	0.167	154	0.0065	1.5	3:1	1.5:1
F	0.98	88	0.05	12	0.1	17	0.1	143	0.25	-	-	-	-	-
Pond	1.44	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: (1) Sheet Flow is restricted to a conservative value of 100ft.

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4664

Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAT Date: 24 Jan 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GO1342 Task No.: 17.4

Table 2 - Input parameters describing the geometry used in the HydroCAD Subcatchment calculations for Stage II

		Sheet Flow 1[1]		Sheet Flow 2[1]		Shallow Concentrated Flow 1		Shallow Concentrated Flow 2		Channel Flow				
Subcatchment Label	Area (ft^2)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Long. Slope (ft/ft)	Flow Depth (ft)	Left Slope (H:V)	Right Slope (H:V)
B	2.59	89	0.05	11	0.1	47	0.1	163	0.167	498	0.006	1.5	1.5:1	3:1
C	2.21	98	0.05	2	0.1	59	0.1	191	0.167	420	0.01	1.5	1.5:1	3:1
E	1.33	89	0.05	11	0.1	47	0.1	205	0.167	154	0.0065	1.5	3:1	1.5:1
F	0.98	88	0.05	12	0.1	17	0.1	143	0.25	-	-	-	-	-
Pond	1.44	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: (1) Sheet Flow is restricted to a conservative value of 100ft.

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Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAO Date: 24 Jan 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

Table 3 - Input parameters describing the geometry used in the HydroCAD Subcatchment calculations for Stage III

		Sheet Flow 1[1]		Sheet Flow 2[1]		Shallow Concentrated Flow 1		Shallow Concentrated Flow 2		Channel Flow				
Subcatchment Label	Area (ft^2)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Slope (ft/ft)	Flow Length (ft)	Long. Slope (ft/ft)	Flow Depth (ft)	Left Slope (H:V)	Right Slope (H:V)
F	3.246	89	0.05	11	0.1	47	0.1	202	0.167	-	-	-	-	-
Pond	0.636	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: (1) Sheet Flow is restricted to a conservative value of 100ft.

CDC 01/23/2002 23 of 115

4664

000034

Table 4 - Input parameters describing the geometry used in HydroCAD Reach calculations for Stage I

Channel Label	Flow Length (ft)	Longitudinal Slope (ft/ft)	Bottom Width (ft)	Flow Depth (ft)	Inlet Elevation (ft)	Outlet Elevation (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)
B	498	0.0065	0	6	604.2	601.2	1.5:1	3:1
C	420	0.01	0	6	601.2	596.9	1.5:1	3:1
E	154	0.006	0	6	597.2	596.2	3:1	1.5:1

Notes:
(1) Dummy nodes were used to collect the flow at each entry point into the IRCA. Dummy nodes do not have any properties; therefore, they are not included in the table above.
(2) Channels A and D were included as a part of their respective subcatchment and were not modelled as reaches.

Table 5 - Input parameters describing the geometry used in HydroCAD Reach calculations for Stage II

Channel Label	Flow Length (ft)	Longitudinal Slope (ft/ft)	Bottom Width (ft)	Flow Depth (ft)	Inlet Elevation (ft)	Outlet Elevation (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)
C	420	0.01	0	6	601.2	596.9	1.5:1	3:1

Notes:
(1) Dummy nodes were used to collect the flow at each entry point into the IRCA. Dummy nodes do not have any properties; therefore, they are not included in the table above.
(2) Channels E and B were included as a part of their respective subcatchment and were not modelled as reaches.
(3) Channels A and D do not contribute to the impacted runoff for Stage II and were not included in the calculation.

Table 6 - Areas of the IRCA taken at various elevations for all three stages of the closure sequence used in HydroCAD calculations

Stage I		Stage II		Stage III	
Elevation (ft)	Area (ft^2)	Elevation (ft)	Area (ft^2)	Elevation (ft)	Area (ft^2)
588	3,412	588	513	595	80
589	7,493	589	1,325	596	1,442
590	13,404	595	7,166	597	4,065
592	29,304	596	9,718	598	7,390
594	38,667	598	18,724	599	10,779
596	45,187	600	35,881	600	14,097
598	50,194	602	55,983	601	17,904
600	55,184	603	62,756	602	22,377
603	62,756			603	27,559

Notes: (1) The areas were computed using AutoCAD.
(2) HydroCAD uses the areas and elevations to establish the IRCA storage volume.

Table 7 - Input parameters describing the geometry of the channels used to solve for the peak depth of flow within the channels

Channel Label	Longitudinal Slope (ft)	Bottom Width (ft)	Left Side Slope (H:V)	Right Side Slope (H:V)
C	0.01	0	1.5:1	3.0:1
E	0.0067	0	3.0:1	1.5:1

Notes: (1) These inputs will be used to solve for the peak depth of flow, h using an Excel spreadsheet.
(2) Values for the Area of Flow, A and the Wetted Perimeter, P are functions of the above parameters and the peak depth of flow, h.

Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAJ Date: 24 Jan 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

Table 8 - Results of IRCA Analysis

Stage	Uncapped Area (acres)	Volume of IRCA Required (ft^3)	Volume Provided By Design (ft^3)	IRCA Containment Elevation[1] (ft)	Volume of Select Impacted Material Remaining to be Placed[3] (cy)	Volume of Non-Select Impacted Material Remaining to be Placed[3] (cy)	Total Volume of Impacted Material Remaining to be Placed[3] (cy)
I	15.09	195,400	588,500	603.0	14,426	26,575	41,001
II	8.55	113,000	269,200	603.0	9,825	19,179	29,004
III	3.88	51,200	58,800[2] DCP 24 JAN 01	603.0[2]	0	0	0

Notes:
(1) The crest of the IRCA for each Stage is El. 604 ft; therefore, the reported elevation corresponds to 1 ft of freeboard.
(2) Corresponds to the volume ~~at the top~~ ABOVE of two lifts of compacted clay. DCP 01/30/02
(3) Volumes of Impacted Material are estimates for information purposes only, the contractor should perform a detailed quantity calculation should exact quantities be required. The computations can be found in Attachment A-4.

CDC 01/23/2002 26 of 115

-- 4664

000037

Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAS Date: 24 Jan 0

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

4664

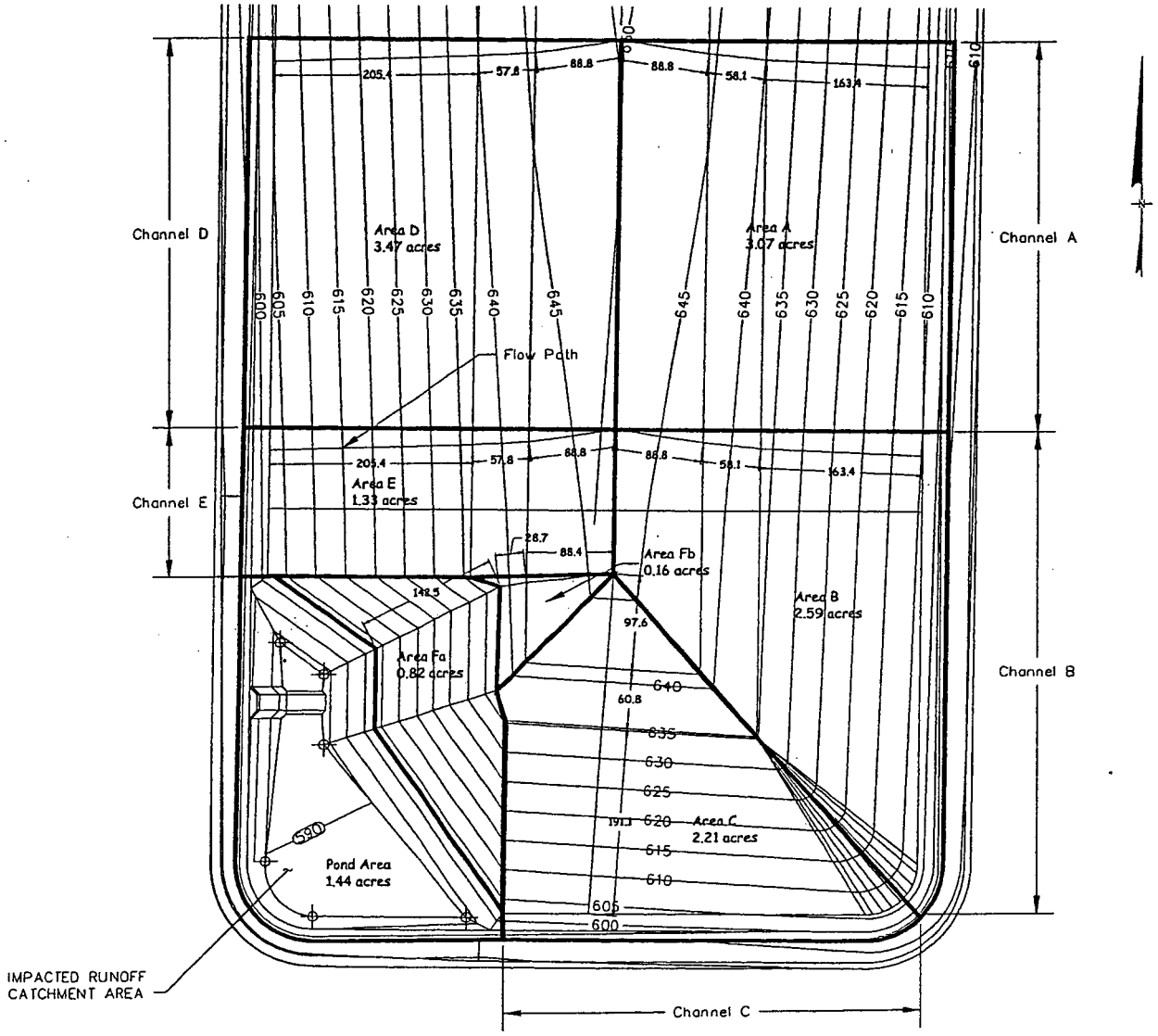

Figure 1 – Stage I: Required IRCA for Cells 6 and 7 uncapped (Not to Scale)

- 4664

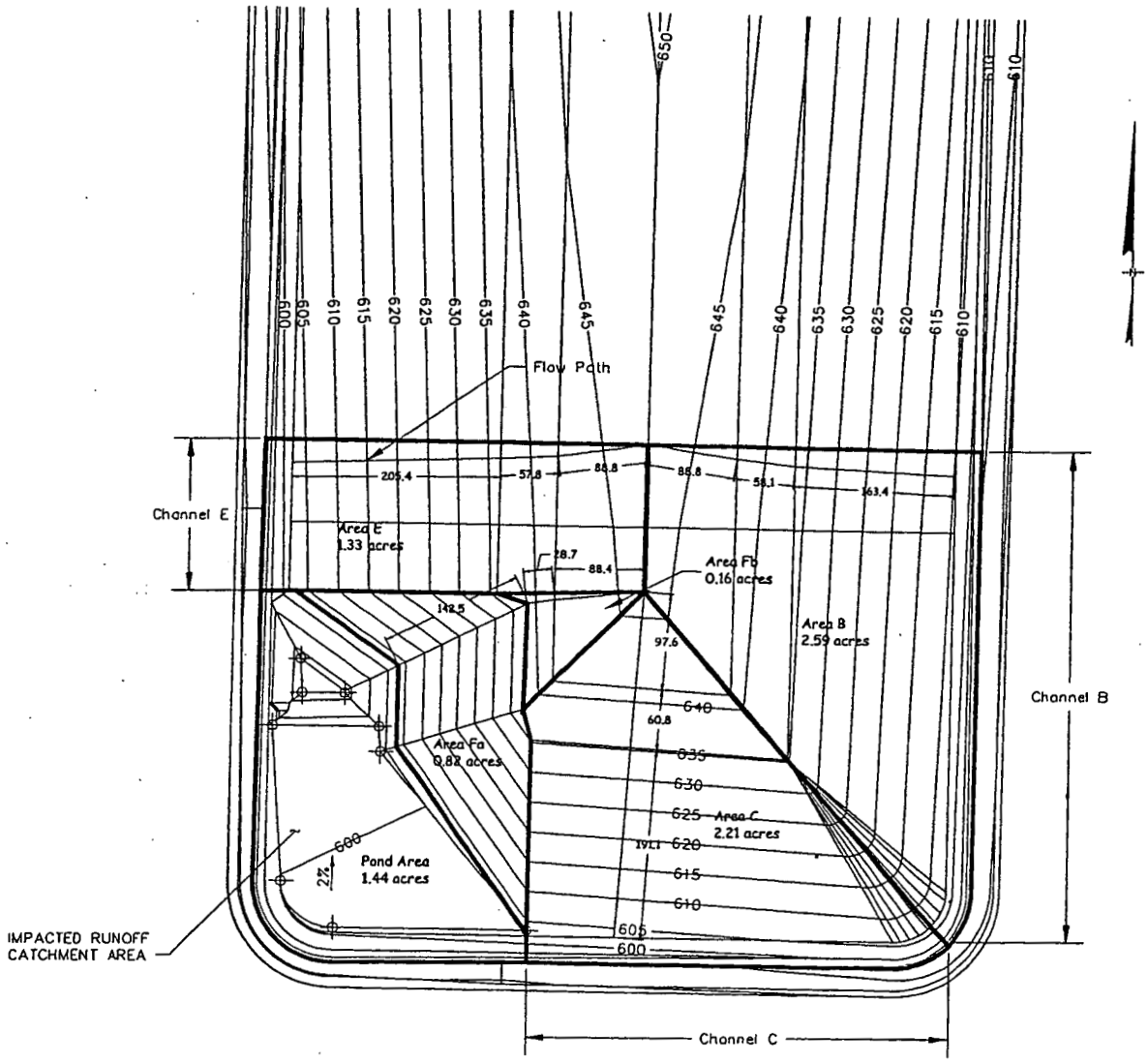

Figure 2 – Stage II: Cell 6 closed and Cell 7 uncapped (Not to Scale)

Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: AMATO Date: 24 Jan 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GO1342 Task No.: 17.4

4664

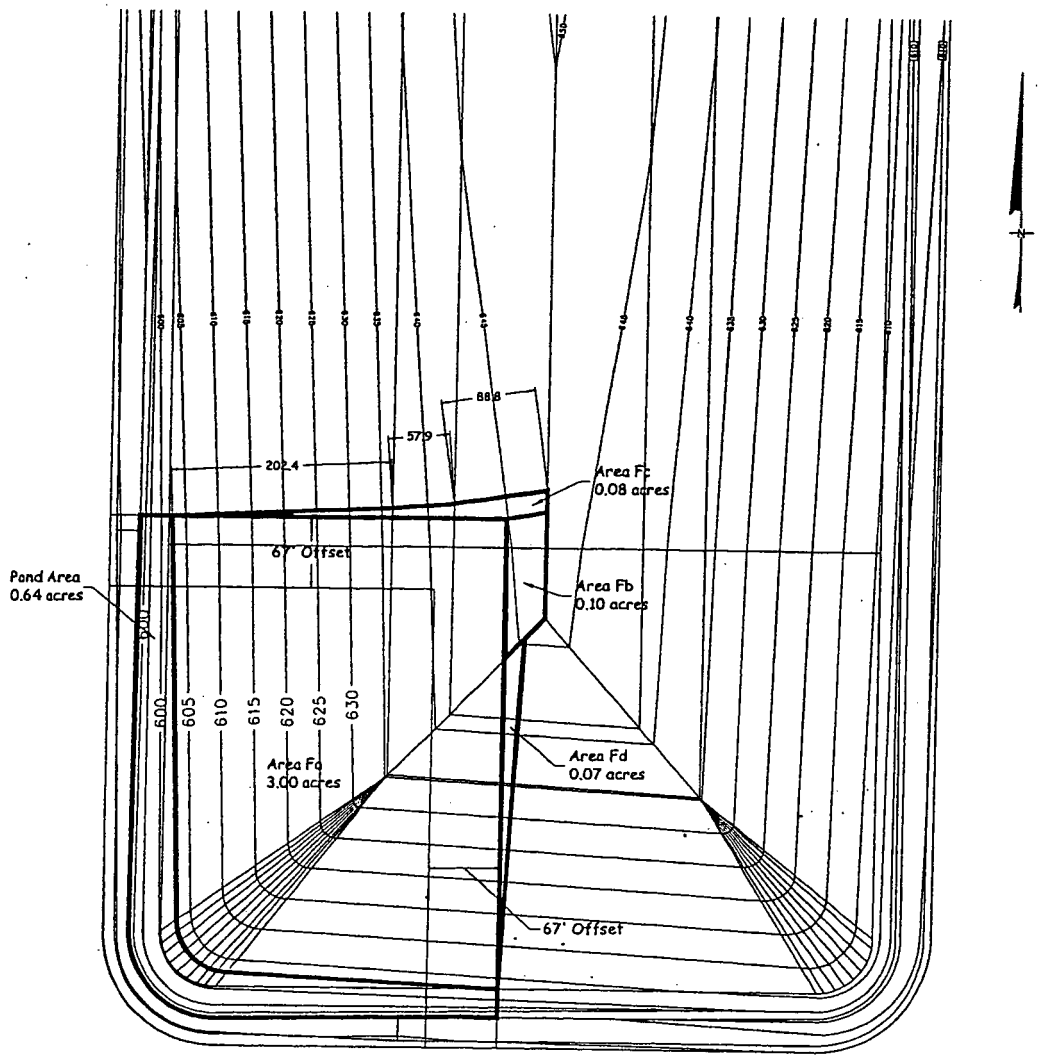

Figure 3 – Stage III: Cell 6 closed and Cell 7 substantially closed (Not to Scale)

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Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

- 4664

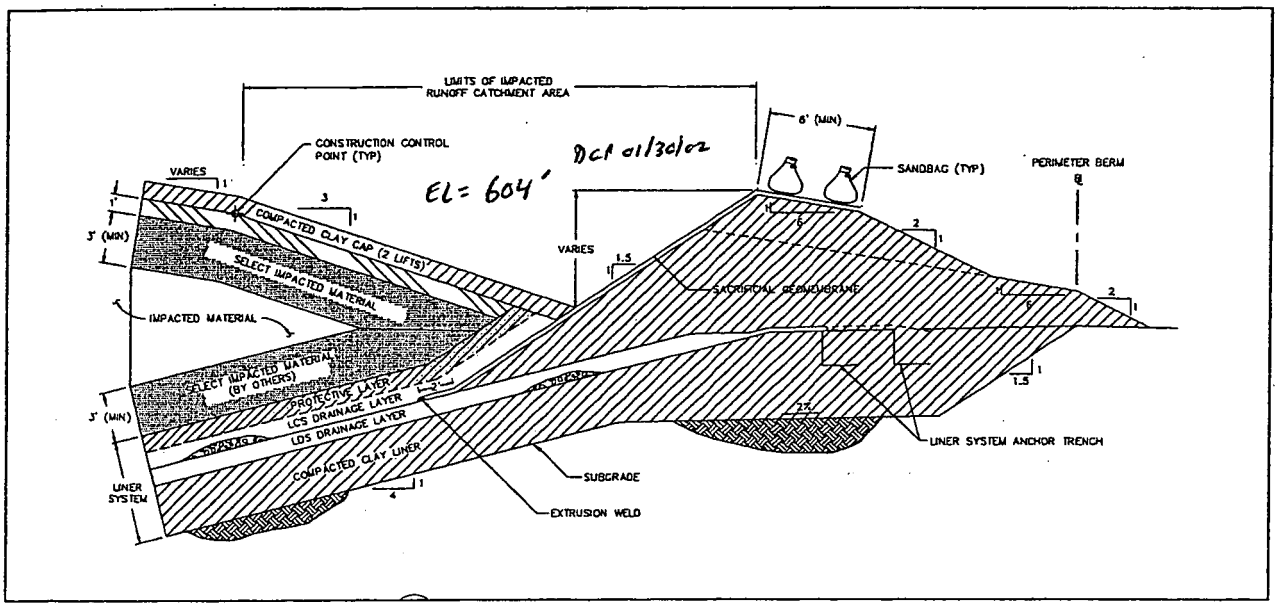
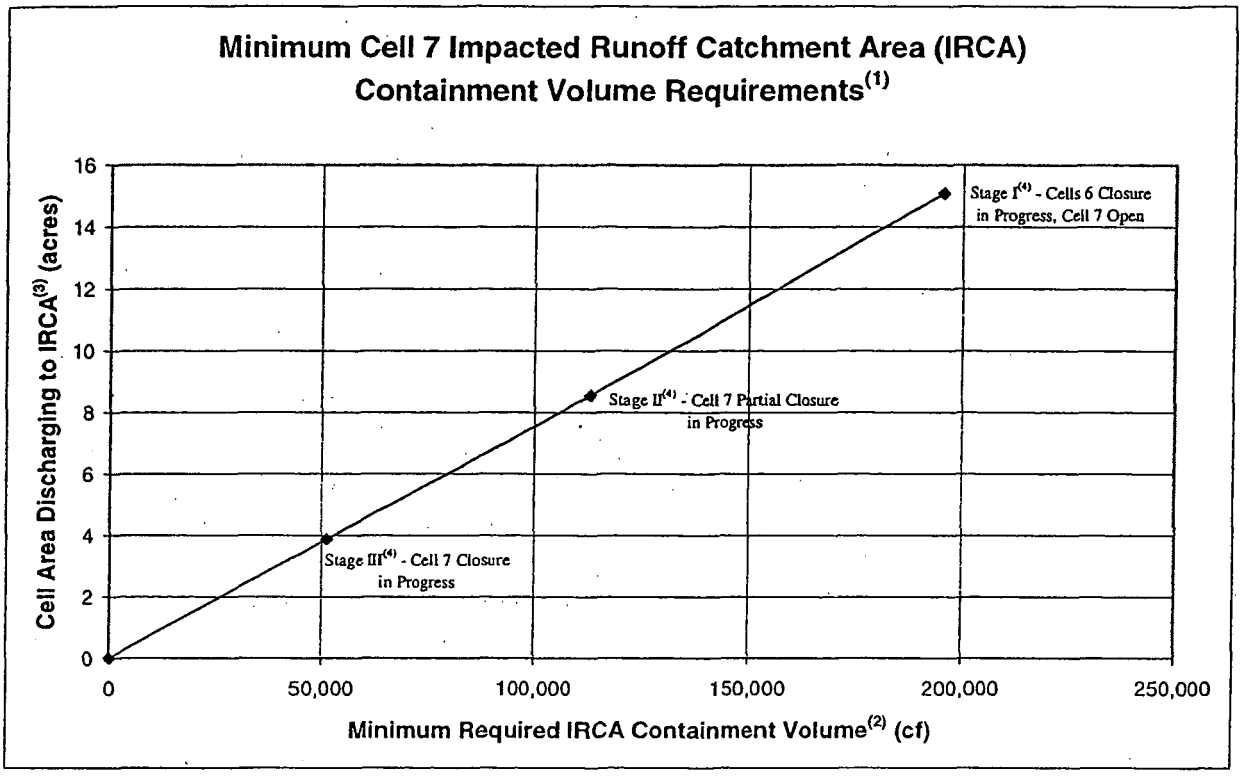


Figure 4 – Cross-Section of "V-Shaped" channel (Not to Scale)



Notes: (1) Minimum required IRCA containment volumes correspond to estimated runoff from cell area discharging to IRCA as computed using HydroCAD.
(2) Minimum required IRCA containment volumes do not include freeboard.
(3) Cell area discharging to IRCA includes area of IRCA.
(4) Stages shown are as indicated on Construction Drawings.

Figure 5 – Design Chart for Sizing IRCA

- 4664

ATTACHMENT A-1

IRCA CAPACITY CALCULATIONS
HYDROCAD OUTPUT

Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAO Date: 24 Jan 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

- 4664

STAGE I CALCULATION

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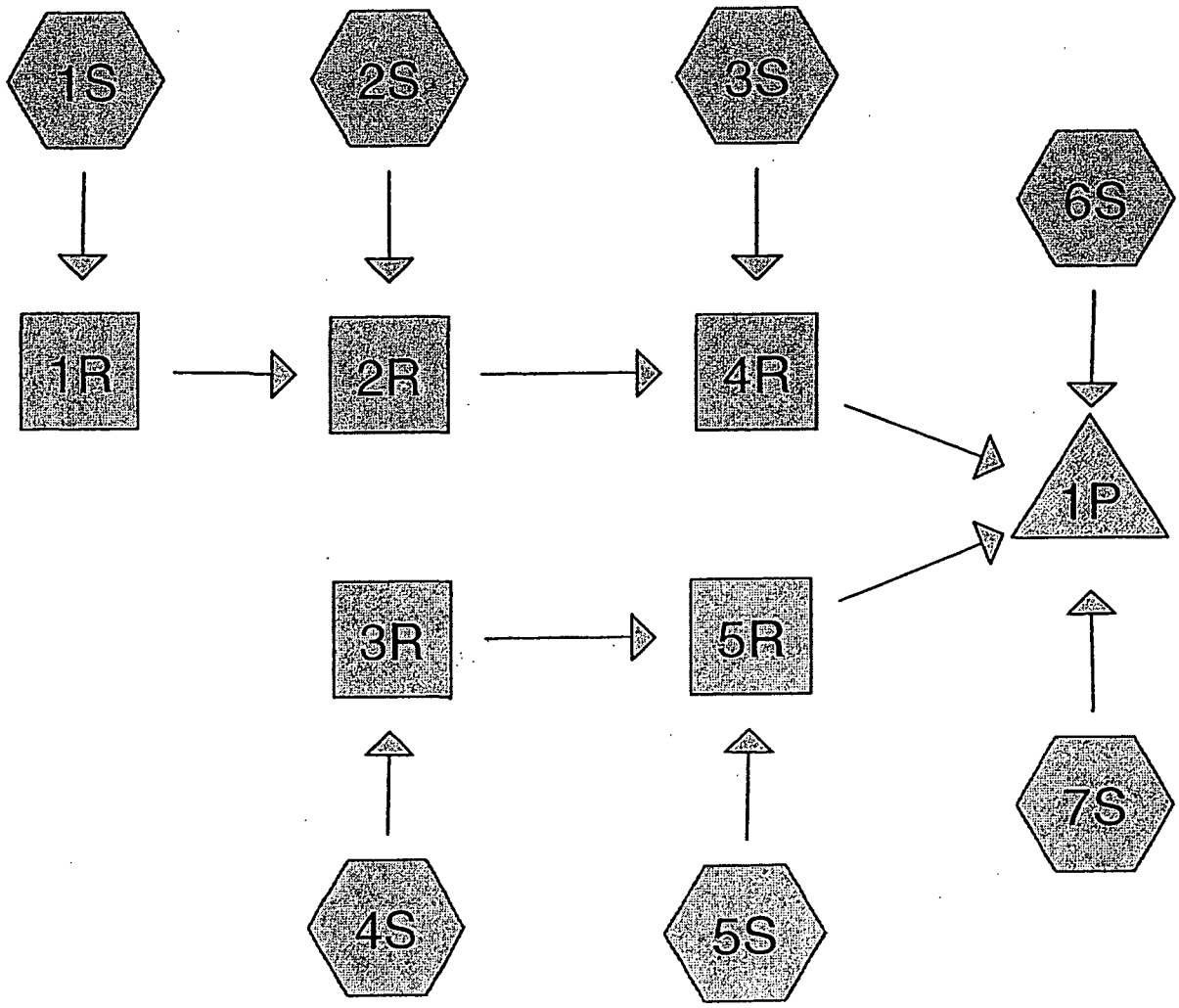

Drainage Diagram for Fernald Cells 6-7 Stage I (Task 17.4)
Prepared by GeoSyntec Consultants 1/22/2002
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MAO 24 Jan 02
CDC 01/23/2002 44 of 115

-- 4664

Time span=0.00-20.00 hrs, dt=0.01 hrs, 2001 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=4.70"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Area A
Tc=2.8 min CN=91 Area=3.070 ac Runoff= 20.84 cfs 0.888 af

Subcatchment 2S: Area B
Tc=3.3 min CN=91 Area=2.590 ac Runoff= 17.31 cfs 0.749 af

Subcatchment 3S: Area C
Tc=2.7 min CN=91 Area=2.210 ac Runoff= 15.05 cfs 0.639 af

Subcatchment 4S: Area D
Tc=2.9 min CN=91 Area=3.470 ac Runoff= 23.48 cfs 1.004 af

Subcatchment 5S: Area E
Tc=2.2 min CN=91 Area=1.330 ac Runoff= 9.20 cfs 0.385 af

Subcatchment 6S: Area Fa and Fb
Tc=1.3 min CN=91 Area=0.980 ac Runoff= 6.96 cfs 0.284 af

Subcatchment 7S: Pond Area
Tc=0.0 min CN=100 Area=1.440 ac Runoff= 11.51 cfs 0.537 af

Reach 1R: Channel B Inflow= 20.84 cfs 0.888 af
Length= 498.0' Max Vel= 4.7 fps Capacity= 1,011.08 cfs Outflow= 19.89 cfs 0.886 af

Reach 2R: Channel C Inflow= 35.36 cfs 1.635 af
Length= 420.0' Max Vel= 6.6 fps Capacity= 1,318.10 cfs Outflow= 34.84 cfs 1.633 af

Reach 3R: Channel E Inflow= 23.48 cfs 1.004 af
Length= 154.0' Max Vel= 5.0 fps Capacity= 1,049.73 cfs Outflow= 23.30 cfs 1.003 af

Reach 4R: Dummy Reach Inflow= 46.30 cfs 2.272 af
Outflow= 46.30 cfs 2.272 af

Reach 5R: Dummy Reach Inflow= 31.90 cfs 1.388 af
Outflow= 31.90 cfs 1.388 af

Pond 1P: Detention Pond Peak Storage= 4.480 af Inflow= 90.33 cfs 4.481 af
Outflow= 0.00 cfs 0.000 af

Runoff Area = 15.090 ac Volume = 4.485 af Average Depth = 3.57"

≈ 195,400 cf

NHO 2 Jan 02
CDL 01/23/2002 45 of 115

- 4664

Subcatchment 1S: Area A

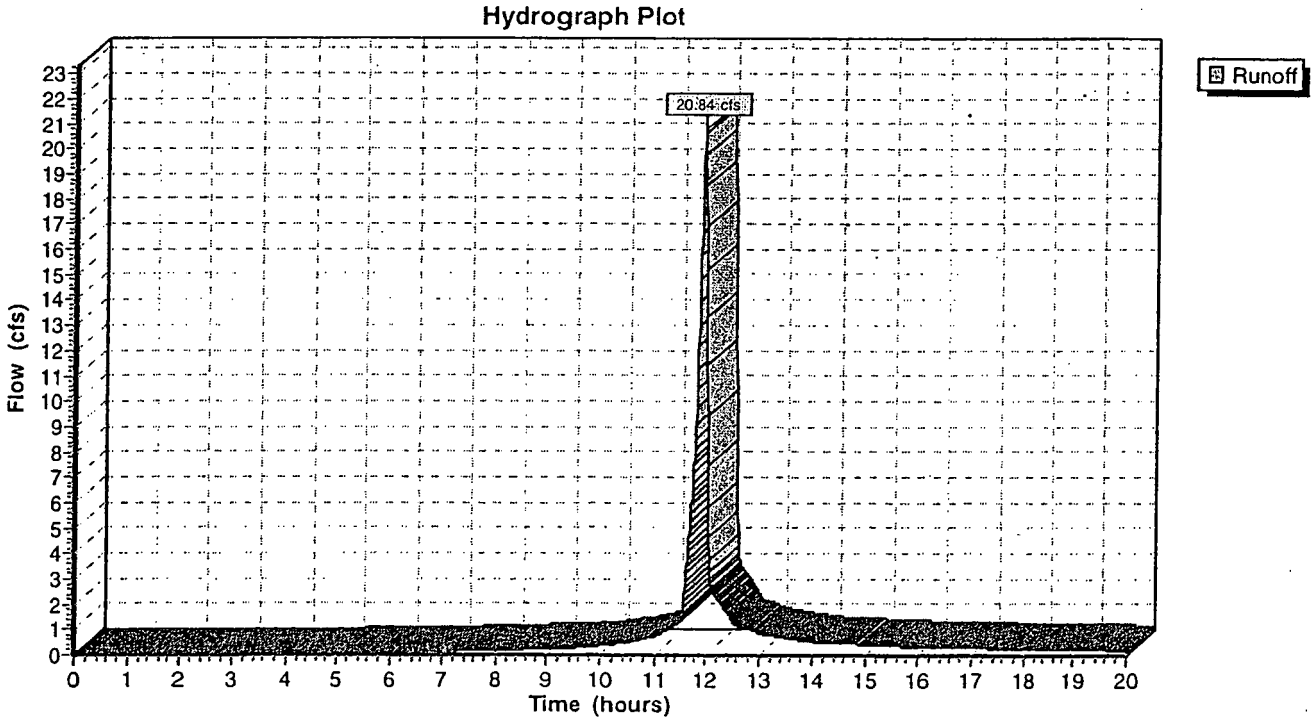
Runoff = 20.84 cfs @ 11.93 hrs, Volume= 0.888 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
3.070	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment A-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment A-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment A-3** Unpaved Kv= 16.1 fps
0.4	163	0.1670	6.6		**Shallow Concentrated Flow, Segment A-4** Unpaved Kv= 16.1 fps
1.2	400	0.0075	5.5	27.98	**Trap/Vee/Rect Channel Flow, Channel A** Bot.W=0.00' D=1.50' Z= 1.5 & 3.0 '/' n= 0.018
2.8	710	Total			

Subcatchment 1S: Area A



Subcatchment 2S: Area B

4664

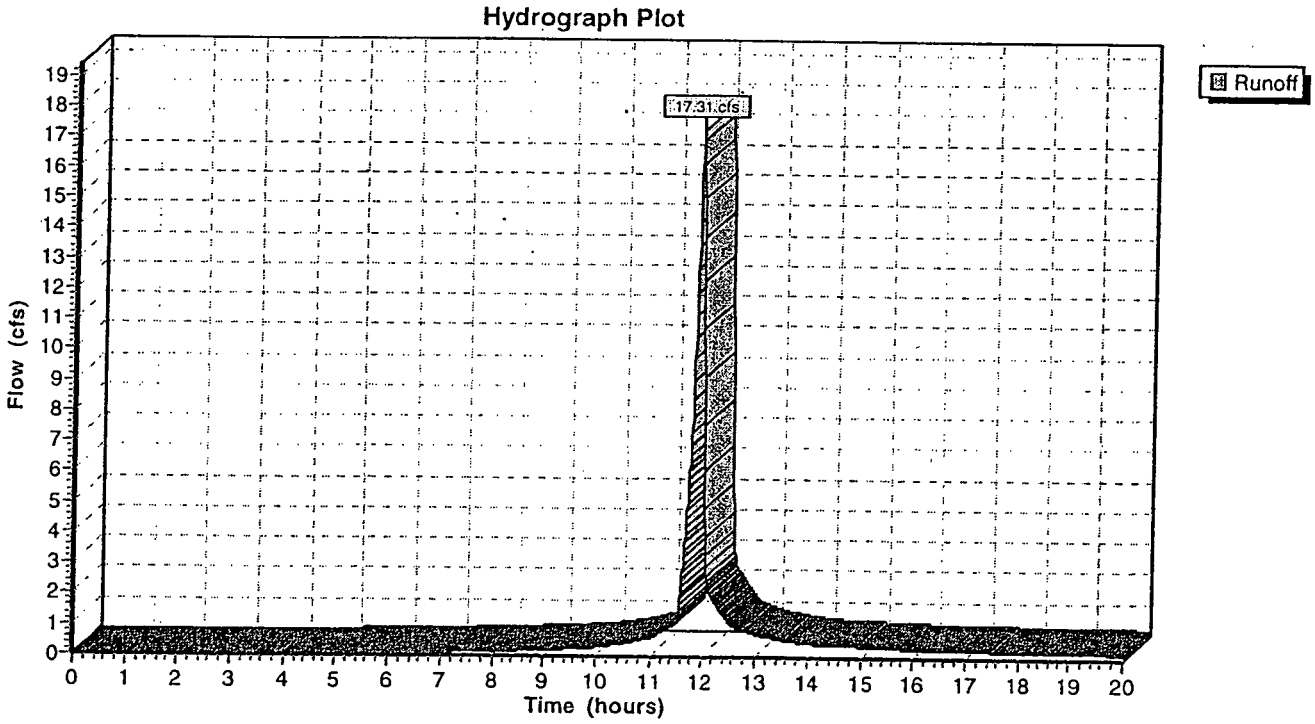
Runoff = 17.31 cfs @ 11.94 hrs, Volume= 0.749 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.590	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment B-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment B-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment B-3** Unpaved Kv= 16.1 fps
0.4	163	0.1670	6.6		**Shallow Concentrated Flow, Segment B-4** Unpaved Kv= 16.1 fps
1.7	498	0.0060	4.9	25.03	**Trap/Vee/Rect Channel Flow, Channel B** Bot.W=0.00' D=1.50' Z= 1.5 & 3.0 '/' n= 0.018
3.3	808	Total			

Subcatchment 2S: Area B



Subcatchment 3S: Area C

- 4664

Runoff = 15.05 cfs @ 11.93 hrs, Volume= 0.639 af

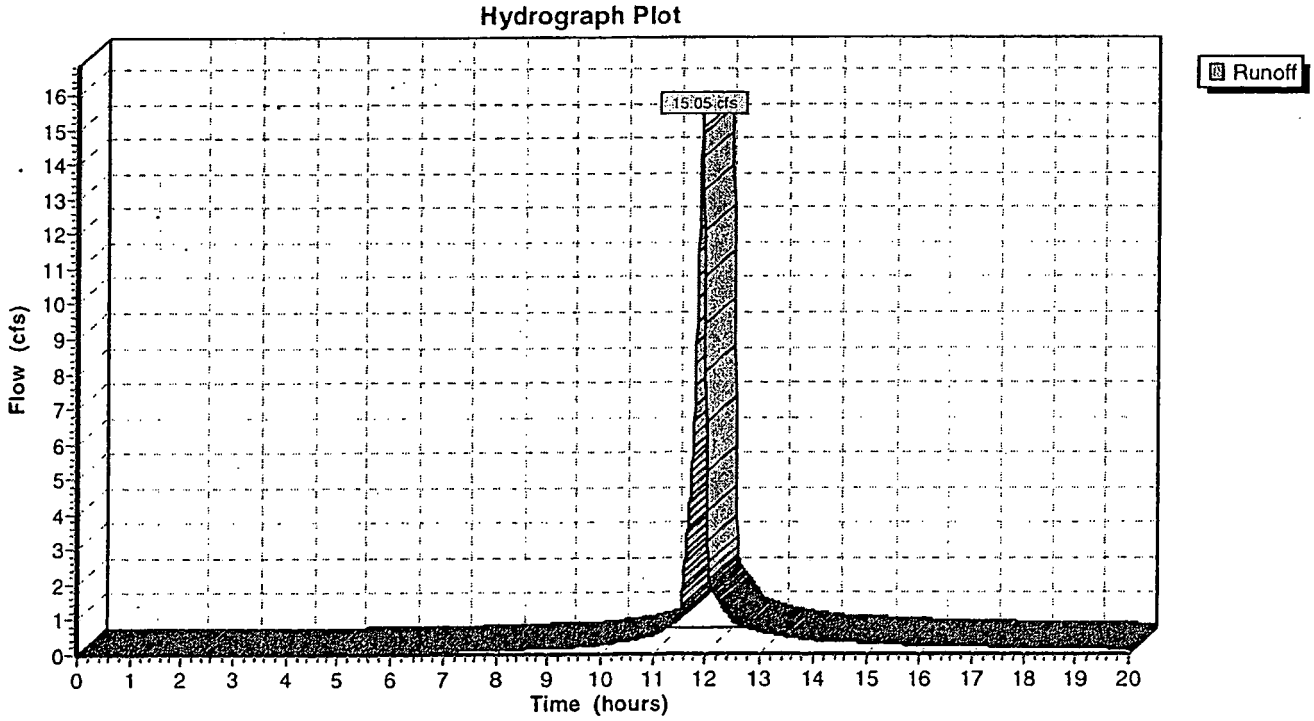
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.210	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	98	0.0500	1.8		**Sheet Flow, Segment C-1** Smooth surfaces n= 0.011 P2= 2.55"
0.0	2	0.1000	1.1		**Sheet Flow, Segment C-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	59	0.1000	5.1		**Shallow Concentrated Flow, Area C-3** Unpaved Kv= 16.1 fps
0.5	191	0.1670	6.6		**Shallow Concentrated Flow, Area C-4** Unpaved Kv= 16.1 fps
1.1	420	0.0100	6.4	32.31	**Trap/Vee/Rect Channel Flow, Channel C** Bot.W=0.00' D=1.50' Z= 1.5 & 3.0 '/' n= 0.018
2.7	770	Total			

Subcatchment 3S: Area C

Hydrograph Plot



Subcatchment 4S: Area D

- 4664

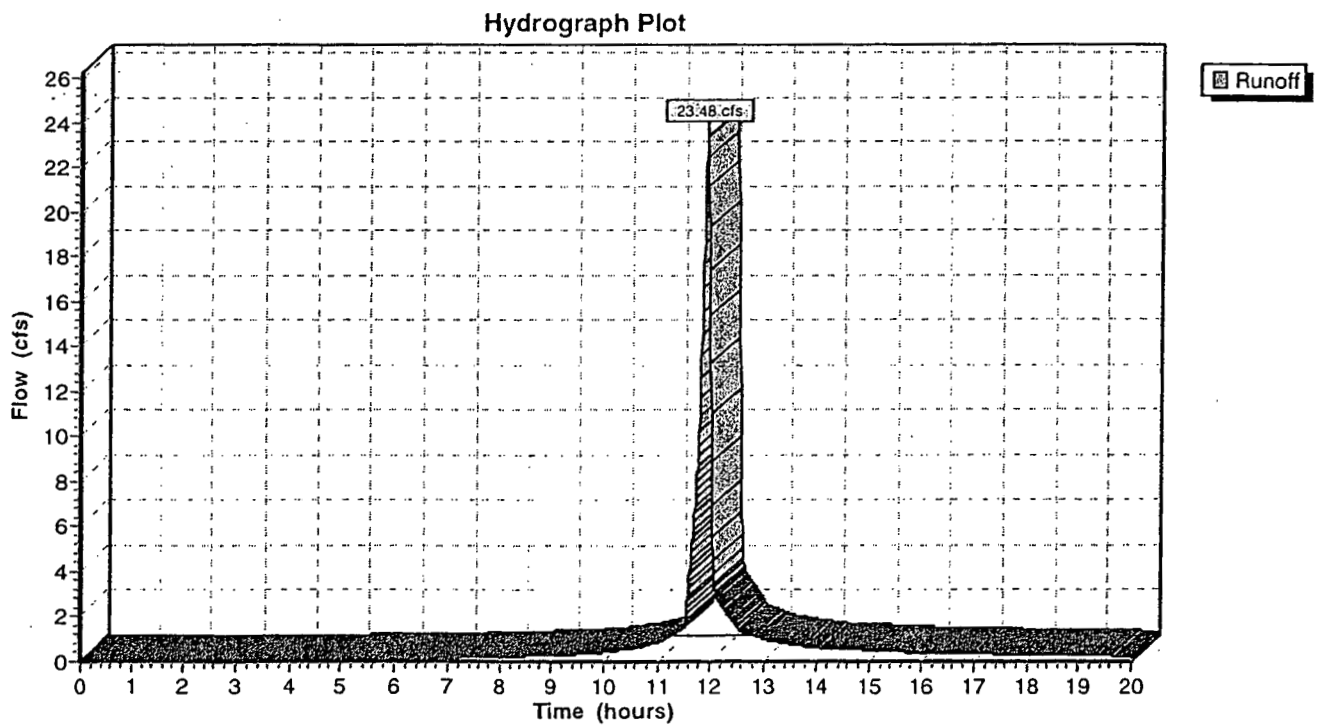
Runoff = 23.48 cfs @ 11.93 hrs, Volume= 1.004 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
3.470	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment D-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment D-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment D-3** Unpaved Kv= 16.1 fps
0.5	205	0.1670	6.6		**Shallow Concentrated Flow, Segment D-4** Unpaved Kv= 16.1 fps
1.2	400	0.0075	5.5	27.98	**Trap/Vee/Rect Channel Flow, Channel D** Bot.W=0.00' D=1.50' Z= 3.0 & 1.5 '/' n= 0.018
2.9	752	Total			

Subcatchment 4S: Area D



Subcatchment 5S: Area E

- 4664

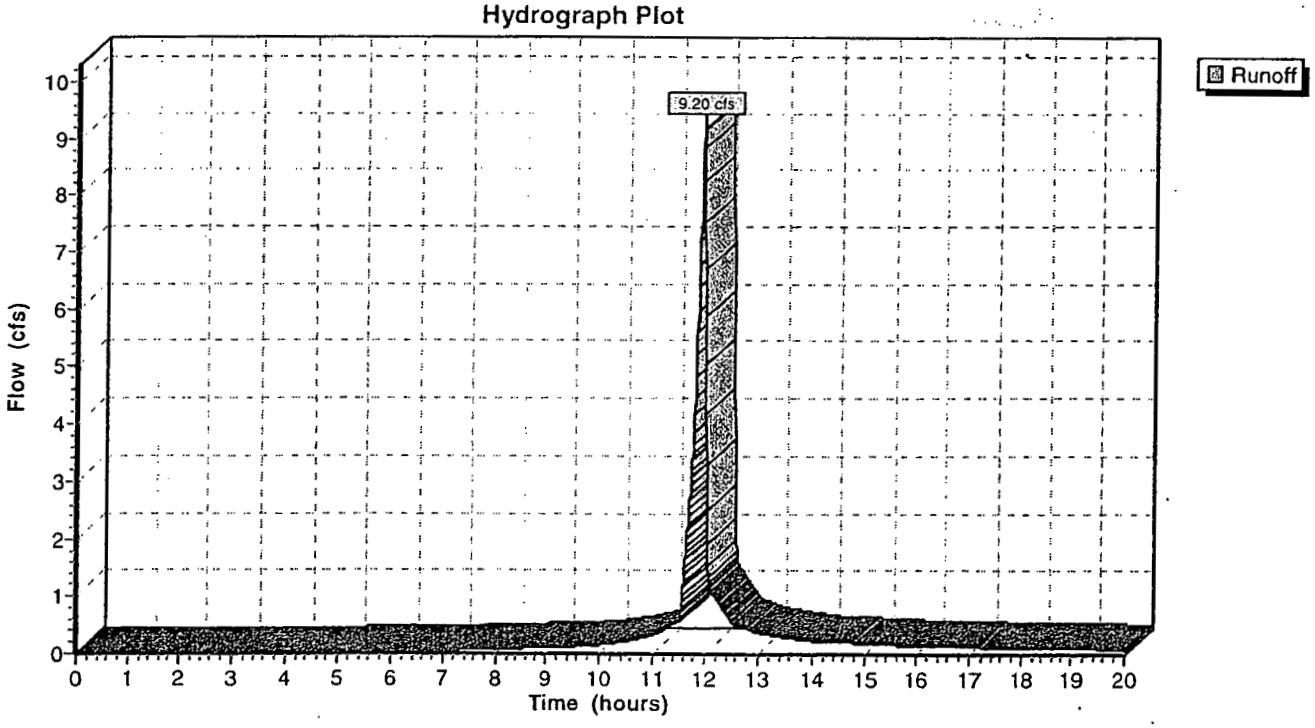
Runoff = 9.20 cfs @ 11.93 hrs, Volume= 0.385 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.330	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment E-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment E-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment E-3** Unpaved Kv= 16.1 fps
0.5	205	0.1670	6.6		**Shallow Concentrated Flow, Segment E-4** Unpaved Kv= 16.1 fps
0.5	154	0.0065	5.1	26.05	**Trap/Vee/Rect Channel Flow, Channel E** Bot.W=0.00' D=1.50' Z= 3.0 & 1.5 '/' n= 0.018
2.2	506	Total			

Subcatchment 5S: Area E



Subcatchment 6S: Area Fa and Fb

-- 4664

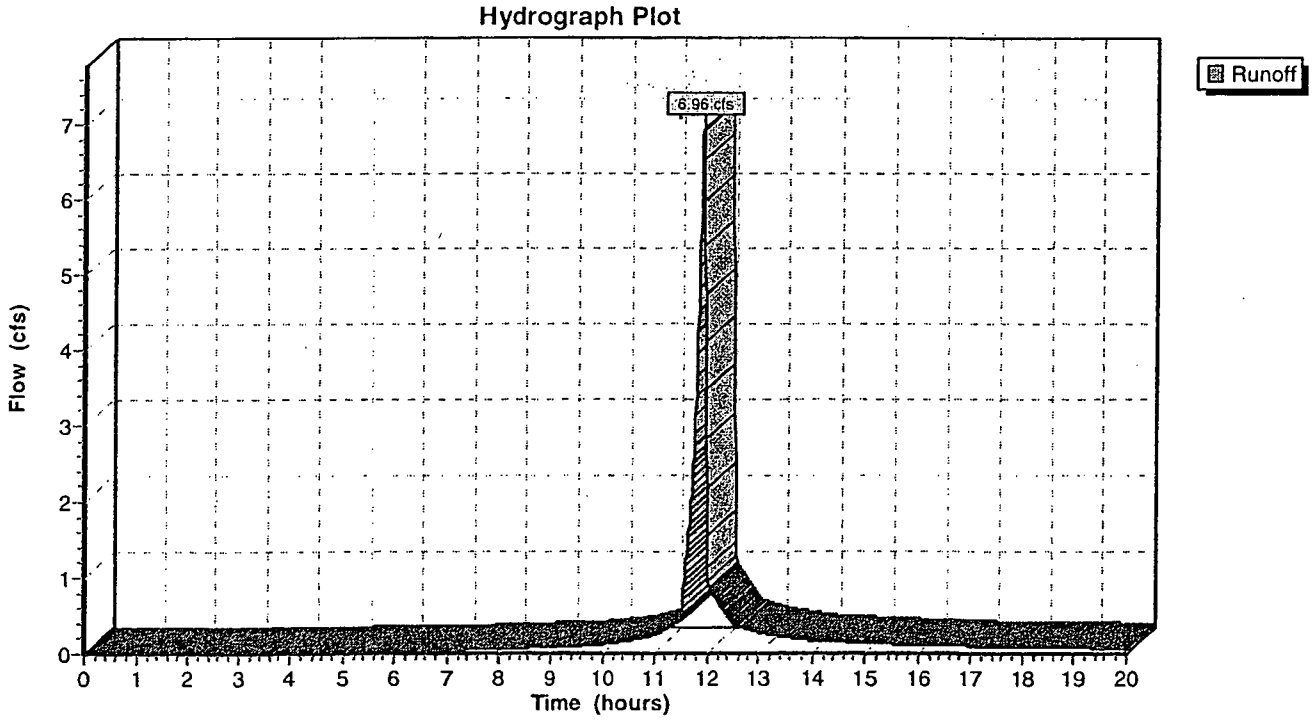
Runoff = 6.96 cfs @ 11.92 hrs, Volume= 0.284 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.980	91	Total Sideslope Area F

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.8	88	0.0500	1.7		**Sheet Flow, Segment F-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	12	0.1000	1.5		**Sheet Flow, Segment F-2** Smooth surfaces n= 0.011 P2= 2.55"
0.1	17	0.1000	5.1		**Shallow Concentrated Flow, Segment F-3** Unpaved Kv= 16.1 fps
0.3	143	0.2500	8.1		**Shallow Concentrated Flow, Section F-4** Unpaved Kv= 16.1 fps
1.3	260	Total			

Subcatchment 6S: Area Fa and Fb



Subcatchment 7S: Pond Area

-- 4664

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

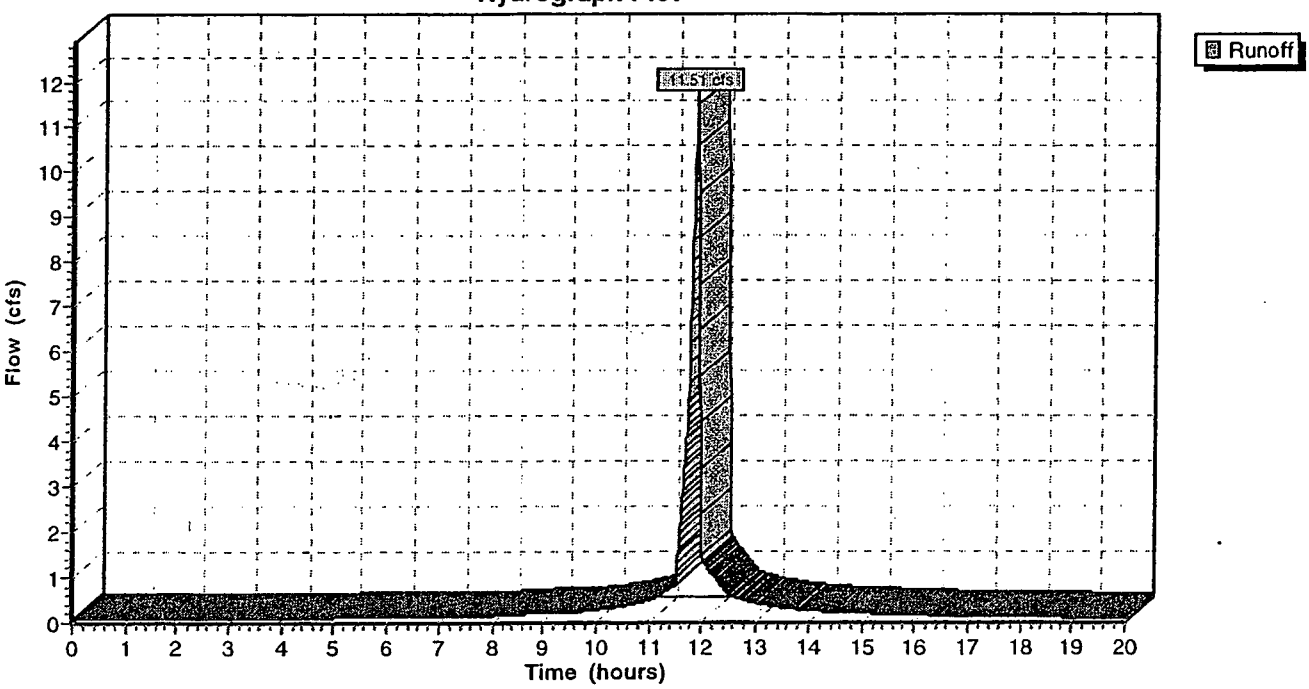
Runoff = 11.51 cfs @ 11.90 hrs, Volume= 0.537 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.440	100	Pond Area

Subcatchment 7S: Pond Area

Hydrograph Plot



MAO 24 June 2
CDC 01/23/2002 52 of 115

Reach 1R: Channel B

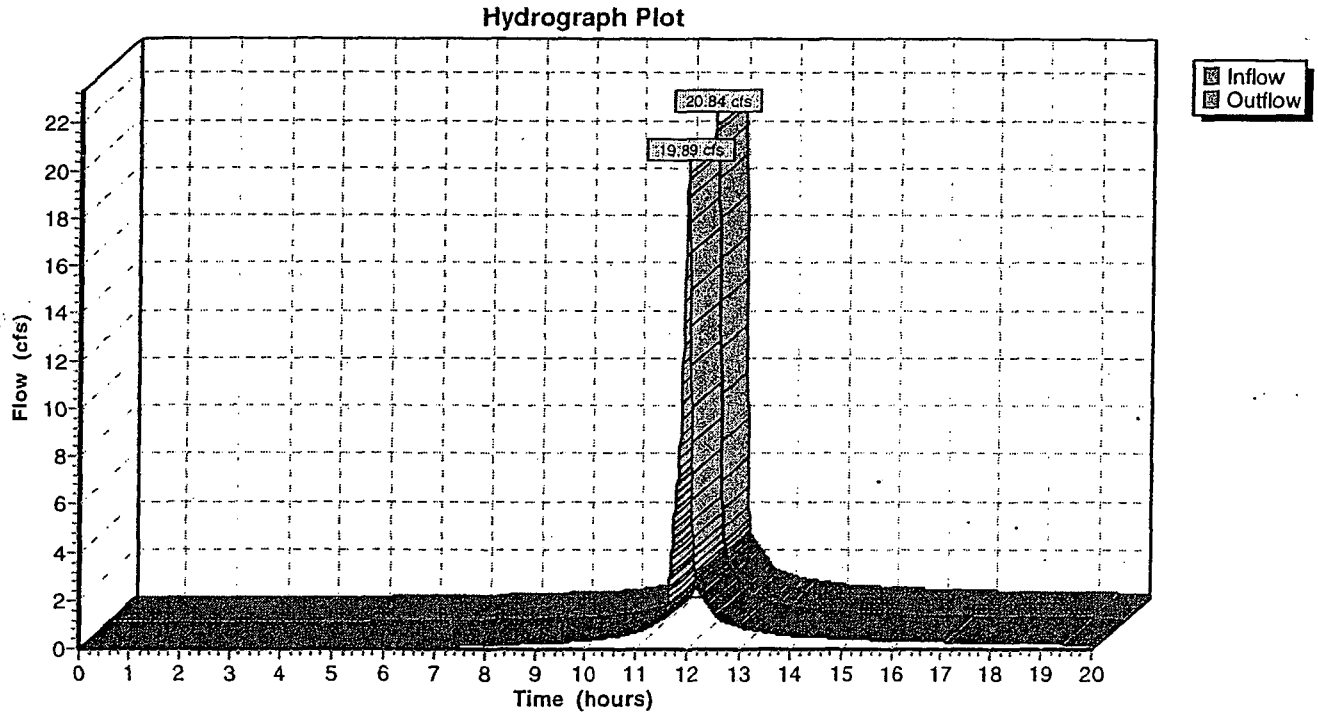
4664

Inflow = 20.84 cfs @ 11.93 hrs, Volume= 0.888 af
Outflow = 19.89 cfs @ 11.98 hrs, Volume= 0.886 af, Atten= 5%, Lag= 2.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.7 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 5.0 min

Peak Depth= 1.38'
Capacity at bank full= 1,011.08 cfs
Inlet Invert= 604.20', Outlet Invert= 601.20'
0.00' x 6.00' deep channel, n= 0.018 Length= 498.0' Slope= 0.0060 '/'
Side Slope Z-value= 1.5 3.0 '/'

Reach 1R: Channel B



Reach 2R: Channel C

-- 4664

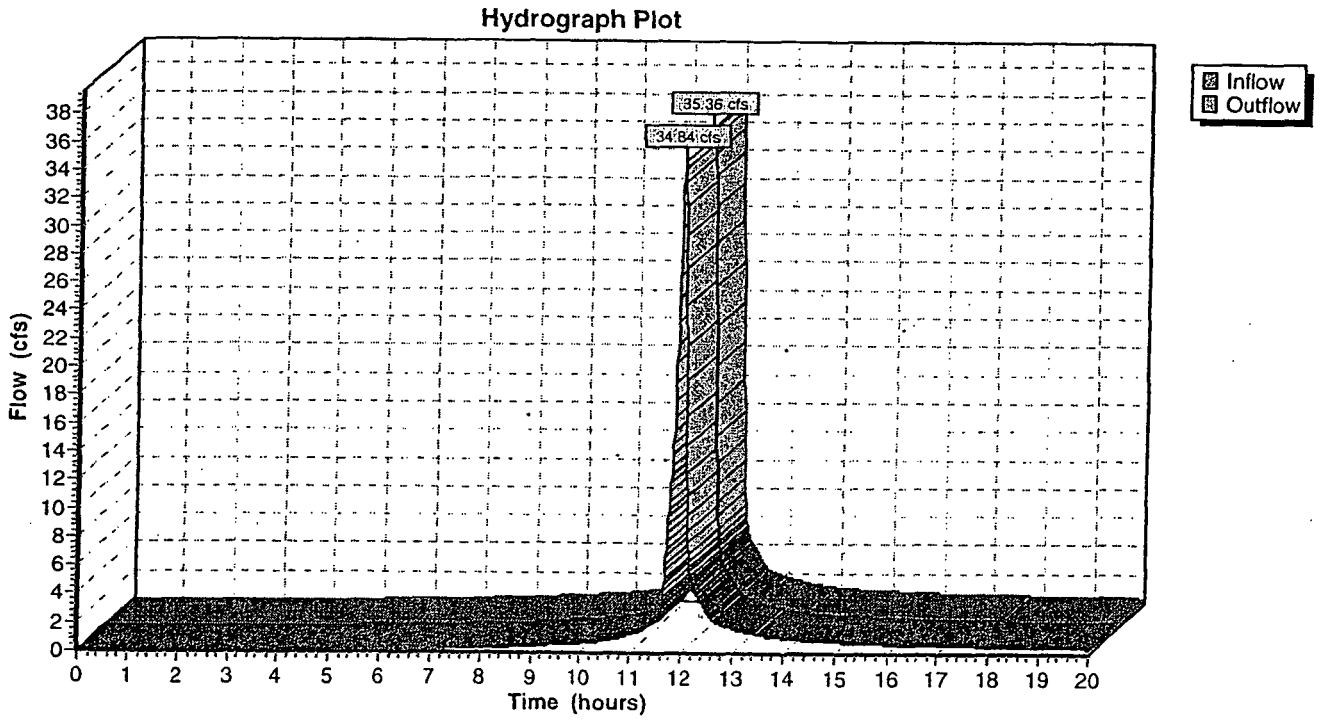
[61] Hint: Submerged 51% of Reach 1R bottom

Inflow	=	35.36 cfs @	11.96 hrs, Volume=	1.635 af	
Outflow	=	34.84 cfs @	11.99 hrs, Volume=	1.633 af, Atten= 1%, Lag= 1.8 min	

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Max. Velocity= 6.6 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 2.3 fps, Avg. Travel Time= 3.0 min

Peak Depth= 1.54'
Capacity at bank full= 1,318.10 cfs
Inlet Invert= 601.20', Outlet Invert= 596.90'
0.00' x 6.00' deep channel, n= 0.018 Length= 420.0' Slope= 0.0102 '/'
Side Slope Z-value= 1.5 3.0 '/'

Reach 2R: Channel C



Reach 3R: Channel E

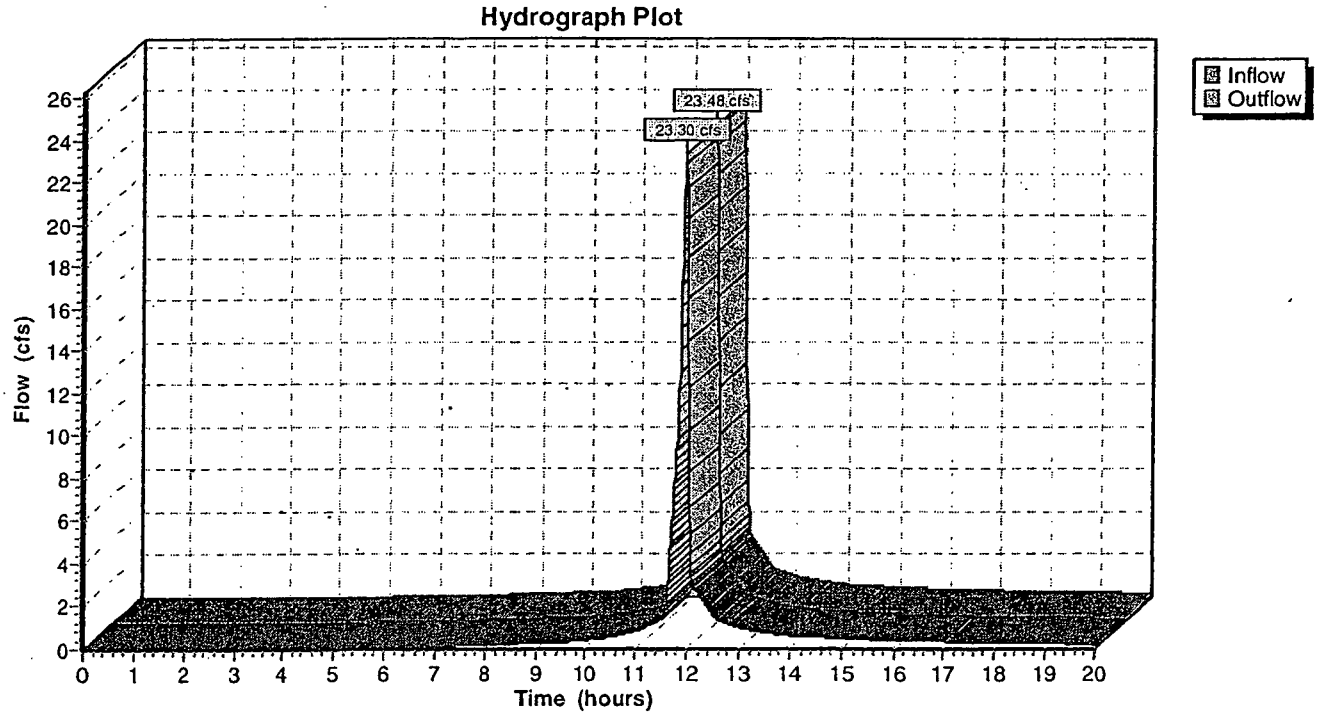
- 4664

Inflow = 23.48 cfs @ 11.93 hrs, Volume= 1.004 af
Outflow = 23.30 cfs @ 11.95 hrs, Volume= 1.003 af, Atten= 1%, Lag= 0.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Max. Velocity= 5.0 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 1.5 min

Peak Depth= 1.44'
Capacity at bank full= 1,049.73 cfs
Inlet Invert= 597.20', Outlet Invert= 596.20'
0.00' x 6.00' deep channel, n= 0.018 Length= 154.0' Slope= 0.0065 '/'
Side Slope Z-value= 3.0 1.5 '/'

Reach 3R: Channel E



Reach 4R: Dummy Reach

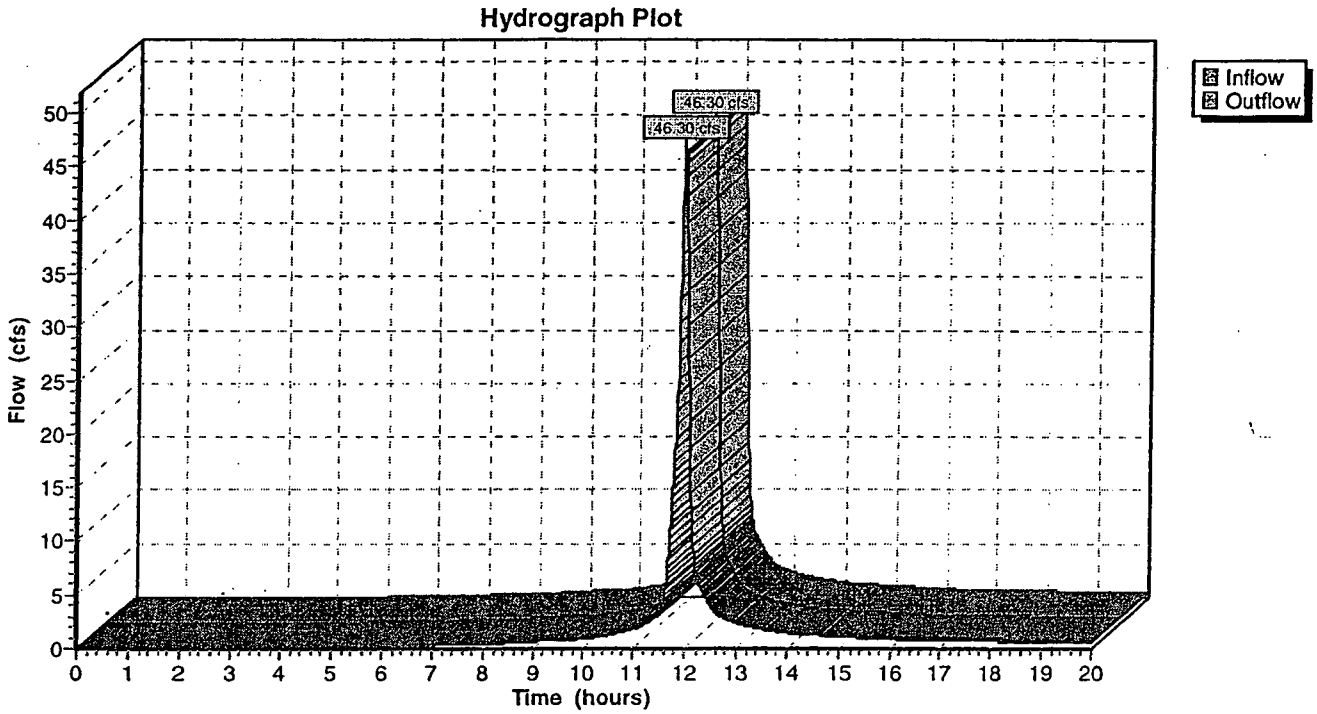
- 4664

[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	46.30 cfs @ 11.96 hrs, Volume=	2.272 af	
Outflow	=	46.30 cfs @ 11.96 hrs, Volume=	2.272 af, Atten= 0%, Lag= 0.0 min	

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 4R: Dummy Reach



Reach 5R: Dummy Reach

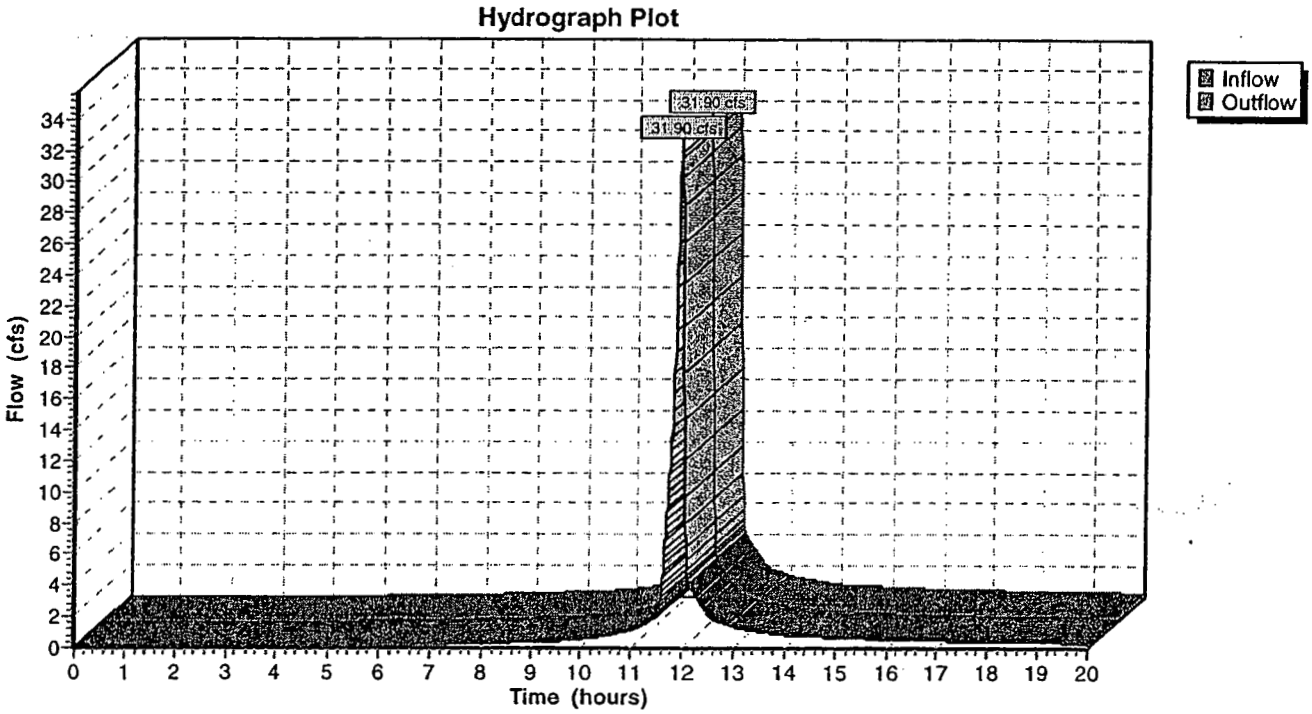
-- 4664

[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	31.90 cfs @	11.94 hrs, Volume=	1.388 af	
Outflow	=	31.90 cfs @	11.94 hrs, Volume=	1.388 af, Atten= 0%, Lag= 0.0 min	

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 5R: Dummy Reach



Pond 1P: Detention Pond

- 4664

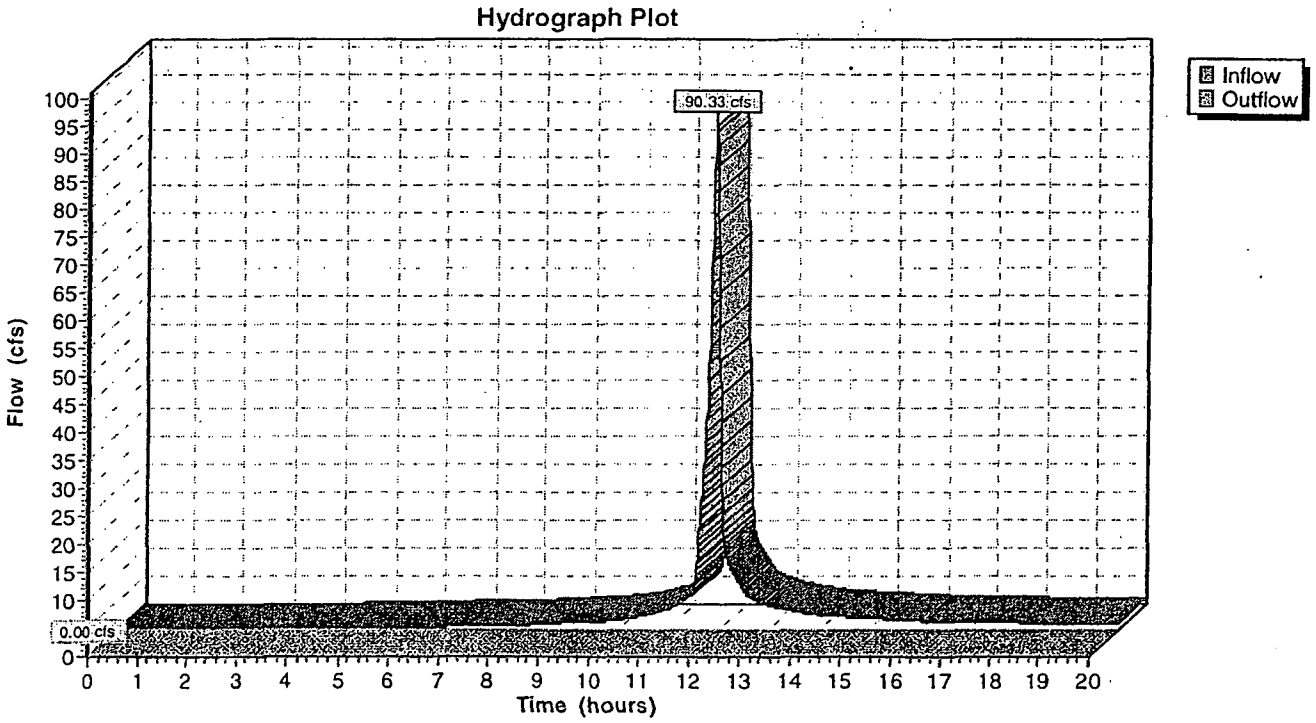
Inflow = 90.33 cfs @ 11.94 hrs, Volume= 4.481 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 595.63' Storage= 4.480 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
587.80	0.000	0.000	0.000
588.00	0.078	0.008	0.008
589.00	0.172	0.125	0.133
590.00	0.308	0.240	0.373
592.00	0.673	0.981	1.354
594.00	0.888	1.561	2.915
596.00	1.037	1.925	4.840
598.00	1.152	2.189	7.029
600.00	1.267	2.419	9.448
603.00	1.441	4.062	13.510 ≈ 588,500 cf

Pond 1P: Detention Pond



Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAS Date: 24 Jan 02

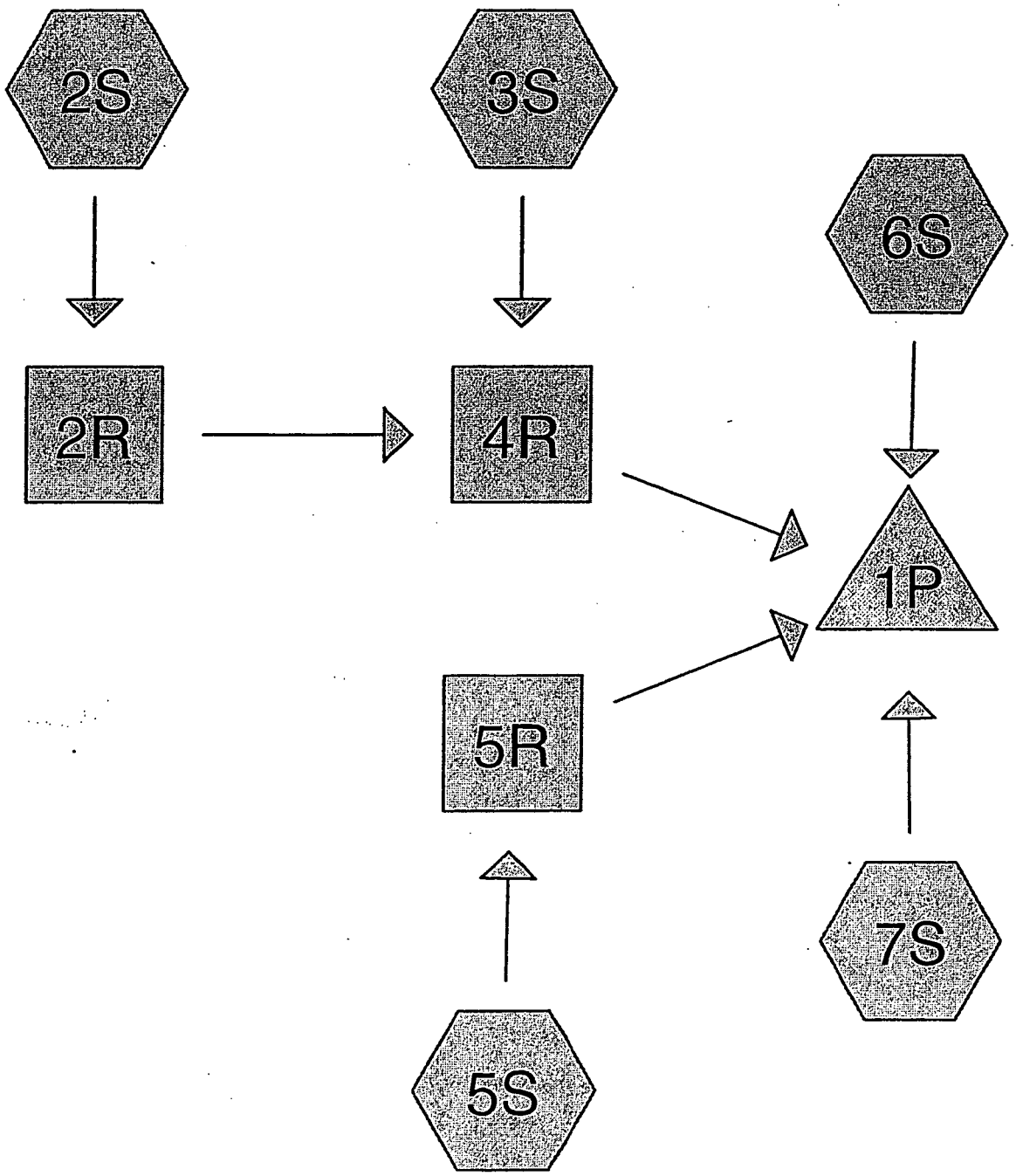
Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

- 4664

STAGE II CALCULATION

MAO 24 Jan 02
CDC 01/23/2002 59 of 115

- 4664



Subcat Reach Pond Link

Drainage Diagram for Fernald Cells 6-7 Stage II (Task 17.4)
Prepared by GeoSyntec Consultants 1/22/2002
HydroCAD® 6.00 s/n 000929 © 1986-2001 Applied Microcomputer Systems

MAO 24Jan02
CDL 01/23/2002 60 of 115

Time span=0.00-20.00 hrs, dt=0.01 hrs, 2001 points -- 4664
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=4.70"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 2S: Area B
Tc=2.7 min CN=91 Area=2.590 ac Runoff= 17.64 cfs 0.749 af

Subcatchment 3S: Area C
Tc=2.3 min CN=91 Area=2.210 ac Runoff= 15.24 cfs 0.639 af

Subcatchment 5S: Area E
Tc=2.0 min CN=91 Area=1.330 ac Runoff= 9.25 cfs 0.385 af

Subcatchment 6S: Area Fa and Fb
Tc=1.3 min CN=91 Area=0.980 ac Runoff= 6.96 cfs 0.284 af

Subcatchment 7S: Pond Area
Tc=0.0 min CN=100 Area=1.440 ac Runoff= 11.51 cfs 0.537 af

Reach 2R: Channel C Inflow= 17.64 cfs 0.749 af
Length= 420.0' Max Vel= 5.5 fps Capacity= 1,318.10 cfs Outflow= 17.12 cfs 0.748 af

Reach 4R: Dummy Reach Inflow= 30.67 cfs 1.387 af
Outflow= 30.67 cfs 1.387 af

Reach 5R: Dummy Reach Inflow= 9.25 cfs 0.385 af
Outflow= 9.25 cfs 0.385 af

Pond 1P: Detention Pond Peak Storage= 2.592 af Inflow= 55.17 cfs 2.593 af
Outflow= 0.00 cfs 0.000 af

Runoff Area = 8.550 ac Volume = 2.594 af Average Depth = 3.64"
≈ 113,000 cf

Subcatchment 2S: Area B

- 4664

Runoff = 17.64 cfs @ 11.93 hrs, Volume= 0.749 af

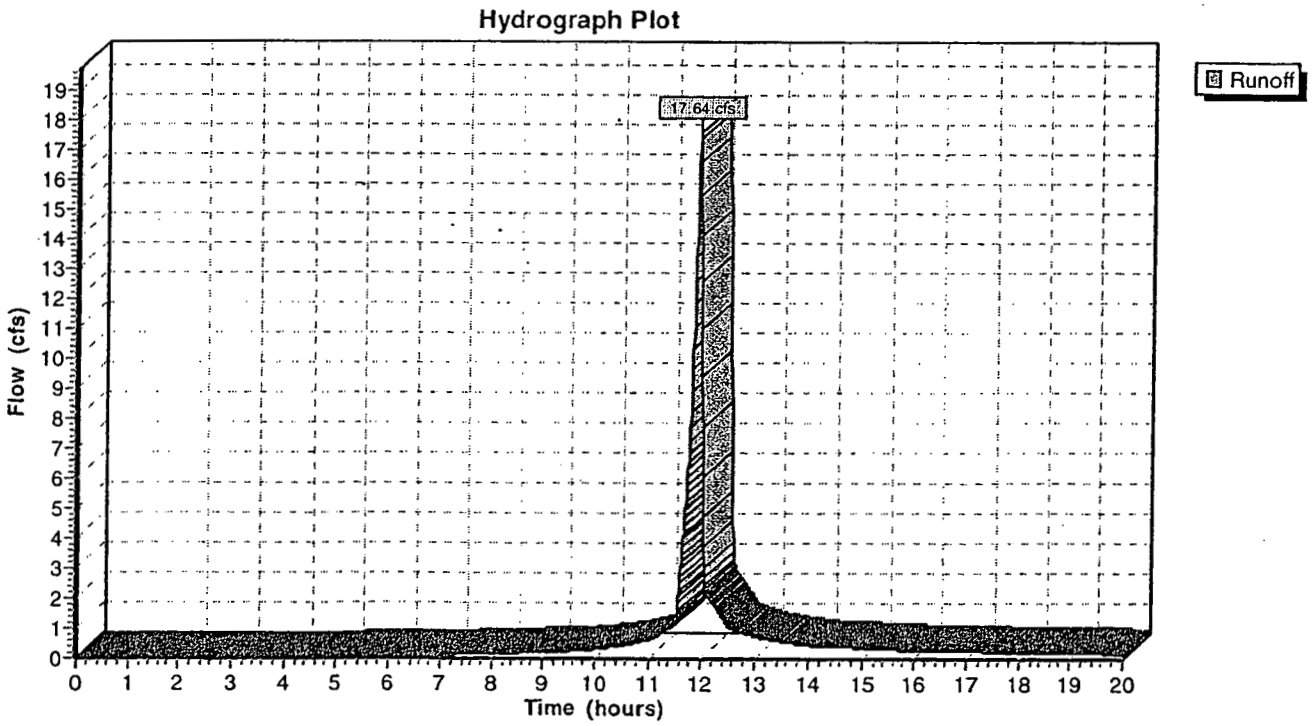
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.590	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment B-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment B-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment B-3** Unpaved Kv= 16.1 fps
0.4	163	0.1670	6.6		**Shallow Concentrated Flow, Segment B-4** Unpaved Kv= 16.1 fps
1.1	498	0.0060	7.8	158.92	**Trap/Vee/Rect Channel Flow, Channel B** Bot.W=0.00' D=3.00' Z= 1.5 & 3.0 '/' n= 0.018
2.7	808	Total			

Subcatchment 2S: Area B

Hydrograph Plot



Subcatchment 3S: Area C

-- 4664

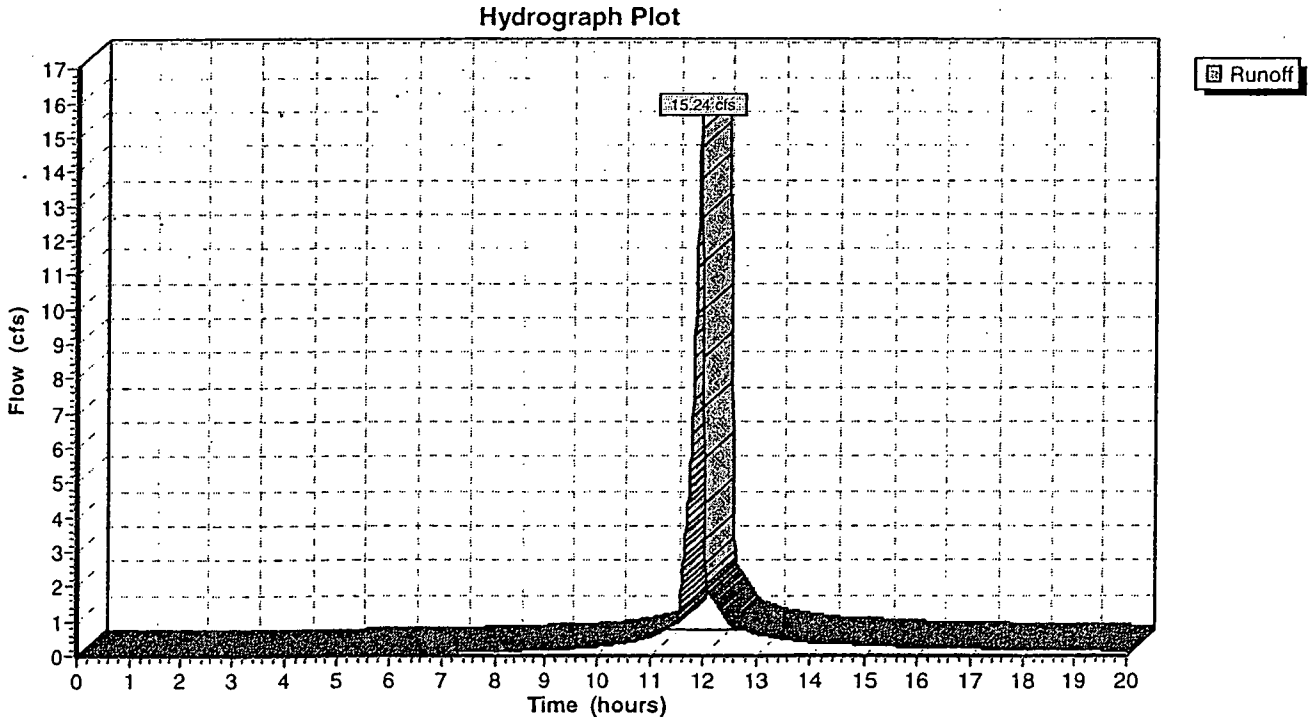
Runoff = 15.24 cfs @ 11.93 hrs, Volume= 0.639 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.210	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	98	0.0500	1.8		**Sheet Flow, Segment C-1** Smooth surfaces n= 0.011 P2= 2.55"
0.0	2	0.1000	1.1		**Sheet Flow, Segment C-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	59	0.1000	5.1		**Shallow Concentrated Flow, Area C-3** Unpaved Kv= 16.1 fps
0.5	191	0.1670	6.6		**Shallow Concentrated Flow, Area C-4** Unpaved Kv= 16.1 fps
0.7	420	0.0100	10.1	205.16	**Trap/Vee/Rect Channel Flow, Channel C** Bot.W=0.00' D=3.00' Z= 1.5 & 3.0 '/' n= 0.018
2.3	770	Total			

Subcatchment 3S: Area C



MAO-24 Jan 02
CDC 01/23/2002 63 of 115

Subcatchment 5S: Area E

- 4664

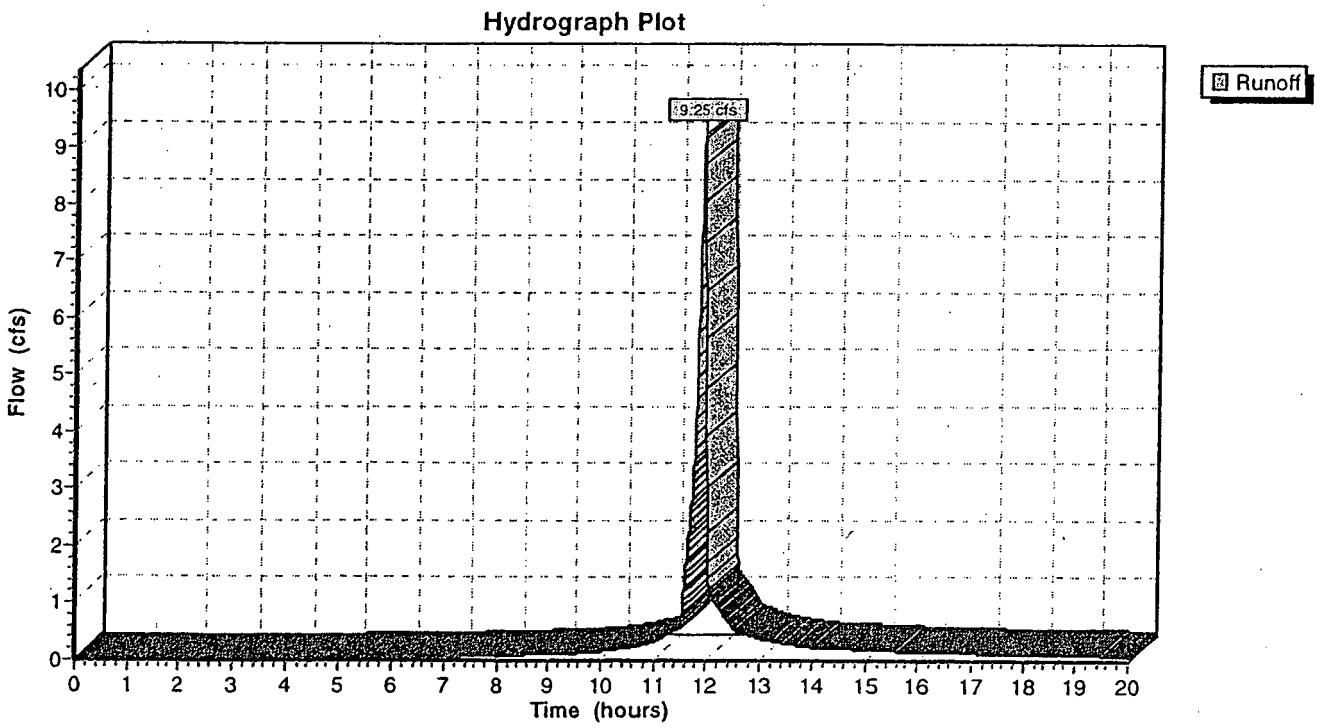
Runoff = 9.25 cfs @ 11.92 hrs, Volume= 0.385 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.330	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment E-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment E-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment E-3** Unpaved Kv= 16.1 fps
0.5	205	0.1670	6.6		**Shallow Concentrated Flow, Segment E-4** Unpaved Kv= 16.1 fps
0.3	154	0.0065	8.2	165.40	**Trap/Vee/Rect Channel Flow, Channel E** Bot.W=0.00' D=3.00' Z= 3.0 & 1.5 '/' n= 0.018
2.0	506	Total			

Subcatchment 5S: Area E



Subcatchment 6S: Area Fa and Fb

- 4664

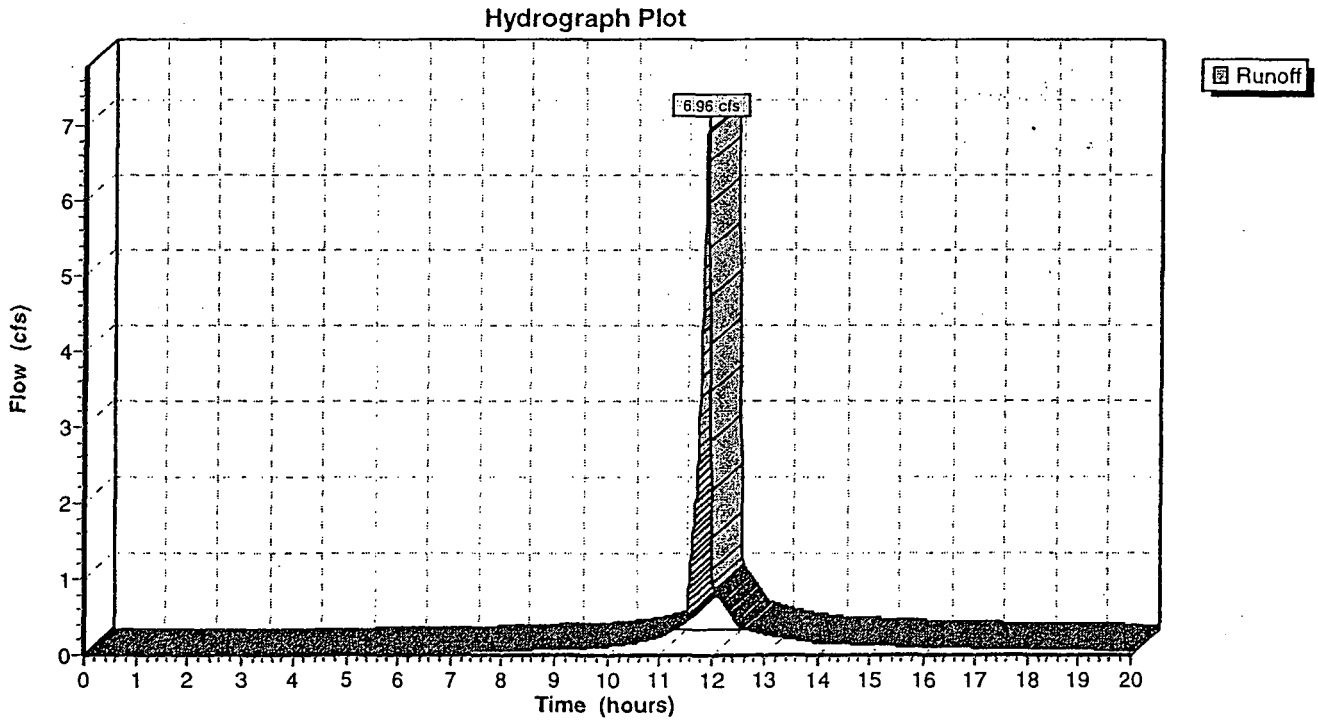
Runoff = 6.96 cfs @ 11.92 hrs, Volume= 0.284 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.980	91	Total Sideslope Area F

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.8	88	0.0500	1.7		**Sheet Flow, Segment F-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	12	0.1000	1.5		**Sheet Flow, Segment F-2** Smooth surfaces n= 0.011 P2= 2.55"
0.1	17	0.1000	5.1		**Shallow Concentrated Flow, Segment F-3** Unpaved Kv= 16.1 fps
0.3	143	0.2500	8.1		**Shallow Concentrated Flow, Section F-4** Unpaved Kv= 16.1 fps
1.3	260	Total			

Subcatchment 6S: Area Fa and Fb



Subcatchment 7S: Pond Area - 4664

[46] Hint: Tc=0 (Instant runoff peak depends on dt)

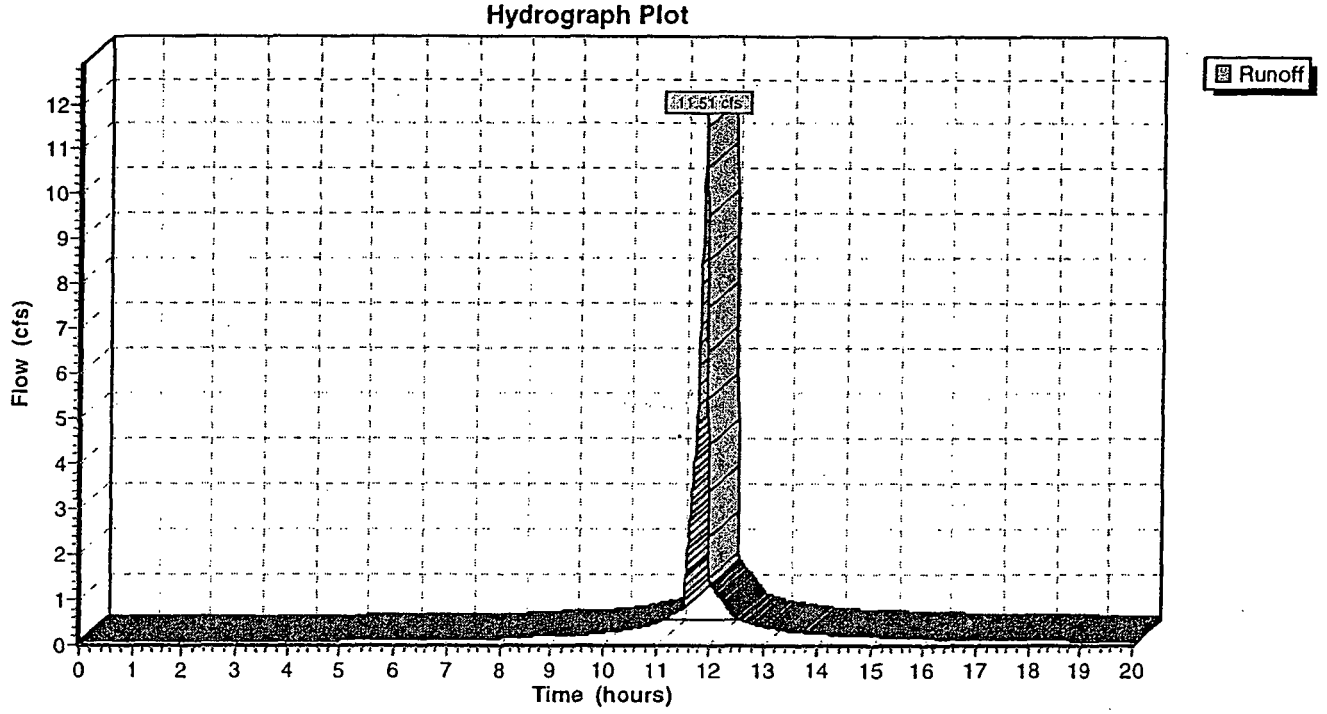
Runoff = 11.51 cfs @ 11.90 hrs, Volume= 0.537 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.440	100	Pond Area

Subcatchment 7S: Pond Area

Hydrograph Plot



Reach 2R: Channel C

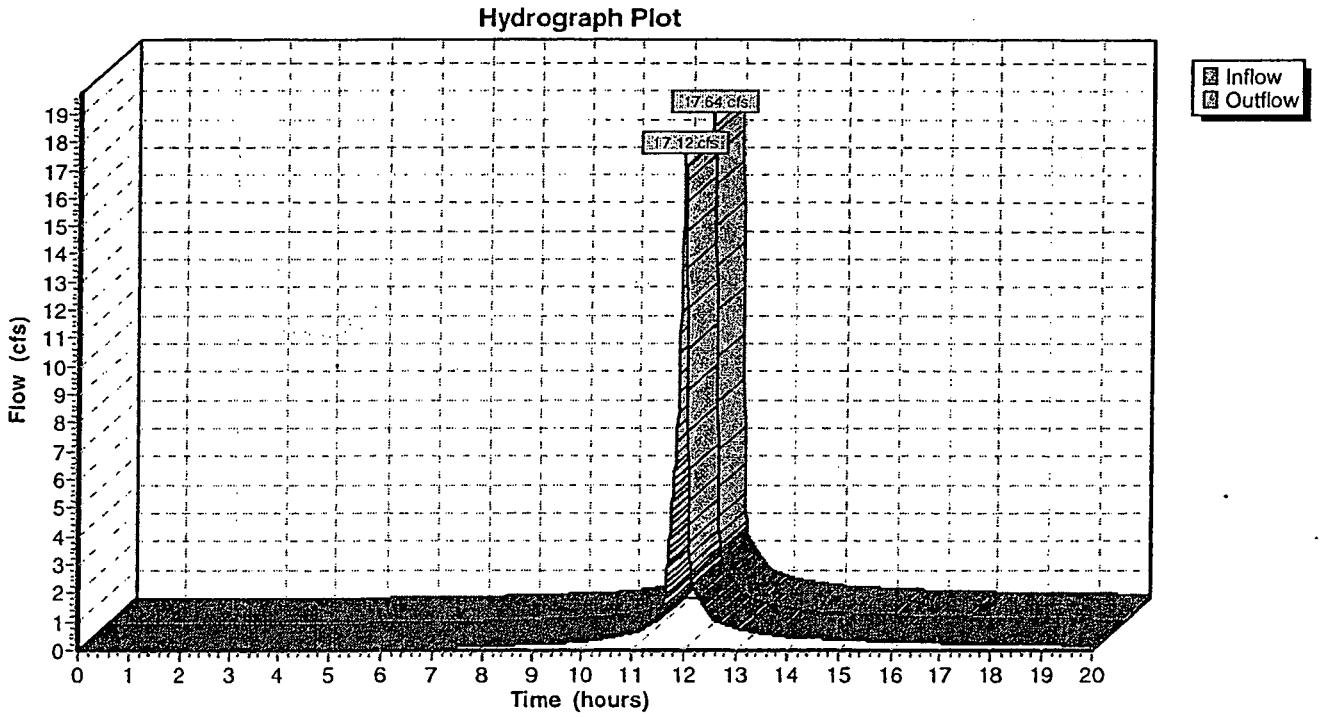
- 4664

Inflow	=	17.64 cfs @	11.93 hrs, Volume=	0.749 af	
Outflow	=	17.12 cfs @	11.97 hrs, Volume=	0.748 af, Atten= 3%, Lag= 2.1 min	

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Max. Velocity= 5.5 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 3.6 min

Peak Depth= 1.18'
Capacity at bank full= 1,318.10 cfs
Inlet Invert= 601.20', Outlet Invert= 596.90'
0.00' x 6.00' deep channel, n= 0.018 Length= 420.0' Slope= 0.0102 '/'
Side Slope Z-value= 1.5 3.0 '/'

Reach 2R: Channel C



Reach 4R: Dummy Reach

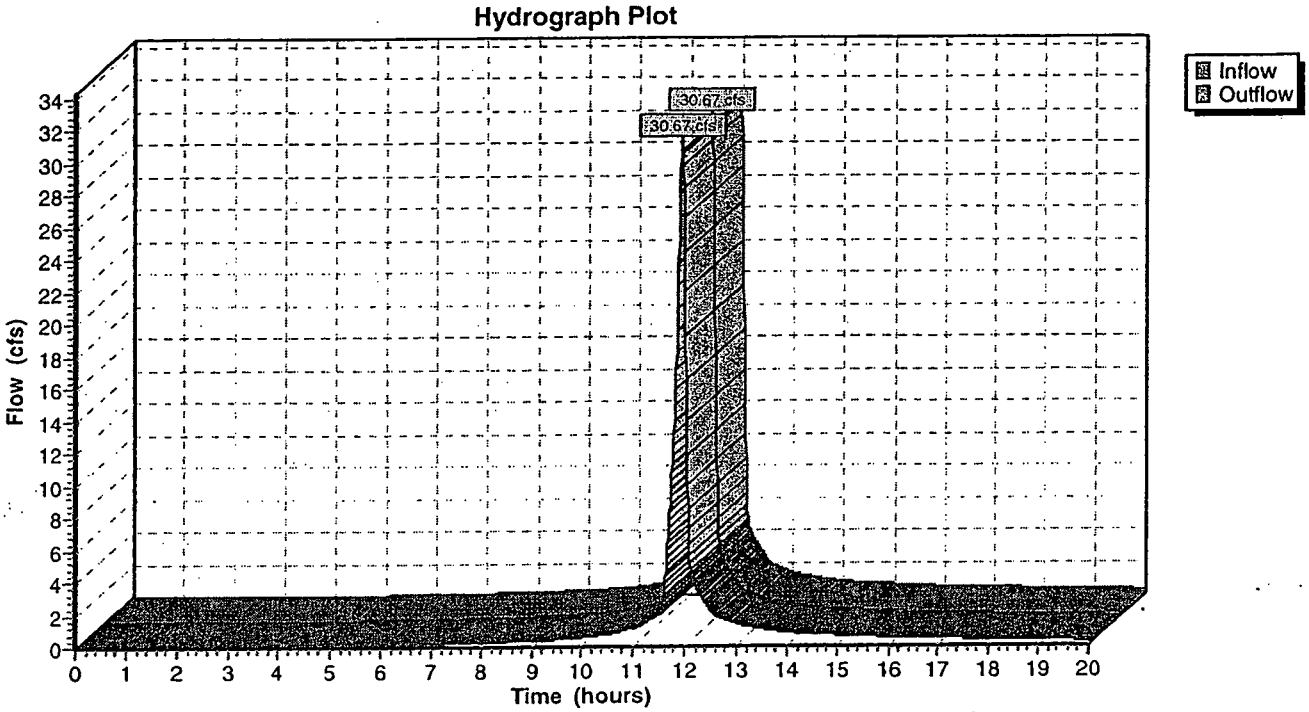
-- 4664

[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	30.67 cfs @ 11.94 hrs,	Volume=	1.387 af
Outflow	=	30.67 cfs @ 11.94 hrs,	Volume=	1.387 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 4R: Dummy Reach



MAo 2u Jan02
CDC 01/23/2002 68 of 115

Reach 5R: Dummy Reach

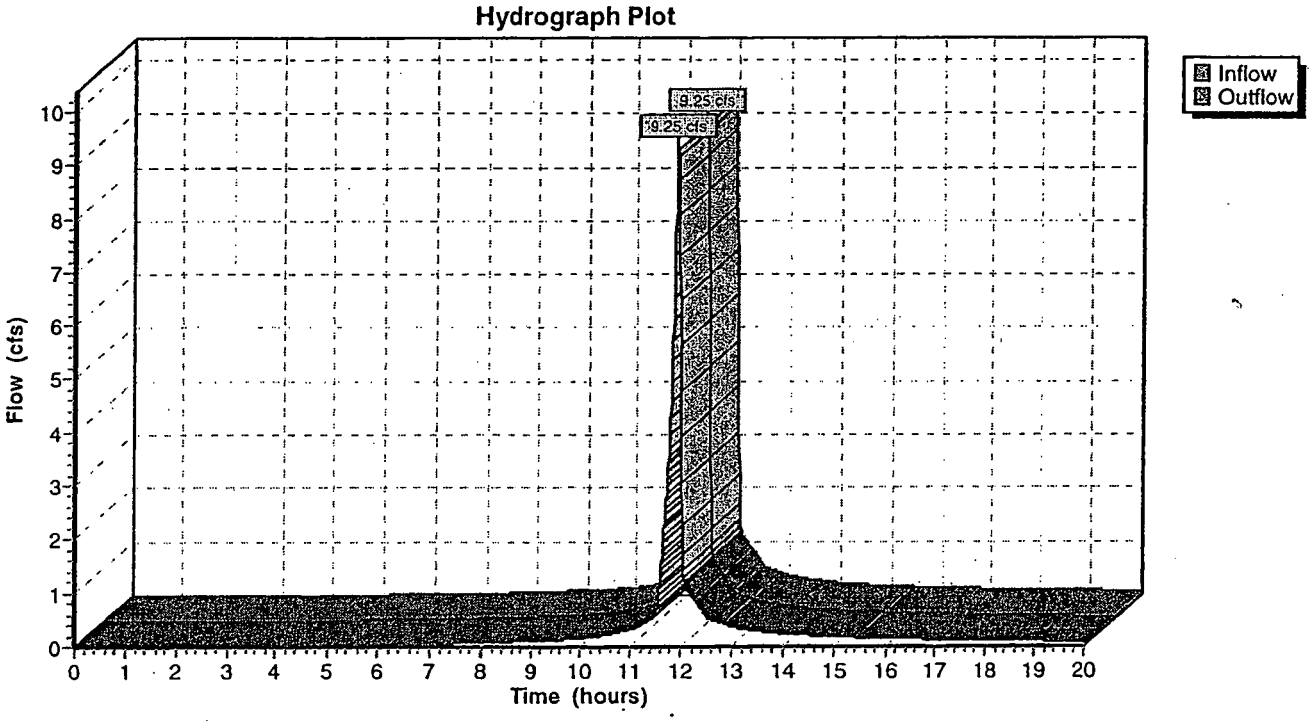
-- 4664

[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	9.25 cfs @	11.92 hrs,	Volume=	0.385 af
Outflow	=	9.25 cfs @	11.92 hrs,	Volume=	0.385 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 5R: Dummy Reach



Pond 1P: Detention Pond

- 4664

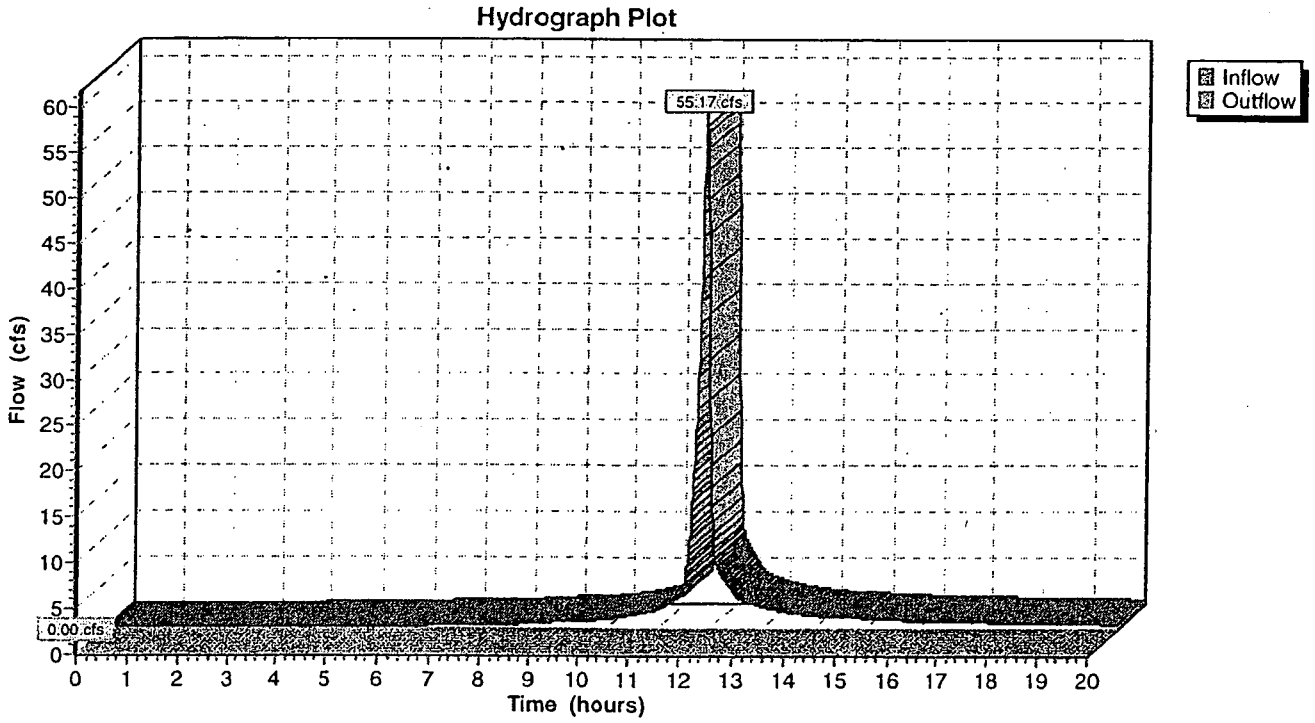
Inflow = 55.17 cfs @ 11.92 hrs, Volume= 2.593 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 599.82' Storage= 2.592 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
587.80	0.000	0.000	0.000
588.00	0.012	0.001	0.001
589.00	0.030	0.021	0.022
595.00	0.165	0.585	0.607
596.00	0.223	0.194	0.801
598.00	0.430	0.653	1.454
600.00	0.824	1.254	2.708
602.00	1.285	2.109	4.817
603.00	1.441	1.363	6.180 ≈ 269,200 cf

Pond 1P: Detention Pond



Written by: Christopher D. Corrigan CDC Date: 1/23/2002 Reviewed by: MAD Date: 24 Jan 02

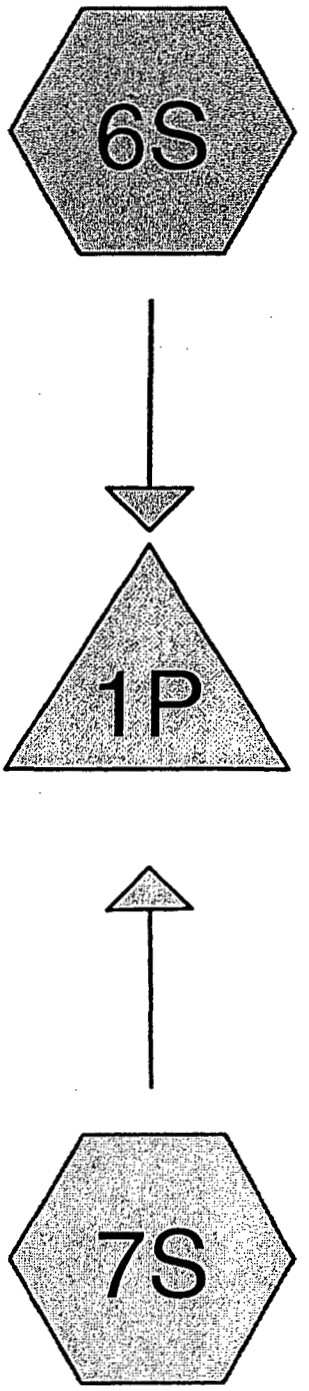
Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17.4

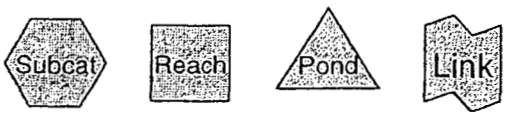
-- 4664

STAGE IIII CALCULATION

MAO 2nJan02
CDC 01/23/2002 71 of 115

-- 4664





Drainage Diagram for Fernald Cells 6-7 Stage III (Task 17.4)
Prepared by GeoSyntec Consultants 1/22/2002
HydroCAD® 6.00 s/n 000929 © 1986-2001 Applied Microcomputer Systems

Time span=0.00-20.00 hrs, dt=0.01 hrs, 2001 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=4.70" - 4664
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 6S: Area F

Tc=1.7 min CN=91 Area=3.246 ac Runoff= 22.81 cfs 0.939 af

Subcatchment 7S: Pond Area

Tc=0.0 min CN=100 Area=0.636 ac Runoff= 5.08 cfs 0.237 af

Pond 1P: Detention Pond

Peak Storage= 1.176 af Inflow= 27.15 cfs 1.176 af
Outflow= 0.00 cfs 0.000 af

Runoff Area = 3.882 ac Volume = 1.176 af Average Depth = 3.64"

≈ 51,200 cf

Subcatchment 6S: Area F

- 4664

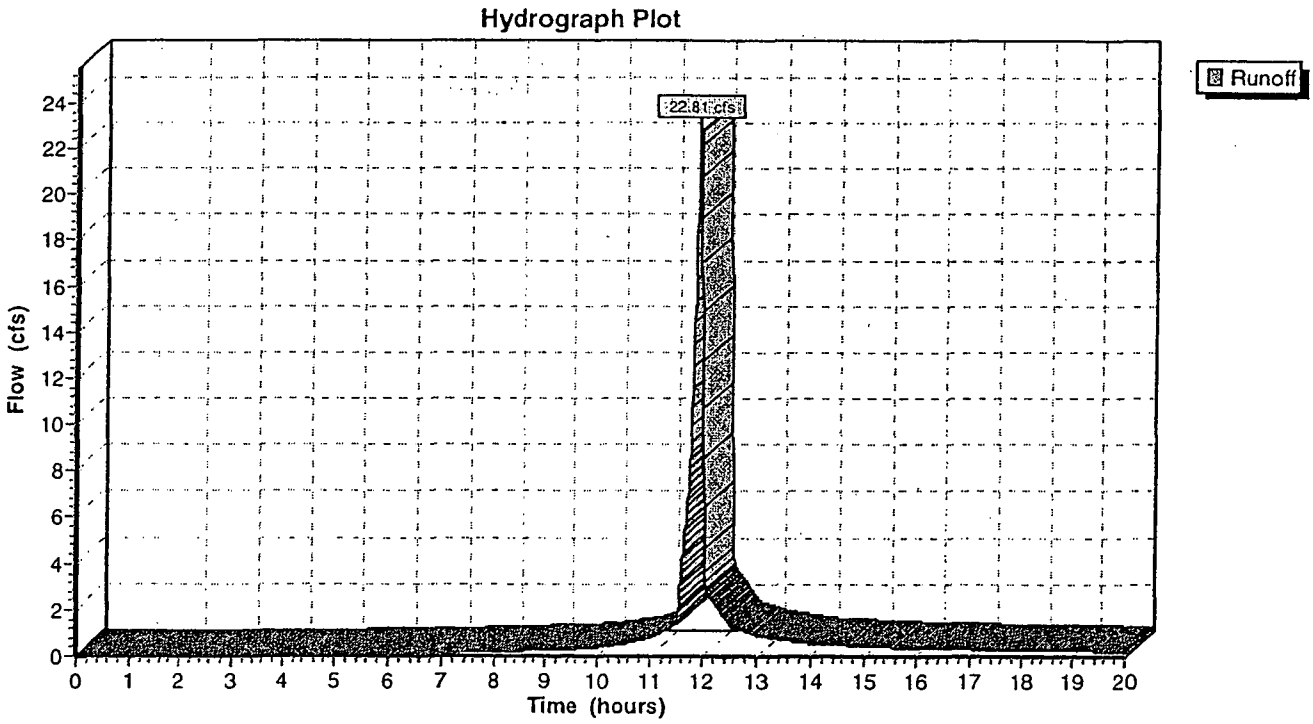
Runoff = 22.81 cfs @ 11.92 hrs, Volume= 0.939 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
3.246	91	Total Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	89	0.0500	1.7		**Sheet Flow, Segment F-1** Smooth surfaces n= 0.011 P2= 2.55"
0.1	11	0.1000	1.5		**Sheet Flow, Segment F-2** Smooth surfaces n= 0.011 P2= 2.55"
0.2	47	0.1000	5.1		**Shallow Concentrated Flow, Segment F-3** Unpaved Kv= 16.1 fps
0.5	202	0.1670	6.6		**Shallow Concentrated Flow, Segment F-4** Unpaved Kv= 16.1 fps
1.7	349	Total			

Subcatchment 6S: Area F



Subcatchment 7S: Pond Area

-- 4664

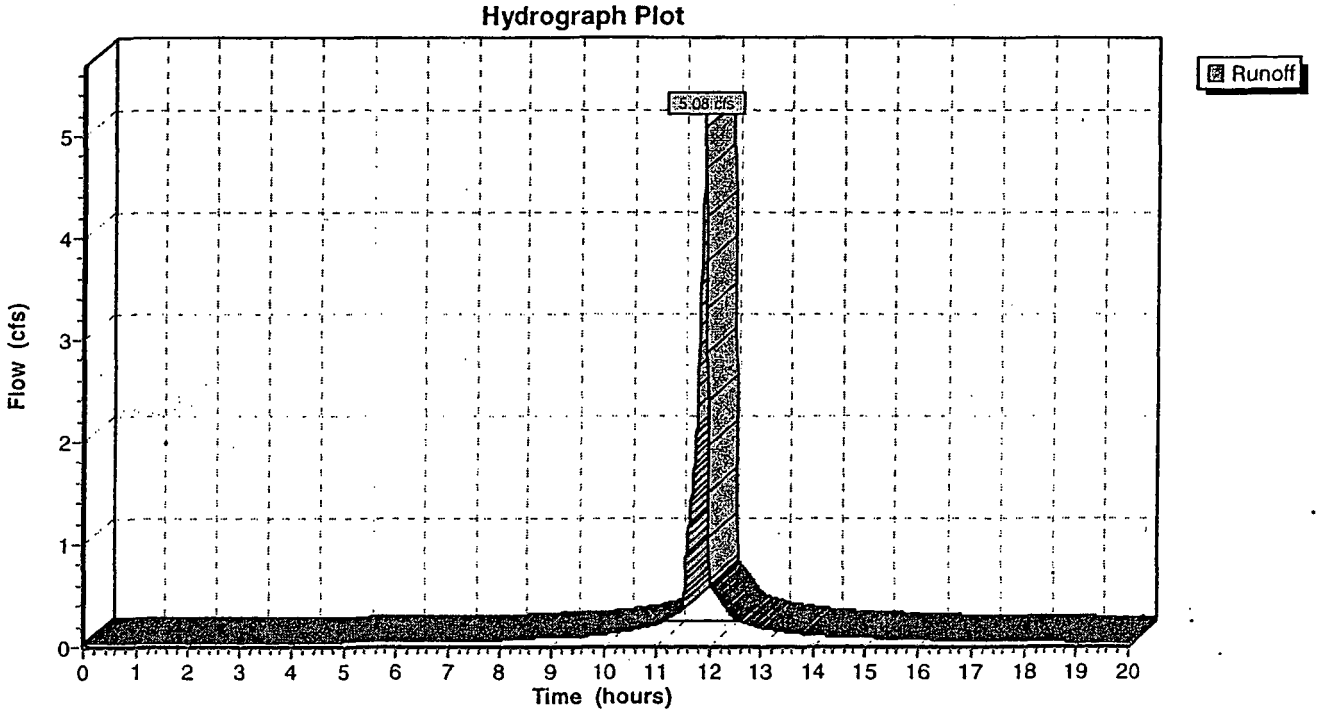
[46] Hint: Tc=0 (Instant runoff peak depends on dt)

Runoff = 5.08 cfs @ 11.90 hrs, Volume= 0.237 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.636	100	Pond Area

Subcatchment 7S: Pond Area



Pond 1P: Detention Pond

-- 4664

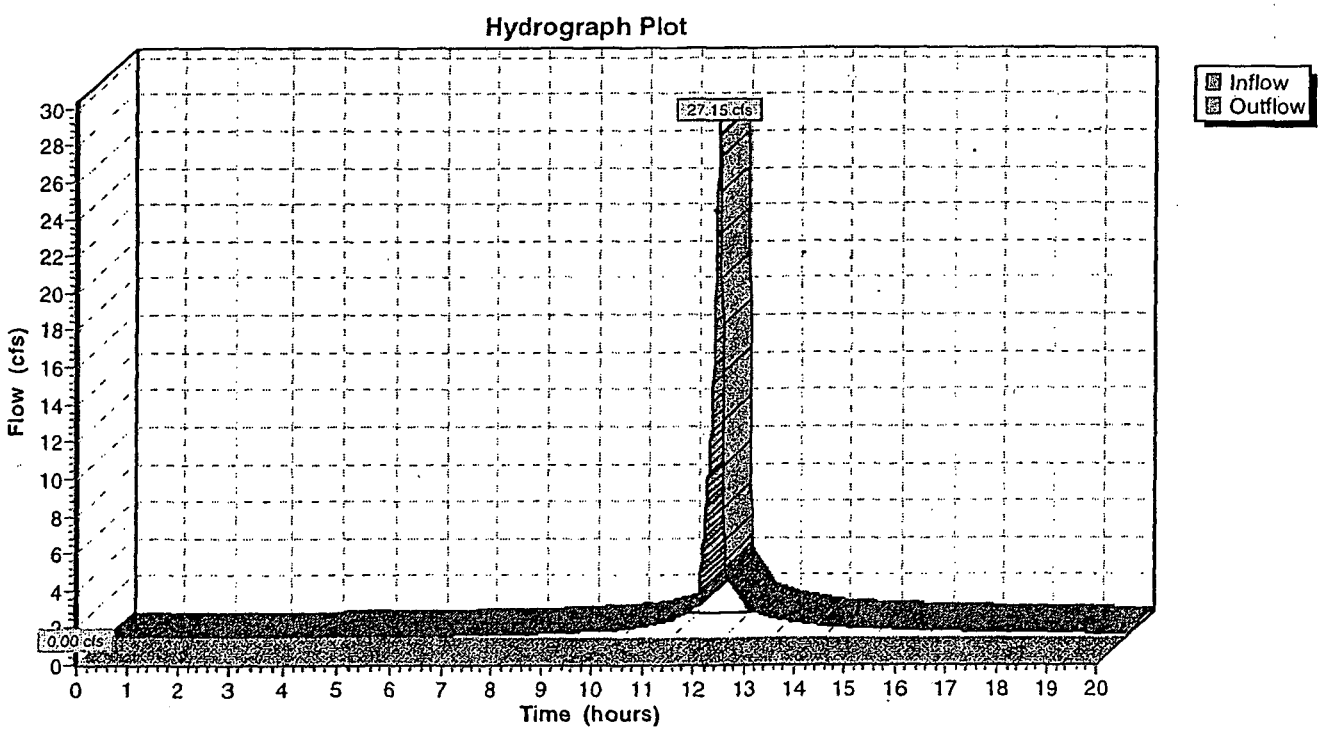
Inflow = 27.15 cfs @ 11.92 hrs, Volume= 1.176 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 601.22' Storage= 1.176 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
594.80	0.000	0.000	0.000
595.00	0.002	0.000	0.000
596.00	0.033	0.017	0.018
597.00	0.093	0.063	0.081
598.00	0.170	0.131	0.212
599.00	0.247	0.208	0.421
600.00	0.324	0.286	0.706
601.00	0.411	0.367	1.074
602.00	0.514	0.462	1.536
603.00	0.633	0.573	2.110

Pond 1P: Detention Pond



Written by: CDC CDC 08/23/2002 Date: YY / MM / DD Reviewed by: MAD Date: 02 / Aug 24 YY MM DD

Client: Project: Project/Proposal No.: Task No.:

4664

Translating Stage III IRCA Volume from Bottom of Contouring Layer to Top of 2 Lifts of Compacted Clay.

Discussion:

(1) Available drawings showed the bottom of contouring layer.
- The IRCA capacity was measured using areas from this surface and letting HydroCAD compute the volume.

(2) Since OSDF areas are considered closed once 2 lifts of clay have been placed, the IRCA capacity should be representative of the top of 2 lifts of compacted clay surface.

(3) In order to represent the top of 2 lifts of compacted clay, the elevations of the bottom of the contouring layer could be transferred/translated by the thickness of the contouring layer plus the 2 lifts of clay.

(4) The vertical shift associated with the thickness of the contouring layer (1' thickness) and the 2 lifts of clay (1' thickness) is 1.4' vertically (See attached figure and discussion).

(5) The HydroCAD volume outputs were corrected by shifting the elevation by 1.4 ft. to represent the volume of the IRCA that has had 2 lifts of clay placed.

Ex: HydroCAD El. 601.6 → 601.6 + 1.4' = El. 603' (Top of 2 lifts)
(Represents bottom of Contouring)

(See Attached HydroCAD Output for the Stage III IRCA)

MJO 24 Jan 02
CDC 01/23/2002 77 of 115

Fernald Cells 6-7 Stage III (Task 17.2) *Type II 24-hr Rainfall=4.70"*
Prepared by {enter your company name here} Page 1
HydroCAD® 6.00 s/n 000929 © 1986-2001 Applied Microcomputer Systems 12/10/2001

Pond 1P: Detention Pond

- 4664

.4'
.2

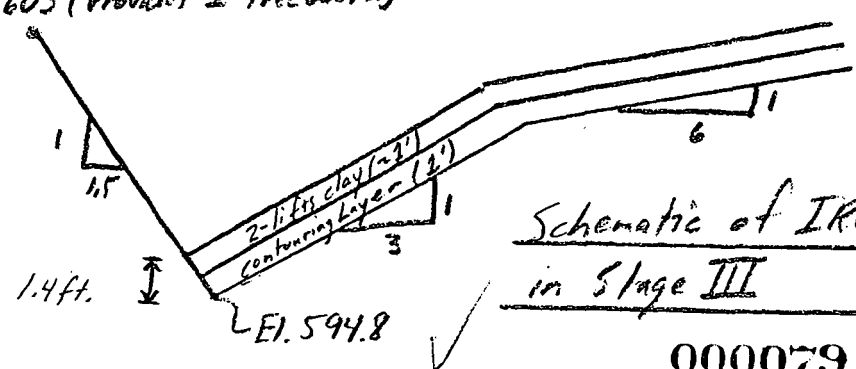
Elevation (feet)	Surface (acres)	Storage (acre-feet)
594.80	0.000	0.000
594.90	0.001	0.000
595.00	0.002	0.000
595.10	0.005	0.002
595.20	0.008	0.004
595.30	0.011	0.005
595.40	0.014	0.007
595.50	0.017	0.009
595.60	0.021	0.011
595.70	0.024	0.012
595.80	0.027	0.014
595.90	0.030	0.016
596.00	0.033	0.018
596.10	0.039	0.024
596.20	0.045	0.030
596.30	0.051	0.037
596.40	0.057	0.043
596.50	0.063	0.049
596.60	0.069	0.055
596.70	0.075	0.062
596.80	0.081	0.068
596.90	0.087	0.074
597.00	0.093	0.081
597.10	0.101	0.094
597.20	0.108	0.107
597.30	0.116	0.120
597.40	0.124	0.133
597.50	0.131	0.146
597.60	0.139	0.160
597.70	0.147	0.173
597.80	0.155	0.186
597.90	0.162	0.199
598.00	0.170	0.212
598.10	0.178	0.233
598.20	0.185	0.254
598.30	0.193	0.275
598.40	0.201	0.296
598.50	0.208	0.316
598.60	0.216	0.337
598.70	0.224	0.358
598.80	0.232	0.379
598.90	0.239	0.400
599.00	0.247	0.421
599.10	0.255	0.449
599.20	0.262	0.478
599.30	0.270	0.506
599.40	0.278	0.535
599.50	0.285	0.563
599.60	0.293	0.592
599.70	0.301	0.621
599.80	0.309	0.649
599.90	0.316	0.678

+1.4

Elevation (feet)	Surface (acres)	Storage (acre-feet)
600.00	0.324	0.706
600.10	0.333	0.743
600.20	0.341	0.780
600.30	0.350	0.816
600.40	0.359	0.853
600.50	0.367	0.890
600.60	0.376	0.927
600.70	0.385	0.963
600.80	0.394	1.000
600.90	0.402	1.037
601.00	0.411	1.074
601.10	0.421	1.120
601.20	0.432	1.166
601.30	0.442	1.212
601.40	0.452	1.259
601.50	0.462	1.305
603' 601.60	0.473	1.351 ≈ 58,800 cf
601.70	0.483	1.397
601.80	0.493	1.444
601.90	0.504	1.490
602.00	0.514	1.536
602.10	0.526	1.594
602.20	0.538	1.651
602.30	0.550	1.708
602.40	0.562	1.766
602.50	0.573	1.823
602.60	0.585	1.880
602.70	0.597	1.938
602.80	0.609	1.995
602.90	0.621	2.052
603.00	**0.633**	**2.110**

Corrected Elevation (See Explanatio Below

El. 603 (Provides 1' freeboard)



Schematic of IRCA in Stage III

000079

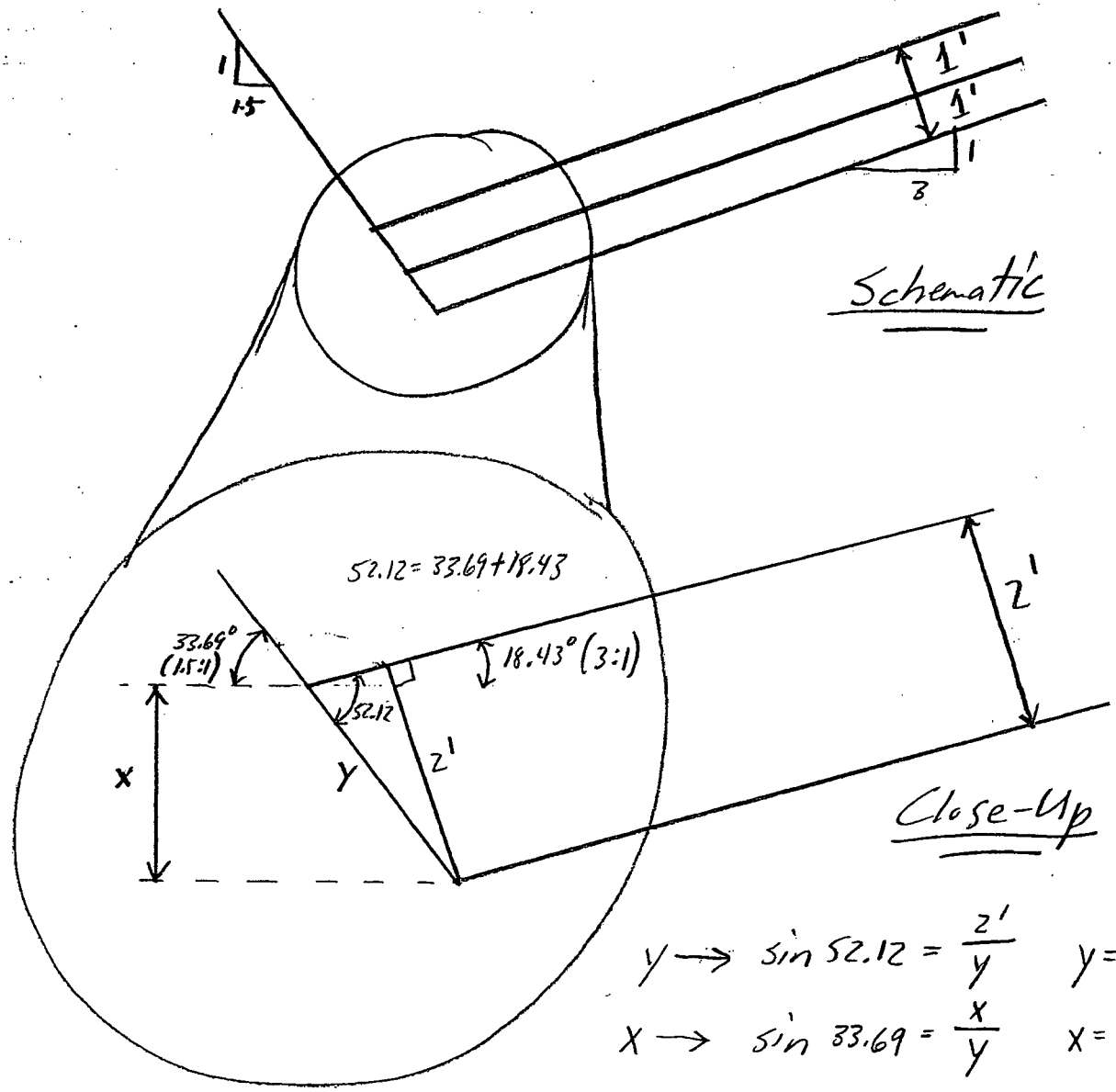
* Elevations in the table above correspond to the bottom of the contouring layer; for conservatism the capacity will be reported for the top of 2-lifts of clay by considering the capacity being reduced by 1.4' using the same geometry and adding 1.4' to the original elevation.

Written by: CDC CDC 01/23/2002 Date: __/__/__ (YY MM DD) Reviewed by: MAO Date: 02/01/24 (YY MM DD)

Client: _____ Project: _____ Project/Proposal No.: _____ Task No.: _____

= 4664

Solution to Vertical Translation of 1.4' from bottom of Contouring Layer to Top of 2 Lifts of Compacted Clay



$y \rightarrow \sin 52.12 = \frac{2'}{y}$ $y = 2.53'$

$x \rightarrow \sin 33.69 = \frac{x}{y}$ $x = 1.41'$

Vertical shift from apex of bottom of contouring to top of 2' of clay = 1.4'.

✓ 000080

-- 4664

ATTACHMENT A-2

INLET CHANNEL CALCULATIONS AND SPREADSHEETS

Written by: CDC CDC 01/23/2002 Date: 01/12/11 (YY MM DD) Reviewed by: MAD Date: 02/01/24 (YY MM DD)

Client: Fluor-Fernald Project: OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.2

Calculating Height of Flow for Discharge Channels to the 4664 Impacted Runoff Catchment Area

- Calculation will be performed for Channel C & Channel E.

Channel C

- n = 0.018 (Manning's # for straight unlined)
- Slope = 0.01
- Right sideslope = 3:1
- Left sideslope = 1.5:1
- Design Depth: ~5 ft (Scaled from drawings) → with 0.5' freeboard = 4.5
- Flow calculated from HydroCAD for Stage I.
  Q = 46.30 cfs @ 11.96 hrs (see HydroCAD output)
- h_{needed} = 1.70 ft < 4.5 ft OK V = 7.01 ft/s
  ↑ from GeoHydraulics.xls (Attached)
- Freeboard = 5' − 1.72' = 3.28' → 3.3'

Channel E

- n = 0.018
- Slope = 0.01
- Right = 1.5:1
- Left = 3:1
- Q = 31.90 cfs @ 11.94 hrs.
- h_{needed} = 1.60 ft < 4.5 ft OK V = 5.47 ft/s
- Freeboard = 5' − 1.60 ft = 3.40'

* According to this calculation, both channels contain an acceptable capacity for flow.

* Flow velocities for both channels exceed the design velocity for unlined channels (V = 2.0 ft/s). Therefore, appropriate erosion control measures should be implemented in the field.

Reach 4R: Dummy Reach (Channel C) -- 4664

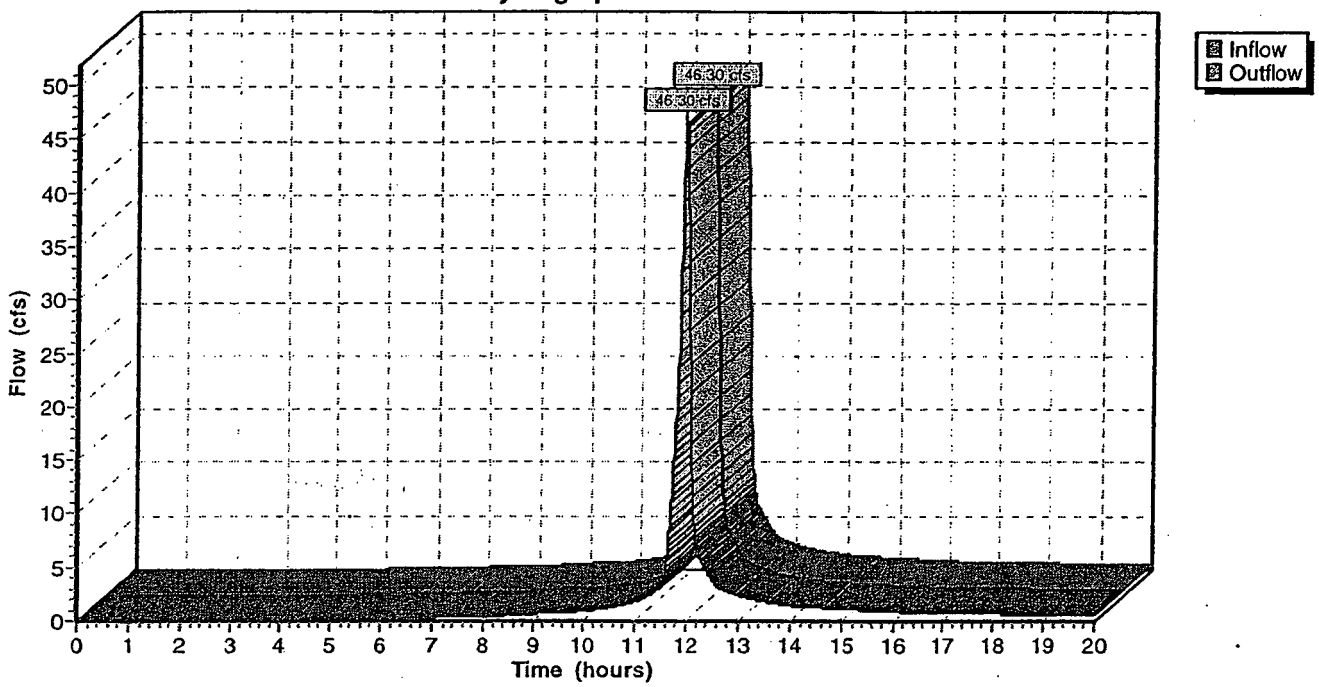
[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	46.30 cfs @ 11.96 hrs,	Volume=	2.272 af
Outflow	=	46.30 cfs @ 11.96 hrs,	Volume=	2.272 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 4R: Dummy Reach

Hydrograph Plot



Reach 5R: Dummy Reach (Channel E) -- 4664

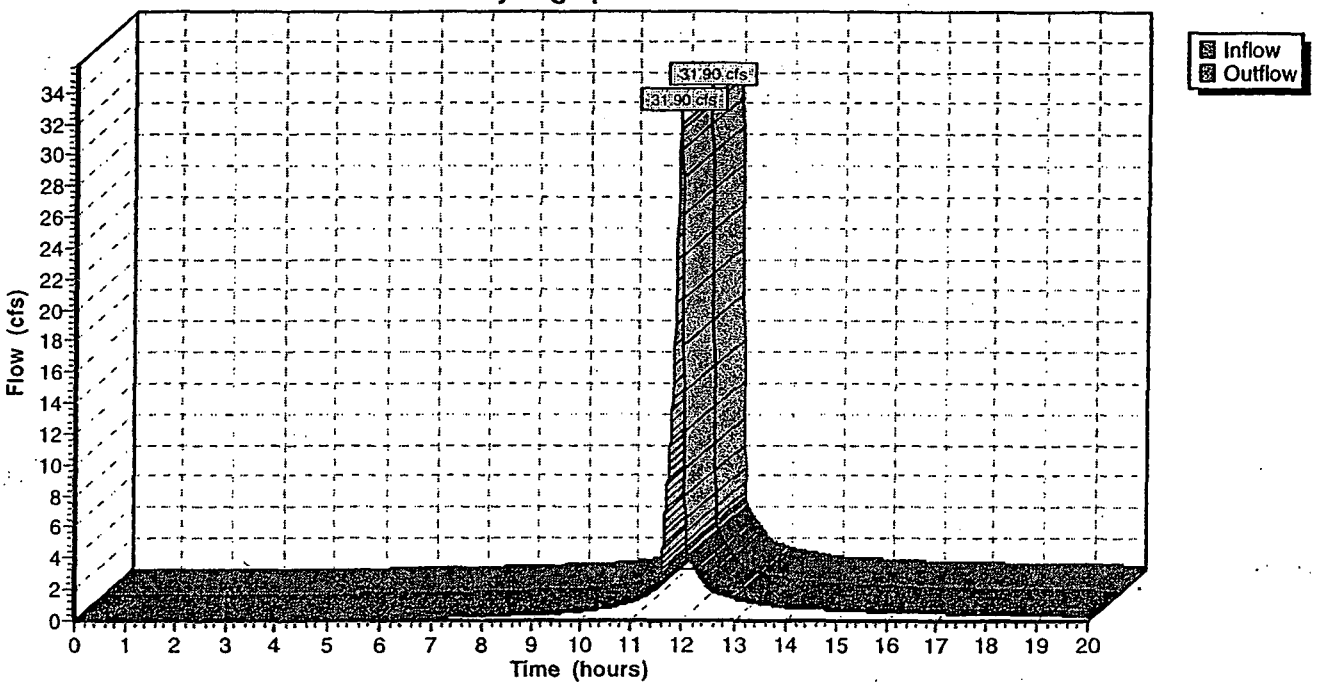
[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	31.90 cfs @ 11.94 hrs,	Volume=	1.388 af
Outflow	=	31.90 cfs @ 11.94 hrs,	Volume=	1.388 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 5R: Dummy Reach

Hydrograph Plot



MAD 24 Jan 02 CDC 01/23/2002 83 of 115

Design/Check: Trapezoidal/Triangular Channel

4664

Methodology: Manning's Equation

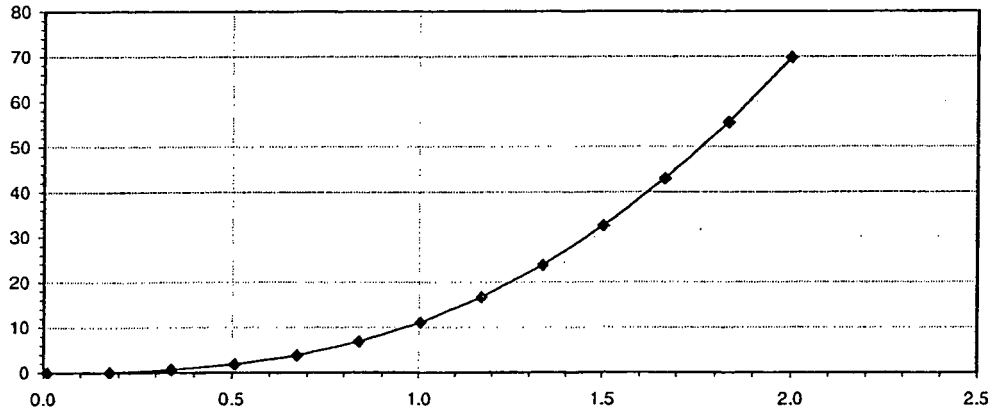
Project: Fernald OSDF Phase V

Ditch ID: Southern Inlet to Pond at Cell 7 (Channel C)

Peak Discharge, Q_{max} = 46.30 cfs
Bottom Width, B = 0.00 ft
Left Side Slope, Z_1 = 1.50 horizontal :1 vertical
Right Side Slope, Z_2 = 3.00 horizontal :1 vertical
Manning's Roughness Coeff., n = 0.018
Longitudinal Channel Slope, S_o = 0.0100 ft/ft

Depth of Flow Y ft	Area of Flow A ft²	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft³/s	Avg. Tractive Stress τ_o lb/ft²	Comments
0.01	0.00	0.05	0.00	0.23	0.00	0.00	
0.18	0.07	0.87	0.08	1.53	0.11	0.05	
0.34	0.26	1.70	0.15	2.39	0.63	0.10	
0.51	0.58	2.52	0.23	3.11	1.80	0.14	
0.67	1.02	3.34	0.31	3.75	3.83	0.19	
0.84	1.58	4.17	0.38	4.34	6.88	0.24	
1.01	2.27	4.99	0.46	4.90	11.13	0.28	
1.17	3.08	5.81	0.53	5.42	16.73	0.33	
1.34	4.02	6.64	0.61	5.93	23.82	0.38	
1.50	5.08	7.46	0.68	6.41	32.54	0.42	
1.67	6.26	8.28	0.76	6.87	43.02	0.47	
1.83	7.57	9.11	0.83	7.32	55.39	0.52	
2.00	9.00	9.93	0.91	7.75	69.77	0.57	
1.72	6.66	8.54	0.78	7.01	46.66	0.49	DESIGN Q

Discharge versus Depth Relationship



MAO 24 Jan 02 CDC 01/23/2002 84 of 115

4664

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

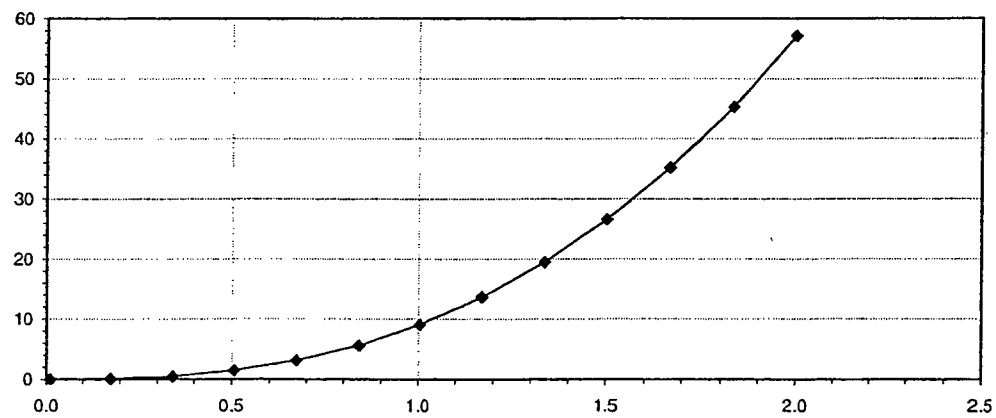
Project: Fernald OSDF Phase V

Ditch ID: Western Inlet to Pond at Cell 7 (Channel E)

Peak Discharge, Q_{max}=	31.90	cfs
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	3.00	horizontal :1 vertical
Right Side Slope, Z_2 =	1.50	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.018	
Longitudinal Channel Slope, S_o =	0.0067	ft/ft

Depth of Flow Y ft	Area of Flow A ft²	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft³/s	Avg. Tractive Stress τ_o lb/ft²	Comments
0.01	0.00	0.05	0.00	0.19	0.00	0.00	
0.18	0.07	0.87	0.08	1.25	0.09	0.03	
0.34	0.26	1.70	0.15	1.95	0.51	0.06	
0.51	0.58	2.52	0.23	2.54	1.47	0.10	
0.67	1.02	3.34	0.31	3.07	3.13	0.13	
0.84	1.58	4.17	0.38	3.56	5.63	0.16	
1.01	2.27	4.99	0.46	4.01	9.11	0.19	
1.17	3.08	5.81	0.53	4.44	13.69	0.22	
1.34	4.02	6.64	0.61	4.85	19.50	0.25	
1.50	5.08	7.46	0.68	5.24	26.63	0.28	
1.67	6.26	8.28	0.76	5.62	35.21	0.32	
1.83	7.57	9.11	0.83	5.99	45.34	0.35	
2.00	9.00	9.93	0.91	6.35	57.11	0.38	
1.60	5.76	7.94	0.73	5.47	31.50	0.30	DESIGN Q

Discharge versus Depth Relationship



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ATTACHMENT A-3

IRCA DRAWDOWN CALCULATION AND SPREADSHEET

Written by: CDC CDC 01/23/2002 Date: / / Reviewed by: MAO Date: 02/01/24

Client: Project: Project/Proposal No.: Task No.:

-- 4664

Stage I

- Vol = 195,400 cf

$Q = KiA$ $\quad Q = \frac{dV}{dt} = \frac{\Delta V}{\Delta t}$ $\quad i = 1$ (conservative to use unit gradient)

$\Delta t = \frac{\Delta V}{KiA}$ $\quad A = 1{,}360\ sf$ (see Sketch)

$k = 0.1\ cm/s = 0.0033\ ft/s$

$$\Delta t = \frac{195{,}400\ cf}{(0.0033\ ft/s)(1)(1{,}360\ sf)}$$

$\Delta t = 43{,}538\ sec = 0.5\ days.$

$Q = (0.0033\ ft/s)(1)(1{,}360\ sf)$

$= 4.488\ cf/s = 2{,}014\ gpm > 200\ gpm$ ∴ EPLTS riser pump will control.

- Ignoring Leachate Generation, Perform Simplified Calc. of Stage I drawdown.

$Q = 200\ gpm$

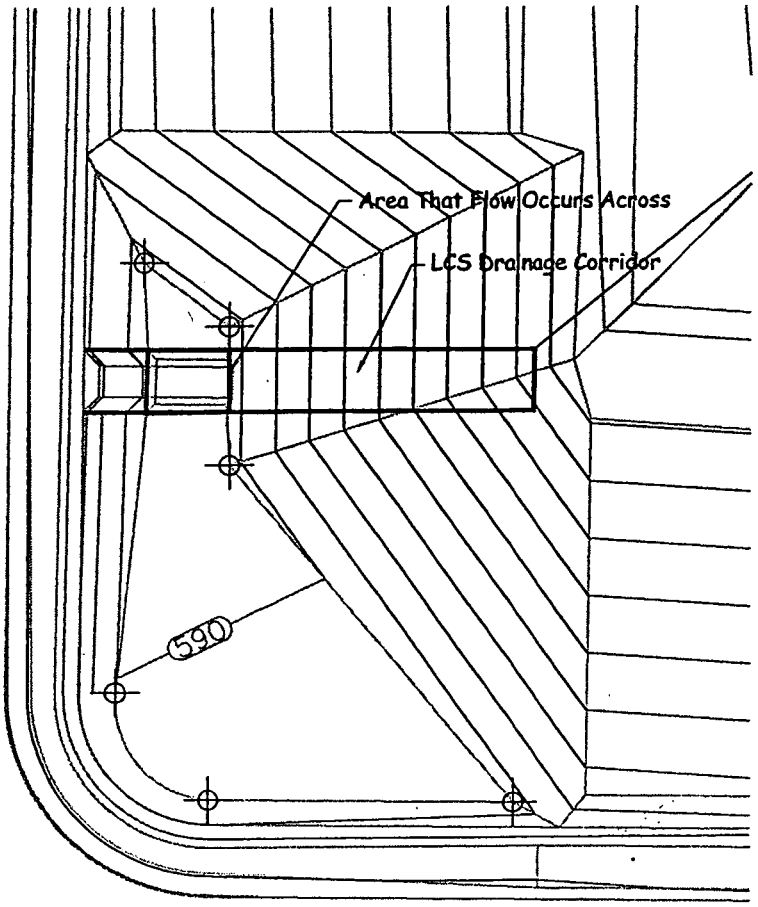
$V = 195{,}400\ cf$

$$t = \frac{V}{Q} = \frac{195{,}400\ cf\ (7.48\ gal/cf)}{200\ gal/min.}$$

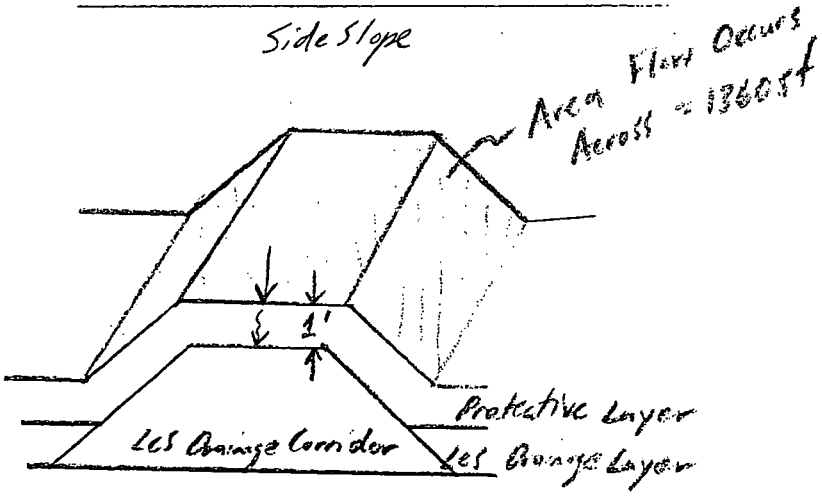
$= 7308\ min.$

$\boxed{t = 5.1\ days}$ ✓

Stage I



Side Slope



* Flow is being computed through the Protective Layer to the LCS Drainage Corridor.

Written by: CDC 01/23/2002 Date: YY/MM/DD Reviewed by: MAO Date: 02/01/24 YY/MM/DD

Client: Project: Project/Proposal No.: Task No.:

-- 4664

Stage II

- Calculation was performed using an Excel Spreadsheet.
- Calculated flow through the LCS Drainage Layer and Protective Soil Layer, which are the same material in the IRCA. (See Sketch)
- Used Darcy's Law.

$$Q = kiA \rightarrow \frac{\Delta V}{\Delta t} = Q$$

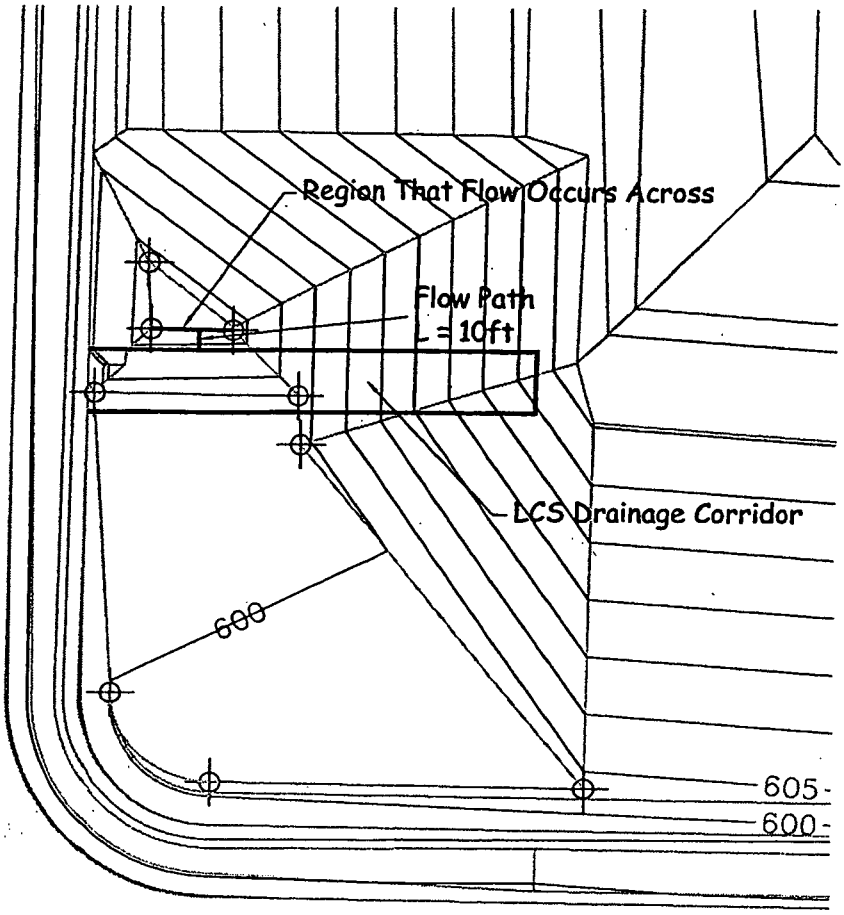
$$\Delta t = \frac{\Delta V}{kiA}$$

- HydroCAD gives the storage capacity at incremental steps in elevation. These can be used to solve for the incremental time, Δt it would take to drawdown the incremental volume, ΔV between two elevations.
- the gradient is related to the height of the water within the basin.
- Peak El. from HydroCAD = 598.82' (See Output)
- Cross-Section Length = 42' (constant)
- Thickness of Flow Area = 2' (1' Protective + 1' LCS Drainage Layer)
- Flow Length = 10' (See Sketch)

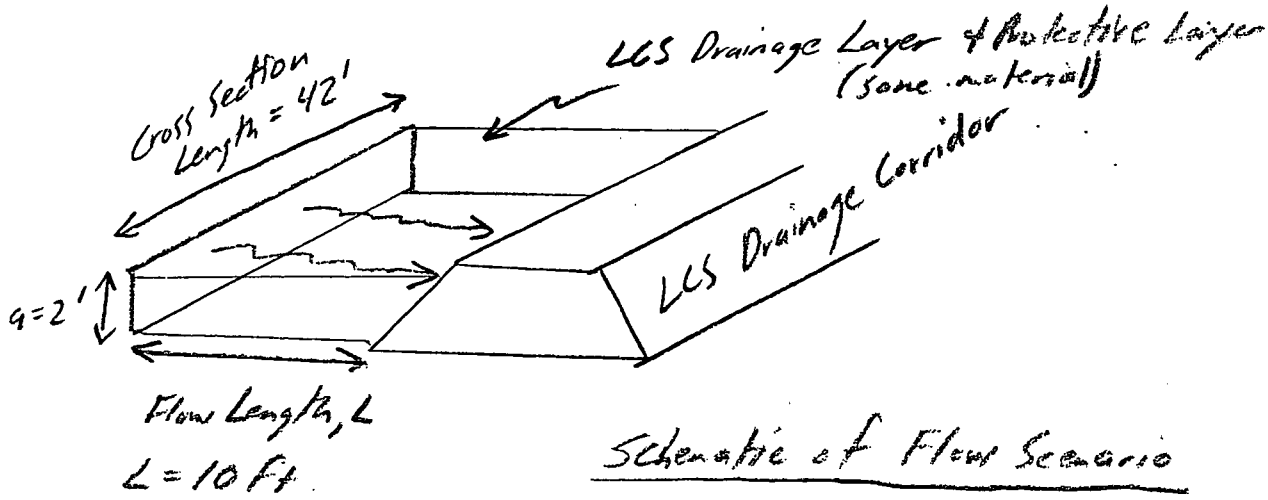
$$\boxed{\text{Total Drawdown Time} = 7.66 \text{ days.}}$$ ✓

* Flow rates are less than 200 gpm.

Stage II



Scale: 1" = 100'



Schematic of Flow Scenario

* Flow is being considered across the LCS Drainage Layer to the LCS Drainage Corridor.

MAO 24Jan02
CDC 01/23/2002 90 of 115

Pond 1P: Detention Pond

-- 4664

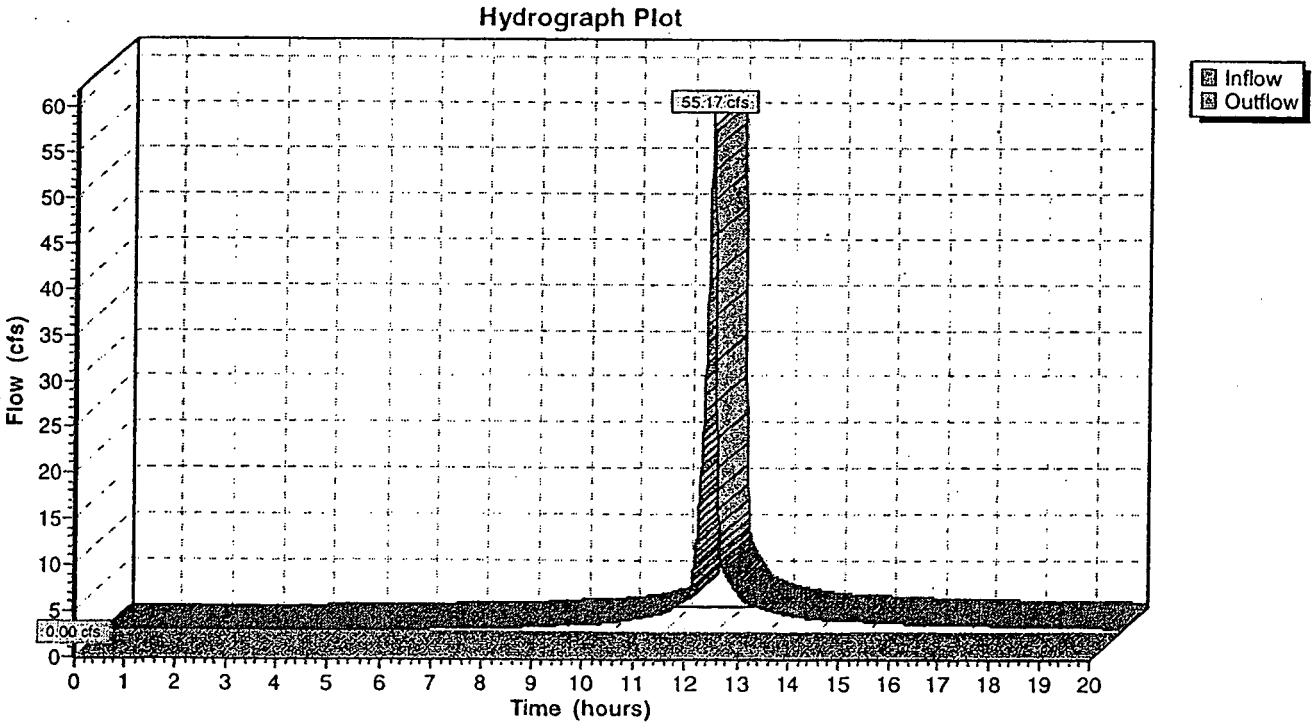
Inflow = 55.17 cfs @ 11.92 hrs, Volume= 2.593 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 599.82' Storage= 2.592 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
587.80	0.000	0.000	0.000
588.00	0.012	0.001	0.001
589.00	0.030	0.021	0.022
595.00	0.165	0.585	0.607
596.00	0.223	0.194	0.801
598.00	0.430	0.653	1.454
600.00	0.824	1.254	2.708
602.00	1.285	2.109	4.817
603.00	1.441	1.363	6.180 ≈ 269,200 cf

Pond 1P: Detention Pond



MAO 2 & JAMO 2
CDL 01/23/2002 91 of 115

Stage II Drawdown Calculation

Q = kIA	k=	0.0033 ft/s	
ΔV/Δt = kIA	L =	10 ft	
Δt = ΔV/kIA	Lfloor =	10 ft	
I = (hwater + zside)/L	Lside =	0 ft	
L = Lfloor + Lside	zside =	0 ft	
A = Cross-Section Length * a	a =	2 ft	

Total Time
661,948 sec
7.66 days

4664

Elevation (ft)	Surface (acres)	Storage (acre-ft)	Storage (cf)	Incremental Storage, ΔV (cf)	hwater (ft)	gradient, I (ft/ft)	Cross Section Length (ft)	Area, A (sf)	Q (cfs)	Q (gpm)	Δt (sec)
587.80	0.000	0.000	0.000	0.00	0.000	0.000	42	84	0	0	0
588.00	0.012	0.001	43.560	43.56	0.200	0.010	42	84	0.002772	1.2440736	15714.286
588.20	0.016	0.005	217.800	174.24	0.400	0.030	42	84	0.008316	3.7322208	20952.381
588.40	0.019	0.010	435.600	217.80	0.600	0.050	42	84	0.01386	6.220368	15714.286
588.60	0.023	0.014	609.840	174.24	0.800	0.070	42	84	0.019404	8.7085152	8979.5918
588.80	0.026	0.018	784.080	174.24	1.000	0.090	42	84	0.024948	11.196662	6984.127
589.00	0.030	0.022	958.320	174.24	1.200	0.110	42	84	0.030492	13.68481	5714.2857
589.20	0.034	0.042	1829.520	871.20	1.400	0.130	42	84	0.036036	16.172957	24175.824
589.40	0.039	0.061	2657.160	827.64	1.600	0.150	42	84	0.04158	18.661104	19904.762
589.60	0.043	0.081	3528.360	871.20	1.800	0.170	42	84	0.047124	21.149251	18487.395
589.80	0.048	0.100	4356.000	827.64	2.000	0.190	42	84	0.052668	23.637398	15714.286
590.00	0.052	0.120	5227.200	871.20	2.200	0.210	42	84	0.058212	26.125546	14965.986
590.20	0.057	0.139	6054.840	827.64	2.400	0.230	42	84	0.063756	28.613693	12981.366
590.40	0.061	0.159	6926.040	871.20	2.600	0.250	42	84	0.0693	31.10184	12571.429
590.60	0.066	0.178	7753.680	827.64	2.800	0.270	42	84	0.074844	33.589987	11058.201
590.80	0.070	0.198	8624.880	871.20	3.000	0.290	42	84	0.080388	36.078134	10837.438
591.00	0.075	0.217	9452.520	827.64	3.200	0.310	42	84	0.085932	38.566282	9631.3364
591.20	0.079	0.237	10323.720	871.20	3.400	0.330	42	84	0.091476	41.054429	9523.8095
591.40	0.084	0.256	11151.360	827.64	3.600	0.350	42	84	0.09702	43.542576	8530.6122
591.60	0.088	0.276	12022.560	871.20	3.800	0.370	42	84	0.102564	46.030723	8494.2085
591.80	0.093	0.295	12850.200	827.64	4.000	0.390	42	84	0.108108	48.51887	7655.6777
592.00	0.097	0.315	13721.400	871.20	4.200	0.410	42	84	0.113652	51.007018	7665.5052
592.20	0.102	0.334	14549.040	827.64	4.400	0.430	42	84	0.119196	53.495165	6943.5216
592.40	0.106	0.354	15420.240	871.20	4.600	0.450	42	84	0.12474	55.983312	6984.127
592.60	0.111	0.373	16247.880	827.64	4.800	0.470	42	84	0.130284	58.471459	6352.5836
592.80	0.115	0.393	17119.080	871.20	5.000	0.490	42	84	0.135828	60.959606	6413.9942
593.00	0.120	0.412	17946.720	827.64	5.200	0.510	42	84	0.141372	63.447754	5854.3417
593.20	0.124	0.432	18817.920	871.20	5.400	0.530	42	84	0.146916	65.935901	5929.9191
593.40	0.129	0.451	19645.560	827.64	5.600	0.550	42	84	0.15246	68.424048	5428.5714
593.60	0.133	0.471	20516.760	871.20	5.800	0.570	42	84	0.158004	70.912195	5513.7845
593.80	0.138	0.490	21344.400	827.64	6.000	0.590	42	84	0.163548	73.400342	5060.5327
594.00	0.142	0.510	22215.600	871.20	6.200	0.610	42	84	0.169092	75.88849	5152.2248
594.20	0.147	0.529	23043.240	827.64	6.400	0.630	42	84	0.174636	78.376637	4739.229
594.40	0.151	0.549	23914.440	871.20	6.600	0.650	42	84	0.18018	80.864784	4835.1648
594.60	0.156	0.568	24742.080	827.64	6.800	0.670	42	84	0.185724	83.352931	4456.29
594.80	0.160	0.588	25613.280	871.20	7.000	0.690	42	84	0.191268	85.841078	4554.8654
595.00	0.165	0.607	26440.920	827.64	7.200	0.710	42	84	0.196812	88.329226	4205.2314
595.20	0.177	0.646	28139.760	1698.84	7.400	0.730	42	84	0.202356	90.817373	8395.3033
595.40	0.188	0.685	29838.600	1698.84	7.600	0.750	42	84	0.2079	93.30552	8171.4286
595.60	0.200	0.724	31537.440	1698.84	7.800	0.770	42	84	0.213444	95.793667	7959.1837
595.80	0.211	0.762	33192.720	1655.28	8.000	0.790	42	84	0.218988	98.281814	7558.7703
596.00	0.223	0.801	34891.560	1698.84	8.200	0.810	42	84	0.224532	100.76996	7566.1376
596.20	0.244	0.866	37722.960	2831.40	8.400	0.830	42	84	0.230076	103.25811	12306.368
596.40	0.264	0.932	40597.920	2874.96	8.600	0.850	42	84	0.23562	105.74626	12201.681
596.60	0.285	0.997	43429.320	2831.40	8.800	0.870	42	84	0.241164	108.2344	11740.558
596.80	0.306	1.062	46260.720	2831.40	9.000	0.890	42	84	0.246708	110.72255	11476.726
597.00	0.326	1.128	49135.680	2874.96	9.200	0.910	42	84	0.252252	113.2107	11397.174
597.20	0.347	1.193	51967.080	2831.40	9.400	0.930	42	84	0.257796	115.69884	10983.103
597.40	0.368	1.258	54798.480	2831.40	9.600	0.950	42	84	0.26334	118.18699	10751.88
597.60	0.389	1.324	57673.440	2874.96	9.800	0.970	42	84	0.268884	120.67514	10692.194
597.80	0.409	1.389	60504.840	2831.40	10.000	0.990	42	84	0.274428	123.16329	10317.46
598.00	0.430	1.454	63336.240	2831.40	10.200	1.010	42	84	0.279972	125.65143	10113.154
598.200	0.469	1.580	68824.800	5488.56	10.400	1.030	42	84	0.285516	128.13958	19223.301
598.400	0.509	1.705	74269.800	5445.00	10.600	1.050	42	84	0.29106	130.62773	18707.483
598.600	0.548	1.830	79714.800	5445.00	10.800	1.070	42	84	0.296604	133.11588	18357.81
598.800	0.588	1.956	85203.360	5488.56	11.000	1.090	42	84	0.302148	135.60402	18165.138
599.000	0.627	2.081	90648.360	5445.00	11.200	1.110	42	84	0.307692	138.09217	17696.268
599.200	0.666	2.207	96136.920	5488.56	11.400	1.130	42	84	0.313236	140.58032	17522.124
599.400	0.706	2.332	101581.920	5445.00	11.600	1.150	42	84	0.31878	143.06846	17080.745
599.600	0.745	2.457	107026.920	5445.00	11.800	1.170	42	84	0.324324	145.55661	16788.767
599.800	0.785	2.583	112515.480	5488.56	12.000	1.190	42	84	0.329868	148.04476	16638.655
599.820	-	2.594	113000.000	484.52	12.020	1.201	42	84	0.3329172	149.41324	1455.3769

Written by: CDC 01/23/2002 Date: YY/MM/DD Reviewed by: MAO Date: 02/01/24 YY/MM/DD

Client: Project: Project/Proposal No.: Task No.:

- 4664

Stage III

- Calculation was performed using same method as Stage II using an Excel Spreadsheet (see attached).
- Calculated flow through LCS Drainage Layer and Protective Soil Layer, which are the same material in the IRCA.
- Used Darcy's Law

$$Q = KiA \qquad \frac{\Delta V}{\Delta t} = Q \rightarrow \Delta t = \frac{\Delta V}{KiA}$$

- Used HydroCAD storage capacity output.
- The gradient is related to the height of the water, hwater and the side slope height, Z sideslope as follows.

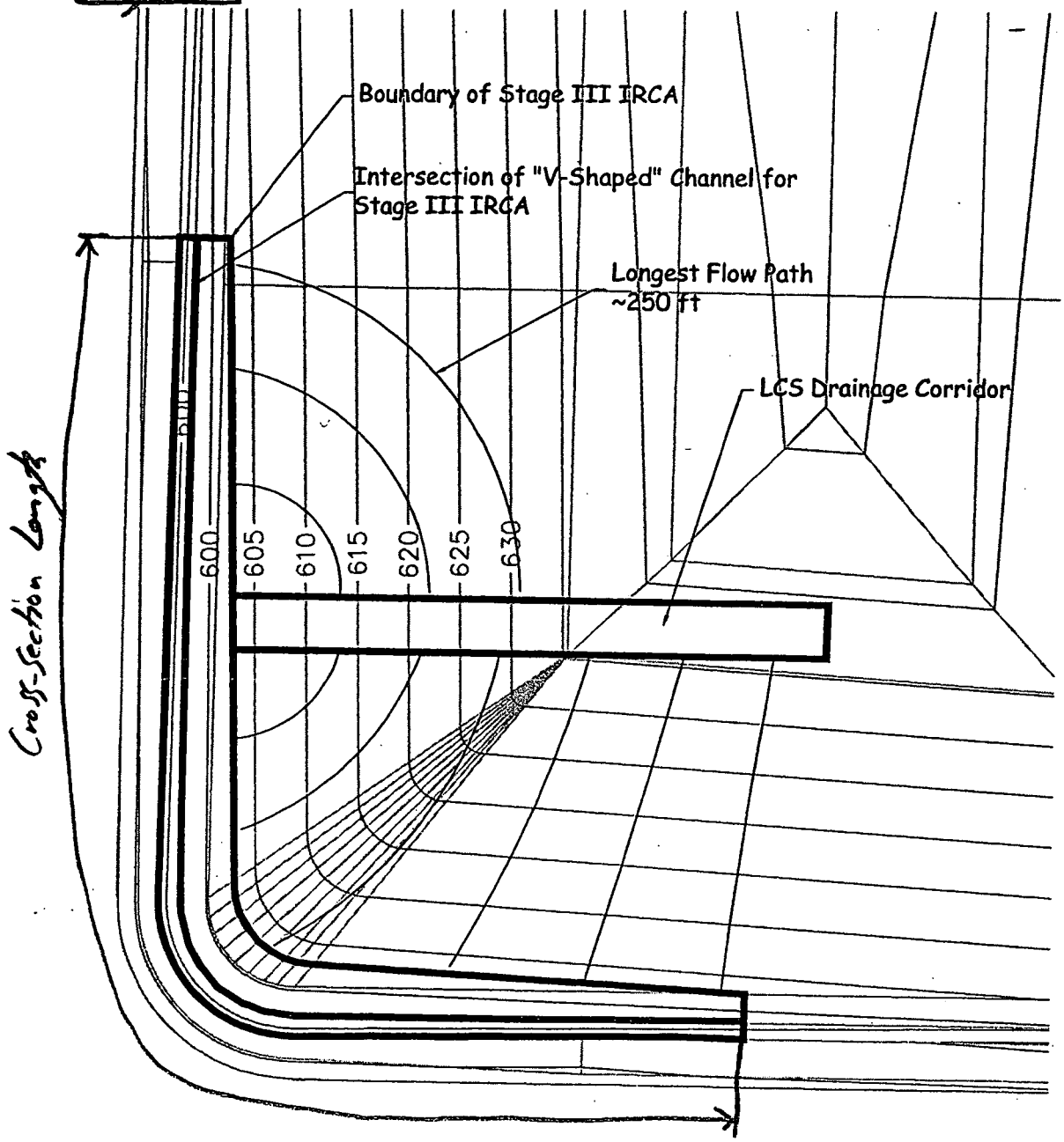
$$i = \frac{h_{water} + Z_{sideslope}}{L}$$ ← Flow length.

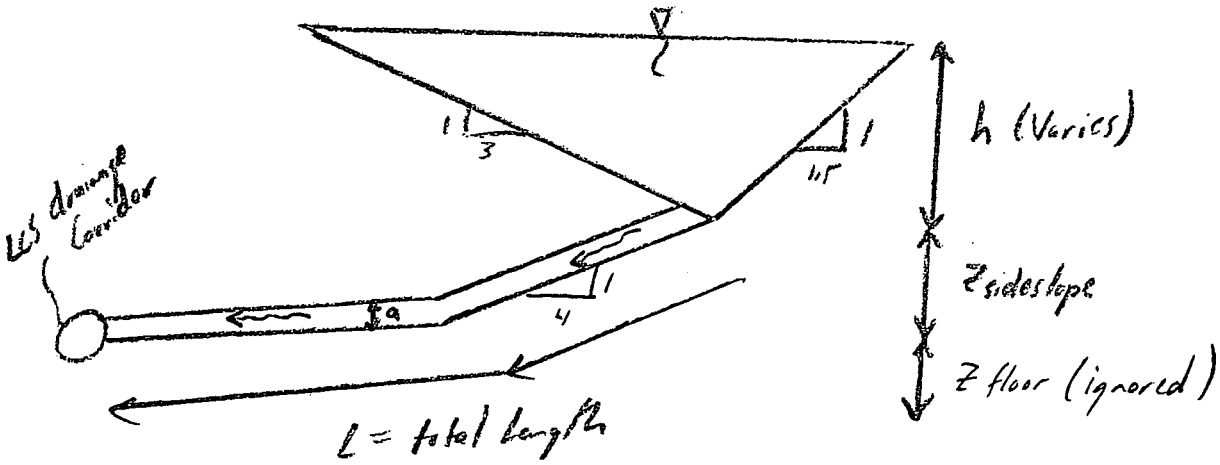
- Peak elev. from Hydrocad = 601.22' (see output sheet)
- Cross-Section Length - Varies from 0 to 750'
  - As Elevation drops below ~El. 597.8 the length of the channel carrying water reduces approximately linearly to 0 ft at El. 594.8.
- Thickness of Flow Area = 2' (1' Protective + 1' LCS Drainage Layer)
- Flow length Across Floor = 250'
- Flow length down sideslope = 12'

$$\boxed{\text{Total Drawdown Time} = 5.22 \text{ days}}$$

4664

Stage III





MAO 24 Jan 02
CDL 01/23/2002 94 of 115

- 4664

Pond 1P: Detention Pond

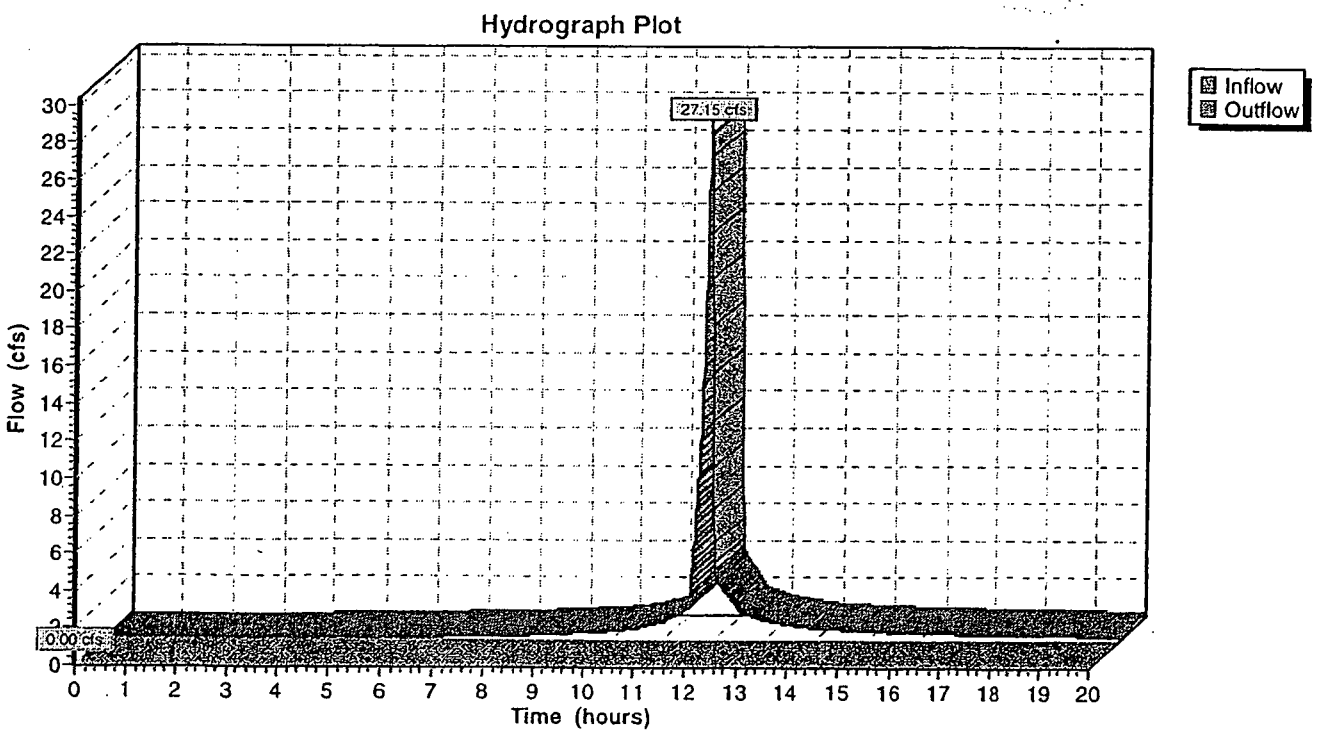
Inflow	=	27.15 cfs @	11.92 hrs,	Volume=	1.176 af
Outflow	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 601.22' Storage= 1.176 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
594.80	0.000	0.000	0.000
595.00	0.002	0.000	0.000
596.00	0.033	0.017	0.018
597.00	0.093	0.063	0.081
598.00	0.170	0.131	0.212
599.00	0.247	0.208	0.421
600.00	0.324	0.286	0.706
601.00	0.411	0.367	1.074
602.00	0.514	0.462	1.536
603.00	0.633	0.573	2.110

Pond 1P: Detention Pond



MATO 2W Jan02
CDC 01/23/2002 95 of 115

- 4664

Stage III Drawdown Calculation

Q = kiA	k=	0.0033 ft/s	
ΔV/Δt = kiA	L =	262 ft	
Δt = ΔV/kiA	Lfloor =	250 ft	
i = (hwater + zsideslope)/L	Lsideslope =	12 ft	
L = Lfloor + Lside	zsideslope =	3 ft	
A = Cross-Section Length * a	a =	2 ft	

Total Time
451.038 sec
5.22 days

Elevation (ft)	Surface (acres)	Storage (acre-ft)	Storage (cf)	Incremental Storage, ΔV (cf)	hwater (ft)	gradient, i (ft/ft)	Cross Section Length (ft)	Area, A (sf)	Q (cfs)	Q (gpm)	Δt (sec)
594.80	0.000	0.000	0.000	0.00	0.000	0.011	0	0	0	0	0
594.90	0.001	0.000	0.000	0.00	0.100	0.012	25	50	0.0019208	0.8620557	0
595.00	0.002	0.000	0.000	0.00	0.200	0.012	50	100	0.0039676	1.7806397	0
595.10	0.005	0.002	87.120	87.12	0.300	0.012	75	150	0.0061403	2.7557519	14188.308
595.20	0.008	0.004	174.240	87.12	0.400	0.013	100	200	0.0084389	3.7873924	10323.582
595.30	0.011	0.005	217.800	43.56	0.500	0.013	125	250	0.0108635	4.8755611	4009.7391
595.40	0.014	0.007	304.920	87.12	0.600	0.014	150	300	0.0134141	6.020258	6494.6479
595.50	0.017	0.009	392.040	87.12	0.700	0.014	175	350	0.0160906	7.2214832	5414.3249
595.60	0.021	0.011	479.160	87.12	0.800	0.014	200	400	0.0188931	8.4792366	4611.2
595.70	0.024	0.012	522.720	43.56	0.900	0.015	225	450	0.0218216	9.7935183	1996.1905
595.80	0.027	0.014	609.840	87.12	1.000	0.015	250	500	0.024876	11.164328	3502.1772
595.90	0.030	0.016	696.960	87.12	1.100	0.015	275	550	0.0280563	12.591666	3105.1852
596.00	0.033	0.018	784.080	87.12	1.200	0.016	300	600	0.0313626	14.075533	2777.8313
596.10	0.039	0.024	1045.440	261.36	1.300	0.016	325	650	0.0347948	15.615927	7511.457
596.20	0.045	0.030	1306.800	261.36	1.400	0.017	350	700	0.0383531	17.21285	6814.5813
596.30	0.051	0.037	1611.720	304.92	1.500	0.017	375	750	0.0420372	18.866302	7253.573
596.40	0.057	0.043	1873.080	261.36	1.600	0.017	400	800	0.0458473	20.576281	5700.6593
596.50	0.063	0.049	2134.440	261.36	1.700	0.018	425	850	0.0497834	22.342789	5249.9431
596.60	0.069	0.055	2395.800	261.36	1.800	0.018	450	900	0.0538454	24.165824	4853.8947
596.70	0.075	0.062	2700.720	304.92	1.900	0.019	475	950	0.0580334	26.045389	5254.216
596.80	0.081	0.068	2962.080	261.36	2.000	0.019	500	1000	0.0623473	27.981481	4192
596.90	0.087	0.074	3223.440	261.36	2.100	0.019	525	1050	0.0667872	29.974102	3913.3239
597.00	0.093	0.081	3528.360	304.92	2.200	0.020	550	1100	0.0713531	32.02325	4273.3981
597.10	0.101	0.094	4094.640	566.28	2.300	0.020	575	1150	0.0760448	34.128927	7446.6584
597.20	0.108	0.107	4660.920	566.28	2.400	0.020	600	1200	0.0808626	36.291133	7002.9907
597.30	0.116	0.120	5227.200	566.28	2.500	0.021	625	1250	0.0858063	38.509866	6599.5156
597.40	0.124	0.133	5793.480	566.28	2.600	0.021	650	1300	0.090876	40.785128	6231.3514
597.50	0.131	0.146	6359.760	566.28	2.700	0.022	675	1350	0.0960716	43.116918	5894.3559
597.60	0.139	0.160	6969.600	609.84	2.800	0.022	700	1400	0.1013931	45.505237	6014.6087
597.70	0.147	0.173	7535.880	566.28	2.900	0.022	725	1450	0.1068406	47.950083	5300.2299
597.80	0.155	0.186	8102.160	566.28	3.000	0.023	750	1500	0.1124141	50.451458	5037.4454
597.90	0.162	0.199	8668.440	566.28	3.100	0.023	750	1500	0.1143034	51.299382	4954.1818
598.00	0.170	0.212	9234.720	566.28	3.200	0.023	750	1500	0.1161927	52.147305	4873.626
598.10	0.178	0.233	10149.480	914.76	3.300	0.024	750	1500	0.1180821	52.995229	7746.816
598.20	0.185	0.254	11064.240	914.76	3.400	0.024	750	1500	0.1199714	53.843153	7624.8189
598.30	0.193	0.275	11979.000	914.76	3.500	0.025	750	1500	0.1218607	54.691076	7506.6047
598.40	0.201	0.296	12893.760	914.76	3.600	0.025	750	1500	0.12375	55.539	7392
598.50	0.208	0.316	13764.960	871.20	3.700	0.025	750	1500	0.1256393	56.386924	6934.1353
598.60	0.216	0.337	14679.720	914.76	3.800	0.026	750	1500	0.1275286	57.234847	7172.9778
598.70	0.224	0.358	15594.480	914.76	3.900	0.026	750	1500	0.1294179	58.082771	7068.2628
598.80	0.232	0.379	16509.240	914.76	4.000	0.027	750	1500	0.1313073	58.930695	6966.5612
598.90	0.239	0.400	17424.000	914.76	4.100	0.027	750	1500	0.1331966	59.778618	6867.7447
599.00	0.247	0.421	18338.760	914.76	4.200	0.027	750	1500	0.1350859	60.626542	6771.6923
599.10	0.255	0.449	19558.440	1219.68	4.300	0.028	750	1500	0.1369752	61.474466	8904.3862
599.20	0.262	0.478	20821.680	1263.24	4.400	0.028	750	1500	0.1388645	62.322389	9096.9252
599.30	0.270	0.506	22041.360	1219.68	4.500	0.028	750	1500	0.1407538	63.170313	8665.3423
599.40	0.278	0.535	23304.600	1263.24	4.600	0.029	750	1500	0.1426431	64.018237	8855.947
599.50	0.285	0.563	24524.280	1219.68	4.700	0.029	750	1500	0.1445324	64.86616	8438.7974
599.60	0.293	0.592	25787.520	1263.24	4.800	0.030	750	1500	0.1464218	65.714084	8627.4065
599.70	0.301	0.621	27050.760	1263.24	4.900	0.030	750	1500	0.1483111	66.562008	8517.5032
599.80	0.309	0.649	28270.440	1219.68	5.000	0.030	750	1500	0.1502004	67.409931	8120.3522
599.90	0.316	0.678	29533.680	1263.24	5.100	0.031	750	1500	0.1520897	68.257855	8305.8882
600.000	0.324	0.706	30753.360	1219.68	5.200	0.031	750	1500	0.153979	69.105779	7921.0798
600.100	0.333	0.743	32365.080	1611.72	5.300	0.031	750	1500	0.1558683	69.953702	10340.267
600.200	0.341	0.780	33976.800	1611.72	5.400	0.032	750	1500	0.1577576	70.801626	10216.431
600.300	0.350	0.816	35544.960	1568.16	5.500	0.032	750	1500	0.1596469	71.64955	9822.6746
600.400	0.359	0.853	37156.680	1611.72	5.600	0.033	750	1500	0.1615363	72.497473	9977.4503
600.500	0.367	0.890	38768.400	1611.72	5.700	0.033	750	1500	0.1634256	73.345397	9862.104
600.600	0.376	0.927	40380.120	1611.72	5.800	0.033	750	1500	0.1653149	74.193321	9749.3943
600.700	0.385	0.963	41948.280	1568.16	5.900	0.034	750	1500	0.1672042	75.041244	9378.7119
600.800	0.394	1.000	43560.000	1611.72	6.000	0.034	750	1500	0.1690935	75.889168	9531.5307
600.900	0.402	1.037	45171.720	1611.72	6.100	0.035	750	1500	0.1709828	76.737092	9426.2099
601.000	0.411	1.074	46783.440	1611.72	6.200	0.035	750	1500	0.1728721	77.585015	9323.1913
601.100	0.421	1.120	48787.200	2003.76	6.300	0.035	750	1500	0.1747615	78.432939	11465.686
601.200	0.432	1.166	50790.960	2003.76	6.400	0.036	750	1500	0.1766508	79.280863	11343.059
601.22	-	1.175	51200.000	409.04	6.420	0.036	750	1500	0.1777844	79.789617	2300.7649

ATTACHMENT A-4

ESTIMATE OF IMPACTED MATERIAL REMAINING TO BE PLACED FOR STAGES I AND II

Written by: CDC CDC 01/23/2002 Date: 01/12/11 Reviewed by: MAO Date: 02/01/24
YY MM DD YY MM DD

Client: Fluor Fernald Project: OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.2

- 4664

Estimate of Impacted Material Remaining to be Placed for Stage I and Stage II.

- Two methods were used to estimate the Volume

① Method 1. - Use of Isopach in AutoCAD to find the volume between two surfaces.

* Used to estimate the Total Impacted Material Volume for Stage I & II (see attached sheets).

② Method 2 - Find Plan area in AutoCAD & correct for the Surface Area and multiply by the thickness

* Used to estimate the Select Impacted Material Volume for Stage I & II. (See attached Sheets).

CDC 123/2002 98 of 115
MAO 24 Jan 02

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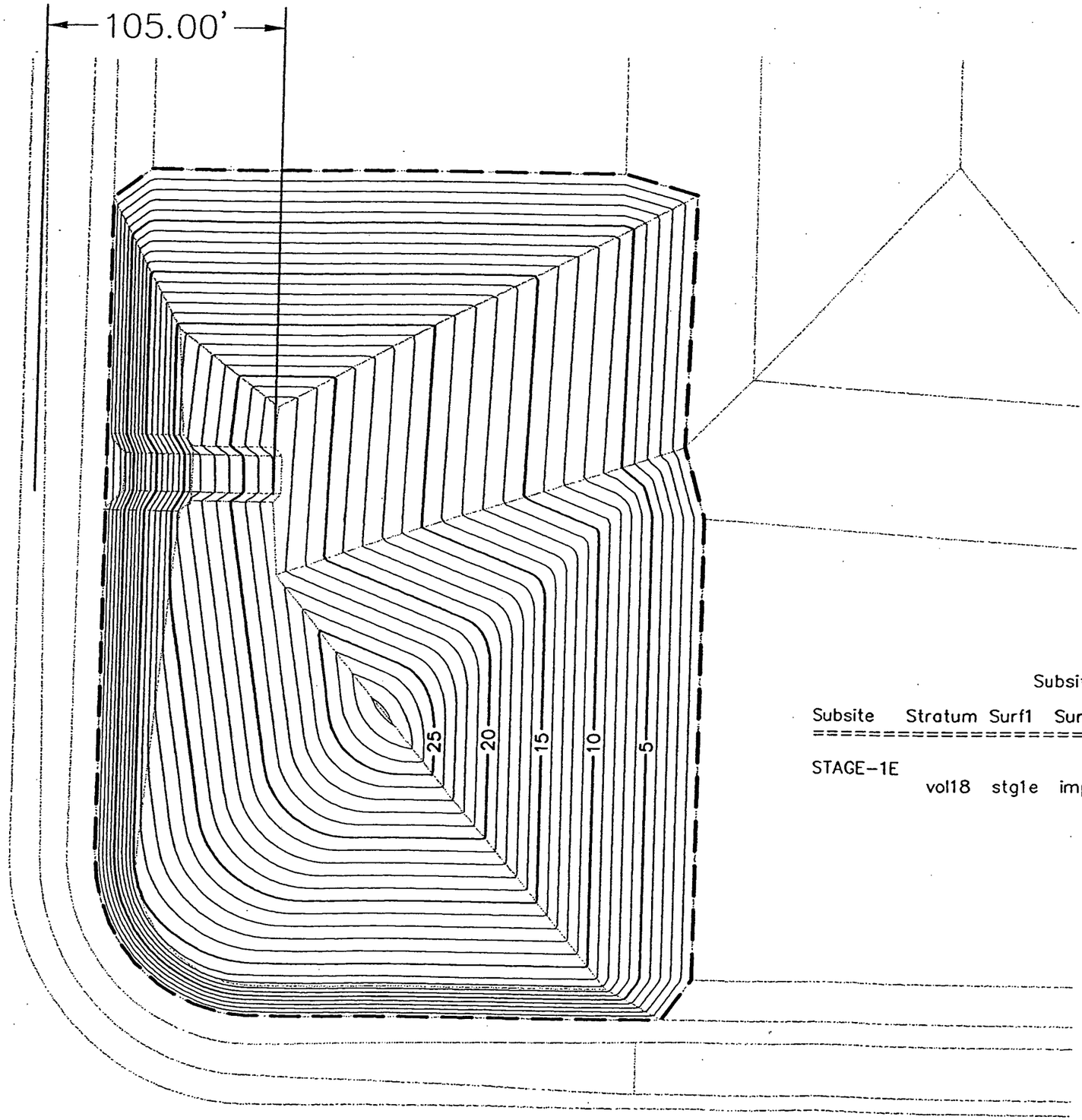

Subsite Volume Table: Unadjusted

Subsite	Stratum	Surf1	Surf2	Cut yards	Fill yards	Net yards
STAGE-1E						
	vol18	stg1e	imp67	0	41001	41001 (F)

CELL 7 CATCHMENT (STAGE I)
TO
CELL 7 FULL CAPACITY

000100

GEOSYNTEC CONSULTANTS
ATLANTA, GA

PROJECT NO. GQ1342-17.2		FIGURE NO.	–
DOCUMENT NO.	–	FILE NO.	F01-V018

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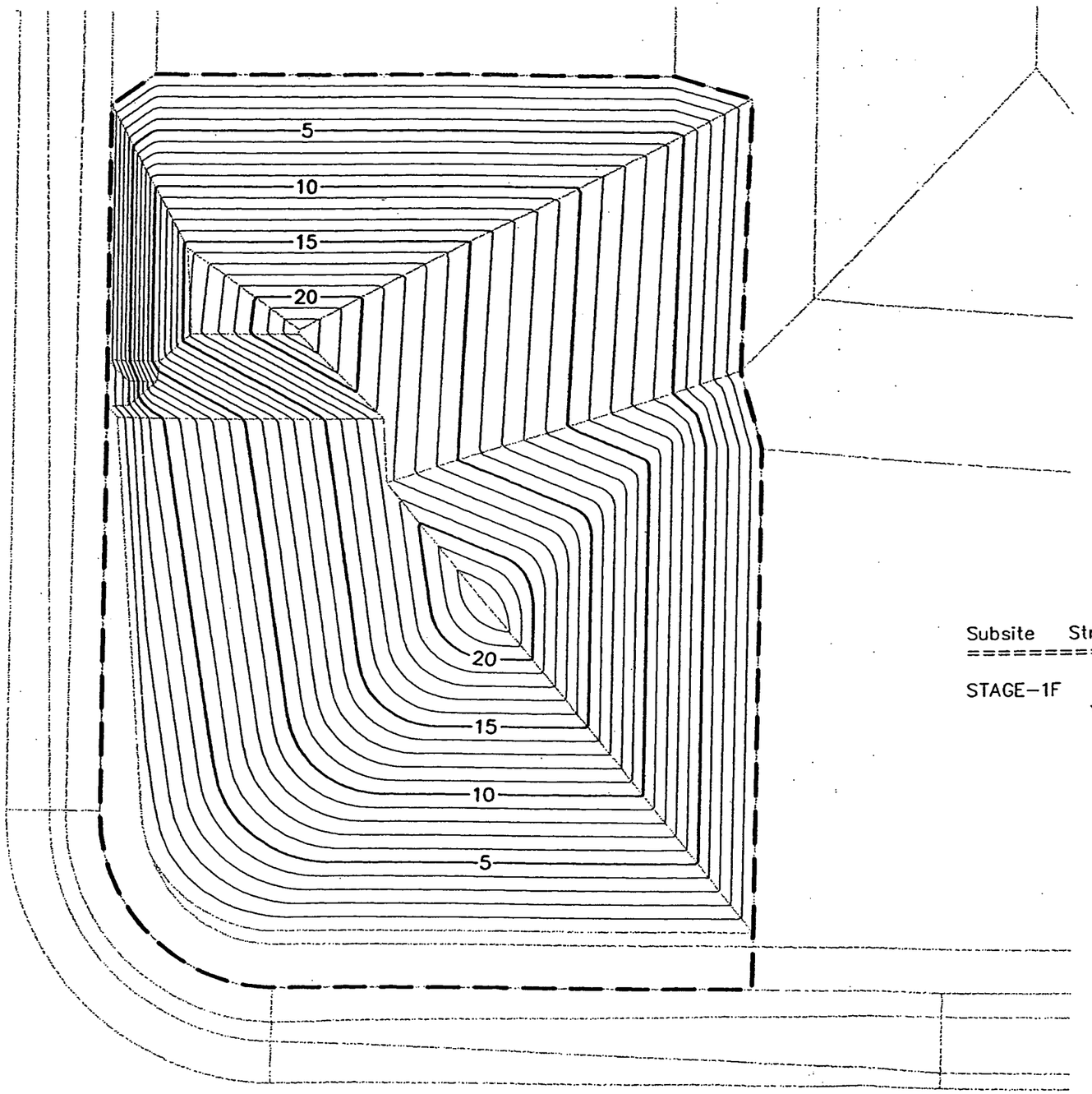

Subsite Volume Table: Unadjusted

Subsite	Stratum	Surf1	Surf2	Cut yards	Fill yards	Net yards
STAGE-1F	vol20	stg1f	imp67	0	29004	29004 (F)

CELL 7 (STAGE II)
TO
CELL 7 (FULL)

000101

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ATLANTA, GA

PROJECT NO. GQ1342-17.2	FIGURE NO. –
DOCUMENT NO. –	FILE NO. F01-V020

Written by: CDC CDC 01/23/2002 Date: / / YY MM DD Reviewed by: MAD Date: 02/01/24 YY MM DD

Client: Fluor Fernald Project: OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.2

Estimating Volume of Select Impacted Material Required for Staged Closure.

Stage I - 4664

Lower Layer – Use Stage I IRIA drawing

– 4:1 Sideslope

Plan Area = 10,700 sf

Corrected Surface Area = $10{,}700\,sf\left(\frac{\sqrt{4^2+1}}{4}\right) = 11{,}029\,sf$

Volume = 11,029 sf * 3' = 33,088 cf = 1225 cy

– Cell Floor

Plan Area = 25,411 sf

Corrected S.A. ≈ Plan Area (Very Shallow Slope)

Volume = 25,411 sf * 3' = 76,233 cf = 2,823 cy

Upper Layer – Use Stage I outline & Stage III drawing.

– 3:1 Plan Area = 9,906 sf

Corrected S.A. = $9{,}906\,sf\left(\frac{\sqrt{3^2+1}}{3}\right) = 10{,}442\,sf$

Vol. = 10,442 sf * 3' = 31,326 cf = 1,160 cy

– 6:1 Plan Area = 77,565 sf

Corrected S.A. = $77{,}565\,sf\left(\frac{\sqrt{6^2+1}}{6}\right) = 78{,}635\,sf$

Vol. = 78,635 sf * 3' = 235,905 cf = 8,737 cy

– 10:1 Plan Area = 4,309 sf

Corrected S.A. = $4309\left(\frac{\sqrt{10^2+1}}{10}\right) = 4331\,sf$

Vol. = 4331 * 3' = 12,991 cf = 481 cy

Total Select Impacted Material Volume

= 11,225 cy + 2,823 cy + 1,160 cy + 8,737 cy + 481 cy

= 14,426 cy

Written by: CDC CDC 01/23/2002 Date: __/__/__ YY MM DD Reviewed by: MAD Date: 02/01/24 YY MM DD

Client: Fluor-Fernald Project: OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.2

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Stage II

Lower Layer – Use Stage II IRCA drawing

- 4:1 Side Slope

  Plan Area = 2234 sf

  Corrected S.A. = $2234\,sf \left(\frac{\sqrt{4^2+1}}{4}\right) = 2303\,sf$

  Vol. = 2,303 sf * 3' = 6908 cf = 256 cy

- Cell Floor

  Plan Area = 762 sf

  Corrected S.A. ≈ Plan Area

  Volume = 762 sf * 3' = 2,286 cf = 85 cy

Upper Layer – Same as Stage I w/exception of southern edge.
(Use Stage II IRCA to subtract Southern edge)

Subtotal (From Stage I)

Vol. = 10,378 cy

Volumes to be subtracted (already constructed prior to Stage II)

- 3:1 Slope

  Plan Area = 6429 sf

  Corrected S.A. = $6429\,sf \left(\frac{\sqrt{3^2+1}}{3}\right) = 6677\,sf$

  Vol. = 6677 sf * 3' = 20,330 cf = 753 cy.

- 6:1 slope

  Plan Area = 1,253 sf

  Corrected S.A. = $1{,}253\,sf \left(\frac{\sqrt{6^2+1}}{6}\right) = 1{,}270\,sf$

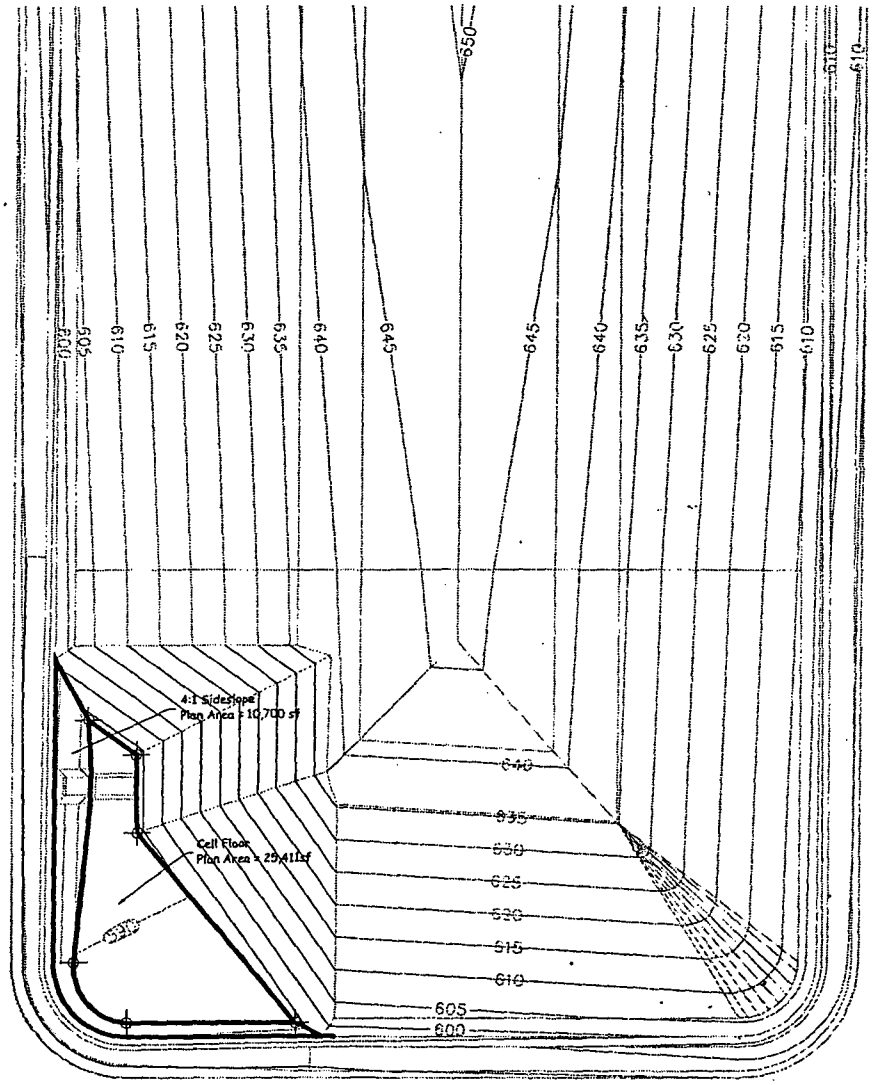
  Vol. = 1,270 * 3' = 3811 cf = 141 cy

Total select Impacted Material Volume

= 256 cy + 85 cy + 10,378 cy − 753 cy − 141 cy

= 9,825 cy

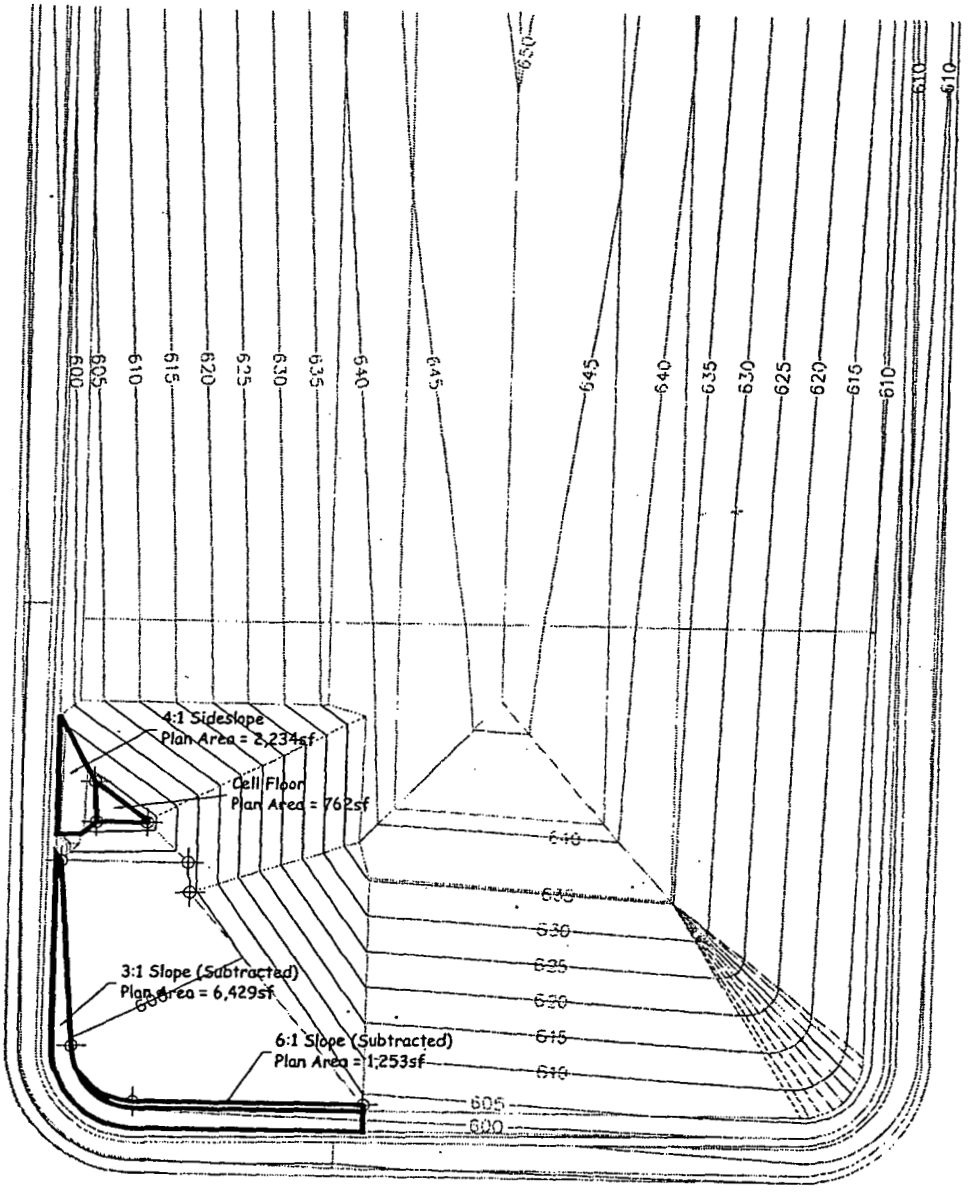
CDL 01/23/2002 102 of 115
MAO 2u Jan02
- 4664



Stage I – Lower Layer of Select Impacted Material

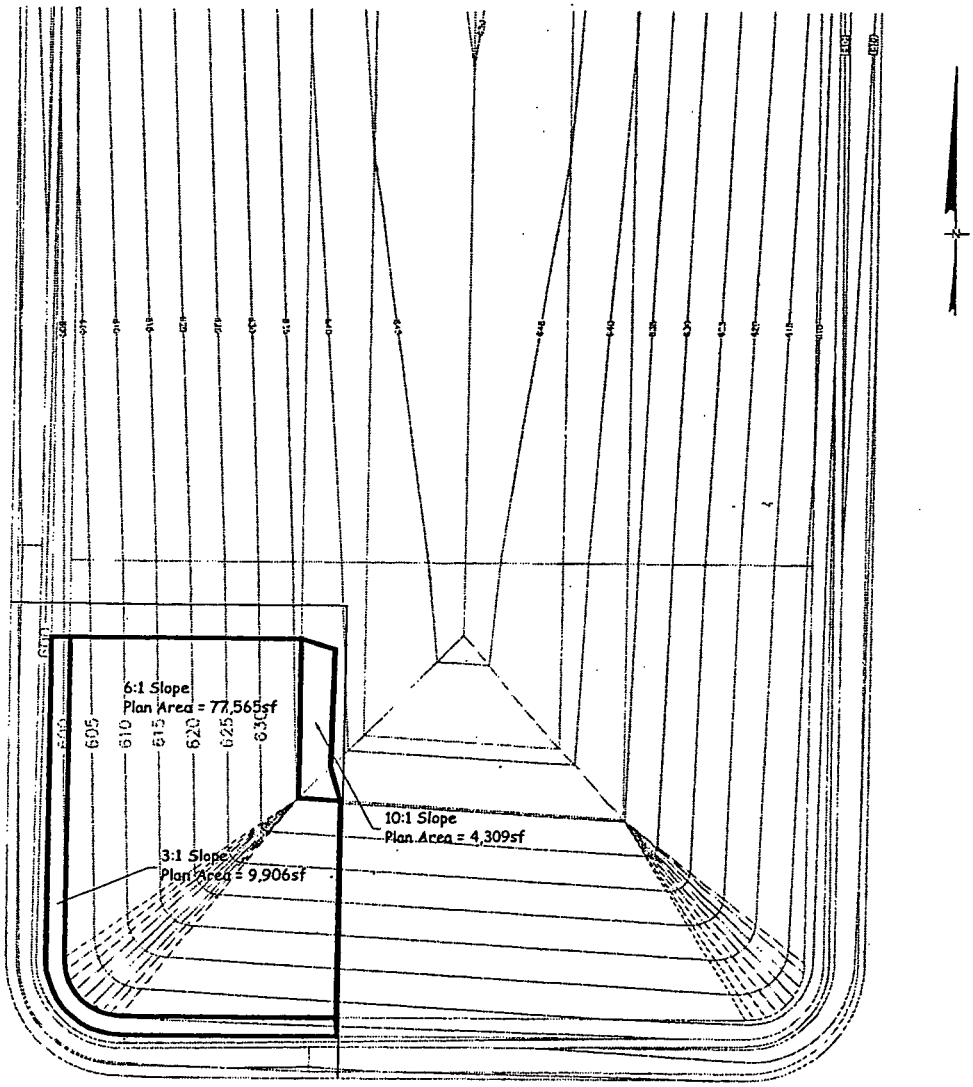
CDC 01/23/2002 103 of 115
MAO 24 Jan02

4664



Stage II – Lower Layer of Select Impacted Material and Previously Placed Upper Layer of Select Impacted Material

CDC 01/23/2002 104 of 115
MAO 24Jan02 - -- 4664



Stage I and Stage II – Upper Layer of Select Impacted Material

- 4664

ATTACHMENT A-5

SIZING CULVERT AT THE TEMPORARY CONSTRUCTION ACCESS ROAD FOR CELL 7 IMPACTED RUNOFF CATCHMENT AREA

Written by: CDC CDC 01/23/2002 Date: 01/12/13 (YY MM DD) Reviewed by: MAD Date: 02/01/24 (YY MM DD)

Client: Fluor-Fernald Project: OSDF Phase II Project/Proposal No.: GQ1342 Task No.: 17.2

Sizing Culvert at Temporary Construction Access Road — 4664
for Cell 7 Impacted Runoff Catchment Area (IRCA)

- A culvert is required to convey water beneath the temporary construction access road for Cell 7 (See attached Figure)
- The access road was left off of the sketches within the calc. package for simplicity.
- The program Culvert Master was used to demonstrate the adequacy of the selected 36" pipe as discussed in Calculation Section 12.4 "Surface Water Management System Design".
- The adequacy of the design will be demonstrated for the two cases that information is available for: Stage I and Stage II.
  * The runoff flows directly into the IRCA for stage III; therefore, the culvert capacity isn't relevant in this case.
- Culvert Master requires the following inputs.
  - Allowable Headwater Elev.
    → Set at 603.0' for both cases based on overtopping elevation of 604' and a 1.0' freeboard.
  - Discharge
    → Established from HydroCAD output for Dummy Reach 4 (Used to collect runoff at inlet to IRCA at the point where the culvert crosses)
    - Stage I Q = 46.3 cfs
    - Stage II Q = 30.67 cfs

    See HydroCAD output attached.
  - Tailwater Elevation
    → Established from HydroCAD for each Stage. (See HydroCAD sheets attached)
    - Stage I El. = 595.63' - Stage II El. = 599.82'

Written by: CDC CDC 01/23/2002 Date: / / Reviewed by: MAO Date: 02 01 24

Client: Fluor Fernald Project: OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.2

- 4664

- Culvert Master Inputs (cont.)
  - Culvert Geometry → From Construction drawings (Same for Stage I + II)
    - Upstream Invert = 597.0 ft.
    - Downstream Invert = 596.0 ft
    - Length = 100' (Drawings show 70', but 100' is conservative)
    - Slope = 0.010 ft/ft.
  - Pipe Section → Same for Stage I + II
    - Section Shape = Circular
    - Section Material = CMP
    - Section Size = 36" diameter
    - Manning's Coeff. = 0.018 (from Contech Pipe Spec. Manual shown on attached sheet)

      FOR HELICAL CORRUGATIONS DCP 01/30/02

- Results.
  - Stage I
    - Computed Headwater Elev. = 601.05'

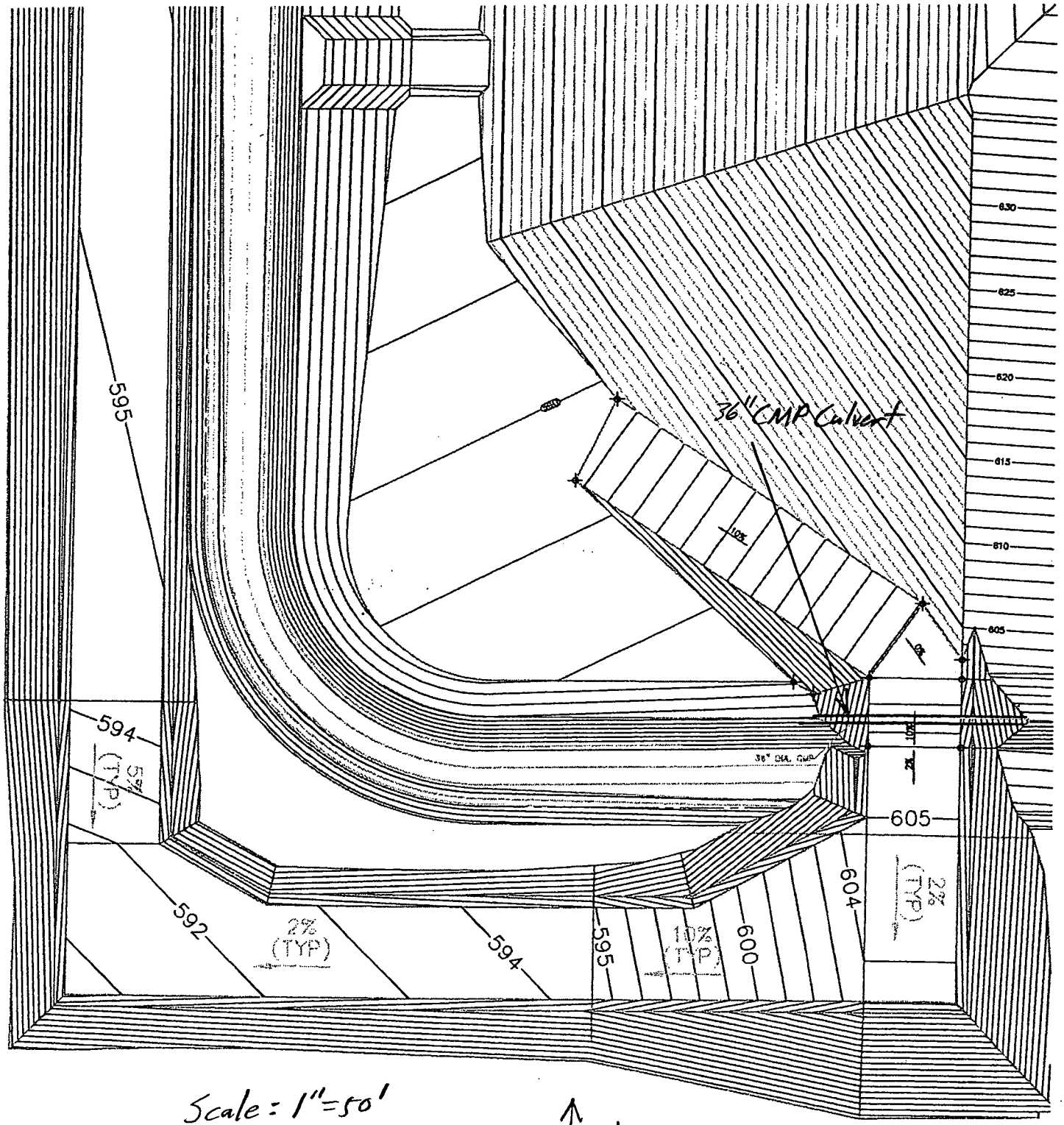
      601.05 < 603' (Allowable HW Elev.) ✓ Okay.
  - Stage II
    - Computed Headwater Elev. = 600.72'

      600.72' < 603' (Allowable HW Elev.) ✓ Okay.

- Conclusions
  - The designed 36" dia. CMP Culvert is adequate to handle the quantities of flow expected for Stage I and Stage II for the 25-year, 24-hour storm event.

CDC 01/23/2002 108 of 115
MAO 24JAN02
- 4664

Stage I IRA Showing Temporary Construction Access Road & Culvert.



Scale: 1"=50'

North

MAO 24Jan02
OX 01/23/2002 109 of 115

Reach 4R: Dummy Reach

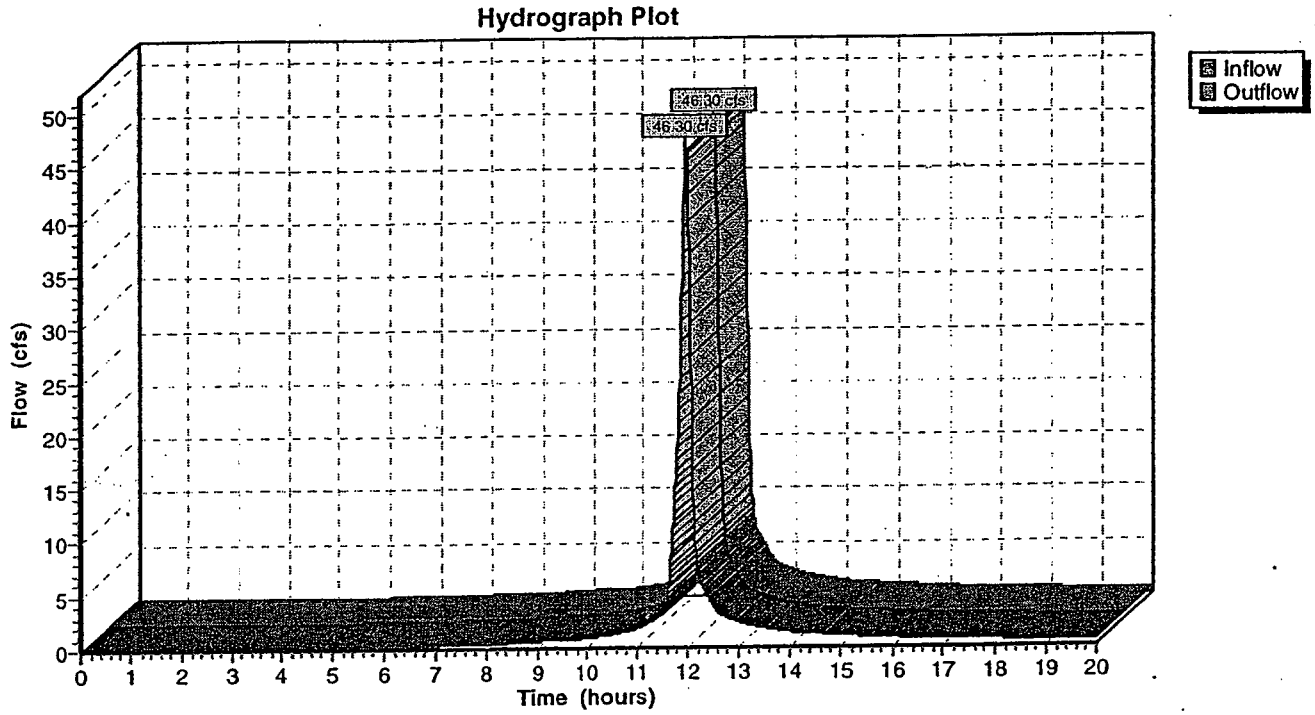
- 4664

[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	46.30 cfs @	11.96 hrs, Volume=	2.272 af	
Outflow	=	46.30 cfs @	11.96 hrs, Volume=	2.272 af,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 4R: Dummy Reach



MAO 24 Jan 02
CDC 01/23/2002 110 of 115

Reach 4R: Dummy Reach

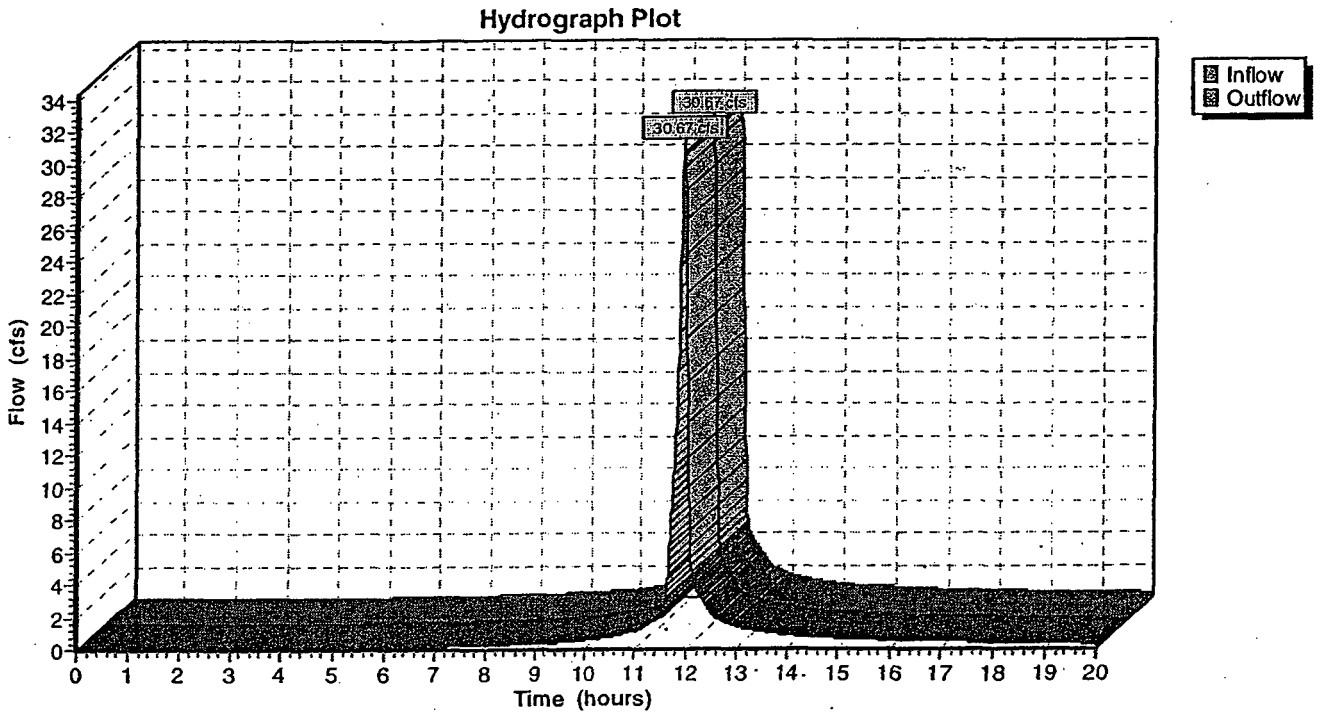
4664

[40] Hint: Not Described (Outflow=Inflow)

Inflow	=	30.67 cfs @	11.94 hrs, Volume=	1.387 af	
Outflow	=	30.67 cfs @	11.94 hrs, Volume=	1.387 af, Atten= 0%, Lag= 0.0 min	

Routing by Stor-Ind+Trans method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Reach 4R: Dummy Reach



MAD 24 Jan 02
CDC 01/23/2002 111 of 115

Pond 1P: Detention Pond

- 4664

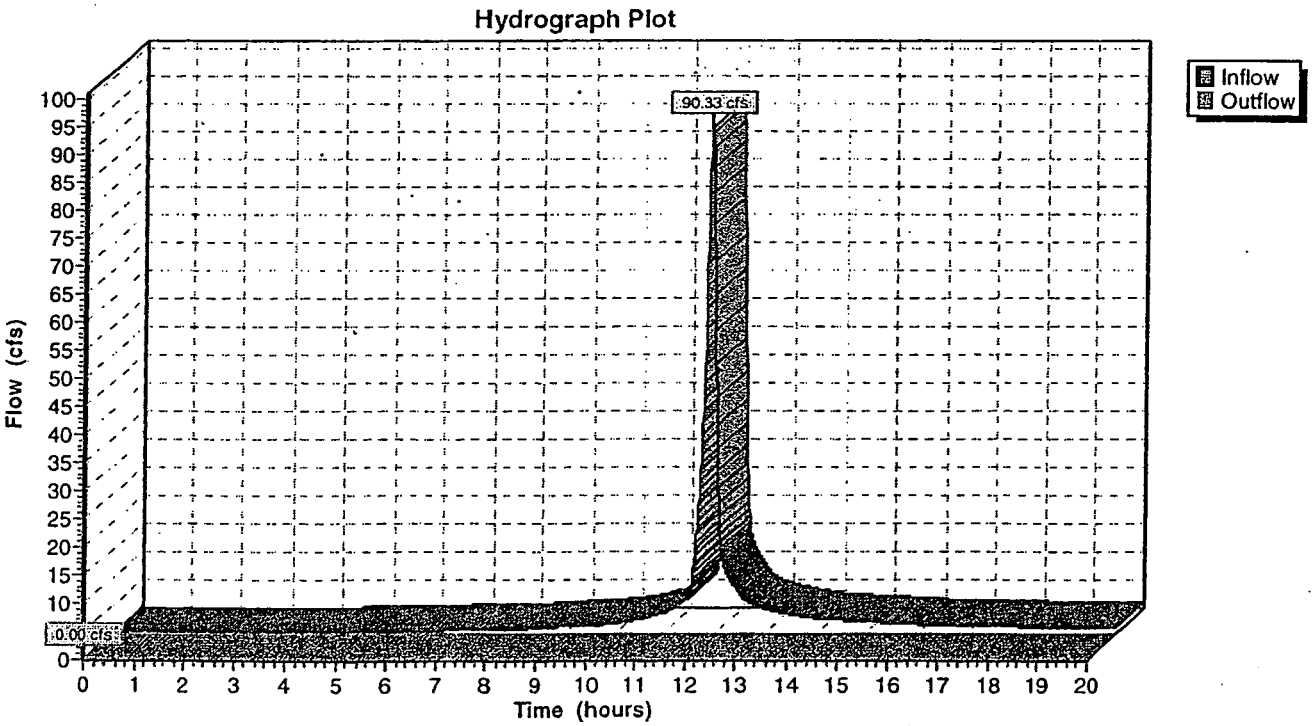
Inflow = 90.33 cfs @ 11.94 hrs, Volume= 4.481 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 595.63' Storage= 4.480 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
587.80	0.000	0.000	0.000
588.00	0.078	0.008	0.008
589.00	0.172	0.125	0.133
590.00	0.308	0.240	0.373
592.00	0.673	0.981	1.354
594.00	0.888	1.561	2.915
596.00	1.037	1.925	4.840
598.00	1.152	2.189	7.029
600.00	1.267	2.419	9.448
603.00	1.441	4.062	13.510

Pond 1P: Detention Pond



MAT 24 Jan 02
CDC 01/23/2002 112 of 115

Pond 1P: Detention Pond

- 4664

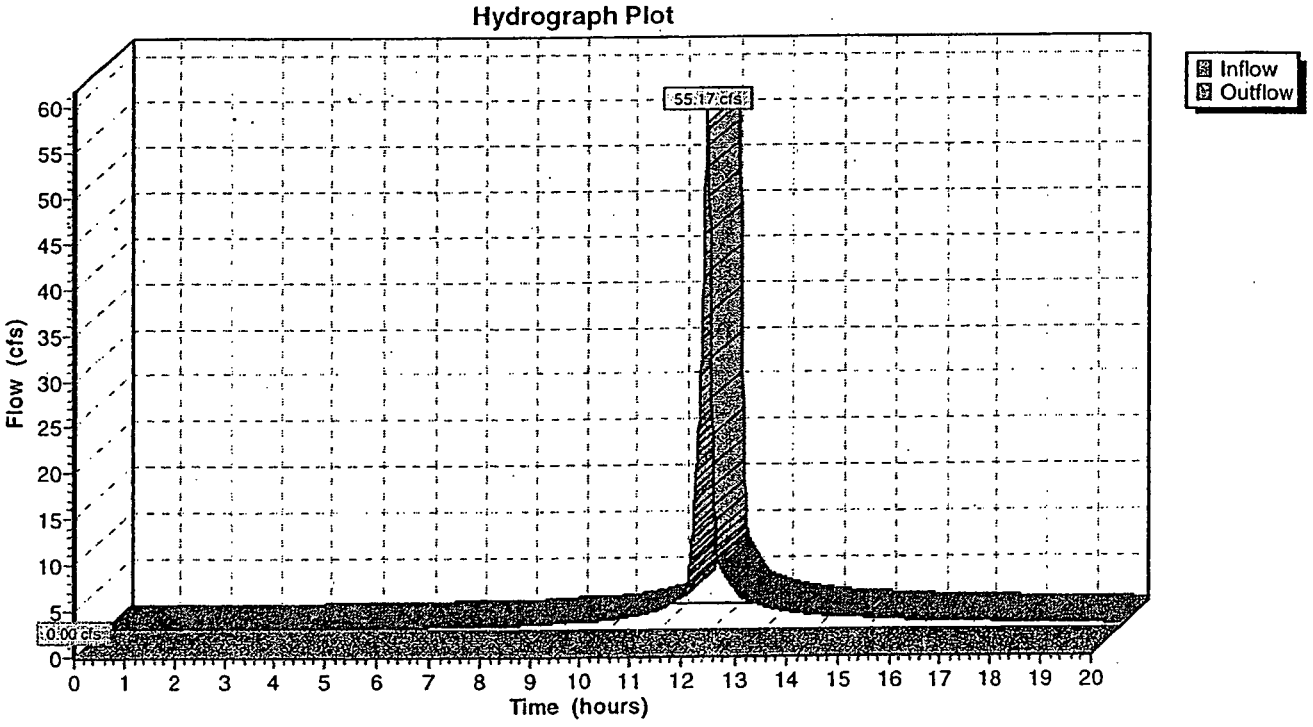
Inflow = 55.17 cfs @ 11.92 hrs, Volume= 2.593 af
Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af, Atten= 100%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-20.00 hrs, dt= 0.01 hrs

Peak Elev= 599.82' Storage= 2.592 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Prismatic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
587.80	0.000	0.000	0.000
588.00	0.012	0.001	0.001
589.00	0.030	0.021	0.022
595.00	0.165	0.585	0.607
596.00	0.223	0.194	0.801
598.00	0.430	0.653	1.454
600.00	0.824	1.254	2.708
602.00	1.285	2.109	4.817
603.00	1.441	1.363	6.180

Pond 1P: Detention Pond



Values of Coefficient of Roughness (n)

-- 4664

For Contech Corrugated Steel Pipe (Manning's Formula)

Corrugations	Annular 2⅔ x ½ in. All Diameters	Helical 1½ x ¼ in. (11 x 12) 8 in.	10 in.	12 in.	18 in.	24 in.	36 in.	48 in.	60 in. and Larger
Unpaved	0.024	0.012	0.014	0.011	0.013	0.015	0.018	0.020	0.021
PAVED-INVERT	0.021					0.014	0.017	0.020	0.019
SMOOTH-FLO	0.012					0.012	0.012	0.012	0.012
HEL-COR CL	0.012					0.012	0.012	0.012	0.012

	Annular 3 x 1 in.	Helical—3 x 1 in. 48 in.	54 in.	60 in.	66 in.	72 in.	78 in. and Larger
Unpaved	0.027	0.023	0.023	0.024	0.025	0.026	0.027
PAVED-INVERT	0.023	0.020	0.020	0.021	0.022	0.022	0.023
SMOOTH-FLO	0.012	0.012	0.012	0.012	0.012	0.012	0.012
HEL-COR CL	0.012		0.012	0.012	0.012	0.012	0.012

	Annular 5 x 1 in.	Helical—5 x 1 in. 54 in.	60 in.	66 in.	72 in. and Larger
Unpaved	0.025	0.022	0.023	0.024	0.025
PAVED-INVERT	0.022	0.019	0.020	0.021	0.022
SMOOTH-FLO	0.012	0.012	0.012	0.012	0.012
HEL-COR CL	0.012	0.012	0.012	0.012	0.012

*Tests on helically corrugated pipe demonstrate a lower coefficient of roughness than for annually corrugated steel pipe when there is a significant amount of helix or spiral in the pipe. For a given diameter, the greater the angle of helix, the less the friction factor. For a given helix, the greater the diameter, the less friction factor.

For additional information refer to the references listed below.

The values in the above table are based on standard helical pipe manufactured from a 24-inch net width strip of steel.

1. Silberman, Edward, "Effect of Helix Angle on flow in Corrugated Pipes" Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY11, Nov., 1970, pp. 2253–2263.

2. Handbook of Steel Drainage and Highway Construction Products, AISI (New York, N.Y., 1983), p. 185.

3. Webster, M.J. and Metcalf, L.R., "Friction Factors in Corrugated Metal Pipe," Journal of the Hydraulics Division, ASCE, Vol. 85, No. HY9, Proc. Paper 2148, Sept., 1959, pp. 35–67.

CDC 01/23/2002 114 of 115
MAB 24 Jan 02
-- 4664

Culvert Calculator Report
Fernald Phase V - IRCA Culvert

Stage I

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	603.00 ft	Headwater Depth/Height	1.35
Computed Headwater Elev:	601.05 ft	Discharge	46.30 cfs
Inlet Control HW Elev.	601.05 ft	Tailwater Elevation	595.63 ft
Outlet Control HW Elev.	600.95 ft	Control Type	Inlet Control

Grades			
Upstream Invert	597.00 ft	Downstream Invert	596.00 ft
Length	100.00 ft	Constructed Slope	0.010000 ft/ft

Hydraulic Profile			
Profile	M2	Depth, Downstream	2.22 ft
Slope Type	Mild	Normal Depth	2.36 ft
Flow Regime	Subcritical	Critical Depth	2.22 ft
Velocity Downstream	8.27 ft/s	Critical Slope	0.011509 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.018
Section Material	CMP	Span	3.00 ft
Section Size	36 inch	Rise	3.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	600.95 ft	Upstream Velocity Head	0.94 ft
Ke	0.70	Entrance Loss	0.66 ft

Inlet Control Properties			
Inlet Control HW Elev.	601.05 ft	Flow Control	Transition
Inlet Type	Mitered to slope	Area Full	7.1 ft²
K	0.02100	HDS 5 Chart	2
M	1.33000	HDS 5 Scale	2
C	0.04630	Equation Form	1
Y	0.75000		

000116

CDC 01/23/2002 115 of 115
MAO 24 Jan 02

Culvert Calculator Report
Fernald Phase V - IRCA Culvert
Stage II

4664

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	603.00 ft	Headwater Depth/Height	1.24
Computed Headwater Elev	600.72 ft	Discharge	30.67 cfs
Inlet Control HW Elev.	599.82 ft	Tailwater Elevation	599.82 ft
Outlet Control HW Elev.	600.72 ft	Control Type	Outlet Control

Grades			
Upstream Invert	597.00 ft	Downstream Invert	596.00 ft
Length	100.00 ft	Constructed Slope	0.010000 ft/ft

Hydraulic Profile			
Profile	PressureProfile	Depth, Downstream	3.82 ft
Slope Type	N/A	Normal Depth	1.74 ft
Flow Regime	N/A	Critical Depth	1.80 ft
Velocity Downstream	4.34 ft/s	Critical Slope	0.009054 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.018
Section Material	CMP	Span	3.00 ft
Section Size	36 inch	Rise	3.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	600.72 ft	Upstream Velocity Head	0.29 ft
Ke	0.70	Entrance Loss	0.20 ft

Inlet Control Properties			
Inlet Control HW Elev.	599.82 ft	Flow Control	Unsubmerged
Inlet Type	Mitered to slope	Area Full	7.1 ft^2
K	0.02100	HDS 5 Chart	2
M	1.33000	HDS 5 Scale	2
C	0.04630	Equation Form	1
Y	0.75000		

000117

Section 12.5

4664

12.5 OSDR PHASE V: SURFACE-WATER MANAGEMENT SYSTEM DESIGN AND POST-CLOSURE HYDROLOGY

000119

COMPUTATION COVER SHEET

- 4664

SUBJECT OF COMPUTATIONS OSDF PHASE V, SURFACE-WATER MANAGEMENT SYSTEM DESIGN AND POST-CLOSURE HYDROLOGY

Computations By:
(Cognizant Engineer)

Signature Dana Beth Mehlman — Date 28 January 200

Printed Name and Title: Dana Beth Mehlman, Staff Engineer

Assumptions and Procedures Checked By:
(Checker)

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Printed Name and Title: Daniel G. Pass, Project Engineer

Computations Checked by:

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Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	SUBMITTAL TO FF/DOE/EPA	30 JAN 01	DBM	DGP	JFB

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP For Date: 30 JAN 02
DCP 4GG

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17 -- 4664

OSDF PHASE V, SURFACE-WATER MANAGEMENT SYSTEM

DESIGN AND POST-CLOSURE HYDROLOGY

EXECUTIVE SUMMARY

PURPOSE OF ANALYSES

The purpose of this calculation package is to design the OSDF surface-water management (SWM) structures to be constructed as part of the Phase V development of the OSDF. These SWM structures are designed to satisfy the requirements of the Surface-Water Management and Erosion Control (SWMEC) Plan [GeoSyntec, 2002b] and the OSDF Design Criteria Package (DCP) [GeoSyntec, 2002a] and are shown on the Construction Drawings. These requirements include those applicable to the OSDF Construction/Filling period and the OSDF Post-Closure period (for permanent structures). Additionally, the adequacy of existing SWM structures is assessed where failure of these structures has the potential to impact the OSDF or where the development of the OSDF significantly impacts the runoff conveyed to these structures. Required modifications or additions to existing structures are incorporated into the Construction Drawings and this calculation package. Peak discharges from sedimentation basins are presented for post-closure conditions for use in future comparison of pre- and post-development runoff from watersheds in the FEMP to Paddy's Run, which is outside the scope of Phase V calculations. Lastly, hydrologic analyses are presented for post-closure conditions and a 2-year-24-hour storm event for use in an evaluation of sedimentation potential of permanent channels in the calculation "Sedimentation Evaluation of Permanent Drainage Channels for High Frequency Design Storms".

METHODS OF ANALYSES

For the purpose of hydrologic analyses and routing through sedimentation basins (basins), the total drainage area is divided into two parts and modeled as the East OSDF and the West OSDF Design Scenarios. Both the East OSDF and West OSDF Design Scenarios presented herein consider the actual conditions anticipated to exist when all seven cells have been constructed, lined, and capped. This represents the "worst case" conditions for the period of Phase V construction. Design Case "A" represents a temporary channel and culvert at the southwest end of Cell 6 constructed as part of the SWM system for Cell 6. Neither the channel nor the culvert is incorporated into either of the OSDF Design Scenarios.

For Phase V SWM structures (i.e., new structures), analyses are performed to design channels, culverts, and a sedimentation basin. Channels and culverts are designed to safely convey peak flow rates from the 25-year, 24-hour storm event. Additional analyses are performed for the selection of channel lining (channel bed stability) and required height of cover

over culverts (structural stability). The sedimentation basin, OSDF Basin 2 is considered adequate if it complies with the design criteria for the 10-, 25-, and 100-year, 24-hour storm events, outlined in the DCP for construction, filling, and closure of the OSDF.

Analyses for 25-year channels along the North, East, and West perimeters of the OSDF were previously performed as part of the OSDF Final Design Package [GeoSyntec, 1997c]. These channels have been constructed, or will be constructed as part of Phases IV and V, consistent the OSDF Final Design Package; therefore, no analyses are performed as part of this Calculation Package to assess the adequacy of these channels.

For existing SWM structures evaluated, analyses are performed to assess the adequacy of channels, culverts, and a sedimentation basin (basin). Channels and culverts are considered to be adequate if they have sufficient hydraulic capacity to convey peak flow rates from the 25-year, 24-hour storm event. The sedimentation basin, Borrow Area Basin, is considered adequate if it complies with the performance criteria for the 25-year, 24-hour storm event, outlined in the DCP for development and restoration of the Borrow Area.

Hydrologic and basin routing analyses are performed using methodologies presented in TR-20 [USDA-SCS, 1982] and TR-55 [USDA-SCS, 1986], as coded into the computer program HydroCAD™. Hydraulic analyses for channels are performed using Manning's equation as coded into a computer spreadsheet. Hydraulic analyses for culverts are performed using methodologies presented in USDOT [1985], as coded into the computer program CulvertMaster®.

CONCLUSIONS

All Phase V (i.e., new) channels, culverts, and OSDF Sedimentation Basin 2 are designed in accordance with the requirements of the SWMEC Plan [GeoSyntec, 2002b] and the DCP [GeoSyntec, 2002a], in particular as follows:

New Channels

- Calculated peak flow velocities for channels (all are grass-lined) are less than the permissible flow velocity of 5.0 fps.
- Calculated freeboards for channels equal or exceed the minimum required of 0.5 ft.

New Culverts

- Calculated headwater elevations at the inlet of culverts allow for 0.5 ft or greater freeboard.
- For all culverts cover provided at road crossings equal or exceed the minimum required thickness of cover for structural stability.

OSDF Sedimentation Basin 2

- The minimum available storage volume exceeds the calculated runoff volume (10-year, 24-hour storm event) and the calculated volume of 0.125 acre-ft/year per acre (disturbed upstream drainage area multiplied by the basin cleanout frequency).

- The calculated peak water elevation for the 25-year, 24-hour storm event is below the elevation of emergency spillway.

- The calculated peak water elevation for the 100-year, 24-hour storm event allows 1 ft of freeboard from the minimum embankment crest elevation.

Existing channels, culverts, and the Borrow Area Sedimentation Basin (with modifications shown in the Construction Drawings) have adequate capacity to convey applicable design storm events, in particular as follows:

Existing Channels

- Calculated freeboard for all channels equal or exceed the minimum required of 0.5 ft.

Existing Culverts

- Calculated headwater elevation at the upstream end of culverts allow for 0.5 ft or greater freeboard.

Borrow Area Sedimentation Basin

- The minimum available storage volume exceeds the calculated volume of 1,800 cubic ft per acre (total upstream drainage area multiplied by the basin cleanout frequency) within the drainage area that will be disturbed by construction during the designed life of the sediment basin.

- The calculated peak water elevation for the 25-year, 24-hour storm event allows more than 1 ft freeboard from the minimum embankment crest elevation.

The required cleanout frequency for basins is one year per cleanout.

OSDF PHASE V, SURFACE-WATER MANAGEMENT SYSTEM

DESIGN AND POST-CLOSURE HYDROLOGY

TABLE OF CONTENTS

EXECUTIVE SUMMARY
TABLE OF CONTENTS
PROCEDURES
INTRODUCTION AND PURPOSE 6
DESIGN CRITERIA 6
DESIGN SCENARIOS 7
SOFTWARE 9
HYDROLOGIC AND BASIN ROUTING ANALYSES 10
Subcatchment Runoff 10
Reaches 14
Sedimentation Basins 15
HYDRAULIC ANALYSES 16
Channels 16
Culverts 17
Sedimentation Basins 19
REFERENCES 21
TABLE A-1 23
ATTACHMENTS
A-1 – DCP SECTIONS 2.8 and 2.10 24
A-2 – LAYOUT OF DESIGN SCENARIO AND DESIGN CASE SWM SYSTEMS 49
A-3 – HydroCAD™ TECHNICAL REFERENCE MANUAL 53
A-4 – CulvertMaster® THEORY SECTION 74
A-5 – USDA-SCS SOIL SURVEY MAP 80
A-6 – HYDROLOGIC SOIL DATA 82
A-7 – TR-55 LAND USE CATEGORIES AND RUNOFF CURVE NUMBERS 89
A-8 – NODAL NETWORK DIAGRAMS 92
A-9 – CMP COVER REQUIREMENTS 96
DATA VERIFICATION
INTRODUCTION 98
HYDROLOGIC AND BASIN ROUTING ANALYSES 98
Subcatchment Runoff 98
Reaches 99
Sedimentation Basins 100
HYDRAULIC ANALYSES 100
Channels 100
Culverts 101
REFERENCES 102
ATTACHMENTS

B-1 – SCS RAINFALL DISTRIBUTION TYPE 103
B-2 – RAINFALL DEPTHS 105
B-3 – SUBCATCHMENT AREA AND WEIGHTED CURVE NUMBER DATA 107
B-4 – DATA FOR CALUCLATION OF TIME OF CONCENTRATION 113
B-5 – CHANNEL INPUT DATA 119
B-6 – CULVERT INPUT DATA 122
B-7 – BASIN ELEVATION CONTOUR AREAS 125
B-8 – BASIN OUTLET STRUCTURE DATA 128

CALCULATIONS

INTRODUCTION 131
HYDROLOGIC AND BASIN ROUTING ANALYSES 131
Subcatchment Runoff 132
HYDRAULIC ANALYSES 132
Channels 132
Culverts 133
Sedimentation Basins 134

ATTACHMENTS

C-1A – HydroCAD™ OUTPUT REPORTS, EAST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO 137
C-1B – HydroCAD™ OUTPUT REPORTS, WEST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO 164
C-1C – HydroCAD™ OUTPUT REPORTS, EAST OSDF POST-DEVELOPMENT DESIGN SCENARIO 182
C-1D – HydroCAD™ OUTPUT REPORTS, WEST OSDF POST-DEVELOPMENT DESIGN SCENARIO 209
C-1E – HydroCAD™ OUTPUT REPORTS, DESIGN CASE "A" 224
C-2 – WEIGHTED RUNOFF CURVE NUMBER CALCULATIONS 231
C-3 – TABULATED ANALYSIS RESULTS FOR CHANNELS 238
C-4A – CulvertMaster® OUTPUT REPORTS FOR CULVERTS 243
C-4B – TABULATED ANALYSIS RESULTS FOR CULVERTS 275
C-5 – TABULATED ANALYSIS RESULTS FOR BASIN OUTLET STRUCTURES 280

OSDF PHASE V, SURFACE-WATER MANAGEMENT SYSTEM

DESIGN AND POST-CLOSURE HYDROLOGY

PROCEDURES

INTRODUCTION AND PURPOSE

The major elements of the OSDF Phase V project include construction of the liner systems for Cells 6 and 7, and capping of Cells 3, 4, 5, 6, and 7. These and other construction elements are listed in Table A-1 along with their relationships to the design scenarios assumed herein. The layout of the surface-water management (SWM) system is shown on Construction Drawings.

The purpose of this Calculation Package is to evaluate the adequacy of OSDF SWM structures to be constructed as part of the Phase V development of the OSDF. Additionally, the adequacy of existing SWM structures is assessed. Required modifications or additions to existing structures are incorporated into the Construction Drawings and this Calculation Package.

Analyses for channels along the North, East, and West perimeters of the OSDF for the 25-year 24-hour storm event were previously performed as part of the OSDF Final Design Package [GeoSyntec, 1997c]. These channels have been constructed, or will be constructed as part of Phase V, consistent with the OSDF Final Design Package; therefore, no analyses are performed as part of this Calculation Package to assess the adequacy of these channels.

DESIGN CRITERIA

The OSDF Phase V SWM system is designed to satisfy the requirements of the Surface-Water Management and Erosion Control (SWMEC) Plan [GeoSyntec, 2002b] and the OSDF Design Criteria Package (DCP) [GeoSyntec, 2002a]. Applicable sections from the DCP [GeoSyntec, 2002a] include Section 2.8, *Surface-Water Management*, which contains requirements for the OSDF runon/runoff structures and Section 2.10.2.4, *Surface-Water*

Management for Borrow Area which contains requirements for the borrow area structures. These sections of the DCP are included as Attachment A-1.

The design of Phase V structures includes analyses for channels and culverts and the OSDF Sedimentation Basin 2. The channels and culverts are designed to safely convey peak flow rates from the 25-year, 24-hour design storm event. Additional analyses are performed for the selection of channel lining (i.e., channel bed stability), required height of cover over culverts (i.e., structural stability), and riprap design for inlet and outlet protection of culverts. The OSDF Basin 2 is considered adequate if it complies with the design criteria for the 10-, 25-, and 100-year, 24-hour design storm events, outlined in the DCP for construction, filling and closure of the OSDF.

The assessment of existing structures includes analyses to assess the adequacy of channels, culverts, and the Borrow Area Sedimentation Basin. Channels and culverts are considered to be adequate if they have sufficient hydraulic capacity to convey peak flow rates from the 25-year, 24-hour storm event. The Borrow Area Basin is considered adequate if it complies with the performance criteria for the 25-year, 24-hour storm event, outlined in the DCP for development and restoration of the Borrow Area.

Peak discharges from sedimentation basins are presented for post-closure conditions. These discharges are for use in future comparison of pre- and post-development runoff from watersheds in the FEMP to Paddy's Run, which is outside the scope of Phase V calculations. Also, hydrologic analyses are presented for post-closure conditions and a 2-year-24-hour storm event for use in an evaluation of sedimentation potential of permanent channels in the calculation "Sedimentation Evaluation of Permanent Drainage Channels for High Frequency Design Storms".

DESIGN SCENARIOS

The design of Phase V SWM structures, and assessment of hydraulic capacity for existing structures, is evaluated in this calculation package using two design scenarios, the East OSDF and the West OSDF Design Scenarios. Both the East and West OSDF Design Scenarios presented herein consider the actual conditions anticipated to exist when all seven cells have

been constructed, lined, and capped. This represents the "worst case" conditions for the period of Phase V construction. In addition, both East and West OSDF Design Scenarios have been analyzed assuming post-development conditions in order to assess potential sedimentation problems from high frequency design storms and to estimate peak discharges from sedimentation basins. Design Case "A" represents system of existing and new channels and culverts at the southwest corner of Cell 6 constructed as part of the SWM system for Cell 6. Neither these channels nor these culverts are incorporated into either of the OSDF Design Scenarios. The East and West OSDF Design Scenarios, and Design Case "A" are further described in Table A-1, and below.

East OSDF Design Scenarios

A schematic layout of the SWM system represented by the East OSDF Design Scenario is provided in Attachment A-2. The East OSDF Design Scenarios incorporate existing and new conditions, including the construction of Cell 6 and Cell 7 liner systems, the Cell 3, 4, 5, 6, and 7 final cover systems, and the East run-off and runon channels which discharge to the Borrow Area Sedimentation Basin south of the OSDF. For this design scenario the Cell 1, 2, 3, 4, and 5 final cover systems are considered vegetated, the Cell 6 and 7 final cover systems are considered to be non-vegetated, and no cells are receiving impacted material. For the post-development design scenario all final cover systems are considered fully vegetated.

All surface-water accounted for in the East OSDF Design Scenarios will flow to the Borrow Area Sedimentation Basin. The Borrow Area Basin has been modified to reflect the final configuration of the Borrow Area Sedimentation Basin as presented in the *Borrow Area Management and Restoration Plan* [GeoSyntec, 2001].

West OSDF Design Scenarios

A schematic layout of the SWM system represented in the West OSDF Design Scenario is provided in Attachment A-2. The West OSDF Design Scenarios incorporate existing and new conditions, including the construction of Cell 6 and Cell 7 liner systems, the Cell 3, 4, 5, 6, and 7 final cover systems, and the OSDF Sedimentation Basin 2. For this design scenario the Cell 1, 2, 3, 4, and 5 final cover systems are considered to be vegetated, the Cell 6 and 7 final cover

systems are considered non-vegetated, and no cells are receiving impacted material. For the post-development design scenario all final cover systems are considered to be fully vegetated. All surface-water accounted for in the West OSDF Design Scenario will flow to the OSDF Sedimentation Basin 2.

Design Case "A"

A schematic layout of the SWM system represented in Design Case "A" is provided in Attachment A-2. Design Case "A" incorporates temporary structures at the southwest end of the temporary termination for the Cell 6 liner system. Design Case "A" considers existing conditions in the construction laydown area to the south of the OSDF and includes runoff from the Cell 6 liner runout and areas south of the OSDF. None of these temporary structures are represented in either of the OSDF Design Scenarios.

SOFTWARE

Hydrologic and Basin Routing Analyses

Surface-water runoff peak flow rates and other hydrologic and hydraulic information are estimated using the computer program HydroCAD™ [HydroCAD™, 2001]. This program uses hydrologic procedures presented in U.S. Soil Conservation Services' TR-20 [SCS, 1982] and TR-55 [SCS, 1986]. Hydrographs for individual subcatchments are routed through a user specified nodal network for each design scenario (see Attachment A-8), using standard hydrologic routing techniques. Runoff hydrographs from subcatchments are developed using input parameters which describe the storm event for which the calculation is being performed and characteristics of the subcatchment. Built-in subroutines allow the user to route the hydrographs through a sediment basin. The HydroCAD™ Technical Reference Manual is provided as Attachment A-3.

Channel Hydraulic Analyses

Hydraulic analyses for channels are performed using Manning's equation, as coded into a computer spreadsheet.

Culvert Hydraulic Analyses

Hydraulic analyses for culverts are performed using methodologies presented in USDOT [1985], as coded into the computer program CulvertMaster® [Haestad Methods, 2000]. Built-in subroutines allow the user to perform calculations for inlet and outlet control. The CulvertMaster® User's Guide [Haestad Methods, 2000] Theory Section is provided as Attachment A-4.

HYDROLOGIC AND BASIN ROUTING ANALYSES

Hydrologic and basin routing analyses are performed using HydroCAD™ for 2-, 10-, 25-, and 100-year, 24-hour storm events. Input parameters are presented in the Data Verification section of this calculation package. HydroCAD™ output reports are presented in Attachment C-1 of the Calculation Section of this calculation package. Major input used in the HydroCAD™ subroutines includes parameters for subcatchments, reaches, and basins. These parameters are introduced and calculation methods described in the following sections.

Subcatchment Runoff

Rainfall Distribution

This parameter characterizes the assumed distribution of the design rainfall depth over a 24-hour duration and is selected based on the location of the Fernald site within the United States. Selection of this parameter is further described in the Data Verification section of this calculation package.

Rainfall Depth

This parameter is the total rainfall for a 24-hour design storm event. The design rainfall depths for return periods of 2, 10, 25, and 100 years are obtained as described in the Data Verification section of this calculation package.

Hydrologic Soil Groups (HSG)

This parameter classifies surficial soils at the site based on hydrologic characteristics, as presented in the Soil Surveys of Butler and Hamilton Counties, Ohio [USDA-SCS, 1980 and

1992]. The soil types and hydrologic soil groups found in the vicinity of the OSDF watershed are shown on a plan view of the OSDF area in Attachment A-5 [USDA-SCS, 1980 and 1992] and soil hydrologic data in Attachment A-6 [USDA-SCS, 1980 and 1992]. The soil names identified for the OSDF area and their respective HSG classification are summarized below.

SCS Map Label	Soil Name	Hydrologic Soil Group
FcA, FdA	Fincastle	C
Rda	Raub	C
RwB2	Russell	B
XeB, XeB2, XfA, XfB2	Xenia	B
MoE2	Miamian	C

An HSG classification of B/C is selected for the final cover system and for liner system runout areas. The final cover system and the liner system runout will be constructed using soil from the borrow area. Soil obtained from the borrow area includes B and C soils, with approximately 85% of the soil being classified as B.

Runoff Curve Numbers (CNs)

CNs are selected based on ground cover type, land use, cover condition, and HSG classification of site soils. A list of land use categories characterizing drainage areas for the Phase V SWM system is presented in the following table. This list is developed based on characterization of the ground cover and land use for anticipated runoff area conditions during and after Phase V construction. Land use categories are associated with TR-55 categories of land use and ground cover (See Attachment A-7 from [SCS, 1986]) and are presented in the following table:

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DLP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17 - 4664

	Construction Phase			Post-Development Phase		
Land Use Description	**TR-55 Land Use/ Ground Cover Category**	**HSG**	**CN**	**TR-55 Land Use/ Ground Cover Category**	**HSG**	**CN**
Non-vegetated final cover system and liner system runout	Newly graded areas	B	86	Not Applicable	-	-
		C	91		-	-
		B/C	89		-	-
Vegetated final cover system	Open space in poor condition - corresponds to less than 50% grass cover	B	79	Open space in fair condition - corresponds to between 50% to 75% grass cover	B	69
		C	86		C	79
		B/C	83		B/C	74
Runon Areas East of the OSDF, Runon Areas North of the Borrow Area	Pasture in fair condition	B	69	Pasture in fair condition	B	69
		C	79		C	79
Borrow Area Runoff, Runon to Borrow Area, Vegetated Borrow Area	Pasture in good condition	B	61	Pasture in good condition	B	61
		C	74		C	74
Areas Adjacent to the OSDF	Construction support (Farmsteads – buildings, lanes, driveways, and surrounding lot)	B	74	Grass in good condition - corresponds to over 75% grass cover	B	61
		C	82		C	74
Subgrade	Bare Soil	C	87	Not Applicable	-	-
Sedimentation basin (SB), direct runoff to SB, pavement	Impervious surfaces	-	98	Impervious surfaces	-	98

For areas indicated in the above table as having an HSG of "B/C", the CN was calculated based on a 1:1 ratio of B and C soils. A weighted CN for each subcatchment (CN_{S-i}) is calculated as a weighted average of CNs present within that subcatchment. The following equation is used, as coded into a spreadsheet:

$$CN_{S-i} = \sum_{i=1}^{n} P_i CN_i$$

Where, P_i is the percentage of total subcatchment area with CN_i.

Subcatchment Time of Concentration

The time of concentration for each subcatchment is calculated as the sum of the travel times for sheet, shallow concentrated, and channel flows, for a flow path from the most hydraulically distant location in the subcatchment to the outlet of the subcatchment. These calculations are performed within HydroCAD™ using specified input parameters for flow regimes. Methods and equations used for these calculations are presented in the HydroCAD™ Technical Reference Manual presented as Attachment A-3. Input parameters include the following:

- For sheet flow travel time: surface description or n = Manning's roughness coefficient (dimensionless); L = flow length (ft); P = 2-year; 24-hour rainfall depth (inches); and S = land slope (rise/run).
- For shallow concentrated flow travel time: surface description; L = flow length (ft); and S = land slope (rise/run).
- For channel flow travel time: L = flow length (feet); s = longitudinal slope (rise/run); n = Manning's roughness coefficient (dimensionless); D = flow depth (feet); W = bottom width (ft); and sideslopes (rise/run).

Manning's roughness coefficients (for sheet flow calculation referenced above) are selected based on a correlation of ground description to TR-55 surface descriptions [SCS, 1986], as shown in the following table:

Ground Description	TR-55 Surface Description	Manning's n for Sheet Flow
Non-vegetated final cover system, liner system runout, pavement and subgrade	Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Vegetated areas, construction support area, vegetated final cover system, runon area east of OSDF, runon area north of borrow area, borrow area runoff, and runon to borrow area	Grass: short grass prairie	0.15

A further description of input parameters for time of concentration computations is provided in the Data Verification section of this calculation.

Reaches

Hydrologic analyses, for estimation of peak flow rates and runoff volumes (for evaluation of SWM structures), are performed by routing the hydrographs for individual subcatchments through reaches. Reaches include channels and culverts, as described below.

Channels

For hydrologic analyses, channel parameters are input into HydroCAD™ based on information from the Construction Drawings. Channels consist of either "V" or trapezoidal-shaped sections, with either grass or riprap lining. Input parameters include: (i) bottom width (ft); (ii) sideslopes (rise/run); (iii) length (ft); (iv) longitudinal slope (rise/run); (v) Manning's roughness coefficient (dimensionless); and (vi) depth (ft). The adequacy of channels is assessed as described in a later section.

Culverts

For hydrologic analyses, culverts are input into HydroCAD™ as multiple 72-in. diameter pipes. Input parameters include: (i) length (ft); (ii) slope (rise/run); and (iii) Manning's roughness coefficient (dimensionless). The culvert sizes selected in the computer model (i.e.,

multiple 72-in. dia. pipes) are fictitious values used solely for ease of computation. Design of culverts (i.e., selection of size and number of pipes) is performed using the computer program CulvertMaster® which uses peak flow rates obtained from hydrologic analyses and accepted methodologies described in a later section.

Sedimentation Basins

Surface-water runoff is routed through individual basins for the scenarios noted below.

- OSDF Basin 2: routed as part of the West OSDF Design Scenario.
- Existing Borrow Area Basin: routed as part of the East OSDF Design Scenario.

Routing through the basins is performed utilizing the Storage-Indication Method as coded into HydroCAD™. For the storage-indication method, the inflow runoff hydrograph at a basin and the stage-storage and stage-discharge relationships of the basin are utilized.

The stage-storage relationship of a basin is developed in HydroCAD™ using the Surface Area – Conic Volume Determination Method where cumulative storage is calculated based on areas within elevation contour lines from the outlet pipe invert elevation to the minimum embankment crest elevation.

The stage-discharge relationship of a basin is modeled in HydroCAD™ using the size and inlet elevations of the principal spillway riser and outlet pipes and the size, shape, and inlet elevation of the emergency spillway. Principal spillways consist of vertical riser and horizontal discharge pipes. Riser pipes are modeled as sharp-crested weirs in low flow conditions and as orifices in high flow conditions. Horizontal outlet pipes are modeled as culverts. Emergency spillways are modeled as broad-crested rectangular weirs. Also, the low-flow orifices (8-in. diameter) located at the bottom of the risers are neglected (conservatively) for this analysis. Additional information concerning development of stage-discharge relationships for these control structures is included in the HydroCAD™ Technical Reference Manual provided as Attachment A-3.

HYDRAULIC ANALYSES

The design of new SWM structures and assessment of existing SWM structures includes hydraulic analyses for channels, culverts, and basins. Peak flow rates and runoff values from HydroCAD™ output reports are utilized.

Channels

The hydraulic capacity of each new and existing channel is evaluated for conveyance of peak flow rates from the 25-year, 24-hour design storm event. In addition for new channels, analyses are performed to evaluate lining stability. For the purpose of these analyses, channels are divided into segments of relatively uniform cross-section and longitudinal slope.

Hydraulic Capacity

The adequacy for the hydraulic capacity of channels is evaluated in terms of an available freeboard for peak flow rates. The available freeboard is calculated as the difference between the minimum available flow depth in the channel and the calculated peak flow depth (peak flow depth). The peak flow depth is calculated based on Manning's equation as coded into a computer spreadsheet. Manning's equation is as follows:

$$Q = \frac{1.49}{n} A R^{2/3} S_0^{1/2}$$

Where, Q is the peak flow rate (cfs), n is Manning's roughness coefficient (dimensionless), A is cross-sectional area of flow (ft^2), R is hydraulic radius (ft) defined as R = A/P where P is wetted perimeter (ft), and S_o is longitudinal slope (rise/run). The minimum required freeboard (from the peak flow level to the level of overtopping of the channel sideslopes or nearby facility which would be adversely impacted if flooded) is 0.5 ft. The minimum available flow depth is obtained from the Construction Drawings.

Channel Lining

For each new channel, a peak flow velocity is calculated and compared to the permissible flow velocity for the selected channel lining. Permissible flow velocities for grass and riprap linings are <5 fps and <12 fps, respectively. Peak flow velocities are calculated based on Manning's equation, using a computer spreadsheet.

Sedimentation

For each permanent channel, hydrology results for post-closure conditions and the 2-year, 24-hour storm event are calculated for use in the Phase V calculation "Sedimentation Evaluation of Permanent Drainage Channels for High Frequency Design Storms".

Culverts

The hydraulic capacity of each new and existing culvert is evaluated for conveyance of peak flow rates from the 25-year, 24-hour design storm event. New culverts will be helically corrugated metal pipe (CMP). Existing culverts include CMP, reinforced concrete pipe (RCP), polyvinyl chloride (PVC), asphalted corrugated metal pipe (CMPA), and high density polyethylene (HDPE) pipes.

Hydraulic Capacity

The adequacy of culverts is evaluated for inlet and outlet control conditions in terms of headwater elevation, using the computer program CulvertMaster®. An allowable headwater elevation is calculated as the overtopping elevation of the channel sideslopes or road crossing or the minimum elevation of a nearby facility which might be adversely impacted if flooded minus 0.5 ft freeboard. The higher of the inlet or outlet headwater elevations is taken as the controlling headwater elevation.

The following input parameters are required: (i) material type and culvert shape; (ii) inlet configuration; (iii) number of culverts and diameter (ft); (iv) length (ft); (v) inlet and outlet invert elevations (ft MSL); (vi) 25-year, 24-hour peak flow rate (cfs); (vii) tailwater elevation; and (viii)

overtopping elevation. CulvertMaster® does not include all diameters and inlet configurations, therefore characteristics are selected within the CulvertMaster® program to best approximate those of the existing culvert. For the case of diameter, the closest diameter was used but no more than two inches larger than the existing diameter. For the case of inlet configuration, an inlet configuration with an entrance loss coefficient equal to that estimated for the actual inlet is selected. In cases where culverts discharge into well-defined channels, tailwater elevations will be assumed as the elevation of the normal flow depth in the downstream channel.

Outlet Protection

For each new temporary culvert, riprap outlet protection requirements are calculated to handle the 25-year, 24-hour storm event using a design chart from USDA-SCS [1987]. This design chart is presented in Attachment C-4B. For each new permanent culvert, outlet protection requirements are calculated to handle the 25-year 24-hour storm event using a design chart from the Ohio Department of Transportation [ODOT, 1992]. This design chart is presented in Attachment C-4B and is also presented in ODNR [1996]. Outlet protection is recommended in terms of downstream riprap length and average riprap particle size (d_{50}). For the purposes of designing outlet protection, the flow depth just downstream of the culvert is assumed as less than one half the diameter of the culvert (i.e., a minimum tailwater condition). Criteria for the selection of downstream riprap length and thickness are listed below.

- The downstream riprap length (at a culvert outlet) is based on the appropriate design chart, but at a minimum will be four times the culvert diameter (hereafter referred to as "minimum riprap length").
- If riprap is not required based on the appropriate design chart but the outlet velocity for the culvert is 5 fps or greater, the minimum riprap length is required.
- If riprap is not required based on the appropriate design chart and outlet velocity for the culvert is less than 5 fps, no outlet protection is required.
- If the direction of discharge (i.e., at culvert outlet) is not aligned with the longitudinal direction of the receiving channel, the minimum riprap length is required.

- Riprap thickness as described in DCP (GeoSyntec, 2002a).

Downstream channel peak flow depths are obtained from the results of hydrologic analyses. Outlet velocities are obtained from CulvertMaster® output reports. Where riprap is recommended for outlet protection, inlet protection is also recommended. The upstream length is two times the culvert diameter with a d_{50} equal to that for the outlet protection riprap.

Structural Stability

For each new culvert, structural stability is evaluated. For culverts crossing roads used by heavy construction vehicles (off-highway vehicle road) a Caterpillar D400E articulated truck (D400E) [Caterpillar, 1998] is selected as the design vehicle. For culverts crossing roads used only by highway vehicles (on-highway road), an HS-20 axle load is selected for design. The design axle load for off-highway vehicle roads of 95 kips is for a fully loaded truck and the combination of both rear axles. The design axle load for on-highway vehicle roads of 32 kips corresponds to an HS-20 loading [ACPA, 1998].

For CMP culverts, structural stability is evaluated using manufacturers guidelines [Contech, 1999 – See Table in Attachment A-9] for unpaved roads. In accordance with these guidelines, the minimum required cover for culvert diameters of 42 in. and less for off-highway and on-highway vehicle roads is 3.0 ft and 2.0 ft, respectively.

Sedimentation Basins

Existing and new basins are evaluated for handling runoff from applicable design storm events. A cleanout frequency of once per year is assumed consistent with the SWMEC Plan.

OSDF Sedimentation Basin 2 (See DCP Section 2.8 in Attachment A-1)

- The available minimum storage volume (below the principal spillway inlet elevation) should exceed the calculated runoff volume from the 10-year, 24-hour design storm event and the calculated volume of 0.125 acre-ft per year per acre (disturbed upstream drainage area multiplied by the basin cleanout frequency). Total drainage area is conservatively used in place of disturbed upstream drainage area.

- The principal spillway should discharge runoff from the 25-year, 24-hour design storm event with no flow entering the emergency spillway.
- The principal and emergency spillways should discharge runoff from the 100-year, 24-hour design storm event, allowing for 1 ft of freeboard from the minimum embankment crest elevation.

Borrow Area Sedimentation Basin (See DCP Section 2.10.2.4 in Attachment A-1)

- The available minimum storage volume should exceed the calculated volume of 1,800 cf per acre (total upstream drainage area multiplied by the basin cleanout frequency) within the drainage area that will be disturbed by construction during the design life of the sediment basin.
- The principal spillway should discharge runoff from the 25-year, 24-hour design storm event, allowing for 1 ft of freeboard from the minimum embankment crest elevation.

In addition, both the OSDF Sedimentation Basin 2 and the Borrow Area Sedimentation Basin are evaluated to determine peak discharges for the post-development 25-year, 24 hour storm event. This analysis assumes that the basins remain unchanged after the closure of the OSDF. These peak discharges are for use in a future comparison of pre- and post-development runoff from watersheds in the FEMP to Paddy's Run, which is outside the scope of Phase V calculations.

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Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

TABLE A-1

OSDF PHASE V CONSTRUCTION ELEMENTS AND DESIGN SCENARIOS

	East OSDF Construction Phase Design Scenario	West OSDF Construction Phase Design Scenario	East OSDF Post-Development Design Scenario	West OSDF Post-Development Design Scenario	Design Case "A"
Cell 1, 2, 3, 4, 5 Liner	Existing	Existing	Existing	Existing	Existing
Cell 6, 7 Liner	New	New	Existing	Existing	New -Cell 6 Liner Only
Cell 1, 2 Final Cover	Existing - Vegetated	Existing - Vegetated	Existing - Vegetated	Existing - Vegetated	Existing - Vegetated
Cell 3, 4, 5 Final Cover	New - Vegetated	New - Vegetated	Existing - Vegetated	Existing - Vegetated	New - Vegetated
Cell 6, 7 Final Cover	New – Non Vegetated	New – Non Vegetated	Existing - Vegetated	Existing - Vegetated	New – Cell 6 Non Vegetated Only
Borrow Area Sedimentation Basin	Existing – Final Configuration	-	Existing – Final Configuration	-	-
OSDF Sedimentation Basin 2	-	New	-	New	-
Existing Channels	Reaches 1, 2, 14, 15, 16, 17	Reach 9	Reaches 1, 2, 14, 15, 16, 17	Reach 9	Reaches 2, 7
Existing Culverts	Reaches 11, 31	Reaches 13, 14	Reaches 11, 31	Reaches 13, 14	Reaches 1, 3, 4
New Channels	Reaches 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 18, 19, 20, 21, 22, 24, 26, 29, 30	Reaches 1, 2, 3, 4, 6, 7, 8, 10, 11	Reaches 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 18, 19, 20, 21, 22, 24, 26, 29, 30	Reaches 1, 2, 3, 4, 6, 7, 8, 10, 11	Reaches 5, 6
New Culverts	Reaches 23, 25, 28	Reach 5	Reaches 23, 25, 28	Reach 5	Reach 8
Existing Culverts to be Replaced with New Culverts	Reach 27	Reach 12	Reach 27	Reach 12	-

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ATTACHMENT A-1

DCP SECTIONS 2.8 AND 2.10

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DCP SECTION 2.8
SURFACE-WATER MANAGEMENT

U.S. Environmental Protection Agency (USEPA), "*Seminar Publication - Requirements for Hazardous Waste Landfill - Design, Construction, and Closure*," EPA/625/4-89/022, U.S. Environmental Protection Agency, 1989.

U.S. Environmental Protection Agency (USEPA), "*Technical Guidance Document - Quality Assurance and Quality Control for Waste Containment Facilities*", EPA/600/R-93/182, U.S. Environmental Protection Agency, 1993.

2.8 Surface-Water Management

2.8.1 Categories of Surface Water

Surface-water management for the OSDF must consider three categories of surface water:

- surface-water runon from outside the battery limit to within the battery limit;
- surface-water runoff, which includes all runoff from disturbed areas within the battery limit, except for wastewater explicitly identified below; and
- wastewater, which includes all waters that must be contained, collected, and conveyed to the biosurge lagoon or the FEMP former production area storm drainage control system.

Wastewater generated as a result of development of the OSDF area includes:

- leachate and runoff from impacted material within the OSDF; these wastewaters will be contained in the OSDF, allowed to percolate into the leachate collection system, and then conveyed by gravity through the leachate collection system pipe to the OSDF EPLTS (as discussed in Section 2.5 of this DCP). Surface-water collected in the OSDF cell catchment area may be conveyed to the FEMP former production area storm drainage control system or other on-site wastewater collection/conveyance point acceptable to DOE and OEPA/USEPA.
- runoff from impacted-material staging areas; these are self-contained units; liquid generated in these units will be conveyed to the FEMP former production area storm drainage control system, or other on-site wastewater collection/conveyance point acceptable to DOE and OEPA/USEPA;

- runoff from impacted-material haul roads; this water will be contained, collected, and conveyed to the FEMP former production area storm drainage control system, or other on-site wastewater collection/conveyance point acceptable to DOE and OEPA/USEPA; and

- perched ground water that seeps into excavations; this water will be contained, collected, and conveyed to the FEMP former production area storm drainage control system, or other on-site wastewater collection/conveyance point acceptable to DOE and OEPA/USEPA.

The remainder of this section of the DCP presents design criteria for management of stormwaters and wastewaters.

2.8.2 General Design Criteria

The functions of the surface-water management system are to: (i) route surface water to designated locations where it can be appropriately managed; (ii) protect the OSDF from damage caused by precipitation and surface-water runon and runoff; and (iii) discharge surface water to existing watercourses in accordance with applicable regulatory and DOE requirements.

The surface-water management system should perform in a manner that meets the project requirements for both temporary conditions (i.e., during construction, filling, and closure of the OSDF) and long-term conditions (i.e., after closure of the OSDF). The system should prevent surface-water runon to the OSDF and uncontrolled stormwater and wastewater runoff from the OSDF. Features of the permanent surface-water management system should be designed to require minimal monitoring and maintenance. The system should be integrated, to the extent possible, with existing topography, features, and facilities (design considerations).

2.8.3 Surface-Water Management During OSDF Construction/Filling/Closure

A. Design Criteria

- Temporary surface-water control structures for the OSDF will be designed for the 25-year, 24-hour storm event (ARAR: EPA 40 CFR §258.26 and OAC 3745-27-08(C)(6)(a) and (b)). For the FEMP property, this event has a rainfall intensity of 4.7 in. [Parsons, 1995a].

- Temporary surface-water control structures will be designed to minimize silting and scouring (ARAR: OAC 3745-27-08(C)(6)(c)).

- Temporary runon control measures should meet the following criteria (design considerations).

  - Upgradient runon should be prevented from entering active working areas. Such runon should be diverted around work areas using berms, dikes, or channels as appropriate. This runon should not be allowed to mix with wastewater.

  - Runon to temporary excavations should be prevented using berms, ditches, or other surface-water control features.

  - Runon to impacted material stockpiles should be prevented using berms, ditches, or other surface-water control features.

  - Prior to placement of impacted material into an OSDF cell, permanent runon controls must be in place. The requirements for permanent runon control are described in more detail in Section 2.8.4 of this DCP.

- Runoff from disturbed areas should be routed to the appropriate temporary sediment basin or managed using other appropriate erosion control practices. There must be no mixing of surface-water runoff and wastewaters (functional requirements).

- Temporary sediment basins will meet the following criteria of OEPA (ARAR: OAC 3745-27-08(C)(6)(d)):

  - the minimum acceptable basin storage will be established as the larger of the calculated runoff volume from a 10-year, 24-hour storm event, or, 0.125 acre-ft per year (for each acre) of upgradient disturbed area) multiplied by the scheduled frequency of basin cleanout (in years) ((6)(d)(i)); for the FEMP property, the 10-year, 24-hour storm event has a rainfall intensity of 4.1 in. [Parsons, 1995a];

  - the principal spillway will be capable of safely discharging the flow from a 10-year, 24-hour storm event; the inlet elevation of the emergency spillway will be designed to provide flood storage, with no flow entering the emergency spillway during a 25-year, 24-hour storm event, with allowance provided for the flow passed by the principal spillway during the event

((6)(d)(ii)); as previously noted, for the FEMP property, the 25-year, 24-hour storm event has a rainfall intensity of 4.7 in. [Parsons, 1995a];

- the combination of principal and emergency spillways should be capable of safely discharging the flow from a 100-year, 24-hour storm event; the basin embankment design should provide for no less than 1 ft of net freeboard when flow is at the design depth, after allowance for embankment settlement ((6)(d)(iii)); for the FEMP property, the 100-year, 24-hour storm event has a rainfall intensity of 5.6 in. [Parsons, 1995a];

- the basin will be constructed using a compacted soil liner, a geomembrane, or a combination thereof ((6)(d)(iv)); and

- sediment basins will be equipped with ring buoys and other safety/drowning equipment in accordance with USOSHA 1926.106.

- With respect to the last ARAR ((6)(d)(iv)), on 24 February 1992, the OEPA DSIWM issued the following guidance on the need for lining sediment basins:

> *"The sole purpose of a liner in a sediment basin is water retention. Therefore, a design capable of ponding water, whether or not it contains a liner, will be acceptable to the Director. In areas with predominantly in-situ low permeability clay, a liner may be unnecessary (it would be wise to scarify and recompact the clay surface). The landfill engineer is responsible for meeting the "ponding" standard. In areas with more permeable soils a recompacted clay liner is necessary, but the QA/QC standards can be minimal and certainly do not need to follow the landfill liner standards."*

  The foregoing requirement is interpreted as allowing the development of unlined sediment basins in the low-permeability tills underlying the FEMP. To assure compliance with the intent of this guidance, the construction specifications for sediment basins associated with the OSDF should require scarification and recompaction of the till exposed in the sediment basin excavation, and overexcavation of any observed granular soil zones, followed by backfilling with till and recompaction (design consideration).

- Surface-water runoff from the FEMP watersheds to the receiving water course (e.g., Paddys Run) should be discharged at a rate no greater than the predevelopment runoff discharge rate [ODNR, 1996] (design consideration).

- Temporary channels for stormwater runoff should be designed to meet the following criteria (design considerations).

  - Channel lining:
    - peak flow velocity in riprap-lined channels should be less than 12 ft per second, unless it is demonstrated that greater velocities will not cause erosion or malfunction of the surface-water management feature; and
    - peak flow velocities in grass-lined channels should be less than 5 ft per second.
  - Channel sideslopes should be no steeper than 3 horizontal to 1 vertical.
  - Channel bottom widths may be zero.
  - The channel freeboard should be at least 0.5 ft under the design storm event.
  - Channels should be sloped at no less than 0.5 percent to prevent sediment buildup and clogging, unless it can be established by calculation that a lesser slope will not clog or build up sediment that will cause loss of flow capacity in the design storm event. Channel slopes should be no steeper than 5 percent unless it can be established by calculation that a steeper slope will not cause unacceptable erosion or other malfunction.

- Temporary culverts should be designed according to the following criteria (design considerations).

  - Culverts may be used in locations as needed and where cost-effective.
  - Channels should be protected from erosion using riprap or erosion mats for a length of at least two culvert diameters upstream and a width of at least three culvert diameters of the culvert inlet. The length and width, of riprap lining and average particle size downstream of the culvert outlet should meet criteria for permanent outlet protection provided in USDA-SCS, 1987.
  - Minimum thickness of riprap lining will be two times D_{50}, but not less than 6 in. and will be underlain by geotextile filters.

- Riprap will be designed according to the following criteria (design considerations).

  - For channel lining, riprap should be sized to meet the following criteria [ODNR, 1996];

- $D_{50} = 62.4$ pcf x d x S/4
  where: D_{50} = theoretical spherical diameter of average stone size; d = peak flow depth for the design storm event (ft); and S = channel slope (rise/run).

- Riprap should meet the following particle size criteria [ODNR, 1996]:

  - $D_{max} = 1.5 \times D_{50}$
  - $D_{15} = 0.5$ to $0.75 \times D_{50}$
    where: D_{max} = theoretical spherical diameter of largest stone size; and D_{15} = theoretical spherical diameter of the stone size for which 15 percent of the material is smaller.

- For channels, the minimum thickness of the riprap lining should be two times D_{50}, but not less than 6 in.

- Riprap used at channel transitions should extend upstream and downstream of the transition a distance of five times the downstream channel depth; the minimum extension should be 15 ft.

- Geotextile filters may be used to control piping and erosion beneath riprap in temporary facilities. Granular soils should be used for filters in permanent structures containing riprap, if required to prevent undermining of the riprap.

- Rock, grade control structures should be designed according to the following criteria (design considerations).

  - Rock, grade control structures may be used in temporary facilities. They should be designed in accordance with standard design procedures.

  - The minimum height of rock, grade control structures should be 1.5 ft and the minimum top width should be 2 ft.

- Temporary erosion control measures should include the items listed below (design considerations).

  - Runoff from all disturbed areas should be routed to sediment basins, or managed using other appropriate sediment control practices, prior to discharge to natural watercourses, except for wastewaters which should be managed as described in Section 2.8.5 of this DCP.

- The size of any excavated or disturbed area should be as small as possible to minimize the potential for erosion (design consideration). Disturbed areas should be revegetated at the earliest possible time.

- Temporary erosion control may be achieved using geosynthetic materials, vegetation, crusting agents, check dams, straw bales, silt fences, or other appropriate structures.

- The use of erosion control materials should be minimized in impacted soils requiring OSDF disposal. Preference should be given to runon control, surface grading, and the selective use of erosion resistant impacted materials to control erosion of impacted areas.

- Maintenance and upkeep procedures for temporary erosion control features should be specified in the *Surface-Water Management and Erosion Control Plan.*

It is noted that surface-water routing and surface-water management system design for watercourses and structures beyond the battery limit will be addressed in other design packages being prepared as part of the integrated FEMP remediation.

B. Calculations

Calculations should be performed to size the sediment basins for each contributory drainage area for each representative phase of the OSDF development. The calculations should be performed as described below.

- The amount of surface-water runon and runoff should be calculated for each contributory drainage area.

- The size of the drainage control structures (e.g., channels) should be calculated for each contributory drainage area.

- The size of the sediment basin, including outlet structures, should be calculated for each contributory drainage area.

The above calculations should be performed using the design storm events previously identified. Runon/Runoff routing and sediment basin sizing may be evaluated using the procedures described in USDA-SCS Technical Releases 20 and/or 55 [USDA-SCS, 1975, 1986a]; an acceptable tool for performing these calculations is the computer program "*HydroCAD™ Stormwater Modeling System*" [Applied

Microcomputer Systems, 1993]. The above evaluations should be based on the information and guidance contained in USDA-SCS manuals [1985, 1986b, and 1988] and ODNR [1996].

Culverts should be sized in accordance with U.S. Federal Highway Administration guidelines [USDOT, 1985] and meet the structural design criteria contained in applicable design references such as the Concrete Pipe Design Manual [America Concrete Pipe Association, 1970].

In the event that a channel bottom grade is less than 0.5 percent, an analysis should be performed to establish that the channel does not clog or build up sediment that will cause loss of flow capacity in the design storm event.

2.8.4 Surface-Water Management After OSDF Closure

A. Design Criteria

- Permanent runon control structures for the OSDF will be designed to limit interruption and damage (i.e., washout) of the OSDF in the 2,000-year, 24-hour storm event (design criterion for assumption of a DOE Performance Category 2 facility). For the FEMP property, this event has a rainfall intensity of 13.0 in. [Parsons, 1995a]. Runon should be controlled and diverted away from and around the OSDF using channels or diversion berms (design consideration).

- Permanent runoff control structures for the OSDF will be designed to limit interruption and damage (i.e., washout) of the OSDF in the 2,000-year, 24-hour storm event (design criterion for assumption of a DOE Performance Category 2 facility).

- Permanent runoff control measures should be designed according to the following criteria (design considerations).

  - Runoff from the 2,000-year, 24-hour storm event should be allowed to sheet flow to the toe of the OSDF final cover.

  - Runoff from the toe of the OSDF final cover should either sheet flow away from the facility or to a drainage channel beyond the toe.

  - Any drainage channels beyond the OSDF final cover system toe should outlet to existing drainage features at the battery limit. The location of the outlets should progress from north to south concurrent with the progressive

development of the OSDF. The final outlet location for runoff from the eastern portions of the OSDF should be immediately south of the southern limit of the OSDF.

- Permanent drainage channels will be designed to meet the following criteria (design considerations).
  - The dimensions of the channel should accommodate both normal low flows and peak precipitation runoff flows.
  - The final grades of the channel should be no less than 0.5 percent to prevent sediment buildup and clogging, unless it can be established by calculation that a lesser slope will not clog or buildup sediment that will cause loss of flow capacity in the design storm event. Channel slopes should be no steeper than 5 percent unless it can be established by calculation that a steeper slope will not cause unacceptable erosion or other malfunction.
  - Peak flow velocity in the channel should not initiate channel gully erosion or scour.
  - Erosion potential should be minimized at channel transitions by utilizing smooth, rounded, and graded transitions wherever possible (preferred) and erosion control structures only when needed.
  - Flow velocity in the channel during high frequency (e.g., 2-year return frequency) and low-intensity (i.e., approximately 1 in. in 24 hours) storm events should be large enough to limit sedimentation in the channels, to the extent possible.
  - Channel sideslopes should be no steeper than 3 horizontal to 1 vertical.
  - The freeboard in the drainage channel should be at least 0.5 ft during the design storm event.
- Permanent drop inlets and culverts may be used downgradient of the OSDF if necessary and if failure of the drop inlet and culvert would not result in damage to, or interruption of, the OSDF. Permanent drop inlets and culverts should be designed to meet the following criteria (design considerations).
  - Culverts beneath roads or access corridors where traffic is limited to highway vehicles should be designed for American Association of State

Highway and Transportation Officials (AASHTO) HS-20 live loads and applicable dead loads.

- Culverts beneath haul roads or access roads used for construction traffic should be designed for vehicle live loads and applicable dead loads.

- Channels should be protected from erosion using riprap for a length of at least two culvert diameters upstream and a width of at least three culvert diameters upstream and downstream of the culvert inlet. The length and thickness of riprap lining and average particle size downstream of the culvert outlet should meet criteria for outlet protection provided in ODNR.

- Permanent culverts should not be used upgradient of the OSDF.

- Riprap, if needed, should be designed as described in Section 2.8.3 of this DCP (design consideration).

- Riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of a good quality, consistent with the UMTRA Technical Approach Document [DOE, 1989] (design consideration).

- Granular soils should be used as filters and bedding for permanent riprap features where necessary to prevent undermining of the riprap (design consideration).

- Rock grade control structures, if used, should be designed to meet the criteria listed in Section 2.8.3 of this DCP (design consideration).

- Surface-water runoff from watersheds in the FEMP to the receiving water course (e.g., Paddys Run) should be discharged at a rate no greater than the predevelopment runoff discharge rate [ODNR, 1996] (design consideration).

It is noted that surface-water routing and surface-water management system design for watercourses and structures beyond the battery limit will be addressed in other design packages being prepared as part of the integrated FEMP remediation.

B. Calculations

Calculations should be performed to size the drainage channels for each contributory drainage area. For these areas where a permanent drainage channel is not

needed, the amount of surface-water runoff should be calculated. The calculations that should be performed are described below.

- The amount of surface-water runon and runoff should be calculated for each contributory drainage area.

- The size of the permanent drainage channel should be calculated for each contributory drainage area.

The above calculations should be performed using the design storm events previously identified. Runon/runoff routing and sediment basin sizing may be evaluated using the procedures described in USDA-SCS Technical Releases 20 and 55 [USDA-SCS, 1975, 1986a]; an acceptable tool for performing these calculation is the computer program "*HydroCAD™ Stormwater Modeling System*" [Applied Microcomputer System, 1993]. The above evaluations should be based on information and guidance contained in USDA-SCS manuals [1985,1986b,1988].

In the event that a channel bottom grade is less than 0.5 percent, an analysis should be performed to establish that the channel does not clog or build up sediment that will cause loss of flow capacity in the design storm event.

The erosion resistance of the permanent drainage channel at the north and east toes of the OSDF should be evaluated as follows:

- obtain the allowable tractive force on the channel vegetation and topsoil using methods established by Temple et al. [1987], as described in the DOE Technical Approach Document [1989] and referenced documents;

- establish the actual tractive force on the channel vegetation and the "effective" tractive force on the channel topsoil using methods established by Temple et al. [1987], as described in the DOE Technical Approach Document [1989] and referenced documents;

- determine the potential for erosion of the drainage channel by comparing the allowable tractive force on the topsoil to the "effective" actual tractive force on the topsoil; and

- evaluate the potential for the riprap portion of the channel lining to erode using the Safety Factors Method as described in the DOE Technical Approach Document [1989] and referenced documents.

2.8.5 Wastewater Management

Wastewaters that will be encountered in development of the OSDF were identified in Section 2.8.1 of this DCP. These wastewaters should be managed as follows.

- *Leachate* - Liquid that has percolated through, or been released from, the impacted material that has been disposed in the OSDF (functional requirement). Placement of impacted material in OSDF cells will be performed such that runoff from active and open portions of a cell resulting from the 25-year, 24-hour storm event can be managed within the cell (ARAR: EPA 40 CFR §258.26 and OAC 3745-27-08(C)(6)(a)). Leachate should be managed as described in Section 2.5 of this DCP.

- *Impacted Runoff* - ~~Precipitation~~ Liquid that comes in contact with impacted material and runs off rather than percolating. Impacted runoff collected in the cell catchment areas may be conveyed as described in this Section. An OMTA will be constructed for the staging of impacted material for subsequent disposal in the OSDF. To the extent possible, the. Runoff from these areas should drain to surface-water control structures within the former production area storm drainage control system (design consideration). Runoff from any staging area located within the OSDF battery limit should also be directed to the FEMP former production area storm drainage control system if possible, or to other on-site wastewater collection/conveyance points (if necessary) acceptable to DOE and OEPA/USEPA (design consideration). Additional discussion of the OMTA is presented in Section 2.11 of this DCP. Runoff from impacted material haul roads should be contained within the haul road boundary and allowed to flow by gravity to the FEMP former production area storm drainage control system, or to other on-site wastewater collection/conveyance points (if necessary) acceptable to DOE and USEPA/OEPA. Drainage control structure for impacted material haul roads should be designed for the 25-year, 24-hour storm event. (design consideration).

- *Perched Ground Water* - Perched ground water that enters the OSDF excavation should be collected in a toe drain, or other suitable sump, and pumped to the FEMP former production area storm drainage control system (including pumpage to the impacted-material haul road, where the water will be allowed to flow by gravity to the FEMP former production area storm drainage control system), or to other on-site wastewater collection/conveyance points (if necessary) acceptable to DOE and OEPA/USEPA (design consideration). The

management of perched ground water that enters the borrow area excavation is not wastewater; management of this latter runoff is discussed in Section 2.10 of this DCP.

2.8.6 References

FEMP property data and information required to design the surface-water management system should be obtained from the references cited in Section 1.5 of this DCP. References from the general technical literature that may be used to design these systems are given below.

American Concrete Pipe Association, "*Concrete Pipe Design Manual*", American Concrete Pipe Association, Arlington, VA, February, 1970.

Applied Microcomputer Systems, "*HydroCAD™ Stormwater Modeling System*", Version 3.10, Chocorua, NH, 1993.

Chow, V.T., *"Open-Channel Hydraulics"*, McGraw-Hill, Inc., 1959.

Department of Labor, OSHA Construction Standard, 29 CFR 1926.106 "*Working Over or Near Water.*"

Fernald Environmental Management Project, *"Fluor Daniel Fernald Safety Performance Requirements Manual"*, RM-0021.

Ohio Department of Natural Resources - Division of Soil and Water Conservation (ODNR), "*Rainwater and Land Development*", 2nd Edition, 1996.

Parsons, *"2,000-Year Flood and Probable Maximum Flood Sitewide Flood Plain Determination"*, CERCLA/RCRA Unit 2, Project Order 148, Fernald Environmental Management Project, Rev. A, Fairfield, OH, August 1995a.

Richardson, E.V., et al., "*Highways in the River Environment - Hydraulic and Environmental Design Considerations*, U.S. Department of Transportation, Available from Publications Office, Engineering Research Center, Colorado State University, Fort Collins, CO, 1975.

Temple, D.M., Robinson, K.M., Ahring, R.M., and Davis, A.G., *Stability Design of Grass-Lined Open Channels*", U.S. Department of Agriculture, Agriculture Research Service, Agriculture Handbook Number 667, 1987.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS), "*Computer Program for Project Formulation, Hydrology*", Technical Release 20 (TR20), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1975.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS), "*National Emergency Handbook, Section 4 - Hydrology*", U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1985.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS), "*Urban Hydrology for Small Watersheds*", Technical Release 55 (TR55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 2nd Edition, 1986a.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS), *Engineering Field Manual for Conservation Practices*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1986b.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS), "*Water Management and Sediment Control for Urbanizing Areas*", U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1987.

U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS), *Ponds - Planning, Design Construction*, Agricultural Handbook Number 590, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., November 1988.

U.S. Department of Transportation (USDOT), "*Hydraulic Design of Highway Culverts*", Hydraulic Design Series No. 5, Federal Highway Administration, McLean, VA, September 1985.

U.S. Department of Energy (DOE), "*Technical Approach Document, Revision II*", Uranium Mill Tailings Remedial Action Project, December 1989.

2.9 Support Facilities and Utilities

2.9.1 General Design Criteria

The function of support elements and utilities is to provide support for, and enhance the performance of, the OSDF during construction, filling, closure, and post-closure care. As identified in Section 1.3 of the DCP, the support elements will include survey benchmarks, construction support area, equipment wash facility, materials storage areas, access control features, construction haul roads and leachate transmission system access corridor. Utilities will include electricity, water, and wastewater systems. Design criteria are presented separately in this section for each of these elements.

DCP SECTION 2.10
SURFACE-WATER MANAGEMENT FOR BORROW AREA

2.10 Borrow Area

2.10.1 General Design Criteria

The function of the borrow area is to provide soil for construction of the liner and final cover systems, and for other earthwork, related to construction, filling, and closure of the OSDF. This consists of soil borrow for construction of the compacted clay liner and cap, vegetative soil layer, compacted fill, and other earthwork associated with the project. The topsoil layer in the borrow area will be removed and stockpiled for later use unless it is determined to be impacted material, in which case it should be disposed of in the OSDF in accordance with the Impacted Material Placement Plan (IMP Plan). The borrow area for OSDF construction is located in the "East Field" area of the FEMP property. This borrow area will be developed over a period of time from 7 to 25 years (depending on the actual schedule for OSDF construction, filling, and closure), with a 10-year design life used for planning purposes. After the borrow area is restored, it should function with minimal maintenance.

The borrow area should be developed in a manner that results in efficient utilization of the available soils, results in efficient utilization of the natural topography of the borrow area to effectively control runon and runoff, provides soils with the engineering properties required for the OSDF earthwork components being constructed, and minimizes the costs associated with the development and restoration of the area (design considerations). In addition to these requirements, the design of the borrow area should consider the requirements described below (design considerations).

- The borrow area should be laid out in a manner that provides easy ingress and egress.
- The area should be developed in a manner that requires minimal additional earthwork after borrow activities are complete to achieve the required restoration grades.
- The borrow area should be developed incrementally as soil is needed for construction of the OSDF.
- The size of disturbed borrow area should be minimized to the extent possible.
- Interim restoration should be performed progressively as excavation in each borrow area subarea is completed.

- Erosion and sediment controls should be implemented in the borrow area prior to excavation, during borrow activities, and in conjunction with restoration activities.

2.10.2 Specific Criteria

2.10.2.1 Location of Borrow Area

A. Design Criteria

- The borrow area should be located in an area having material quantities and types sufficient for OSDF construction, filling, and closure (design consideration).

- The borrow area should be located within the FEMP property and should not encroach on the transmission line, oil pipeline, or other easements (design consideration).

- The borrow area should not extend vertically into the gray till except as noted in the approved *Borrow Area Strategy Report* (Fluor Fernald, Inc. 2000). The reasons for this are: (i) the efficiency of the borrow area operation will be improved by limiting the depth of excavation; and (ii) by limiting the depth of excavation, the restored borrow grades will be flatter and restoration of the area will be more cost effective. The borrow area should be constructed with sufficient final slope to minimize erosion and support final restoration (design considerations).

- Within the above constraints, the borrow area should be as deep as possible to minimize the size of the area (design consideration).

B. Calculations

No formal calculation is required for the location of the borrow area. A review of past geotechnical investigations and the results of ongoing laboratory testing of borrow area soil samples collected in November 1995 should be conducted to assess the engineering properties of the material and to predict the suitability of the materials for use as compacted clay liner and cap materials, as well as other earthwork components of the OSDF, as listed in Section 2.10.1.

2.10.2.2 Layout of Borrow Area

A. Design Criteria

- The borrow area should be laid out to facilitate surface-water management throughout the life of the borrow area (design consideration).
- The borrow area should be graded to promote surface-water runoff and prevent ponding of surface water (design consideration).
- The borrow area should be laid out to avoid interferences with roads, utility corridors, easements, etc. (design consideration).
- A soil contingency volume (equal to at least 15 percent of the required soil bank/unbulked volume based on the design estimate) should be provided in the borrow area for possible use in (design consideration):
  - construction of an OSDF contingency cell if disposal volumes are larger than anticipated;
  - backfilling to subgrade elevations beneath the footprint of the OSDF in the event that additional excavation of impacted material is necessary;
  - constructing portions of the contouring layer of the cover system and the non-granular portion of the protective layer of the liner system with "non-impacted" soil; and
  - providing material for "seasonal" closure between construction seasons in the event that suitable impacted soil is not available for this purpose.
- Intermediate borrow area slopes should be cut at a safe angle of repose for the material (design consideration).
- Permanent restored slopes within the borrow area should be no steeper than 5H:1V (design consideration).
- As may be required, design will comply with OSHA requirements, 29 CFR 1926 Subpart P-Excavations.

B. Calculations

A review of previous geotechnical field and laboratory test data, including brown till in-situ densities and moisture contents, standard Proctor compaction test results, and permeability test results should be made. The results of previous laboratory testing of borrow area soil should also be reviewed. The calculations described below should be undertaken in support of the design of the borrow area.

- The bank/unbulked volume of borrow soil required to build the earthwork components of the OSDF described in 2.10.1 should be calculated. The calculation should be conducted using the required compacted earthwork volume of on-site borrow material. This required compacted earthwork volume should be corrected to account for shrinkage/bulking of the borrow soil, the possible need for contingency volume, and the removal of the topsoil layer for stockpiling and later use as the topsoil layer in the OSDF final cover system.

- The bank/unbulked volume of available borrow soil, as calculated using computed-aided design (CAD) techniques, should be verified by hand calculation.

- The in-situ moisture content of the soil at the borrow area should be compared to the anticipated compaction moisture contents for the various earthwork components of the OSDF liner and final cover systems to assess the construction water demand and/or amount of soil drying required to moisture condition the borrow soils.

2.10.2.3 Development of Borrow Area

A. Design Criteria

- The borrow area should be developed in a manner that produces consistent materials for construction of the OSDF and effectively utilizes the existing topography to control surface-water runoff and runon (design consideration).

- Requirements for processing of the borrow area soils should be identified during design. If possible, such processing should be performed in the borrow area or any temporary stockpile area. Such processing could include moisture conditioning, blending, screening, or admixture modification (design consideration).

- Prior to the start of construction in the borrow area, the following activities should be performed (design considerations):
  - establishment of temporary surface-water management and erosion and sediment controls for the borrow area, including sediment basins;
  - establishment of access controls for the borrow area (consistent with the requirements of Section 2.9.2.6 of the DCP); and
  - establishment of soil processing facilities (if any are needed).
- Prior to the start of borrow area development, topsoil in the area should be removed and stockpiled for later use for closure of the OSDF unless it is determined to be impacted material, in which case it should be disposed in the OSDF in accordance with the IMP Plan (design consideration).

B. Calculations

No formal calculations are required for the development of the borrow area.

2.10.2.4 Surface-Water Management for Borrow Area

A. Design Criteria

- Temporary and permanent surface-water control structures for the borrow area with the exception of sediment basins, should be designed for the 25-year, 24-hour storm event (design consideration). Depending on the size of the contributory area, sediment basins should be designed for either the 10-year, 24-hour storm event, or the 25-year, 24-hour storm event [ODNR, 1996]. This criterion is discussed further later in this section of the DCP.
- Surface-water runoff from the FEMP watersheds to the receiving water course (e.g., Paddys Run) should be discharged at a rate no greater than the predevelopment runoff discharge rate [ODNR, 1996] (design consideration).
- Surface-water runoff should be managed so that, after restoration of the borrow area, the effects of erosion of the borrow area ground surface are minimal. Long-term erosion of the ground surface in the borrow area must not impact the OSDF (design considerations).

- Temporary runon control structures should be implemented to minimize runon from entering work areas. Such runon should be diverted around work areas using diversion dikes or channels as appropriate (design consideration).

- Temporary channels for surface-water runoff should be designed to meet the criteria presented in Section 2.8.3 of the DCP (design consideration).

- Permanent channels should be designed to meet the criteria presented in Section 2.8.4 of the DCP (design consideration).

- Culverts should be designed to meet the criteria presented in Section 2.8.4 of the DCP (design consideration).

- Riprap should be designed to meet the criteria presented in Section 2.8.4 of the DCP (design consideration).

- Sediment basins should meet the following criteria [ODNR, 1996] (design considerations).

  - The minimum capacity of the sediment basin to the elevation of the crest of the pipe spillway should be 1,800 cubic ft for each acre within the drainage area that will be disturbed by construction during the design life of the sediment basin.

  - The capacity of the pipe spillway should be sufficient to pass the runoff from the 2-year, 24-hour storm event. For the FEMP property, this event has a rainfall intensity of 2.5 in. [Parsons, 1995a].

  - The combination of the principal and emergency spillways should be capable of safely discharging the flow from the 10-year, 24-hour storm event if the drainage area to the sediment basin is less than or equal to 20 acres, or the 25-year, 24-hour storm event if the drainage area to the sediment basin is greater than 20 acres.

  - Consideration should be given to using the permanent Fernald facility main entrance road as a containment dike for the surface-water runoff in lieu of an emergency spillway.

  - If an emergency spillway is implemented, a minimum freeboard of 1 ft measured from the peak water elevation in the emergency spillway to the top of the embankment, should be provided.

- Temporary erosion control measures should include those items described in Section 2.8.3 in the DCP (design consideration).

It is noted that surface-water routing and surface-water management system design for watercourses and structures beyond the battery limit will be addressed in other design packages being prepared as part of the integrated FEMP remediation.

B. Calculations

Calculations should be performed to route the design storm through the borrow area for existing conditions and for construction conditions (i.e., during borrow activities), and to size sediment basins. The calculations should be performed as described below.

- The amount of surface-water runon and runoff should be calculated for each contributory drainage area.

- The size of the sediment basin, including outlet structures, should be calculated for each contributory drainage area.

The above calculations should be performed using the design storm events previously identified. Runon/runoff routing and sediment basin sizing should be evaluated using the procedures described in USDA-SCS Technical Release 20 and/or 55 [USDA-SCS, 1975, 1986a]; an acceptable tool for performing these calculations is the computer program "*HydroCAD™ Stormwater Modeling System*" [Applied Microcomputer Systems, 1993]. The above evaluations should be based on the information and guidance contained in USDA-SCS manuals [1985, 1986b, 1987, 1988].

In the event that a channel bottom grade is less than 0.5 percent, an analysis should be performed to establish that the channel does not clog or build up sediment that will cause loss of flow capacity in the design storm event.

2.10.2.5 Restoration

A. Design Criteria

The borrow area should be restored in accordance with the approved *Borrow Area Strategy Report* (Fluor Fernald, Inc., 2000) and *Borrow Area Management and Restoration Plan* (GeoSyntec, 2000) to a condition that requires minimal maintenance (functional requirement). The borrow area should be restored to a condition that is consistent with the geomorphological character of the area surrounding the FEMP

(design consideration). The following criteria should be followed in preparing the restoration plan for the borrow area.

- Final grades should be selected that minimize long-term erosion in the area. The final grades should not result in erosion that is greater than the calculated erosion rate for stabilized slopes in the vicinity of the FEMP that have similar grades and similar soil types (design consideration).

- Surface-water runoff from the restored borrow area should be routed as indicated in Section 2.10.2.4 (design consideration).

- The restored borrow area should be revegetated with plant species that minimize erosion, that can be successfully established given the design final grades and soil types, and that are self-propagating in the expected conditions of the restored borrow area (design consideration).

- The design of the restoration plan should provide for progressive restoration of the borrow area, with commencement of restoration in an area as soon as borrow activities have been completed. To the extent possible, activities should not be performed in portions of the borrow area that have been restored (design consideration).

B. Calculations

No formal calculations are required for restoration of the borrow area. Procedures and materials for establishing permanent vegetation in the borrow area should be consistent with those procedures and materials selected for the OSDF final cover system (see Section 2.6 of this DCP). ~~Additional references are as follows;~~

2.10.3 References

FEMP property data and information required to design the borrow area should be obtained from the references cited in Section 1.5 of this DCP. References from the general technical literature that may be used to design the borrow area are given in Section 2.8.6 of the DCP. Additional references are as follows:

Fluor Fernald, Inc. "*Borrow Area Strategy Report*", Revision O, Fernald, OH, April 2000.

GeoSyntec Consultants, Inc., "*Borrow Area Management and Restoration Plan*", Revision 1C, Atlanta, GA, April 2000.

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ATTACHMENT A-2

LAYOUT OF DESIGN SCENARIO AND DESIGN CASE SWM SYSTEMS

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DCP 30 JAN 02
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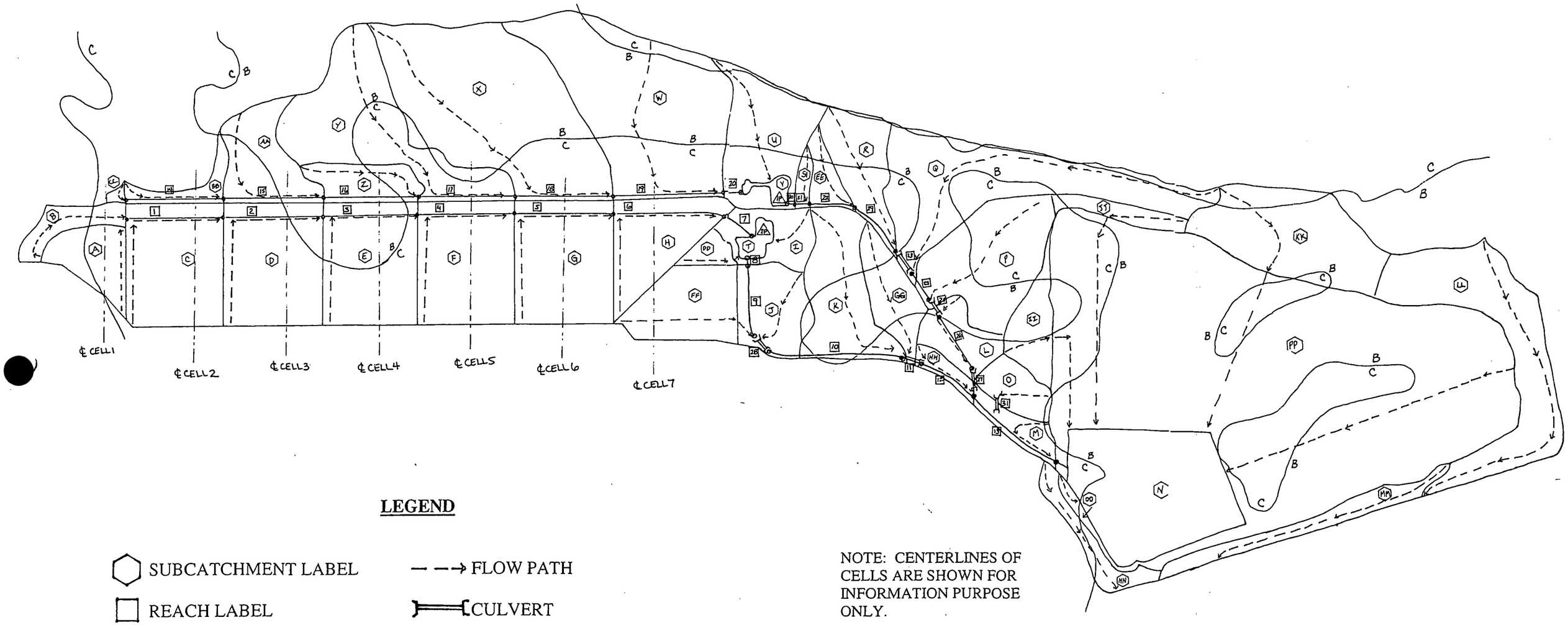


NOTE: CENTERLINES OF CELLS ARE SHOWN FOR INFORMATION PURPOSE ONLY.

LEGEND

- SUBCATCHMENT LABEL
- REACH LABEL
- POND LABEL
- REACH ALIGNMENT
- FLOW PATH
- CULVERT
- CENTERLINE OF CELL
- B / C DELINEATION OF HSG B & C AREAS

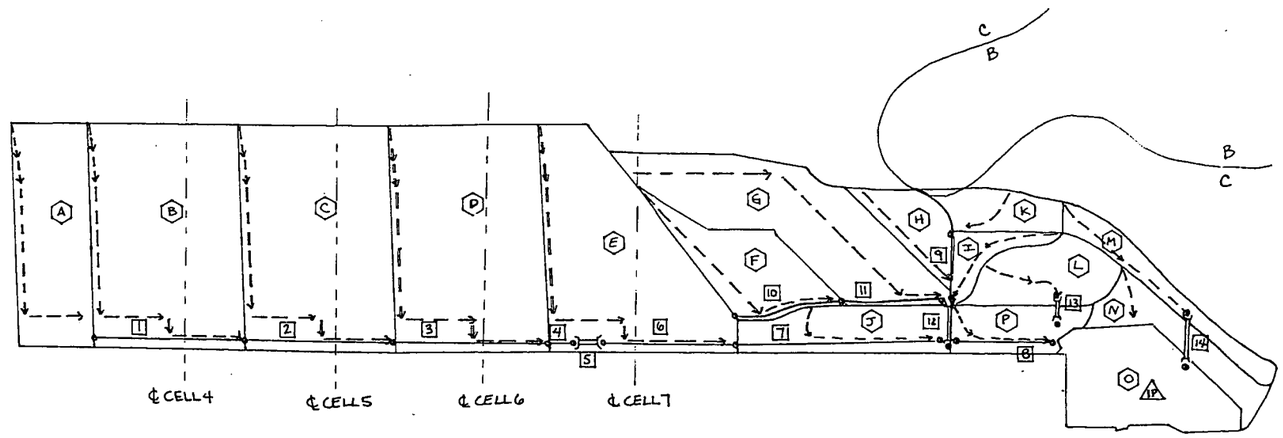
Phase V
East OSDF Design Scenarios
Scale 1" = 400'
0 400

DBM 1/30/02

51 /282

DCP 30 JAN 02

4664



NOTE: CENTERLINES OF CELLS ARE SHOWN FOR INFORMATION PURPOSE ONLY.

LEGEND

SUBCATCHMENT LABEL

REACH LABEL

POND LABEL

REACH ALIGNMENT

FLOW PATH

CULVERT

CENTERLINE OF CELL

B C DELINEATION OF HSG B & C AREAS

Phase V
West OSDF Design Scenarios
Scale 1" = 400'
0 400

DBM 1/30/02
52/282
DCP 30JAN02

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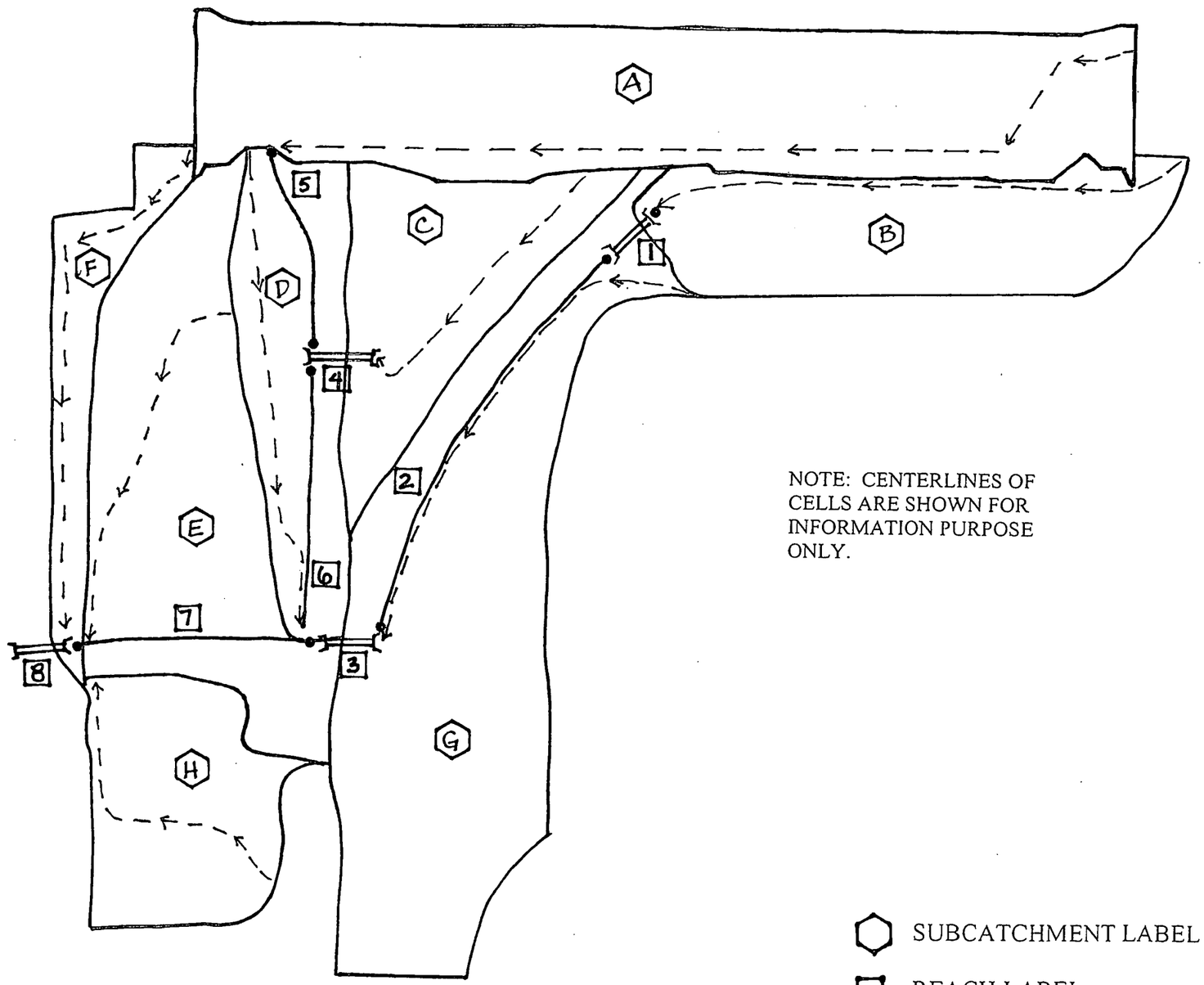

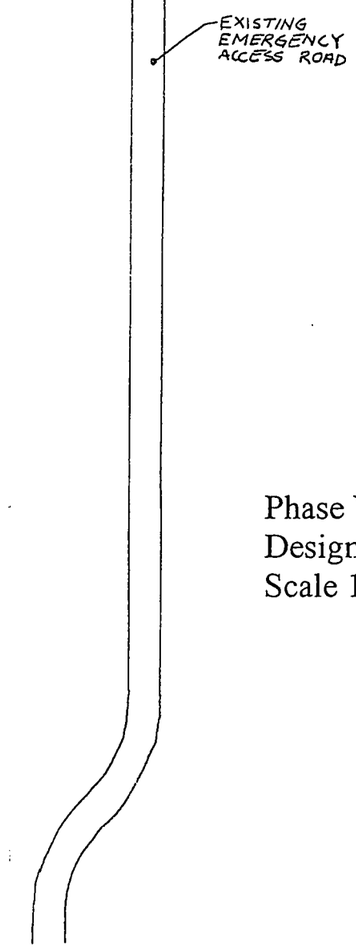

NOTE: CENTERLINES OF CELLS ARE SHOWN FOR INFORMATION PURPOSE ONLY.

Phase V
Design Case"A"
Scale 1" = 100'

LEGEND

- SUBCATCHMENT LABEL
- REACH LABEL
- REACH ALIGNMENT
- FLOW PATH
- CULVERT
- CENTERLINE OF CELL

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ATTACHMENT A-3

HydroCAD™ TECHNICAL REFERENCE MANUAL

54/282

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HydroCAD Technical Reference

This section contains detailed information on the calculations performed by HydroCAD. It is intended to help program users and reviewers fully understand the specific techniques and formulas employed by HydroCAD.

Section 10 - Units of Measure

Most equations in this Manual are given in a universal format that may be directly evaluated in metric (SI) or English units. When evaluating these equations, care must be taken to use only *primary* units as listed in the following table.

	Metric (SI)	English	Conversion Factor
Time	Seconds	Seconds	1
Length	Meters	Feet	3.281
Area	Square Meters	Square Feet	10.76
Volume	Cubic Meters	Cubic Feet	35.31
Velocity	Meters per Second	Feet per Second	3.281
Flow	Cubic Meters per Second	Cubic Feet per Second	35.31
Weir Coefficient	$\sqrt{Meters}$ / *Second*	$\sqrt{Feet}$ / *Second*	1.811

Some empirical equations were developed with specific units (such as inches in the SCS runoff equation), and cannot be readily expressed in a unit-less form. These equations are marked with the original units.

HydroCAD also supports many secondary units, such as acres and hectares, which are automatically converted to and from primary units as required. When evaluating equations by hand, be sure to use the appropriate primary units as listed above.

You can change the units for any project as described on page 21.

000174

Section 11 - Understanding Hydrology

What is Stormwater and why does it need to be modeled?

During a rainstorm, precipitation reaching the ground is dissipated by several mechanisms: some is lost to evaporation, some infiltrates into the ground, and the remainder appears as stormwater runoff. This runoff can cause a variety of undesirable effects, such as erosion and flooding. In order to prevent such damage, the runoff must be safely conveyed through suitable channels, pipes, streams, and rivers to a suitable point of disposal, and eventually to the sea. By determining the nature of the runoff and the way it will flow through these channels, it is possible to predict how, where, and when damage may occur. Steps can then be taken to reduce the chances of damage, such as enlarging a stream to prevent overflow of its banks, or detaining some of the runoff in a pond to reduce flooding downstream.

Why is there an increased need for stormwater modeling now?

Most new construction involves changes in the usage of the surrounding land. A new shopping center, for example, may remove a stand of trees and replace it with a paved parking lot and several buildings. Such a change in the ground cover has a dramatic effect on the runoff, greatly increasing its total volume and the rate of runoff. This directly increases the potential for erosion and flooding in all areas downstream of the new construction. To prevent such damage, the runoff must be predicted before construction so that suitable steps can be taken to handle the runoff in a safe and effective manner.

In the past, such analysis and design was often not performed. As a result, a significant amount of stormwater damage now occurs, ranging from minor flooding of local streams, to erosion of farmland, to flooding of major rivers. The resultant burden on many drainage systems and the increasing rate of construction means that all new construction and development should include a careful analysis of the effects on stormwater runoff. This not only reduces possible liability for stormwater damage, but is required by law in a growing number of states and towns.

How is stormwater modeled?

Stormwater modeling can be divided into two basic fields: Hydrology, which is the study of runoff and the factors that influence it, and Hydraulics, which is the study of water flow in the channels, pipes, streams, ponds, and rivers that convey it to the sea. In each field there are many techniques available for performing the required analysis. A qualified engineer must choose the best methods for each situation.

In the past, a number of simplified techniques have been employed for predicting runoff and its effects. With the advent of low-cost computers, it is now possible to use more sophisticated techniques to perform a more accurate and complete analysis in less time.

Different Approaches to Hydrology

55/282

There are many different approaches to stormwater modeling and drainage design. These techniques can be divided into two basic groups:

1) Steady-state (constant flow) methods, such as the Rational method as applied to storm sewer pipe networks.

2) Hydrograph generation and routing procedures designed to simulate the time-varying nature of actual runoff.

Although HydroCAD can be used for steady-state designs and does include the Rational method, it is designed primarily as a *hydrograph generation and routing* program. (See page 105 for a discussion of several related topics.)

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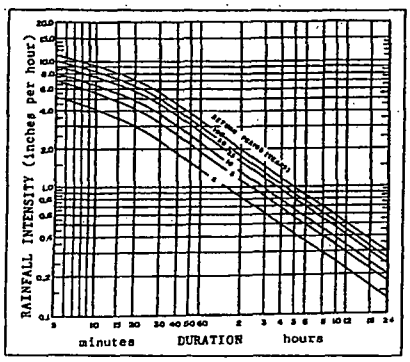
The Intensity-Duration-Frequency Relationship

Based on rainfall observations, IDF curves can be compiled for any location:



These curves indicate the relationship between the intensity (i) and duration (d) of a rainfall event with a given return period (T). They are typically used to determine the intensity of a specific design event.

Instead of return period, it is more accurate to think in terms of the exceedence probability (p), where p=1/T. Thus, a "25 year storm" actually designates a rainfall event which has a 4% chance of occurring in any given year.

The Rational Method for Predicting Runoff

The Rational method may be used to predict the peak runoff according to the formula:

$$Q = C \cdot i \cdot A$$

Q=Peak Runoff
C=Runoff Coefficient
i=Rainfall Intensity
A=Area

(See page 61 for a discussion of rational method units.)

Although the rational method appears straightforward, it is totally dependent on the "correct" selection of C and i.

C is based on the soil, ground cover, and other factors.

i is obtained from the local IDF curve for a given return period and duration.

One of the major challenges of the rational method is choosing the *critical duration*. The duration must be just long enough for maximum runoff to occur. A longer duration will yield a lower intensity from the IDF curve, and thus a lower runoff.

For a single subcatchment, the critical duration is usually equal to the time-of-concentration. However, when several subcatchments are combined in a complete drainage system, *the critical duration can have any value between the shortest and longest Tc.*

The rational method is intended to determine only peak runoff. It does not yield accurate runoff volumes, and therefore should not be used when subsequent volume-sensitive routing calculations are required.[6]

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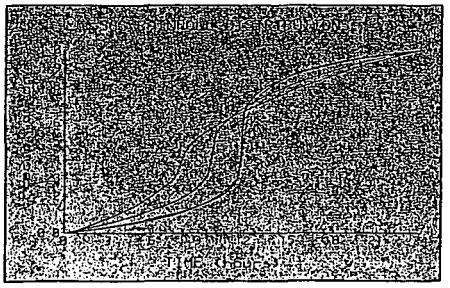
[6] If the Rational Method is selected for runoff calculations, HydroCAD generates a trapezoidal hydrograph for each subcatchment. This makes it possible to study the complex behavior that results from the combination of multiple subcatchments. Although HydroCAD is capable of routing the resultant hydrograph, such calculations exceed the intent and scope of the Rational Method and are best performed with other runoff techniques that provide more meaningful runoff volumes.

The SCS Storm Distributions

By studying the Weather Bureau's Rainfall Frequency Atlases, the Soil Conservation Service determined that virtually all rainfalls over the United States could be characterized by just four *dimensionless* rainfall distributions.[6] Each distribution is expressed as a *mass curve* indicating what *fraction* of the total 24-hour precipitation has fallen at any time.



These curves are *synthetic rainfall distributions*. They are intended as a tool for determining the behavior of a watershed under a wide range of conditions, and are not intended to represent an actual event.

Each curve is developed from the same depth-duration-frequency data used for IDF curves. Using 30 minute increments, the incremental rainfall is calculated for durations of 30 minutes to 24 hours. For example, the 30 minute depth is subtracted from the one hour depth, and the one hour depth from the 1½ hour depth. The largest 30 minute increment is placed at the middle of the hypothetical storm, which is 12 hours. The second largest 30-minute incremental depth is placed in the next 30 minutes, and the third largest in the previous 30 minutes. This process is repeated to develop the entire 24-hour curve.

- The most significant feature of the SCS storm distributions is that each curve contains depth information for events of *all* durations up to 24 hours.

- Furthermore, the SCS distributions give the cumulative rainfall at any point in time, thus making them suitable for volume-dependent routing calculations.

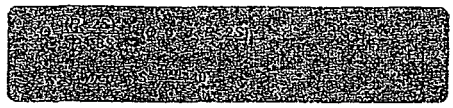
Although an actual event may be shorter than 24 hours, the same distribution is suitable for all events of 24 hour duration *or less*. Longer distributions are required only for very large watersheds where the overall travel time nears or exceeds 24 hours.

[6] While the SCS synthetic rainfalls are intended to cover most projects in the United States, some situations may require the use of a localized design storm, or even an actual rainfall distribution. HydroCAD contains a large library of such specialized storms, and additional custom storms are easily added.

The SCS Runoff Equation

56/282

Studies by the SCS resulted in the following empirical relationship for runoff:



Q=Precipitation excess (runoff) [inches]
P=Cumulative precipitation [inches]
S=Potential maximum retention [inches]
CN=SCS Curve Number

4664

The SCS runoff equation predicts the *volume* of runoff resulting from a given precipitation depth. The key factor in this translation is the SCS Curve Number.

The Curve Number is based on the soil type, ground cover, and other factors. High curve numbers (up to 100) indicate complete runoff with little retention, and low numbers indicate high retention and reduced runoff. (See page 49 for further information.)

- One of the most common effects of land development is an increase in the Curve Number. The transition from woods to lawn, or lawn to pavement, is accompanied by a significant increase in the CN. A close study of the SCS runoff equation will reveal that even a modest increase in the curve number can produce a dramatic increase in the volume of runoff.

Determining the Time of Concentration

While the SCS runoff equation predicts the *volume* of runoff, it doesn't specify *when* the runoff will occur. To determine how the runoff is distributed over time, we must introduce a time-dependent factor. The *time-of-concentration*, or Tc, is commonly used.

The Tc is typically defined as *the time required for a particle of water to travel from the most hydrologically remote point in the watershed to the point of collection*. There are several methods available for calculating Tc, one of which is the Lag Method:

T_c=Time of concentration [hours]
L=Lag time [hours]
l=Hydraulic length of watershed [feet]
Y=Average land slope [percent]
S=Potential maximum retention [inches]
CN=Weighed Curve Number

Other methods in common use include:

- TR-55 Sheet Flow
- TR-55 Shallow Concentrated Flow
- Channel Flow (Based on the Manning's velocity)
- Upland Method (Described in NEH-4)

All of these techniques are provided by HydroCAD. This allows selection of the method(s) best suited to each situation. Other techniques may be employed by entering the resultant Tc directly into HydroCAD.

The SCS Dimensionless Unit Hydrograph

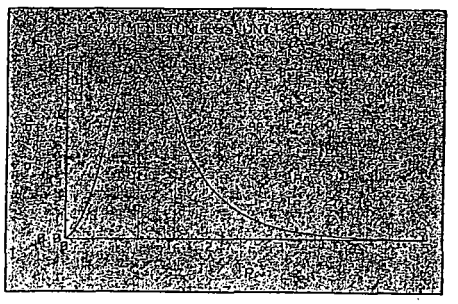
A unit hydrograph represents the runoff resulting from:

- One inch of precipitation excess,
- Generated uniformly over the watershed,
- At a uniform rate,
- For a duration D.

The hydrograph is made dimensionless by expressing:

- Ordinates as a fraction of the peak discharge q_p,
- Time axis as a fraction of the time-to-peak T_p.

By analyzing a large amount of measured data, the SCS developed an average dimensionless unit hydrograph:



000176

To dimension the time axis of the UH, we use the following relationships:

[illegible]

T_p=Time to peak
T_c=Time of concentration
D=Burst duration

This allows the burst duration D, and the overall duration of the UH, to be determined based solely on the time of concentration.

To dimension the ordinates of the UH, we can use the following relationship between the volume and peak of the UH:

[illegible]

q_p=Peak discharge [CFS]
484="Peak factor"
A=Area [sq-miles]
Q=Precipitation excess (runoff) [inches]

This allows the ordinates of the UH to be dimensioned based on the precipitation excess (Q), as previously determined by the SCS runoff equation.

- The SCS Dimensionless Unit Hydrograph is significant in that it is applicable to an extremely wide range of conditions. Only a few locations require a different curve, such as the Delmarva[7] unit hydrograph, which has a peak factor of 284.

[7] The Delmarva UH was developed for the peninsula between Delaware, Maryland, and Virginia for which it is named. It may also be used in other locations where the reduced peak factor of 284 is appropriate.

Convolution: The Heart of TR-20

57/282

The unit hydrograph, when dimensioned, tells us what the runoff will be for a *single* burst of rainfall. To determine the runoff for the entire storm, we must perform a *convolution of the unit hydrograph with the precipitation excess*. This is simply a summation of many unit hydrographs, each of which represents one burst of runoff.

The process is as follows:

1) For the first burst (of duration D) we determine the precipitation excess and create a corresponding Unit Hydrograph.

2) For the next burst we determine the precipitation excess occurring *during* the interval D which is $\Delta Q=Q(t+D)-Q(t)$. We create the corresponding UH, translate it by the duration D, and add it to the previous result.

3) Step 2 is repeated for all durations D needed to compose the entire 24-hour storm.

The resulting hydrograph represents the runoff from the entire storm. This is the fundamental method used by TR-20 for predicting runoff. It is commonly referred to as the SCS Unit Hydrograph procedure (SCS-UH), or simply the Unit Hydrograph procedure.

Note that if T_c=7.5 minutes and D=1 minute, then a 24-hour storm will consist of 1440 bursts generating an equal number of unit hydrographs. If the UH consists of 100 coordinates, about 140,000 coordinates must be summed to produce the composite hydrograph! Obviously, such a technique is not practical to perform by hand.

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TR-55 and the Tabular Method

Because of the enormous computational requirements of the unit hydrograph procedure, the SCS derived a simplified tabular method which it published in Technical Release 55 (TR-55).

The tabular method consists of a number of composite hydrographs produced with TR-20, which are then scaled and interpolated in order to approximate the results that would have been produced with TR-20 itself.

In order to keep the number of tables to a minimum, *average* values were used for several variables. The equations of TR-55 were then designed to reintroduce the dependencies on these parameters.

The two primary assumptions of TR-55 are a Curve Number of 75 and a runoff of 3 inches. TR-20 and TR-55 can be expected to deviate as these assumptions become invalid.

A number of other conditions also indicate the use of TR-20:

- T_c<.1 hours or T_c>2 hours
- Drainage subareas differ by a factor of 5 or more
- The entire hydrograph is required for routing
- Accurate volumes are required for routing

The approximations of TR-55 are sufficient to cause the SCS to place the following warnings in the documentation:

> "This method (TR-55) approximates TR-20, a more detailed hydrograph procedure.... Use TR-20 if the watershed is very complex or a higher degree of accuracy is required."

This applies particularly to the design of detention basins, since they are very sensitive to changes in the inflow hydrograph. Again quoting from TR-55:

> "The procedure (TR-55) should not be used to perform final design if an error in storage of 25 percent cannot be tolerated.... More detailed hydrograph development and routing will often pay for itself through reduced construction costs."

When evaluating TR-55, keep in mind that it was developed primarily for manual use. When computers are available, the original TR-20/SCS-UH methodology would appear to be preferred.

HydroCAD, TR-20, TR-55 Comparison

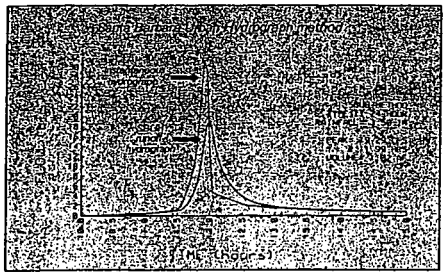
The following table summarizes the technical similarities and differences between these three programs. Note that HydroCAD combines the most-used capabilities of TR-20 and TR-55, plus many other techniques and features not provided by either program.

	HydroCAD	TR-20	TR-55
Unit hydrograph methodology	SCS unit hydrograph procedure (unlimited points)	SCS unit hydrograph procedure (301 points)	Tabular method derived from TR-20
Rainfall distributions	Extensive rainfall library plus user-defined storms	SCS type I, IA, II & III	SCS type I, IA, II & III
Unit hydrographs	SCS or Delmarva U.H., plus user defined curves	SCS Unit Hydrograph or user defined curve	SCS Unit Hydrograph only
Curve number lookup & weighting	Automatic curve number lookup and weighting	Requires direct entry of composite curve number	Automatic curve number lookup and weighting
Curve number adjustments	No restrictions	No restrictions	Reduced accuracy as CN differs from 75
Time of concentration calculations	All TR-55 methods plus common channel shapes, upland method, and CN method	Contains no Tc calculations: Requires direct entry of Tc	Calculates Tc for sheet, shallow concentrated, & channel flow
Tc limitations	No restrictions	No restrictions	Limited to .1 to 2 hrs
Tc precision	1/10 minute or 1/600 hour	1/100 hour	Rounded to nearest step
Subarea scaling limitations	None	None	Must not differ by more than factor of 5
Runoff accuracy	Within 1% of TR-20	"The standard"	Within ±25% of TR-20
Reach routing	Storage-indication method with optional routing delay (translation)	Modified Att-Kin procedure	No routing, separate tables for travel times of 0 to 3 hours
Pond routing	Storage-indication method or coupled pond routing	Storage-indication	None, only estimates ponding effects
Detention Time	By plug-flow method	not calculated	not calculated
Stage-discharge hydraulics	Automatic calculation for simple and compound outlets	Must be entered directly, no calculations provided	n/a, no pond routing
Stage-storage curve	Automatic calculation from pond surface areas, plus direct entry	Direct entry only	n/a, no pond routing
Flow diversions (split flows)	Automatic diversion of outflow from specified pond outlet(s)	Separate "Divert" procedure based on user-defined curve	n/a
Routing diagram	Interactive, on-screen	none	none
Calculation procedure	Automatically calculated as required	"Batch mode" calculation of entire watershed	Manual initiation of each calculation
Graphics capabilities	Full graphics to screen or printer	none	none
Reports	Automatic reports with headings, graphics, etc.	Manual	Manual
Data Storage	Automatic by job name	Manual	Manual

000177

The Santa Barbara Urban Hydrograph

Another common runoff technique is the Santa Barbara Urban Hydrograph method or SBUH.[8] This technique is similar to the SCS-UH procedure in that it employs the same SCS curve numbers, runoff equation, and rainfall distributions. The difference is that rather than utilizing a Unit Hydrograph to generate the runoff hydrograph, the SBUH method generates an instantaneous hydrograph which is routed through an imaginary reservoir with a time delay equal to the subcatchment's time of concentration.



A significant feature of the SBUH method is that the calculations are relatively simple in comparison to the SCS-UH procedure. Although it is rarely advisable to perform either technique by hand, it is at least possible to compute the SBUH runoff manually, and it can be done quite readily with a basic spreadsheet program.

While the availability of the SCS-UH procedure would appear to eliminate the need for the SBUH method, some localities prefer the SBUH method for specific situations. HydroCAD provides both techniques, and the ease of switching from one method to another makes it a simple matter to provide the required analysis, and even to compare the results of different techniques.

[8] Note that the "UH" stands for *Urban* Hydrograph, not *Unit* Hydrograph. This is a common point of confusion regarding the SBUH method. In fact, the SBUH method does not employ a Unit Hydrograph at all.

58/282

- 4664

Section 12 - HydroCAD Fundamentals

Understanding HydroCAD

HydroCAD provides a number of techniques for the generation and routing of hydrographs. It also provides many other related calculations, such as time of concentration, weighted curve numbers, pond volumes, stage-discharge curves, etc. This broad range of capabilities allows a large number of studies to be performed entirely within HydroCAD.

HydroCAD is a *hydrograph routing model*. It is designed specifically to handle *time varying flows*, as required for pond design and other volume-sensitive calculations.

Certain calculations, such as channel backwater or pressurized pipe networks, are normally analyzed under *constant flow* conditions. These tasks may be best addressed by steady-state numerical techniques, and not by a hydrograph routing system such as HydroCAD. Some projects may require the use of HydroCAD to model the overall drainage system, combined with a steady-state analysis of specific components. This is an unavoidable consequence of the different methodologies.

Although HydroCAD's sequence of operations is *very* flexible, its power is most easily understood by viewing it in four phases.

Phase I - Construction of Routing Diagram

A diagram is constructed showing the functional components, or nodes, that make up the watershed. The diagram shows the location of each node and how water is routed from one node to another.

Phase II - Description of each Node

Each node is described in detail so that HydroCAD can calculate the outflow from each node once the inflow is known.

Phase III- Calculation of flow through each Node

Calculations occur automatically whenever a report is selected. Starting at the upstream end of the diagram and working downstream, HydroCAD calculates the outflow and other results for each node. Multiple inflows are summed automatically. A *minimal recalculation* feature automatically reuses the results of previous calculations where no changes have occurred.

Phase IV - Display and Examination of Results

Opening one or more report windows lets the user verify the behavior of the watershed. If any changes are required, the user may modify the watershed, causing the calculations and reports to e automatically updated.

000178

Section 13 - Curve Number Selection & Use

Determining the Curve Number

The curve number (CN) characterizes the type of soil and ground cover. A high CN (such as 98 for pavement) indicates minimum retention, while a low CN (such as 30 for certain wooded areas) indicates a large retention capability. For subcatchments with multiple CN values, HydroCAD calculates a composite CN by summing the products of each CN multiplied by its percentage of the total area.

HydroCAD includes a complete curve number lookup table based on data developed by the SCS (NRCS) and published in TR-55. This table is based partly on the Hydrologic Soil Group, which may be determined for any soil type by clicking Help on the lookup table screen. For further information see page 111 and NEH-4, which provides additional guidance on CN selection.

Curve Number Effects

The curve number is used to determine the fraction of the precipitation depth that will occur as runoff. This relationship is specified by the SCS runoff equation as shown on page 57.

Adjustments for Antecedent Moisture Condition

The antecedent moisture condition specifies the moisture level in the ground immediately prior to the storm. Three conditions are defined:

AMC I - Dry
AMC II - Normal
AMC III - Wet

It is common policy to use AMC II for most design work. Other values should be used only under special circumstances. AMC III is sometimes used to study extremely wet conditions, such as a spring storm falling on saturated ground. AMC III usually causes a dramatic increase in runoff, and is not normally used for design purposes.

The AMC works by adjusting the Curve Numbers in all subcatchments according to a predefined table as shown on page 116. In general terms, AMC I reduces all CN values while AMC III increases the values. AMC II uses the original values without adjustment.

The AMC is set for each project by selecting Settings|Calculation: Rainfall.

59/282

4664

Section 14 - Determining the Time of Concentration

One of the key elements required for any runoff calculation is the *Time of Concentration*, or T_c. The T_c is typically defined as the time required for runoff to travel from the most hydrologically distant point of the watershed to the point of collection.

The time of concentration is commonly determined by summing the travel time (T_t) for each consecutive *flow segment* along the subcatchment's hydraulic path. This process requires identification of the type of flow occurring in each segment, and application of the appropriate method for calculating the T_t. Although these segments will occur in a given physical order, the order in which they are used in the program has no effect on the total travel time.

HydroCAD provides a variety of techniques for calculating the T_t, plus other procedures (such as the Curve Number method) which are designed to directly determine the overall T_c. These procedures are discussed below. If necessary, the T_c or T_t may also be determined by other procedures and entered into HydroCAD directly.

☞ The determination of the time of concentration is one of the most widely discussed areas of hydrology. The actual method(s) used on any given project depends upon actual site conditions, regulatory requirements, and sound engineering judgement.

Curve Number Method

The Curve Number Method (see NEH-4 p.15-7) was developed to allow calculation of the overall T_c under a wide range of conditions. The method is designed for areas of 2000 acres or less. The calculation is quite simple, but requires a proper understanding of the input requirements:

$$T_c = \frac{L}{6} \quad \text{where} \quad L = \frac{l^{0.8}(s+1)}{1900\,Y^{0.5}} \quad \text{and} \quad S = \frac{1000}{CN} - 10 \qquad \text{Eq. 6}$$

T_c=Time of concentration [hours]
L=Lag time [hours]
l=Hydraulic length of the watershed [feet]
Y=Average land slope [percent]
S=Potential maximum retention [inches]
CN=Weighted Curve Number (See page 111)

Note the use of the average *land* slope, as described below. (This is distinct from the slope of the hydraulic path, as used in most Tc calculations.) Although some care is required to determine this value, the Curve Number method has the advantage of using a small number of fairly objective parameters. This provides more consistent results than some other approaches.

Average Land Slope

The average land slope (or average watershed slope) is a critical factor in the use of the Curve Number method, as described above. A theoretical determination would require placing a grid over the subcatchment and averaging the slopes for all squares. Other techniques are available that have more modest data requirements, such as the following equation from Ponds-Planning, Design & Construction:

$$Y = \frac{C}{I} \qquad \text{Eq. 8}$$

Y=Average land slope [percent]
C=Total Contour length [feet] or [m]
I=Contour Interval [feet] or [m]

C is obtained by adding the length of all contour lines within the subcatchment. The accuracy of this technique depends on having a sufficient number of contour lines within the subcatchment. Reducing the contour interval will generally increase the accuracy of the result.

TR-55 Sheet Flow Procedure

The Sheet Flow procedure is designed for flow over plane surfaces, as usually occurs in the headwaters of a stream. (See TR-55 p.3-3) The following equation is used for sheet flow:

$$T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}} \qquad \text{Eq. 9}$$

T_t=Travel time [hours]
n=Manning's coefficient for sheet flow (See page 135)
L=Flow length [feet]
P_2=2-year, 24-hour rainfall [inches] (See map on page 121)
s=Land slope (along flow path) [ft/ft]

Determining the actual length of sheet flow is critical to this method. Although the technique was intended for lengths up to 300 feet, some agencies now recommend a maximum of 100 feet. In any case, the length should not extend past the point where there is evidence of concentrated flow on the ground. The length is also critical in that Sheet Flow is often a dominant factor in a subcatchment's total Tc.

000179

Upland Method

The Upland Method (see NEH-4 p.15-6) is designed for conditions that occur in the headwaters of a watershed, including overland flow, grassed waterways, paved areas, and through small upland gullies. Upland method is applicable to areas of 2000 acres or less. Although commonly published as a chart of velocity vs. slope for various surfaces, upland method is based on the following equation:

$$T_t = \frac{L}{60 \times V} \qquad V = K_v \times s^{0.5} \qquad \text{Eq 9}$$

T_t=Travel time [hours]
L=Flow length [feet] or [m]
V=Average velocity [FPS] or [m/s]
K_v=Velocity factor [FPS] or [m/s] (See page 137)
s=Land slope (along flow path) [ft/ft] or [m/m]

Shallow Concentrated Flow

The TR-55 Shallow Concentrated Flow procedure (see TR-55 p.3-3) is of the same mathematical form as the Upland Method (above). The essential difference is that it utilizes only two surface types, *paved* and *unpaved*. (See page 137 for the corresponding K_v values for these surfaces.) Due to the similarity between Upland Method and Shallow Concentrated Flow, HydroCAD utilizes a single screen for both methods, and combines the K_v values from both methods into a single table.

Channel Flow

60/282

The Channel Flow procedure (see TR-55 p.3-3) is commonly employed where surveyed cross sections are available, or anywhere the velocity can be reasonably determined by Manning's equation.

$$T_t = \frac{L}{60 \times V} \qquad V = \frac{1.486}{n} \times r^{2/3} \times s^{1/2} \qquad \text{Eq 10}$$

T_t=Travel time [hours]
L=Flow length [feet] or [m]
V=Average velocity [fps] or [m/s]
n=Manning's coefficient (See table on page 128) — 4664
s=Channel slope [ft/ft] or [m/m]
r=Hydraulic radius [feet] or [m]
a=Cross-sectional flow area [sq-feet] or [m^2]
P_w=Wetted perimeter [feet] or [m]
1.486=English factor (use 1 for metric evaluation)

In addition to allowing direct entry of cross sectional area and wetted perimeter, HydroCAD can automatically calculate these parameters for rectangular, vee, trapezoidal, parabolic, and circular channels as described on page 138.

Other Tc Procedures

Other T_c procedures can be employed by entering the calculated value directly into HydroCAD. This can be used as the total T_c for a subcatchment, or combined with additional flow segments calculated by other means. One situation that calls for direct T_c entry is modeling the "runoff" on the surface of a pond. This requires the direct entry of a T_c of zero.[9]

[9] When used in combination with a Curve Number of 100, this will produce complete, instantaneous "runoff."

Section 15 - SCS Unit Hydrograph Procedure

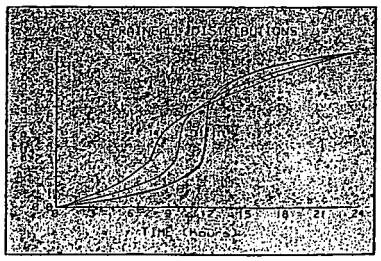
The US Department of Agriculture Soil Conservation Service[10] has developed a number of techniques for analyzing stormwater runoff. One of the most widely used is the SCS Unit Hydrograph procedure (SCS-UH). The SCS-UH procedure is a principal component of SCS/NRCS Technical Release 20, commonly known as TR-20.

The SCS-UH procedure is the primary runoff technique provided by HydroCAD. Although HydroCAD does not employ any of the actual code from TR-20, it is based on the same SCS-UH procedure and will produce essentially the same runoff results.

Due to the computational requirements of TR-20, the SCS produced a simplified, derivative tool in the form of the TR-55 Tabular method. The Tabular method is designed to approximate the results that would be obtained from TR-20, but uses various approximations that cause reduced accuracy in many situations. Because of this relationship, TR-20 will always provide equal or greater runoff accuracy, and is therefore preferable for most projects that call for the TR-55 Tabular method. (See page 43 for a detailed comparison of these techniques.)

Synthetic Rainfall Distributions

The SCS unit hydrograph procedure commonly utilizes a *synthetic rainfall distribution*. The SCS has developed several standard distributions that cover the entire U.S. These are commonly expressed as *mass curves*, as shown at right and discussed on page 117. When combined with national rainfall maps (starting on page 121), these distributions eliminate the need for local "IDF" curves as employed by the Rational method. In fact, the rainfall distributions contain the same information in a reduced form.



While the unit hydrograph procedure may initially appear more complex than the Rational method, it is actually easier to apply with a system such as HydroCAD. This is because the synthetic rainfall distributions encompass *all duration events* in a single calculation, while the Rational method requires a separate calculation for each duration.[11]

[illegible]stom rainfall distributions may also be used with the unit hydrograph procedure, but this is [illegible]ely necessary. It is not uncommon to confuse a local IDF curve with a rainfall distribution. An [illegible]F curve is not only inapplicable to the unit hydrograph procedure, but it usually duplicates the [illegible]a already contained in one of the rainfall distributions.

[10] Now the Natural Resources Conservation Service or NRCS.

[11] The SCS technique also provides accurate *volume* information for volume-sensitive studies such as ponds. In comparison, the Rational method is intended primarily for determining *peak* flows, and does not provide accurate volume information.

Data Requirements for the SCS-UH Procedure

The following data is required for the SCS unit hydrograph procedure as employed in both TR-20 and HydroCAD. Some of these items are provided for each individual subcatchment, while others apply to the entire watershed.

> The **curve number** (CN) characterizes the type of soil and ground cover, as discussed on page 49.
>
> The **time of concentration** (Tc) indicates the time required for all parts of the subcatchment to contribute to the runoff. (See page 51.)
>
> The **total storm rainfall** (in inches) is determined for any specific location from U.S. Weather Bureau maps based on the desired return period (2, 5, 10, 25, 50, or 100 years). This is the total precipitation that will occur during the storm. Rainfall maps for the United States (reprinted from TR-55) begin on page 121.
>
> The **storm type** is selected according to the geographic location and any special project requirements. For each storm, HydroCAD contains a mass curve indicating how the rainfall will be distributed over the total duration of the storm.

HydroCAD provides an extensive library of rainfall distributions, including the SCS 24-hour type I, IA, II, and III. (See page 117 for details.) The SCS rainfall data is in the form of second-order fitted equations, which guarantee a smooth runoff hydrograph free of "steps" or other irregularities. Specialized rainfall distributions are also provided for Florida, Illinois, and other areas, and custom rainfalls may be added if required.

> Most storms include a default **rainfall duration** (such as 24 hours) which is employed for most studies. The duration may be changed for special applications, such as the Illinois Huff Distributions.
>
> The **unit hydrograph** is a dimensionless curve that shows the runoff distribution resulting from one inch of precipitation excess occurring uniformly over the watershed during a specified duration. (See Hydrologic Analysis and Design p.399 for details.)

HydroCAD provides the standard SCS and Delmarva unit hydrographs (see TR-20 p.240) which have peak factors[12] of 484 and 284 respectively. Additional unit hydrographs may be defined if a different peak factor is required. (For details see the UH.txt file which is installed in the HydroCAD/Rainfall folder.)

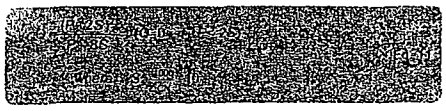
000180

[12] The peak factor is a characteristic of the unit hydrograph curve, representing the peak-to-volume ratio of the curve. The peak factor does not appear directly in the SCS-UH runoff procedure, and can be changed only by using a different UH.

SCS-UH Runoff Generation

The runoff hydrograph is generated by performing a *convolution of the unit hydrograph with the rainfall excess.* (For details see NEH-4 p.16-2.) A brief description of the HydroCAD implementation follows:

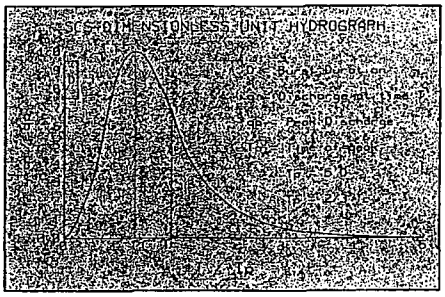
1) At any time during the storm, the cumulative precipitation (rainfall depth) can be determined from the selected rainfall distribution when multiplied by the total rainfall depth. The cumulative *precipitation excess* (runoff) can then be determined by the SCS runoff equation. (See TR-55 p.2-1 and NEH-4 p.10-5.)



Q=Precipitation excess (runoff) [inches]
P=Cumulative precipitation [inches]
S=Potential maximum retention [inches]
CN=Curve number

2) The storm is divided into a series of rainfall *bursts* of duration D=2/15 Tc. The precipitation excess occurring *during* any interval D at time t can be calculated by:

3) For each burst, the unit hydrograph defines how this volume of runoff will occur over time. The *volume* of the unit hydrograph is given by dQ (above). The *duration* of the unit hydrograph is related to Tc and D as shown. The result is that the *dimensionless* unit hydrograph has been dimensioned.



4) The runoff from the entire storm is determined by summing the hydrographs resulting from each rainfall burst.

SCS-UH Runoff Considerations

61/282

1) The runoff hydrograph consists of a series of ordinates (CFS flows) at evenly spaced intervals "dt." Each ordinate specifies the *average* flow during the interval. As a result, if a narrow peak occurred within one interval; the hydrograph would indicate an average flow that *might* be significantly less than the instantaneous peak. This is likely to occur when T_c is less than 2dt, so HydroCAD displays an informative warning in these cases.

When you encounter this situation, keep in mind that the instantaneous peak can exceed the average for a time no longer than dt, which is commonly 6 minutes or less. In practice, such a short instantaneous peak is usually attenuated to the average value by the storage characteristics of the first reach or pond. However, if a true instantaneous peak is required, the runoff interval (dt) may be reduced to approximately one-half the T_c.

2) TR-20 has no inherent limitations on the time of concentration. As T_c approaches 0, the runoff curve approaches the precipitation excess curve, which is the expected limiting case.[13] Similarly, for a very large T_c, the entire storm becomes a single rainfall "burst" and the runoff approaches the shape of the unit hydrograph.

3) When making comparisons to TR-55, note that the TR-55 tables were produced for a curve number of 75 and require a precipitation excess of at least 1.5 inches. As conditions deviate from these, an increasing difference of up to 25% can be expected.

4) Runoff hydrographs are generated for a specified *time span*, such as 10 to 20 hours. You must ensure that this span is suitable for the purposes of your analysis and the rainfall type being used. If you are primarily concerned with peak flows, you can reduce calculation time by using a shorter time span. However, for ponds and other volume-sensitive studies, make sure the time span begins at or before the earliest runoff, or this early volume won't be included in your calculations. HydroCAD will generate an automatic warning message if the span is not adequate to include the earliest inflow into a pond. Also keep in mind that the volumes displayed by HydroCAD include only the specified time span. By increasing the ending time to 25 hours or so, you'll get a complete picture of the storm.

5) As a safeguard, HydroCAD performs an automatic check of runoff peaks in relation to the time span. A warning message is displayed if the calculated time of the peak doesn't fall within the middle 90% of the time span. If this warning appears, you should examine the hydrograph and adjust the time span accordingly.[14]

- Although HydroCAD applies a number of tests to check the accuracy of your model, a visual examination of all hydrographs is *highly recommended.* This will help to detect erroneous input data and ensure meaningful results.

-- 4664

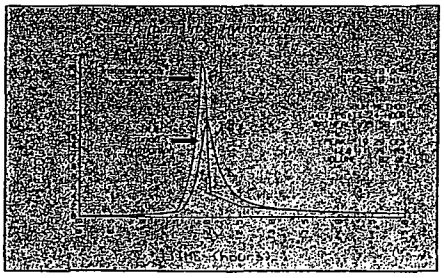
[13] If desired, the HydroCAD runoff procedure is specially designed to permit a Tc of zero. This can be used to model the instantaneous "runoff" from rain falling on the surface of a pond.

[14] This test is for the peak only. If the entire volume is required, you must still determine if the span is sufficient.

Section 16 - Santa Barbara Urban Hydrograph

The Santa Barbara Urban Hydrograph method (SBUH) was developed by the Santa Barbara County (California) Flood Control and Water Conservation District. The SBUH method has many similarities to the SCS Unit Hydrograph procedure discussed in the previous chapter. Both techniques employ the same SCS curve numbers, runoff equation, and rainfall distributions. However, the SBUH method does not utilize a unit hydrograph or the convolution process. Instead, an instantaneous hydrograph is generated and then routed through an imaginary reservoir with a time delay equal to the subcatchment's time of concentration.

This calculation is relatively simple in comparison to the SCS-UH procedure, and takes less time to perform. While the availability of the SCS-UH procedure might appear to eliminate the need for the SBUH method, some localities prefer the SBUH method for specific situations.



Runoff Procedure

There are two distinct steps involved in generating a runoff hydrograph by the SBUH method:

1) Compute the instantaneous hydrograph: The storm is divided into equal time increments (dt). At each increment, the SCS Runoff Equation (see page 57) is used to determine the precipitation excess. The difference between the successive values represents the instantaneous runoff at that point in time. A typical instantaneous hydrograph is represented by the dashed line in the above graph.

2) Compute the runoff hydrograph: The runoff hydrograph is obtained by routing the instantaneous hydrograph through an imaginary reservoir with a time delay equal to the time of concentration. The following equation is used to estimate the routed flow at each point in time:

Q_t=Runoff at time t [CFS]
I_t=Instantaneous runoff at time t [CFS]
dt=Calculation time increment [minutes]
T_c=Time of concentration [minutes]
w=Routing Coefficient

A typical runoff hydrograph is shown by a solid line in the graph above. Note the delay and reduction in the peak caused by the routing procedure.

000181

Section 17 - Rational Method

The Rational method may be used to generate runoff hydrographs. However, since Rational method was developed primarily for predicting peak flow, its use is *not* advised for volume-sensitive routing calculations.

The Rational method predicts the peak runoff according to the formula:

$$Q = C\,I\,A \qquad \text{Eq. 14}$$

Q=Peak Runoff
C=Runoff Coefficient
I=Rainfall intensity
A=Area

The equation can be evaluated using English or metric units, as long as proper dimensions are observed. For English use, it is traditional to employ inches-per-hour and acres for the intensity and area, respectively. Converting the units yields the following relationship, in which the factor of 1.01 is often omitted:

$$q[cfs] = 1.01\,C\,I[inches/hr]\,A[acres] \qquad \text{Eq. 15}$$

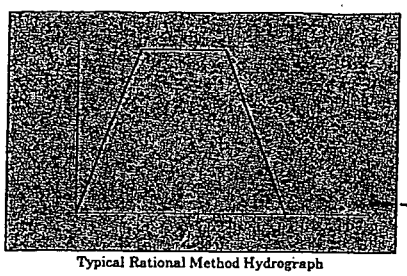
For metric use we can substitute mm/hr and hectares for the intensity and area, respectively. Converting the units yields the following relationship:

$$q[m^3/s] = \frac{1}{360}\,C\,I[mm/hr]\,A[ha] \qquad \text{Eq. 16}$$

In order to generate a complete hydrograph (as required by HydroCAD), it is assumed that the runoff begins at the start of the storm and increases linearly to the peak value, which is sustained until the storm duration (D) has elapsed, and then decreases linearly to zero.

The rate at which the hydrograph rises and falls is based on the Tc and a rise/fall factor. For "standard" Rational method, the rise and fall factors are both one. That is, the rise and fall occur over the exact interval Tc. Variations of the Rational method (often called the Modified Rational method), may use different rise and fall factors, which can be set directly using **Settings|Calculation**.

Rational method runoff traditionally begins at zero hours, although it can start at whatever time is specified in the calculation settings. A typical rational method hydrograph is shown below.



Typical Rational Method Hydrograph

The user must choose the *critical duration* (and the corresponding intensity) that results in the maximum combined runoff at *each point of study*. Depending on the specific watershed, this may occur at any duration between the shortest and longest T_c. As the study progresses downstream, the critical duration generally increases, but some trial and error is required for an accurate determination. Note that as the duration is changed, all upstream subcatchments are properly recalculated for the new value. This is the correct procedure for applying the Rational method, despite frequent misuse of the method in which these values are held constant.

Since a hydrograph produced by the Rational method does not reflect the total storm runoff or the variation in intensity, it is not recommended for the design and analysis of detention ponds. It is strongly advised that the SCS-UH or SBUH runoff methodology be used when pond routing calculations will be performed.

Section 18 - Reach Routing Calculations

A reach is used to perform an *independent hydrograph routing* for an open channel or a pipe flowing under open-channel conditions. A channel or pipe can alternatively be modeled as a flow segment within a subcatchment, where its travel time will contribute to the Tc. The later approach is usually simpler, and may even be necessary in the case of a subcatchment that is draining along the entire length of the reach. However, for a long reach with a significant inflow at one end, a separate reach routing may be called for. This section details the procedures used to perform an independent reach routing.

The Routing Curves

Reach routing requires that the reach first be characterized by two curves: the end-area vs. depth, and the discharge vs. depth (stage-discharge). This information may be determined by one of three procedures:

1) The user may directly specify the end-area and discharge at any number of depths.

2) The user may enter the wetted perimeter at each depth, and Manning's equation (see Basic Hydraulics p.77) is used to determine the discharge as follows:

$$V = \frac{1.486\,R^{2/3}\,S^{1/2}}{n} \qquad \text{Eq. 17}$$

V=Average velocity of flow [feet/sec] or [m/s]
1.486=English factor (use 1.0 for metric)
R=Hydraulic radius [feet] or [m]
S=Slope of channel bottom [rise/run]
n=Manning's number (See table on page 128)

$$\text{also } R = \frac{A}{P} \text{ and } Q = VA \qquad \text{Eq. 18}$$

A=Area of flow [sq-feet] or [m²]
P=Wetted perimeter [feet] or [m]
Q=Flow [CFS] or [m³/sec]

$$\text{thus } Q = \frac{1.486}{n}\left(\frac{A}{P}\right)^{2/3} S^{1/2} A \qquad \text{Eq. 19}$$

3) For certain standard shapes (rectangular, vee, trapezoidal, parabolic channel, or a circular pipe), the user may provide the appropriate dimensions, and HydroCAD will determine the end area and discharge curves. These are calculated using the area and perimeter equations on page 138, and Manning's equation as shown above.

Reach Routing Limitations

Since the stage-discharge relationship is based solely on Manning's equation, it does *not* consider inlet or outlet conditions. It assumes that the Manning's flow, and not the inlet, outlet, or tailwater, is the controlling factor. If a complete analysis is desired for a pipe reach, including entrance losses, the reach should be modeled as a pond with a culvert outlet.

Reach Routing Methods

HydroCAD currently provides three techniques for reach routing, which are described in the remainder of this section.

- Storage-Indication Method (Stor-Ind)
- Storage-Indication plus translation (Stor-Ind+Trans)
- Simultaneous Method (Sim-Route)

Storage-Indication Method

The Storage-Indication method (Stor-Ind) is the basic reach routing technique provided by HydroCAD, and is based on the routing equations developed on page 85. The actual routing procedure is as follows.

1) The reach's stage-discharge relationship is calculated as described above.

2) The stage-storage relationship is determined from the reach cross-section multiplied by the length.

3) The stage-discharge and stage-storage curves are used to create a storage-indication curve.

4) Routing is performed using the specified time span and time increment. At each point in time, a storage-indication value is calculated based on the current inflow, plus the previous inflow, outflow, and volume in the reach.

5) The current storage-indication value and the storage-indication curve are used to determine the new elevation.

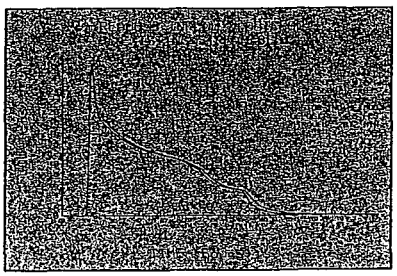
6) Using the new elevation, the stage-storage and stage-discharge curves are consulted to determine the new storage and discharge.

7) This process is repeated for all points in the inflow hydrograph.

In practice, the procedure may incorporate a number of other factors, such as a base flow or inflow loss. Any unusual conditions, such as the channel overtopping, will produce a specific warning message as listed on page 97.

Effects of Reach Routing

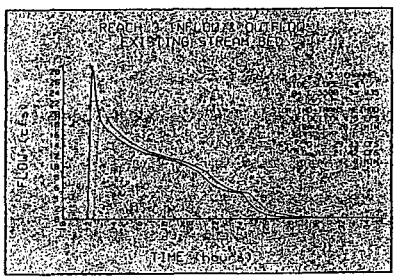
A reach will normally *attenuate and delay* the hydrograph that is routed through it. The extent of this transformation depends on many factors, including the reach dimensions, slope, and Manning's number. Short reaches (up to several hundred feet) often have a minimal effect on the routed hydrograph. For this reason they are frequently modeled as a flow segment within a subcatchment. This is the only option for some methods such as TR-55, which includes no reach routing procedures at all.



On the other hand, for long reaches with large cross-sections, low slopes and/or high Manning's numbers, the routing effect can be significant. The graph at right shows the effects of storage-indication routing through a 5500 foot long channel. Significant attenuation may also occur on shorter reaches if the inflow peak is of short duration.

Allowing for Travel Time

The storage-indication method, as described above, accounts for only the storage effects of the reach. Other techniques must be used to account for the kinematic effects of long reaches. HydroCAD provides the option of adding a time lag or *translation* to the normal storage-indication routing. Setting the reach routing method to "Stor-Ind+Trans" causes the storage-routed hydrograph to be further translated by the travel time, as defined on page 95. A close examination of the example at right reveals that the peak discharge no longer corresponds to a point on the inflow curve, but is translated by the prescribed amount.



Simultaneous Reach Routing

63/282

The Sim-Route reach routing procedure is provided for compatibility with simultaneous pond routing. Although this method does *not* currently allow reaches to respond to tailwater changes, its does allow the overall watershed to be analyzed in a simultaneous manner so that *ponds* may respond to tailwater effects as described on page 89.

Simultaneous reach routing is based on the basic equation for conservation of mass. (See Hydrologic Analysis and Design p.545.)

$$\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} = \frac{S_2 - S_1}{\Delta t} \qquad \text{Eq. 20}$$

I=Inflow rate
O=Outflow rate
Δt=Time increment (dt)
ΔS=Change in storage
S_1=Storage at start of time interval
S_2=Storage at end of time interval

— 4664

The following procedure is used to perform the actual hydrograph routing:

1) Routing is performed using the specified time span and time increment, and begins with no water stored in the reach.

2) The new reach storage (S_2) is calculated using the above equation with the previous rates of inflow and outflow. (Using the previous value allows non-sequential flows, for which the current inflow is unknown.)

3) Using the new storage volume, a new flow depth is calculated based on the assumption of normal flow.

4) Using the new flow depth, a new discharge is calculated from Manning's equation or from the user-defined stage-discharge relationship.

5) Steps 2 through 4 are repeated at each time interval until the entire hydrograph has been developed.

Additional considerations apply to all simultaneous routing procedures as described on page 88.

Section 19 - Pond Storage Calculations

All pond routing techniques require basic information about the pond's stage-storage relationship. HydroCAD provides several options for obtaining this information:

1) Direct entry of *cumulative* (total) storage at various elevations.

2) Entry of *incremental* storage, that is, the volume of horizontal sections across the pond. These sections are summed by the program to produce the cumulative storage.

3) Entry of *surface areas* at various elevations, from which HydroCAD determines the incremental (and cumulative) storage at each elevation.

The third option is often the most convenient, since it uses readily available data, such as the surface area at each contour elevation.

Pond Shape

Knowing the pond's general shape allows an accurate determination of the storage volume and wetted area, based on the surface area specified at each stage. HydroCAD provides specific volume calculations for the following basic pond shapes:

Prismatic
Each stage is taken as a horizontal section of a prism. This provides accurate volumes for four-sided ponds when zero, one or two (opposing) sides of the pond are sloping, and the other sides are vertical. The traditional "average area" method accurately determines the volume of these shapes. (Since the aspect ratio of prismatic shapes is undefined, the wetted area cannot be determined, making this shape incompatible with exfiltration calculations. One of the other shapes should be selected when wetted area is required.)

Pyramidal
Each stage is taken as a horizontal section of a pyramid. This assumes four sides of equal length and slope, and includes any shape with horizontal cross-sections that are square and concentric, such as a square box.

Conic
Each stage is taken as a horizontal section of a cone. This assumes circular sections with equally sloping sides. This includes any shape with horizontal cross-sections that are circular and concentric, such as a vertical cone or cylinder.

Irregular
No assumptions are made concerning the shape. Instead, the area and perimeter are specified at each stage. This allows accurate determination of wetted area for a wide range of irregular shapes, including elongated shapes such as trenches or underground storage chambers.

Storage Volume Calculations

The following equations are used to calculate the pond volume, depending on the prevailing shape of the pond.

Prismatic volume determination (Average area method)

This technique assumes that the areas are horizontal planes through a *prism*.[15] The calculation involves taking the average of the area at the top and bottom of the section and multiplying by the thickness. Although this is a commonly used method for calculating volume, it should be noted that it is completely accurate only for prismatic sections.

$$V = h\left(\frac{A_1 + A_2}{2}\right) \qquad \text{Eq. 21}$$

V=Volume of section
h=Height of section
A_1=Area of bottom of section
A_2=Area of top of section

Conic or pyramidal volume determination (Frustum of a cone or pyramid)

Most real-world ponds are not prismatic. They may be more round than rectangular, and may have more than two sloping sides. For these situations, the volume may be more accurately determined by assuming that the areas are horizontal sections of a *cone or pyramid*.

$$V = \frac{\pi h}{3}\left(\frac{A_1 + A_2}{\pi} - \sqrt{\frac{A_1 A_2}{\pi}}\right) \qquad \text{Eq. 22}$$

V=Volume of section
h=Height of section
A_1=Area of bottom of section
A_2=Area of top of section

Irregular volume determination

For ponds with an irregular horizontal section, the actual shape is unknown, however an approximate volume can be calculated using the previous equation for sections of a cone or pyramid. This provides reasonable accuracy for natural ponds with equally sloping (or vertical) sides, or when small section heights are used.

000183

[15] A prismatic section must have four sides, with no more than two sloping sides, which must be opposite.

Adjusting for Available Storage

By default, the defined volume of a pond is assumed to be 100% open space. If the available volume is reduced by gravel, sand, or other materials, the fraction of open space (voids) must be specified.

Open space is specified on the pond storage screen when "Set Open Space" is selected. This causes an additional column to appear in the stage-storage table.

When setting open space, a value must be provided at each defined stage, and applies to the storage between the current and *previous* line in the table. (Therefore the first open space value is not used in the calculation.) Setting the open space at each stage allows for ponds that are partially filled with gravel, filled with varying materials, or contain voids such as pipes or chambers.

> Note: Although the surface area could be reduced to account for gravel fill, this would yield incorrect wetted areas and exfiltration results. Hence the need to specify the open space separately.

Wetted Area Calculations

For some calculations (such as exfiltration) it may be necessary to determine the wetted area of the pond. Several methods are provided, depending on the shape of the pond. (Since prismatic shapes have an undefined aspect ratio, their wetted area cannot be determined. One of the following shapes should be selected when wetted area calculations are required.)

Wetted area for sections of a pyramid

The following equation is used to determine the wetted-area for a horizontal section (frustum) of a pyramid.

$$A = (\sqrt{A_1} + \sqrt{A_2}) \cdot \sqrt{(\sqrt{A_1} - \sqrt{A_2})^2 + 4h^2} \qquad \text{Eq. 23}$$

A=Wetted (side) area of section
h=Height of section
A_1=Area of bottom section
A_2=Area of top section

64/282

Wetted area for conic sections

The following equation is used to determine the wetted-area for a horizontal section (frustum) of a cone. The results are accurate for all sections of cylinders and cones, making it suitable for most dry wells and natural ponds.

$$A = (\sqrt{A_1} + \sqrt{A_2}) \cdot \sqrt{(\sqrt{A_1} - \sqrt{A_2})^2 + h^2} \qquad \text{Eq. 24}$$

A=Wetted (side) area of section
h=Height of section
A_1=Area of bottom section
A_2=Area of top section

-- 4664

Wetted area for irregular sections

For ponds with irregular horizontal sections, it is possible to determine the wetted area by specifying the linear perimeter at each stage. Taking this distance as the circumference of a circle allows an equivalent radius and area to be determined. Substituting into the previous equation for the wetted area of a conic section yields a reasonable estimate of the wetted area:

$$r_1 = \frac{P_1}{2\pi} \quad A_1 = \frac{P_1^2}{4\pi} \qquad \text{Eq. 25}$$

$$\text{and } A_2 = \frac{P_2^2}{4\pi} \quad r_2 = \frac{P_2}{2\pi}$$

A=Wetted (side) area of section
h=Height of section
P_1=Perimeter of bottom section
P_2=Perimeter of top section

Section 20 - Pond Hydraulics

This section details the hydraulic calculations used within HydroCAD. These equations are used to determine the discharge of each device under specific headwater and tailwater conditions. They are used primarily in determining the stage-discharge curve(s) for a pond. All equations determine the discharge Q, in CFS or m^3/sec.

Sharp-Crested Rectangular Weir

The basic equation for a sharp-crested weir is derived in Open Channel Hydraulics p.362.

$$Q = C \cdot L_e \cdot H^{3/2} \qquad \text{Eq. 26}$$

C=Weir coefficient
L_e=Effective crest length
H=Head [above crest or invert elevation]

The effective crest length L_e may include an adjustment for the number of end contractions.

$$L_e = L - \frac{nH}{10} \qquad \text{Eq. 27}$$

L=Crest length
n=Number of end contractions (0, 1, or 2)

The weir coefficient C varies slightly based on the crest height and the resulting turbulence. The *English* weir coefficient is given by:

$$C = 3.27 + \frac{H}{P} \qquad \text{Eq. 28}$$

C=Weir coefficient [$\sqrt{feet}$/sec]
P=Crest height [above approach channel]

To obtain a metric weir coefficient, divide this value by 1.81 as described on page 31.

Broad-Crested Rectangular Weir

A broad-crested rectangular weir differs from a sharp-crested weir in that the weir coefficient may vary as an arbitrary function of head. (See Practical Hydraulics p.274.) This allows more accurate modeling of a wide range of real-world weirs.

$$Q = C \cdot L \cdot H^{3/2} \qquad \text{Eq. 29}$$

C=Weir coefficient
L=Crest length
H=Head [above crest]

C varies with H by means of a lookup-table, which supplies the appropriate weir coefficient at specific heads. For intermediate heads, HydroCAD interpolates linearly between the given values. For heads that fall outside the given range, HydroCAD uses the first or last coefficient *without* extrapolation.

- For weirs with a sharp-edged crest, the coefficient lookup values can be supplied automatically by specifying the breadth of the crest. This causes the lookup table to be filled with coefficients as listed on page 130.
- Other crest profiles can be modeled by manually entering weir coefficients at appropriate heads. A table of various profiles is given on page 131.

V-Notch Weir

The basic equation for a v-notch weir is derived in Handbook of Hydraulics p.5-15:

$$Q = C \cdot \tan\frac{\theta}{2} \cdot H^{2.5} \qquad \text{Eq. 30}$$

C=Weir coefficient
θ=Notch angle (between two sides, not from vertical)
H=Head [above apex of V]

The weir coefficient may be entered manually, or automatically calculated using the following equation:

$$C = 2.46 + \frac{\tan(90-\theta/2)}{25} \qquad \text{Eq. 31}$$

C=*English* weir coefficient [$\sqrt{feet}$/sec]

To obtain a metric weir coefficient, divide this value by 1.81 as described on page 31.

000184

Trapezoidal Weir

The trapezoidal weir equation is a more general form of the v-notch weir. (Setting the crest length to zero yields the previous equation for a v-notch weir.)

$$Q = C \tan(\theta/2) H_1^{2.5} + C L H_1^{1.5} \qquad \text{Eq. 31}$$

C=Weir coefficient
θ=Notch angle (between two sides, not from vertical)
H=Head [above weir crest]
H_1=Head above imaginary apex of V
L=Length of horizontal crest (if any)

The weir coefficient may be entered manually, or automatically determined by Eq. 31 above.

Submerged Weirs

The preceding equations specify the discharge for various weirs under conditions of free discharge. If the tailwater of a weir exceeds the crest elevation, the crest becomes submerged, and the discharge is reduced according to the following equation from Handbook of Hydraulics p.5-18:

$$Q_s = Q_f \left[1 - \left(\frac{H_2}{H_1}\right)^n\right]^{0.385} \qquad \text{Eq. 33}$$

Q_f=Free discharge
Q_s=Submerged discharge
H_1=Upstream head above crest
H_2=Downstream head above crest
n=1.5 for rectangular weirs
n=2.5 for vee/trapezoidal weirs

Although this adjustment was derived specifically for sharp-crested weirs, it is also used to estimate the discharge for submerged broad-crested weirs.

Rectangular Orifice in a *Vertical Plane*

65/282

For a rectangular opening in a vertical plane, the discharge under any head is derived from the discharge through a thin horizontal strip. (See Handbook of Hydraulics p.4-3.)

$$dQ = C L \sqrt{2gY}\, dY \qquad \text{Eq. 34}$$

C=Discharge coefficient (Default is .60)
L=Strip length (width of orifice)
g=Gravitational constant
Y=Head over center of strip
dY=Height of horizontal strip

4664

Integrating over the height of the orifice yields:

$$Q = \frac{2}{3} C L \sqrt{2g}\, \left[(H+M)^{1.5} - (H-M)^{1.5}\right] \qquad \text{Eq. 35}$$

H=Head above invert elevation
M=Height of orifice

When the orifice is partially submerged (H<M) the term [H-M] becomes zero and this reduces to the weir equation:

$$Q = C L \sqrt{2g}\, H^{1.5} = 3.21\, L H^{1.5} \qquad \text{Eq. 36}$$

The above equations apply to free-discharge conditions. When the tailwater exceeds the orifice invert, the discharge is the sum of two components:

1) The discharge for the portion of the orifice (if any) that lies *above* the tailwater elevation is given by the previous equations, with the head and height measured from the tailwater level rather than from the invert.

2) The portion of the orifice that lies *below* the tailwater is subject to a constant head differential, with the discharge given by the basic orifice equation:

$$Q = C L Y \sqrt{2g\,(H-TW)} \qquad \text{Eq. 37}$$
where Y = lesser of M and TW

Rectangular Orifice in a *Horizontal Plane*

For an orifice opening in a horizontal plane, the discharge is given by the basic orifice equation as derived in Handbook of Hydraulics p.4-3:

$$Q = C a \sqrt{2gh} \qquad \text{Eq. 38}$$
$$h = H - TW \text{ (for TW below invert)} \qquad \text{Eq. 39}$$

C=Discharge coefficient (default is .60)
a=Orifice area
h=Effective head
H=Headwater depth
TW=Tailwater depth

Under low-head conditions, you may also wish to consider the possibility of weir flow as described on page 77.

Circular Orifice

The discharge for a circular orifice is derived in Handbook of Hydraulics p.4-3:

$$Q = C a \sqrt{2gh} \qquad \text{Eq. 40}$$

C=Discharge coefficient (default is .60)
a=Submerged area
g=Gravitational constant
h=Effective head

Circular Vertical Orifice

For an opening in a *vertical plane*, the effective head is given by:

$$h = H - \max(r, TW) \text{ (if fully submerged)} \qquad \text{Eq. 41}$$
$$h = H - \max(H, TW) \text{ (if partially submerged)} \qquad \text{Eq. 42}$$

H=Headwater depth above invert
TW=Tailwater depth above invert
r=Radius

When partially submerged, the head adjustment closely approximates the weir discharge of an orifice. It also provides continuity between the fully and partially submerged conditions. For critical situations, the resulting discharge curve should be verified by independent means.

Circular Horizontal Orifice

For an orifice opening in a *horizontal plane*, the effective head is given by:

$$h = H \text{ (for free discharge)} \qquad \text{Eq. 43}$$
$$h = H - TW \text{ (for TW above invert)} \qquad \text{Eq. 44}$$

Under low-head conditions, you may also wish to consider the possibility of weir flow as described on page 77.

000185

Orifices Under Low-head Conditions

The previous orifice equations for openings in a *vertical* plane are generally valid under all head conditions. No adjustment is required under low-head (partially submerged) conditions, since these equations reduce to the appropriate weir equation.

For orifice openings in a *horizontal* plane, the equations assume that the head is large in relation to the orifice size. This can lead to overestimating the discharge under low-head conditions. To ensure correct flow under all conditions, discharge can be automatically limited to that predicted by the weir equation:

$$Q = 3.33 \times L \times H^{3/2} \qquad \text{Eq 42}$$

Q=Discharge [cfs]
L=Crest length (orifice perimeter) [feet]
H=Head [feet above invert elevation]

This will cause the weir equation to control at low heads, without affecting the high-head discharge predicted by the orifice equation. The result is useful for a range of real-world "orifices," such as the top of a standpipe.

- This adjustment is performed automatically whenever "Use weir flow at low heads" is selected for a horizontal orifice.

Modeling a Grate

A grate typically consists of several identical openings, each of which can be modeled as an orifice. The orifice dimensions are specified for each opening, and the discharge multiplier is used to specify the number of openings. (This technique may not be appropriate for *vertical* grates with circular or horizontal openings, since the openings are at different elevations and therefore not identical.)

Culvert Flow — 4664 66/282

When evaluating a culvert, HydroCAD checks multiple flow conditions in order to determine the prevailing control *at each elevation*. This is based on six types of culvert flow as identified in Culverts - Hydrology & Hydraulics page E-1. (Also see Standard Handbook for Civil Engineers p.21-18,19.)

Type	Inlet	Outlet	Slope	Flow Type	Tailwater Dependent?	Type of Control
1a	Submerged	Submerged	Any	Pipe	Yes	Outlet
1b	Submerged	Free	Mild	Pipe	No	Outlet
1c	Submerged	Free	Any	Channel	No	Inlet (orifice)
2a	Free	TW>Yc	Mild	Channel	Yes	Outlet
2b	Free	TW<Yc	Mild	Channel	No	Outlet
2c	Free	TW<Yc	Steep	Channel	No	Inlet (weir)

TW=Tailwater, Yc=Critical Depth

For type 1b, assuming that the culvert is full along its entire length, the velocity is given by the following equation. (See Culverts - Hydrology & Hydraulics page D-11.)

$$V^2 = \frac{H + D - S \times L}{K_e + \frac{2 \times g \times n^2 \times L}{C^2 \times R^{1/3}}} \qquad Q = A \times V \qquad \text{Eq 43}$$

V=Average velocity of flow
H=Headwater depth above inlet invert
D=Depth of flow (=culvert height)
S=Slope [rise/run]
L=Length
Ke=Entrance energy loss coefficient (See table on page 133)
g=Gravitational constant
n=Manning's number (See table on page 128)
C=2.22 for English, 1 for metric
R=Hydraulic radius
A=Cross-sectional flow area

Type 2b discharge is the same as type 1b except that the depth (D) is less than the culvert height. Under these conditions, open channel flow exists and backwater calculations must be performed to precisely determine the depth. To reduce calculation time, the depth is approximated by:

$$D = \frac{3}{4} \times H \qquad \text{Eq 44}$$

Rather than directly determining whether type 1b or 2b flow exists, HydroCAD uses the lesser of this depth and the culvert height. This also ensures continuity between the two flow conditions, with the cross over occurring when the head is 4/3 of the culvert height.

Types 1a and 2a are similar to types 1b and 2b, except for the tailwater dependency. This is accommodated by setting D equal to the tailwater depth whenever this value exceeds the normal flow depth.

Types 1c and 2c operate under inlet control, and the discharge is determined with the orifice equations given previously. The orifice discharge coefficient is given by:

$$C_d = \frac{C_c}{\sqrt{K_e + 1}} \qquad \text{Eq 45}$$

Cc=Contraction coefficient (default is .90)

Note that for Ke=.5 this yields Cd=.6, which is the default discharge coefficient for a sharp-edged orifice.

The final determination of culvert discharge is made by calculating the type 1a/2a, 1b/2b *and* 1c/2c flows as described above. The least of these values (a, b, and c) is then used as the final discharge for a given head.

NOTE: The approximations used for culvert discharge have generally been found to provide sufficient accuracy for most hydrograph routing purposes. However, it is strongly recommended that the resulting stage-discharge curve be verified using independent culvert data. If a significant discrepancy is found, the desired discharge data should be entered directly as a Special Outlet instead of using the built-in culvert equations.

Special Outlet Device

The special outlet device is designed to handle unusual stage-discharge relationships that can't be reproduced with standard devices. With HydroCAD's ability to model complex series-parallel devices (see page 84), there should be very few situations which actually require a special outlet.

A special outlet consists of user-defined stage-discharge curve. The first discharge value must always be zero and may occur at any desired elevation. Additional discharge values are specified at higher elevations as required to adequately represent the true shape of the desired curve. When choosing the elevations, keep in mind that HydroCAD performs a linear interpolation to determine the discharge at any required intermediate elevations.

If the last defined elevation is exceeded, HydroCAD can extrapolate from the last two values if desired. Otherwise, the final discharge value is used without extrapolation.

Exfiltration Calculations

Since exfiltration is incorporated into a pond's stage-discharge curve, it is classified as an "outlet device." Exfiltration is also distinct from an "inflow loss," in that it continues to occur even when there is no inflow.

To separate exfiltration from other "true" outflows, it is usually directed to the discarded outflow to prevent further routing. Although there are few standards as to how to determine exfiltration, HydroCAD provides two basic procedures that can be used to implement a wide range of design methods:

1) A **constant exfiltration rate** Q may be specified in CFS or m³/sec. This value may be applied whenever there is water in the pond, or only when the level exceeds the specified "invert elevation." This feature may be used to model a pump or other "outlet" that "turns on" at a given elevation. The invert may also be used to prevent exfiltration through (lower) impervious regions of the pond.

2) An **exfiltration velocity** V may be specified in FPM or mm/min. This is multiplied by the available exfiltration area at a given elevation to determine the final exfiltration rate.

$$Q_Y = V \times A_Y \qquad \text{Eq 46}$$

Q_Y=Exfiltration at elevation Y
V=Exfiltration velocity
A_Y=Exfiltration area at elevation Y

The exfiltration area may be defined in two ways: (A) if all exfiltration is assumed to be downward (none through the sides of the pond), you may use the pond's *surface area*; (B) if exfiltration occurs through all exposed surfaces regardless of slope, you may use the pond's *wetted area*.

You may also elect to exclude the area of the pond that lies at or below the invert elevation. This option causes the discharge equation to be modified as follows:

$$Q_Y = V \times (A_Y - A_{invert}) \qquad \text{Eq 47}$$

A_{invert}=Exfiltration area at invert elevation

This causes exfiltration to occur only over the area of the pond that lies *above* the invert elevation, and is useful in preventing exfiltration through impervious (lower) regions of the pond.

000186

Tips for Using Exfiltration

Using surface area vs. wetted area

For ponds with gentle side-slopes, the surface area and wetted area are almost identical, and the two methods will give similar results. In such cases, the surface area method is recommended for simplicity. By basing exfiltration on surface area, you are stating that all flow is essentially downward. Only horizontal areas (above any invert) are available for exfiltration. All vertical areas are excluded.

If you wish to allow exfiltration through vertical surfaces, such as the sides of a drywell, then you must specify wetted area (See page 69 for details on wetted area calculations.) As always, it is your responsibility to ensure that this computation is applicable to your particular situation.

Using a percolation rate

A measured percolation rate *can* be converted to an equivalent exfiltration velocity by the following equation. However, other factors must be considered to determine if this is a reasonable design value for a proposed exfiltration area. (For example, can a large pond be expected to perc for 24 hours at the same rate as a small test pit for over a much shorter period?)

$$V = \frac{12}{P} \qquad \text{Eq 48}$$

V=Exfiltration velocity [FPM]
P=Perc Rate [Minutes per Inch]

Advanced techniques

While most cases will require just a single exfiltration device, it is also possible to use several exfiltration devices on a single pond. This could be used to model multistage exfiltration schemes, such as a drywell that overflows into a perforated pipe.

As with all pond designs, you should view and understand the stage-discharge plot to make sure the pond is exhibiting the behavior you expect. Do not rely solely on a review of the hydrograph where the pond's behavior is intertwined with the complexities of the inflow hydrograph.

67/282

- 4664

Section 21 - Pond Routing Calculations

Before routing through any pond, the storage vs. elevation (stage-storage) and the discharge vs. elevation (stage-discharge) relationships must be determined as described below.

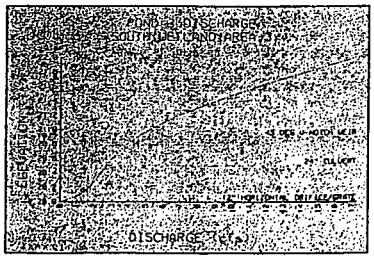
Stage-Storage Calculations

The cumulative stage-storage curve may be entered directly, or HydroCAD can sum incremental values to determine the cumulative storage. A third option is to enter surface areas at certain elevations and have HydroCAD calculate the storage. (These calculations are detailed on page 68.) In any case, a minimum of two storage points are required to permit interpolation for intermediate elevations. You should use as many points as necessary to accurately represent the true stage-storage curve for the pond. If the available storage space is less than 100%, or a storage multiplier is specified, the stage-storage curve is adjusted by these factors.

Stage-Discharge Calculations

The stage-discharge curve is automatically compiled based on the selected outlet devices. Each device is evaluated using the equations in the previous section. Each outlet also has a "discharge multiplier" which may be used for adjusting the normal rating curve or handling several identical devices.

The individual outlet devices are combined into one, two, or three stage-discharge curves based on the specified *device routing*. In the default configuration, all outlets are routed directly to the primary outflow, as shown in the sample stage-discharge curve at right. They are considered to be independent, *parallel* outlets whose flows are additive. The composite stage-discharge curve covers the same elevation range for which pond storage is defined, with the total discharge at each elevation determined by adding the discharge from each individual device.



If any devices are routed to a *secondary or discarded outflow*, additional stage-discharge curves are compiled using the same basic procedure. Each device is included in the stage-discharge curve to which it is routed. To perform the actual pond routing, a *total discharge curve* is obtained by adding the individual curves. When routing is complete, the total outflow hydrograph is split into primary, secondary, and discarded outflows based on the ratio of the stage-discharge curves. This produces an automatic split-flow, or "diversion." This is most commonly used when one or more outlets require separate routing, such as an emergency spillway or an exfiltration outflow.

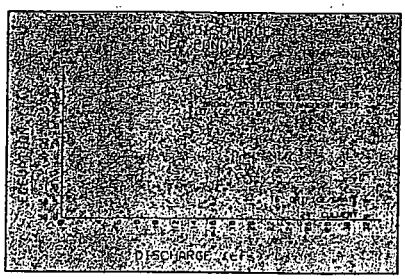
Compound Outlet Devices

More complex outlets can be modeled by placing standard devices in *series*. An orifice, for example, could be routed through a culvert. To calculate the discharge at each elevation, HydroCAD evaluates the standard flow through each device, and uses the lower (controlling) flow to build the stage-discharge curve. By making this comparison at each elevation step, different devices may control the outflow at different pond stages.[16]

Even more complex outlets can be modeled by utilizing simultaneous series/parallel device combinations. A standpipe is a common example of a compound outlet device. This could be modeled by a combination of standard devices as shown in the schematic representation at right.

Reading from the bottom up: Device 3 is a horizontal orifice representing the flow into the top of the riser. Device 2 is used to model one or more openings in the side of the riser. Devices 2 and 3 are summed together, and routed through the final outlet culvert, device 1.

This graph shows a typical stage-discharge curve for a pond with a compound outlet. A culvert is positioned with the inlet invert at 50 feet; however, no discharge occurs until the water level reaches an orifice 50.5 feet. (This example might represent an orifice plate used to reduce the flow through an existing culvert.) Above 50.5 feet, both devices are evaluated to determine which will control at each elevation. The resulting curve is labeled "pri" for primary.



This example also includes a broad-crested weir which is directed to the secondary discharge. This might represent an emergency spillway that is being routed separately from the culvert/orifice combination.

☞ When describing compound outlet devices, it is generally easiest to start with the *final* device (such as the culvert shown above) that contributes directly to the primary discharge. Then work *up* from the final device, entering each device that limits flow or contributes to the discharge. The process is then repeated for any secondary and/or discarded discharge.

000187

[16] This procedure uses the standard hydraulic equations given previously, with consideration of the minimum tailwater created when a device is lower than the next device downstream. However, it does not consider more complex interactions that may occur between devices, except to limit the flow to the lesser of the two. Like all complex calculations, it is important to verify these results by independent means to ensure they are sufficiently accurate for your purposes.

Pond Routing Procedures

HydroCAD currently provides two basic procedures for pond routing:

- Storage-Indication method
- Simultaneous pond routing

Storage-Indication Method

The storage-indication method is based on the conservation of mass, as expressed in the following relationship. (See Hydrologic Analysis and Design p.545.)

$$\frac{I_1 + I_2}{2}\Delta t - \frac{O_1 + O_2}{2}\Delta t = \Delta S \qquad \text{Eq. 49}$$

I=Inflow rate
O=Outflow rate
Δt=Time increment (dt)
ΔS=Change in storage

Using subscripts 1 and 2 to denote values at the beginning and end of the time interval Δt, yields the following expression:

$$\frac{I_1 + I_2}{2}\Delta t - \frac{O_1 + O_2}{2}\Delta t = S_2 - S_1 \qquad \text{Eq. 50}$$

Rearranging the equation with unknown terms on the left and known terms on the right yields:

$$\frac{I_1 + I_2}{2}\Delta t + \left(S_1 - \frac{O_1}{2}\Delta t\right) = \left(S_2 + \frac{O_2}{2}\Delta t\right) \qquad \text{Eq. 51}$$

The right hand portion of this equation is known as the storage-indication value, which can be evaluated at any stage (elevation) using the stage-storage and stage-discharge relationships previously determined.

Performing the Storage-Indication Routing

The following procedure is used to perform the actual hydrograph routing:

1) The pond's stage-discharge relationship is calculated based on the specified outlet devices.

2) The stage-storage relationship is determined from the specified stage-area or stage-storage data.

3) The stage-discharge and stage-storage curves are used to create the storage-indication curve.

- 4664

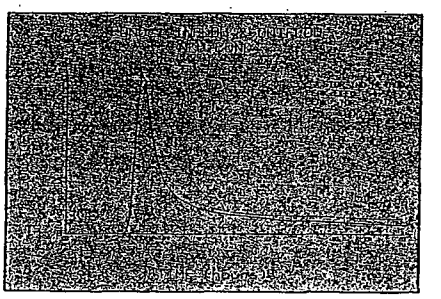
001252

4) Routing is performed using the specified time span and time increment. At each point in time, a storage-indication value is calculated based on the current inflow, plus the previous inflow, outflow, and volume in the pond.

5) The current storage-indication value and the storage-indication curve are used to determine the new elevation.

6) Using the new elevation, the stage-storage and stage-discharge curves are consulted to determine the new storage and discharge.

7) This process is repeated for all points in the inflow hydrograph, producing a complete outflow hydrograph as shown below.[17]



Special Considerations

When using the storage-indication method, keep in mind that a zero velocity is assumed in the pond. This is an accurate assumption for most ponds where the storage volume is large in comparison to the inflow. However, if the velocity approaching the outlet device(s) is significant, this method may underestimate the discharge and overestimate the peak elevation and storage of the pond.

[17] If the pond has multiple outlets, the routing is performed based on the total discharge, and is then split according to the characteristics of the individual outlets.

Additional Routing Features

In addition to the basic routing procedure described above, HydroCAD provides the following special routing capabilities.

1) The inflow hydrograph is automatically adjusted for any base flow (or inflow loss) by adding (or subtracting) the specified value from each point on the hydrograph. If "automatic base flow" is selected, the base flow is set to the pond's discharge at the specified starting elevation. This places the pond in an equilibrium condition (stable water surface elevation) when routing begins.

2) If a starting elevation is specified, routing begins with the water at this level. If this is above the lowest outlet device, the pond begins discharging immediately, possibly before any inflow has occurred. If the starting elevation is below the lowest device, no outflow occurs until this level is attained. (The outflow volume will also be reduced by the amount of storage below this level.)

3) Routing is normally performed using the time interval (dt) of the inflow hydrograph, although a finer interval may be specified for each pond to provide improved tracking. The normal dt is *divided* by the specified finer routing value. Finer routing (usually 2) can also be used to eliminate any oscillations in the pond's outflow, which will usually be indicated by a specific warning message.

4) If the peak elevation exceeds the specified flood elevation, a warning message is issued and routing will *continue*. The setting of the flood elevation has *no effect* on the routing itself.

Simultaneous vs. Sequential Routing

Previous versions of HydroCAD provided only sequential routing techniques, in which each node is routed in its entirety before the next node is evaluated. The storage-indication method is one of the most common sequential routing methods. This technique requires a static rating curve, that is, the stage-discharge relationship must be known before routing begins, and cannot change until the routing is complete. This prevents any node from responding to downstream conditions (such as varying tailwater) and enforces a sequential evaluation of the watershed.

To respond to downstream variations it is necessary to use a simultaneous pond routing technique, in which all nodes are routed essentially at the same time. To produce this effect, all nodes are routed one time increment at a time, allowing them to respond to changes elsewhere in the drainage system. (For details see Tailwater Capabilities on page 89.)

While simultaneous routing tends to provide greater capabilities, it is inherently more complex and requires more time to perform. It may also require that upstream nodes be recalculated, if they are sensitive to tailwater that has changed as a result of downstream modifications.

Since HydroCAD now provides a choice of sequential and simultaneous routing techniques, you can select the best approach for each project. In general, the storage-indication method can continue to be used for projects that operate with free discharge or fixed tailwater conditions. The SI method also has the advantages of being fast, widely used, and compatible with TR-20 pond routing. On the other hand, systems that are influenced by variable tailwater conditions may be better handled by simultaneous routing.

Simultaneous Pond Routing

The Sim-Route pond routing procedure allows each pond to respond to dynamic changes in the watershed, such as a variable tailwater created by a downstream node. This procedure re-evaluates the pond's discharge capability at each time increment during the routing, rather than using the static stage-discharge relationship employed by the storage-indication method.

Simultaneous pond routing is based on a direct application of the basic equation for conservation of mass. (See Hydrologic Analysis and Design p.545.)

$$\frac{I_1 + I_2}{2}\Delta t - \frac{O_1 + O_2}{2}\Delta t = \Delta S = S_2 - S_1$$

I=Inflow rate
O=Outflow rate
Δt=Time increment (dt)
ΔS=Change in storage
S_1=Storage at start of time interval
S_2=Storage at end of time interval

The following procedure is used to perform the actual hydrograph routing:

1) Routing is performed using the specified time span and time increment. The initial storage is assumed to be zero, unless an initial elevation is specified.

2) The new pond storage (S_2) is calculated using the above equation with the *previous* rates of inflow and outflow. (Using the *previous* value allows non-sequential flows, for which the current inflow is unknown.)

3) Using the new storage, a new elevation is determined directly from the stage-storage relationship.

4) New outflow(s) are calculated using the new pond elevation (the headwater) and the previous elevation of each downstream node (the tailwater.) Each outlet structure is directly evaluated under these conditions, without use of an intermediate stage-discharge table.

5) Steps 2 through 4 are repeated at each time interval until the entire hydrograph has been developed.

Special Considerations

When performing a simultaneous routing, each outflow is calculated based on the inflow, outflow, and elevations that existed at the *previous* time step. This eliminates the need to calculate the nodes in a fixed flow order, making it possible to model systems where the nodes may not have a fixed linear sequence. However, it also introduces an inherent time delay, which can be minimized by using the smallest feasible time increment.

Since this technique directly evaluates all outlet devices at each time increment, it eliminates the approximations inherent in a pre-calculated stage-discharge curve, as used by the storage-indication method. The drawback is slower calculation time, particularly with small time increments.

000188

Simultaneous routing also requires a small enough time increment to permit accurate "tracking" during the routing procedure. As the amount of available storage decreases, so does the required dt. An inadequate dt will cause the outflow to oscillate, which will usually generate a warning message. Very small reaches or ponds (such as catch basins) may require so small a time increment as to make simultaneous routing impractical. (See page 106 for further information on when to use the Sim-Route procedure.)

Tailwater Capabilities

When using any sequential routing method, nodes can respond to tailwater influences only when the tailwater is set by hand. This occurs because the downstream node (which creates the tailwater) cannot be calculated until after the upper node has been routed.

In contrast, a simultaneous routing method updates all interdependent nodes at each time step, providing the possibility for each node to respond to the current condition of its neighbors, including any tailwater they may produce. In order for tailwater effects to be automatically accommodated, two conditions must exist:

1) The upper node must use a routing procedure that is "tailwater-aware." That is, it must take the downstream condition (tailwater) into account when performing the routing calculation.

2) The lower node must use a routing procedure that defines a water surface elevation, which is seen as the tailwater for inflowing nodes.

The following table summarizes these characteristics for each type of node when using the Sim-Route procedure.

	Tailwater Aware?	Defines Elevation?
Subcat	no	no
Reach	no	yes
Pond	yes	yes
Link	no	no

Applying the previous rules to all node combinations indicates that automatic tailwater calculations occur for the following combinations:

- A pond flowing into another pond
- A pond flowing into a reach

Reverse Flows

69/282

HydroCAD is designed to model flows that occur in the same direction as the outflow arrows on the routing diagram. If the potential exists for flow in the reverse direction, an appropriate warning message is issued. Since HydroCAD does not automatically model reverse flows, the user must take appropriate action to address the situation. This may include the following options:

1) Systems with tailwater or reverse flow effects should generally be modeled using a simultaneous routing technique. This allows each pond to respond to dynamic tailwater conditions.

2) To model a reverse flow from one pond to another, create an appropriate outlet going in the reverse direction, that is, routed from the "lower" pond to the "upper" pond. (This will appear on the diagram as a double-ended arrow.) This outlet will mirror the normal down flow from the upper pond, but is described from the standpoint of water flowing in the opposite direction.[18]

- 4664

[18] A reverse outlet is permitted only for a simultaneous routing, which doesn't require a linear flow sequence. Sequential routing methods cannot accommodate such a "flow loop" and will report an error condition.

Section 22 - Link Calculations

Basic Applications

A link is a multipurpose mechanism that can be used to:

- Manually enter a hydrograph
- Import a hydrograph from an ASCII file
- Import a hydrograph from another project
- Apply a flow threshold or flow limit
- Change the duration of a hydrograph
- Rescale a hydrograph to a different peak
- Sum hydrographs without performing any routing

These capabilities are provided by the following basic types of links:

- An **internal link** is used to process only the inflows that are connected on the routing diagram.
- A **manual link** is used to manually enter an arbitrary hydrograph.
- A **file link** is used to read a hydrograph from an external data file. This capability can be used to import a hydrograph from another program, or to link several projects as described below.

Note that any type of link may have inflows on the routing diagram. For a manual link or file link, the imported hydrograph is added to any inflows shown on the diagram.

Advanced Settings

A link also provides several settings that can be used to perform special hydrograph operations:

Flow Threshold If a threshold is specified, only the portion of the inflow that exceeds this value is retained. The default threshold of zero causes all flow to be passed.

Flow Limit If a limit is specified, only the portion of the inflow below this limit is retained.

Discharge Multiplier After applying any flow threshold and/or limit, each flow is multiplied by this value. The default value of one produces no net change to the hydrograph.

Time Multiplier Scales any external inflow to a different duration. The default value of one produces no net change to the hydrograph. Internal (onscreen) inflows are *not* affected by this setting.

(The Time Multiplier allows the use of dimensionless hydrographs, as used for runoff studies in Ohio. A link file containing the Ohio rural hydrograph is included in the Ohio rural hydrograph.hce file supplied with HydroCAD.)

Link Routing Procedure

The basic link routing procedure is as follows:

1) If a Time Multiplier is specified, it is applied to any external inflow by multiplying each time ordinate by this value. The time multiplier has no effect on any internal (onscreen) inflows.

2) The adjusted external inflow is converted to the current time span and dt, and is added to any internal (onscreen) inflows. The result is considered to be the total inflow for the link.

3) If a Flow Threshold is specified, only the portion of the inflow hydrograph above the threshold is retained.

4) If a Flow Limit is specified, only the remainder of the inflow that falls below the threshold is retained

5) If a Discharge Multiplier is specified, each hydrograph ordinate (flow) is multiplied by the specified value.

6) If the Flow Limit, Threshold, or Discharge Multiplier has caused a reduction of the inflow hydrograph, a secondary outflow will be generated containing the remainder of the inflow hydrograph. In some cases this may then be routed separately, providing a basic flow-diversion mechanism.

The results of these operations are readily apparent upon viewing the link's hydrograph, which shows the inflow and outflow curves as described above.

000189

Using a Link to Model a Large Watershed

If you exceed the node capacity of your program, you can break a project into two (or more) sections and then connect them using an automatic link. (This technique does *not* apply to the HydroCAD Sampler, which does not have the file export capability.)

1) First break the project into two or more sections. You can do this by dragging nodes from one project to another, or by cut-and-paste. One project will typically contain the upstream portion of the watershed, and will end with an unrouted outflow, as show at right.

Upstream section

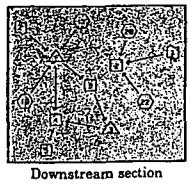
2) Verify the calculation settings for the upstream portion of the project. These must be set independently for each section of the project. On the Advanced tab of the calculation settings, set the Export Mode to "Unrouted Outflows" and click OK.

3) Close and save the upstream project. As the project is closed, the unrouted nodes are automatically updated and exported.

4) Open the downstream portion of the split project and create a link. Edit the link and select File Link. Select the File tab and press Browse to see a list of available export files. Select the desired file from the upstream portion of the project.

5) If the file contains multiple outflows, use the "File Hydrograph" box to select the desired hydrograph. Click OK to save the link's description.

6) You can now route the link's outflow on the diagram as shown at the right. The link will automatically import the hydrograph as calculations are performed.


Downstream section

Important: If you change the upstream project while the downstream portion is open, the downstream project will retain the earlier (outdated) inflow. To update the downstream project you must either (1) close and reopen the downstream project, or (2) Select Settings|Calculation and press OK. In either case, you must close the upstream project in order for the exported flow(s) to become available.

External Data Files

466470 / 282

External data files are commonly used to connect separate projects with a file link, as described above. HydroCAD automatically creates and deletes these files as required, based on the Export Mode. External data files may also be created manually or generated by other software. These are ASCII text files with an .hce extension, and must follow the format described in the sample file LinkTest.hce

To edit an external file by hand, click on the file and select "Notepad" when asked what program you want to use to open it. Windows will remember this selection the next time you attempt to open an external data file.

External files created by HydroCAD use the same file name as their project, with a tilde and the node number added to the end. If you create your own external files, you may use any name that does not match this format. Any files that match this specification will be overwritten each time the project is opened by HydroCAD!

To import an external data file into HydroCAD, create a file link on the diagram and use it to import the file.

Export Mode

The Export Mode indicates which node outflows (if any) will be exported from the current project:

- None: No nodes are exported. (default)
- Unrouted Outflows: Only unrouted outflows are exported.
- All Outflows: All node outflows are exported.

The export mode is set under Settings|Calculation:Advanced. When the project is saved and closed, the specified outflows are exported. The exported data is *not* available while the project is open.

The export mode allows HydroCAD to automatically export calculation results to a file for use with an automatic link or with other software. In order to conserve disk space, the Export Mode should normally be set to "None."

If you plan to route the current project into another project using a link, use the "Unrouted Outflows" setting. This optimizes disk space by exporting only the outflows that are not being routed on the diagram. This will include all outflows that are likely to be imported with a link.

The "All Outflows" setting should be used only when absolutely necessary, since it can consume large amounts of disk space. (The exact amount depends primarily on the number of points in each hydrograph. A 1000-point hydrograph requires about 15K of storage per outflow, or 150K for a 10-node project.)

Section 23 - Additional Calculations

This section explains the procedures used to calculate certain values appearing in HydroCAD reports, and to perform certain hydrograph operations.

Hydrograph Parameters

The **peak flow** for each hydrograph is calculated using the three highest points on the hydrograph.[19] A parabola is fitted to these points and the apex of the parabola specifies the true peak. This eliminates variations in the peak that would occur if only a single point were considered. This improvement in accuracy is most pronounced with a narrow peak, where the two closest points fall on either side of the peak and may be several percent below the actual peak.

The **peak attenuation** indicates the percentage reduction in peak inflow caused by a routing operation. This is determined by comparing the peak of the inflow and outflow hydrographs as calculated above.

The **time of peak** is determined by the same parabolic fit to the three highest points. The apex of the parabola establishes a time of peak with far greater resolution than the time between points. Like the peak flow, this value is not affected by the placement of the points on the "true" curve.

The **time lag** caused by a reach or pond is the difference between the time of peak obtained from the inflow and outflow hydrographs. (This is distinct from the *travel time*, described below.)

The **hydrograph volume** is determined by integrating the flow over the time span of the hydrograph. Since the volume can include flow only within the given time span, any flow before or after is excluded. Also note that the lag introduced by a pond or reach can cause a discrepancy between the calculated inflow and outflow volume. If necessary, this can be remedied by increasing the calculation time span to include the entire duration of the inflow and outflow hydrographs.

The **peak elevation, peak depth, and peak storage** are determined by interpolation, in the same manner as peak flow. (This is a change from HydroCAD-5, which reported the highest discrete value as the peak.)

The **maximum velocity** is the largest value obtained by dividing each discrete flow rate by the corresponding cross-sectional area. This result may be somewhat different than dividing the peak flow by the corresponding area.

The **average velocity** is determined by averaging the flow rate divided by the corresponding area at each time interval during the routing calculation.

The **travel time** is calculated by dividing the length of the reach, channel, or pipe by the velocity. For a reach routing, the average and minimum travel time are calculated using the average and maximum velocity, respectively. For some reach routing procedures, the travel time is used to further translate (delay) the outflow.

[19] HydroCAD also checks for flat-topped hydrographs, where curve fitting and extrapolation are not appropriate.

Adding Hydrographs

When adding hydrographs with the same starting time (To) and time interval (dT), the ordinates at matching times are added directly. If the hydrographs differ as to To or dT, such direct addition is not possible. (This can occur when using a link to introduce an external hydrograph.) In this case, HydroCAD will interpolate from the external hydrograph in order to obtain values at the same time steps as the current project. The resulting hydrograph will always have the same time span and dt as the current project.

Detention Time

When addressing water *quality*, one of the more useful and objective measures is the *average detention time*. This is a measure of how long water is detained in a pond or other impoundment, and can be used to determine the time available for removal of sediments or the neutralization of runoff contaminants. (For further details see Applied Hydrology and Sedimentology for Disturbed Areas p.257.)

The *center of mass* method is one of the most basic methods of calculating detention time. It evaluates the difference in time between the center-of-mass of the inflow and outflow hydrographs. One of the chief advantages of this technique is that it is easily calculated, and can even be estimated graphically. However, the technique does not consider the actual movement of water through the pond, and can fail to give a good measure of detention time in many situations.

The *plug flow method* provides a more physically meaningful measure of the average detention time. This technique divides the inflow hydrograph into a number of "plugs" of equal volume, and then calculates the time between each plug entering and leaving the pond. The average time for all plugs is then calculated and used as an overall measure of detention time.

HydroCAD employs the plug flow method to determine the average detention time for each pond.[20] The *theoretical* detention time is calculated by assuming that water initially in the pond is allowed to discharge *before* the first plug from the inflow is allowed to discharge. This "first-in first-out" assumption will yield a maximum detention time, and means that the amount of water initially in the pond *will* affect the calculated result. (Since all water in the pond is displaced before any of the inflow starts to discharge, the detention time is increased by the time required to flush the initial volume.)

Any water retained in the pond, or discharging after the specified time span, is excluded from the calculation. To obtain an accurate measure of detention time, it is therefore important to use a time span that allows the pond to discharge fully. This can be determined by comparing the *volume* of inflow and outflow. These should be roughly the same (unless the pond was surcharged or water was retained). Also compare the volume of flow included in the plug flow calculation (this is shown to the right of the detention time). For accurate (maximum) results, this should be close to the volume of the outflow hydrograph.

When evaluating detention time regulations, care must be taken to understand the exact standard that must be met. Wording such as "detain the ten-year storm for 24 hours" is common, but is sometimes incomplete or ambiguous. The plug flow method provides a more specific standard that can be used to address water quality issues related to detention time.

000190

[20] Note that the plug flow method is *not* a routing method. It is used *after* the hydrograph routing has been performed.

Section 24 - Calculation Messages

This appendix lists samples of the various messages that may occur during runoff and routing calculations. In actual use, the text of each message will vary to reflect the exact situation, however the message number (shown in brackets) will remain the same.

☞ When running HydroCAD, you can click on any item in the message window for complete information. This will display the entire text shown here, as well as links to related topics, calculations and definitions.

[01] Note: {node} Duplicate node number skipped

A node was encountered with a number that was already in use. The node is skipped, and the program continues to process any additional nodes.

This message usually occurs while adding a project that contains nodes that don't have unique numbers. Before adding a project, you should generally renumber any nodes with conflicting numbers. To add any nodes that were skipped, renumber the applicable nodes and add the project again.

The message can also occur when pasting nodes from the clipboard, or opening a project that contains duplicate node numbers. Tip: To make a clone of an existing node use Ctrl-drag (rather than cut and paste.)

[02] Note: Exceeded node capacity

The current project has exceeded the nominal node capacity of your program.

You can continue to work with the project, but you will not be able to save the project or produce multi-page reports unless you reduce the number of nodes.

Warning: If you're using the HydroCAD Sampler, your changes will be lost when the Sampler's time limit expires. To save your project you must reduce the number of nodes before the time limit expires.

[10] Note: Updating to {node} as needed

Routing calculations are being performed up to a specific node. To save time, downstream nodes are not being calculated, unless a simultaneous routing is being performed. Any other nodes will be automatically updated when required.

[13] Note: Time span = 5-20 hrs, dt= .05 hrs, 301 Points

This message indicates the time span and time increment (dt) being used to generate and route hydrographs. The message also indicates the number of points in the resulting hydrographs.

[16] Note: Runoff by SCS TR-20 method, UH=SCS 71 / 282

This message indicates the method being used to produce runoff hydrographs. When using the SCS method, the message also indicates the Unit Hydrograph (UH) being employed.

When using the Rational method, the message indicates the hydrograph rise/fall rates. These parameters may be changed with Settings|Calculation.

[18] Note: Rainfall Duration=20 min, Inten=4.30 in/hr -- 4664

This message indicates the rainfall durstion and intensity being used with the Rational method. These parameters may be changed with Settings|Calculation.

[19] Note: Type II 24-hr Rainfall= 4.30" x 2 (AMC=2)

This message indicates the rainfall distribution and depth being used to generate runoff hydrographs.

An "x" at the end indicates the number of back-to-back storms to generate. In the case of back-to-back storms, note that the specified rainfall depth occurs in each of the storms.

Finally, the Antecedent Moisture Condition (AMC) is shown. These parameters may be changed with Settings|Calculation.

[22] Note: Reach routing by Stor-Ind+Trans method

This message indicates the method being used to perform hydrograph routing through each reach. The routing method may be changed using Settings|Calculation.

[25] Note: Pond routing by Stor-Ind method

This message indicates the method being used to perform hydrograph routing through each pond. The routing method may be changed using Settings|Calculation.

[28] Note: Updating {node}

This message indicates that runoff or routing calculations are being updated for a given node.

Routing calculations are automatically updated as required to view or print reports. HydroCAD employs a "minimal recalculation" feature, so that only the required nodes are updated at any given time.

When updating a node, all upstream nodes are automatically updated when required. Downstream nodes may also be updated during a simultaneous routing.

Additional information is available on the calculation process employed for each subcatchment, reach, pond, and link.

[31] Note: Calculations complete

This message indicates that all the calculations required at this time have been completed. Some nodes may not have been updated, if their results were not immediately required.

[40] Hint: {node} Not described

No description has been entered for the node, or the data is incomplete. For a subcatchment, no runoff is produced. For a reach, pond, or link, any inflow is passed through unchanged.

To describe the node, select Node|Edit.

An undescribed node can be useful during initial design work, since it allows a node to be placed on the diagram but not described until later.

[43] Hint: {node} Has no inflow (Outflow=Zero)

This node has no inflow on the routing diagram, so it will produce no outflow unless it has a base flow and/or initial water surface elevation.

[45] Hint: Subcat Runoff=Zero

The subcatchment has produced no runoff. This can occur in any of the following situations:

1) The entire runoff may be occurring before or after the specified time span. To change the time span use Settings|Calculation.

2) For the SCS or SBUH methods, the rainfall depth may be insufficient to generate any runoff as determined by the SCS runoff equation. This is normal when low rainfall depths are used in combination with low curve numbers.

[46] Hint: Subcat Tc=0 (Instant runoff peak depends on dt)

When the time-of-concentration is zero, the precipitation excess appears immediately as runoff. Since the calculated peak flow is based on the average over each time interval (dt), using a longer dt (in relation to the peak duration) will yield a lower "peak" flow.

If the instantaneous peak is required, reduce the dt. The dt may be changed using Settings|Calculation: Time Span.

Note: The calculated runoff volume is not effected by the dt setting.

[49] Hint: Subcat Tc<2dt may require smaller dt

When the time-of-concentration is less than twice the time increment (dt), the instantaneous peak may exceed the (average) hydrograph peak for a brief time (less than dt).

If the instantaneous peak is required, reduce the dt. A dt of one-half the smallest Tc will prevent this message from occurring. The dt may be changed using Settings|Calculation: Time Span.

Note: The runoff *volume* is not affected by the dt setting.

[52] Hint: Reach Inlet conditions not evaluated

Reach routing calculations assume normal-flow conditions in the channel or pipe. The software does not evaluate inlet conditions for the reach, although these may often be a controlling factor.

If you wish to consider entrance losses, pressure flow, or other conditions for a pipe, it should be modeled as a pond with a culvert outlet.

[55] Hint: Reach Peak inflow is 105% of Manning's capacity

The reach is operating above its Manning's normal-flow capacity, but has not overtopped. This may be acceptable depending on the design criteria.

[58] Hint: {node} Peaked x.x' above defined flood level

The peak depth in a reach or pond has exceeded the defined flood elevation. Routing continues as usual.

The significance of this message depends on the flood level that has been specified for this node. The message does not indicate that the calculations themselves have been compromised.

A separate warning message is produced whenever a reach or pond exceeds the highest defined stage.

[61] Hint: {node} Submerged 45% of Reach 4 bottom

The node's peak elevation has partially submerged the bottom of an inflowing reach.

This message occurs when the peak elevation (tailwater) is greater then the outlet invert but less than the inlet invert. The percentage indicates the fraction of the reach length that is submerged. If the tailwater had risen above the inlet invert a separate warning message would have been issued.

Important: The reach routing calculations are not altered by this situation. The routing continues to be performed as if the reach were operating under normal Manning's flow with no tailwater influence. The user is responsible for adjusting the model in any way that is deemed necessary to accommodate this situation. In some situations an alternate routing method or modeling technique may be required.

Reminder: In most situations, a pipe reach is best modeled as a pond with a culvert outlet.

 000191

[62] Warning: {node} Submerged 25% of Reach 4 inlet

This node's peak elevation has partially submerged the inlet of an inflowing reach.

This message occurs when the peak elevation (tailwater) rises above the inlet invert but remains below the calculated inlet depth at all times. The percentage indicates the fraction of the defined reach depth that is submerged at the inlet.

Important: The reach routing calculations are not altered by this situation, even though it may reduce the reach discharge or even cause a reverse flow. The routing continues to be performed as if the reach were operating under normal Manning's flow with no tailwater influence. Since these basic routing assumptions are no longer valid, an alternate routing method or modeling technique may be required. The user is responsible for adjusting the model in any way that is deemed necessary to accommodate this situation.

Reminder: In most situations, a pipe reach is best modeled as a pond with a culvert outlet, which can accommodate a wider range of tailwater conditions.

[63] Warning: {node} Exceeded Reach 4 inflow depth by 0.0' @ 0.0 hrs

At some point during the routing, the node's elevation has exceeded the depth of flow at the reach inlet, creating a potential for reverse flow. The message shows the maximum amount of reverse head and the time at which it occurred

Important: The reach routing calculations are not altered by this situation, even though the higher tailwater may in reality cause a reverse flow. The routing continues to be performed as if a one-way valve were preventing the backflow. The user is responsible for adjusting the model in any way that is deemed necessary to accommodate this situation.

[65] Warning: Reach Inlet elevation not specified

The reach inlet elevation has not been specified. This information is required in order to detect potential tailwater effects.

Note: An undefined invert elevation commonly occurs with projects that were imported from HydroCAD 5 or earlier. These projects considered only the reach depth, and had no knowledge of the reach elevation in relation to other nodes.

Use **Node|Edit: Profile** to specify the inlet elevation for each reach.

[67] Warning: {node} Inflow not allowed - Ignored

This node cannot accept an inflow hydrograph. The inflow is ignored.

Separate procedures are available if you need to route a hydrograph through a subcatchment.

[70] Warning: Subcat Tc<8dt requires smaller dt 72/282

The rising limb of a Rational Method hydrograph contains fewer than eight ordinates. A smaller dt is recommended in order to accurately represent the hydrograph. (A dt of .01 hours is generally appropriate for most Rational method calculations.) Inspection of the hydrograph is also advised. The dt may be changed using **Settings|Calculation: Time Span.**

[73] Warning: Subcat Peak may fall outside time span -- 4664

The calculated runoff peak isn't within the middle 90% of the specified time span. Under these conditions, the reported "peak" is the highest flow within the time span, and may not be the true peak.

Inspect the hydrograph and change the time span to include the peak. The time span may be changed using **Settings|Calculation: Time Span.**

[76] Warning: Reach Detained 1.23 AF (Pond w/culvert advised)

A pipe reach has filled with water, causing the flow to be limited and the excess volume to be detained without head.

IMPORTANT: Pipe reach calculations assume normal-flow conditions in the pipe. If you wish to consider entrance losses, pressure flow, or other conditions, the pipe should be modeled as a pond with a culvert outlet.

[79] Warning: {node} Submerged Pond 5 device # by 0.0'

The node's peak elevation has submerged the specified pond outlet device. This message occurs when the peak elevation (tailwater) rises above the invert of one of the pond's final outlet device(s).

Important: The pond routing calculations are not altered by this situation, even though the tailwater may reduce the pond's discharge or even cause a reverse flow. The routing continues to be performed based on the existing stage-discharge relationship, as if the tailwater did not exist.

Since a static stage-discharge curve cannot accommodate a variable tailwater, the tailwater must be specified manually using **Node|Edit:Tailwater.** If one of these tailwater options isn't sufficient, an alternate routing method may be required, such as a simultaneous routing. The user is responsible for adjusting the model in any way that is deemed necessary to accommodate this situation.

[80] Warning: {node} Exceeded Pond 5 by 0.0' @ 0.0 hrs (0.0 cfs)

At some point during the routing, the node's elevation has exceeded the elevation of an inflowing pond, creating a potential for reverse flow. The message shows the maximum amount of reverse head, the time at which it occurred, and an estimate of the potential reverse flow.

Important: The pond routing calculations are not altered by this situation, even though the higher tailwater may in reality cause a reverse flow. The routing continues to be performed as if a one-way valve were preventing the backflow. The user is responsible for adjusting the model in any way that is deemed necessary to accommodate this situation. For further details read about modeling reverse flows.

[82] Warning: Early inflow requires earlier time span

Some inflow may be occurring before the beginning of the specified time span, and is therefore not included in the routing. An earlier time span is required in order to include the early part of the inflow hydrograph.

The time span may be changed using **Settings|Calculation: Time Span.**

[85] Warning: {node} Oscillations may require Finer Routing>1

The outflow of a pond or reach contains a greater number of peaks than the inflow, suggesting that oscillations may have been induced by the routing.

If a visual inspection reveals oscillations, they can usually be eliminated by setting the finer routing value to 2 for that particular node. If this fails to correct the problem, the available storage may be too small to permit an accurate routing for this node.

Note: Reducing the overall time increment (dt) may also resolve the problem, but this will unnecessarily increase the calculation time for other nodes.

[86] Warning: {node} Oscillations may require smaller dt

The outflow of a pond or reach contains a greater number of peaks than the inflow. This suggests that oscillations were induced by the routing and that the routing results may not be valid!

If a visual inspection reveals oscillations, reduce the time increment (dt) until the situation is corrected. This may require a reduction to the minimum dt of 0.01 hours.

If the problem persists, the available storage may be too small to permit an accurate routing with the simultaneous routing method. This method is intended for "coupled ponds" of reasonable size. In general, it is not intended for reaches or ponds with very small amounts of storage, such as catch basins or manholes.

[88] Warning: {node} Qout>Qin may require Finer Routing>1 or smaller dt

The peak outflow of a pond or reach was greater than the peak inflow. This can occur if the storage is very small in relation to the inflow volume, or if there are abrupt changes in the stage-discharge curve or inflow hydrograph.

This can usually be corrected by setting the finer routing value to 2 for that particular node, or using a smaller time increment for the entire project. (The choice is determined by the current routing method and will be reflected in the actual warning message that is issued.)

[91] Warning: {node} Storage range exceeded by xx'

The depth in a reach or pond has exceeded the highest defined stage. Routing continues using a linear extrapolation of the storage and discharge curves.

Important: For accuracy, you must extend the storage and discharge curves to prevent extrapolation.

000192

Section 25 - Frequently Asked Questions

Why can't I route an upstream node through a subcatchment?

A subcatchment contains only the information needed to perform a runoff calculation. Use a reach if you want to route another hydrograph through this land area. For shallow overland flow, use a wide channel with a suitable Manning's number.

Why isn't the entire outflow of my pond being routed?

Make sure there isn't an un-routed primary or secondary discharge, which will appear as an outflow handle on the node. If so, you must route the outflow to another node or reconfigure the outlet devices to eliminate the outflow.

What is the best way to model a pipe?

A pipe can be modeled in three ways. 1) If the pipe always operates under open channel flow, you can model it as a separate pipe reach. 2) Some open-channel pipes are most easily modeled as a flow segment within a subcatchment. 3) The most complete solution is to model the pipe as a culvert outlet on a pond, even if the "pond" is simply a roadway impoundment, approach channel, or drop inlet.

How do I model a catch basin?

A catch-basin is best modeled as a pond with a culvert outlet. The "pond" should include not only the below-ground volume of the catch-basin, but also any above-ground storage that is used when the basin overflows. (Always enter enough stage-storage data to prevent a "data exceeded" warning.) This will allow a more accurate culvert analysis to be performed on the pipe, including the effects of headwater and inlet losses. In some cases the simultaneous routing procedure can also be used to handle varying tailwater conditions, although it may be unable to track the rapid changes in water level that can occur in such small "ponds."

What about a closed storm sewer?

A storm sewer can sometimes be modeled as a series of ponds with culvert outlets as described above, subject to the same tailwater considerations. Due to the computational problems of routing hydrographs through a closed storm sewer, these systems may have to be modeled with two separate tools, first performing a steady-state analysis of the closed drainage system, followed by a hydrograph routing to consider detention effects.

Can HydroCAD calculate the Hydraulic Grade Line (HGL) ?

Determining the HGL requires that the entire drainage system be at equilibrium. Since hydrograph routing models are handling a time-varying flow, there is no single HGL for the system. The closest approximation would be to determine the HGL at the peak flow, but even this is flawed, since the peak flows occur at different times throughout the drainage system.

How do I compare the existing and proposed conditions for my site? 73/282

First create and save the model for the existing conditions. Then use Project|SaveAs to save a copy of the project under a new name for modeling the proposed conditions.

How do I compare different rainfall events? - 4664

Due to the large volume of information associated with any given rainfall, HydroCAD retains only one set of results at a time. The easiest way to compare multiple events is to print a report for each one. Automatic calculations make this very easy. Using a separate "project" for each rainfall is not recommended, since each project will have to be manually updated whenever changes are required.

When should I use the new "simultaneous" routing procedures?

The new Sim-Route procedure is intended specifically to model "coupled ponds." This includes many situations where the upper pond's outlet(s) are influenced by a varying tailwater created by the lower pond. A common example is a culverted road crossing with ponding occurring on both sides of the road.

If there is no tailwater effect, or the tailwater is constant, the traditional storage-indication method is still recommended. The Sim-Route procedure may also be precluded for very small ponds (such as catch basins) that will not "track" properly, even with the smallest dt. Although the Sim-Route procedure may work with some catch basins, it is intended for larger ponds that have a significant storage volume in relation to the inflow hydrograph.

Section 26 - References

The following references contain additional information on the hydrology and hydraulics utilized by HydroCAD. These publications are referred to by number throughout this manual and are listed in approximate order of usage.

[1] McCuen, Richard H. A Guide to Hydrologic Analysis Using SCS Methods, Prentice Hall, 1982. (Out of print. Also see [13], Chapter 8.)

[2] Soil Conservation Service Technical Release Number 20 (TR-20), National Technical Information Service, 1982.

[3] Smith, P.D. Basic Hydraulics, Butterworth Scientific, 1982.

[4] Sharp, J.J. & Sawden, P. Basic Hydrology, Butterworth Scientific, 1984.

[5] King, H.W. & Brater, E.F. Handbook of Hydraulics, McGraw Hill, 1963.

[6] Simon, Andrew Practical Hydraulics, John Wiley & Sons, 1981.

[7] Chow, Ven Te Open Channel Hydraulics, McGraw Hill, 1959.

[8] Merrit, Frederick Standard Handbook for Civil Engineers

[9] Jerome M. Norman et al Culverts - Hydrology & Hydraulics, Lehigh University, 1980.

[10] Soil Conservation Service National Engineering Handbook, Section 4 - Hydrology (NEH-4), National Technical Information Service, 1985.

[11] Soil Conservation Service Technical Release Number 55 (TR-55), 1986.

[12] American Concrete Pipe Association Concrete Pipe Handbook, 1981.

[13] McCuen, Richard H. Hydrologic Analysis and Design, Prentice Hall, 1989.

[14] Barfield and Warner Applied Hydrology and Sedimentology for Disturbed Areas, Oklahoma Technical Press, 1983.

[15] NRCS (Formerly SCS) Agricultural Handbook Number 590, Ponds - Planning, Design, Construction.

000193

ATTACHMENT A-4

CulvertMaster® THEORY SECTION

Chapter 5

CulvertMaster Theory

Analysis of Culvert Systems

When engineers analyze culvert systems, they are usually trying to make one or more of the following basic determinations:

- Determine the size, shape, and number of new or additional culverts required to pass a design discharge.
- Predict the hydraulic capacity of an existing culvert system under some allowable headwater elevation.
- Predict the upstream flood level at an existing culvert system resulting from some check discharge or other discharge magnitude of special interest.
- Develop hydraulic performance curves for a culvert system for assessing hydraulic risk at a crossing or as input to another hydraulic or hydrologic model.

CulvertMaster models complete culvert systems. A roadway cross-drainage culvert system is typically designed to safely carry flood flows from one side of the road to the other. The culvert system consists of the following hydraulic components:

- **Hydrology** – An upstream watershed drainage area discharging design and check storm flows to the culvert system. The magnitude of these discharges is computed using an accepted hydrological method such as Rational, SCS Peak, application of a state Regression Equation, or some other suitable methodology.
- **Culvert Hydraulics** – One or more culvert barrels along with associated headwalls, wingwalls, and other types of end treatments, which convey flow through a roadway embankment. The performance of these culverts is described using culvert hydraulics.
- **Roadway Overtopping** – A roadway embankment may be subject to overtopping flows if the total capacity of the culvert(s) is exceeded. Such overtopping flows are analyzed using weir hydraulics.
- **Tailwater** – A natural stream, improved channel, or other waterway at the discharge or tailwater side of the roadway embankment. The hydraulic response of the downstream discharge areas affects the capacity of the total culvert system. Tailwater is analyzed using uniform flow assumptions or separate floodplain analyses.

75/282

5.2 Hydrology

CulvertMaster offers the Rational Method, SCS peak discharge method, and user-defined peak discharge for determination of the design and check storm flows.

5.2.1 Rational Method

The Rational Method solves for peak discharge based on watershed area, rational coefficient, and rainfall intensity for the watershed.

The Rational Method is based on the simple rational equation:

4664

$$Q = CiA \quad \text{or} \quad Q = AiR \tag{5.1}$$

Where
- Q = Design flow rate (ft^3/s, m^3/s)
- C = Rational coefficient for drainage area
- R = Rational coefficient for drainage area
- i = Rainfall intensity (in/hr, mm/hr)
- A = Drainage area (acres, hectares)

Because of the units that are used in the above equation, CulvertMaster uses a factor to convert the units of intensity and drainage area to units of flow. In English units, this conversion factor is 1.008 ac-in/hr per ft^3/s, and in SI units it is 0.002778 hectare-mm/hr per m^3/s. C, the rational coefficient, is the parameter that is most open to engineering judgment. Engineering references contain tables that will help you estimate C. The following table shows rational coefficients for common land uses. In many cases, an area weighted average of C coefficients is used for the entire drainage area. CulvertMaster will automatically calculate the weighted C for drainage areas.

Table 5-1

Table of Rational Coefficients

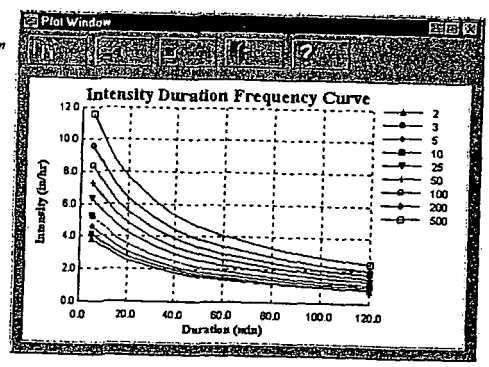
AREA	C Values
Business	
Downtown	0.70-0.95
Neighborhood	0.50-0.70
Residential	
Single Family	0.30-0.50
Multiunit detached	0.40-0.60
Multiunit attached	0.60-0.75
Suburban resident	0.25-0.40
Apartment	0.50-0.70
Residential (1.2 acre lots or more)	0.30-0.45
Industrial	
Light	0.50-0.80
Heavy	0.60-0.90
Parks and Cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Unimproved	0.10-0.30
Pavement	
Asphalt/Concrete	0.70-0.95
Brick	0.70-0.85
Drives and Walks	0.75-0.85
Lawns, Sandy soils	
Flat, 2%	0.05-0.10
Average, 2-7%	0.10-0.15
Steep, 7%	0.15-0.20
Lawns, Heavy Soils	
Flat, 2%	0.13-0.17
Average, 2-7%	0.18-0.22
Steep, 7%	0.25-0.35
Railroad Yard	0.20-0.40
Roofs	0.70-0.95

nsity-Duration-Frequency (IDF) Curves

ainfall intensities for which you will be designing your culverts are determined by regulatory es, which typically analyze historical rainfall information and compile it into IDF Curves based on quency of the storm events. These curves provide a quick reference for determining the intensity of nfall that will occur at given return periods.

Figure 5.1

Intensity Duration Frequency Curve



IDF curves can be extremely useful when performing hand calculations using the Rational Method. They are less useful when used for computer programs or spreadsheet calculations because you have to look up values and enter them each time you need intensity data. For this reason, it is often easier to use rainfall tables or rainfall equations to calculate IDF curves.

Rainfall Tables

CulvertMaster lets you enter data in a rainfall table and saves the data so you may use it again for other projects. Entering the design intensities for your culvert analysis is simply a matter of looking up data from a graph and entering it into the Rainfall Table. Once the rainfall intensities are gathered, it is helpful if you make a table to enter the data.

Table 5-2

Table of Rainfall Intensities (in/hr)

Duration	Return Periods					
	2-year	5-year	10-year	25-year	50-year	100-year
5 min	7.20	7.86	8.42	9.33	10.01	10.80
10 min	6.02	6.67	7.20	8.04	8.71	9.38
15 min	5.20	5.84	6.35	7.14	7.77	8.40
30 min	3.88	4.42	4.84	5.48	5.98	6.49
60 min	2.50	2.94	3.26	3.74	4.12	4.50

CulvertMaster has provided a tabular format for entering rainfall volumes obtained from the National Weather Services' Hydro-35 technical report. Hydro-35 provides a methodology for estimating rainfall volumes for durations of 5 minutes to 60 minutes for the eastern United States.

Rainfall Equations

Equations can generally be fit to IDF curves with high accuracy. The most common form of these equations is:

000195

$$i = \frac{a}{(b+D)^n} \quad (5.2)$$

Where
- i = Intensity of rainfall
- D = Duration of rainfall
- a, b = Equation coefficients
- n = Exponent

Other equations supported in CulvertMaster are:

$$i = \frac{a(RP)^m}{(b+D)^n} \quad (5.3)$$

$$i = a + b(\ln D) + c(\ln D)^2 + d(\ln D)^3 \quad (5.4)$$

Where
- i = Intensity of rainfall
- D = Duration of rainfall
- RP = Return period
- a, b, c, d = Equation coefficients
- m, n = Equation exponents

SCS Peak Discharge Method

The SCS Peak Discharge method solves for peak discharge based on watershed area, site specific hydrologic conditions expressed through the curve number (CN), rainfall distribution type, and rainfall depth.

SCS Peak Discharge method is based on the following equations:

$$Q_p = q_u A Q F_p \quad (5.5)$$

Where
- Q_p = Peak discharge (ft^3/s)
- q_u = Unit peak discharge ($cfs/mi^2/in$)
- A = Drainage area (mi^2)
- Q = Runoff (in)
- F_p = Pond and swamp adjustment factor

$$Q = \frac{(P-I_a)^2}{(P-I_a)+S} \quad (5.6)$$

Where
- Q = Runoff (in)
- P = Rainfall (in)
- S = Potential maximum retention after runoff begins (in)
- I_a = Initial abstraction (in)

$$I_a = 0.2S \quad (5.7)$$

76/282

Where $S = \frac{1000}{CN} - 10$

4664

The CulvertMaster implementation of the SCS-graphical peak discharge follows the procedures and methodology set forth in Chapter 4 and Appendix F of the SCS-TR-55 (1986) manual.

Table 5-3

Runoff Curve Numbers for Urban Areas[1]

Cover description	Curve number for hydrologic soil group			
	A	B	C	D
Fully developed urban areas (vegetation established)				
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50 to 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roof, driveways, etc. (excluding right-of-way)	98	98	98	98
Streets and roads:				
Paved; curbs and storm sewers (excluding right-of-way)	83	89	92	93
Paved, open ditches (including right-of-way)	76	85	89	91
Gravel (including right-of-way)	72	82	87	89
Dirt (including right-of-way)				
Western desert urban areas:				
Natural desert landscaping (pervious areas only)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)	96	96	96	96
Urban districts:				
Commercial and business	85	89	92	94	95
Industrial	42	81	88	91	93
Residential districts by average lot size:				
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82

[1]Average runoff condition, and $I_a = 0.2S$.

Other runoff curve number tables can be found in Chapter 2 of the SCS-TR-55 (1986) manual.

Culvert Hydraulics

Obtaining an accurate solution of culvert hydraulics represents a formidable computational task. Culverts often act as a significant constriction to flow and are subject to a range of flow types including both rapidly varied and gradually varied flow.

It is this mix of flow conditions and the highly transitional nature of culvert hydraulics that make the culvert hydraulic solution difficult. For this reason, the accepted approach is to simplify the hydraulics problem and solve the culvert using two different assumptions of flow control:

- **Inlet control assumption** – Computes the upstream energy grade or headwater depth resulting from the constriction effect at the culvert entrance while neglecting the culvert barrel friction and other minor losses.
- **Outlet control assumption** – Computes the upstream headwater depth using conventional hydraulic methodologies that consider the predominant losses due to the culvert barrel friction as well as the minor entrance and exist losses.

CulvertMaster uses the methodologies set forth in *Hydraulic Design Series No. 5, Hydraulic Design of Highway Culverts* (1985) as prepared for the U.S. Federal Highway Administration, and included as Chapter 6 in this manual, to perform these hydraulic calculations automatically under each control assumption. The controlling headwater depth is then the greater of the inlet control headwater or the outlet control headwater.

Inlet Control Hydraulics

When a culvert is operating under inlet control, the hydraulic control section is the culvert entrance itself. The losses due to barrel friction and other minor losses are not as significant as the losses caused by the entrance constriction. This entrance capacity is determined primarily by available opening area, the shape of the opening, and the inlet configuration of the entrance.

Generally, since the control section of a culvert operating under inlet control is at the upstream end of the culvert, barrel flows are in the supercritical flow regime and outlet velocities are determined using frontwater gradually varied flow profiles.

Three types of inlet control hydraulics are in effect over a range of culvert discharges:

- **Unsubmerged** – Occurs in low discharge conditions, and the culvert entrance is performing mainly as a weir. The hydraulics of weir flow are governed by empirical working equations developed as a result of model tests.
- **Submerged** – Occurs in higher discharge ranges when the culvert entrance is fully submerged and the culvert is assumed to be operating as an orifice.

Transition – Occurs in the poorly defined region just above the unsubmerged zone below the culvert entrance crown and the fully submerged zone above the culvert entrance crown.

vertMaster computes the inlet control headwater depth using a set of inlet control working equations ich are implemented by the design nomographs published in HDS-5 and many other hydraulics manuals and handbooks.

Inlet Control Working Equations

The equations for unsubmerged (weir) and submerged (orifice) flow conditions are presented below. The transition zone is taken by linear interpolation in the region described by Notes 1 and 3. The constant coefficients for use in the working equations, as well as the use of Form (1) and Form (2) unsubmerged equations, vary according to section shape and material.

Inlet Control Design Equations

Unsubmerged[1]:

Form (1) 2:
$$\frac{HW_i}{D} = \frac{H_c}{D} + K\left[\frac{Q}{AD^{0.5}}\right]^M - 0.5S \quad (5.8a)$$

Form (2):
$$\frac{HW_i}{D} = K\left[\frac{Q}{AD^{0.5}}\right]^M \quad (5.8b)$$

Submerged[3]:

$$\frac{HW_i}{D} = c\left[\frac{Q}{AD^{0.5}}\right]^2 + Y - 0.5S \quad (5.9)$$

Where
- HW_i = Headwater depth above inlet control section invert (ft, m)
- D = Interior height of culvert barrel (ft, m)
- H_c = Specific head at critical depth ($d_c+V_c^2/2g$) (ft, m)
- Q = Discharge (ft^3/s, m^3/s)
- A = Full cross-sectional area of culvert barrel (ft^2, m^2)
- S = Culvert barrel slope (ft/ft, m/m)
- K, M, c, Y = Constants from the following table

Notes:

[1] Unsubmerged equations apply up to $Q/AD^{0.5} = 3.5$
[2] For mitered inlets, use +0.7S instead of –0.5S as the slope correction factor
[3] The submerged equation applies above $Q/AD^{0.5} = 4.0$.

Table 5-4

Constants for Inlet Control Design Equations

Ch No	Shape and Material	Nomograph Scale	Inlet Edge Description	Unsubmerged Form	Unsubmerged K	Unsubmerged M	Submerged C	Submerged Y
1	Circular Concrete	1	Square edge w/headwall	1	.0098	2.00	.0398	.67
		2	Groove end w/headwall		.0045	2.00	.0317	.69
		3	Groove end projecting		.0045	2.00	.0317	.69
2	Circular CMP	1	Headwall	1	.0078	2.0	.0379	.69
		2	Mitered to slope		.0210	1.33	.0463	.75
		3	Projecting		.0340	1.50	.0553	.54
3	Circular	A	Beveled ring, 45°bevels	1	.0018	2.50	.0400	.74
		B	Beveled ring, 33.7°bevels		.0018	2.50	.0423	.83
8	Rectangular Box	1	30°to 75°wingwall flares	1	0.26	1.0	.0347	.86
		2	90°to 15°wingwall flares		.061	.75	.0400	.80
		3	0°wingwall flares		.061	.75	.0423	.82
9	Rectangular Box	1	45°wingwall flare d=.0430	2	.510	.667	.0309	.80
		2	18°-33.7°wall flare d=.0830		.486	.667	.0249	.83

000196

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Ch No	Shape and Material	Nomo-graph Scale	Inlet Edge Description	Unsubmerged Form	Unsubmerged K	Unsubmerged M	Submerged C	Submerged Y
13	Rectangular Box	1 2 3	90°headwall w/¾" chamfers 90°headwall w/45° bevels 90°headwall w/33.7° bevels	2	.515 .495 .486	.667 .667 .667	.0375 .0314 .0252	.79 .82 .865
12	Rectangular Box	1 2 3	45°non-offset wingwall flares 18.4°non-offset wingwall flares 18.4°non-offset wingwall flares 30°skewed barrel	2	.497 .493 .495	.667 .667 .667	.0339 .0361 .0386	.803 .806 .71
16-19	C M Boxes	1 2 3	90°headwall Thick wall projecting Thin wall projecting	1	.0083 .0145 .0340	2.0 1.75 1.5	.0379 .0419 .0496	.69 .64 .57
30	Vertical Ellipse Concrete	1 2 3	Square edge w/headwall Grove end w/headwall Groove end projecting	1	0.0100 .0018 .0095	2.0 2.5 2.0	0.0398 .0292 .0317	0.67 .74 .69
34	Pipe Arch 18" Corner Radius CM	1 2 3	90° headwall Mitered to slope Projecting	1	.0083 .0300 .0340	2.0 1.0 1.5	.0379 .0463 .0496	.69 .75 .57
36	Pipe Arch 31" Corner Radius CM	1 2 3	Projecting No bevels 33.7° bevels	1	.03 .0088 .0030	1.5 2.0 2.0	.0496 .0368 .0269	.57 .68 .77
35	Arch CM	1 2 3	90° headwall Mitered to slope Thin wall projecting		.0083 .0300 .034	2.0 1.0 1.5	.0379 .0463 .0496	.69 .75 .57
55	Circular	1 2	Smooth tapered inlet throat Rough tapered inlet throat	2	.534 .519	.555 .64	.0196 .021	.90 .90
56	Elliptical Inlet Face	1 2 3	Tapered inlet-beveled edges Tapered inlet-square edges Tapered inlet-thin edge projecting	2	.536 .5035 .542	.622 .719 .80	.0368 .0478 .0598	.83 .80 .75
57	Rectangular	1	Tapered inlet throat	2	.475	.667	.0179	.97
58	Rectangular Concrete	1 2	Side tapered-less favorable edges side tapered-more favorable edges	2	.56 .56	.667 .667	.0446 .0378	.85 .87
59	Rectangular Concrete	1 2	Slope tapered-less favorable edges Slope tapered-more favorable edges	2	.50 .50	.667 .667	.0446 .0378	65 .71

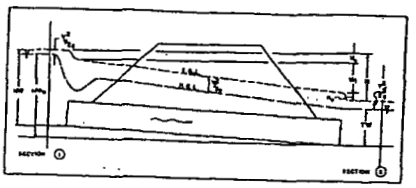
3.2 Outlet Control Hydraulics

Outlet control headwater depths are computed by summing entrance, exit, friction, and other losses along the culvert barrel. The energy basis for solving the outlet control headwater, *HW*, for a culvert is presented graphically in Figure 5.2 and the basic energy equation, Equation 5.10.

4664 77/282

Figure 5.2

Full flow energy and hydraulic grade lines



$$HW_e + \frac{V_e^2}{2g} = TW + \frac{V_d^2}{2g} + H_L \qquad (5.10)$$

Where
- HW_e = Headwater depth above the outlet invert (ft, m)
- V_e = Approach velocity (ft/s, m/s)
- TW = Tailwater depth above the outlet invert (ft,m)
- V_d = Exit velocity (ft/s, m/s)
- H_L = Sum of all losses including entrance (H_e), friction loss (H_f), exit loss (H_o), and other losses
- g = Gravitational acceleration constant (ft/s², m/s²)

HDS-5 presents some simplified procedures and nomographs that can be used to compute outlet control losses, H_L. However, such simplified approaches will result in degenerative solutions in low flow or part-full barrels. With the need for performance curves, which quantify culvert response and upstream and downstream impacts over a full range of flow magnitudes, it is necessary to take a more rigorous energy approach to computing outlet control hydraulics.

Since culverts are frequently hydraulically short, uniform flow depths are not always achieved. CulvertMaster incorporates a powerful set of gradually varied flow algorithms, which can correctly analyze the following conditions:

- **Partial flow** – Water surface profiles are computed so the actual flow depths at the entrance and exit of the culvert during part-full conditions are accurately calculated.
- **Pressure flow** – Backwater is computed during full barrel submergence.
- **Composite pressure and free surface flows** – Both sealing and unsealing conditions are used for computations.
- **Composite flow regime profiles** - Mixed supercritical and subcritical flow profiles can be analyzed.
- **Adverse and horizontal culverts** – Backwater profiles can be performed for culverts for which uniform flows are undefined.

Entrance Minor Loss

The entrance loss H_e is a function of the barrel velocity head just inside the entrance, and is expressed by the equation:

$$H_e = k_e\left(\frac{V^2}{2g}\right) \qquad (5.11)$$

Where
- H_e = Entrance loss (ft, m)
- V = Velocity head inside of barrel entrance (ft/s, m/s)
- k_e = Entrance loss coefficient (unitless)
- g = Gravitational acceleration constant (ft/s², m/s²)

The entrance loss coefficient, k_e, is a function of inlet configuration. Values for the coefficients are presented in table 5-5 below.

Table 5-5

Entrance Loss Coefficients: Outlet Control, Full or Partly Full Entrance Head Loss

Type and Description	Coefficient
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/2D)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded 3 edges to radius to 1/12 barrel dimension, or beveled edges 3 sides	0.2

Table 5-5

Continued

Type and Description	Coefficient
Box, Reinforced Concrete (continued)	
Wingwalls at 30° to 75° barrel	
Square-edged at crown	0.5
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side- or slope-tapered inlet	0.2

* "End Section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance.

Exit Minor Loss

The exit loss is actually an expansion loss, which is a function of the change in velocity head occurring at the discharge location. In culvert hydraulics, the sudden expansion loss is expressed as:

$$H_o = 1.0\left[\frac{V^2}{2g} - \frac{V_d^2}{2g}\right] \qquad (5.12)$$

Where
- H_o = Exit minor loss (ft, m)
- V = Velocity just inside the barrel exit (ft/s, m/s)
- V_d = Outfall channel velocity (ft/s, m/s)
- g = Gravitational acceleration constant (ft/s², m/s²)

The discharge velocity can be neglected, in which case CulvertMaster assumes the exit loss is equal to the barrel velocity head.

Friction Loss

CulvertMaster calculates friction losses using gradually varied flow profiles.

000197

Gradually Varied Flow

Gradually varied flow occurs for free surface flow conditions. Starting from a given boundary control depth, usually the tailwater elevation, the depth will change gradually until (if the barrel or conduit is sufficiently long) normal depth is achieved. If the water surface moves above or below the crown of the conduit in sealing or unsealing flow conditions, the program will automatically transition into and out of a pressure analysis mode. Friction losses for the submerged part of the barrel or conduit will be based on full flow friction slope.

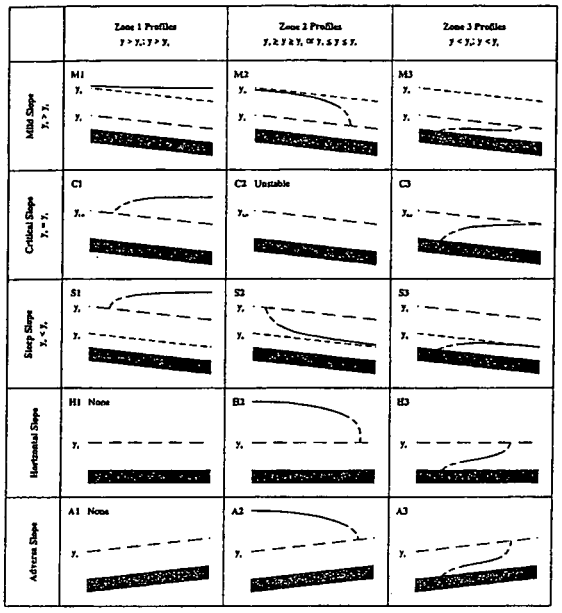
CulvertMaster computes both frontwater and backwater profiles. The program automatically determines whether a structure is operating under upstream or downstream control, and then performs the correct gradually varied flow analysis.

Gradually varied flow profiles express the water surface depth curve along the length of the barrel and are developed in an upstream or downstream direction depending on the hydraulic slope of the conduit and the controlling water surface elevations. For structures on a mild slope, which is when the constructed slope is less than critical slope, the depth of flow will increase gradually if the downstream starting elevation is less than normal depth (M2 drawdown curve, Figure 5.3). The depth of flow will decrease gradually if the starting water surface elevation is greater than normal depth (M1 backwater curve, Figure 5.3). In these types of water surface profiles, the flow is operating under subcritical flow conditions.

For a structure operating at a hydraulically steep slope (i.e. constructed slope is greater than critical slope), gradually varied flow profiles will be developed in an upstream direction whenever the controlling tailwater elevation lies well above critical depth and subcritical flow exists at the pipe exit. Unless the pipe is very short, steep pipes that have tailwater depths above critical depth will experience a hydraulic jump somewhere along their length.

Figure 5.3

Gradually Varied Flow Classifications



Usually, culverts on a steep slope are either entrance controlled or inlet controlled, and operate under supercritical flow. The gradually varied flow algorithm sets the upstream hydraulic grade equal to the critical depth elevation at the entrance and develops a frontwater curve by computing depth variation in a

downstream direction. In this type of frontwater analysis, the depth decreases from critical depth and approaches normal depth at the culvert exit.

CulvertMaster uses two different algorithms for computing the gradually varied flow profile through the culvert barrel depending on the hydraulic context of the pipe component as defined by the constructed slope and the governing tailwater elevations. The two methods are direct step and standard step. Both are computationally equivalent, and the choice of which method to use is based on performance considerations.

Figure 5.4

Plot of Hydraulic Jump

Backwater Analysis

A backwater analysis for outlet control computations starts at the downstream outfall under free discharge, submerged, or tailwater control, and proceeds in an upstream direction. CulvertMaster will perform backwater analysis in both free surface flow conditions and pressure flow computations under full flow conditions.

Frontwater Analysis

CulvertMaster will perform a frontwater analysis in a steep culvert operating under supercritical flow. The hydraulic control will be at the upstream end of a hydraulically steep culvert, and the gradually varied flow analysis will proceed in a downstream direction until normal depth is achieved, a hydraulic jump occurs, or the end of the culvert is reached. Even though outlet control rarely occurs in supercritical flow situations, the frontwater analysis is still performed for purposes of determining exit velocity.

Direct Method

This is a method for solving gradually varied flow profiles in which a series of explicit solutions for flow length are made that will result in a specified depth of flow. In the direct step method, the program iterates over a range of depth changes resulting from a backwater or drawdown curve, and computes the interval distance that results in the correct amount of headloss to produce the energy balance. This interval distance is then summed with all previous intervals to compute the total distance over which the flow profile has been computed, and the next interval computation is performed.

The program uses a trial and error procedure to solve for a depth that will yield a final interval, which, when summed with the previous profile distance, will equal the total length of the conduit.

The basic equation for energy balance is:

$$H_1 = H_2 + h_f + h_e \tag{5.13}$$

Where
- H_1 = Total head at section 1
- H_2 = Total head at section 2
- h_f = Friction loss
- h_e = Eddy loss

For prismatic channels, the eddy loss, h_e is practically zero and is assumed as zero by the program.

The total head at both ends of the section is defined as:

$$H = Z + \frac{V^2}{2g} \tag{5.14}$$

Where
- H = Total head (ft, m)
- Z = Water surface elevation (ft, m)
- V = Velocity at the end of the section (ft/s, m/s)
- g = Gravitational acceleration constant (ft/s², m/s²)

The friction loss, h_f, is the product of step length and uniform flow friction slope, or:

$$S_f \Delta x = \frac{1}{2}(S_1 + S_2)\Delta x \tag{5.15}$$

Where
- S_f = Friction slope (ft/ft, m/m)
- Δx = Change in horizontal distance in the section (ft, m)
- S_1, S_2 = Friction slopes at the end of the section (ft/ft, m/m)

In the direct step solution, the only unknown given two depths at each end of a sub-reach is the parameter Δx. This is solved for each trial depth.

Standard Step Method

The standard step method is the most popular method of determining the profiles of gradually varied flow. In standard step analysis, the reach is divided into a number of sub-reaches. Computations are performed in steps from one section to the next, where the depth is either incremented or decremented to yield a correct energy balance in the basic equation.

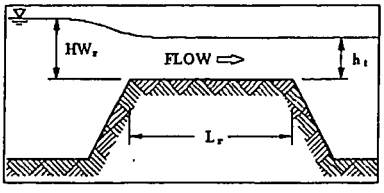
Unlike the direct step method, the standard step method varies the depth at the next section until the friction slope relationship, shown above, yields an average friction slope, S_f, which balances energy between each end of the sub-reach.

4 Roadway Overtopping

Whenever the culvert headwater begins to rise above the minimum elevation of the roadway, overtopping will occur. Overtopping flow is modeled as a special type of weir flow expressed by the general broad-crested weir equation. Overtopping flow is one component of the total culvert system.

Figure 5.5

Roadway overtopping



$$Q_o = C_d \times L \times HW_r^{1.5} \tag{5.16}$$

Where
- Q_o = Overtopping flow rate (ft³/s, m³/s)
- C_d = Overtopping discharge coefficient
- L = Length of the roadway crest (ft, m)
- HW_r = Overtopping depth (ft, m)

The overtopping discharge coefficient is a function of submergence using the equation:

$$C_d = k_s C_r \tag{5.17}$$

along with the figures below. The first two figures are used to derive the base weir coefficient resulting from deep and shallow overtopping, respectively. The submergence correction is determined implicitly using the final figure and applied against the base coefficient.

Figure 5.6

Discharge coefficient for $HW_r/L_r > 0.15$

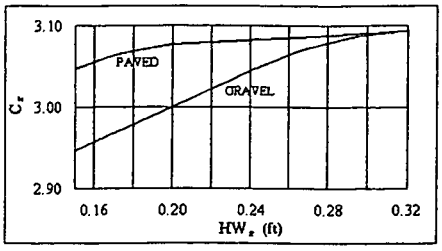


Figure 5.7

Discharge coefficient for $HW_r/L_r \leq 0.15$

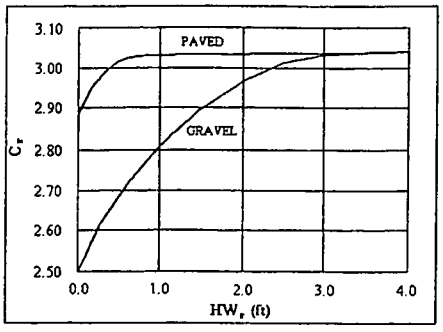
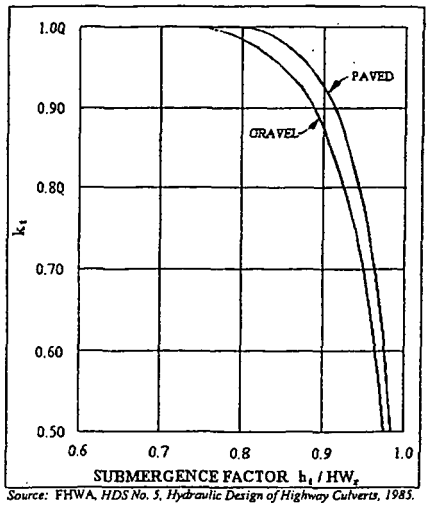


Figure 5.8

Submergence Factor h/HW,



Source: FHWA, *HDS No. 5, Hydraulic Design of Highway Culverts, 1985.*

5 Tailwater

The tailwater depth at the culvert discharge channel is an important parameter for computing the response of the culvert. For backwater analyses, the tailwater elevation may be the starting gradually varied flow boundary. CulvertMaster will automatically compute discharge variable tailwater depths using its uniform flow calculation capability.

.5.1 Uniform Flow

In uniform flow, the discharge, depth, and velocity are constant with distance along the pipe or ditch section. The physical slope of the flow element, friction slope or energy slope, and the water surface slope are all parallel. This means that the hydraulic grade line of flow is parallel to the channel slope and that the depth will be the same at all points along its length. This depth of uniform flow is called the *normal depth*. Uniform flow can occur as free surface flow in a prismatic conduit flowing partially full. A prismatic channel or conduit has a non-varying cross-section and a constant bottom slope.

Uniform flow can be described by the generalized friction equation:

$$V = CR^x S^y \tag{5.18}$$

Where
- V = Mean velocity (ft/s, m/s)
- R = Hydraulic radius (ft, m)

= 4664 79/282

- S = Energy slope (ft/ft, m/m)
- C = Flow resistance factor (units vary by method)
- x = Exponent
- y = Exponent.

The roughness, or flow resistance, factor, C, is usually determined by the material lining the flow channel. However, the ultimate value of the C component may be a function of the channel shape, depth, and velocity of flow. The hydraulic radius, R, is a strict function of the channel shape. For every geometric shape, R can be readily calculated once a depth is known or assumed. The energy slope, S, is constant under the uniform flow assumption.

Since velocity is constant under uniform flow conditions, combining the general uniform flow equation with the continuity equation

$$Q = VA \tag{5.19}$$

results in the equation:

$$Q = ACR^x S^y \tag{5.20}$$

Where
- Q = Discharge (ft^3/s, m^3/s)
- A = Cross-sectional flow area (ft^2, m^2)
- C = Flow resistance factor (units vary by method)
- R = Hydraulic radius (ft, m)
- S = Energy slope (ft/ft, m/m)
- x = Exponent
- y = Exponent

[redacted]

Manning's Formula

CulvertMaster implements the Manning's formula for computing uniform flows in tailwater channels, and for computing friction slopes in its gradually varied flow computations in culvert barrels.

The use of Manning's formula is applicable to uniform flow provided the slope of the energy grade line is used and is applied when the flow range is rough. Culvert flow tends to be turbulent when the flow range is rough and during peak flows. The turbulent regime is comprised of three ranges of flow: smooth, transition, and rough. When the flow is rough, Manning's formula is most often used.

Manning's formula is derived from the Chezy Formula, which computes velocity based on a C coefficient, hydraulic radius, and friction slope. Manning's formula relates this C coefficient to a roughness coefficient and hydraulic radius. The original format incorporates the roughness coefficient:

$$V = CR^{1/2}S^{1/2} \tag{5.21}$$

Where
- C = Factor of flow resistance
- R = Hydraulic radius (ft, m)
- S = Energy slope (ft/ft, m/m)

This equation was further modified by others to become the well-known Manning's formula:

U.S. Units:

$$V = \frac{1.49}{n} R^{2/3} S^{1/2} \tag{5.22a}$$

Where
- V = Section velocity (ft/s)
- R = Hydraulic radius (ft)
- S = Energy slope
- n = Manning's roughness coefficient

Metric:

$$V = \frac{1}{n} R^{2/3} S^{1/2} \tag{5.22b}$$

Where
- V = Section velocity (m/s)
- R = Hydraulic radius (m)
- S = Energy slope
- n = Manning's roughness coefficient

Comparing Results with HY-8

CulvertMaster results will generally be similar to HY-8 results. However, in some complex hydraulic cases, HY-8 uses a simplified solution technique that may produce differences. The following is a list of cases where calculation methodology between CulvertMaster and HY-8 differ:

1. CulvertMaster computes inlet control headwater strictly by the inlet control equations presented in HDS-5. HY-8 uses polynomial curve fits for inlet control headwater computation.
2. HY-8 simplifies the computation of the M2 backwater profile for the case where a culvert has unsubmerged tailwater and has discharge in excess of full flow capacity. In this case, HY-8 will assume pressure flow for the full length of the culvert. CulvertMaster will compute the M2 profile backwater curve, and will transition to pressure flow where the profile runs into the top of the pipe.

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ATTACHMENT A-5

USDA-SCS SOIL SURVEY MAP

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30 JAN 02
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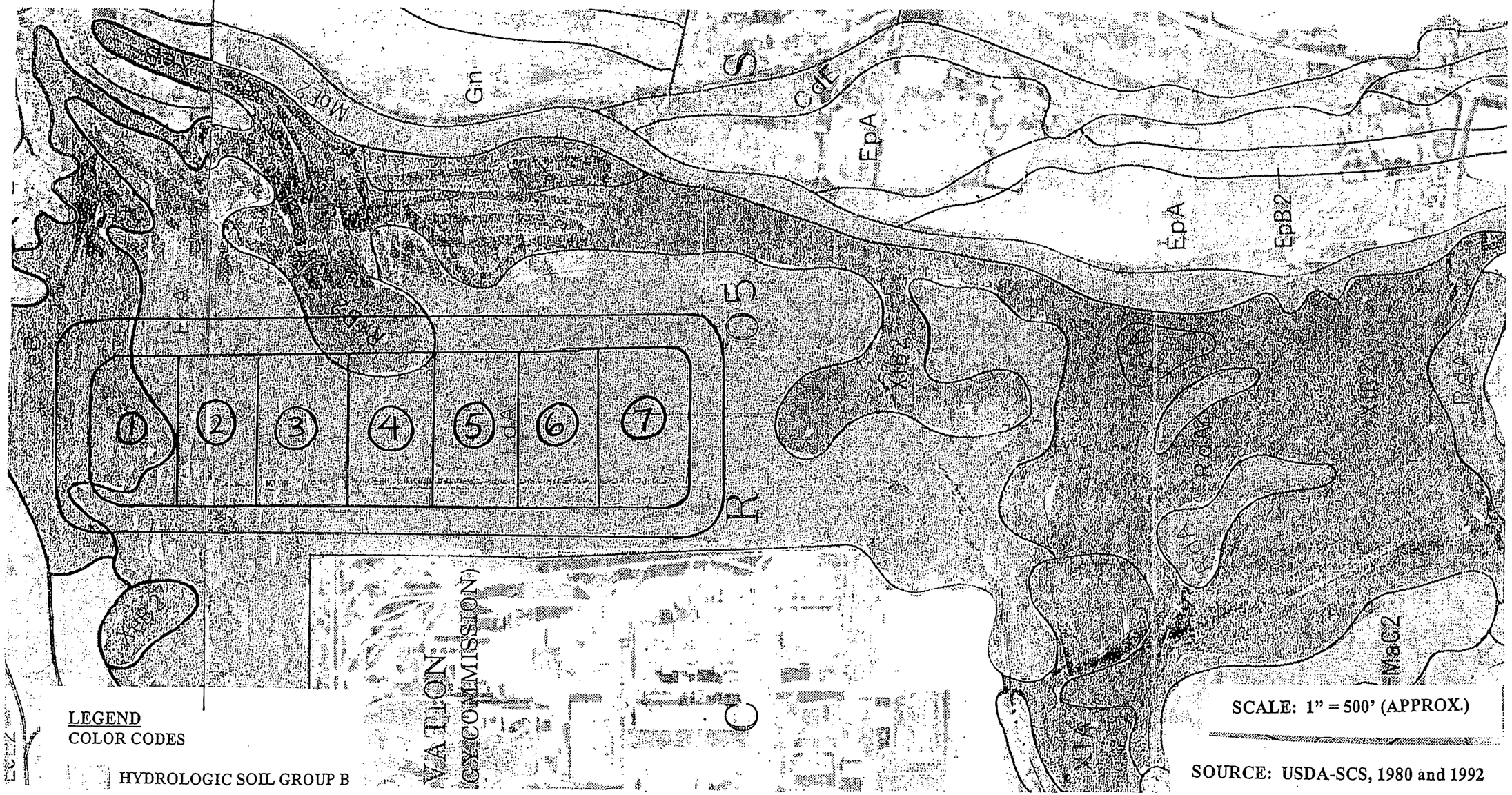
USDA-SCS SOIL SURVEY MAP
BULTER AND HAMILTON COUNTIES , OHIO

N



LEGEND
COLOR CODES

HYDROLOGIC SOIL GROUP B

HYDROLOGIC SOIL GROUP C

SOURCE: USDA-SCS, 1980 and 1992

OSDF – PHASE V
FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

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ATTACHMENT A-6

HYDROLOGIC SOIL DATA

TABLE 18.--SOIL AND WATER FEATURES

["Flooding" and "water table" and terms such as "rare," "brief," "apparent," and "perched" are explained in the text. The symbol < means less than; > means more than. Absence of an entry indicates that the feature is not a concern]

Soil name and map symbol	Hydrologic group	Flooding			High water table			Bedrock		Potential frost action	Risk of corrosion	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness		Uncoated steel	Concrete
					Ft			In				
ArA, ArB2, ArC2---- Ava	C	None---------	---	---	2.0-4.0	Perched	Mar-Jun	>60	---	High------	Moderate	High.
AsB*, AsC*:												
Ava----------	C	None---------	---	---	2.0-4.0	Perched	Mar-Jun	>60	---	High------	Moderate	High.
Urban land.												
AvA---------- Avonburg	D	None---------	---	---	1.0-3.0	Perched	Jan-Apr	>60	---	High------	High------	High.
AwA*:												
Avonburg----------	D	None---------	---	---	1.0-3.0	Perched	Jan-Apr	>60	---	High------	High------	High.
Urban land.												
BoD, BoE, BoF------ Bonnell	C	None---------	---	---	>6.0	---	---	>60	---	Moderate	High------	Moderate.
CcC2, CdD, CdE, CdF---------- Casco	B	None---------	---	---	>6.0	---	---	>60	---	Low-------	Low-------	Low.
CnB2, CnC2--------- Cincinnati	C	None---------	---	---	>4.0	Perched	Jan-Apr	>60	---	High------	Moderate	High.
DaB---------- Dana	B	None---------	---	---	3.0-6.0	Perched	Mar-Apr	>60	---	High------	Moderate	Moderate.
EcB2, EcC2, EcD, EcE, EdF--------- Eden	C	None---------	---	---	>6.0	---	---	20-40	Soft	High------	Moderate	Low.
EeB*, EeC*, EeD*:												
Eden----------	C	None---------	---	---	>6.0	---	---	20-40	Soft	High------	Moderate	Low.
Urban land.												
EpA, EpB2, EpC2---- Eldean	B	None---------	---	---	>6.0	---	---	>60	---	Moderate	High------	Moderate.
ErA*, ErB*:												
Eldean----------	B	None---------	---	---	>6.0	---	---	>60	---	Moderate	High------	Moderate.
Urban land.												
FdA---------- Fincastle	C	None---------	---	---	1.0-3.0	Apparent	Jan-Apr	>60	---	High------	High------	Moderate.

See footnotes at end of table.

Source: USDA-SCS, 1992

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83/282

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Soil surv

name and map symbol	Hydro-logic group	Flooding: Frequency	Flooding: Duration	Flooding: Months	Depth	ater table: Kind	ater table: Months	Bedrock: Depth	Bedrock: Hardness	Potential frost action	Risk of cor: Uncoated steel	Risk of cor: Concrete
					Ft			In				
FeA*:												
Fincastle	C	None	---	---	1.0-3.0	Apparent	Jan-Apr	>60	---	High	High	Moderate.
Urban land.												
FoA, FoB2 Fox	B	None	---	---	>6.0	---	---	>60	---	Moderate	Low	Moderate.
FpA*:												
Fox	B	None	---	---	>6.0	---	---	>60	---	Moderate	Low	Moderate.
Urban land.												
Gn Genesee	B	Occasional	Brief	Oct-Jun	>6.0	---	---	>60	---	Moderate	Low	Low.
Go*:												
Genesee	B	Occasional	Brief	Oct-Jun	>6.0	---	---	>60	---	Moderate	Low	Low.
Urban land.												
HeF Hennepin	B	None	---	---	>6.0	---	---	>60	---	Moderate	Low	Low.
HoA Henshaw	C	None	---	---	1.0-2.0	Apparent	Nov-Mar	>60	---	High	High	Moderate.
Hu Huntington	B	Occasional	Brief	Dec-May	4.0-6.0	Apparent	Dec-Apr	>60	---	High	Low	Moderate.
Ju Jules	B	Occasional	Brief	Mar-Jun	>6.0	---	---	>60	---	High	Low	Low.
Lg Lanier	A	Occasional	Brief	Nov-Jun	>6.0	---	---	>60	---	Low	Low	Low.
MaB, MaC2, MaD2, MaE2 Markland	C	None	---	---	3.0-6.0	Perched	Mar-Apr	>60	---	Moderate	High	Moderate.
McA, McB Martinsville	B	None	---	---	>6.0	---	---	>60	---	Moderate	Moderate	Moderate.
MnC2 Miamian	C	None	---	---	>6.0	---	---	>60	---	Moderate	Moderate	Moderate.
MoD2*, MoE2*:												
Miamian	C	None	---	---	>6.0	---	---	>60	---	Moderate	Moderate	Moderate.
Hennepin	B	None	---	---	>6.0	---	---	>60	---	Moderate	Low	Low.
MuC*:												
Miamian	C	None	---	---	>6.0	---	---	>60	---	Moderate	Moderate	Moderate.

See footnotes at end of table.

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84/282

Dep 30 JAN 02 215

DBH 1/30/02

Source: USDA-SCS-1992.

000204

TABLE 18.--SOIL AND WATER FEATURES--Continued

Soil name and map symbol	Hydrologic group	Flooding			High water table			Bedrock		Potential frost action	Risk of corrosion	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness		Uncoated steel	Concrete
					Ft			In				
MuC*:												
Urban land.												
PbB2, PbC2, PbD, PbE---------- Parke	B	None---------	---	---	>6.0	---	---	>60	---	High------	Moderate	High.
PcB*, PcC*:												
Parke----------	B	None---------	---	---	>6.0	---	---	>60	---	High------	Moderate	High.
Urban land.												
PfC, PfD, PfE------ Pate	C	None---------	---	---	>6.0	---	---	>50	Soft	Moderate	High------	Moderate.
PhD*:												
Pate----------	C	None---------	---	---	>6.0	---	---	>50	Soft	Moderate	High------	Moderate.
Urban land.												
Pn**---------- Patton	B/D	None---------	---	---	+.5-2.0	Apparent	Mar-Jun	>60	---	High------	High------	Low.
Po*.												
Pits												
PrA, PrB, PrC2---- Princeton	B	None---------	---	---	>6.0	---	---	>60	---	Moderate	Moderate	Moderate.
RdA---------- Raub	C	None---------	---	---	1.0-3.0	Apparent	Jan-Apr	>60	---	High------	High------	Moderate.
Rn---------- Ross	B	Rare---------	---	---	4.0-6.0	Apparent	Feb-Apr	>60	---	Moderate	Low-------	Low.
RpA, RpB2, RpC2--- Rossmoyne	C	None---------	---	---	1.5-3.0	Perched	Jan-Apr	>60	---	High------	High------	High.
RtA*, RtB*, RtC*:												
Rossmoyne---------	C	None---------	---	---	1.5-3.0	Perched	Jan-Apr	>60	---	High------	High------	High.
Urban land.												
RwB2---------- Russell	B	None---------	---	---	>6.0	---	---	>60	---	High------	Moderate	Moderate.
RxB*:												
Russell----------	B	None---------	---	---	>6.0	---	---	>60	---	High------	Moderate	Moderate.
Urban land.												
St---------- Stonelick	B	Frequent-----	Very brief	Nov-Jun	>6.0	---	---	>60	---	Moderate	Low-------	Low.

See footnotes at end of table.

Source: USDA-SCS, 1992.

000205

Soil survey

DBM 1/30/02

Dep 30 JAN 02

85/282

- 4664

TABLE 18.--SOIL AND WATER FEATURES--Continued

Soil name and map symbol	Hydro-logic group	Flooding			High water table			Bedrock		Potential frost action	Risk of corrosion	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness		Uncoated steel	Concrete
					Ft			In				
XfA, XfB2---------- Xenia	B	None---------	---	---	2.0-6.0	Apparent	Mar-Apr	>60	---	High-----	High-----	Moderate.

* See description of the map unit for composition and behavior characteristics of the map unit.
** The plus sign preceding the range in depth to the water table means that the range in this soil is from .5 foot above the surface to 2.0 feet below.

- 4664

86/282
DOP BUSANGZ Soil survey
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000206

Source: USDA-SCS, 1992

TABLE 10. WATER FEATURES

[The definitions of "flooding" and "water table" in the text explain terms such as "rare," "brief," "apparent," and "perched." The symbol < means less than; > means more than. Absence of an entry indicates that the feature is not a concern]

Soil name and map symbol	Hydrologic group	Flooding: Frequency	Flooding: Duration	Flooding: Months	High water table: Depth	High water table: Kind	High water table: Months	Bedrock: Depth	Bedrock: Hardness	Potential frost action	Risk of corrosion: Uncoated steel	Risk of corrosion: Concrete
					Ft			In				
AvA---------- Avonburg	D	None---------	---	---	1.0-3.0	Perched	Jan-Apr	>60	---	High-----	High-----	High.
Bt---------- Brenton	B	None---------	---	---	1.0-3.0	Apparent	Mar-Jun	>60	---	High-----	High-----	Moderate.
CdD2*, CdE*:												
Casco----------	B	None---------	---	---	>6.0	---	---	>60	---	Moderate	Low------	Low.
Rodman----------	A	None---------	---	---	>6.0	---	---	>60	---	Low------	Low------	Low.
CeB---------- Celina	C	None---------	---	---	1.5-3.0	Perched	Jan-Apr	>60	---	High-----	High-----	Moderate.
CnC2---------- Cincinnati	C	None---------	---	---	>6.0	---	---	>60	---	High-----	Moderate	High.
CrA---------- Crosby	C	None---------	---	---	1.0-3.0	Apparent	Jan-Apr	>60	---	High-----	High-----	Moderate.
DaA, DaB---------- Dana	B	None---------	---	---	3.0-6.0	Perched	Mar-Apr	>60	---	High-----	Moderate	Moderate.
DbB---------- Dana	B	None---------	---	---	3.5-6.0	Perched	Mar-Apr	40-60	Rippable	High-----	Moderate	Moderate.
EcE2, EcF2-------- Eden	C	None---------	---	---	>6.0	---	---	20-40	Rippable	---	Moderate	Low.
Ee---------- Eel	C	Occasional	Brief-----	Oct-Jun	3.0-6.0	Apparent	Jan-Apr	>60	---	High-----	Moderate	Low.
ElA, ElB2, ElC2, EnA, EnB2-------- Eldean	B	None---------	---	---	>6.0	---	---	>60	---	Moderate	High-----	Moderate.
EuA*, EuB*:												
Eldean----------	B	None---------	---	---	>6.0	---	---	>60	---	Moderate	High-----	Moderate.
Urban land.												
FcA, FcB---------- Fincastle	C	None---------	---	---	1.0-3.0	Apparent	Jan-Apr	>60	---	High-----	High-----	Moderate
FdA, FdB---------- Fincastle	C	None---------	---	---	1.0-3.0	Perched	Jan-Apr	48-72	Rippable	High-----	High-----	Moderate
Gn---------- Genesee	B	Common------	Brief-----	Oct-Jun	>6.0	---	---	>60	---	Moderate	Low------	Low.

See footnote at end of table.

Source: USDA-SCS, 1980.

000207

87/282

DEP 3/JAN/02

DBH 1/30/02

171

— 4664

TABLE 16.--SOIL AND WATER FEATURES--Continued

Soil name and map symbol	Hydro-logic group	Flooding			High water table			Bedrock		Potential frost action	Risk of corrosion	
		Frequency	Duration	Months	Depth	Kind	Months	Depth	Hardness		Uncoated steel	Concrete
					Ft			In				
UnA, UnB---------- Uniontown	B	None--------	---	---	2.5-6.0	Apparent	Nov-May	>60	---	High-----	Low------	Moderate.
UpA*: Urban land.												
Eldean----------	B	None--------	---	---	>6.0	---	---	>60	---	Moderate	High-----	Moderate.
UsA*: Urban land.												
Patton----------	B/D	None--------	---	---	0-2.0	Apparent	Mar-Jun	>60	---	High-----	High-----	Low.
WbA---------- Warsaw	B	None--------	---	---	>6.0	---	---	>60	---	Moderate	Low------	Moderate.
WeA, WeB---------- Wea	B	None--------	---	---	>6.0	---	---	>60	---	Moderate	Moderate	Moderate.
WyB, WyB2, WyC2, WzC3---------- Wynn	B	None--------	---	---	>6.0	---	---	20-40	Rippable	Moderate	High-----	Low.
WuB*, WuC*: Wynn----------	B	None--------	---	---	>6.0	---	---	20-40	Rippable	Moderate	High-----	Low.
Urban land.												
XeA, XeB, XeB2---- Xenia	B	None--------	---	---	2.0-6.0	Apparent	Mar-Apr	>60	---	High-----	High-----	Moderate.
XfA, XfB, XfB2---- Xenia	B	None--------	---	---	2.0-4.0	Perched	Mar-Apr	48-72	Rippable	High-----	High-----	Moderate.

* See map unit description for the composition and behavior of the map unit.

Source: USDA-SCS, 1980.

000208

88/282

DEP 30 JAN 02

DBH 1/30/02

SOIL SURVEY

-- 4664

- 4664

ATTACHMENT A-7

TR-55 LAND USE CATEGORIES AND RUNOFF CURVE NUMBERS

— 4664 90/282

DGP 30 JAN 02
DBM 1/30/02

BORROW AREA SOILS B/C

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)		VEGETATED FINAL COVER SYSTEM CONSTRUCTION PHASE			
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:			83		
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:	VEGETATED FINAL COVER SYSTEM POST DEVELOPMENT				
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:	PAVEMENT				
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]	NON VEGETATED FINAL COVER SYSTEM LINER POST	77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).			89		

AREAS ADJACENT TO OSDF, POST DEVELOPMENT

SUBGRADE

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

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91/282
DCP 30 JAN 02
DBM 1/30/02

Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description			Curve numbers for hydrologic soil group—			
Cover type		Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	RUNON AREAS EAST OF OSDF, NORTH OF BORROW AREA	Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	BORROW AREA RUNOFF, RUNON TO BORROW AREA, VEGETATED BORROW AREA	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]		Poor	48	67	77	83
		Fair	35	56	70	77
		Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]		Poor	57	73	82	86
		Fair	43	65	76	82
		Good	32	58	72	79
Woods.[6]		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	AREAS ADJACENT TO OSDF. CONSTRUCTION PHASE	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

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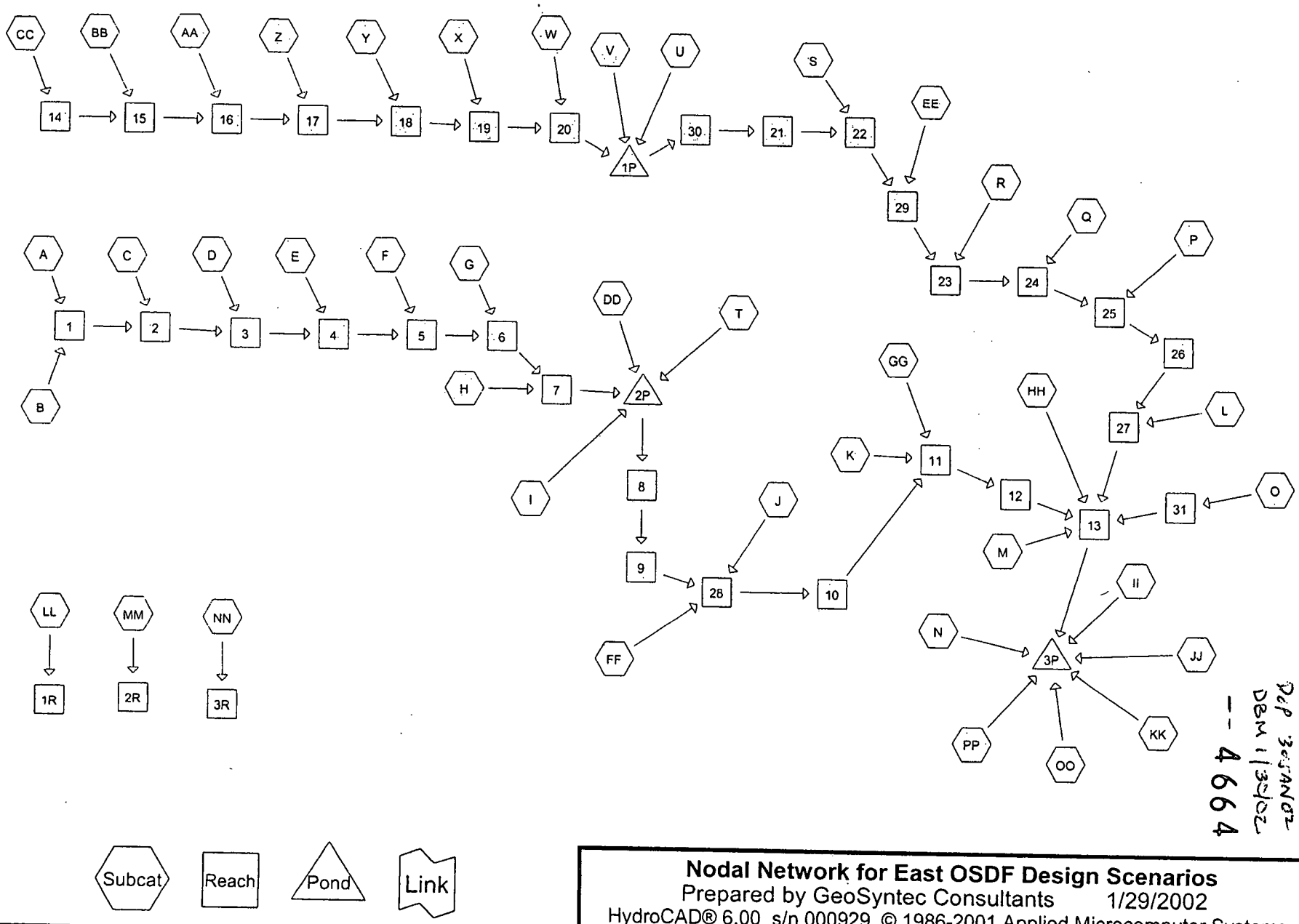
ATTACHMENT A-8

NODAL NETWORK DIAGRAMS



Nodal Network for East OSDF Design Scenarios
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93/282

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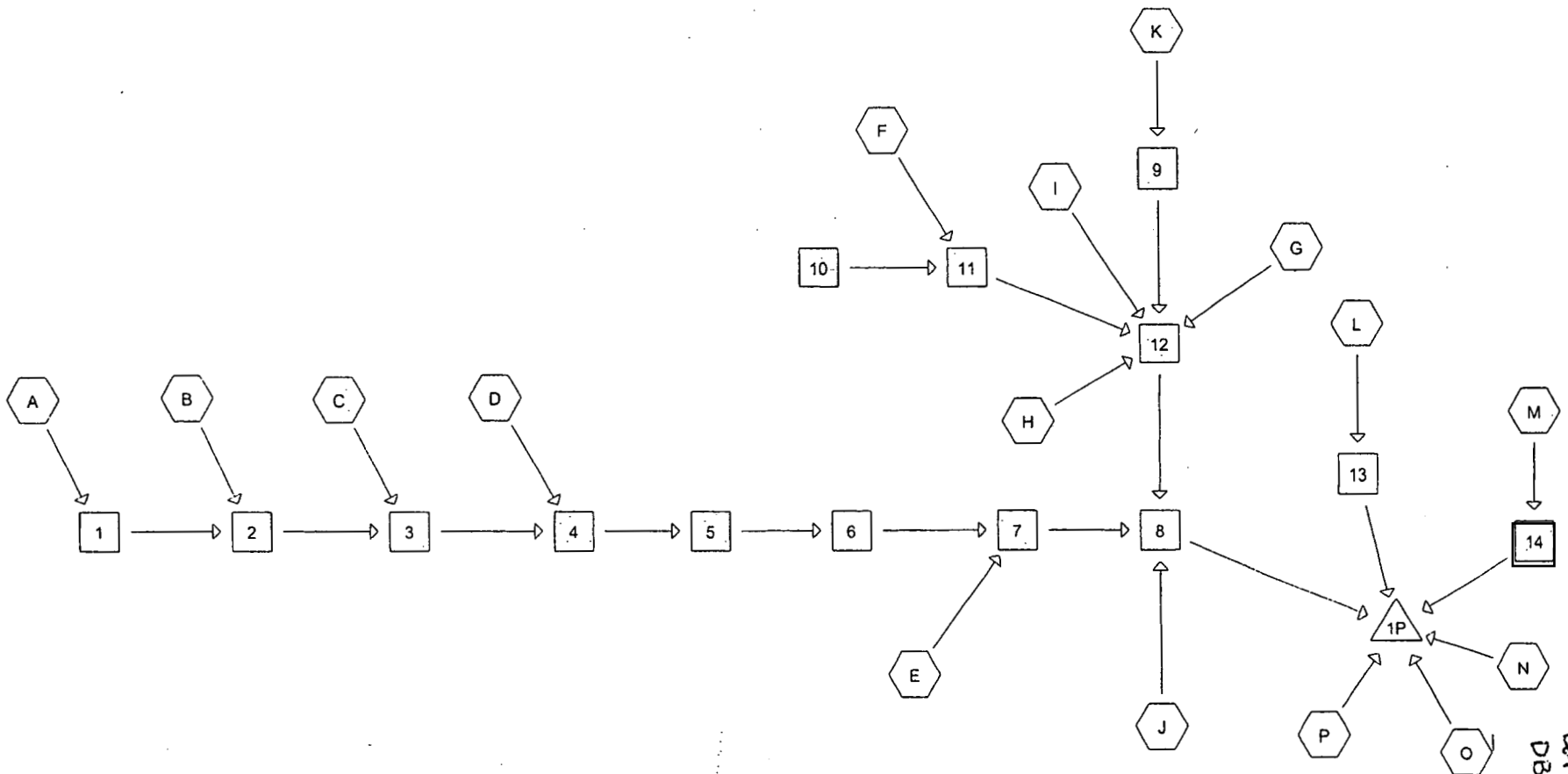

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4664

94 / 282

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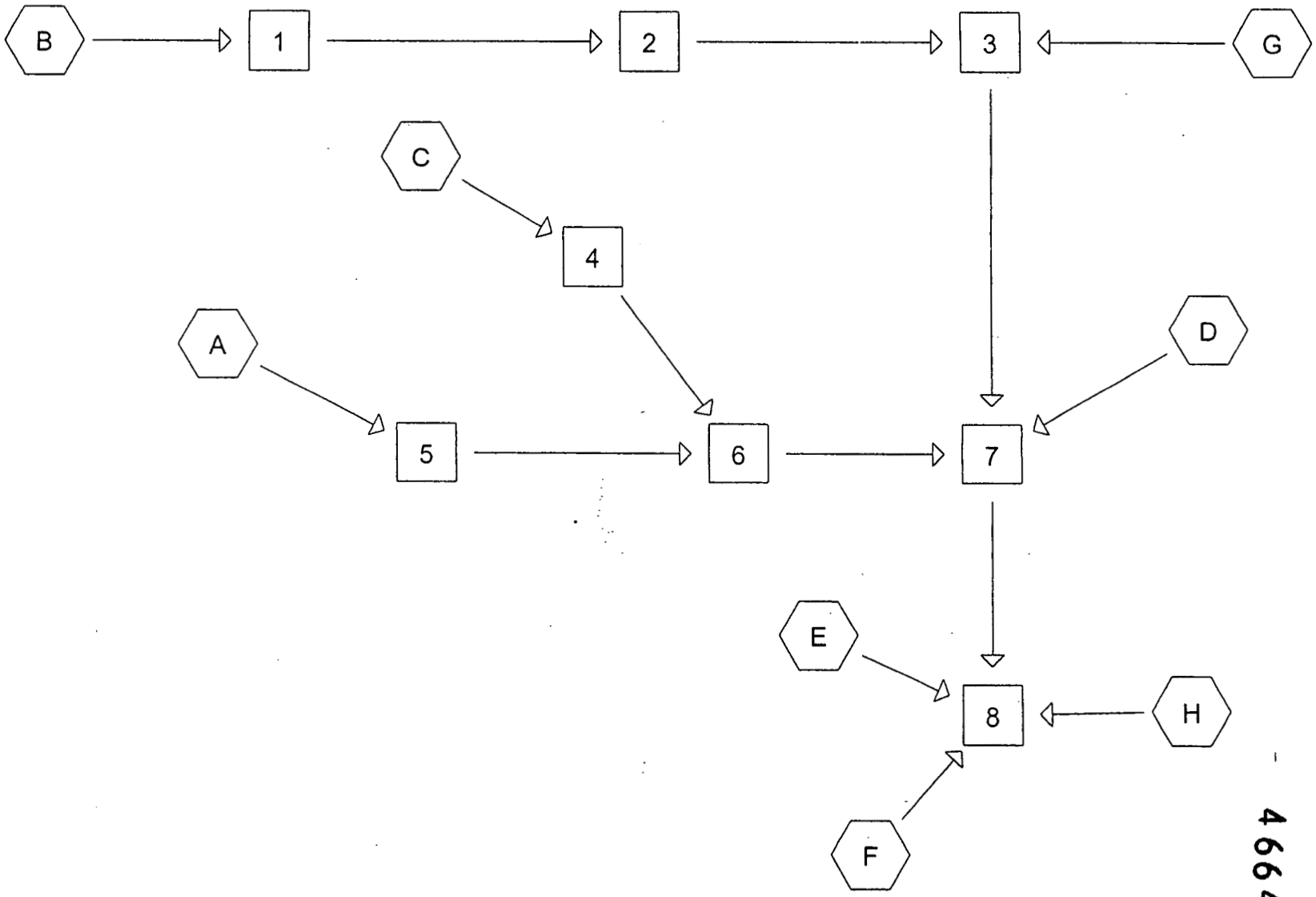

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4664

DCP 30 JAN 02
PBM 1/30/02

95/282

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ATTACHMENT A-9

CMP COVER REQUIREMENTS

97/282
DGP 30 JAN 02
DBM 1/30/02

CMP COVER REQUIREMENTS

4664

General Guidelines for Minimum Cover Required for Heavy Off-Road Construction Equipment				
Pipe Span, Inches	Minimum Cover (feet) for Indicated Axle Loads (kips)			
	18-50	50-75	75-110	110-150
12-42	2.0	2.5	3.0	3.0
48-72	3.0	3.0	3.5	4.0
78-120	3.0	3.5	4.0	4.0
126-144	3.5	4.0	4.5	4.5

Information reproduced from: [Contech, 1999]

PHASE V SURFACE-WATER MANAGEMENT SYSTEM DESIGN

DATA VERIFICATION

INTRODUCTION

As described in the Procedures Section, the purpose of this calculation package is to design the OSDF surface-water management (SWM) structures to be constructed as part of the Phase V development of the OSDF. In addition, the adequacy of existing SWM structures to convey the 25-year, 24-hour storm event is assessed. Required modifications or additions to existing structures are incorporated into the Construction Drawings. This section presents the selection of parameters used to perform analyses in the Calculation Section of this calculation package.

HYDROLOGIC AND BASIN ROUTING ANALYSES [HydroCad™, 2001]

Subcatchment Runoff

For both design scenarios and both design cases, the relationships of subcatchments, reaches, and basins are shown in the nodal network diagrams presented in Attachment A-8.

Rainfall Distribution

A SCS Type II Rainfall Distribution is selected for the Fernald site location. Attachment B-1 shows the location of the OSDF on a rainfall distribution map of the United States [SCS, 1986].

Rainfall Depth

Attachment B-2 [Parsons, 1995] provides rainfall depths for design storms of 24-hour duration for the Fernald site. The rainfall depths for use in these analyses are listed below.

-- 4664

Return Period (years)	Rainfall Depth (inches)
2	2.6
10	4.1
25	4.7
100	5.6

Runoff curve numbers

Subcatchment characteristics including total area and data for calculation of weighted CN are tabulated for each design scenario and design case in Attachment B-3. Data includes the percentage of subcatchment area for combinations of HSG, CN, and land use for each subcatchment.

Subcatchment Time of Concentration

Subcatchment characteristics for calculation of time of concentration are tabulated in Attachment B-4. Parameters include those for sheet, shallow concentrated, pipe, and channel flow.

Reaches

Channels

For the purpose of hydrologic modeling, the Manning's roughness coefficient for all channels, both grass and riprap (permanent channels along OSDF perimeter) lined, is selected as 0.030. Similarly, representative average geometric characteristics (i.e., sideslopes, width, longitudinal slope) were selected. Data for additional channel parameters are tabulated in Attachment B-5.

Culverts

The Manning's roughness coefficients for annular CMP, RCP, PVC, CMPA and HDPE culverts are selected as 0.024, 0.013, 0.010, 0.018, and 0.010 respectively. For new culverts, which will be helically corrugated CMP, a Manning's roughness coefficient of 0.017, 0.018,

0.019, and 0.020 for equivalent diameters of 30, 36, 42, and 48 inches, respectively are selected [American Iron and Steel Institute, 1994]. - 4664

Sedimentation Basins

Planimetered areas within contour elevation lines (for calculation of the stage-storage relationship) are presented in Attachment B-7. Coefficients for principal and emergency spillways are selected as follows and input into the HydroCAD™ models.

Principal Spillway Riser Pipes

- Discharge coefficient for orifice flow, C = 0.60

Principal Spillway Outlet Pipes

- Manning's roughness coefficient, n = 0.024 (for CMP)
- Entrance energy loss coefficient, Ke = 0.7
- Contraction coefficient, Cc = 0.9

OSDF Basin 2 Emergency Spillway

- Type, shape = broad crested weir, rectangular (approximation)
- Weir coefficient (English units), C = 3.0 [Stahre and Urbonas, 1990]

Borrow Area Sedimentation Basin Emergency Spillway

- Type, shape = broad crested weir, rectangular (approximation)
- Weir coefficient (English units), C = 3.0 [Stahre and Urbonas, 1990]

Additional data concerning the size, shapes, and elevations of the principal and emergency spillways are tabulated in Attachment B-8.

HYDRAULIC ANALYSES

Channels

Data for channel segments are obtained from the Construction Drawings and are presented in Attachment B-5. The Manning's roughness coefficient for all channels (grass-lined) is selected as 0.030 [Chow, 1959].

4664

Culverts

Input data for culverts includes: (i) physical characteristics; (ii) CulvertMaster® modeling characteristics; and (iii) profile. Physical characteristics and profile data were obtained from the following sources: (i) as-built drawings; (ii) inspection by GeoSyntec or Fluor Fernald personnel; (iii) existing maps showing topography and features; (iv) optical survey; and (v) site utility plans. Available thickness of cover for each culvert is obtained from the Construction Drawings and presented along with input data for hydraulic analyses in Attachment B-6.

REFERENCES

American Iron and Steel Institute. *Handbook of Steel Drainage & Highway Construction Products*, American Iron and Steel Institute, Washington, D.C., 1994.

Chow, V.T. *Open Channel Hydraulics*, McGraw-Hill, Inc., New York, 1959, 680 p.

HydroCAD. *HydroCAD™: Stormwater Modeling System, Version 6.0.* Applied Microcomputer Systems, Chocorua, New Hampshire, 2001.

Parsons. *2000-Year Peak Water and Probable Maximum Peak Water, Site-Wide Peak Water Plain Determination*, Parsons Engineering, Revision A, Aug 1995.

Stahre, P. and Urbonas, B. *Stormwater Detention*, Prentice Hall, Englewood Cliffs, New Jersey, 1990, 338 p.

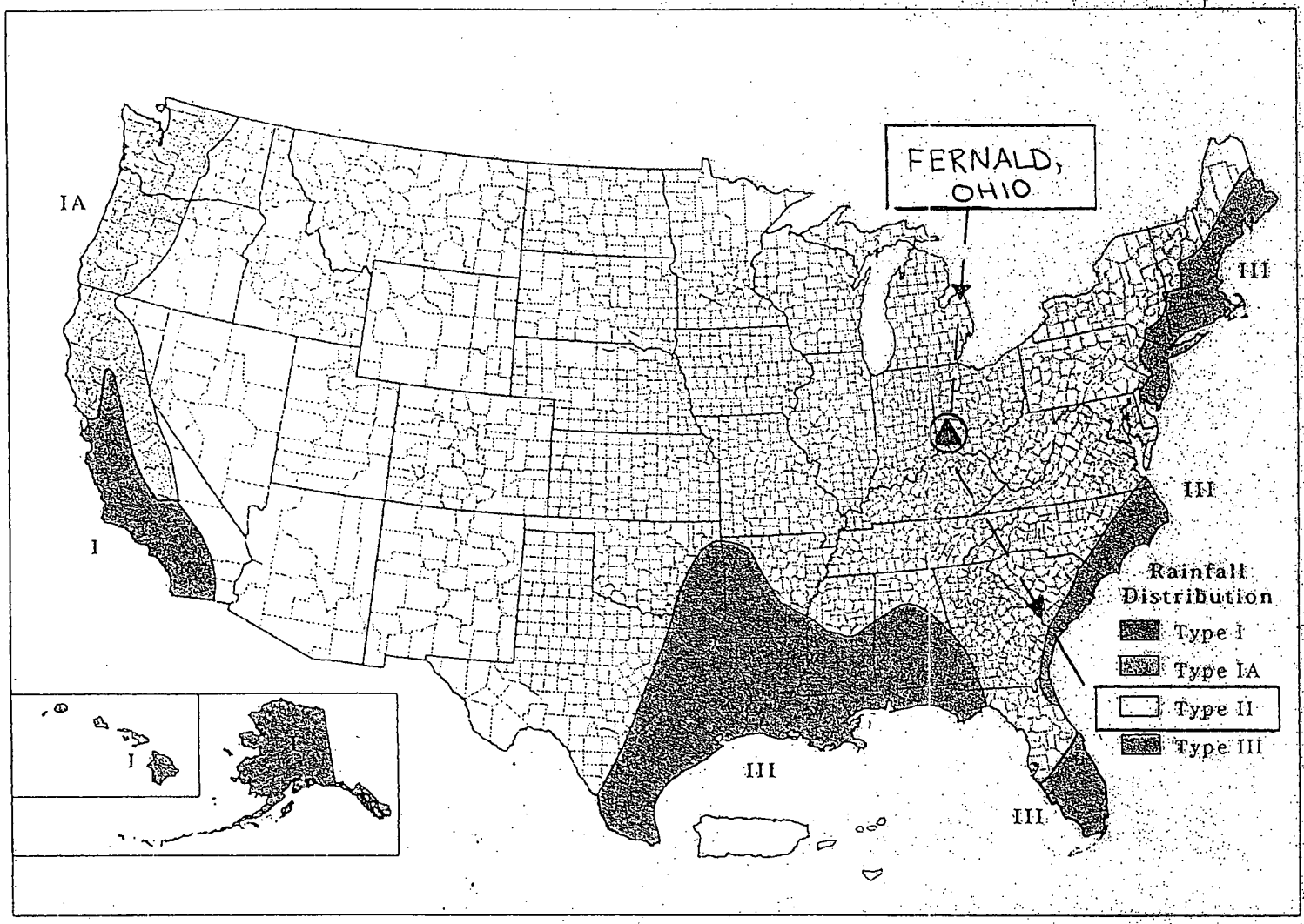
U.S. Department of Agriculture (USDA-SCS). *Urban Hydrology for Small Watersheds, Technical Release 55.* 2nd ed., Soil Conservation Service Washington, D.C., 1986.

4664

ATTACHMENT B-1

SCS RAINFALL DISTRIBUTION TYPE

Figure B-2 Approximate geographic boundaries for NRCS (SCS) rainfall distributions



104/282
DBM 11/30/02
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- 4664

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4664

ATTACHMENT B-2

RAINFALL DEPTHS

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DGP 30 JAN 02
DBM 1/30/02

TABLE 1 - RAINFALL DEPTH FOR A GIVEN DURATION
(INCHES)

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DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points for 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These Values are used on PH records for HEC-1.

Reference: Parsons, "2,000-Year Flood and Probable Maximum Flood, Sitewide Flood Plan Determination", August 1995.

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ATTACHMENT B-3

SUBCATCHMENT AREA AND WEIGHTED CURVE NUMBER DATA

108/282
DCP 30 JAN 02
DBM 1/30/02

— 4664

SUBCATCHMENT AREA AND HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF WEIGHTED CN

East OSDF Construction Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	1.96	100%	B/C	vegetated final cover	83	Intentionally left blank. Is addressed in the calculation section.
B	1.18	100%	B/C	vegetated final cover	83	
C	5.21	100%	B/C	vegetated final cover	83	
D	5.13	100%	B/C	vegetated final cover	83	
E	5.09	100%	B/C	vegetated final cover	83	
F	5.05	100%	B/C	vegetated final cover	83	
G	5.31	100%	B/C	unvegetated final cover	89	
H	3.49	100%	B/C	unvegetated final cover	89	
I	1.69	100%	C	construction laydown	82	
J	2.65	10% 90%	B C	construction laydown construction laydown	74 82	
K	4.14	50% 50%	B C	construction laydown construction laydown	74 82	
L	1.68	30% 70%	B C	runon north of borrow area runon north of borrow area	69 79	
M	1.00	100%	C	runon north of borrow area	79	
N	7.82	100%	N/A	direct runon to pond	98	
O	1.32	100%	C	runon north of borrow area	79	
P	5.24	45% 55%	B C	runon north of borrow area runon north of borrow area	69 79	
Q	7.70	70% 30%	B C	runon north of borrow area runon north of borrow area	69 79	
R	2.61	55% 45%	B C	runon north of borrow area runon north of borrow area	69 79	
S	0.40	10% 90%	B C	runon north of borrow area runon north of borrow area	69 79	
T	0.42	100%	N/A	direct runon to pond	98	
U	4.15	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	
V	0.27	100%	N/A	direct runon to pond	98	
W	10.59	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	
X	11.85	80% 20%	B C	runon east of OSDF runon east of OSDF	69 79	
Y	6.52	60% 40%	B C	runon east of OSDF runon east of OSDF	69 79	
Z	1.61	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	
AA	2.71	55% 45%	B C	runon east of OSDF runon east of OSDF	69 79	
BB	0.76	100%	C	runon east of OSDF	79	
CC	0.12	100%	C	runon east of OSDF	79	
DD	0.54	100%	B/C	unvegetated final cover	89	
EE	0.93	20% 80%	B C	runon north of borrow area runon north of borrow area	69 79	
FF	3.09	100%	B/C	unvegetated final cover	89	
GG	1.98	55% 45%	B C	construction laydown construction laydown	74 82	
HH	0.55	100%	C	runon north of borrow area	79	
II	1.67	50% 50%	B C	runon area to borrow area runon area to borrow area	61 74	
JJ	0.91	93% 7%	B C	runon area to borrow area runon area to borrow area	61 74	
KK	5.89	80% 20%	B C	runon area to borrow area runon area to borrow area	61 74	
LL	7.05	100%	B	runoff	61	
MM	1.94	100%	B	runoff	61	
NN	1.27	60% 40%	B C	runoff runoff	61 74	
OO	0.40	65% 35%	B C	runon area to borrow area runon area to borrow area	61 74	
PP	40.96	80% 20%	B C	vegetated borrow area vegetated borrow area	61 74	

N/A - Not Applicable

109/282
DGP 30JAN 02
DBM 1/30/02

SUBCATCHMENT AREA AND HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF WEIGHTED CN

West OSDF Construction Design Scenario

4664

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	2.73	100%	B/C	vegetated final cover	83	Intentionally left blank. Is addressed in the calculation section.
B	5.34	100%	B/C	vegetated final cover	83	
C	5.40	100%	B/C	vegetated final cover	83	
D	5.53	100%	B/C	unvegetated final cover	89	
E	4.81	100%	B/C	unvegetated final cover	89	
F	1.64	60% 40%	B/C C	unvegetated final cover construction laydown	89 82	
G	3.64	40% 60%	B/C C	unvegetated final cover construction laydown	89 82	
H	0.80	100%	C	construction laydown	82	
I	0.51	100%	C	construction laydown	82	
J	1.45	100%	C	construction laydown	82	
K	0.77	100%	C	runon north of borrow area	79	
L	1.28	100%	C	construction laydown	82	
M	0.96	100%	C	runon north of borrow area	79	
N	1.04	100%	C	construction laydown	82	
O	2.25	100%	N/A	direct runon to pond	98	
P	0.94	100%	C	construction laydown	82	

N/A - Not Applicable

110/282
DGP 30 JAN 02
DBM 1/30/02

— 4664

SUBCATCHMENT AREA AND HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF WEIGHTED CN

East OSDF Post Development Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	1.96	100%	B/C	vegetated final cover	74	Intentionally left blank. Is addressed in the calculation section.
B	1.18	100%	B/C	vegetated final cover	74	
C	5.21	100%	B/C	vegetated final cover	74	
D	5.13	100%	B/C	vegetated final cover	74	
E	5.09	100%	B/C	vegetated final cover	74	
F	5.05	100%	B/C	vegetated final cover	74	
G	5.31	100%	B/C	vegetated final cover	74	
H	3.49	100%	B/C	vegetated final cover	74	
I	1.69	100%	C	grass area	74	
J	2.65	10% 90%	B C	grass area grass area	61 74	
K	4.14	50% 50%	B C	grass area grass area	61 74	
L	1.68	30% 70%	B C	runon north of borrow area runon north of borrow area	69 79	
M	1.00	100%	C	runon north of borrow area	79	
N	7.83	100%	N/A	direct runon to pond	98	
O	1.32	100%	C	runon north of borrow area	79	
P	5.24	45% 55%	B C	runon north of borrow area runon north of borrow area	69 79	
Q	7.70	70% 30%	B C	runon north of borrow area runon north of borrow area	69 79	
R	2.61	55% 45%	B C	runon north of borrow area runon north of borrow area	69 79	
S	0.40	10% 90%	B C	runon north of borrow area runon north of borrow area	69 79	
T	0.42	100%	N/A	direct runon to pond	98	
U	4.15	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	
V	0.27	100%	N/A	direct runon to pond	98	
W	10.59	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	
X	11.85	80% 20%	B C	runon east of OSDF runon east of OSDF	69 79	
Y	6.52	60% 40%	B C	runon east of OSDF runon east of OSDF	69 79	
Z	1.61	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	
AA	2.71	55% 45%	B C	runon east of OSDF runon east of OSDF	69 79	
BB	0.76	100%	C	runon east of OSDF	79	
CC	0.12	100%	C	runon east of OSDF	79	
DD	0.54	100%	B/C	vegetated final cover	74	
EE	0.93	20% 80%	B C	runon north of borrow area runon north of borrow area	69 79	
FF	3.09	100%	B/C	vegetated final cover	74	
GG	1.98	55% 45%	B C	grass area grass area	61 74	
HH	0.55	100%	C	runon north of borrow area	79	
II	1.67	50% 50%	B C	runon area to borrow area runon area to borrow area	61 74	
JJ	0.91	93% 7%	B C	runon area to borrow area runon area to borrow area	61 74	
KK	5.89	80% 20%	B C	runon area to borrow area runon area to borrow area	61 74	
LL	7.05	100%	B	borrow area runoff	61	
MM	1.94	100%	B	borrow area runoff	61	
NN	1.27	60% 40%	B C	borrow area runoff borrow area runoff	61 74	
OO	0.46	65% 35%	B C	runon area to borrow area runon area to borrow area	61 74	
PP	40.96	80% 20%	B C	vegetated borrow area vegetated borrow area	61 74	

N/A - Not Applicable

111/282
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SUBCATCHMENT AREA AND HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF WEIGHTED CN

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West OSDF Post Development Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	2.73	100%	B/C	vegetated final cover	74	Intentionally left blank. Is addressed in the calculation section.
B	5.34	100%	B/C	vegetated final cover	74	
C	5.40	100%	B/C	vegetated final cover	74	
D	5.53	100%	B/C	vegetated final cover	74	
E	4.81	100%	B/C	vegetated final cover	74	
F	1.64	60% 40%	B/C C	vegetated final cover grass area	74 74	
G	3.64	40% 60%	B/C B/C	vegetated final cover grass area	74 74	
H	0.80	100%	C	grass area	74	
I	0.51	100%	C	grass area	74	
J	1.45	100%	C	grass area	74	
K	0.77	100%	C	runon north of borrow area	79	
L	1.28	100%	C	grass area	74	
M	0.96	100%	C	runon north of borrow area	79	
N	1.04	100%	C	grass area	74	
O	2.25	100%	N/A	direct runon to pond	98	
P	0.94	100%	C	grass area	74	

N/A - Not Applicable

112/282
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SUBCATCHMENT AREA AND HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF WEIGHTED CN

Design Case "A"

— 4664

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	1.93	100%	B/C	liner runout	89	Intentionally left blank. Is addressed in the calculation section.
B	0.88	100%	C	construction laydown	82	
C	0.71	100%	C	construction laydown	82	
D	0.65	100%	C	construction laydown	82	
E	1.29	100%	C	construction laydown	82	
F	0.34	100%	C	construction laydown	82	
G	1.86	100%	C	construction laydown	82	
H	0.65	60%	C	pavement	98	
		40%	C	construction laydown	82	

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ATTACHMENT B-4

DATA FOR CALCULATION OF TIME OF CONCENTRATION

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DOP 31JAN02

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HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
EAST OSDF CONSTRUCTION DESIGN SCENARIO

2-year, 24-hr Design Rainfall Depth, P_{2-24} = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW			SHALLOW CONCENTRATED FLOW			SHALLOW CONCENTRATED FLOW			CHANNEL FLOW 1						CHANNEL FLOW 2					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	80	UNPAVED	0.1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	VEGETATED FINAL COVER	50	GRASS: SHORT	0.150	0.1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	450	0	1.02	6.0, 3.0	0.030	0.0045	-	-	-	-	-	-
C	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	400	0	1.02	6.0, 4.0	0.030	0.0045	-	-	-	-	-	-
D	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	250	0	1.29	5.0, 3.0	0.030	0.0045	150	0	1.59	4.0, 3.0	0.030	0.0050
E	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	380	0	1.60	4.0, 3.0	0.030	0.0050	-	-	-	-	-	-
F	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	390	0	1.60	4.0, 3.0	0.030	0.0050	-	-	-	-	-	-
G	NON VEGETATED FINAL COVER	90	SMOOTH	0.011	0.0500	60	SMOOTH	0.011	0.1000	150	SMOOTH	0.011	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	410	0	1.60	4.0, 3.0	0.030	0.0050	-	-	-	-	-	-
H	NON VEGETATED FINAL COVER	90	SMOOTH	0.011	0.0500	60	SMOOTH	0.011	0.1000	150	SMOOTH	0.011	0.1700	140	UNPAVED	0.1700	-	-	-	-	-	-	440	0	2.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
I	CONSTRUCTION LAYDOWN	230	GRASS: SHORT	0.150	0.0440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0176	-	-	-	-	-	-	-	-	110	UNPAVED	0.0176	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0200	-	-	-	-	-	-	-	-	250	UNPAVED	0.0200	-	-	-	-	-	-	200	10	2.00	3.0, 3.0	0.030	0.0045	-	-	-	-	-	-
L	RUNON NORTH OF BORROW AREA	140	GRASS: SHORT	0.150	0.0200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290	0	2.00	3.0, 3.0	0.030	0.0075	-	-	-	-	-	-
M	RUNON NORTH OF BORROW AREA	170	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	200	20	2.50	3.0, 3.0	0.030	0.0045	-	-	-	-	-	-
N	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	RUNON NORTH OF BORROW AREA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	230	0	1.00	5.0, 5.0	0.030	0.0086	-	-	-	-	-	-
P	RUNON NORTH OF BORROW AREA	300	GRASS: SHORT	0.150	0.0150	-	-	-	-	-	-	-	-	350	UNPAVED	0.0070	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q	RUNON NORTH OF BORROW AREA	300	GRASS: SHORT	0.150	0.0260	-	-	-	-	-	-	-	-	1280	UNPAVED	0.0260	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R	RUNON NORTH OF BORROW AREA	300	GRASS: SHORT	0.150	0.0400	-	-	-	-	-	-	-	-	350	UNPAVED	0.0400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S	RUNON NORTH OF BORROW AREA	280	GRASS: SHORT	0.150	0.0150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	0	3.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
T	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U	RUNON EAST OF OSDF	300	GRASS: SHORT	0.150	0.0140	-	-	-	-	-	-	-	-	240	UNPAVED	0.0140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W	RUNON EAST OF OSDF	300	GRASS: SHORT	0.150	0.1780	-	-	-	-	-	-	-	-	400	UNPAVED	0.1780	-	-	-	-	-	-	270	0	3.00	3.0, 30.0	0.030	0.0144	-	-	-	-	-	-
X	RUNON EAST OF OSDF	300	GRASS: SHORT	0.150	0.0190	-	-	-	-	-	-	-	-	730	UNPAVED	0.0190	-	-	-	-	-	-	330	0	2.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
Y	RUNON EAST OF OSDF	300	GRASS: SHORT	0.150	0.0130	-	-	-	-	-	-	-	-	510	UNPAVED	0.0130	-	-	-	-	-	-	340	0	2.00	5.0, 4.0	0.030	0.0110	-	-	-	-	-	-
Z	RUNON EAST OF OSDF	300	GRASS: SHORT	0.150	0.0310	-	-	-	-	-	-	-	-	250	UNPAVED	0.0310	-	-	-	-	-	-	50	0	2.00	5.0, 4.0	0.030	0.0070	-	-	-	-	-	-
AA	RUNON AREA EAST OF OSDF	300	GRASS: SHORT	0.150	0.0800	-	-	-	-	-	-	-	-	170	UNPAVED	0.0800	-	-	-	-	-	-	300	0	2.00	3.0, 3.0	0.030	0.0070	-	-	-	-	-	-
BB	RUNON AREA EAST OF OSDF	110	GRASS: SHORT	0.150	0.0800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	360	0	1.50	3.0, 5.0	0.030	0.0040	-	-	-	-	-	-
CC	RUNON AREA EAST OF OSDF	110	GRASS: SHORT	0.150	0.0800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DD	NON VEGETATED FINAL COVER	230	SMOOTH	0.011	0.1700	20	GRASS: SHORT	0.150	0.0600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EE	RUNON NORTH OF BORROW AREA	300	GRASS: SHORT	0.150	0.0230	-	-	-	-	-	-	-	-	80	UNPAVED	0.0230	-	-	-	-	-	-	40	0	4.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
FF	NON VEGETATED FINAL COVER	90	SMOOTH	0.011	0.0500	60	SMOOTH	0.011	0.1000	150	SMOOTH	0.011	0.1700	210	UNPAVED	0.1700	120	UNPAVED	0.0141	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GG	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0200	-	-	-	-	-	-	-	-	290	UNPAVED	0.0200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH	RUNON NORTH OF BORROW AREA	90	GRASS: SHORT	0.150	0.0100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	230	20	2.50	3.0, 3.0	0.030	0.0045	-	-	-	-	-	-
II	RUNON AREA TO BORROW AREA	210	GRASS: SHORT	0.150	0.0400	-	-	-	-	-	-	-	-	70	UNPAVED	0.1660	360	UNPAVED	0.0025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JJ	RUNON AREA TO BORROW AREA	300	GRASS: SHORT	0.150	0.0250	-	-	-	-	-	-	-	-	40	UNPAVED	0.0250	110	UNPAVED	0.1660	840	UNPAVED	0.0025	-	-	-	-	-	-	-	-	-	-	-	-
KK	RUNON AREA TO BORROW AREA	300	GRASS: SHORT	0.150	0.0280	-	-	-	-	-	-	-	-	150	UNPAVED	0.0140	110	UNPAVED	0.1660	630	UNPAVED	0.0030	-	-	-	-	-	-	-	-	-	-	-	-
LL	RUNOFF	300	GRASS: SHORT	0.150	0.0240	-	-	-	-	-	-	-	-	200	UNPAVED	0.0240	-	-	-	-	-	-	900	0	3.00	3.0, 3.0	0.030	0.0090	-	-	-	-	-	-
MM	RUNOFF	100	GRASS: SHORT	0.150	0.0700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	980	0	3.00	5.0, 4.0	0.030	0.0060	-	-	-	-	-	-
NN	RUNOFF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	600	0	3.00	3.0, 3.0	0.030	0.0130	-	-	-	-	-	-
OO	RUNON AREA TO BORROW AREA	120	GRASS: SHORT	0.150	0.1660	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PP	VEGETATED BORROW AREA	150	GRASS: SHORT	0.150	0.1660	150	GRASS: SHORT	0.150	0.0025	-	-	-	-	1190	UNPAVED	0.0025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

115/282
DBM 1/30/02
DCP 30 JAN 02
- 4664

HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
WEST OSDF CONSTRUCTION DESIGN SCENARIO

2-year, 24-hr Design Rainfall Depth, $P_{2,24}$ = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW 1			SHALLOW CONCENTRATED FLOW 2			CHANNEL FLOW 1						PIPE FLOW				CHANNEL FLOW 2					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Diameter (inch)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	190	UNPAVED	0.1700	-	-	-	180	0	2.00	3.0, 6.0	0.030	0.0075	-	-	-	-	-	-	-	-	-	-
B	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	200	UNPAVED	0.1700	-	-	-	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	200	0	2.00	6.0, 3.0	0.030	0.0075
C	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	200	UNPAVED	0.1700	-	-	-	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	195	0	2.00	6.0, 3.0	0.030	0.0075
D	NON VEGETATED FINAL COVER	90	SMOOTH	0.011	0.0500	60	SMOOTH	0.011	0.1000	150	SMOOTH	0.011	0.1700	205	UNPAVED	0.1700	-	-	-	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	195	0	2.00	6.0, 3.0	0.030	0.0075
E	NON VEGETATED FINAL COVER	90	SMOOTH	0.011	0.0500	60	SMOOTH	0.011	0.1000	150	SMOOTH	0.011	0.1700	205	UNPAVED	0.1700	-	-	-	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	305	0	2.00	6.0, 3.0	0.030	0.0075
F	NON VEGETATED FINAL COVER	300	SMOOTH	0.011	0.1700	-	-	-	-	-	-	-	-	135	UNPAVED	0.1700	50	UNPAVED	0.0141	185	0	1.50	3.0, 5.0	0.030	0.0133	-	-	-	-	-	-	-	-	-	-
G	NON VEGETATED FINAL COVER	50	SMOOTH	0.011	0.0500	230	SMOOTH	0.011	0.1000	20	SMOOTH	0.011	0.1700	110	UNPAVED	0.1700	450	UNPAVED	0.0141	130	0	2.50	3.0, 5.0	0.030	0.0066	-	-	-	-	-	-	-	-	-	-
H	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0141	-	-	-	-	-	-	-	-	50	UNPAVED	0.0141	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0230	-	-	-	-	-	-	-	-	30	UNPAVED	0.0230	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J	CONSTRUCTION LAYDOWN	110	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	350	0	3.50	3.0, 3.0	0.030	0.0075	-	-	-	-	-	-	-	-	-	-
K	RUNON NORTH OF BORROW AREA	220	GRASS: SHORT	0.150	0.0347	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L	CONSTRUCTION LAYDOWN	220	GRASS: SHORT	0.150	0.0285	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	RUNON NORTH OF BORROW AREA	50	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	390	0	3.00	3.0, 3.0	0.030	0.0110	-	-	-	-	-	-	-	-	-	-
N	CONSTRUCTION LAYDOWN	170	GRASS: SHORT	0.150	0.0250	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	CONSTRUCTION LAYDOWN	90	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	235	0	3.50	3.0, 3.0	0.030	0.0075	-	-	-	-	-	-	-	-	-	-

116/282
DBM 1/30/02
DGP 30 JAN 02

HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
EAST OSDF POST DEVELOPMENT DESIGN SCENARIO

2-year, 24-hr Design Rainfall Depth, P_{2-24} = 2.60 inches

— 4664

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW 1			SHALLOW CONCENTRATED FLOW 2			SHALLOW CONCENTRATED FLOW 3			CHANNEL FLOW 1						CHANNEL FLOW 2					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	80	UNPAVED	0.1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	VEGETATED FINAL COVER	50	GRASS: SHORT	0.150	0.1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	450	0	1.02	6.0, 3.0	0.030	0.0045	-	-	-	-	-	-
C	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	400	0	1.02	6.0, 4.0	0.030	0.0045	-	-	-	-	-	-
D	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	250	0	1.29	5.0, 3.0	0.030	0.0045	150	0	1.59	4.0, 3.0	0.030	0.0050
E	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	380	0	1.60	4.0, 3.0	0.030	0.0050	-	-	-	-	-	-
F	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	390	0	1.60	4.0, 3.0	0.030	0.0050	-	-	-	-	-	-
G	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	170	UNPAVED	0.1700	-	-	-	-	-	-	410	0	1.60	4.0, 3.0	0.030	0.0050	-	-	-	-	-	-
H	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	140	UNPAVED	0.1700	-	-	-	-	-	-	440	0	2.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
I	OPEN SPACE WITH GOOD GRASS COVER	230	GRASS: SHORT	0.150	0.0440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0176	-	-	-	-	-	-	-	-	150	UNPAVED	0.0176	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0200	-	-	-	-	-	-	-	-	250	UNPAVED	0.0200	-	-	-	-	-	-	200	10	2.00	3.0, 3.0	0.030	0.0045	-	-	-	-	-	-
L	OPEN SPACE WITH GOOD GRASS COVER	140	GRASS: SHORT	0.150	0.0200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	290	0	2.00	3.0, 3.0	0.030	0.0075	-	-	-	-	-	-
M	OPEN SPACE WITH GOOD GRASS COVER	170	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	200	20	2.50	3.0, 3.0	0.030	0.0045	-	-	-	-	-	-
N	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	230	0	1.00	5.0, 5.0	0.030	0.0086	-	-	-	-	-	-
P	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0150	-	-	-	-	-	-	-	-	350	UNPAVED	0.0070	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0260	-	-	-	-	-	-	-	-	1280	UNPAVED	0.0260	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0400	-	-	-	-	-	-	-	-	350	UNPAVED	0.0400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S	OPEN SPACE WITH GOOD GRASS COVER	280	GRASS: SHORT	0.150	0.0150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	0	3.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
T	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
U	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0140	-	-	-	-	-	-	-	-	240	UNPAVED	0.0140	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.1780	-	-	-	-	-	-	-	-	400	UNPAVED	0.1780	-	-	-	-	-	-	270	0	3.00	3.0, 30.0	0.030	0.0144	-	-	-	-	-	-
X	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0190	-	-	-	-	-	-	-	-	730	UNPAVED	0.0190	-	-	-	-	-	-	330	0	2.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
Y	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0130	-	-	-	-	-	-	-	-	510	UNPAVED	0.0130	-	-	-	-	-	-	340	0	2.00	5.0, 4.0	0.030	0.0110	-	-	-	-	-	-
Z	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0310	-	-	-	-	-	-	-	-	250	UNPAVED	0.0310	-	-	-	-	-	-	50	0	2.00	5.0, 4.0	0.030	0.0070	-	-	-	-	-	-
AA	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0800	-	-	-	-	-	-	-	-	170	UNPAVED	0.0800	-	-	-	-	-	-	300	0	2.00	3.0, 3.0	0.030	0.0070	-	-	-	-	-	-
BB	OPEN SPACE WITH GOOD GRASS COVER	110	GRASS: SHORT	0.150	0.0800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	360	0	1.50	3.0, 5.0	0.030	0.0040	-	-	-	-	-	-
CC	OPEN SPACE WITH GOOD GRASS COVER	110	GRASS: SHORT	0.150	0.0800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DD	VEGETATED FINAL COVER	230	GRASS: SHORT	0.150	0.1700	20	GRASS: SHORT	0.150	0.0600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EE	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0230	-	-	-	-	-	-	-	-	80	UNPAVED	0.0230	-	-	-	-	-	-	40	0	4.00	3.0, 3.0	0.030	0.0100	-	-	-	-	-	-
FF	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	210	UNPAVED	0.1700	120	UNPAVED	0.0141	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GG	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0200	-	-	-	-	-	-	-	-	290	UNPAVED	0.0200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HH	OPEN SPACE WITH GOOD GRASS COVER	90	GRASS: SHORT	0.150	0.0100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	230	20	2.50	3.0, 3.0	0.030	0.0045	-	-	-	-	-	-
II	OPEN SPACE WITH GOOD GRASS COVER	210	GRASS: SHORT	0.150	0.0400	-	-	-	-	-	-	-	-	70	UNPAVED	0.1660	380	UNPAVED	0.0025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JJ	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0250	-	-	-	-	-	-	-	-	40	UNPAVED	0.0250	110	UNPAVED	0.1660	840	UNPAVED	0.0025	-	-	-	-	-	-	-	-	-	-	-	-
KK	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0280	-	-	-	-	-	-	-	-	150	UNPAVED	0.0140	110	UNPAVED	0.1660	630	UNPAVED	0.0030	-	-	-	-	-	-	-	-	-	-	-	-
LL	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0240	-	-	-	-	-	-	-	-	200	UNPAVED	0.0240	-	-	-	-	-	-	900	0	3.00	3.0, 3.0	0.030	0.0090	-	-	-	-	-	-
MM	OPEN SPACE WITH GOOD GRASS COVER	100	GRASS: SHORT	0.150	0.0700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	980	0	3.00	5.0, 4.0	0.030	0.0060	-	-	-	-	-	-
NN	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	600	0	3.00	3.0, 3.0	0.030	0.0130	-	-	-	-	-	-
OO	OPEN SPACE WITH GOOD GRASS COVER	120	GRASS: SHORT	0.150	0.1660	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PP	OPEN SPACE WITH GOOD GRASS COVER	150	GRASS: SHORT	0.150	0.1660	150	GRASS: SHORT	0.150	0.0025	-	-	-	-	1190	UNPAVED	0.0025	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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117/282
PBM 1/30/02
DCP 30 JAN 02

- 4664

HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
WEST OSDF POST DEVELOPMENT DESIGN SCENARIO

2-year, 24-hr Design Rainfall Depth, $P_{2,24}$ = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW 1			SHALLOW CONCENTRATED FLOW 2		
No	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)
A	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	190	UNPAVED	0.1700	-	-	-
B	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	200	UNPAVED	0.1700	-	-	-
C	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	200	UNPAVED	0.1700	-	-	-
D	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	205	UNPAVED	0.1700	-	-	-
E	VEGETATED FINAL COVER	90	GRASS: SHORT	0.150	0.0500	60	GRASS: SHORT	0.150	0.1000	150	GRASS: SHORT	0.150	0.1700	205	UNPAVED	0.1700	-	-	-
F	VEGETATED FINAL COVER	300	GRASS: SHORT	0.150	0.1700	-	-	-	-	-	-	-	-	135	UNPAVED	0.1700	50	UNPAVED	0.0141
G	VEGETATED FINAL COVER	50	GRASS: SHORT	0.150	0.0500	230	GRASS: SHORT	0.150	0.1000	20	GRASS: SHORT	0.150	0.1700	110	UNPAVED	0.1700	450	UNPAVED	0.0141
H	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0141	-	-	-	-	-	-	-	-	50	UNPAVED	0.0141	-	-	-
I	OPEN SPACE WITH GOOD GRASS COVER	300	GRASS: SHORT	0.150	0.0230	-	-	-	-	-	-	-	-	30	UNPAVED	0.0230	-	-	-
J	OPEN SPACE WITH GOOD GRASS COVER	110	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K	OPEN SPACE WITH GOOD GRASS COVER	220	GRASS: SHORT	0.150	0.0347	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L	OPEN SPACE WITH GOOD GRASS COVER	230	GRASS: SHORT	0.150	0.0285	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	OPEN SPACE WITH GOOD GRASS COVER	50	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	OPEN SPACE WITH GOOD GRASS COVER	170	GRASS: SHORT	0.150	0.0250	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	OPEN SPACE WITH GOOD GRASS COVER	90	GRASS: SHORT	0.150	0.0500	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SUBCATCHMENT LABEL AND DESCRIPTION		CHANNEL FLOW 1						PIPE FLOW				CHANNEL FLOW 2					
No	Description	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Diameter (inch)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	VEGETATED FINAL COVER	180	0	2.00	3.0, 6.0	0.030	0.0075	-	-	-	-	-	-	-	-	-	-
B	VEGETATED FINAL COVER	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	200	0	2.00	6.0, 3.0	0.030	0.0075
C	VEGETATED FINAL COVER	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	195	0	2.00	6.0, 3.0	0.030	0.0075
D	VEGETATED FINAL COVER	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	195	0	2.00	6.0, 3.0	0.030	0.0075
E	VEGETATED FINAL COVER	190	0	2.00	3.0, 6.0	0.030	0.0075	60	72	0.013	0.0100	305	0	2.00	6.0, 3.0	0.030	0.0075
F	VEGETATED FINAL COVER	185	0	1.50	3.0, 5.0	0.030	0.0133	-	-	-	-	-	-	-	-	-	-
G	VEGETATED FINAL COVER	130	0	2.50	3.0, 5.0	0.030	0.0066	-	-	-	-	-	-	-	-	-	-
H	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
I	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
J	OPEN SPACE WITH GOOD GRASS COVER	350	0	3.50	3.0, 3.0	0.030	0.0075	-	-	-	-	-	-	-	-	-	-
K	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	OPEN SPACE WITH GOOD GRASS COVER	390	0	3.00	3.0, 3.0	0.030	0.0110	-	-	-	-	-	-	-	-	-	-
N	OPEN SPACE WITH GOOD GRASS COVER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	DIRECT RUNON TO POND	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P	OPEN SPACE WITH GOOD GRASS COVER	235	0	3.50	3.0, 3.0	0.030	0.0075										

P:\Attachments\Est West OSDF PO

118/282
DBM 1/30/02
DGP 30 JAN 02

- 4664

HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
DESIGN CASE "A"

2-year, 24-hr Design Rainfall Depth, P_{2-24} = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHEET FLOW 4				SHALLOW CONCENTRATED FLOW			CHANNEL FLOW					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	LINER RUNOUT	8	SMOOTH	0.011	0.6660	18	SMOOTH	0.011	0.0215	31	SMOOTH	0.011	0.2500	90	SMOOTH	0.011	0.0222	-	-	-	590	0	2.50	3.0, 50.0	0.030	0.0100
B	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0125	-	-	-	-	-	-	-	-	-	-	-	-	145	UNPAVED	0.0125	-	-	-	-	-	-
C	CONSTRUCTION LAYDOWN	260	GRASS: SHORT	0.150	0.0154	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D	CONSTRUCTION LAYDOWN	85	GRASS: SHORT	0.150	0.0500	215	GRASS: SHORT	0.150	0.0136	-	-	-	-	-	-	-	-	30	UNPAVED	0.0136	60	0	1.50	3.0, 3.0	0.030	0.0050
E	CONSTRUCTION LAYDOWN	300	GRASS: SHORT	0.150	0.0133	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F	CONSTRUCTION LAYDOWN	20	SMOOTH	0.011	0.3750	60	GRASS: SHORT	0.150	0.0500	55	GRASS: SHORT	0.150	0.0600	165	GRASS: SHORT	0.015	0.0161	150	UNPAVED	0.0161	-	-	-	-	-	-
G	CONSTRUCTION LAYDOWN	85	GRASS: SHORT	0.150	0.0235	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	330	0	2.00	4.0, 6.0	0.030	0.0150
H	CONSTRUCTION LAYDOWN/PAVEMENT	165	SMOOTH	0.011	0.0182	115	GRASS: SHORT	0.150	0.0087	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

4664

ATTACHMENT B-5

CHANNEL INPUT DATA

OSDF CONSTRUCTION/FILLING PERIOD CONDITIONS
SUMMARY OF CHANNEL INPUT DATA

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node[3]	HydroCAD Q (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth Y (ft)	Estimated Q (cfs)	Channel Freeboard (ft)	Peak Flow Velocity (fps)	Lining Type
7	new	E OSDF	vee	4.0	1.00%	0.030	0	6	3	2P - T - 1 - DD									
8	new	E OSDF	trapezoidal	4.5	0.46%	0.030	10	3	3	8									
9	new	E OSDF	trapezoidal	3.5	0.45%	0.030	10	3	3	9									
10	new	E OSDF	trapezoidal	2.0	0.45%	0.030	10	3	3	11 - GG									
12	new	E OSDF	trapezoidal	2.0	0.45%	0.030	10	3	3	12 + HH									
13	new	E OSDF	trapezoidal	2.0	0.45%	0.030	20	3	3	13	Intentionally left blank. Is addressed in the calculation section.								
18	new	E OSDF	vee	3.0	1.00%	0.030	0	3	3	19									
19	new	E OSDF	vee	3.0	0.90%	0.030	0	3	3	20									
20	new	E OSDF	vee	3.0	0.83%	0.030	0	3	3	1P - U - V									
30	new	E OSDF	vee	2.5	1.00%	0.030	0	3	3	30									
21	new	E OSDF	vee	3.0	1.00%	0.030	0	3	3	22									
22	new	E OSDF	vee	4.0	1.00%	0.030	0	3	3	29									
29	new	E OSDF	vee	3.5	1.00%	0.030	0	3	3	23									
24	new	E OSDF	trapezoidal	2.0	0.75%	0.030	8.5	3	3	24									
26	new	E OSDF	vee	2.5	0.75%	0.030	0	3	3	27									
7	new	W OSDF	vee	4	0.75%	0.030	0	3	3	8 - 12									
8	new	W OSDF	vee	4	0.75%	0.030	0	3	3	8 + P	Intentionally left blank. Is addressed in the calculation section.								
9	existing	W OSDF	vee	1.5	2.61%	0.030	0	3	3	9 + H + I									
10	new	W OSDF	vee	1.5	1.48%	0.030	0	3	3	10 + F									
11	new	W OSDF	vee	2.5	0.66%	0.030	0	3	3	11 + G									
2	existing	DC A	vee	3.0	1.50%	0.030	0	4	6	1 + G									
5	new	DC A	vee	2.5	0.34%	0.030	0	3	3	5	Intentionally left blank. Is addressed in the calculation section.								
6	new	DC A	vee	2.5	0.23%	0.030	0	3	3	6 + D									
7	existing	DC A	vee	2.0	2.00%	0.030	0	4	6	7 + E									

E OSDF = East OSDF Construction-Phase Design Scenario
W OSDF = West OSDF Construction-Phase Design Scenario
DC A = Design Case "A"

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from the Drawings.
3. N/A indicates that there is not specific HydroCAD node associated with the particular channel.

120/282
DFP 30 JAN 02
DBM 1/30/02
- 4664

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B attachments/B5 CF

OSDF POST DEVELOPMENT PERIOD CONDITIONS
SUMMARY OF CHANNEL INPUT DATA

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations								
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node	HydroCAD Q (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth Y (ft)	Estimated Q (cfs)	Channel Freeboard (ft)	Peak Flow Velocity (fps)	Sufficient to Minimize Sedimentation?	Lining Type
1	existing	E OSDF PD	vee	5	0.45%	0.030	0	6	4	2										
2	existing	E OSDF PD	vee	6.5	0.45%	0.030	0	3	5	3										
3	new	E OSDF PD	vee	7.4	0.50%	0.030	0	3	4	4										
4	new	E OSDF PD	vee	6.5	0.50%	0.030	0	3	4	5										
5	new	E OSDF PD	vee	3	0.50%	0.030	0	3	6	6										
6	new	E OSDF PD	vee	3	1.00%	0.030	0	3	6	7										
7	new	E OSDF PD	vee	4.0	1.00%	0.030	0	6	3	2P - T - I - DD										
8	new	E OSDF PD	trapezoidal	4.5	0.45%	0.030	10	3	3	8	Intentionally left blank. Is addressed in the calculation section.									
9	new	E OSDF PD	trapezoidal	3.5	0.45%	0.030	10	3	3	9										
10	new	E OSDF PD	trapezoidal	2.0	0.45%	0.030	10	3	3	11 - GG										
12	new	E OSDF PD	trapezoidal	2.0	0.45%	0.030	10	3	3	12 + HH										
13	new	E OSDF PD	trapezoidal	2.0	0.45%	0.030	20	3	3	13										
14	existing	E OSDF PD	vee	1.5	0.40%	0.030	0	3	5	15										
15	existing	E OSDF PD	vee	2.0	0.63%	0.030	0	3	5	16										
16	existing	E OSDF PD	vee	3.4	0.74%	0.030	0	2.5	5	17										
17	existing	E OSDF PD	vee	3.5	1.25%	0.030	0	4	5	18										
18	new	E OSDF PD	vee	3.0	1.00%	0.030	0	3	3	19										
19	new	E OSDF PD	vee	3.0	0.90%	0.030	0	3	3	20										
20	new	E OSDF PD	vee	3.0	0.83%	0.030	0	3	3	1P - U - V										
30	new	E OSDF PD	vee	2.5	1.00%	0.030	0	3	3	30										
21	new	E OSDF PD	vee	3.0	1.00%	0.030	0	3	3	22										
22	new	E OSDF PD	vee	4.0	1.00%	0.030	0	3	3	29										
29	new	E OSDF PD	vee	3.5	1.00%	0.030	0	3	3	23										
24	new	E OSDF PD	trapezoidal	2.0	0.75%	0.030	8.5	3	3	24										
26	new	E OSDF PD	vee	2.5	0.75%	0.030	0	3	3	27										
1	new	W OSDF PD	vee	3	0.75%	0.030	0	3	6	2										
2	new	W OSDF PD	vee	3	0.75%	0.030	0	3	6	3										
3	new	W OSDF PD	vee	3	0.75%	0.030	0	3	6	4										
4	new	W OSDF PD	vee	3	0.76%	0.030	0	3	6	5	Intentionally left blank. Is addressed in the calculation section.									
6	new	W OSDF PD	vee	3.5	0.75%	0.030	0	3	6	7										
7	new	W OSDF PD	vee	4	0.75%	0.030	0	3	3	8 - 12										
8	new	W OSDF PD	vee	4	0.75%	0.030	0	3	3	8 + P										
9	new	W OSDF PD	vee	1.5	2.61%	0.030	0	3	3	9 + H + I										
10	new	W OSDF PD	vee	1.5	1.48%	0.030	0	3	3	10 + F										
11	existing	W OSDF PD	vee	2.5	0.66%	0.030	0	3	3	11 + G										

E OSDF PD= East OSDF Post Development Design Scenario
W OSDF PD= West OSDF Post Development Design Scenario

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from the Drawings.

121/282
DCP 30 JAN 02
DBM 1/30/02
- 4664

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B attachments/B5 PDF

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ATTACHMENT B-6

CULVERT INPUT DATA

123/282
DBM1/30/02
DCP 30 JAN 02
4664

OSDF CONSTRUCTION/FILLING PERIOD CONDITION
SUMMARY OF CULVERT DESIGN PARAMETERS

CULVERT IDENTIFICATION			PHYSICAL CHARACTERISTICS OF CULVERT						CULVERT PROFILE				CULVERTMASTER® MODELING CHARACTERISTICS			HYDRAULIC CAPACITY					STRUCTURAL CAPACITY				OUTLET PROTECTION				
Culvert Name	Status (1)	Design Scenario	Material - Type	Entrance Loss Coefficient (Ke)	Manning's n	Entrance Configuration	Number of Culverts - Diameter	Approximate Length (ft)	Inlet Invert Elevation (ft MSL)	Outlet Invert Elevation (ft MSL)	Slope ft/ft	Overtopping Elevation (ft MSL)	Entrance Configuration(2)	Entrance Loss Coefficient (Ke)	Number of Culverts - Diameter (3)	HydroCad Node for Peak Flow Rate (cfs)	Tailwater Elevation (ft MSL)	Depth of Flow Downstream - HydroCad Results (ft)	Calculated Headwater Depth Outlet Control (ft MSL)	Calculated Freeboard (ft)	Available Cover (ft)	Design Traffic Type	Minimum Required Cover (ft)	Structurally Stable	Outlet Velocity (ft/s)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	d_{50} (in)	Thickness (in)
11a	reconfigured	E OSDF	HDPE	0.2	0.010	Projecting	2 - 27 inch	60	583.84	583.57	0.0045	587.50	Groove - Projecting	0.2	3 - 27 inch	11 / 76.91													
11b	reconfigured	E OSDF	RCP	0.2	0.013	Projecting	1 - 30 inch	60																					
23	new	E OSDF	Helical CMP	0.9	0.018	Projecting	2 - 36 inch	92	586.32	585.78	0.0059	590.00	Projecting	0.9	2 - 36 inch	23 / 48.76	Intentionally left blank. Is addressed in the calculation section.												
25	new	E OSDF	Helical CMP - Arch	0.9	0.018	Projecting	2 - 42 x 29 inch	53	584.85	584.53	0.0060	588.50	Thin Wall Projecting	0.9	2 - 42 x 29 inch	25 / 64.23													
27	new	E OSDF	Helical CMP - Arch	0.9	0.018	Projecting	2 - 42 x 29 inch	106	582.80	582.36	0.0042	587.00	Thin Wall Projecting	0.9	2 - 42 x 29 inch	27 / 64.98													
28	new - temporary	E OSDF	Helical CMP - Arch	0.7	0.019	Mitered to Slope	2 - 49 x 33 inch	92	586.95	586.53	0.0046	590.50	Mitered to Slope	0.7	2 - 49 x 33 inch	28 / 70.77													
31	existing	E OSDF	HDPE	0.9	0.012	Projecting	1 - 27 inch	80	584.00	583.00	0.0125	588.50	Projecting	0.9	1 - 27 inch	31 / 6.54													
5	new - temporary	W OSDF	Helical CMP	0.9	0.019	Projecting	1 - 42 inch	95	580.68	579.98	0.00737	585.00	Projecting	0.9	1 - 42 inch	5 / 44.48													
12	new	W OSDF	Helical CMP	0.9	0.018	Projecting	1 - 30 inch	115	577.05	576.00	0.0091	581.50	Projecting	0.9	1 - 30 inch	12 / 30.11	Intentionally left blank. Is addressed in the calculation section.												
13	existing	W OSDF	RCP	0.2	0.013	Groove End Projecting	1 - 15 inch	65	579.80	579.00	0.0123	581.80	Groove End Projecting	0.2	1 - 15 inch	13 / 4.24													
14	existing	W OSDF	CMP	0.9	0.024	Projecting	1 - 50 x 31 inch	112	578.60	575.00	0.0321	582.20	Projecting	0.9	1 - 50 x 31 inch	14 / 4.33													
1	existing - temporary	DC A	CMPA - Arch	0.5	0.018	Flared End Section	1 - 13 x 17 inch	80	587.35	586.37	0.0123	590.00	Headwall	0.5	1 - 11 x 18 inch	1 / 2.02													
3	existing - temporary	DC A	PVC	0.2	0.010	Concrete Headwall	2 - 18 inch	55	581.60	581.30	0.0055	585.50	Groove Headwall	0.2	2 - 18 inch	3 / 8.41	Intentionally left blank. Is addressed in the calculation section.												
4	existing - temporary	DC A	PVC	0.2	0.010	Concrete Headwall	2 - 18 inch	60	582.70	581.50	0.0200	587.00	Groove Headwall	0.2	2 - 18 inch	4 / 1.90													
8	new - temporary	DC A	Helical CMP	0.9	0.017	Projecting	2 - 30 inch	49	579.33	578.84	0.0100	582.50	Projecting	0.9	2 - 30 inch	8 / 24.73													

- E OSDF = East OSDF Construction-PhaseDesign Scenario
- W OSDF = West OSDF Construction-Phase Design Scenario
- DC A = Design Case "A"
- N/A = Not Applicable
- d_{50} = Average particle diameter

Notes
(1) New indicates a new culvert to be installed.
(2) Entrance configuration assumed.
(3) Dimensions and entrance configurations used in the Culvertmaster software package were selected to match existing culvert characteristics as closely as possible.

124/282
DBM 1/30/02
DCP 30 JAN 02
4664

OSDF CONSTRUCTION/FILLING PERIOD CONDITIONS
SUMMARY OF CULVERT RIP RAP ANALYSES RESULTS

CULVERT IDENTIFICATION			PHYSICAL CHARACTERISTICS OF CULVERT				OUTLET PROTECTION									
									Temporary Protection		Permanent Protection		DCP Minimum Apron Length			
Culvert Name	Status [1]	Design Scenario	Material - Type	Manning's n	Number of Culverts - Diameter	Approximate Length (ft)	HydroCad Node / Peak Flow Rate (cfs)	Outlet Velocity (ft/s)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	d_{50} (in)	Thickness (in)
11a	reconfigured	E OSDF	HDPE	0.010	2 - 27 inch	60	11									
11b	reconfigured	E OSDF	RCP	0.013	1 - 30 inch	60	11									
23	new	E OSDF	Helical CMP	0.018	2 - 36 inch	92	23	Intentionally left blank. Is adressed in the calculation section.								
25	new	E OSDF	Helical CMP - Arch	0.018	2 - 42 x 29 inch	53	25									
27	new	E OSDF	Helical CMP - Arch	0.018	2 - 42 x 29 inch	106	27									
28	new - temporary	E OSDF	Helical CMP - Arch	0.019	2 - 49 x 33 inch	92	28									
31	existing	E OSDF	HDPE	0.012	1 - 27 inch	80	31									
5	new - temporary	W OSDF	Helical CMP	0.019	1 - 42 inch	95	5									
12	new	W OSDF	Helical CMP	0.018	1 - 30 inch	115	12	Intentionally left blank. Is adressed in the calculation section.								
13	existing	W OSDF	RCP	0.013	1 - 15 inch	65	13									
14	existing	W OSDF	CMP	0.024	1 - 50 x 31 inch	112	14									
1	existing - temporary	DC A	CMPA - Arch	0.018	1 - 13 x 17 inch	80	1									
3	existing - temporary	DC A	PVC	0.010	2 - 18 inch	55	3	Intentionally left blank. Is adressed in the calculation section.								
4	existing - temporary	DC A	PVC	0.010	2 - 18 inch	60	4									
8	new - temporary	DC A	Helical CMP	0.017	2 - 30 inch	49	8									

- E OSDF = East OSDF Construction-Phase Design Scenario
- W OSDF = West OSDF Construction-Phase Design Scenario
- DC A = Design Case "A"
- N/A = Not Applicable
- d_{50} = Average particle diameter

--4664

ATTACHMENT B-7

BASIN ELEVATION CONTOURS DATA

126/282
DGP 30 JAN 02
DBM 1/30/02

- 4664

STAGE-STORAGE INPUT DATA FOR SEDIMENTATION BASIN

BORROW AREA BASIN	
Elevation (ft MSL)	Planimetered Area (acres)
570.0	6.391
571.0	6.687
572.0	7.017
573.0	7.290
574.0	7.613
575.0	7.921
-	-
-	-

127/282
DCP 30 JAN 02
DBM 1/30/02

-- 4664

STAGE-STORAGE INPUT DATA FOR SEDIMENTATION BASIN

OSDF SEDIMENTATION BASIN 2	
Elevation (ft MSL)	Planimetered Area (acres)
570.5	1.460
571.0	1.512
572.0	1.614
573.0	1.713
574.0	1.819
575.0	1.917
576.0	2.026
577.0	2.162

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ATTACHMENT B-8

BASIN OUTLET STRUCTURE DATA

BORROW AREA BASIN ROUTING INPUT DATA

ITEM		BORROW AREA BASIN		
		DESCRIPTION	PARAMETER VALUE IN UNITS SHOWN	
PRINCIPAL SPILLWAY	Riser Pipe	Existing Twin 48" CMP	ELEVATION (ft MSL)	575.3
	Outlet Pipe	Existing Twin 48" CMP		569.8
EMERGENCY SPILLWAY		20' long rectangular		578.0
EMBANKMENT		Cut to existing ground surface		579.0
AVAILABLE STORAGE VOLUME (TO RISER INLET)		To primary spillway riser pipe inlet	VOLUME (acre-ft)	35.8
SUBCATCHMENT		Total Upstream Drainage area	AREA (acres)	174.86

000249

129/282
DBM 1/30/02
Dep 30 JAN 02

- 4664

OSDF SEDIMENTATION BASIN 2 ROUTING INPUT DATA

ITEM		OSDF SEDIMENTATION BASIN 2		
		DESCRIPTION	PARAMETER VALUE IN UNITS SHOWN	
PRINCIPAL SPILLWAY	Riser Pipe	48"	ELEVATION (ft MSL)	575.5
	Outlet Pipe	New 36" CMP pipe/72" x 44" CMP pipe arch bulkhead eccentric reducer coupled to existing 72" x 44" CMP pipe arch		570.8
EMERGENCY SPILLWAY		20' long rectangular		576.0
EMBANKMENT		Cut to existing ground surface		577.0
AVAILABLE STORAGE VOLUME (TO RISER INLET)		To primary spillway riser pipe inlet	VOLUME (acre-ft)	8.6
SUBCATCHMENT		Total Upstream Drainage area	AREA (acres)	39.09

000250

B attachments/B8 OSDF2

130/282
DBM 1/30/02
DGP 30 JAN 02

-- 4664

PHASE V SURFACE-WATER MANAGEMENT SYSTEM DESIGN

CALCULATIONS

INTRODUCTION

As described in the Procedures Section, the purpose of this calculation package is to design the OSDF surface-water management (SWM) structures to be constructed as part of the Phase V development of the OSDF. In addition, the adequacy of existing SWM structures is assessed. Required modifications or additions to existing structures are incorporated into the Construction Drawings and this calculation package. This section presents calculations based on procedures and data presented in the Procedures and Data Verification Sections of this calculation package.

HYDROLOGIC AND BASIN ROUTING ANALYSES

Hydrologic analyses are completed for the construction and the post-development phases of both the East OSDF and the West OSDF design scenarios and for the construction phase of Design Case "A". For each design scenario (i.e., West OSDF and East OSDF Design Scenarios) and design case, a nodal network is prepared, for a total of three nodal networks. For the East OSDF Construction Phase Design Scenario, HydroCAD™ runs are performed for the 2-year and 25-year, 24-hour storm events. For the West OSDF Construction Phase Design Scenario, HydroCAD™ runs are performed for the 10-year, 25-year, and 100-year, 24-hour storm events. For both the East and West OSDF Post-Development Design Scenario, HydroCAD™ runs are performed for the 2-year 24-hour and the 25-year 24-hour storm events. For Design Case "A", a HydroCAD™ run is performed for the 25-year, 24-hour storm event. In total, 10 runs are performed. HydroCAD™ output reports for these runs are presented in Attachments C-1A, C-1B, C-1C, C-1D, and C-1E for the East OSDF Construction Phase, West OSDF Construction Phase, East OSDF Post-Development, West OSDF Post-Development Design Scenarios, and Design Case "A", respectively.

Subcatchment Runoff

4664

Runoff curve numbers

Weighted runoff curve numbers are calculated using a spreadsheet. Results are presented in Attachment C-2. An example calculation is provided in the same attachment. The calculated weighted runoff curve numbers are input directly to HydroCAD™.

HYDRAULIC ANALYSES

Calculation parameters obtained from HydroCAD™ for use in design include the following.

- For channels: 25-year, 24-hour peak flow rates (cfs).
- For evaluating sedimentation potential in permanent channels: 2-year, 24-hour velocities (fps).
- For culverts: 25-year, 24-hour peak flow rates (cfs).
- For the OSDF Basin 2: 25-year and 100-year, 24-hour peak water elevations (ft MSL), and 10-year, 24-hour runoff volumes (acre-ft).
- For the Borrow Area Basin: 25-year, 24-hour peak water elevations (ft MSL), and 2-year, 24-hour runoff volumes (acre-ft).

Channels

Hydraulic Capacity

For each new and existing channel, peak flow depths are calculated using a computer spreadsheet. The peak flow depth is subtracted from the minimum available depth (from Construction Drawings) to obtain the minimum available freeboard. A computer spreadsheet is presented in Attachment C-3 that includes minimum available freeboard and example calculations for the computations performed in the spreadsheets. For both new and existing channels, the minimum available freeboard is equal or greater than 0.5 ft with only one exception. For the exception, the channel has a 0.3 ft of freeboard. However, if this channel were to overflow, the water would be contained and routed back into the channel by the existing ground topography.

Lining

For each new channel, peak flow velocity is calculated using a computer spreadsheet. Peak flow velocities and channel linings are presented for each new channel, in Attachment C-3. All new channels will be grass-lined channels and have maximum flow velocities less than 5 fps.

Sedimentation

For each permanent channel, hydrology results for post-closure conditions and the 25-year 24-hour storm event are calculated for use in the Phase V calculation "Sedimentation Evaluation of Permanent Drainage Channels for High Frequency Design Storms". These results are provided as part of HydroCAD™ output reports presented in Attachments C-1C and C-1D.

Culverts

Hydraulic Capacity

For each culvert, peak flow rates are obtained from HydroCAD™ output. Based on peak flow rates and culvert input data, CulvertMaster® is used to calculate headwater elevations for inlet and outlet control conditions. CulvertMaster® output summary sheets are presented in Attachment C-4A. Calculated headwater elevations and overtopping elevations are tabulated and presented in Attachment C-4B.

For all new culverts, the overtopping elevation exceeds the maximum calculated headwater elevation by at least 0.5 feet.

Outlet Protection

For each new culvert, recommendations for outlet protection, based on guidelines described in the Procedure Section of this calculation package, are presented in Attachment C-4B. Downstream riprap length for the outlet of culverts 11, 23, 25, 27, 28, and 31 from the East OSDF Design Scenario are 10 ft, 12 ft, 0 ft, 12ft, 12 ft, and 0 ft respectively. Upstream riprap length for the inlet of culverts 11, 23, 25, 27, 28, and 31 from the East OSDF Design Scenario are 5 ft, 6 ft, 0 ft, 6 ft, 6 ft, and 0 ft respectively. Downstream riprap length for the outlet of culverts 5, 12, 13, and 14 from the West OSDF Design Scenario are 14 ft, 10 ft, 5 ft, and 0 ft respectively. Upstream riprap length for the inlet of culverts 5, 12, 13, and 14 from the West

OSDF Design Scenario are 7 ft, 5 ft, 2.5 ft, and 0 ft respectively. Upstream riprap length for the inlet of culverts 1, 3, 4, and 8 from Design Case "A" are 0 ft, 6 ft, 0 ft, and 10 ft respectively. Downstream riprap length for the outlet of culverts 1, 3, 4, and 8 from Design Case "A" are 0 ft, 3 ft, 0 ft, and 5 ft respectively.

Structural Stability

For each new CMP culvert, minimum required and available cover are tabulated and presented in Attachment C-4B. For each new culvert, the available cover exceeds the minimum required cover. Calculations are provided in Attachment C-4B.

Sedimentation Basins

OSDF Basin 2

The required storage volume based on the 10-year, 24-hour storm event is obtained from HydroCAD™ output. In addition, the required storage based on total upstream drainage area is calculated (an example calculation is provided in Attachment C-5). The available storage volume exceeds both of the required storage volumes. Analysis results are tabulated and presented in Attachment C-5.

The peak water elevations for the 25-year and 100-year storm events are obtained from HydroCAD™ output. The peak water elevation for the 25-year storm event is below the elevation of the emergency spillway, and the peak water elevation for the 100-year storm allows for more than 1 ft of freeboard to the minimum embankment crest elevation. Analysis results are tabulated and presented in Attachment C-5.

Borrow Area Sedimentation Basin

The minimum required storage volume based on the total upstream drainage area is calculated (an example calculation is provided in Attachment C-5). The available storage volume exceeds the minimum required storage volume. Analysis results are tabulated and presented in Attachment C-5.

The peak water elevation in the emergency spillway for the 25-year, 24-hour storm event allows in excess of 1 ft of freeboard from the minimum embankment crest elevation.

Post-Development Sedimentation Basin Discharges

The post-development outflow from the 25-year, 24-hour storm event for the OSDF Sedimentation Basin 2 is 0 cfs. In addition, the post-development outflow from the 25-year, 24-hour storm event for the Borrow Area Sedimentation Basin is 0 cfs. HydroCAD™ output reports for these runs are presented in Attachments C-1C and C-1D for the East OSDF Post-Development (for the Borrow Area Sedimentation Basin) and West OSDF Post-Development (for the OSDF Sedimentation Basin 2) Design Scenarios, respectively.

4664

ATTACHMENT C

HydroCAD™ OUTPUT REPORTS

4664

ATTACHMENT C-1A

HydroCAD™ OUTPUT REPORTS

EAST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

EAST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO
2-YEAR, 24-HOUR STORM EVENT

DGP 30 JAN 02
DBM 1/30/02
139/282

Pond 3P: Borrow Area Basin - 4664

Inflow	=	40.30 cfs @	12.85 hrs,	Volume=	10.163 af	
Outflow	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af,	Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Peak Elev= 571.53' Storage= 10.157 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.00	6.391	0.000	0.000	6.391
571.00	6.687	6.538	6.538	6.690
572.00	7.017	6.851	13.390	7.023
573.00	7.290	7.153	20.543	7.300
574.00	7.613	7.451	27.994	7.626
575.00	7.921	7.766	35.760	7.938

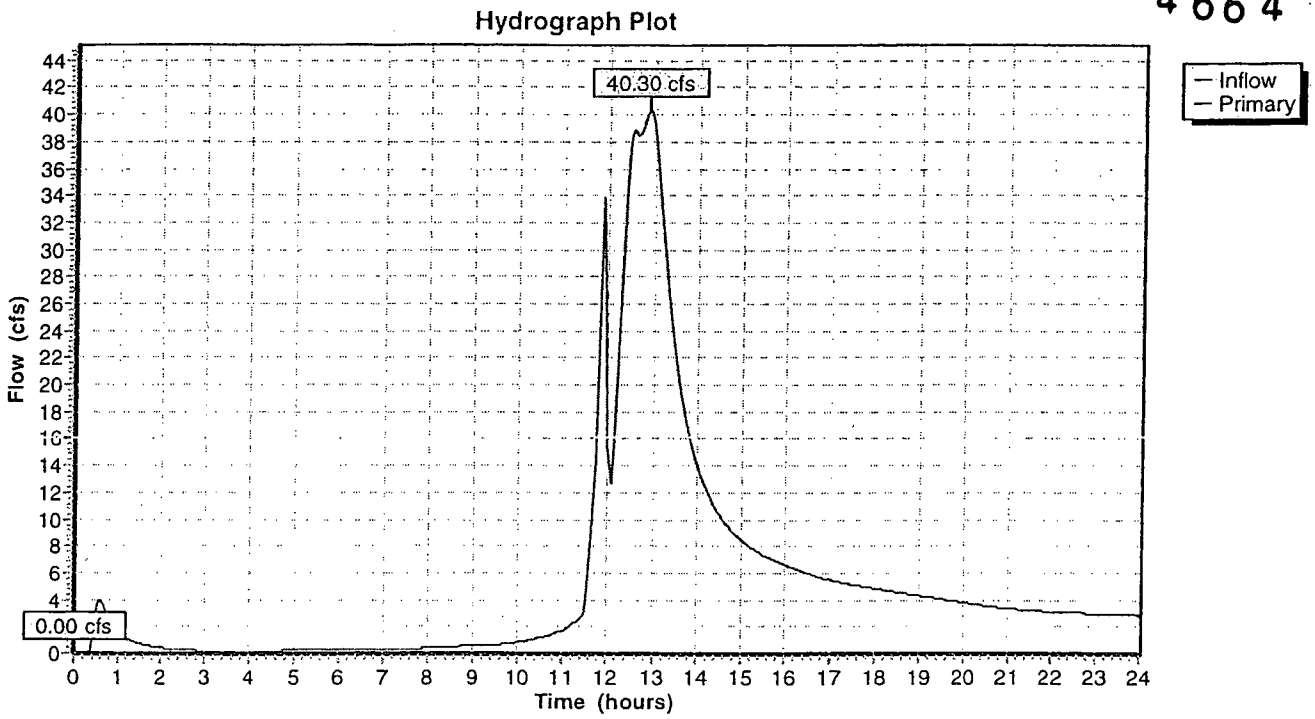
Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.30'	**48.0" Horiz. Orifice/Grate X 2.00** Limited to weir flow C= 0.600
2	Primary	569.80'	**48.0" x 200.0' long Culvert X 2.00** Ke= 0.700
			Outlet Invert= 569.00' S= 0.0040 '/' n= 0.024 Cc= 0.900
3	Primary	578.00'	**20.0' long Broad-Crested Rectangular Weir**
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

DCP 30 JAN 02
DBM 11/30/02 140/282

Pond 3P: Borrow Area Basin

4664



DGB 30 JAN 02

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: _____ Date: _____

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

EAST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO 25-YEAR, 24-HOUR STORM EVENT

-- 4664 KDH DGS 30 JAN 02 142/282

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=4.70"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover system
Tc=17.3 min CN=83 Area=1.964 ac Runoff= 6.81 cfs 0.473 af

Subcatchment AA: runon area east of OSDF
Tc=16.8 min CN=74 Area=2.708 ac Runoff= 6.97 cfs 0.478 af

Subcatchment B: vegetated final cover system
Tc=6.2 min CN=83 Area=1.179 ac Runoff= 5.75 cfs 0.285 af

Subcatchment BB: runon east of OSDF
Tc=9.1 min CN=79 Area=0.761 ac Runoff= 3.03 cfs 0.161 af

Subcatchment C: vegetated final cover
Tc=20.7 min CN=83 Area=5.209 ac Runoff= 16.37 cfs 1.255 af

Subcatchment CC: runon east of OSDF
Tc=6.7 min CN=79 Area=0.121 ac Runoff= 0.52 cfs 0.026 af

Subcatchment D: vegetated final cover
Tc=20.1 min CN=83 Area=5.131 ac Runoff= 16.39 cfs 1.236 af

Subcatchment DD: unvegetated final cover system
Tc=3.0 min CN=89 Area=0.544 ac Runoff= 3.42 cfs 0.158 af

Subcatchment E: vegetated final cover
Tc=19.7 min CN=83 Area=5.092 ac Runoff= 16.48 cfs 1.227 af

Subcatchment EE: runon north of borrow area
Tc=25.4 min CN=77 Area=0.925 ac Runoff= 2.10 cfs 0.182 af

Subcatchment F: vegetated final cover
Tc=19.7 min CN=83 Area=5.053 ac Runoff= 16.35 cfs 1.217 af

Subcatchment FF: unvegetated final cover system
Tc=3.0 min CN=89 Area=3.089 ac Runoff= 19.43 cfs 0.897 af

Subcatchment G: un-vegetated final cover
Tc=4.9 min CN=89 Area=5.309 ac Runoff= 31.66 cfs 1.541 af

Subcatchment GG: construction laydown area
Tc=28.3 min CN=78 Area=1.975 ac Runoff= 4.34 cfs 0.402 af

Subcatchment H: un-vegetated final cover
Tc=4.1 min CN=89 Area=3.487 ac Runoff= 21.41 cfs 1.012 af

Subcatchment HH: runon north of borrow area
Tc=13.9 min CN=79 Area=0.548 ac Runoff= 1.86 cfs 0.116 af

Subcatchment I: construction support
Tc=15.4 min CN=82 Area=1.690 ac Runoff= 6.01 cfs 0.395 af

Subcatchment II: runon area to borrow area
Tc=23.0 min CN=68 Area=1.669 ac Runoff= 2.73 cfs 0.230 af

Subcatchment J: construction support
Tc=28.5 min CN=81 Area=2.647 ac Runoff= 6.45 cfs 0.596 af

Subcatchment JJ: runon area to borrow area
Tc=41.9 min CN=62 Area=0.914 ac Runoff= 0.69 cfs 0.094 af

Subcatchment K: construction support
Tc=28.8 min CN=78 Area=4.135 ac Runoff= 9.00 cfs 0.841 af

Subcatchment KK: runon area to borrow area
Tc=36.4 min CN=64 Area=5.893 ac Runoff= 5.63 cfs 0.674 af

Subcatchment L: runon north of borrow area
Tc=15.4 min CN=76 Area=1.683 ac Runoff= 4.88 cfs 0.320 af

Subcatchment LL: runoff area
Tc=28.1 min CN=61 Area=7.049 ac Runoff= 6.61 cfs 0.693 af

Subcatchment M: runon north of borrow area
Tc=12.1 min CN=79 Area=1.000 ac Runoff= 3.60 cfs 0.212 af

Subcatchment MM: runoff area
Tc=9.9 min CN=61 Area=1.943 ac Runoff= 3.30 cfs 0.192 af

Subcatchment N: direct runon to pond
Tc=1.0 min CN=98 Area=7.818 ac Runoff= 57.89 cfs 2.908 af

Subcatchment NN: runoff area
Tc=1.4 min CN=66 Area=1.274 ac Runoff= 3.78 cfs 0.162 af

Subcatchment O: runon north of borrow area
Tc=1.3 min CN=79 Area=1.317 ac Runoff= 6.54 cfs 0.279 af

Subcatchment OO: runon area to borrow area
Tc=5.4 min CN=66 Area=0.399 ac Runoff= 1.06 cfs 0.051 af

Subcatchment P: runon north of borrow area
Tc=33.7 min CN=75 Area=5.238 ac Runoff= 9.16 cfs 0.955 af

Subcatchment PP: vegetated borrow area
Tc=65.5 min CN=64 Area=40.964 ac Runoff= 25.40 cfs 4.631 af

Subcatchment Q: runon north of borrow area
Tc=31.8 min CN=72 Area=7.700 ac Runoff= 12.29 cfs 1.252 af

Subcatchment R: runon north of borrow area
Tc=21.6 min CN=74 Area=2.612 ac Runoff= 5.83 cfs 0.460 af

Subcatchment S: runon north of borrow area
Tc=27.9 min CN=78 Area=0.402 ac Runoff= 0.89 cfs 0.082 af

Subcatchment T: direct runon to pond
Tc=1.0 min CN=98 Area=0.416 ac Runoff= 3.08 cfs 0.155 af

Subcatchment U: runon east of OSDF
Tc=32.3 min CN=72 Area=4.149 ac Runoff= 6.57 cfs 0.674 af

Subcatchment V: direct runon to pond
Tc=1.0 min CN=98 Area=0.274 ac Runoff= 2.03 cfs 0.102 af

Subcatchment W: runon east of OSDF
Tc=12.6 min CN=72 Area=10.593 ac Runoff= 28.88 cfs 1.733 af

Subcatchment X: runon east of OSDF
Tc=33.4 min CN=71 Area=11.853 ac Runoff= 17.50 cfs 1.851 af

Subcatchment Y: runon area east of OSDF
Tc=36.8 min CN=73 Area=6.522 ac Runoff= 9.84 cfs 1.101 af

Subcatchment Z: runon area east of OSDF
Tc=23.7 min CN=72 Area=1.606 ac Runoff= 3.11 cfs 0.262 af

Reach 1: east drainage channel — Inflow= 10.81 cfs 0.758 af
Length= 420.0' Max Vel= 2.1 fps Capacity= 754.76 cfs Outflow= 10.06 cfs 0.756 af

Reach 1R: (new node) — Inflow= 6.61 cfs 0.693 af
Length= 100.0' Max Vel= 5.4 fps Capacity= 1,101.12 cfs Outflow= 6.59 cfs 0.693 af

Reach 2: east drainage channel — Inflow= 26.37 cfs 2.010 af
Length= 420.0' Max Vel= 2.7 fps Capacity= 1,205.98 cfs Outflow= 25.59 cfs 2.005 af

Reach 2R: (new node) — Inflow= 3.30 cfs 0.192 af
Length= 100.0' Max Vel= 4.3 fps Capacity= 1,101.12 cfs Outflow= 3.25 cfs 0.192 af

Reach 3: east drainage channel — Inflow= 40.77 cfs 3.241 af
Length= 420.0' Max Vel= 3.3 fps Capacity= 1,563.67 cfs Outflow= 39.76 cfs 3.234 af

Reach 3R: (new node) — Inflow= 3.78 cfs 0.162 af
Length= 100.0' Max Vel= 4.5 fps Capacity= 1,101.12 cfs Outflow= 3.72 cfs 0.162 af

Reach 4: east drainage channel — Inflow= 53.10 cfs 4.461 af
Length= 420.0' Max Vel= 3.5 fps Capacity= 1,106.53 cfs Outflow= 52.07 cfs 4.451 af

Reach 5: east drainage channel — Inflow= 63.69 cfs 5.669 af
Length= 440.0' Max Vel= 3.5 fps Capacity= 182.58 cfs Outflow= 62.69 cfs 5.656 af

Reach 6: east drainage channel — Inflow= 66.14 cfs 7.197 af
Length= 480.0' Max Vel= 4.5 fps Capacity= 258.21 cfs Outflow= 65.27 cfs 7.185 af

Reach 7: runoff diversion channel — Inflow= 67.32 cfs 8.197 af
Length= 140.0' Max Vel= 4.6 fps Capacity= 556.08 cfs Outflow= 67.02 cfs 8.193 af

Reach 8: runoff diversion channel — Inflow= 65.98 cfs 9.092 af
Length= 20.0' Max Vel= 2.7 fps Capacity= 1,379.30 cfs Outflow= 65.95 cfs 9.067 af

Reach 9: runoff diversion channel — Inflow= 65.95 cfs 9.067 af
Length= 295.0' Max Vel= 3.4 fps Capacity= 407.65 cfs Outflow= 65.46 cfs 9.051 af

Reach 10: runoff diversion channel — Inflow= 70.70 cfs 10.542 af
Length= 610.0' Max Vel= 3.5 fps Capacity= 134.00 cfs Outflow= 70.22 cfs 10.507 af

Reach 11: new CMP arch — Inflow= 76.92 cfs 11.750 af
Length= 65.0' Max Vel= 5.5 fps Capacity= 408.61 cfs Outflow= 76.87 cfs 11.747 af

Reach 12: runoff diversion channel — Inflow= 76.87 cfs 11.747 af
Length= 270.0' Max Vel= 3.6 fps Capacity= 134.16 cfs Outflow= 76.68 cfs 11.730 af

Reach 13: runoff diversion channel — Inflow= 142.35 cfs 21.698 af
Length= 450.0' Max Vel= 3.9 fps Capacity= 235.94 cfs Outflow= 142.00 cfs 21.641 af

Reach 14: east runon channel — Inflow= 0.52 cfs 0.026 af
Length= 420.0' Max Vel= 0.9 fps Capacity= 22.78 cfs Outflow= 0.38 cfs 0.025 af

Reach 15: east runon channel — Inflow= 3.20 cfs 0.186 af
Length= 420.0' Max Vel= 1.8 fps Capacity= 61.62 cfs Outflow= 2.82 cfs 0.186 af

Reach 16: east runon channel — Inflow= 9.76 cfs 0.664 af
Length= 420.0' Max Vel= 2.6 fps Capacity= 256.58 cfs Outflow= 9.33 cfs 0.661 af

Reach 17: east runon channel — Inflow= 12.43 cfs 0.923 af
Length= 420.0' Max Vel= 3.2 fps Capacity= 436.18 cfs Outflow= 12.07 cfs 0.921 af

Reach 18: east runon channel — Inflow= 21.43 cfs 2.022 af
Length= 440.0' Max Vel= 3.7 fps Capacity= 169.20 cfs Outflow= 20.99 cfs 2.017 af

DCI 3USANO2 143/282

Reach 19: east runon channel — Inflow= 38.43 cfs 3.868 af
Length= 470.0' Max Vel= 2.8 fps Capacity= 911.12 cfs Outflow= 37.75 cfs 3.855 af

Reach 20: east runon channel — Inflow= 43.35 cfs 5.587 af
Length= 75.0' Max Vel= 4.2 fps Capacity= 153.84 cfs Outflow= 43.26 cfs 5.586 af

Reach 21: east runon channel — Inflow= 45.89 cfs 6.151 af
Length= 65.0' Max Vel= 4.5 fps Capacity= 169.20 cfs Outflow= 45.84 cfs 6.149 af

Reach 22: east runon channel — Inflow= 46.33 cfs 6.231 af
Length= 190.0' Max Vel= 4.5 fps Capacity= 364.40 cfs Outflow= 46.18 cfs 6.226 af

Reach 23: new CMP culverts — Inflow= 48.76 cfs 6.862 af
Length= 95.0' Max Vel= 5.4 fps Capacity= 473.85 cfs Outflow= 48.69 cfs 6.859 af

Reach 24: runon channel — Inflow= 57.16 cfs 8.111 af
Length= 160.0' Max Vel= 4.0 fps Capacity= 153.54 cfs Outflow= 56.98 cfs 8.104 af

Reach 25: new CMP arch — Inflow= 64.23 cfs 9.058 af
Length= 60.0' Max Vel= 5.7 fps Capacity= 453.67 cfs Outflow= 64.20 cfs 9.056 af

Reach 26: runon channel — Inflow= 64.20 cfs 9.056 af
Length= 300.0' Max Vel= 4.4 fps Capacity= 90.11 cfs Outflow= 64.04 cfs 9.045 af

Reach 27: new CMP arch — Inflow= 64.98 cfs 9.365 af
Length= 110.0' Max Vel= 5.7 fps Capacity= 455.55 cfs Outflow= 64.87 cfs 9.361 af

Reach 28: new CMP culverts — Inflow= 70.78 cfs 10.544 af
Length= 65.0' Max Vel= 5.4 fps Capacity= 408.61 cfs Outflow= 70.70 cfs 10.542 af

Reach 29: east runon channel — Inflow= 47.10 cfs 6.408 af
Length= 230.0' Max Vel= 4.6 fps Capacity= 255.23 cfs Outflow= 46.91 cfs 6.402 af

Reach 30: east runon channel — Inflow= 45.98 cfs 6.152 af
Length= 30.0' Max Vel= 4.5 fps Capacity= 104.05 cfs Outflow= 45.89 cfs 6.151 af

Reach 31: culvert — Inflow= 6.54 cfs 0.279 af
Length= 80.0' Max Vel= 4.8 fps Capacity= 946.99 cfs Outflow= 6.33 cfs 0.279 af

Pond 1P: (new node) — Peak Storage= 1.584 af Inflow= 49.32 cfs 6.362 af
Primary= 45.98 cfs 6.152 af Outflow= 45.98 cfs 6.152 af

Pond 2P: (new node) — Peak Storage= 2.250 af Inflow= 69.22 cfs 8.900 af
Primary= 65.98 cfs 9.092 af Outflow= 65.98 cfs 9.092 af

Pond 3P: Borrow Area Basin — Peak Storage= 30.214 af Inflow= 174.19 cfs 30.229 af
Primary= 0.00 cfs 0.000 af Outflow= 0.00 cfs 0.000 af

Runoff Area = 174.855 ac Volume = 31.570 af Average Depth = 2.17"

- 4664

Subcatchment A: vegetated final cover system

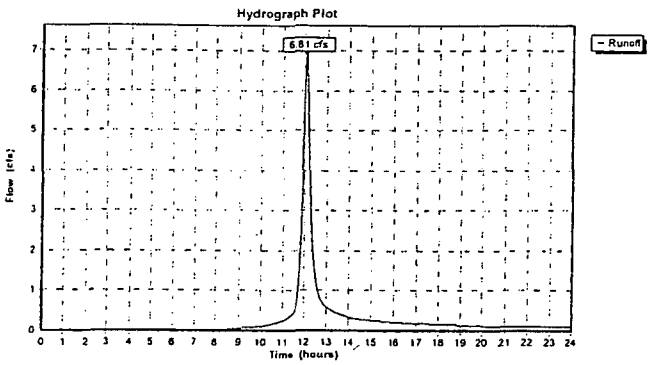
Runoff = 6.81 cfs @ 12.10 hrs, Volume= 0.473 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.964	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	80	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
17.3	380	Total			

Subcatchment A: vegetated final cover system



Subcatchment AA: runon area east of OSDF

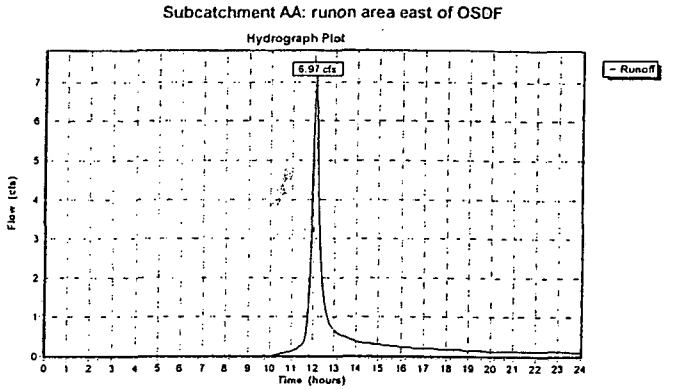
Runoff = 6.97 cfs @ 12.10 hrs, Volume= 0.478 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.708	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0	300	0.0800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.6	170	0.0800	4.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	300	0.0070	4.0	48.01	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
16.8	770	Total			

Subcatchment AA: runon area east of OSDF



DEP 30 JAN 02
DBM 1/30/02 144/282

Subcatchment B: vegetated final cover system

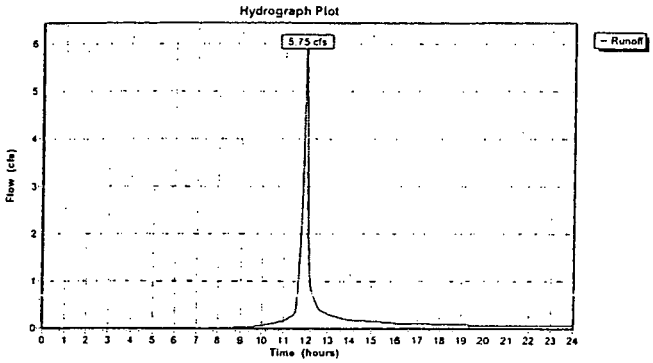
Runoff = 5.75 cfs @ 11.97 hrs, Volume= 0.285 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.179	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	50	0.1800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.6	450	0.0045	2.1	9.75	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.02' Z= 6.0 & 3.0 '/' n= 0.030
6.2	500	Total			

Subcatchment B: vegetated final cover system



Subcatchment BB: runon east of OSDF

Runoff = 3.03 cfs @ 12.01 hrs, Volume= 0.161 af

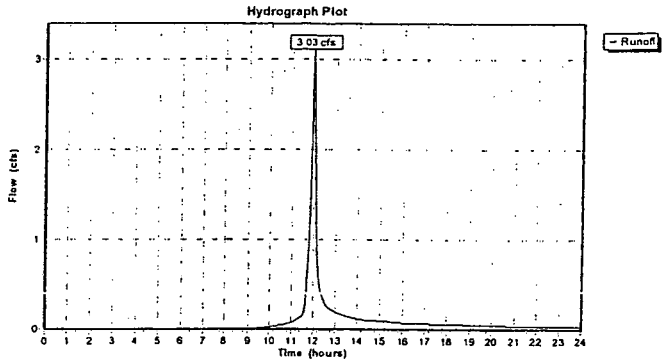
— 4664

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.761	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	110	0.0800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.4	360	0.0040	2.5	22.78	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.50' Z= 3.0 & 5.0 '/' n= 0.030
9.1	470	Total			

Subcatchment BB: runon east of OSDF



Subcatchment C: vegetated final cover

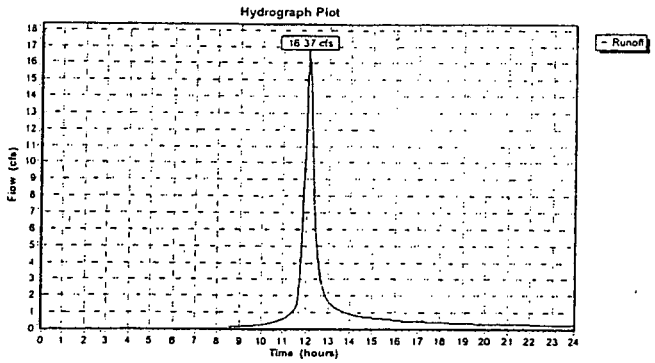
Runoff = 16.37 cfs @ 12.13 hrs, Volume= 1.255 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.209	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.2	400	0.0045	2.1	10.88	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.02' Z= 6.0 & 4.0 '/' n= 0.030
20.7	870	Total			

Subcatchment C: vegetated final cover



Subcatchment CC: runon east of OSDF

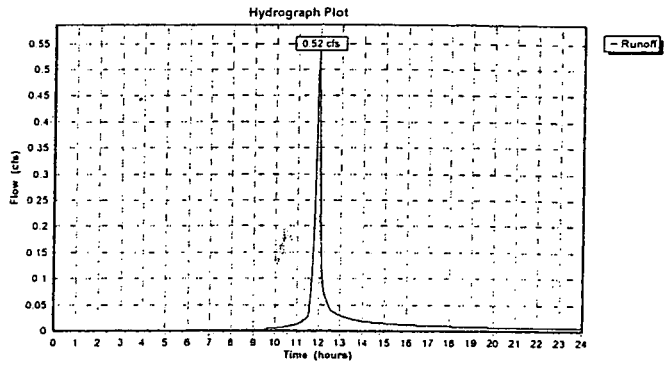
Runoff = 0.52 cfs @ 11.98 hrs, Volume= 0.026 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.121	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	110	0.0800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment CC: runon east of OSDF



Subcatchment D: vegetated final cover

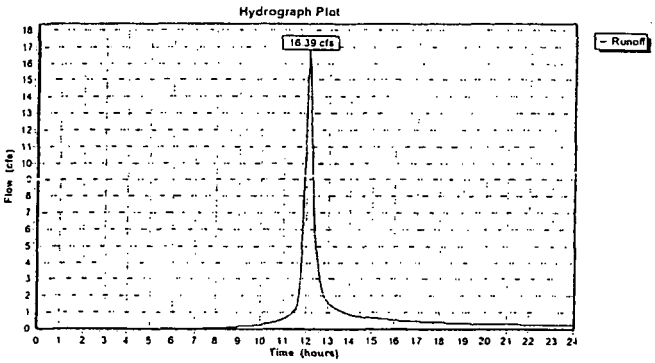
Runoff = 16.39 cfs @ 12.13 hrs, Volume= 1.236 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.131	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.7	250	0.0045	2.4	16.16	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.29' Z= 5.0 & 3.0 '/' n= 0.030
0.9	150	0.0050	2.9	25.90	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.59' Z= 4.0 & 3.0 '/' n= 0.030
20.1	870	Total			

Subcatchment D: vegetated final cover



Dep 30 JAN 02 DBM 1/30/02 145/282

Subcatchment DD: unvegetated final cover system

[49] Hint: Tc<2dt may require smaller dt

Runoff = 3.42 cfs @ 11.93 hrs, Volume= 0.158 af

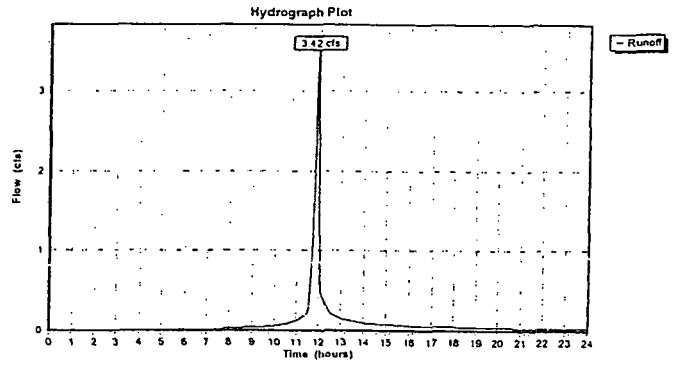
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.544	89	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.1	230	0.1700	3.4		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
1.9	20	0.0600	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.0	250	Total			

Subcatchment DD: unvegetated final cover system



Subcatchment E: vegetated final cover

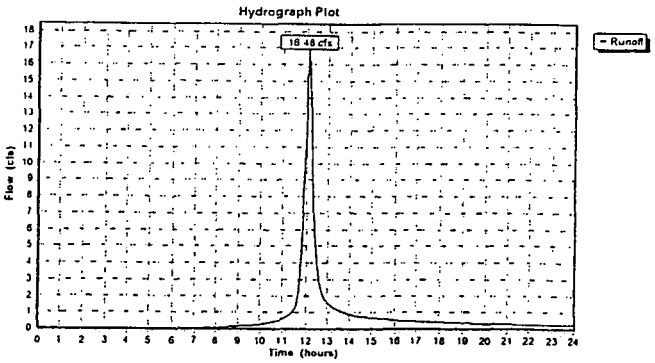
Runoff = 16.48 cfs @ 12.12 hrs, Volume= 1.227 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.092	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.2	380	0.0050	2.9	26.33	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.60' Z= 4.0 & 3.0 '/' n= 0.030
19.7	850	Total			

Subcatchment E: vegetated final cover



Subcatchment EE: runon north of borrow area

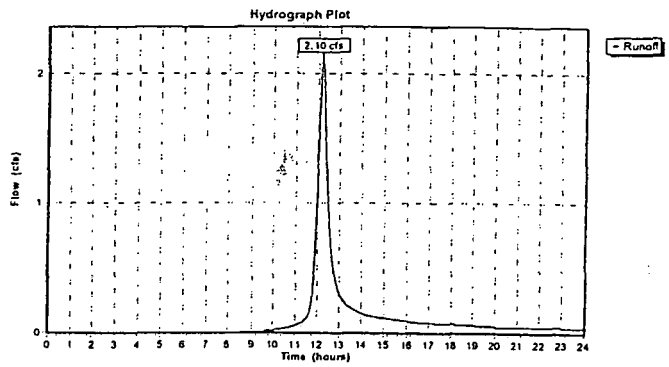
Runoff = 2.10 cfs @ 12.19 hrs, Volume= 0.182 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.925	77	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
24.8	300	0.0230	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	80	0.0230	2.4		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.1	40	0.0100	7.6	364.40	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.00' Z= 3.0 '/' n= 0.030
25.4	420	Total			

Subcatchment EE: runon north of borrow area



Subcatchment F: vegetated final cover

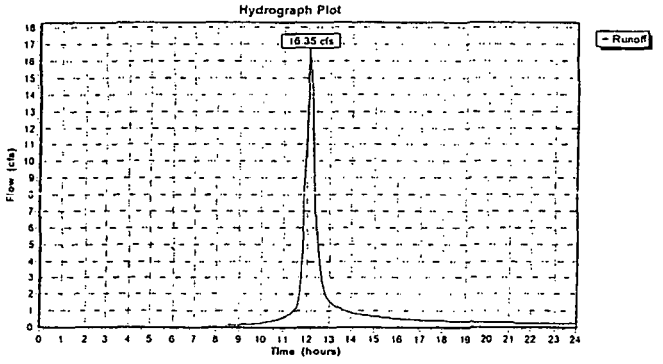
Runoff = 16.35 cfs @ 12.12 hrs, Volume= 1.217 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.053	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.2	390	0.0050	2.9	26.33	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.60' Z= 4.0 & 3.0 '/' n= 0.030
19.7	860	Total			

Subcatchment F: vegetated final cover



DCP 30JAN02 146/282
DBM 1/30/02

Subcatchment FF: unvegetated final cover system

[49] Hint: Tc<2dt may require smaller dt

-- 4664

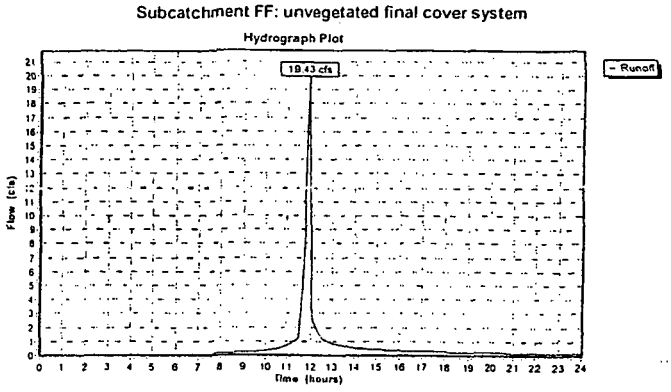
Runoff = 19.43 cfs @ 11.93 hrs, Volume= 0.897 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
3.089	89	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	90	0.0500	1.8		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	60	0.1000	2.1		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.8	150	0.1700	3.2		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	210	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.3	120	0.1410	6.0		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.0	630	Total			

Subcatchment FF: unvegetated final cover system



Subcatchment G: un-vegetated final cover

[49] Hint: Tc<2dt may require smaller dt

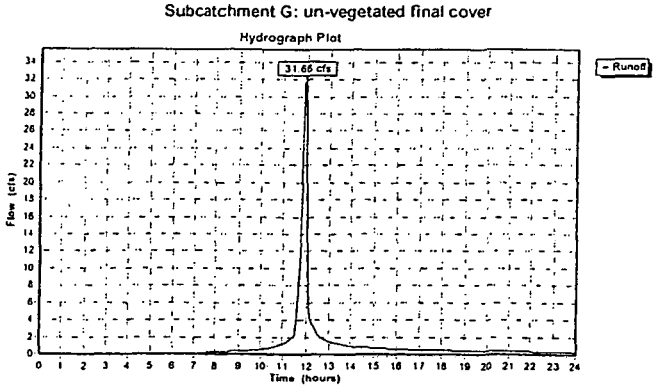
Runoff = 31.66 cfs @ 11.95 hrs, Volume= 1.541 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.309	89	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	90	0.0500	1.8		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	60	0.1000	2.1		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.8	150	0.1700	3.2		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.3	410	0.0050	2.9	26.33	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.60' Z= 4.0 & 3.0 '/' n= 0.030
4.9	880	Total			

Subcatchment G: un-vegetated final cover



Subcatchment GG: construction laydown area

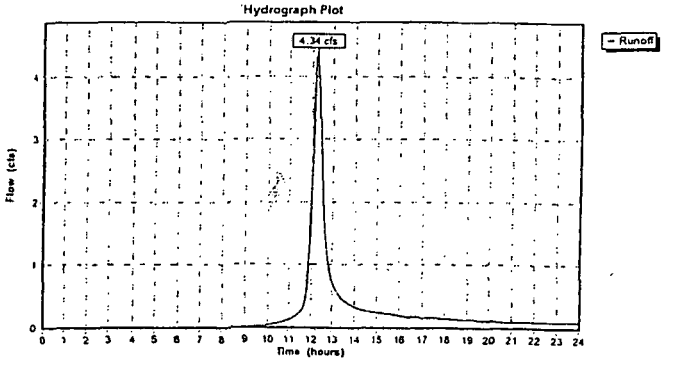
Runoff = 4.34 cfs @ 12.23 hrs, Volume= 0.402 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.975	78	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.2	300	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.1	290	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
28.3	590	Total			

Subcatchment GG: construction laydown area



Subcatchment H: un-vegetated final cover

[49] Hint: Tc<2dt may require smaller dt

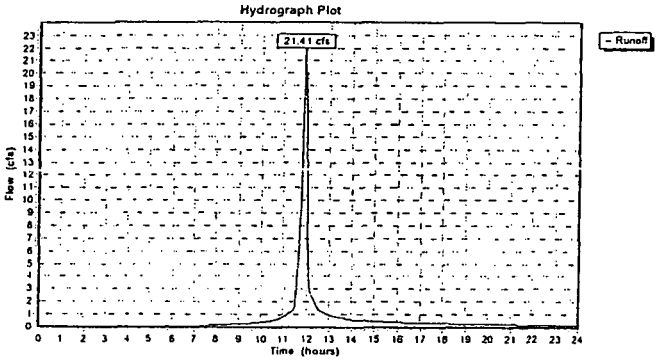
Runoff = 21.41 cfs @ 11.94 hrs, Volume= 1.012 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
3.487	89	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	90	0.0500	1.8		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	60	0.1000	2.1		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.8	150	0.1700	3.2		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.4	140	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.5	440	0.0100	4.8	57.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
4.1	880	Total			

Subcatchment H: un-vegetated final cover



DGS 30JAN02 147/282
DBM 1/30/02

Subcatchment HH: runon north of borrow area

Runoff = 1.86 cfs @ 12.06 hrs, Volume= 0.116 af

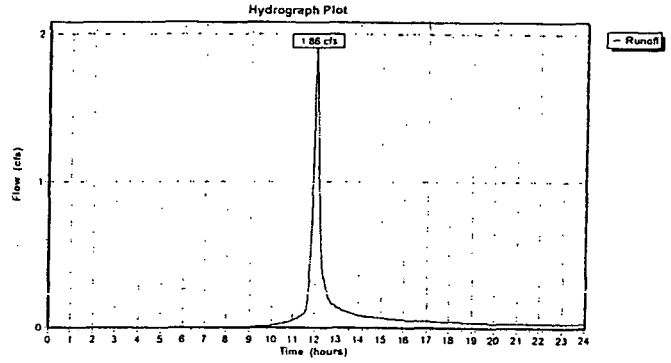
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

4664

Area (ac)	CN	Description
0.548	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.2	90	0.0100	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.7	230	0.0045	5.1	352.87	Trap/Vee/Rect Channel Flow, Bot.W=20.00' D=2.50' Z= 3.0 '/' n= 0.030
13.9	320	Total			

Subcatchment HH: runon north of borrow area



Subcatchment I: construction support

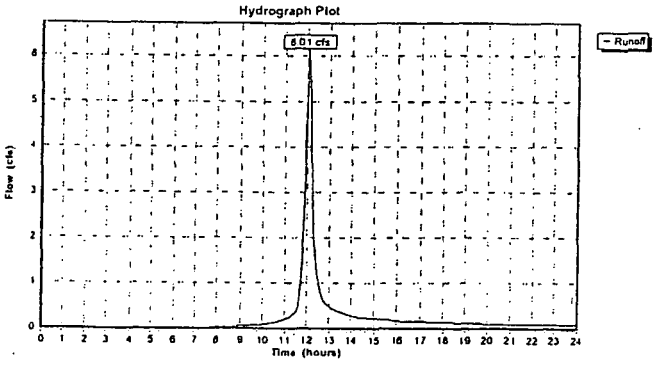
Runoff = 6.01 cfs @ 12.07 hrs, Volume= 0.395 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.690	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.4	230	0.0440	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment I: construction support



Subcatchment II: runon area to borrow area

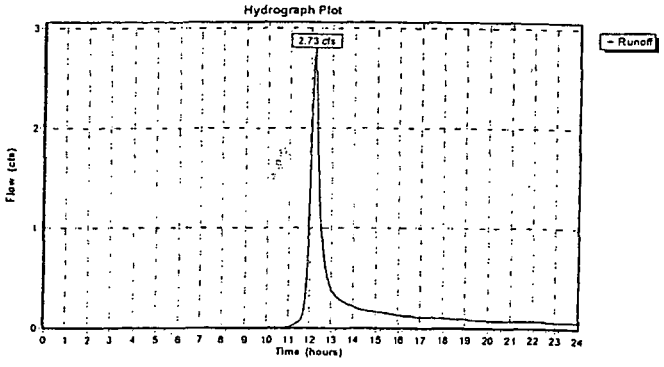
Runoff = 2.73 cfs @ 12.17 hrs, Volume= 0.230 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.669	68	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	210	0.0400	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	70	0.1660	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
7.9	380	0.0025	0.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
23.0	660	Total			

Subcatchment II: runon area to borrow area



Subcatchment J: construction support

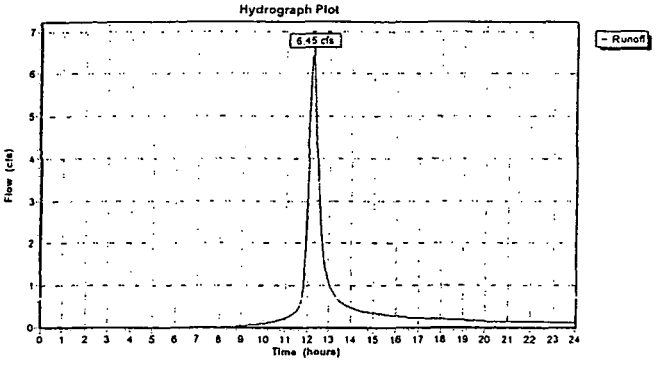
Runoff = 6.45 cfs @ 12.22 hrs, Volume= 0.596 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.647	81	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.6	300	0.0176	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.9	110	0.0176	2.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
28.5	410	Total			

Subcatchment J: construction support



DCF 2/JAN 02 148/282
DBM 1/30/02

Subcatchment JJ: runon area to borrow area

Runoff = 0.69 cfs @ 12.44 hrs, Volume= 0.094 af

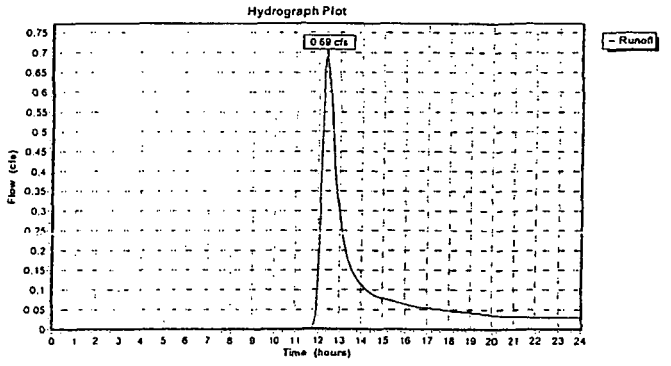
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.914	62	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
23.9	300	0.0250	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	40	0.0250	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.3	110	0.1660	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
17.4	840	0.0025	0.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
41.9	1,290	Total			

Subcatchment JJ: runon area to borrow area



Subcatchment K: construction support

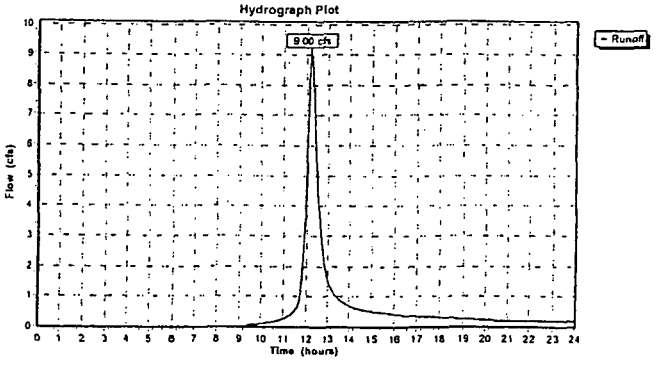
Runoff = 9.00 cfs @ 12.23 hrs, Volume= 0.841 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
4.135	78	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.2	300	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.8	250	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	200	0.0045	4.2	133.88	Trap/Vee/Rect Channel Flow, Bot.W=10.00' D=2.00' Z= 3.0 '/' n= 0.030
28.8	750	Total			

Subcatchment K: construction support



Subcatchment KK: runon area to borrow area

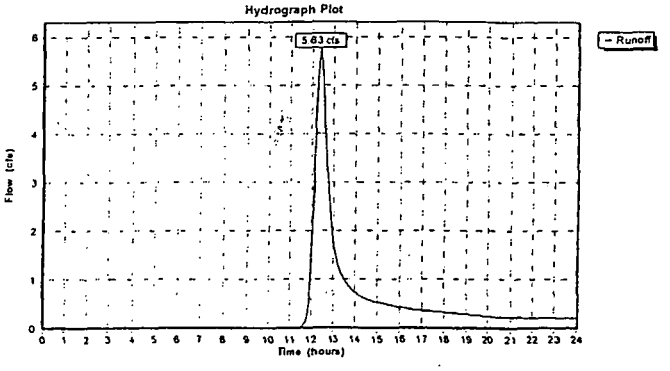
Runoff = 5.63 cfs @ 12.36 hrs, Volume= 0.674 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.893	64	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
22.9	300	0.0280	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.3	150	0.0140	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.3	110	0.1660	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
11.9	630	0.0030	0.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
36.4	1,190	Total			

Subcatchment KK: runon area to borrow area



DCP 30 JAN 02 149/282
DBM 1/30/02

Subcatchment L: runon north of borrow area

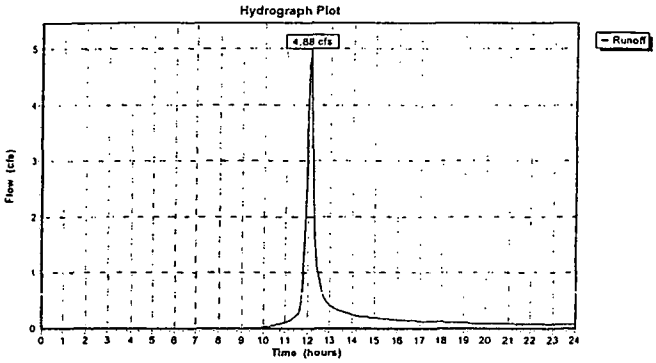
Runoff = 4.88 cfs @ 12.08 hrs, Volume= 0.320 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.683	76	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.2	140	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.2	290	0.0075	4.1	49.70	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
15.4	430	Total			

Subcatchment L: runon north of borrow area



Subcatchment LL: runoff area

Runoff = 6.61 cfs @ 12.25 hrs, Volume= 0.693 af

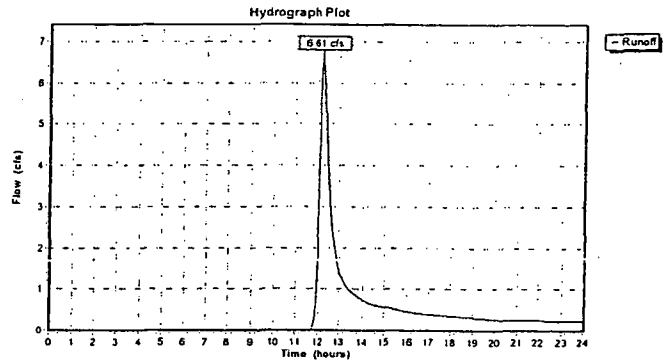
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

4664

Area (ac)	CN	Description
7.049	61	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
24.3	300	0.0240	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.3	200	0.0240	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.5	900	0.0090	5.9	160.52	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
28.1	1,400	Total			

Subcatchment LL: runoff area



Subcatchment M: runon north of borrow area

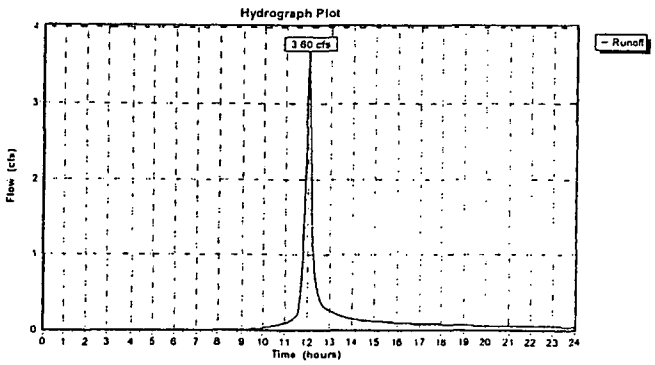
Runoff = 3.60 cfs @ 12.04 hrs, Volume= 0.212 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.000	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.5	170	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.6	200	0.0045	5.1	352.87	Trap/Vee/Rect Channel Flow, Bot.W=20.00' D=2.50' Z= 3.0 '/' n= 0.030
12.1	370	Total			

Subcatchment M: runon north of borrow area



Subcatchment MM: runoff area

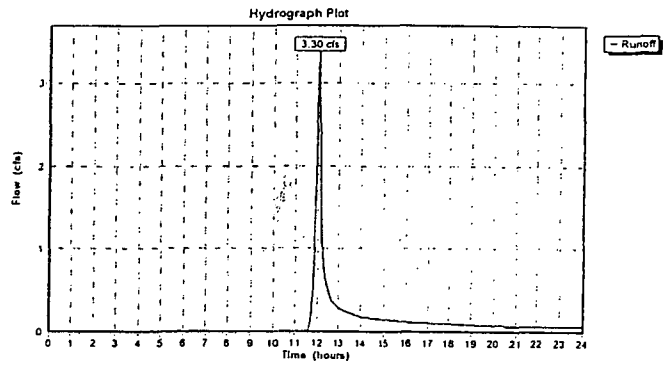
Runoff = 3.30 cfs @ 12.03 hrs, Volume= 0.192 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.943	61	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.6	100	0.0700	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.3	980	0.0060	4.9	200.34	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 5.0 & 4.0 '/' n= 0.030
9.9	1,080	Total			

Subcatchment MM: runoff area



Subcatchment N: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

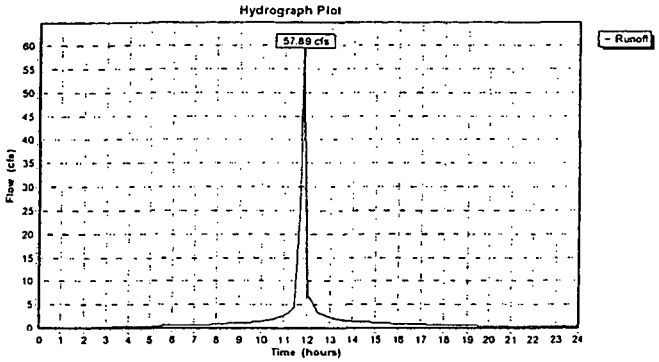
Runoff = 57.89 cfs @ 11.90 hrs, Volume= 2.908 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
7.818	98	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment N: direct runon to pond



DGF 30 JAN 02 DBM 1/30/02 150/282

Subcatchment NN: runoff area

[49] Hint: Tc<2dt may require smaller dt

Runoff = 3.78 cfs @ 11.92 hrs, Volume= 0.162 af

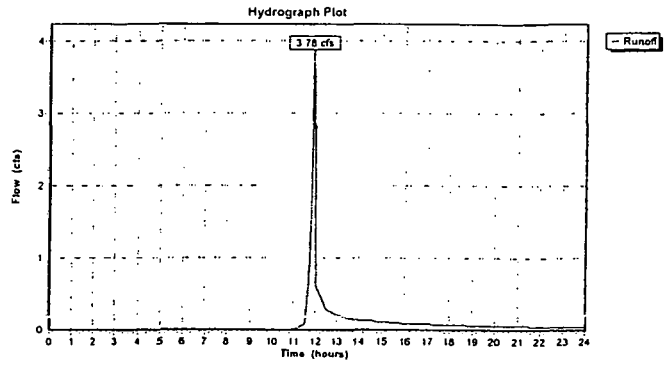
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.274	66	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.4	600	0.0130	7.1	192.92	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030

Subcatchment NN: runoff area



Subcatchment O: runon north of borrow area

[49] Hint: Tc<2dt may require smaller dt

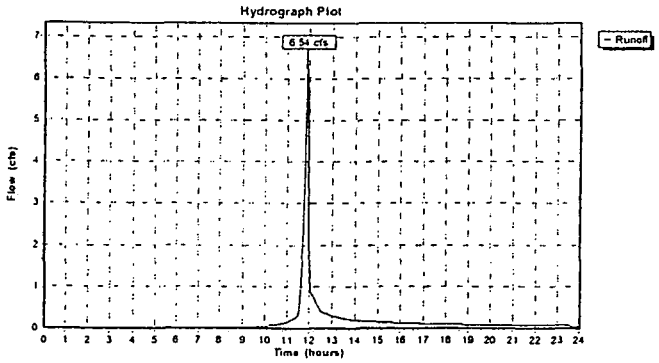
Runoff = 6.54 cfs @ 11.91 hrs, Volume= 0.279 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.317	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.3	230	0.0086	2.9	14.28	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.00' Z= 5.0 '/' n= 0.030

Subcatchment O: runon north of borrow area



Subcatchment OO: runon area to borrow area

[49] Hint: Tc<2dt may require smaller dt

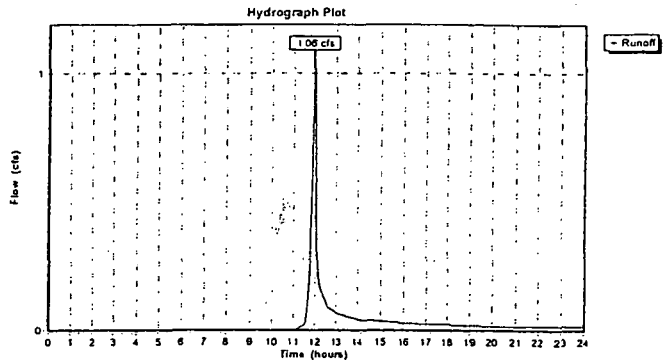
Runoff = 1.06 cfs @ 11.97 hrs, Volume= 0.051 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.399	66	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	120	0.1660	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment OO: runon area to borrow area



Subcatchment P: runon north of borrow area

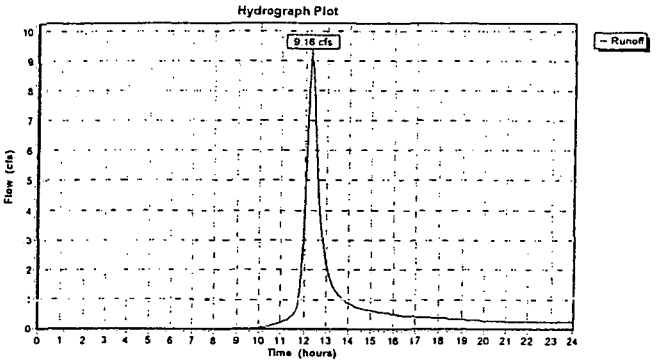
Runoff = 9.16 cfs @ 12.30 hrs, Volume= 0.955 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.238	75	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4	300	0.0150	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
4.3	350	0.0070	1.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
33.7	650	Total			

Subcatchment P: runon north of borrow area



DGP 30 JAN 02 151/282
DBM 1/30/02

Subcatchment PP: vegetated borrow area

Runoff = 25.40 cfs @ 12.75 hrs, Volume= 4.631 af

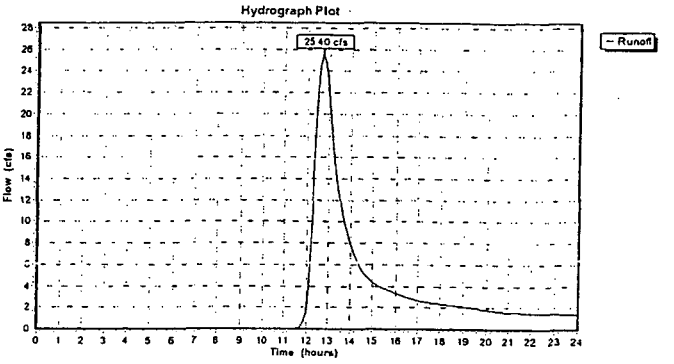
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
40.964	64	

– 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.4	150	0.1660	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
34.5	150	0.0025	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
24.6	1,190	0.0025	0.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
65.5	1,490	Total			

Subcatchment PP: vegetated borrow area



Subcatchment Q: runon north of borrow area

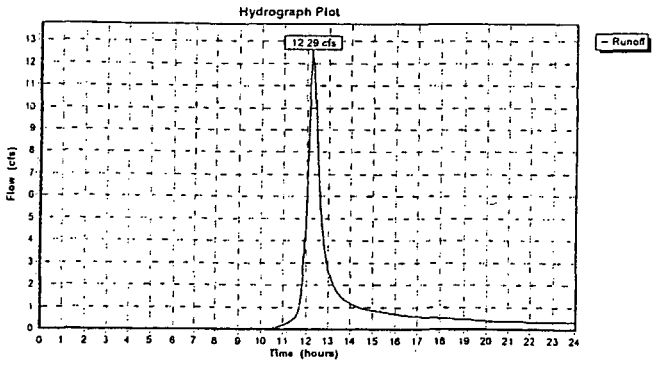
Runoff = 12.29 cfs @ 12.28 hrs, Volume= 1.252 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
7.700	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
23.6	300	0.0260	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
8.2	1,280	0.0260	2.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
31.8	1,580	Total			

Subcatchment Q: runon north of borrow area



Subcatchment R: runon north of borrow area

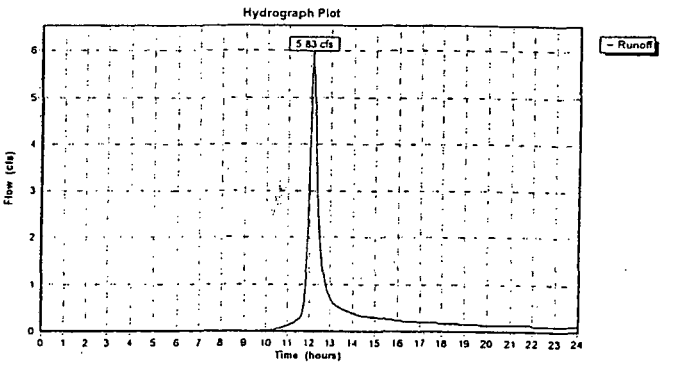
Runoff = 5.83 cfs @ 12.15 hrs, Volume= 0.460 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.612	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
19.8	300	0.0400	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.8	350	0.0400	3.2		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
21.6	650	Total			

Subcatchment R: runon north of borrow area



DCP 30 JAN 02 152/282
DBM 1/30/02

Subcatchment S: runon north of borrow area

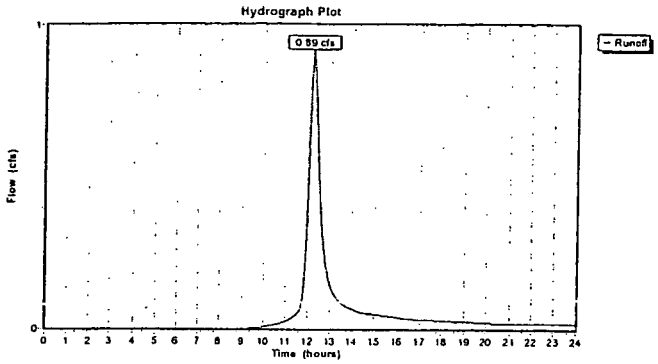
Runoff = 0.89 cfs @ 12.22 hrs, Volume= 0.082 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.402	78	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.8	280	0.0150	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.1	30	0.0100	6.3	169.20	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
27.9	310	Total			

Subcatchment S: runon north of borrow area



Subcatchment T: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

Runoff = 3.08 cfs @ 11.90 hrs, Volume= 0.155 af

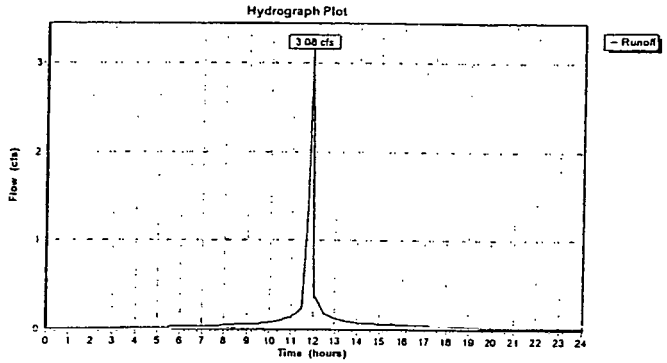
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.416	98	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment T: direct runon to pond



Subcatchment U: runon east of OSDF

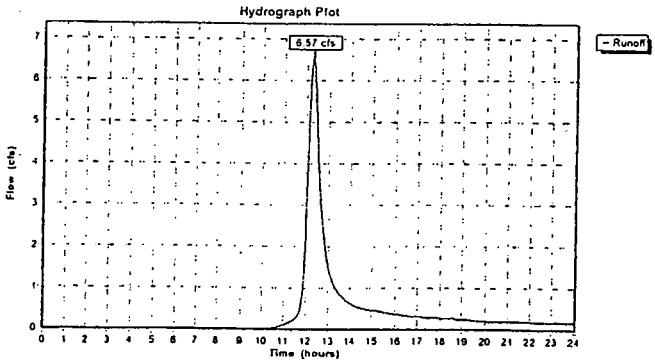
Runoff = 6.57 cfs @ 12.28 hrs, Volume= 0.674 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
4.149	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
30.2	300	0.0140	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.1	240	0.0140	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
32.3	540	Total			

Subcatchment U: runon east of OSDF



Subcatchment V: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

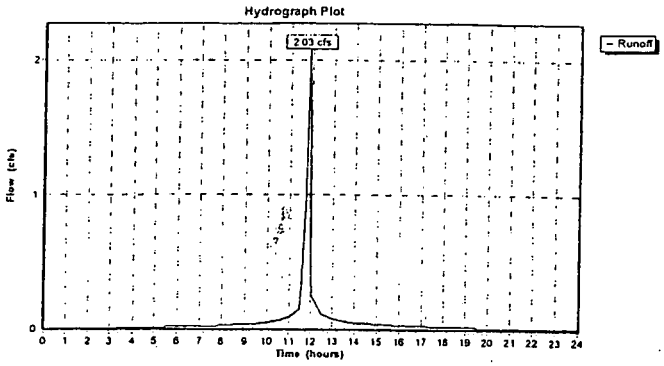
Runoff = 2.03 cfs @ 11.90 hrs, Volume= 0.102 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.274	98	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment V: direct runon to pond



Subcatchment W: runon east of OSDF

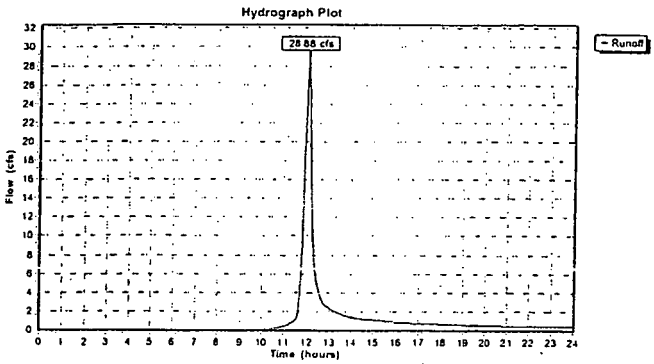
Runoff = 28.88 cfs @ 12.05 hrs, Volume= 1.733 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
10.593	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	300	0.1780	0.5		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.0	400	0.1780	6.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.7	270	0.0114	6.9	1,025.43	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 & 30.0 '/' n= 0.030
12.6	970	Total			

Subcatchment W: runon east of OSDF



DCP 30 JAN 02 DBM 1/30/02 153/282

Subcatchment X: runon east of OSDF

Runoff = 17.50 cfs @ 12.30 hrs, Volume= 1.851 af

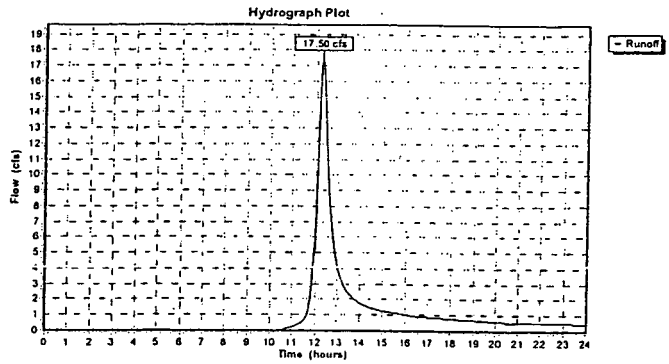
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
11.853	71	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.7	300	0.0190	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
5.5	730	0.0190	2.2		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	330	0.0100	4.8	57.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
33.4	1,360	Total			

Subcatchment X: runon east of OSDF



Subcatchment Y: runon area east of OSDF

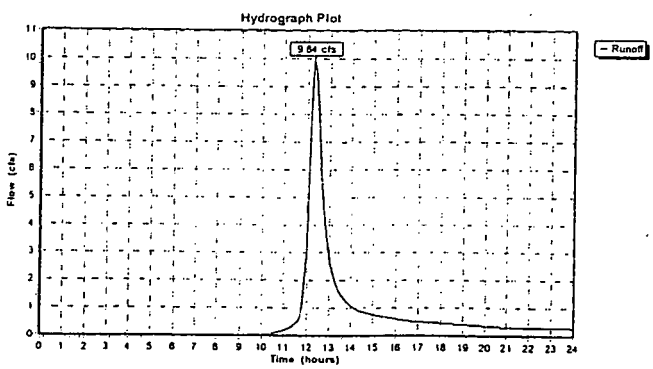
Runoff = 9.84 cfs @ 12.34 hrs, Volume= 1.101 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
6.522	73	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
31.1	300	0.0130	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
4.6	510	0.0130	1.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.1	340	0.0110	5.1	92.00	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 5.0 & 4.0 '/' n= 0.030
36.8	1,150	Total			

Subcatchment Y: runon area east of OSDF



Subcatchment Z: runon area east of OSDF

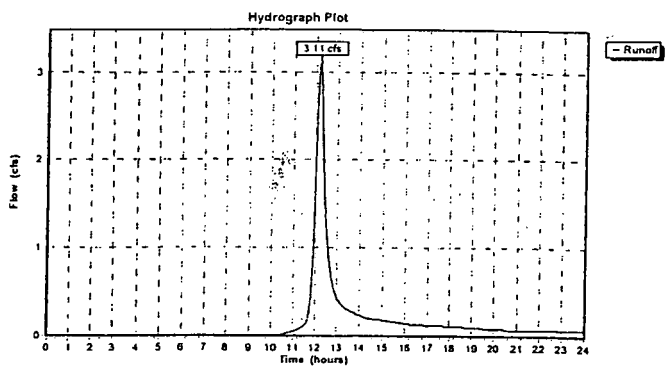
Runoff = 3.11 cfs @ 12.18 hrs, Volume= 0.262 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.606	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
22.0	300	0.0310	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.5	250	0.0310	2.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.2	50	0.0070	4.1	73.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 5.0 & 4.0 '/' n= 0.030
23.7	600	Total			

Subcatchment Z: runon area east of OSDF



DEP 30JAN02 154/282
DBM 1/30/02

Reach 1: east drainage channel

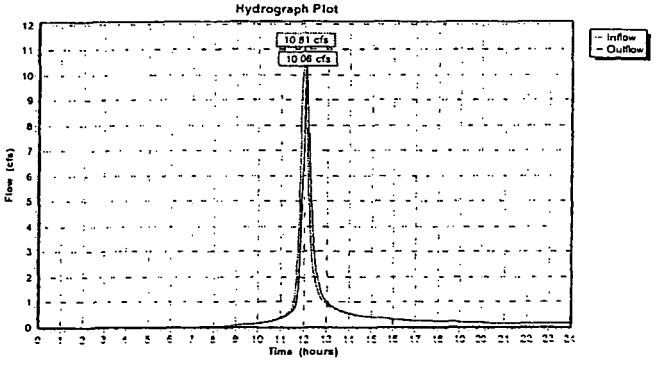
[65] Warning: Inlet elevation not specified

Inflow = 10.81 cfs @ 12.01 hrs, Volume= 0.758 af
Outflow = 10.06 cfs @ 12.11 hrs, Volume= 0.756 af, Atten= 7%, Lag= 6.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.1 fps, Min. Travel Time= 3.4 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 8.5 min

Peak Depth= 0.99'
Capacity at bank full= 754.76 cfs
0.00' x 5.00' deep channel, n= 0.030 Length= 420.0' Slope= 0.0045 '/'
Side Slope Z-value= 6.0 4.0 '/'

Reach 1: east drainage channel



Reach 1R: (new node)

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

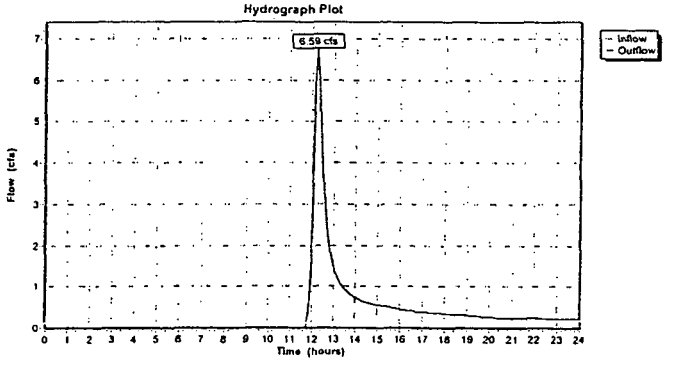
Inflow = 6.61 cfs @ 12.25 hrs, Volume= 0.693 af
Outflow = 6.59 cfs @ 12.26 hrs, Volume= 0.693 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.4 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 2.5 fps, Avg. Travel Time= 0.7 min

- 4664

Peak Depth= 0.33'
Capacity at bank full= 1,101.12 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 100.0' Slope= 0.0100 '/'

Reach 1R: (new node)



Reach 2: east drainage channel

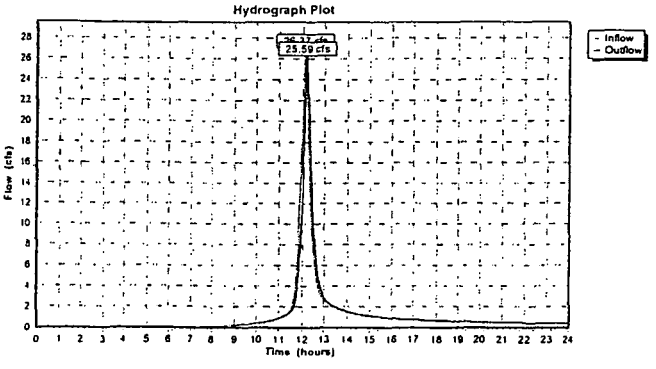
[65] Warning: Inlet elevation not specified

Inflow = 26.37 cfs @ 12.12 hrs, Volume= 2.010 af
Outflow = 25.59 cfs @ 12.20 hrs, Volume= 2.005 af, Atten= 3%, Lag= 4.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.7 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 6.3 min

Peak Depth= 1.54'
Capacity at bank full= 1,205.98 cfs
0.00' x 6.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 5.0 '/'

Reach 2: east drainage channel



Reach 2R: (new node)

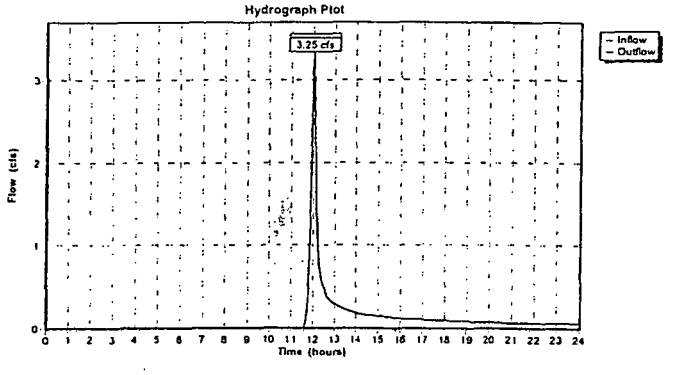
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 3.30 cfs @ 12.03 hrs, Volume= 0.192 af
Outflow = 3.25 cfs @ 12.04 hrs, Volume= 0.192 af, Atten= 1%, Lag= 0.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.3 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 0.9 min

Peak Depth= 0.24'
Capacity at bank full= 1,101.12 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 100.0' Slope= 0.0100 '/'

Reach 2R: (new node)



Reach 3: east drainage channel

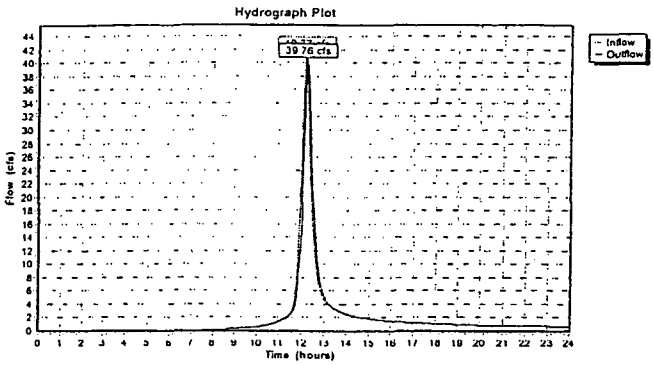
[65] Warning: Inlet elevation not specified

Inflow = 40.77 cfs @ 12.17 hrs, Volume= 3.241 af
Outflow = 39.76 cfs @ 12.24 hrs, Volume= 3.234 af, Atten= 2%, Lag= 4.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.3 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 5.3 min

Peak Depth= 1.87'
Capacity at bank full= 1,563.67 cfs
0.00' x 7.40' deep channel, n= 0.030 Length= 420.0' Slope= 0.0050 '/'
Side Slope Z-value= 3.0 4.0 '/'

Reach 3: east drainage channel



DEP 30 JAN 02 155/282
DBM 1/30/02

Reach 3R: (new node)

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

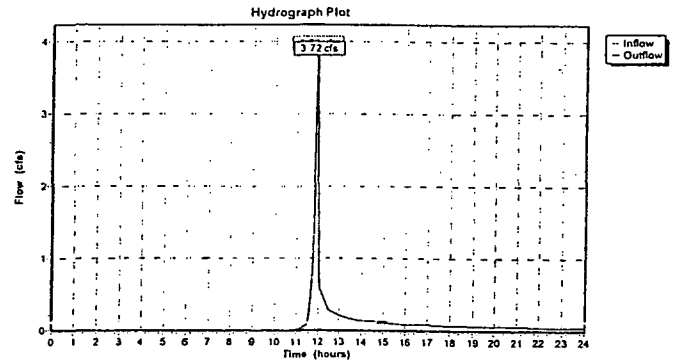
Inflow = 3.78 cfs @ 11.92 hrs, Volume= 0.162 af
Outflow = 3.72 cfs @ 11.93 hrs, Volume= 0.162 af, Atten= 2%, Lag= 0.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.5 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 0.9 min

4664

Peak Depth= 0.25'
Capacity at bank full= 1,101.12 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 100.0' Slope= 0.0100 '/'

Reach 3R: (new node)



Reach 4: east drainage channel

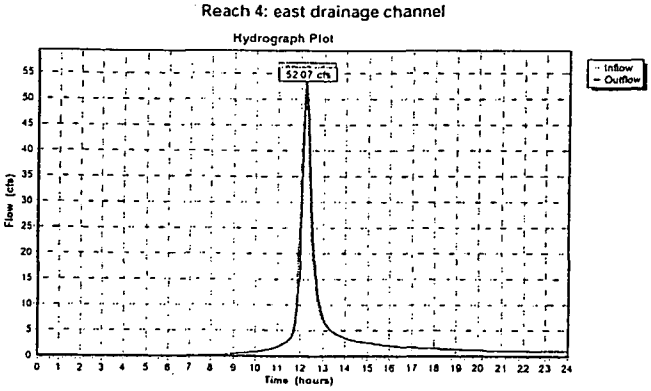
[65] Warning: Inlet elevation not specified

Inflow = 53.10 cfs @ 12.21 hrs, Volume= 4.461 af
Outflow = 52.07 cfs @ 12.27 hrs, Volume= 4.451 af, Atten= 2%, Lag= 3.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.5 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 1.4 fps, Avg. Travel Time= 4.9 min

Peak Depth= 2.07'
Capacity at bank full= 1,106.53 cfs
0.00' x 6.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0050 '/'
Side Slope Z-value= 3.0 4.0 '/'

Reach 4: east drainage channel



Reach 5: east drainage channel

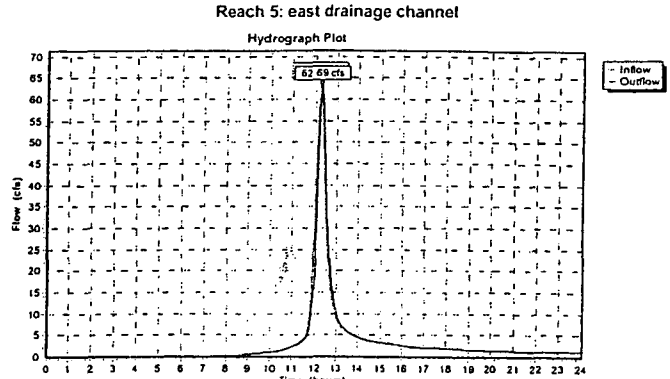
[65] Warning: Inlet elevation not specified

Inflow = 63.69 cfs @ 12.24 hrs, Volume= 5.669 af
Outflow = 62.69 cfs @ 12.30 hrs, Volume= 5.656 af, Atten= 2%, Lag= 3.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.5 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 1.4 fps, Avg. Travel Time= 5.1 min

Peak Depth= 2.01'
Capacity at bank full= 182.58 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 440.0' Slope= 0.0050 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 5: east drainage channel



Reach 6: east drainage channel

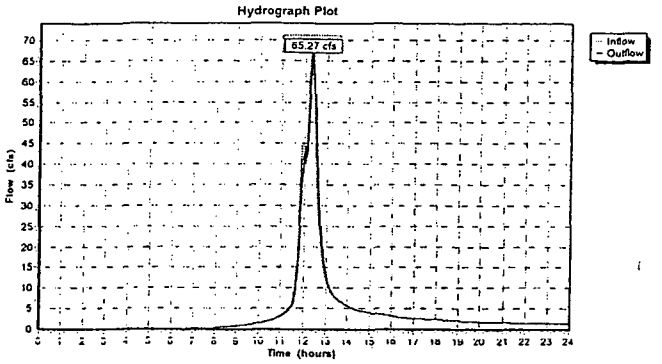
[65] Warning: Inlet elevation not specified

Inflow = 66.14 cfs @ 12.30 hrs, Volume= 7.197 af
Outflow = 65.27 cfs @ 12.35 hrs, Volume= 7.185 af, Atten= 1%, Lag= 3.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.5 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 4.3 min

Peak Depth= 1.80'
Capacity at bank full= 258.21 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 480.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 6: east drainage channel



DGP 30 JAN 02 156/282
DBM 1/30/02

Reach 7: runoff diversion channel

[65] Warning: Inlet elevation not specified

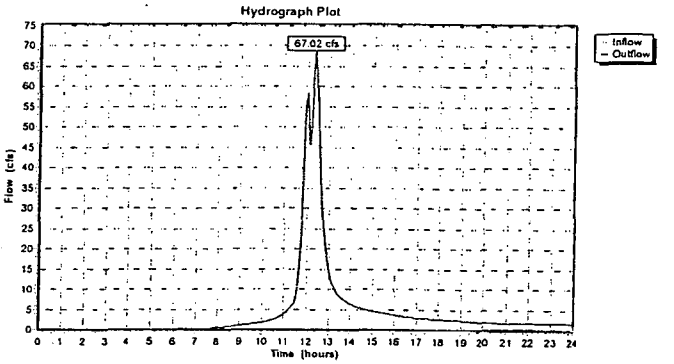
Inflow = 67.32 cfs @ 12.35 hrs, Volume= 8.197 af
Outflow = 67.02 cfs @ 12.36 hrs, Volume= 8.193 af, Atten= 0%, Lag= 0.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.6 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 1.2 min

Peak Depth= 1.81'
Capacity at bank full= 556.08 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 140.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 6.0 '/'

- 4664

Reach 7: runoff diversion channel



Reach 8: runoff diversion channel

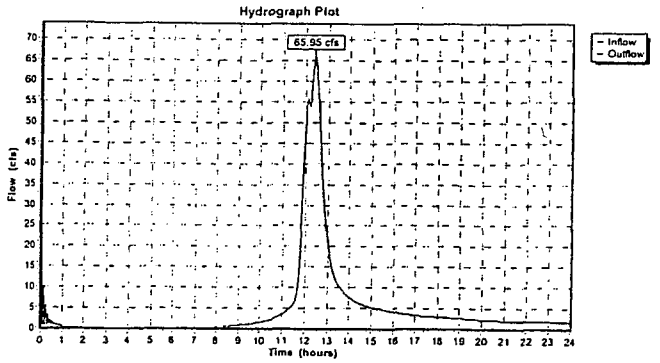
[65] Warning: Inlet elevation not specified
[85] Warning: Oscillations may require Finer Routing>1

Inflow = 65.98 cfs @ 12.43 hrs, Volume= 9.092 af
Outflow = 65.95 cfs @ 12.43 hrs, Volume= 9.067 af, Atten= 0%, Lag= 0.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.7 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 0.4 min

Peak Depth= 0.94'
Capacity at bank full= 1,379.30 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
10.00' x 4.50' deep channel, n= 0.030 Length= 20.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 8: runoff diversion channel



Reach 9: runoff diversion channel

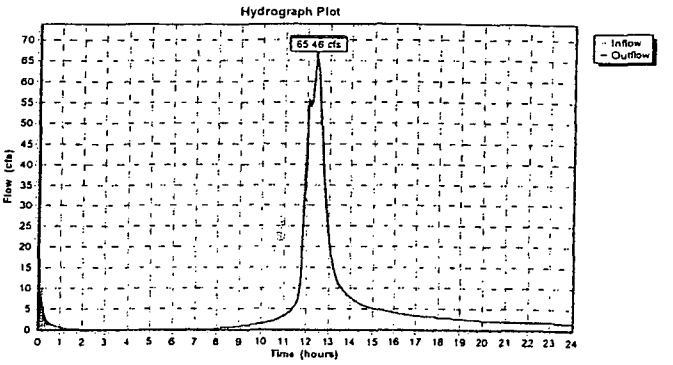
[65] Warning: Inlet elevation not specified

Inflow = 65.95 cfs @ 12.43 hrs, Volume= 9.067 af
Outflow = 65.46 cfs @ 12.47 hrs, Volume= 9.051 af, Atten= 1%, Lag= 2.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.4 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 4.7 min

Peak Depth= 1.37'
Capacity at bank full= 407.65 cfs
10.00' x 3.50' deep channel, n= 0.030 Length= 295.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 9: runoff diversion channel



Reach 10: runoff diversion channel

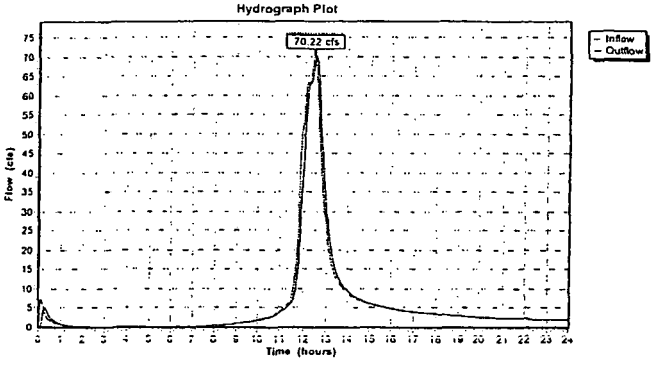
[65] Warning: Inlet elevation not specified

Inflow = 70.70 cfs @ 12.46 hrs, Volume= 10.542 af
Outflow = 70.22 cfs @ 12.54 hrs, Volume= 10.507 af, Atten= 1%, Lag= 4.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.5 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 9.4 min

Peak Depth= 1.42'
Capacity at bank full= 134.00 cfs
10.00' x 2.00' deep channel, n= 0.030 Length= 610.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 10: runoff diversion channel



DGP 30JAN02 157/282
DBM 1/30/02

Reach 11: new CMP arch

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

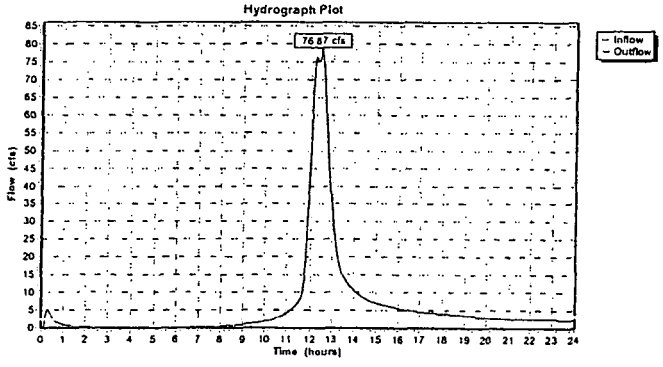
Inflow = 76.92 cfs @ 12.51 hrs, Volume= 11.750 af
Outflow = 76.87 cfs @ 12.51 hrs, Volume= 11.747 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.5 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.0 fps, Avg. Travel Time= 0.6 min

4664

Peak Depth= 1.76'
Capacity at bank full= 408.61 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 65.0' Slope= 0.0045 '/'

Reach 11: new CMP arch



Reach 12: runoff diversion channel

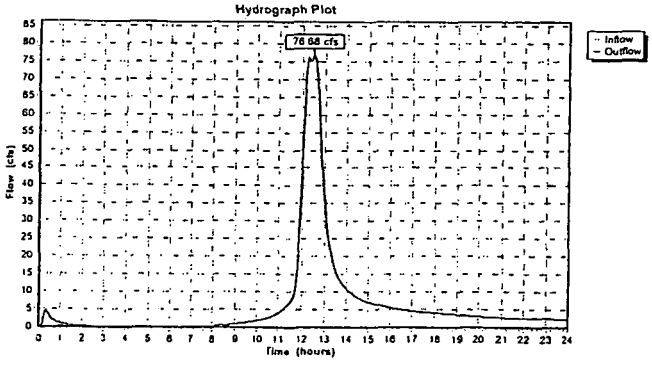
[65] Warning: Inlet elevation not specified

Inflow = 76.87 cfs @ 12.51 hrs, Volume= 11.747 af
Outflow = 76.68 cfs @ 12.54 hrs, Volume= 11.730 af, Atten= 0%, Lag= 1.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.6 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 4.0 min

Peak Depth= 1.49'
Capacity at bank full= 134.16 cfs
10.00' x 2.00' deep channel, n= 0.030 Length= 270.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 12: runoff diversion channel



Reach 13: runoff diversion channel

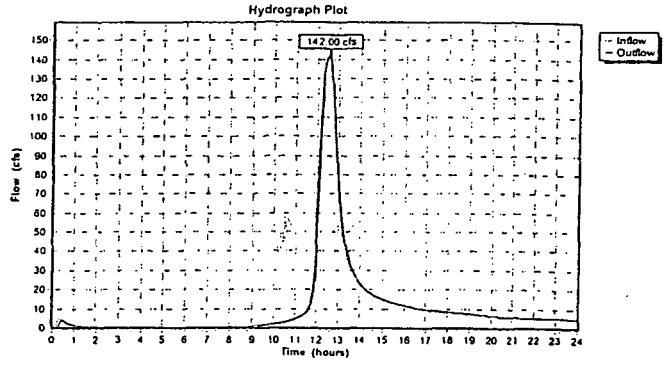
[65] Warning: Inlet elevation not specified

Inflow = 142.35 cfs @ 12.51 hrs, Volume= 21.698 af
Outflow = 142.00 cfs @ 12.56 hrs, Volume= 21.641 af, Atten= 0%, Lag= 2.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.9 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 6.8 min

Peak Depth= 1.50'
Capacity at bank full= 235.94 cfs
20.00' x 2.00' deep channel, n= 0.030 Length= 450.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 13: runoff diversion channel



DCP 30JAN02 158/282
DBM 1/30/02

Reach 14: east runon channel

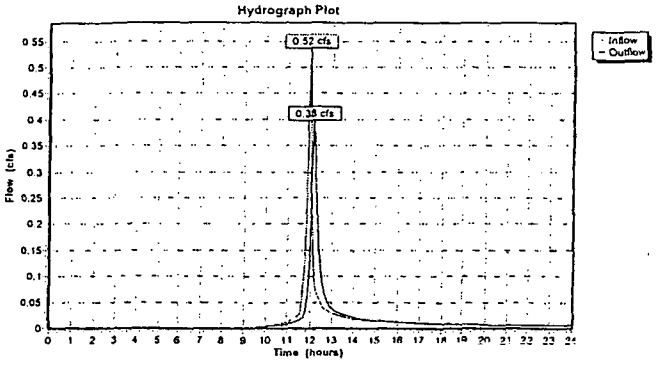
[65] Warning: Inlet elevation not specified

Inflow = 0.52 cfs @ 11.98 hrs, Volume= 0.026 af
Outflow = 0.38 cfs @ 12.17 hrs, Volume= 0.025 af, Atten= 27%, Lag= 11.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.9 fps, Min. Travel Time= 7.6 min
Avg. Velocity = 0.4 fps, Avg. Travel Time= 19.1 min

Peak Depth= 0.33'
Capacity at bank full= 22.78 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0040 '/'
Side Slope Z-value= 3.0 5.0 '/'

Reach 14: east runon channel



Reach 15: east runon channel

[65] Warning: Inlet elevation not specified

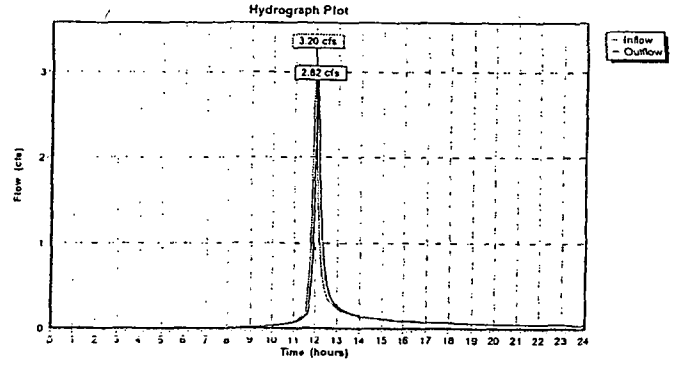
Inflow = 3.20 cfs @ 12.01 hrs, Volume= 0.186 af
Outflow = 2.82 cfs @ 12.12 hrs, Volume= 0.186 af, Atten= 12%, Lag= 6.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.8 fps, Min. Travel Time= 3.9 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 9.9 min

Peak Depth= 0.64'
Capacity at bank full= 61.62 cfs
0.00' x 2.00' deep channel, n= 0.030 Length= 420.0' Slope= 0.0063 '/'
Side Slope Z-value= 3.0 5.0 '/'

4664

Reach 15: east runon channel



Reach 16: east runon channel

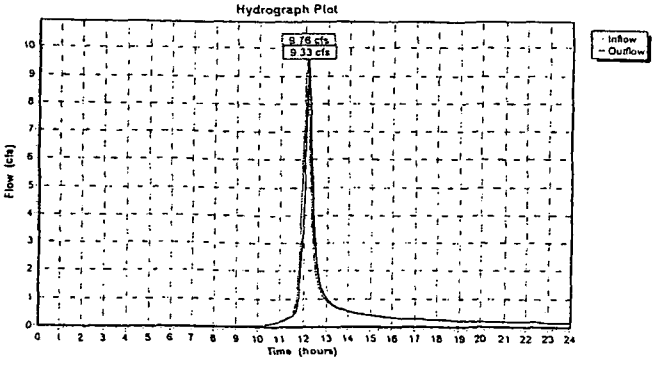
[65] Warning: Inlet elevation not specified

Inflow = 9.76 cfs @ 12.10 hrs, Volume= 0.664 af
Outflow = 9.33 cfs @ 12.19 hrs, Volume= 0.661 af, Atten= 4%, Lag= 4.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.6 fps, Min. Travel Time= 2.7 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 6.7 min

Peak Depth= 0.98'
Capacity at bank full= 256.58 cfs
0.00' x 3.40' deep channel, n= 0.030 Length= 420.0' Slope= 0.0074 '/'
Side Slope Z-value= 2.5 5.0 '/'

Reach 16: east runon channel



Reach 17: east runon channel

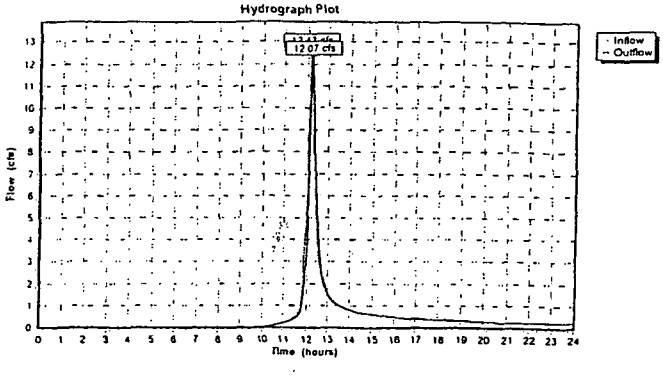
[65] Warning: Inlet elevation not specified

Inflow = 12.43 cfs @ 12.18 hrs, Volume= 0.923 af
Outflow = 12.07 cfs @ 12.25 hrs, Volume= 0.921 af, Atten= 3%, Lag= 4.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.2 fps, Min. Travel Time= 2.2 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 5.3 min

Peak Depth= 0.92'
Capacity at bank full= 436.18 cfs
0.00' x 3.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0125 '/'
Side Slope Z-value= 4.0 5.0 '/'

Reach 17: east runon channel



DGP 30 JAN 02 159/282
PBM 1/30/02

Reach 18: east runon channel

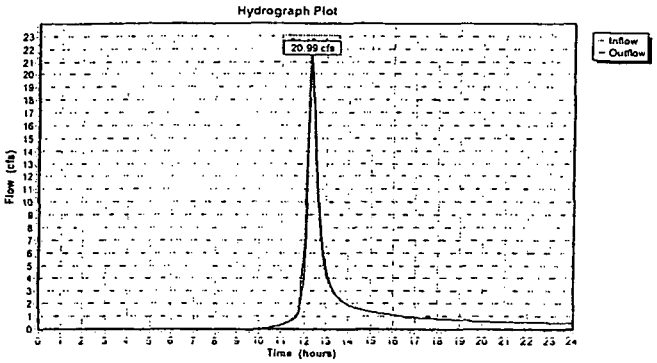
[65] Warning: Inlet elevation not specified

Inflow = 21.43 cfs @ 12.27 hrs, Volume= 2.022 af
Outflow = 20.99 cfs @ 12.33 hrs, Volume= 2.017 af, Atten= 2%, Lag= 3.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.7 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 4.5 min

Peak Depth= 1.38'
Capacity at bank full= 169.20 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 440.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 18: east runon channel



Reach 19: east runon channel

[65] Warning: Inlet elevation not specified

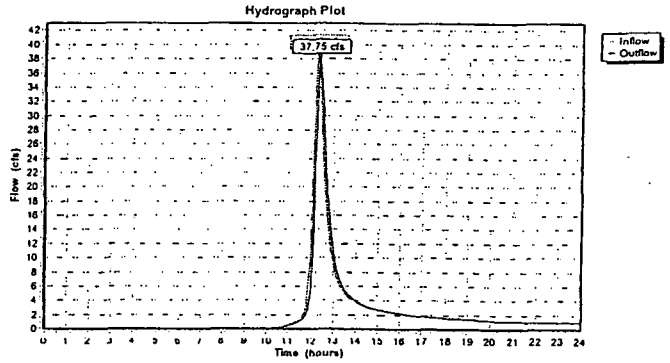
-- 4664

Inflow = 38.43 cfs @ 12.32 hrs, Volume= 3.868 af
Outflow = 37.75 cfs @ 12.41 hrs, Volume= 3.855 af, Atten= 2%, Lag= 5.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.8 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 6.4 min

Peak Depth= 0.91'
Capacity at bank full= 911.12 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 470.0' Slope= 0.0090 '/'
Side Slope Z-value= 3.0 30.0 '/'

Reach 19: east runon channel



Reach 20: east runon channel

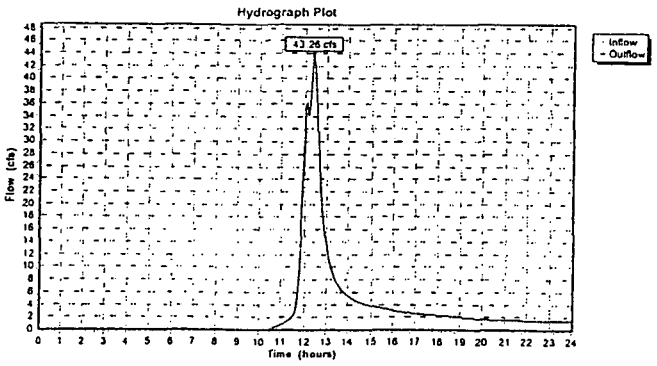
[65] Warning: Inlet elevation not specified

Inflow = 43.35 cfs @ 12.39 hrs, Volume= 5.587 af
Outflow = 43.26 cfs @ 12.40 hrs, Volume= 5.586 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.2 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 2.0 fps, Avg. Travel Time= 0.6 min

Peak Depth= 1.87'
Capacity at bank full= 153.84 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 75.0' Slope= 0.0083 '/'
Side Slope Z-value= 3.0 '/'

Reach 20: east runon channel



Reach 21: east runon channel

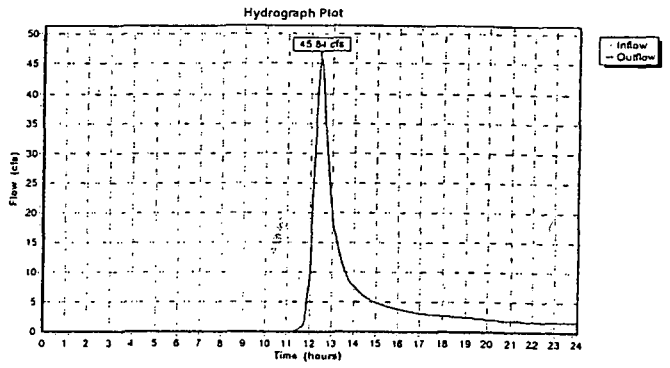
[65] Warning: Inlet elevation not specified

Inflow = 45.89 cfs @ 12.48 hrs, Volume= 6.151 af
Outflow = 45.84 cfs @ 12.49 hrs, Volume= 6.149 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.5 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 0.7 min

Peak Depth= 1.84'
Capacity at bank full= 169.20 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 65.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 21: east runon channel



DG! 30 JAN 02 160/282
DBM 1/30/02

Reach 22: east runon channel

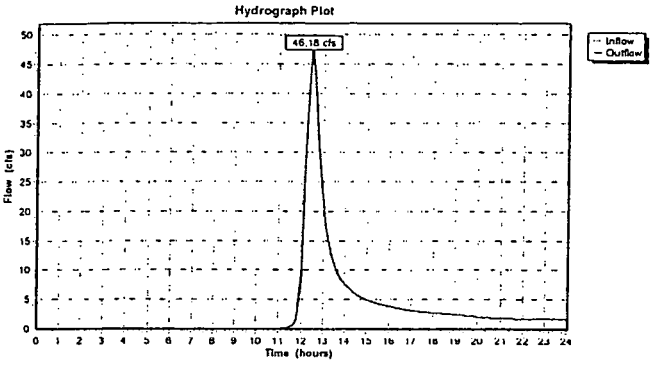
[65] Warning: Inlet elevation not specified

Inflow = 46.33 cfs @ 12.49 hrs, Volume= 6.231 af
Outflow = 46.18 cfs @ 12.51 hrs, Volume= 6.226 af, Atten= 0%, Lag= 1.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.5 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 2.0 min

Peak Depth= 1.85'
Capacity at bank full= 364.40 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 190.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 22: east runon channel



Reach 23: new CMP culverts

4664

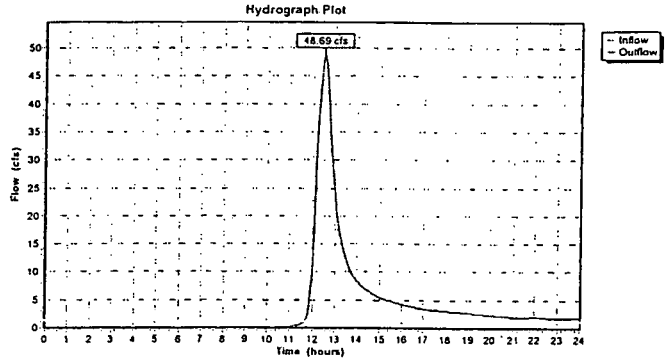
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 48.76 cfs @ 12.51 hrs, Volume= 6.862 af
Outflow = 48.69 cfs @ 12.52 hrs, Volume= 6.859 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.4 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 0.9 min

Peak Depth= 1.30'
Capacity at bank full= 473.85 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 95.0' Slope= 0.0060 '/'

Reach 23: new CMP culverts



Reach 24: runon channel

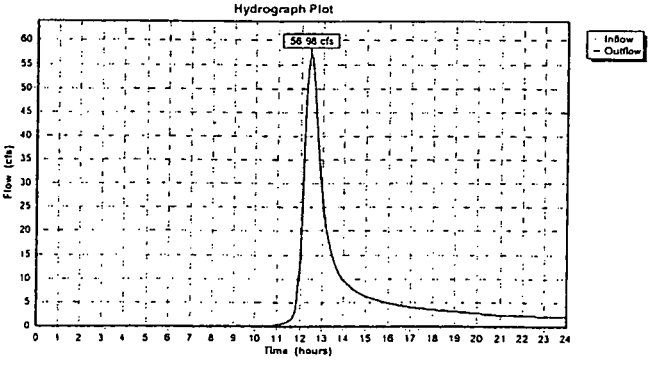
[65] Warning: Inlet elevation not specified

Inflow = 57.16 cfs @ 12.48 hrs, Volume= 8.111 af
Outflow = 56.98 cfs @ 12.49 hrs, Volume= 8.104 af, Atten= 0%, Lag= 1.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs / 2
Max. Velocity= 4.0 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 2.3 min

Peak Depth= 1.19'
Capacity at bank full= 153.54 cfs
8.50' x 2.00' deep channel, n= 0.030 Length= 160.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 24: runon channel



Reach 25: new CMP arch

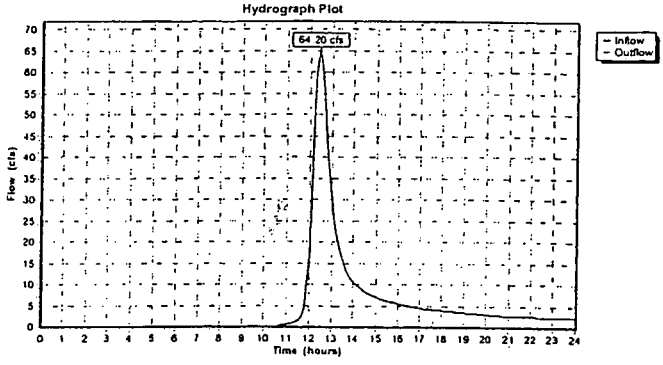
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 64.23 cfs @ 12.45 hrs, Volume= 9.058 af
Outflow = 64.20 cfs @ 12.46 hrs, Volume= 9.056 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.7 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 0.5 min

Peak Depth= 1.52'
Capacity at bank full= 453.67 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 60.0' Slope= 0.0055 '/'

Reach 25: new CMP arch



Reach 26: runon channel

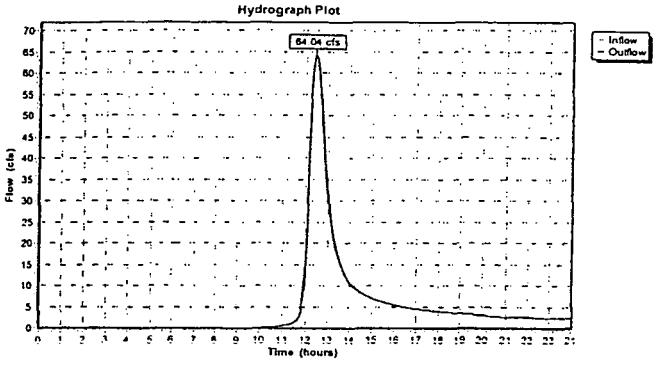
[65] Warning: Inlet elevation not specified

Inflow = 64.20 cfs @ 12.46 hrs, Volume= 9.056 af
Outflow = 64.04 cfs @ 12.49 hrs, Volume= 9.045 af, Atten= 0%, Lag= 2.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.4 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 3.2 min

Peak Depth= 2.20'
Capacity at bank full= 90.11 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 300.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 26: runon channel



DCP 30 JAN 02 61/282
DBM 1/30/02
4664

Reach 27: new CMP arch

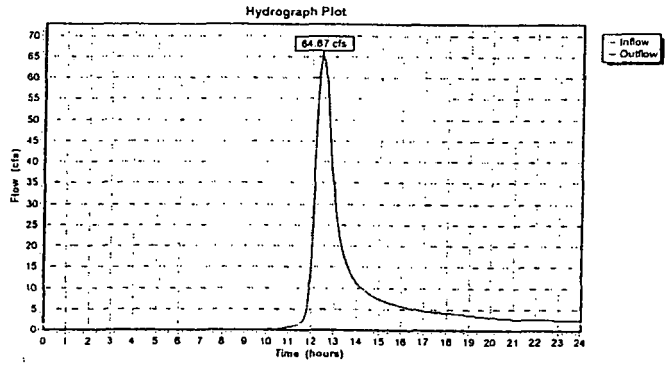
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 64.98 cfs @ 12.48 hrs, Volume= 9.365 af
Outflow = 64.87 cfs @ 12.49 hrs, Volume= 9.361 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs / 2
Max. Velocity= 5.7 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 2.0 fps, Avg. Travel Time= 0.9 min

Peak Depth= 1.53'
Capacity at bank full= 455.55 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 110.0' Slope= 0.0055 '/'

Reach 27: new CMP arch



Reach 28: new CMP culverts

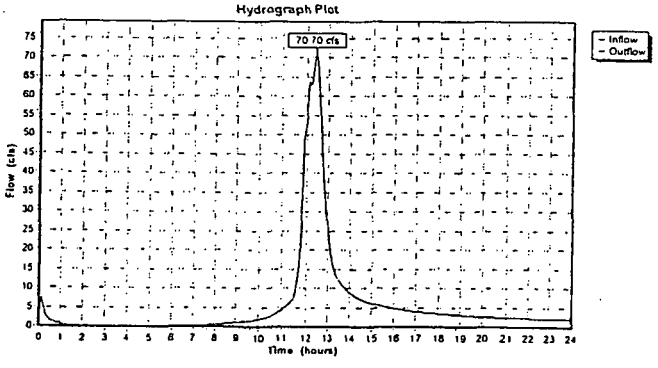
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 70.78 cfs @ 12.45 hrs, Volume= 10.544 af
Outflow = 70.70 cfs @ 12.46 hrs, Volume= 10.542 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.4 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 0.6 min

Peak Depth= 1.69'
Capacity at bank full= 408.61 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 65.0' Slope= 0.0045 '/'

Reach 28: new CMP culverts



Reach 29: east runon channel

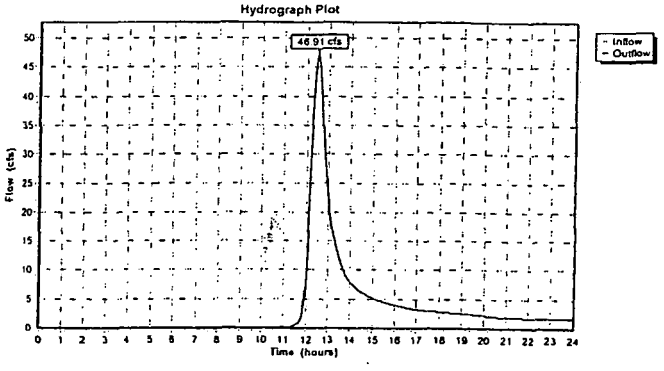
[65] Warning: Inlet elevation not specified

Inflow = 47.10 cfs @ 12.50 hrs, Volume= 6.408 af
Outflow = 46.91 cfs @ 12.53 hrs, Volume= 6.402 af, Atten= 0%, Lag= 1.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.6 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 2.4 min

Peak Depth= 1.86'
Capacity at bank full= 255.23 cfs
0.00' x 3.50' deep channel, n= 0.030 Length= 230.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 29: east runon channel



Reach 30: east runon channel

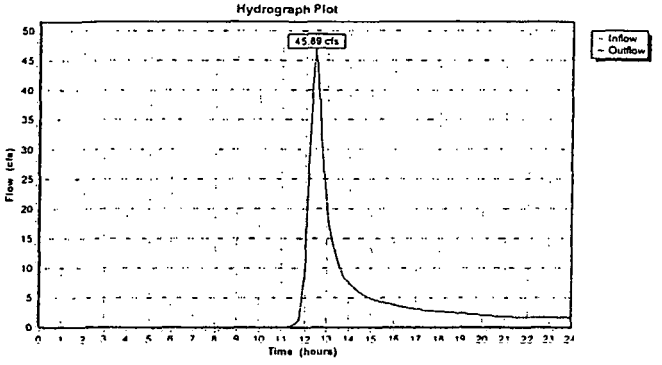
[65] Warning: Inlet elevation not specified

Inflow = 45.98 cfs @ 12.48 hrs, Volume= 6.152 af
Outflow = 45.89 cfs @ 12.48 hrs, Volume= 6.151 af, Atten= 0%, Lag= 0.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs / 2
Max. Velocity= 4.5 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 0.3 min

Peak Depth= 1.84'
Capacity at bank full= 104.05 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 30.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 30: east runon channel



DGP 30JAN02 DBM 1/30/02 1602/282

Reach 31: culvert

4664

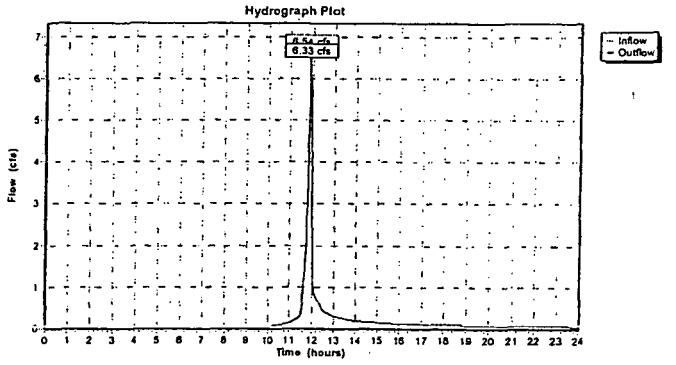
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 6.54 cfs @ 11.91 hrs, Volume= 0.279 af
Outflow = 6.33 cfs @ 11.91 hrs, Volume= 0.279 af, Atten= 3%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.8 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 0.8 min

Peak Depth= 0.35'
Capacity at bank full= 946.99 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.013 Length= 80.0' Slope= 0.0125 '/'

Reach 31: culvert



Pond 1P: (new node)

Inflow = 49.32 cfs @ 12.39 hrs, Volume= 6.362 af
Outflow = 45.98 cfs @ 12.48 hrs, Volume= 6.152 af, Atten= 7%, Lag= 5.4 min
Primary = 45.98 cfs @ 12.48 hrs, Volume= 6.152 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

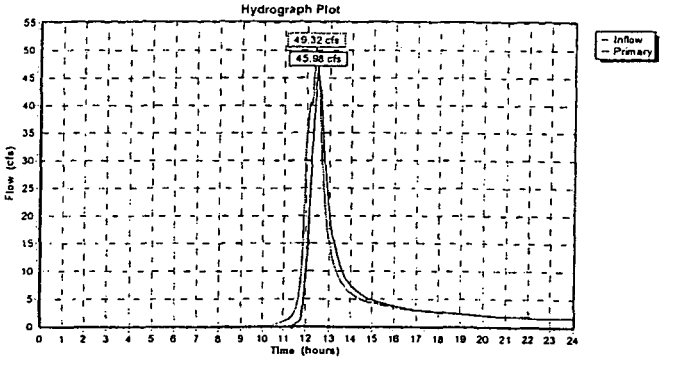
Starting Elev= 592.00' Storage= 0.691 af
Peak Elev= 593.91' Storage= 1.584 af (0.893 af above starting storage)
Plug-Flow detention time= 101.9 min calculated for 5.449 af (86% of inflow)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
589.30	0.186	0.000	0.000	0.186
590.00	0.210	0.139	0.139	0.211
591.00	0.278	0.243	0.382	0.279
592.00	0.342	0.309	0.691	0.344
593.00	0.463	0.401	1.092	0.465
594.00	0.624	0.542	1.634	0.627

Primary OutFlow (Free Discharge)
└─1=Special (user-defined)

#	Routing	Invert	Outlet Devices
1	Primary	592.00'	Special (user-defined)
			Head (feet) 0.00 0.01 0.18 0.51 1.01 1.34 1.67 2.00
			Disch. (cfs) 0.00 0.00 0.08 1.33 8.21 17.57 31.73 51.47

Pond 1P: (new node)



Pond 2P: (new node)

Inflow	=	69.22 cfs @	12.36 hrs, Volume=	8.900 af	
Outflow	=	65.98 cfs @	12.43 hrs, Volume=	9.092 af,	Atten= 5%, Lag= 4.1 min
Primary	=	65.98 cfs @	12.43 hrs, Volume=	9.092 af	

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Starting Elev= 589.00' Storage= 1.765 af
Peak Elev= 589.83' Storage= 2.250 af (0.485 af above starting storage)
Plug-Flow detention time= 115.9 min calculated for 7.312 af (82% of inflow)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
584.30	0.260	0.000	0.000	0.260
585.00	0.286	0.191	0.191	0.287
586.00	0.328	0.307	0.498	0.330
587.00	0.397	0.362	0.860	0.400
588.00	0.448	0.422	1.282	0.452
589.00	0.519	0.483	1.765	0.524
590.00	0.647	0.582	2.347	0.652

Primary OutFlow (Free Discharge)
└─1=Special (user-defined)

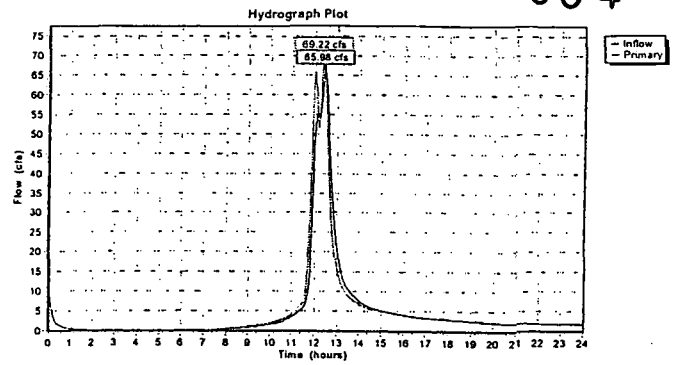
#	Routing	Invert	Outlet Devices
1	Primary	588.50'	Special (user-defined) Head (feet) 0.00 0.01 0.18 0.51 1.01 1.34 1.67 2.00 Disch. (cfs) 0.00 0.02 1.97 11.93 39.57 66.41 100.28 141.52

DCP 30JAN02 DBM 1/30/02 163/282

Pond 2P: (new node)

4664

Hydrograph Plot



Pond 3P: Borrow Area Basin

Inflow	=	174.19 cfs @	12.58 hrs, Volume=	30.229 af	
Outflow	=	0.00 cfs @	0.00 hrs, Volume=	0.000 af,	Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Peak Elev= 574.29' Storage= 30.214 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

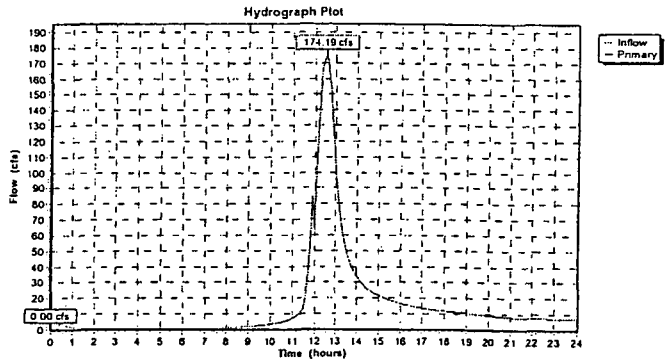
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.00	6.391	0.000	0.000	6.391
571.00	6.687	6.538	6.538	6.690
572.00	7.017	6.851	13.390	7.023
573.00	7.290	7.153	20.543	7.300
574.00	7.613	7.451	27.994	7.626
575.00	7.921	7.766	35.760	7.938

Primary OutFlow (Free Discharge)
├─2=Culvert
│ └─1=Orifice/Grate
└─3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.30'	48.0" Horiz. Orifice/Grate X 2.00 Limited to weir flow C= 0.600
2	Primary	569.80'	48.0" x 200.0' long Culvert X 2.00 Ke= 0.700 Outlet Invert= 569.00' S= 0.0040 '/' n= 0.024 Cc= 0.900
3	Primary	578.00'	20.0' long Broad-Crested Rectangular Weir Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00 Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Pond 3P: Borrow Area Basin

Hydrograph Plot



ATTACHMENT C-1B

HydroCAD™ OUTPUT REPORTS

WEST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO

4664

WEST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO
10-YEAR, 24-HOUR STORM EVENT

DCP 30 JAN 02
DBM 1/30/02 166/282

Pond 1P: Sedimentation Basin 2

4664

Inflow	=	87.24 cfs @	12.05 hrs,	Volume=	8.417 af
Outflow	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af, Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Peak Elev= 575.41' Storage= 8.414 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.50	1.460	0.000	0.000	1.460
571.00	1.512	0.743	0.743	1.513
572.00	1.614	1.563	2.306	1.617
573.00	1.713	1.663	3.969	1.719
574.00	1.819	1.766	5.735	1.827
575.00	1.917	1.868	7.602	1.928
576.00	2.026	1.971	9.574	2.039
577.00	2.162	2.094	11.667	2.177

Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.50'	**48.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600
2	Primary	570.78'	**36.0" x 680.0' long Culvert** Ke= 0.700
			Outlet Invert= 563.30' S= 0.0110 '/' n= 0.024 Cc= 0.900
3	Primary	576.00'	**20.0' long Broad-Crested Rectangular Weir**
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

DCP 30 JAN 02
DBM 1/30/02
167 /282

Pond 1P: Sedimentation Basin 2

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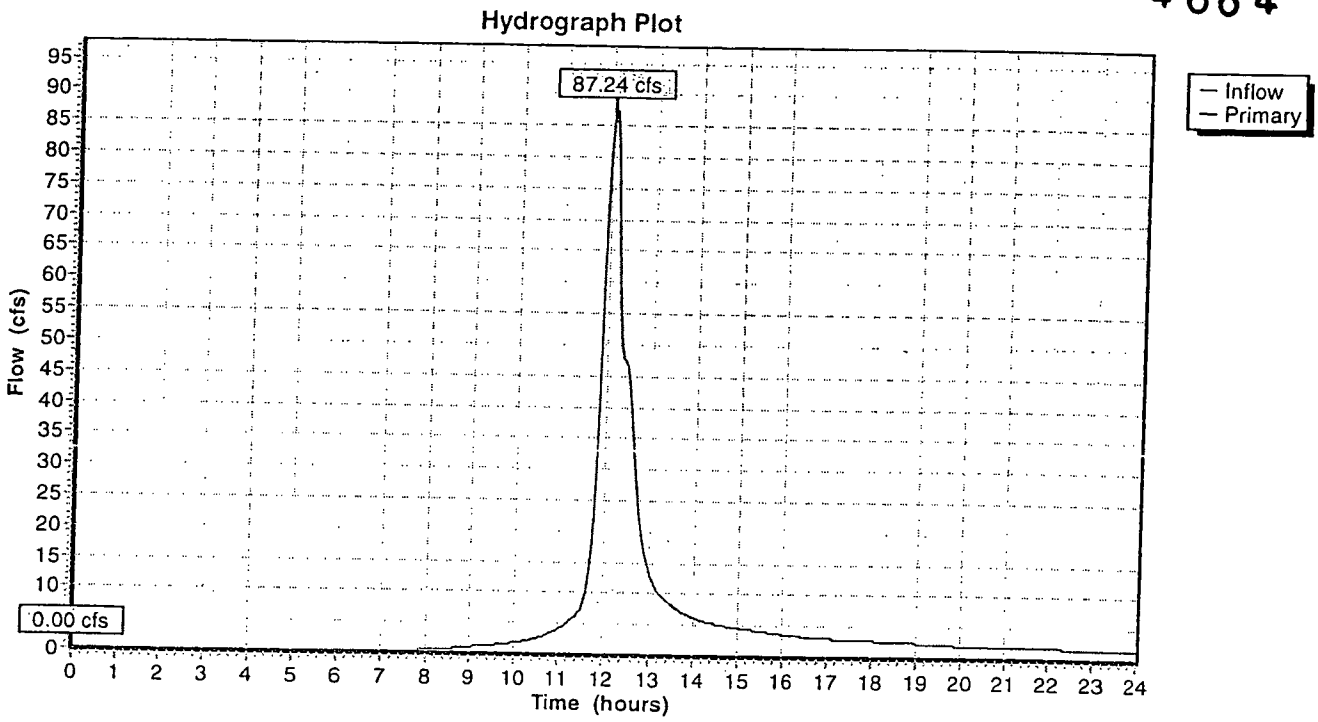

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WEST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO
25-YEAR, 24-HOUR STORM EVENT

4664 DCP 30 JAN 02 DBM 1/30/02 169/282

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=4.70"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover
Tc=18.3 min CN=83 Area=2.730 ac Runoff= 9.20 cfs 0.658 af

Subcatchment B: vegetated final cover
Tc=19.3 min CN=83 Area=5.342 ac Runoff= 17.49 cfs 1.287 af

Subcatchment C: vegetated final cover
Tc=19.3 min CN=83 Area=5.399 ac Runoff= 17.67 cfs 1.301 af

Subcatchment D: non-vegetated final cover
Tc=4.4 min CN=89 Area=5.530 ac Runoff= 33.61 cfs 1.605 af

Subcatchment E: non-vegetated final cover
Tc=4.8 min CN=89 Area=4.807 ac Runoff= 28.78 cfs 1.395 af

Subcatchment F: non-vegetated final cover/construction laydown
Tc=2.8 min CN=86 Area=1.640 ac Runoff= 9.68 cfs 0.436 af

Subcatchment G: non-vegetated final cover/construction laydown
Tc=6.8 min CN=85 Area=3.637 ac Runoff= 18.59 cfs 0.936 af

Subcatchment H: construction laydown area
Tc=30.5 min CN=82 Area=0.797 ac Runoff= 1.92 cfs 0.185 af

Subcatchment I: construction laydown area
Tc=25.0 min CN=82 Area=0.512 ac Runoff= 1.40 cfs 0.119 af

Subcatchment J: construction laydown area
Tc=9.1 min CN=82 Area=1.452 ac Runoff= 6.35 cfs 0.340 af

Subcatchment K: runon north of borrow area
Tc=16.4 min CN=79 Area=0.765 ac Runoff= 2.40 cfs 0.162 af

Subcatchment L: construction laydown area
Tc=17.7 min CN=82 Area=1.277 ac Runoff= 4.24 cfs 0.298 af

Subcatchment M: runon north of borrow area
Tc=5.3 min CN=79 Area=0.964 ac Runoff= 4.33 cfs 0.204 af

Subcatchment N: construction laydown area
Tc=15.2 min CN=82 Area=1.043 ac Runoff= 3.73 cfs 0.244 af

Subcatchment O: pond
Tc=1.0 min CN=98 Area=2.252 ac Runoff= 16.67 cfs 0.838 af

Subcatchment P: construction laydown area
Tc=7.6 min CN=82 Area=0.943 ac Runoff= 4.35 cfs 0.221 af

Reach 1: west channel
Inflow= 9.20 cfs 0.658 af
Length= 400.0' Max Vel= 2.5 fps Capacity= 223.61 cfs Outflow= 8.86 cfs 0.656 af

Reach 2: west channel
Inflow= 25.64 cfs 1.943 af
Length= 400.0' Max Vel= 3.2 fps Capacity= 223.61 cfs Outflow= 24.99 cfs 1.939 af

Reach 3: west channel
Inflow= 40.94 cfs 3.240 af
Length= 400.0' Max Vel= 3.6 fps Capacity= 223.61 cfs Outflow= 40.07 cfs 3.234 af

Reach 4: west channel
Inflow= 45.76 cfs 4.839 af
Length= 90.0' Max Vel= 3.7 fps Capacity= 224.44 cfs Outflow= 44.48 cfs 4.837 af

Reach 5: culvert
Inflow= 44.48 cfs 4.837 af
Length= 100.0' Max Vel= 4.6 fps Capacity= 397.33 cfs Outflow= 44.18 cfs 4.835 af

Reach 6: west channel
Inflow= 44.18 cfs 4.835 af
Length= 380.0' Max Vel= 3.7 fps Capacity= 337.31 cfs Outflow= 42.92 cfs 4.827 af

Reach 7: west channel
Inflow= 63.64 cfs 6.222 af
Length= 550.0' Max Vel= 4.4 fps Capacity= 315.77 cfs Outflow= 60.74 cfs 6.210 af

Reach 8: west channel
Inflow= 93.02 cfs 8.386 af
Length= 280.0' Max Vel= 4.8 fps Capacity= 315.58 cfs Outflow= 90.72 cfs 8.378 af

Reach 9: channel
Inflow= 2.40 cfs 0.162 af
Length= 200.0' Max Vel= 3.1 fps Capacity= 43.05 cfs Outflow= 2.34 cfs 0.161 af

Reach 10: access road diversion channel
Length= 260.0' Max Vel= 0.0 fps Capacity= 32.43 cfs Outflow= 0.00 cfs 0.000 af

Reach 11: access road diversion channel
Inflow= 9.68 cfs 0.436 af
Length= 310.0' Max Vel= 2.6 fps Capacity= 84.62 cfs Outflow= 8.69 cfs 0.435 af

Reach 12: culvert
Inflow= 30.19 cfs 1.837 af
Length= 116.0' Max Vel= 8.5 fps Capacity= 1,112.19 cfs Outflow= 29.92 cfs 1.836 af

Reach 13: culvert
Inflow= 4.24 cfs 0.298 af
Length= 65.0' Max Vel= 4.5 fps Capacity= 1,040.04 cfs Outflow= 4.22 cfs 0.298 af

Reach 14: culvert
Inflow= 4.33 cfs 0.204 af
Length= 112.0' Max Vel= 3.8 fps Capacity= 822.56 cfs Outflow= 4.22 cfs 0.204 af

Pond 1P: Sedimentation Basin 2
Peak Storage= 8.908 af Inflow= 106.51 cfs 10.182 af
Primary= 2.73 cfs 1.332 af Outflow= 2.73 cfs 1.332 af

Runoff Area = 39.090 ac Volume = 10.228 af Average Depth = 3.14"

Subcatchment A: vegetated final cover

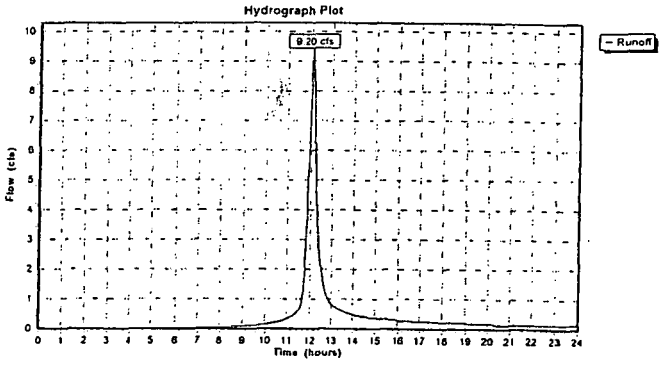
Runoff = 9.20 cfs @ 12.11 hrs, Volume= 0.658 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.730	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.7	180	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
18.3	670	Total			

Subcatchment A: vegetated final cover



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Subcatchment B: vegetated final cover

Runoff = 17.48 cfs @ 12.12 hrs, Volume= 1.287 af

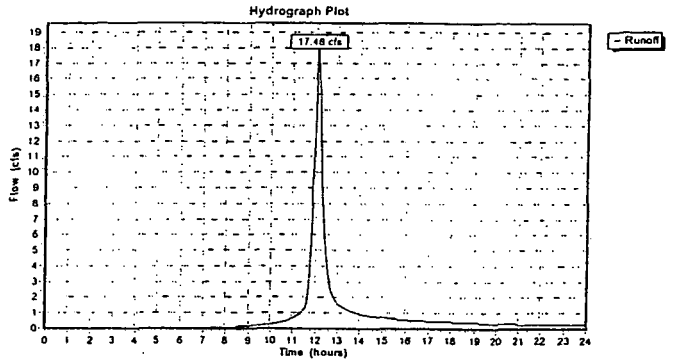
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.342	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	200	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
0.8	200	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
19.3	950	Total			

DCP 30 JAN 02 170/282
DBH 1/30/02

Subcatchment B: vegetated final cover



- 4664

Subcatchment C: vegetated final cover

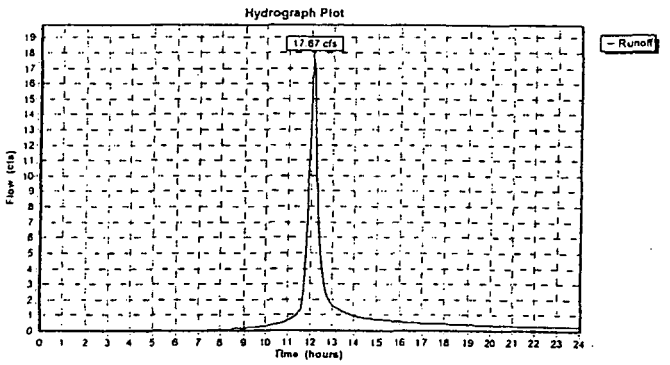
Runoff = 17.67 cfs @ 12.12 hrs, Volume= 1.301 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.399	83	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	200	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
0.8	195	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
19.3	945	Total			

Subcatchment C: vegetated final cover



Subcatchment D: non-vegetated final cover

[49] Hint: Tc<2dt may require smaller dt

Runoff = 33.61 cfs @ 11.95 hrs, Volume= 1.605 af

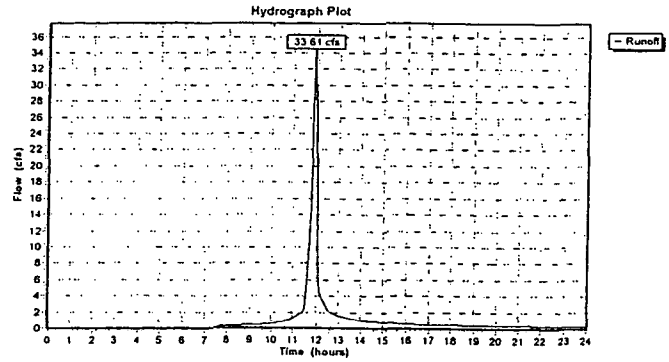
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
5.530	89	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	90	0.0500	1.8		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	60	0.1000	2.1		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.8	150	0.1700	3.2		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	205	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
0.8	195	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
4.4	950	Total			

DGP 30 JAN 02 171/282
DDM 1/30/02

Subcatchment D: non-vegetated final cover



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Subcatchment E: non-vegetated final cover

[49] Hint: Tc<2dt may require smaller dt

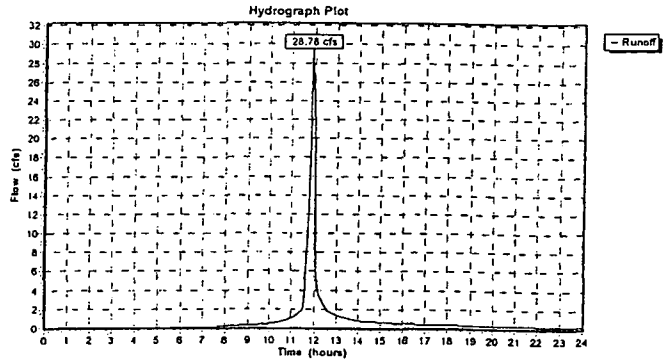
Runoff = 28.78 cfs @ 11.95 hrs, Volume= 1.395 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
4.807	89	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.9	90	0.0500	1.8		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	60	0.1000	2.1		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.8	150	0.1700	3.2		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.5	205	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
1.2	305	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
4.8	1,060	Total			

Subcatchment E: non-vegetated final cover



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Subcatchment F: non-vegetated final cover/construction laydown

[49] Hint: Tc<2dt may require smaller dt

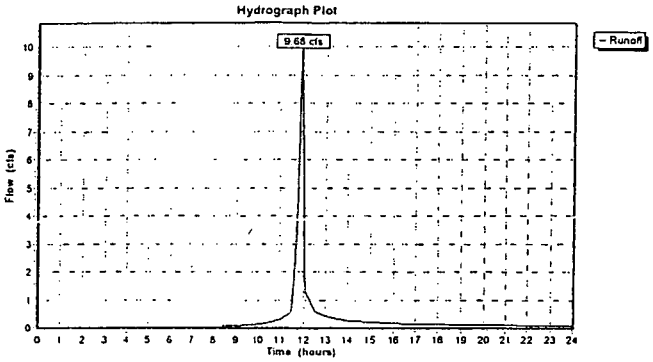
Runoff = 9.68 cfs @ 11.93 hrs, Volume= 0.436 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.640	86	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.4	300	0.1700	3.6		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.3	135	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.4	50	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.7	185	0.0133	4.6	41.54	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.50' Z= 3.0 & 5.0 '/' n= 0.030
2.8	670	Total			

Subcatchment F: non-vegetated final cover/construction laydown



DGP 30 JAN 02 172/282
PBM 1/30/02

Subcatchment G: non-vegetated final cover/construction laydown

Runoff = 18.59 cfs @ 11.98 hrs, Volume= 0.936 af

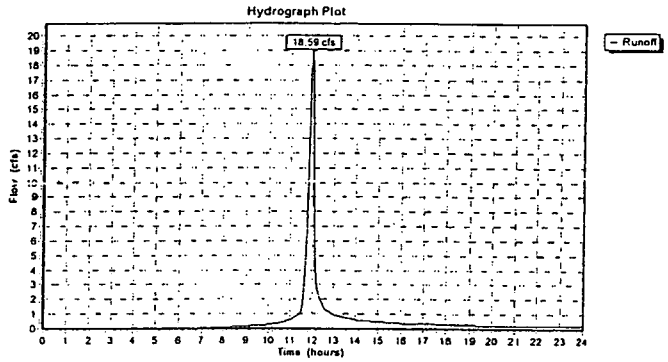
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

4664

Area (ac)	CN	Description
3.637	85	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	50	0.0500	1.6		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
1.4	230	0.1000	2.8		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.2	20	0.1700	2.1		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.3	110	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.9	450	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.5	130	0.0066	4.6	114.26	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.50' Z= 3.0 & 5.0 '/' n= 0.030
6.8	990	Total			

Subcatchment G: non-vegetated final cover/construction laydown



Subcatchment H: construction laydown area

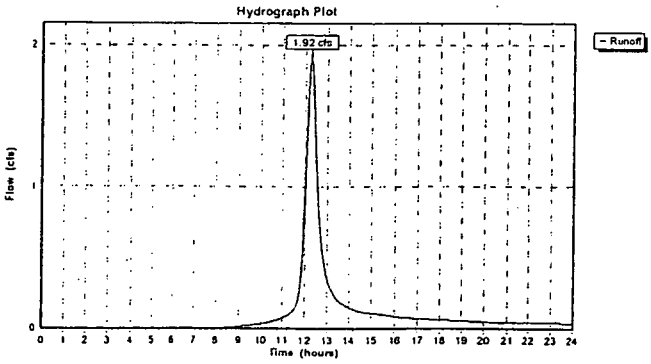
Runoff = 1.92 cfs @ 12.25 hrs, Volume= 0.185 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.797	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
30.1	300	0.0141	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	50	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
30.5	350	Total			

Subcatchment H: construction laydown area



Subcatchment I: construction laydown area

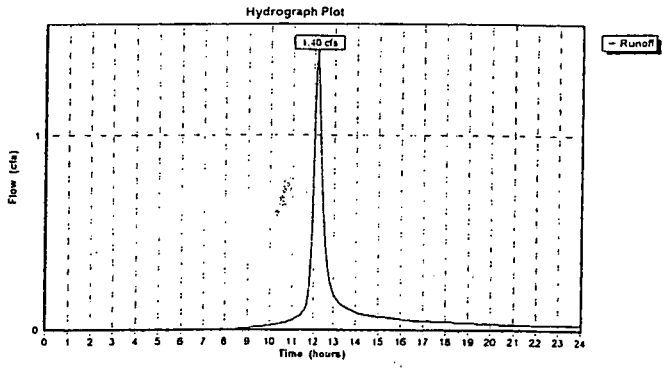
Runoff = 1.40 cfs @ 12.18 hrs, Volume= 0.119 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.512	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
24.8	300	0.0230	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	30	0.0230	2.4		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
25.0	330	Total			

Subcatchment I: construction laydown area



Subcatchment J: construction laydown area

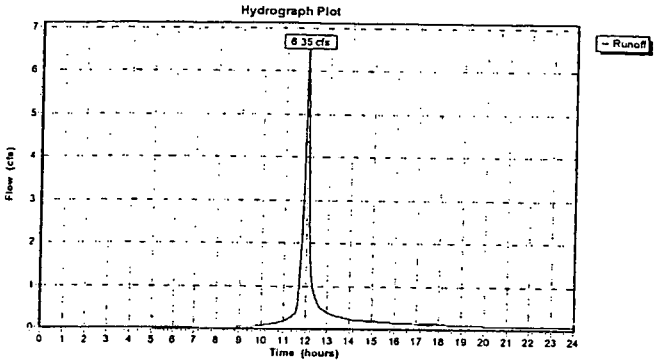
Runoff = 6.35 cfs @ 12.00 hrs, Volume= 0.340 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.452	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	110	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.0	350	0.0075	6.0	221.03	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.50' Z= 3.0 '/' n= 0.030
9.1	460	Total			

Subcatchment J: construction laydown area



DGP 30 JAN 02 173/282
DBM 1/30/02

Subcatchment K: runon north of borrow area

Runoff = 2.40 cfs @ 12.09 hrs, Volume= 0.162 af

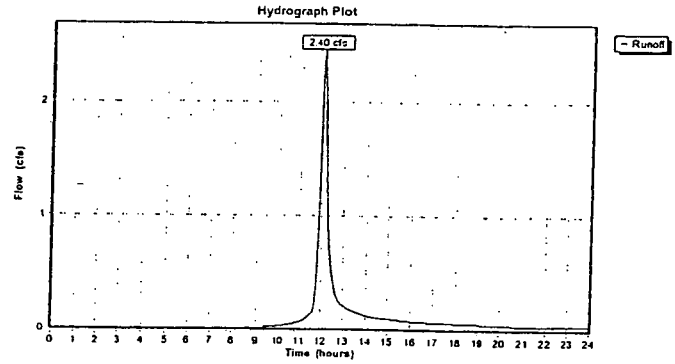
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.765	79	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.4	220	0.0347	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment K: runon north of borrow area



Subcatchment L: construction laydown area

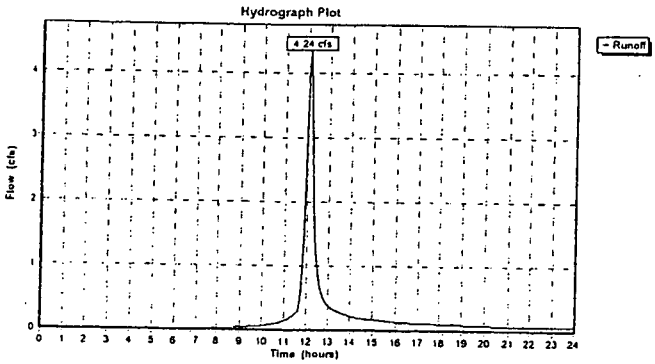
Runoff = 4.24 cfs @ 12.10 hrs, Volume= 0.298 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.277	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.7	220	0.0285	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment L: construction laydown area



Subcatchment M: runon north of borrow area

[49] Hint: Tc<2dt may require smaller dt

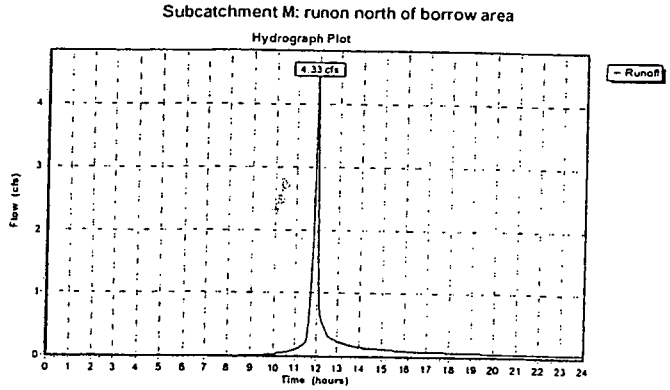
Runoff = 4.33 cfs @ 11.96 hrs, Volume= 0.204 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.964	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.0	390	0.0110	6.6	177.46	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
5.3	440	Total			

Subcatchment M: runon north of borrow area



Subcatchment N: construction laydown area

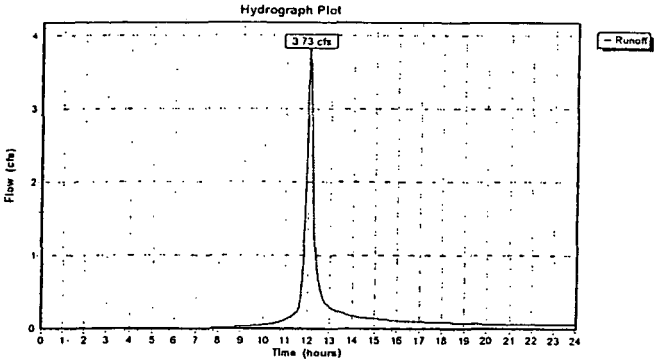
Runoff = 3.73 cfs @ 12.07 hrs, Volume= 0.244 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.043	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.2	170	0.0250	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment N: construction laydown area



DGP 31 JAN 02 174/282
DBM 1/30/02

Subcatchment O: pond

[49] Hint: Tc<2dt may require smaller dt

Runoff = 16.67 cfs @ 11.90 hrs, Volume= 0.838 af

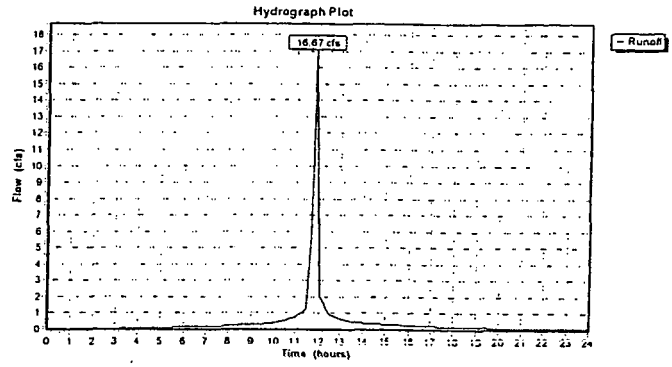
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
2.252	98	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment O: pond



Subcatchment P: construction laydown area

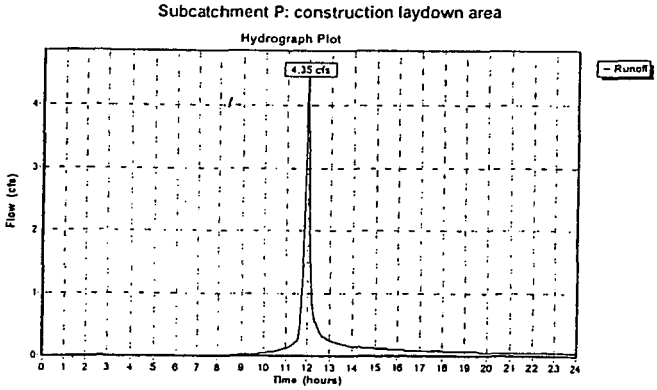
Runoff = 4.35 cfs @ 11.99 hrs, Volume= 0.221 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.943	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.7	235	0.0075	6.0	221.03	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.50' Z= 3.0 '/' n= 0.030
7.6	325	Total			

Subcatchment P: construction laydown area



Reach 1: west channel

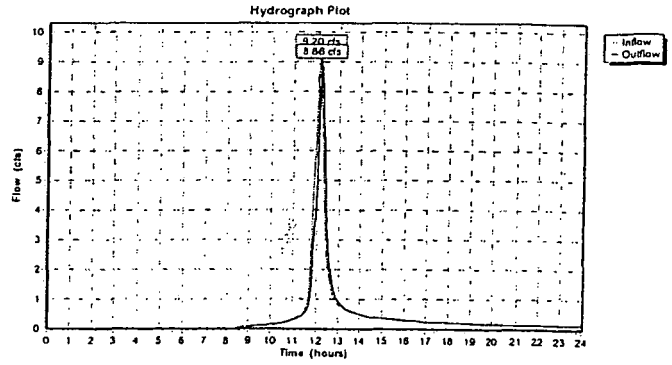
[65] Warning: Inlet elevation not specified

Inflow = 9.20 cfs @ 12.11 hrs, Volume= 0.658 af
Outflow = 8.86 cfs @ 12.19 hrs, Volume= 0.656 af, Atten= 4%, Lag= 4.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.5 fps, Min. Travel Time= 2.7 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 6.8 min

Peak Depth= 0.90'
Capacity at bank full= 223.61 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 400.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 1: west channel



Reach 2: west channel

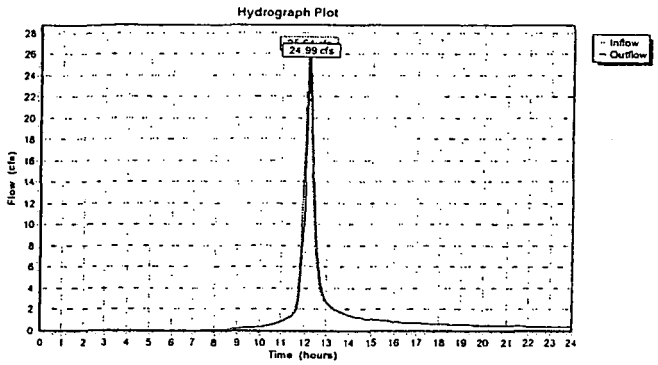
[65] Warning: Inlet elevation not specified

Inflow = 25.64 cfs @ 12.14 hrs, Volume= 1.943 af
Outflow = 24.99 cfs @ 12.20 hrs, Volume= 1.939 af, Atten= 3%, Lag= 3.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.2 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 5.2 min

Peak Depth= 1.32'
Capacity at bank full= 223.61 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 400.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 2: west channel



DCP 30 JAN 02
DBM 1/30/02

175/282

Reach 3: west channel

[65] Warning: Inlet elevation not specified

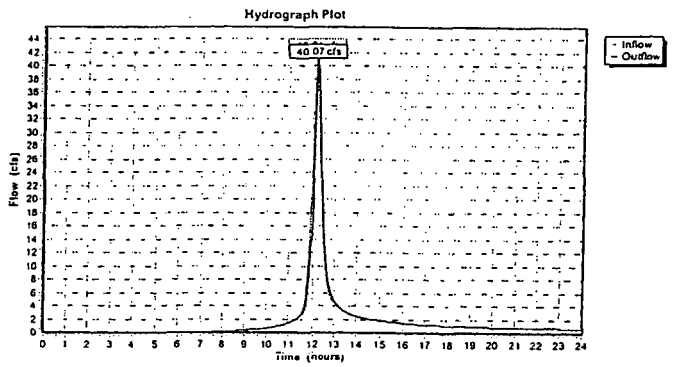
Inflow = 40.94 cfs @ 12.17 hrs, Volume= 3.240 af
Outflow = 40.07 cfs @ 12.22 hrs, Volume= 3.234 af, Atten= 2%, Lag= 3.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.6 fps, Min. Travel Time= 1.9 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 4.6 min

- 4664

Peak Depth= 1.58'
Capacity at bank full= 223.61 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 400.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 3: west channel



Reach 4: west channel

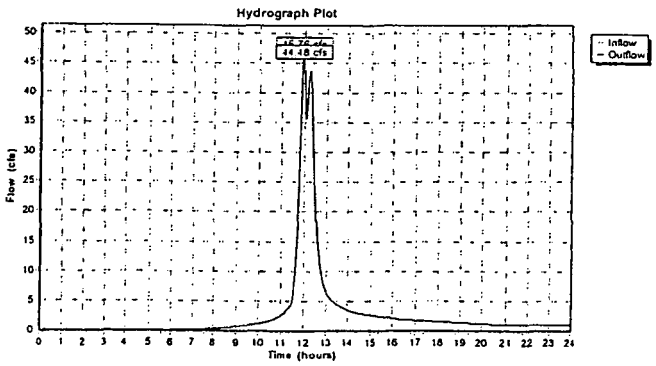
[65] Warning: Inlet elevation not specified

Inflow = 45.76 cfs @ 11.96 hrs, Volume= 4.839 af
Outflow = 44.48 cfs @ 11.98 hrs, Volume= 4.837 af, Atten= 3%, Lag= 0.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.7 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 1.0 min

Peak Depth= 1.65'
Capacity at bank full= 224.44 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 90.0' Slope= 0.0076 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 4: west channel



Reach 5: culvert

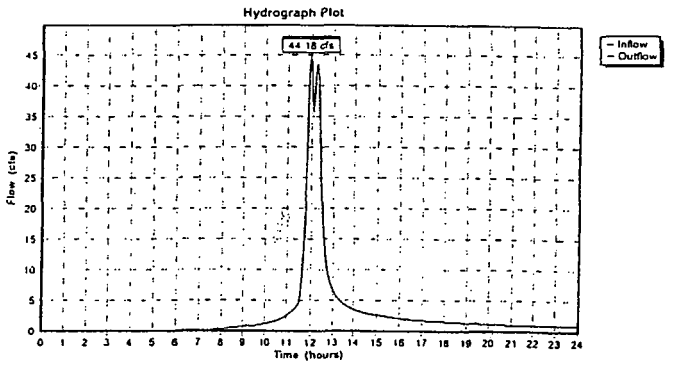
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 44.48 cfs @ 11.98 hrs, Volume= 4.837 af
Outflow = 44.18 cfs @ 11.99 hrs, Volume= 4.835 af, Atten= 1%, Lag= 0.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.6 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 1.0 min

Peak Depth= 1.36'
Capacity at bank full= 397.33 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.024 Length= 100.0' Slope= 0.0075 '/'

Reach 5: culvert



Reach 6: west channel

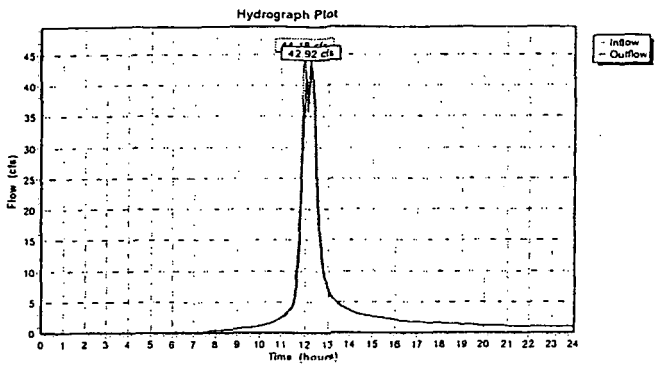
[65] Warning: Inlet elevation not specified

Inflow = 44.18 cfs @ 11.99 hrs, Volume= 4.835 af
Outflow = 42.92 cfs @ 12.29 hrs, Volume= 4.827 af, Atten= 3%, Lag= 18.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.7 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 4.1 min

Peak Depth= 1.62'
Capacity at bank full= 337.31 cfs
0.00' x 3.50' deep channel, n= 0.030 Length= 380.0' Slope= 0.0075 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 6: west channel



DCI 30 JAN 02 DBM 1/30/02 176/282

Reach 7: west channel

[65] Warning: Inlet elevation not specified

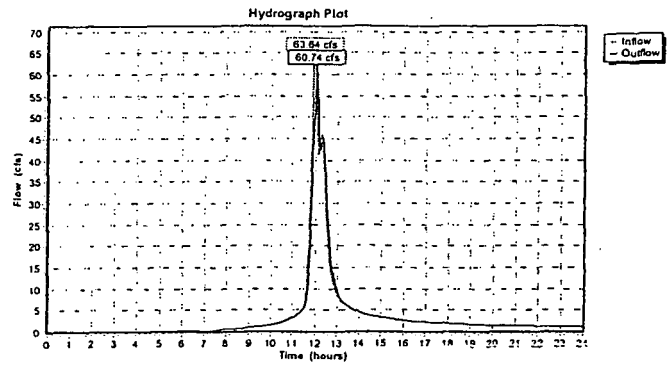
Inflow = 63.64 cfs @ 11.99 hrs, Volume= 6.222 af
Outflow = 60.74 cfs @ 12.05 hrs, Volume= 6.210 af, Atten= 5%, Lag= 3.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.4 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 5.1 min

4664

Peak Depth= 2.17'
Capacity at bank full= 315.77 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 550.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 7: west channel



Reach 8: west channel

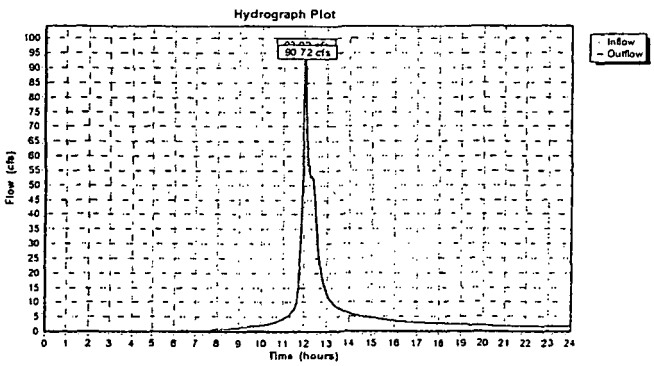
[65] Warning: Inlet elevation not specified

Inflow = 93.02 cfs @ 12.02 hrs, Volume= 8.386 af
Outflow = 90.72 cfs @ 12.05 hrs, Volume= 8.378 af, Atten= 2%, Lag= 1.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.8 fps, Min. Travel Time= 1.0 min
Avg. Velocity = 1.9 fps, Avg. Travel Time= 2.4 min

Peak Depth= 2.52'
Capacity at bank full= 315.58 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 280.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 8: west channel



Reach 9: channel

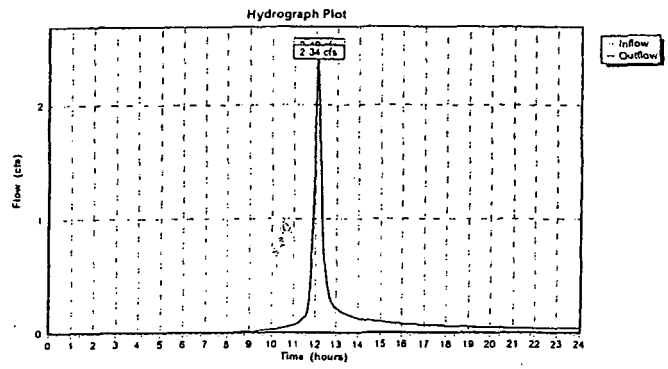
[65] Warning: Inlet elevation not specified

Inflow = 2.40 cfs @ 12.09 hrs, Volume= 0.162 af
Outflow = 2.34 cfs @ 12.12 hrs, Volume= 0.161 af, Atten= 2%, Lag= 1.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.1 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 2.7 min

Peak Depth= 0.51'
Capacity at bank full= 43.05 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 200.0' Slope= 0.0261 '/'
Side Slope Z-value= 3.0 '/'

Reach 9: channel



Reach 10: access road diversion channel

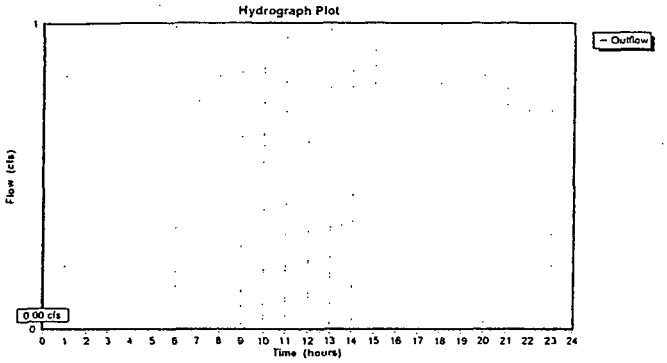
[43] Hint: Has no inflow (Outflow=Zero)

Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

outing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.0 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.0 fps, Avg. Travel Time= 0.0 min

Peak Depth= 0.00'
Capacity at bank full= 32.43 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 260.0' Slope= 0.0148 '/'
Side Slope Z-value= 3.0 '/'

Reach 10: access road diversion channel



DGP 30JAN 02
DBM 1/30/02

177/282

Reach 11: access road diversion channel

[65] Warning: Inlet elevation not specified

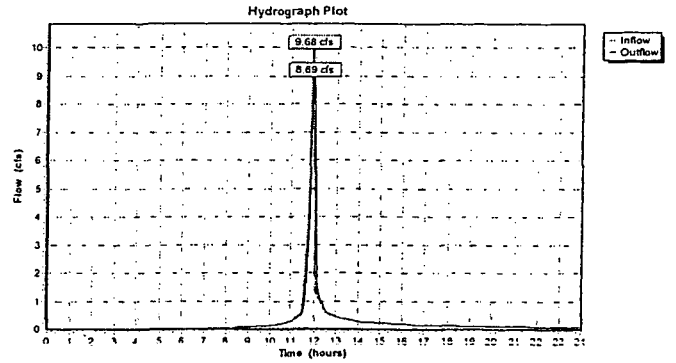
Inflow = 9.68 cfs @ 11.93 hrs, Volume= 0.436 af
Outflow = 8.69 cfs @ 11.98 hrs, Volume= 0.435 af, Atten= 10%, Lag= 3.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.6 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 5.7 min

4664

Peak Depth= 1.08'
Capacity at bank full= 84.62 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 310.0' Slope= 0.0066 '/'
Side Slope Z-value= 3.0 '/'

Reach 11: access road diversion channel



Reach 12: culvert

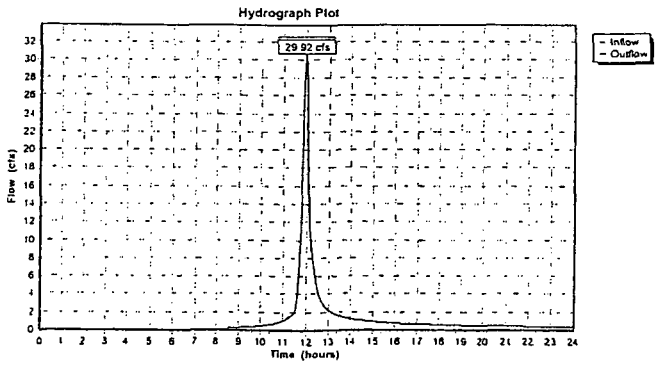
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 30.19 cfs @ 11.99 hrs, Volume= 1.837 af
Outflow = 29.92 cfs @ 11.99 hrs, Volume= 1.836 af, Atten= 1%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 8.5 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.7 fps, Avg. Travel Time= 0.7 min

Peak Depth= 0.68'
Capacity at bank full= 1,112.19 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.013 Length= 116.0' Slope= 0.0172 '/'

Reach 12: culvert



Reach 13: culvert

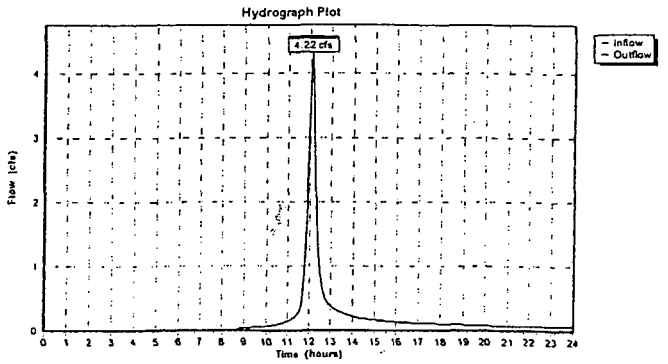
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 4.24 cfs @ 12.10 hrs, Volume= 0.298 af
Outflow = 4.22 cfs @ 12.11 hrs, Volume= 0.298 af, Atten= 1%, Lag= 0.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.5 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 0.6 min

Peak Depth= 0.28'
Capacity at bank full= 1,040.04 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.013 Length= 65.0' Slope= 0.0151 '/'

Reach 13: culvert



Reach 14: culvert

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

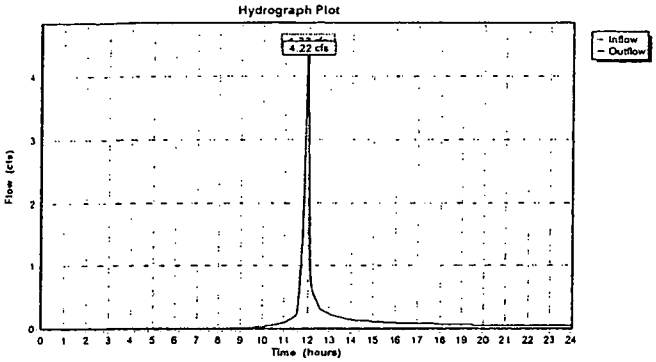
Outflow	=	4.33 cfs @	11.96 hrs,	Volume=	0.204 af
Inflow	=	4.22 cfs @	11.98 hrs,	Volume=	0.204 af, Atten= 3%, Lag= 0.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.8 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.4 fps, Avg. Travel Time= 1.3 min

Peak Depth= 0.31'
Capacity at bank full= 822.56 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.024 Length= 112.0' Slope= 0.0321 '/'

Reach 14: culvert

Hydrograph Plot



DCP 31 JAN 02 178/282
DBM 1/30/02

Pond 1P: Sedimentation Basin 2

Inflow	=	106.51 cfs @	12.04 hrs,	Volume=	10.182 af
Outflow	=	2.73 cfs @	19.11 hrs,	Volume=	1.332 af, Atten= 97%, Lag= 424.0 min
Primary	=	2.73 cfs @	19.11 hrs,	Volume=	1.332 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Peak Elev= 575.66' Storage= 8.908 af
Plug-Flow detention time= 605.6 min calculated for 1.330 af (13% of inflow)
Storage and wetted areas determined by Conic sections

4664

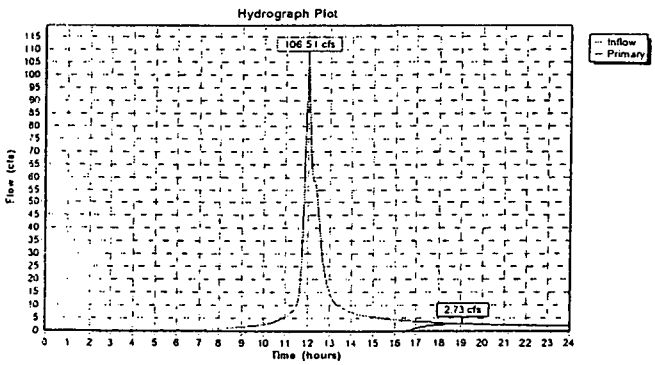
Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.50	1.460	0.000	0.000	1.460
571.00	1.512	0.743	0.743	1.513
572.00	1.614	1.563	2.306	1.617
573.00	1.713	1.663	3.969	1.719
574.00	1.819	1.766	5.735	1.827
575.00	1.917	1.868	7.602	1.928
576.00	2.026	1.971	9.574	2.039
577.00	2.162	2.094	11.667	2.177

Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.50'	**48.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600
2	Primary	570.78'	**36.0" x 680.0' long Culvert** Ke= 0.700 Outlet Invert= 563.30' S= 0.0110 '/' n= 0.024 Cc= 0.900
3	Primary	576.00'	**20.0' long Broad-Crested Rectangular Weir** Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00 Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Pond 1P: Sedimentation Basin 2

Hydrograph Plot



Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DGP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

WEST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO
100-YEAR, 24-HOUR STORM EVENT

DGP 30 JAN 02
JBM 1/30/02 180/282

Pond 1P: Sedimentation Basin 2

4664

Inflow	=	135.91 cfs @	12.04 hrs, Volume=	12.886 af	
Outflow	=	8.01 cfs @	14.26 hrs, Volume=	4.002 af,	Atten= 94%, Lag= 133.5 min
Primary	=	8.01 cfs @	14.26 hrs, Volume=	4.002 af	

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Peak Elev= 575.84' Storage= 9.250 af
Plug-Flow detention time= 378.6 min calculated for 4.002 af (31% of inflow)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.50	1.460	0.000	0.000	1.460
571.00	1.512	0.743	0.743	1.513
572.00	1.614	1.563	2.306	1.617
573.00	1.713	1.663	3.969	1.719
574.00	1.819	1.766	5.735	1.827
575.00	1.917	1.868	7.602	1.928
576.00	2.026	1.971	9.574	2.039
577.00	2.162	2.094	11.667	2.177

Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.50'	**48.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600
2	Primary	570.78'	**36.0" x 680.0' long Culvert** Ke= 0.700
			Outlet Invert= 563.30' S= 0.0110 '/' n= 0.024 Cc= 0.900
3	Primary	576.00'	**20.0' long Broad-Crested Rectangular Weir**
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

DGP 30JAN02
DBM 1/30/02 181/282

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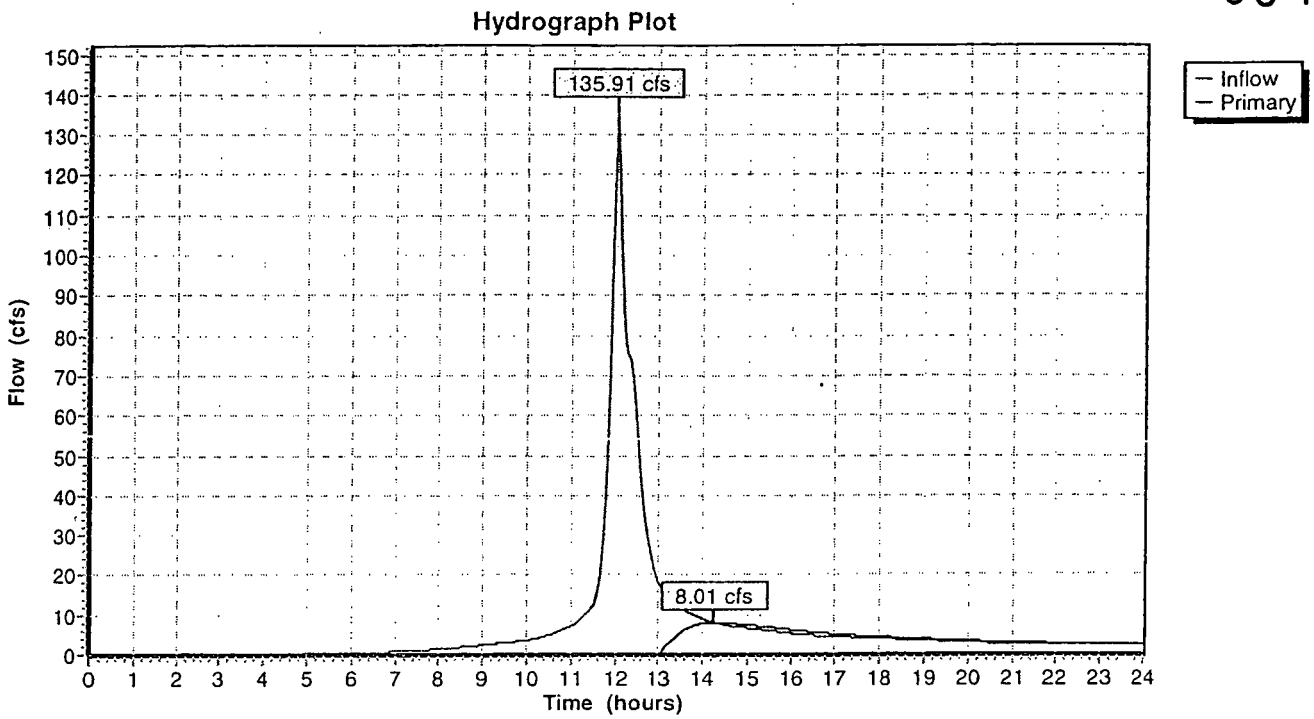
Pond 1P: Sedimentation Basin 2



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ATTACHMENT C-1C

HydroCAD™ OUTPUT REPORTS

EAST OSDF POST-DEVELOPMENT DESIGN SCENARIO

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

EAST OSDF POST-DEVELOPMENT DESIGN SCENARIO
2-YEAR, 24-HOUR STORM EVENT

-- 4664 DGP 30JAN02184/282

Time span=0.00-36.00 hrs, dt=0.05 hrs, 721 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=2.55"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover system
Tc=17.3 min CN=74 Area=1.964 ac Runoff= 1.34 cfs 0.104 af

Subcatchment AA: open space with good grass cover
Tc=16.8 min CN=74 Area=2.708 ac Runoff= 1.89 cfs 0.144 af

Subcatchment B: vegetated final cover system
Tc=6.2 min CN=74 Area=1.179 ac Runoff= 1.25 cfs 0.063 af

Subcatchment BB: open space with good grass cover
Tc=9.1 min CN=79 Area=0.761 ac Runoff= 1.02 cfs 0.055 af

Subcatchment C: vegetated final cover system
Tc=20.7 min CN=74 Area=5.209 ac Runoff= 3.18 cfs 0.276 af

Subcatchment CC: open space with good grass cover
Tc=6.7 min CN=79 Area=0.121 ac Runoff= 0.18 cfs 0.009 af

Subcatchment D: vegetated final cover system
Tc=20.1 min CN=74 Area=5.131 ac Runoff= 3.20 cfs 0.272 af

Subcatchment DD: vegetated final cover system
Tc=10.9 min CN=74 Area=0.544 ac Runoff= 0.47 cfs 0.029 af

Subcatchment E: vegetated final cover system
Tc=19.7 min CN=74 Area=5.092 ac Runoff= 3.21 cfs 0.270 af

Subcatchment EE: open space with good grass cover
Tc=25.4 min CN=77 Area=0.925 ac Runoff= 0.63 cfs 0.059 af

Subcatchment F: vegetated final cover system
Tc=19.7 min CN=74 Area=5.053 ac Runoff= 3.19 cfs 0.268 af

Subcatchment FF: vegetated final cover system
Tc=18.6 min CN=74 Area=3.089 ac Runoff= 2.02 cfs 0.164 af

Subcatchment G: vegetated final cover system
Tc=19.8 min CN=74 Area=5.309 ac Runoff= 3.34 cfs 0.282 af

Subcatchment GG: open space with good grass cover
Tc=28.3 min CN=67 Area=1.975 ac Runoff= 0.45 cfs 0.062 af

Subcatchment H: vegetated final cover system
Tc=19.0 min CN=74 Area=3.487 ac Runoff= 2.25 cfs 0.185 af

Subcatchment HH: open space with good grass cover
Tc=13.9 min CN=79 Area=0.548 ac Runoff= 0.62 cfs 0.040 af

Subcatchment I: open space with good grass cover
Tc=15.4 min CN=74 Area=1.690 ac Runoff= 1.23 cfs 0.090 af

Subcatchment II: open space with good grass cover
Tc=23.0 min CN=68 Area=1.669 ac Runoff= 0.50 cfs 0.057 af

Subcatchment J: open space with good grass cover
Tc=28.8 min CN=73 Area=2.647 ac Runoff= 1.18 cfs 0.131 af

Subcatchment JJ: open space with good grass cover
Tc=41.9 min CN=62 Area=0.914 ac Runoff= 0.07 cfs 0.018 af

Subcatchment K: open space with good grass cover
Tc=28.8 min CN=68 Area=4.135 ac Runoff= 1.05 cfs 0.141 af

Subcatchment KK: open space with good grass cover
Tc=36.4 min CN=64 Area=5.893 ac Runoff= 0.70 cfs 0.141 af

Subcatchment L: open space with good grass cover
Tc=15.4 min CN=76 Area=1.683 ac Runoff= 1.45 cfs 0.102 af

Subcatchment LL: open space with good grass cover
Tc=28.1 min CN=61 Area=7.049 ac Runoff= 0.54 cfs 0.124 af

Subcatchment M: open space with good grass cover
Tc=12.1 min CN=79 Area=1.000 ac Runoff= 1.20 cfs 0.073 af

Subcatchment MM: open space with good grass cover
Tc=9.9 min CN=81 Area=1.943 ac Runoff= 0.29 cfs 0.034 af

Subcatchment N: direct runon to pond
Tc=1.0 min CN=98 Area=7.818 ac Runoff= 31.03 cfs 1.512 af

Subcatchment NN: open space with good grass cover
Tc=1.4 min CN=66 Area=1.274 ac Runoff= 0.73 cfs 0.037 af

Subcatchment O: open space with good grass cover
Tc=1.3 min CN=79 Area=1.317 ac Runoff= 2.25 cfs 0.096 af

Subcatchment OO: open space with good grass cover
Tc=5.4 min CN=66 Area=0.399 ac Runoff= 0.19 cfs 0.012 af

Subcatchment P: open space with good grass cover
Tc=33.7 min CN=75 Area=5.238 ac Runoff= 2.50 cfs 0.297 af

Subcatchment PP: open space with good grass cover
Tc=79.5 min CN=64 Area=40.964 ac Runoff= 3.01 cfs 0.983 af

Subcatchment Q: open space with good grass cover
Tc=31.8 min CN=72 Area=7.700 ac Runoff= 2.89 cfs 0.356 af

Subcatchment R: open space with good grass cover
Tc=21.6 min CN=74 Area=2.612 ac Runoff= 1.55 cfs 0.139 af

Subcatchment S: open space with good grass cover
Tc=27.9 min CN=78 Area=0.402 ac Runoff= 0.28 cfs 0.027 af

Subcatchment T: direct runon to pond
Tc=1.0 min CN=98 Area=0.416 ac Runoff= 1.65 cfs 0.080 af

Subcatchment U: open space with good grass cover
Tc=32.3 min CN=72 Area=4.149 ac Runoff= 1.54 cfs 0.192 af

Subcatchment V: direct runon to pond
Tc=1.0 min CN=98 Area=0.274 ac Runoff= 1.09 cfs 0.053 af

Subcatchment W: open space with good grass cover
Tc=12.6 min CN=72 Area=10.593 ac Runoff= 7.22 cfs 0.490 af

Subcatchment X: open space with good grass cover
Tc=33.4 min CN=71 Area=11.853 ac Runoff= 3.87 cfs 0.510 af

Subcatchment Y: open space with good grass cover
Tc=36.8 min CN=73 Area=6.522 ac Runoff= 2.43 cfs 0.323 af

Subcatchment Z: open space with good grass cover
Tc=23.7 min CN=72 Area=1.606 ac Runoff= 0.74 cfs 0.074 af

Reach 1: east drainage channel — Inflow= 2.09 cfs 0.167 af
Length= 420.0' Max Vel= 1.3 fps Capacity= 754.76 cfs Outflow= 1.79 cfs 0.167 af

Reach 1R: (new node) — Inflow= 0.54 cfs 0.124 af
Length= 100.0' Max Vel= 2.6 fps Capacity= 1,101.12 cfs Outflow= 0.54 cfs 0.124 af

Reach 2: east drainage channel — Inflow= 4.96 cfs 0.443 af
Length= 420.0' Max Vel= 1.8 fps Capacity= 1,205.98 cfs Outflow= 4.62 cfs 0.443 af

Reach 2R: (new node) — Inflow= 0.29 cfs 0.034 af
Length= 100.0' Max Vel= 2.1 fps Capacity= 1,101.12 cfs Outflow= 0.27 cfs 0.034 af

Reach 3: east drainage channel — Inflow= 7.06 cfs 0.715 af
Length= 420.0' Max Vel= 2.1 fps Capacity= 1,563.67 cfs Outflow= 6.83 cfs 0.715 af

Reach 3R: (new node) — Inflow= 0.73 cfs 0.037 af
Length= 100.0' Max Vel= 2.7 fps Capacity= 1,101.12 cfs Outflow= 0.67 cfs 0.037 af

Reach 4: east drainage channel — Inflow= 8.67 cfs 0.985 af
Length= 420.0' Max Vel= 2.2 fps Capacity= 1,106.53 cfs Outflow= 8.51 cfs 0.985 af

Reach 5: east drainage channel — Inflow= 9.97 cfs 1.253 af
Length= 440.0' Max Vel= 2.2 fps Capacity= 182.58 cfs Outflow= 9.82 cfs 1.253 af

Reach 6: east drainage channel — Inflow= 11.07 cfs 1.535 af
Length= 480.0' Max Vel= 2.9 fps Capacity= 258.21 cfs Outflow= 10.99 cfs 1.535 af

Reach 7: runoff diversion channel — Inflow= 11.66 cfs 1.720 af
Length= 140.0' Max Vel= 2.9 fps Capacity= 556.08 cfs Outflow= 11.63 cfs 1.720 af

Reach 8: runoff diversion channel — Inflow= 10.72 cfs 1.919 af
Length= 20.0' Max Vel= 1.5 fps Capacity= 1,379.30 cfs Outflow= 10.71 cfs 1.919 af

Reach 9: runoff diversion channel — Inflow= 10.71 cfs 1.919 af
Length= 295.0' Max Vel= 1.9 fps Capacity= 407.65 cfs Outflow= 10.67 cfs 1.919 af

Reach 10: runoff diversion channel — Inflow= 11.44 cfs 2.214 af
Length= 610.0' Max Vel= 1.9 fps Capacity= 134.00 cfs Outflow= 11.30 cfs 2.214 af

Reach 11: new CMP arch — Inflow= 11.82 cfs 2.417 af
Length= 65.0' Max Vel= 3.2 fps Capacity= 408.61 cfs Outflow= 11.81 cfs 2.417 af

Reach 12: runoff diversion channel — Inflow= 11.81 cfs 2.417 af
Length= 270.0' Max Vel= 2.0 fps Capacity= 134.16 cfs Outflow= 11.77 cfs 2.417 af

Reach 13: runoff diversion channel — Inflow= 22.39 cfs 5.420 af
Length= 450.0' Max Vel= 2.0 fps Capacity= 235.94 cfs Outflow= 22.29 cfs 5.418 af

Reach 14: east runon channel — Inflow= 0.18 cfs 0.009 af
Length= 420.0' Max Vel= 0.7 fps Capacity= 22.78 cfs Outflow= 0.11 cfs 0.009 af

Reach 15: east runon channel — Inflow= 1.04 cfs 0.064 af
Length= 420.0' Max Vel= 1.3 fps Capacity= 61.62 cfs Outflow= 0.86 cfs 0.064 af

Reach 16: east runon channel — Inflow= 2.68 cfs 0.208 af
Length= 420.0' Max Vel= 1.9 fps Capacity= 256.58 cfs Outflow= 2.47 cfs 0.208 af

Reach 17: east runon channel — Inflow= 3.20 cfs 0.282 af
Length= 420.0' Max Vel= 2.3 fps Capacity= 436.18 cfs Outflow= 3.08 cfs 0.282 af

Reach 18: east runon channel — Inflow= 5.48 cfs 0.605 af
Length= 440.0' Max Vel= 2.6 fps Capacity= 169.20 cfs Outflow= 5.35 cfs 0.605 af

Reach 19: east runon channel — Inflow= 9.08 cfs 1.115 af
Length= 470.0' Max Vel= 1.9 fps Capacity= 911.12 cfs Outflow= 8.71 cfs 1.115 af

Reach 20: east runon channel — Inflow= 10.07 cfs 1.605 af
Length= 75.0' Max Vel= 2.9 fps Capacity= 153.84 cfs Outflow= 10.03 cfs 1.605 af

Reach 21: east runon channel — Inflow= 7.74 cfs 1.817 af
Length= 65.0' Max Vel= 2.9 fps Capacity= 169.20 cfs Outflow= 7.74 cfs 1.817 af

Reach 22: east runon channel — Inflow= 7.81 cfs 1.844 af
Length= 190.0' Max Vel= 2.9 fps Capacity= 364.40 cfs Outflow= 7.80 cfs 1.844 af

Reach 23: new CMP culverts — Inflow= 8.22 cfs 2.042 af
Length= 95.0' Max Vel= 3.2 fps Capacity= 473.85 cfs Outflow= 8.21 cfs 2.042 af

Reach 24: runon channel — Inflow= 9.31 cfs 2.398 af
Length= 160.0' Max Vel= 2.2 fps Capacity= 153.54 cfs Outflow= 9.29 cfs 2.397 af

Reach 25: new CMP arch — Inflow= 10.27 cfs 2.694 af
Length= 60.0' Max Vel= 3.3 fps Capacity= 453.67 cfs Outflow= 10.26 cfs 2.694 af

Reach 26: runon channel — Inflow= 10.26 cfs 2.694 af
Length= 300.0' Max Vel= 2.8 fps Capacity= 90.11 cfs Outflow= 10.24 cfs 2.694 af

Reach 27: new CMP arch — Inflow= 10.41 cfs 2.795 af
Length= 110.0' Max Vel= 3.3 fps Capacity= 455.55 cfs Outflow= 10.40 cfs 2.795 af

Reach 28: new CMP culverts — Inflow= 11.45 cfs 2.214 af
Length= 65.0' Max Vel= 3.2 fps Capacity= 408.61 cfs Outflow= 11.44 cfs 2.214 af

Reach 29: east runon channel — Inflow= 7.95 cfs 1.904 af
Length= 230.0' Max Vel= 2.9 fps Capacity= 255.23 cfs Outflow= 7.93 cfs 1.903 af

Reach 30: east runon channel — Inflow= 7.74 cfs 1.817 af
Length= 30.0' Max Vel= 2.9 fps Capacity= 104.05 cfs Outflow= 7.74 cfs 1.817 af

Reach 31: culvert — Inflow= 2.25 cfs 0.096 af
Length= 80.0' Max Vel= 3.5 fps Capacity= 946.99 cfs Outflow= 2.19 cfs 0.096 af

Pond 1P: (new node) — Peak Storage= 1.082 af Inflow= 11.25 cfs 1.850 af
Primary= 7.74 cfs 1.817 af Outflow= 7.74 cfs 1.817 af

Pond 2P: (new node) — Peak Storage= 1.509 af Inflow= 12.06 cfs 1.919 af
Primary= 10.72 cfs 1.919 af Outflow= 10.72 cfs 1.919 af

Pond 3P: Borrow Area Basin — Peak Storage= 8.141 af Inflow= 31.84 cfs 8.141 af
Primary= 0.00 cfs 0.000 af Outflow= 0.00 cfs 0.000 af

DCP 30JAN02 185/282
UBM 1/30/02

Runoff Area = 174.855 ac Volume = 8.373 af Average Depth = 0.57"

- 4664

Subcatchment A: vegetated final cover system

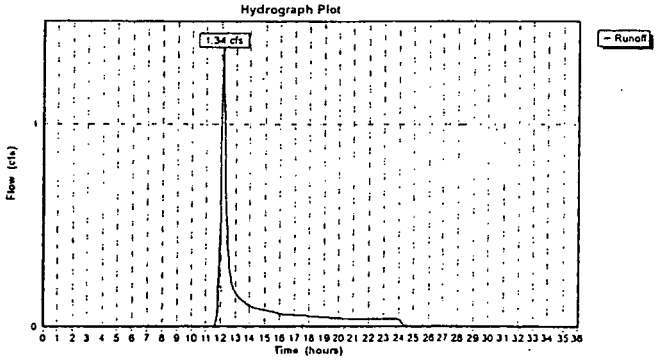
Runoff = 1.34 cfs @ 12.12 hrs, Volume= 0.104 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.964	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	80	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
17.3	380	Total			

Subcatchment A: vegetated final cover system



Subcatchment AA: open space with good grass cover

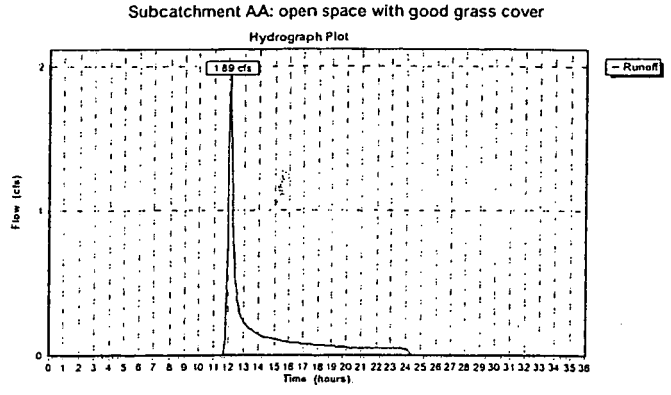
Runoff = 1.89 cfs @ 12.11 hrs, Volume= 0.144 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
2.708	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0	300	0.0800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.6	170	0.0800	4.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	300	0.0070	4.0	48.01	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
16.8	770	Total			

Subcatchment AA: open space with good grass cover



Subcatchment B: vegetated final cover system

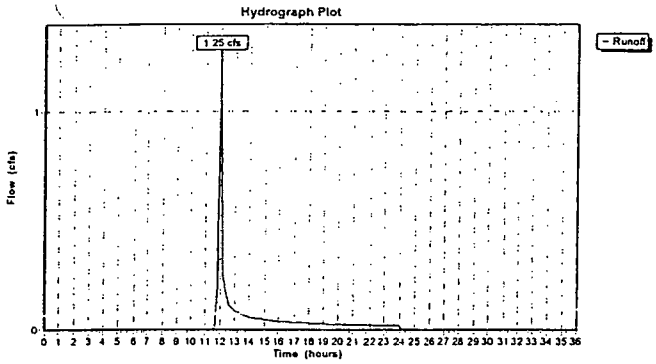
Runoff = 1.25 cfs @ 11.99 hrs, Volume= 0.063 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.179	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	50	0.1800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.6	450	0.0045	2.1	9.75	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.02' Z= 6.0 & 3.0 '/' n= 0.030
6.2	500	Total			

Subcatchment B: vegetated final cover system



UGT 30 JAN 02 DBH 1/30/02 186/282

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Subcatchment BB: open space with good grass cover

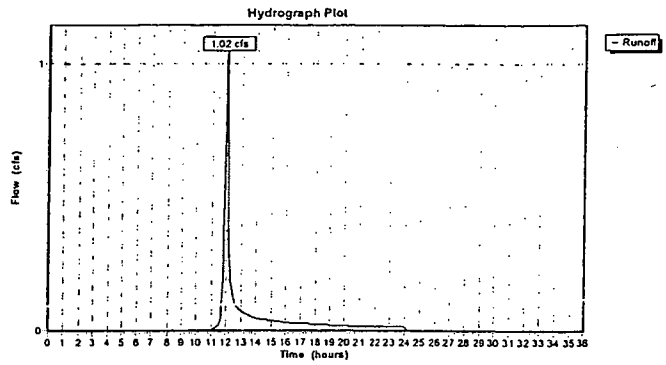
Runoff = 1.02 cfs @ 12.01 hrs, Volume= 0.055 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.761	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	110	0.0800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.4	360	0.0040	2.5	22.78	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.50' Z= 3.0 & 5.0 '/' n= 0.030
9.1	470	Total			

Subcatchment BB: open space with good grass cover



Subcatchment C: vegetated final cover system

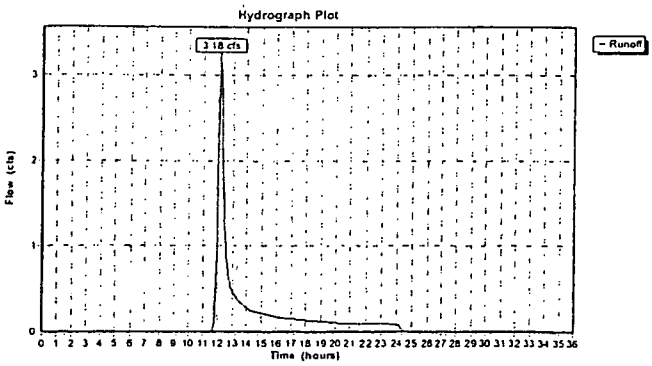
Runoff = 3.18 cfs @ 12.16 hrs, Volume= 0.276 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.209	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.2	400	0.0045	2.1	10.88	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.02' Z= 6.0 & 4.0 '/' n= 0.030
20.7	870	Total			

Subcatchment C: vegetated final cover system



Subcatchment CC: open space with good grass cover

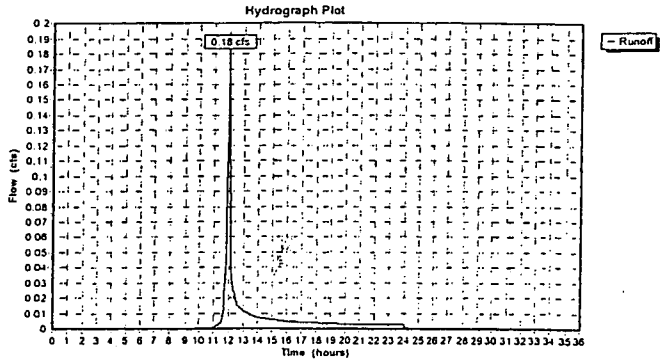
Runoff = 0.18 cfs @ 11.99 hrs, Volume= 0.009 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.121	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	110	0.0800	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment CC: open space with good grass cover



DCP 30 JAN 02 DBM 1/30/02 187/282

Subcatchment D: vegetated final cover system

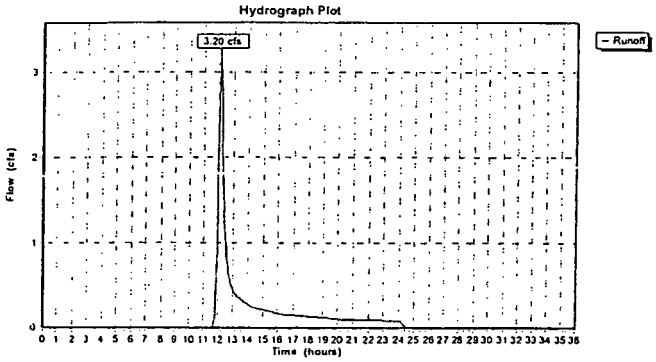
Runoff = 3.20 cfs @ 12.15 hrs, Volume= 0.272 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.131	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.7	250	0.0045	2.4	16.16	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.29' Z= 5.0 & 3.0 '/' n= 0.030
0.9	150	0.0050	2.9	25.90	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.59' Z= 4.0 & 3.0 '/' n= 0.030
20.1	870	Total			

Subcatchment D: vegetated final cover system



Subcatchment DD: vegetated final cover system

Runoff = 0.47 cfs @ 12.04 hrs, Volume= 0.029 af

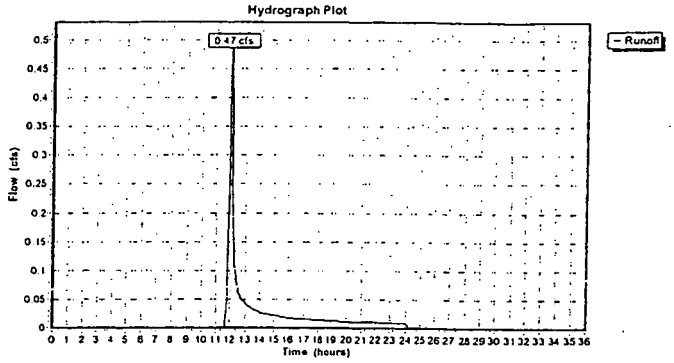
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.544	74	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.0	230	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.9	20	0.0600	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
10.9	250	Total			

Subcatchment DD: vegetated final cover system



Subcatchment E: vegetated final cover system

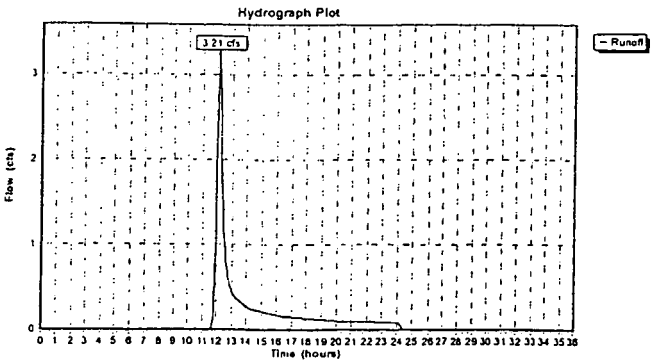
Runoff = 3.21 cfs @ 12.15 hrs, Volume= 0.270 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.092	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.2	380	0.0050	2.9	26.33	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.60' Z= 4.0 & 3.0 '/' n= 0.030
19.7	850	Total			

Subcatchment E: vegetated final cover system



Subcatchment EE: open space with good grass cover

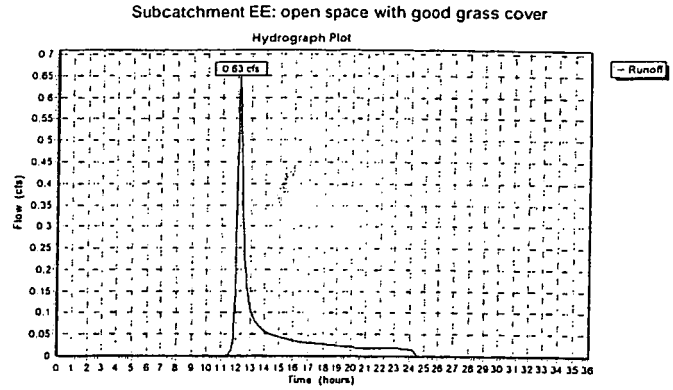
Runoff = 0.63 cfs @ 12.21 hrs, Volume= 0.059 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.925	77	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
24.8	300	0.0230	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	80	0.0230	2.4		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.1	40	0.0100	7.6	364.40	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.00' Z= 3.0 '/' n= 0.030
25.4	420	Total			

Subcatchment EE: open space with good grass cover



DGF 30 JAN 02 DBM 1/30/02 188/282

Subcatchment F: vegetated final cover system

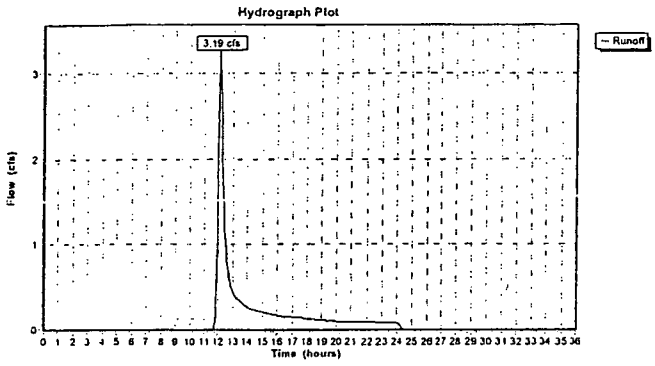
Runoff = 3.19 cfs @ 12.15 hrs, Volume= 0.268 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.053	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.2	390	0.0050	2.9	26.33	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.60' Z= 4.0 & 3.0 '/' n= 0.030
19.7	860	Total			

Subcatchment F: vegetated final cover system



Subcatchment FF: vegetated final cover system

Runoff = 2.02 cfs @ 12.13 hrs, Volume= 0.164 af

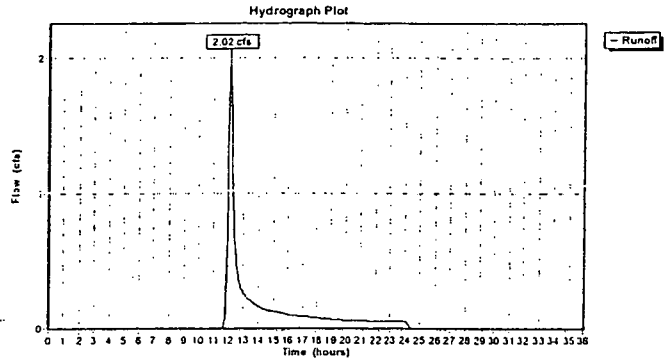
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
3.089	74	

— 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	210	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.0	120	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
18.6	630	Total			

Subcatchment FF: vegetated final cover system



Subcatchment G: vegetated final cover system

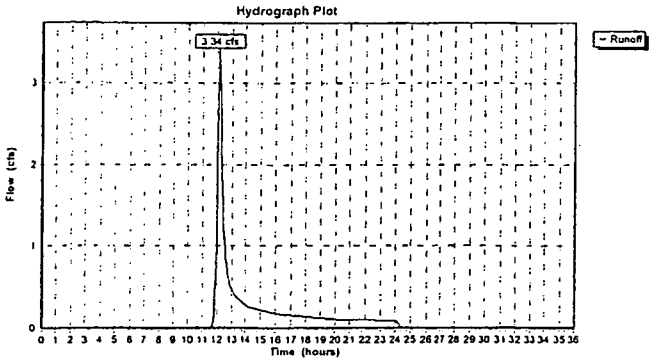
Runoff = 3.34 cfs @ 12.15 hrs, Volume= 0.282 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.309	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.3	410	0.0050	2.9	26.33	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.60' Z= 4.0 & 3.0 '/' n= 0.030
19.8	880	Total			

Subcatchment G: vegetated final cover system



Subcatchment GG: open space with good grass cover

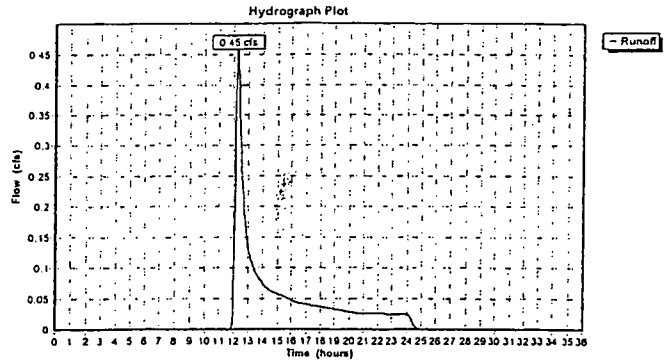
Runoff = 0.45 cfs @ 12.30 hrs, Volume= 0.062 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.975	67	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.2	300	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.1	290	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
28.3	590	Total			

Subcatchment GG: open space with good grass cover



DGP 30 JAN 02 DBM 1/30/02 189/282

Subcatchment H: vegetated final cover system

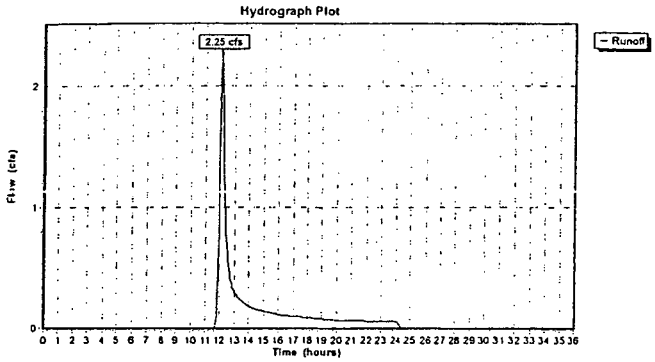
Runoff = 2.25 cfs @ 12.14 hrs, Volume= 0.185 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
3.487	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	140	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.5	440	0.0100	4.8	57.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
19.0	880	Total			

Subcatchment H: vegetated final cover system



Subcatchment HH: open space with good grass cover

Runoff = 0.62 cfs @ 12.07 hrs, Volume= 0.040 af

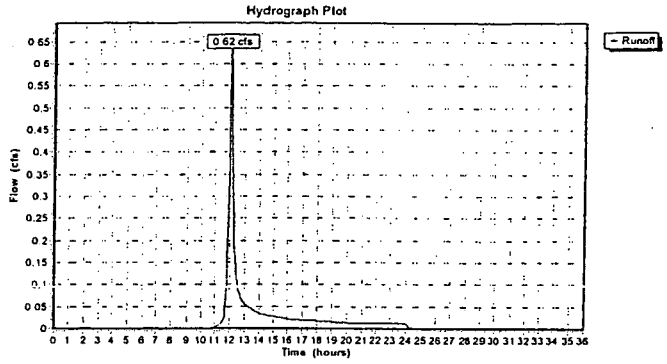
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.548	79	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.2	90	0.0100	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.7	230	0.0045	5.1	352.87	Trap/Vee/Rect Channel Flow, Bot.W=20.00' D=2.50' Z= 3.0 '/' n= 0.030
13.9	320	Total			

Subcatchment HH: open space with good grass cover



Subcatchment I: open space with good grass cover

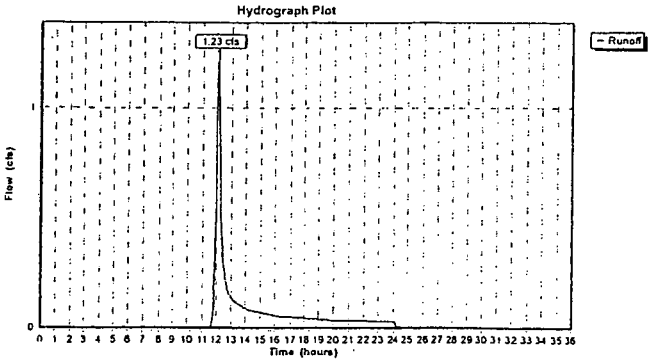
Runoff = 1.23 cfs @ 12.10 hrs, Volume= 0.090 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.690	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.4	230	0.0440	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment I: open space with good grass cover



Subcatchment II: open space with good grass cover

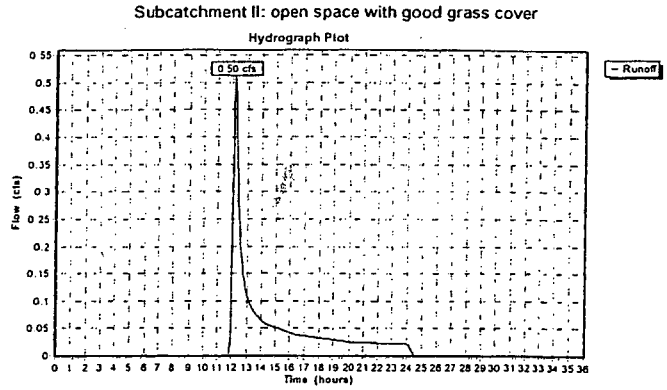
Runoff = 0.50 cfs @ 12.21 hrs, Volume= 0.057 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.669	68	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.9	210	0.0400	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	70	0.1660	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
7.9	380	0.0025	0.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
23.0	660	Total			

Subcatchment II: open space with good grass cover



Subcatchment J: open space with good grass cover

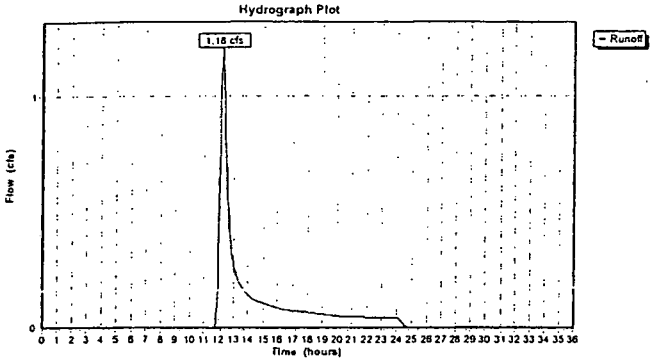
Runoff = 1.18 cfs @ 12.27 hrs, Volume= 0.131 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
2.647	73	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.6	300	0.0176	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.2	150	0.0176	2.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
28.8	450	Total			

Subcatchment J: open space with good grass cover



DGP 30JAN02 190/282
DBM 1/30/02

Subcatchment JJ: open space with good grass cover

Runoff = 0.07 cfs @ 12.58 hrs, Volume= 0.018 af

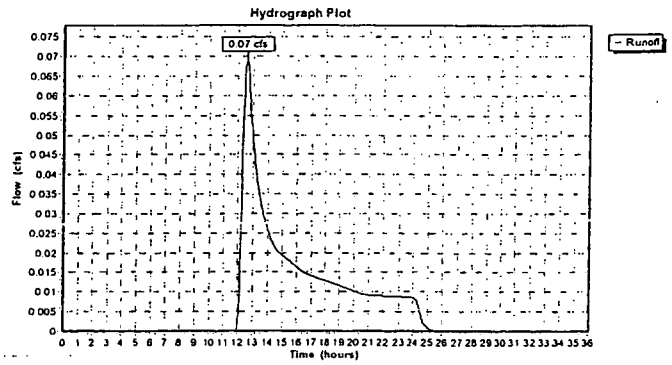
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.914	62	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
23.9	300	0.0250	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	40	0.0250	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.3	110	0.1660	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
17.4	840	0.0025	0.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
41.9	1,290	Total			

Subcatchment JJ: open space with good grass cover



Subcatchment K: open space with good grass cover

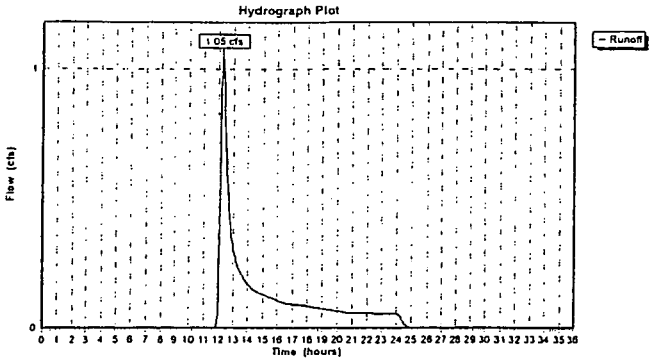
Runoff = 1.05 cfs @ 12.30 hrs, Volume= 0.141 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
4.135	68	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.2	300	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.8	250	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	200	0.0045	4.2	133.88	Trap/Vee/Rect Channel Flow, Bot.W=10.00' D=2.00' Z= 3.0 '/' n= 0.030
28.8	750	Total			

Subcatchment K: open space with good grass cover



Subcatchment KK: open space with good grass cover

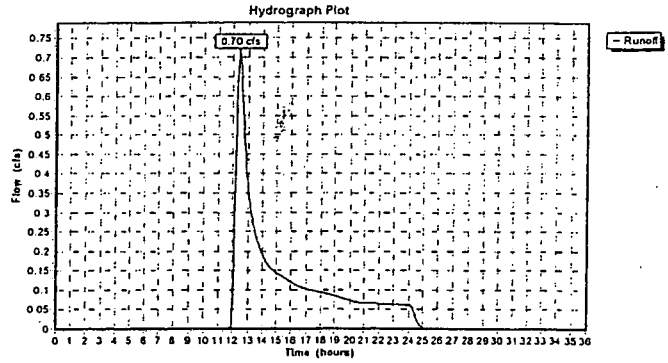
Runoff = 0.70 cfs @ 12.45 hrs, Volume= 0.141 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.893	64	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
22.9	300	0.0280	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.3	150	0.0140	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.3	110	0.1660	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
11.9	630	0.0030	0.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
36.4	1,190	Total			

Subcatchment KK: open space with good grass cover



DGP 30 JAN 02 DBM 1/30/02 191/282

Subcatchment L: open space with good grass cover

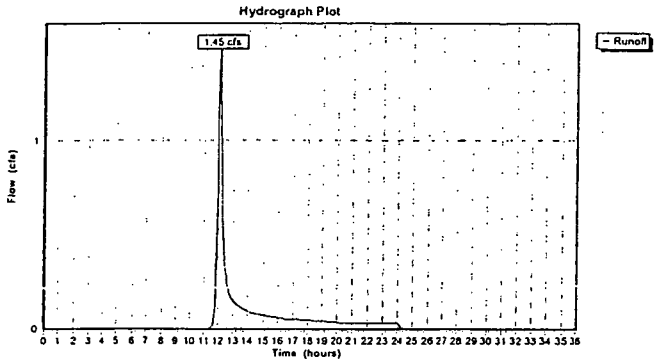
Runoff = 1.45 cfs @ 12.09 hrs, Volume= 0.102 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.683	76	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
14.2	140	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.2	290	0.0075	4.1	49.70	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
15.4	430	Total			

Subcatchment L: open space with good grass cover



Subcatchment LL: open space with good grass cover

Runoff = 0.54 cfs @ 12.36 hrs, Volume= 0.124 af

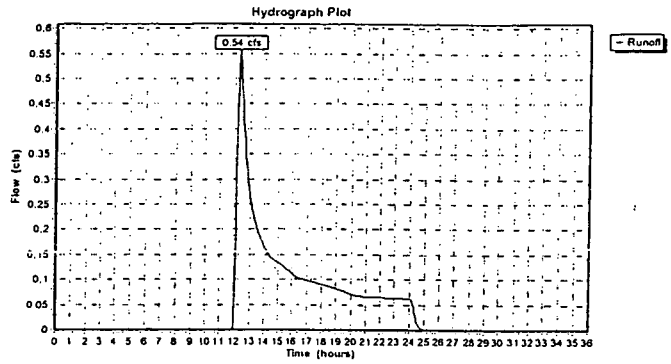
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
7.049	61	

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
24.3	300	0.0240	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.3	200	0.0240	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.5	900	0.0090	5.9	160.52	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
28.1	1,400	Total			

Subcatchment LL: open space with good grass cover



Subcatchment M: open space with good grass cover

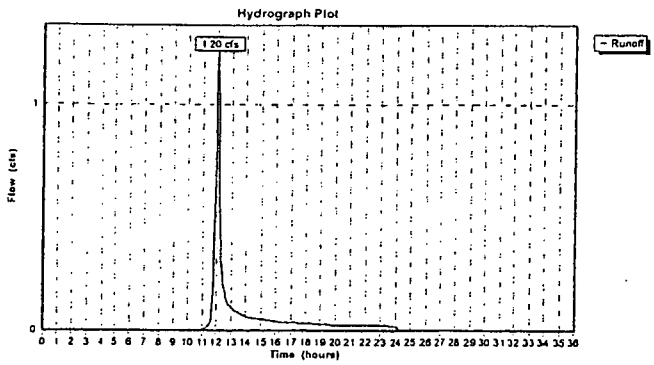
Runoff = 1.20 cfs @ 12.05 hrs, Volume= 0.073 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.000	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.5	170	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.6	200	0.0045	5.1	352.87	Trap/Vee/Rect Channel Flow, Bot.W=20.00' D=2.50' Z= 3.0 '/' n= 0.030
12.1	370	Total			

Subcatchment M: open space with good grass cover



Subcatchment MM: open space with good grass cover

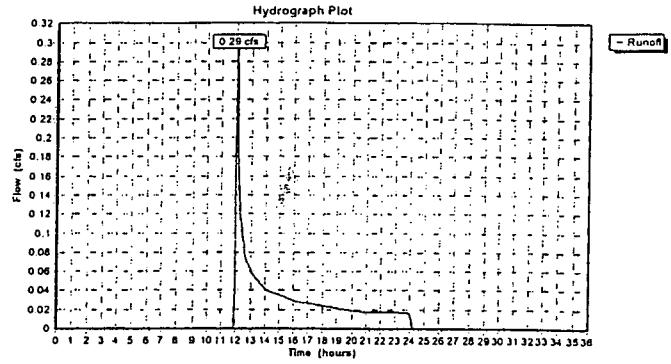
Runoff = 0.29 cfs @ 12.07 hrs, Volume= 0.034 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.943	61	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.6	100	0.0700	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.3	980	0.0060	4.9	200.34	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 5.0 & 4.0 '/' n= 0.030
9.9	1,080	Total			

Subcatchment MM: open space with good grass cover



DCP 30 JAN 02 192/282

DBM 1/30/02

Subcatchment N: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

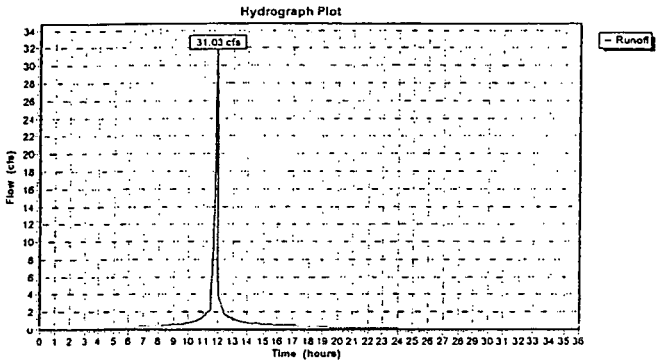
Runoff = 31.03 cfs @ 11.90 hrs, Volume= 1.512 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
7.818	98	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment N: direct runon to pond



Subcatchment NN: open space with good grass cover

[49] Hint: Tc<2dt may require smaller dt

Runoff = 0.73 cfs @ 11.94 hrs, Volume= 0.037 af

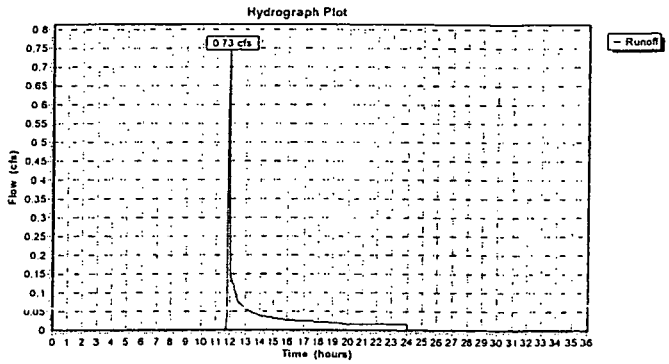
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.274	66	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.4	600	0.0130	7.1	192.92	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030

Subcatchment NN: open space with good grass cover



Subcatchment O: open space with good grass cover

[49] Hint: Tc<2dt may require smaller dt

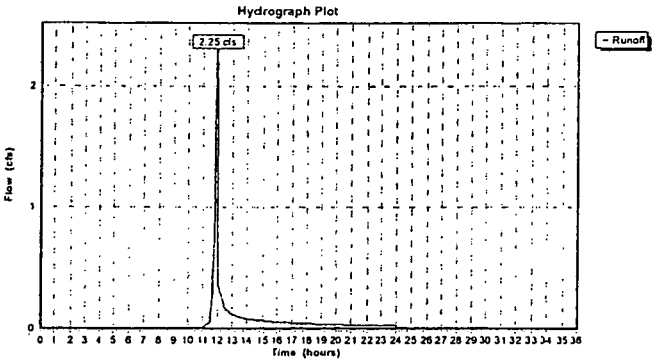
Runoff = 2.25 cfs @ 11.91 hrs, Volume= 0.096 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.317	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.3	230	0.0086	2.9	14.28	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.00' Z= 5.0 '/' n= 0.030

Subcatchment O: open space with good grass cover



Subcatchment OO: open space with good grass cover

[49] Hint: Tc<2dt may require smaller dt

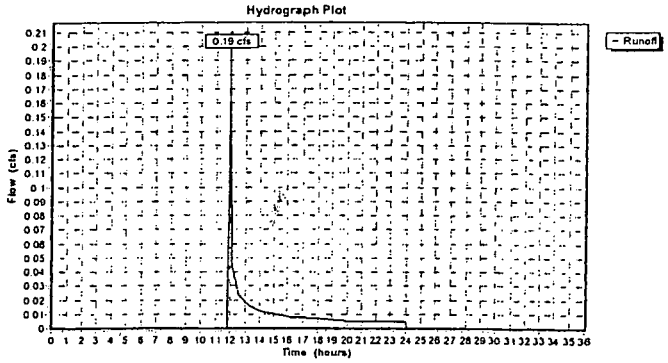
Runoff = 0.19 cfs @ 11.99 hrs, Volume= 0.012 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.399	66	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	120	0.1660	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment OO: open space with good grass cover



DEP 30 JAN 02 193/282
DBM 1/30/02

Subcatchment P: open space with good grass cover

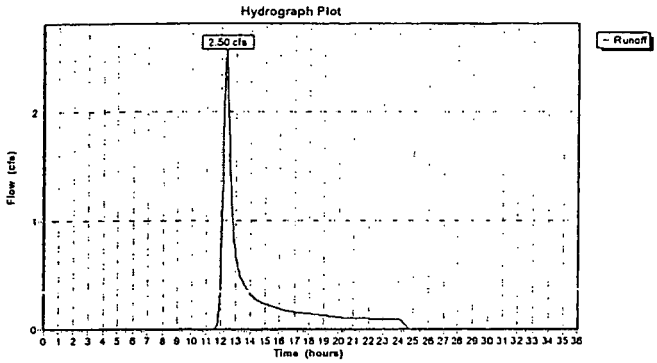
Runoff = 2.50 cfs @ 12.32 hrs, Volume= 0.297 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.238	75	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
29.4	300	0.0150	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
4.3	350	0.0070	1.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
33.7	650	Total			

Subcatchment P: open space with good grass cover



Subcatchment PP: open space with good grass cover

Runoff = 3.01 cfs @ 13.15 hrs, Volume= 0.983 af

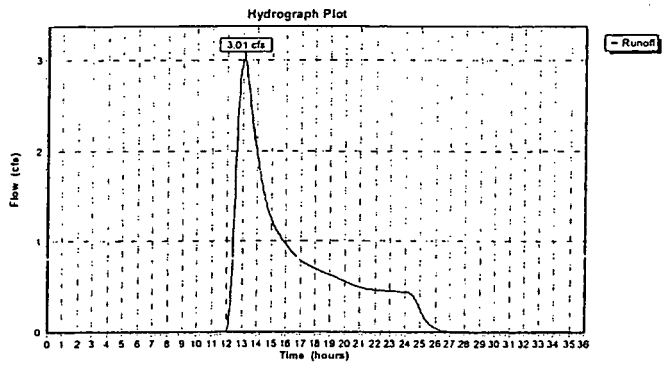
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
40.964	64	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.4	150	0.1660	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 0.26"
34.5	150	0.0025	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
24.6	1,190	0.0025	0.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
79.5	1,490	Total			

Subcatchment PP: open space with good grass cover



Subcatchment Q: open space with good grass cover

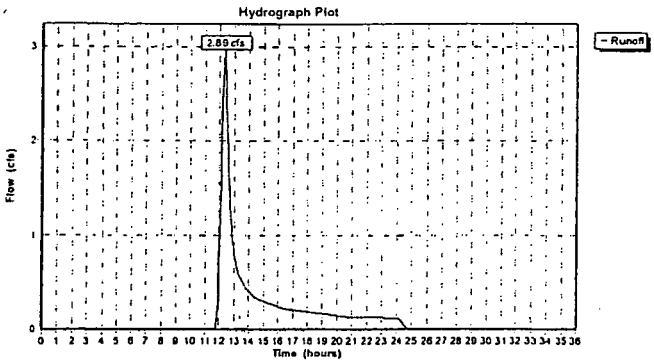
Runoff = 2.89 cfs @ 12.32 hrs, Volume= 0.356 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
7.700	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
23.6	300	0.0260	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
8.2	1,280	0.0260	2.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
31.8	1,580	Total			

Subcatchment Q: open space with good grass cover



Subcatchment R: open space with good grass cover

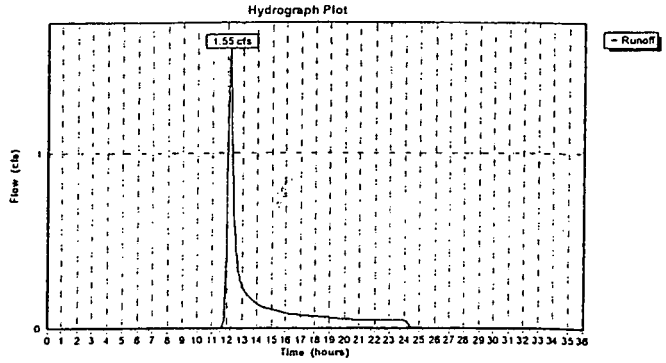
Runoff = 1.55 cfs @ 12.17 hrs, Volume= 0.139 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
2.612	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
19.8	300	0.0400	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.8	350	0.0400	3.2		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
21.6	650	Total			

Subcatchment R: open space with good grass cover



DGP 30 JAN 02 194/282

DBM 1/30/02

Subcatchment S: open space with good grass cover

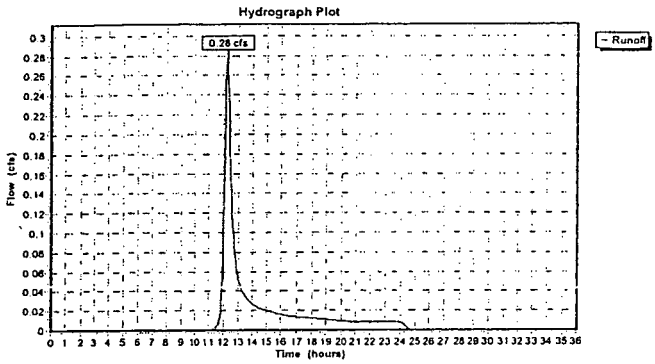
Runoff = 0.28 cfs @ 12.24 hrs, Volume= 0.027 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.402	78	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
27.8	280	0.0150	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.1	30	0.0100	6.3	169.20	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
27.9	310	Total			

Subcatchment S: open space with good grass cover



Subcatchment T: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

Runoff = 1.65 cfs @ 11.90 hrs, Volume= 0.080 af

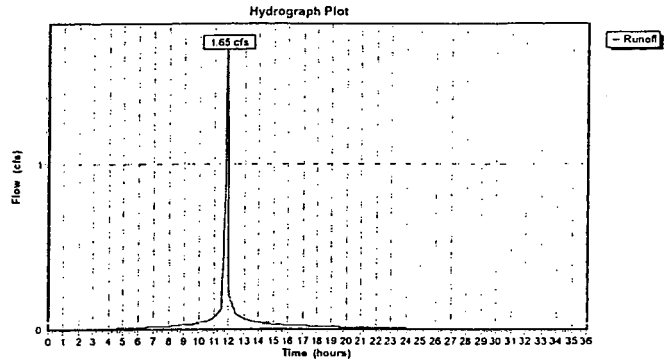
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

4664

Area (ac)	CN	Description
0.416	98	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment T: direct runon to pond



Subcatchment U: open space with good grass cover

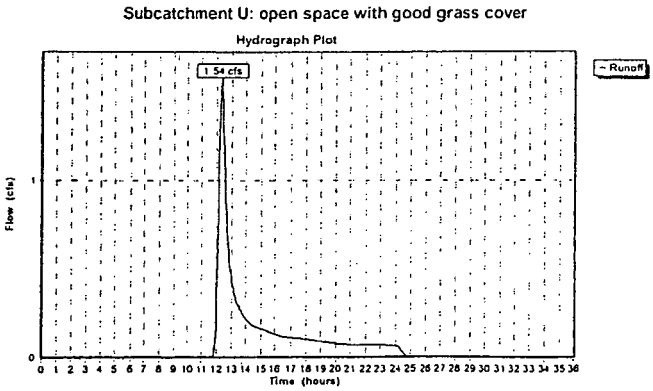
Runoff = 1.54 cfs @ 12.32 hrs, Volume= 0.192 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
4.149	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
30.2	300	0.0140	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.1	240	0.0140	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
32.3	540	Total			

Subcatchment U: open space with good grass cover



Subcatchment V: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

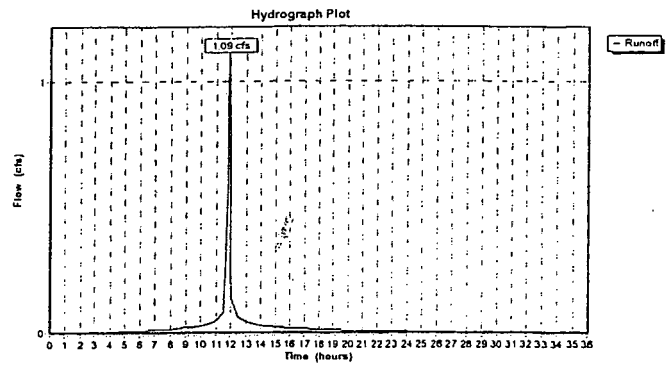
Runoff = 1.09 cfs @ 11.90 hrs, Volume= 0.053 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.274	98	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

Subcatchment V: direct runon to pond



DEP 3CJANO2 95/282
DBM 1/30/02

Subcatchment W: open space with good grass cover

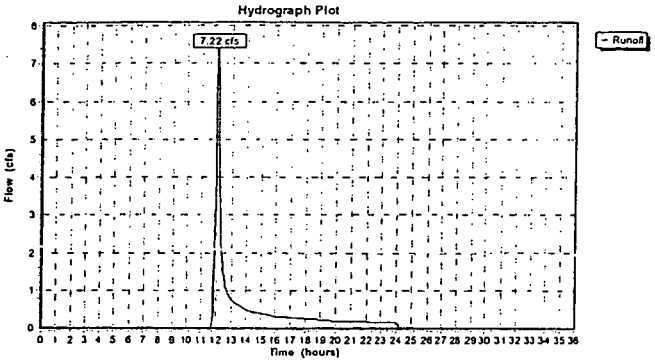
Runoff = 7.22 cfs @ 12.06 hrs, Volume= 0.490 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
10.593	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.9	300	0.1780	0.5		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.0	400	0.1780	6.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.7	270	0.0114	6.7	180.66	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
12.6	970	Total			

Subcatchment W: open space with good grass cover



Subcatchment X: open space with good grass cover

Runoff = 3.87 cfs @ 12.34 hrs, Volume= 0.510 af

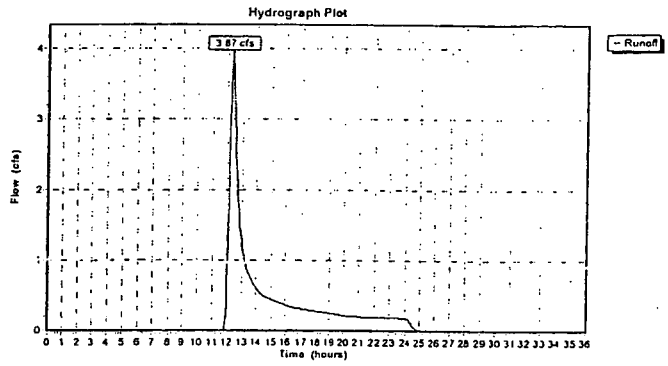
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
11.853	71	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.7	300	0.0190	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
5.5	730	0.0190	2.2		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	330	0.0100	4.8	57.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 '/' n= 0.030
33.4	1,360	Total			

Subcatchment X: open space with good grass cover



Subcatchment Y: open space with good grass cover

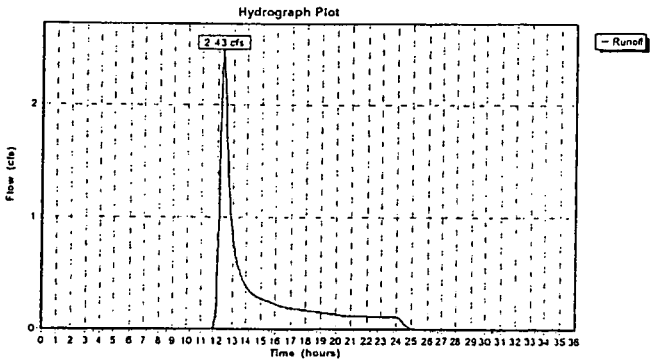
Runoff = 2.43 cfs @ 12.38 hrs, Volume= 0.323 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
6.522	73	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
31.1	300	0.0130	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
4.6	510	0.0130	1.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.1	340	0.0110	5.1	92.00	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 5.0 & 4.0 '/' n= 0.030
36.8	1,150	Total			

Subcatchment Y: open space with good grass cover



Subcatchment Z: open space with good grass cover

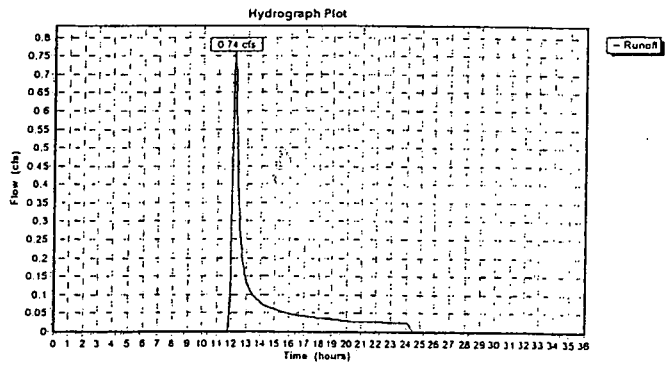
Runoff = 0.74 cfs @ 12.21 hrs, Volume= 0.074 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.606	72	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
22.0	300	0.0310	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.5	250	0.0310	2.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.2	50	0.0070	4.1	73.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 5.0 & 4.0 '/' n= 0.030
23.7	600	Total			

Subcatchment Z: open space with good grass cover



Reach 1: east drainage channel

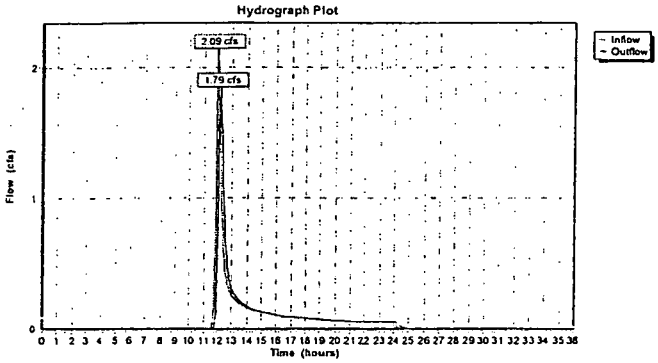
[65] Warning: Inlet elevation not specified

flow	=	2.09 cfs @	12.02 hrs,	Volume=	0.167 af
rflow	=	1.79 cfs @	12.20 hrs,	Volume=	0.167 af, Atten= 14%, Lag= 10.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.3 fps, Min. Travel Time= 5.2 min
Avg. Velocity = 0.6 fps, Avg. Travel Time= 11.6 min

Peak Depth= 0.52'
Capacity at bank full= 754.76 cfs
0.00' x 5.00' deep channel, n= 0.030 Length= 420.0' Slope= 0.0045 '/'
Side Slope Z-value= 6.0 4.0 '/'

Reach 1: east drainage channel



DCP 30 JAN 02 1960 / 282
DBM 1/30/02

Reach 1R: (new node)

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

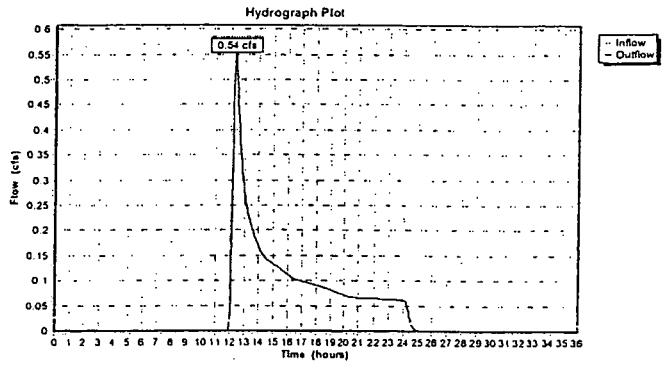
— 4664

Inflow	=	0.54 cfs @	12.36 hrs,	Volume=	0.124 af
Outflow	=	0.54 cfs @	12.38 hrs,	Volume=	0.124 af, Atten= 1%, Lag= 1.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.6 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 0.9 min

Peak Depth= 0.10'
Capacity at bank full= 1,101.12 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 100.0' Slope= 0.0100 '/'

Reach 1R: (new node)



Reach 2: east drainage channel

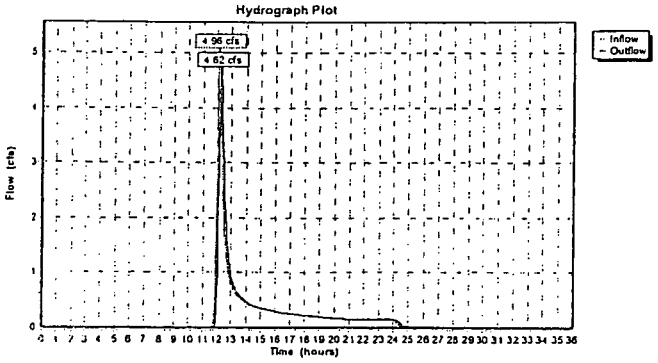
[65] Warning: Inlet elevation not specified

Inflow	=	4.96 cfs @	12.17 hrs,	Volume=	0.443 af
Outflow	=	4.62 cfs @	12.30 hrs,	Volume=	0.443 af, Atten= 7%, Lag= 7.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.8 fps, Min. Travel Time= 3.9 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 8.9 min

Peak Depth= 0.81'
Capacity at bank full= 1,205.98 cfs
0.00' x 6.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 5.0 '/'

Reach 2: east drainage channel



Reach 2R: (new node)

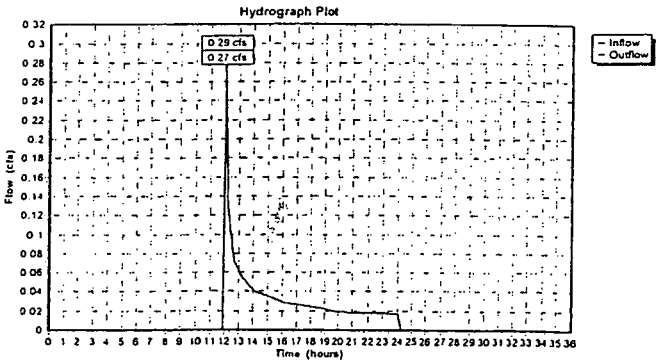
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow	=	0.29 cfs @	12.07 hrs,	Volume=	0.034 af
Outflow	=	0.27 cfs @	12.10 hrs,	Volume=	0.034 af, Atten= 5%, Lag= 1.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.1 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 1.0 min

Peak Depth= 0.07'
Capacity at bank full= 1,101.12 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 100.0' Slope= 0.0100 '/'

Reach 2R: (new node)



DGT 30 JAN 02 197 /282

DBM 1/30/02

Reach 3: east drainage channel

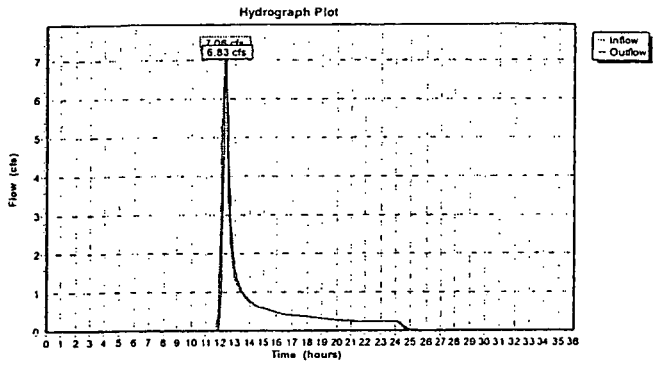
[65] Warning: Inlet elevation not specified

Inflow = 7.06 cfs @ 12.25 hrs, Volume= 0.715 af
Outflow = 6.83 cfs @ 12.35 hrs, Volume= 0.715 af, Atten= 3%, Lag= 6.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.1 fps, Min. Travel Time= 3.3 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 7.5 min

Peak Depth= 0.97'
Capacity at bank full= 1,563.67 cfs
0.00' x 7.40' deep channel, n= 0.030 Length= 420.0' Slope= 0.0050 '/'
Side Slope Z-value= 3.0 4.0 '/'

Reach 3: east drainage channel



Reach 3R: (new node)

4664

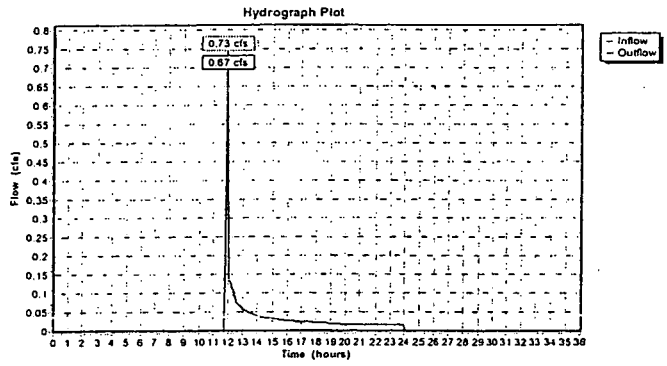
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 0.73 cfs @ 11.94 hrs, Volume= 0.037 af
Outflow = 0.67 cfs @ 11.95 hrs, Volume= 0.037 af, Atten= 7%, Lag= 0.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.7 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 1.0 min

Peak Depth= 0.12'
Capacity at bank full= 1,101.12 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 100.0' Slope= 0.0100 '/'

Reach 3R: (new node)



Reach 4: east drainage channel

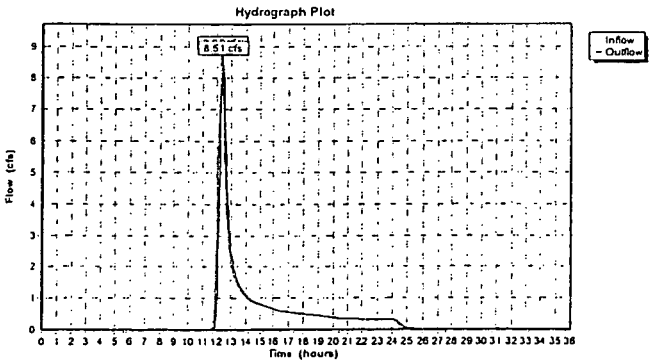
[65] Warning: Inlet elevation not specified

Inflow = 8.67 cfs @ 12.31 hrs, Volume= 0.985 af
Outflow = 8.51 cfs @ 12.41 hrs, Volume= 0.985 af, Atten= 2%, Lag= 5.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.2 fps, Min. Travel Time= 3.2 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 7.2 min

Peak Depth= 1.05'
Capacity at bank full= 1,106.53 cfs
0.00' x 6.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0050 '/'
Side Slope Z-value= 3.0 4.0 '/'

Reach 4: east drainage channel



Reach 5: east drainage channel

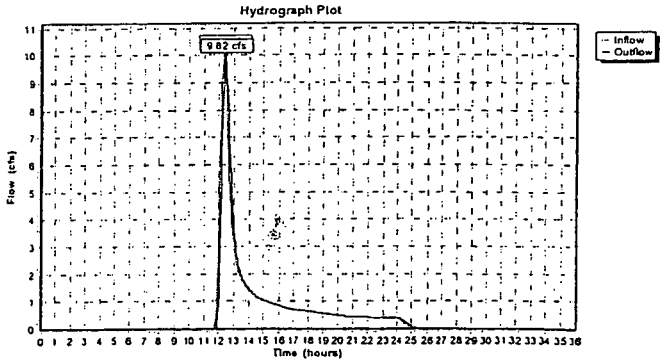
[65] Warning: Inlet elevation not specified

Inflow = 9.97 cfs @ 12.38 hrs, Volume= 1.253 af
Outflow = 9.82 cfs @ 12.48 hrs, Volume= 1.253 af, Atten= 2%, Lag= 5.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.2 fps, Min. Travel Time= 3.4 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 8.1 min

Peak Depth= 1.00'
Capacity at bank full= 182.58 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 440.0' Slope= 0.0050 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 5: east drainage channel



DGP 30 JAN 02 198/282
DBM 1/30/02

Reach 6: east drainage channel

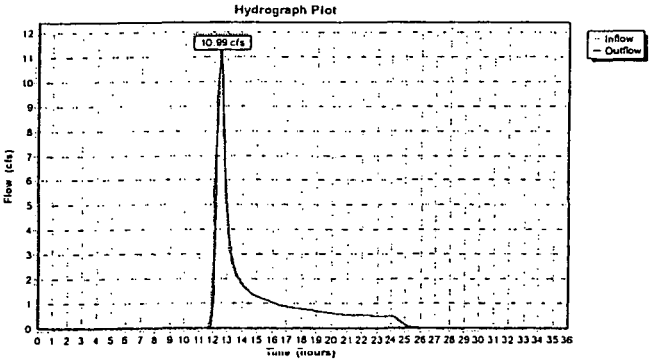
[65] Warning: Inlet elevation not specified

Inflow = 11.07 cfs @ 12.45 hrs, Volume= 1.535 af
Outflow = 10.99 cfs @ 12.53 hrs, Volume= 1.535 af, Atten= 1%, Lag= 4.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 6.6 min

Peak Depth= 0.92'
Capacity at bank full= 258.21 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 480.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 6: east drainage channel



Reach 7: runoff diversion channel

[65] Warning: Inlet elevation not specified

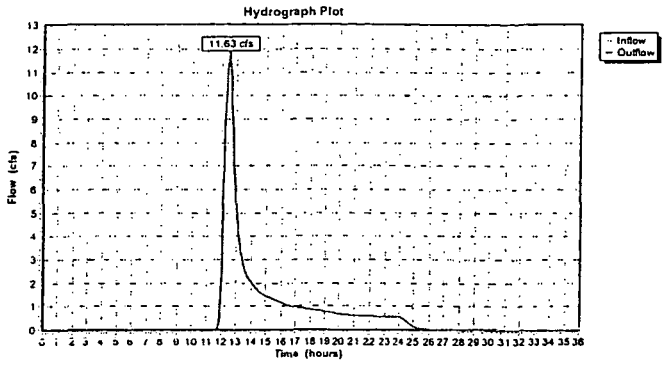
Inflow = 11.66 cfs @ 12.51 hrs, Volume= 1.720 af
Outflow = 11.63 cfs @ 12.54 hrs, Volume= 1.720 af, Atten= 0%, Lag= 1.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 1.9 min

4664

Peak Depth= 0.94'
Capacity at bank full= 556.08 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 140.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 7: runoff diversion channel



Reach 8: runoff diversion channel

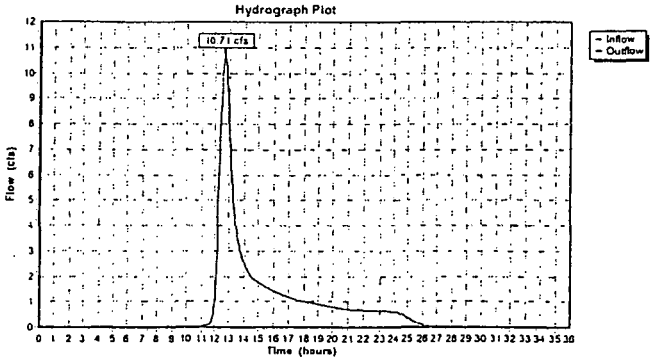
[65] Warning: Inlet elevation not specified

Inflow = 10.72 cfs @ 12.69 hrs, Volume= 1.919 af
Outflow = 10.71 cfs @ 12.69 hrs, Volume= 1.919 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.5 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 0.5 fps, Avg. Travel Time= 0.6 min

Peak Depth= 0.33'
Capacity at bank full= 1,379.30 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
10.00' x 4.50' deep channel, n= 0.030 Length= 20.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 8: runoff diversion channel



Reach 9: runoff diversion channel

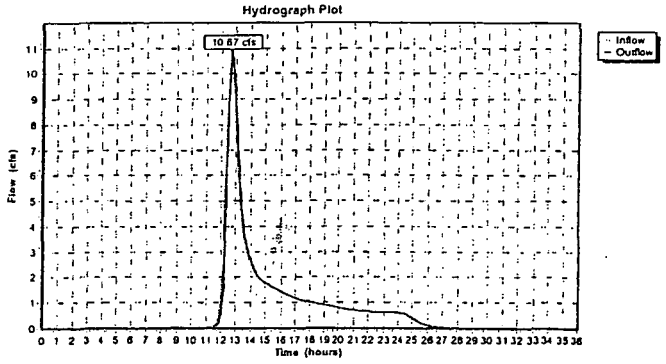
[65] Warning: Inlet elevation not specified

Inflow = 10.71 cfs @ 12.69 hrs, Volume= 1.919 af
Outflow = 10.67 cfs @ 12.77 hrs, Volume= 1.919 af, Atten= 0%, Lag= 4.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.9 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 0.6 fps, Avg. Travel Time= 8.8 min

Peak Depth= 0.49'
Capacity at bank full= 407.65 cfs
10.00' x 3.50' deep channel, n= 0.030 Length= 295.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 9: runoff diversion channel



Reach 10: runoff diversion channel

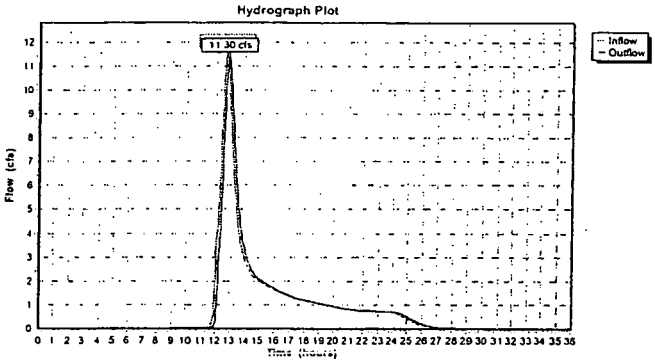
[65] Warning: Inlet elevation not specified

Inflow = 11.44 cfs @ 12.76 hrs, Volume= 2.214 af
Outflow = 11.30 cfs @ 12.91 hrs, Volume= 2.214 af, Atten= 1%, Lag= 8.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.9 fps, Min. Travel Time= 5.3 min
Avg. Velocity = 0.5 fps, Avg. Travel Time= 19.4 min

Peak Depth= 0.51'
Capacity at bank full= 134.00 cfs
10.00' x 2.00' deep channel, n= 0.030 Length= 610.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 10: runoff diversion channel



DGP 30 JAN 02 199/282
DBM 1/30/02

Reach 11: new CMP arch

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

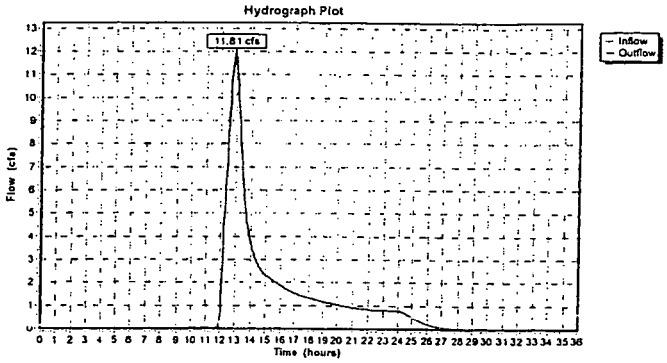
Inflow = 11.82 cfs @ 12.90 hrs, Volume= 2.417 af
Outflow = 11.81 cfs @ 12.91 hrs, Volume= 2.417 af, Atten= 0%, Lag= 0.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.2 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 1.0 min

4664

Peak Depth= 0.70'
Capacity at bank full= 408.61 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 65.0' Slope= 0.0045 '/'

Reach 11: new CMP arch



Reach 12: runoff diversion channel

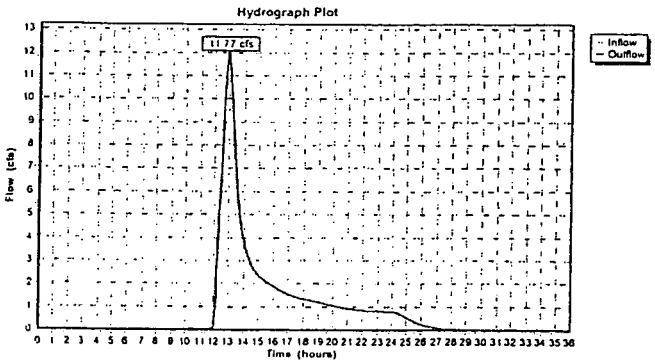
[65] Warning: Inlet elevation not specified

Inflow = 11.81 cfs @ 12.91 hrs, Volume= 2.417 af
Outflow = 11.77 cfs @ 12.97 hrs, Volume= 2.417 af, Atten= 0%, Lag= 3.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.0 fps, Min. Travel Time= 2.3 min
Avg. Velocity = 0.5 fps, Avg. Travel Time= 8.3 min

Peak Depth= 0.52'
Capacity at bank full= 134.16 cfs
10.00' x 2.00' deep channel, n= 0.030 Length= 270.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 12: runoff diversion channel



Reach 13: runoff diversion channel

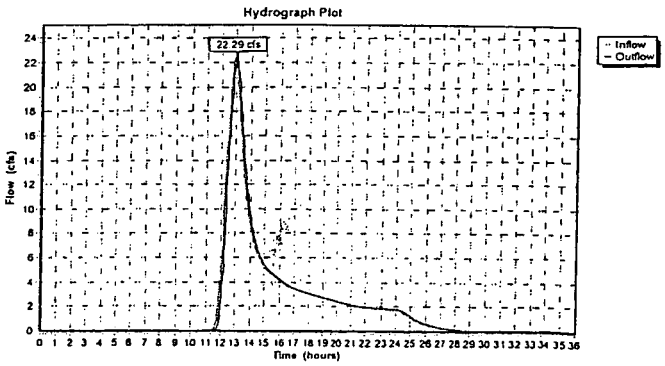
[65] Warning: Inlet elevation not specified

Inflow = 22.39 cfs @ 12.94 hrs, Volume= 5.420 af
Outflow = 22.29 cfs @ 13.04 hrs, Volume= 5.418 af, Atten= 0%, Lag= 6.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.0 fps, Min. Travel Time= 3.7 min
Avg. Velocity = 0.6 fps, Avg. Travel Time= 12.9 min

Peak Depth= 0.51'
Capacity at bank full= 235.94 cfs
20.00' x 2.00' deep channel, n= 0.030 Length= 450.0' Slope= 0.0045 '/'
Side Slope Z-value= 3.0 '/'

Reach 13: runoff diversion channel



DGF 30 JAN 02 DBM 1/30/02 200/282

Reach 14: east runon channel

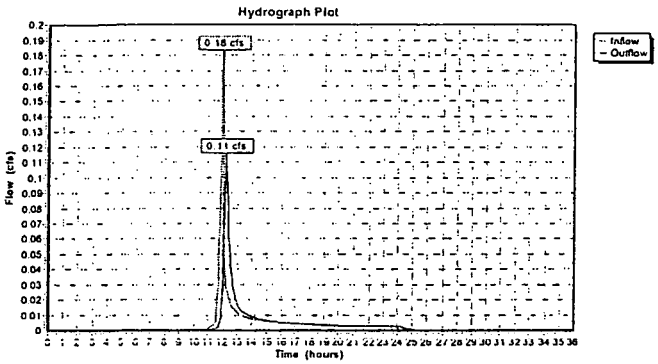
[65] Warning: Inlet elevation not specified

Inflow = 0.18 cfs @ 11.99 hrs, Volume= 0.009 af
Outflow = 0.11 cfs @ 12.24 hrs, Volume= 0.009 af, Atten= 38%, Lag= 15.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.7 fps, Min. Travel Time= 10.4 min
Avg. Velocity = 0.3 fps, Avg. Travel Time= 25.8 min

Peak Depth= 0.21'
Capacity at bank full= 22.78 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0040 '/'
Side Slope Z-value= 3.0 5.0 '/'

Reach 14: east runon channel



Reach 15: east runon channel

[65] Warning: Inlet elevation not specified

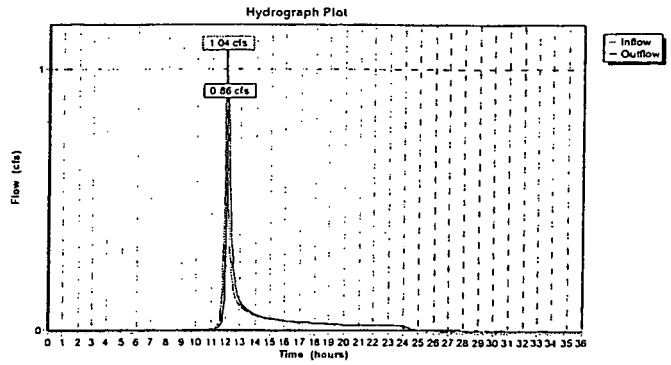
Inflow = 1.04 cfs @ 12.01 hrs, Volume= 0.064 af
Outflow = 0.86 cfs @ 12.16 hrs, Volume= 0.064 af, Atten= 17%, Lag= 8.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.3 fps, Min. Travel Time= 5.3 min
Avg. Velocity = 0.5 fps, Avg. Travel Time= 14.0 min

4664

Peak Depth= 0.41'
Capacity at bank full= 61.62 cfs
0.00' x 2.00' deep channel, n= 0.030 Length= 420.0' Slope= 0.0063 '/'
Side Slope Z-value= 3.0 5.0 '/'

Reach 15: east runon channel



Reach 16: east runon channel

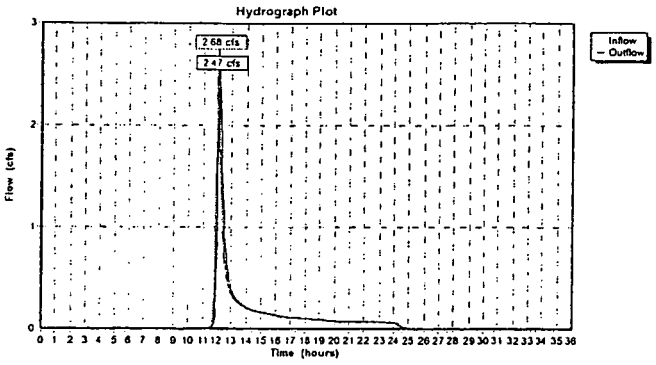
[65] Warning: Inlet elevation not specified

Inflow = 2.68 cfs @ 12.13 hrs, Volume= 0.208 af
Outflow = 2.47 cfs @ 12.24 hrs, Volume= 0.208 af, Atten= 8%, Lag= 6.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.9 fps, Min. Travel Time= 3.8 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 9.7 min

Peak Depth= 0.60'
Capacity at bank full= 256.58 cfs
0.00' x 3.40' deep channel, n= 0.030 Length= 420.0' Slope= 0.0074 '/'
Side Slope Z-value= 2.5 5.0 '/'

Reach 16: east runon channel



Reach 17: east runon channel

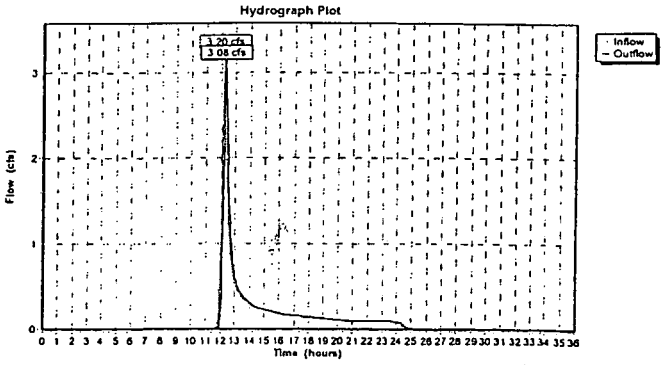
[65] Warning: Inlet elevation not specified

Inflow = 3.20 cfs @ 12.24 hrs, Volume= 0.282 af
Outflow = 3.08 cfs @ 12.33 hrs, Volume= 0.282 af, Atten= 4%, Lag= 5.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.3 fps, Min. Travel Time= 3.1 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 7.6 min

Peak Depth= 0.55'
Capacity at bank full= 436.18 cfs
0.00' x 3.50' deep channel, n= 0.030 Length= 420.0' Slope= 0.0125 '/'
Side Slope Z-value= 4.0 5.0 '/'

Reach 17: east runon channel



DGP 3: JAN 02
DBM 1/30/02
201/282

Reach 18: east runon channel

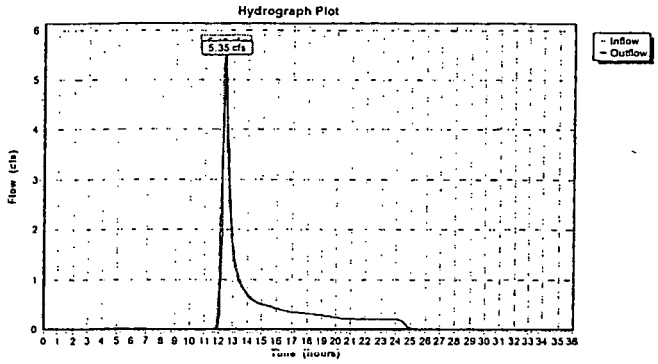
[65] Warning: Inlet elevation not specified

Inflow = 5.48 cfs @ 12.34 hrs, Volume= 0.605 af
Outflow = 5.35 cfs @ 12.43 hrs, Volume= 0.605 af, Atten= 2%, Lag= 5.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.6 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 6.9 min

Peak Depth= 0.82'
Capacity at bank full= 169.20 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 440.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 18: east runon channel



Reach 19: east runon channel

[65] Warning: Inlet elevation not specified

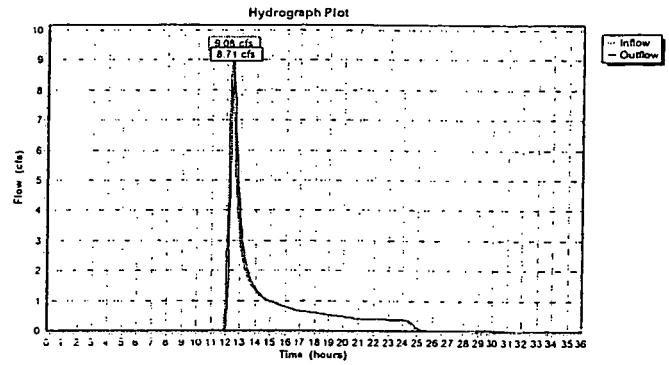
Inflow = 9.08 cfs @ 12.41 hrs, Volume= 1.115 af
Outflow = 8.71 cfs @ 12.53 hrs, Volume= 1.115 af, Atten= 4%, Lag= 7.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.9 fps, Min. Travel Time= 4.1 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 9.7 min

- 4664

Peak Depth= 0.53'
Capacity at bank full= 911.12 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 470.0' Slope= 0.0090 '/'
Side Slope Z-value= 3.0 30.0 '/'

Reach 19: east runon channel



Reach 20: east runon channel

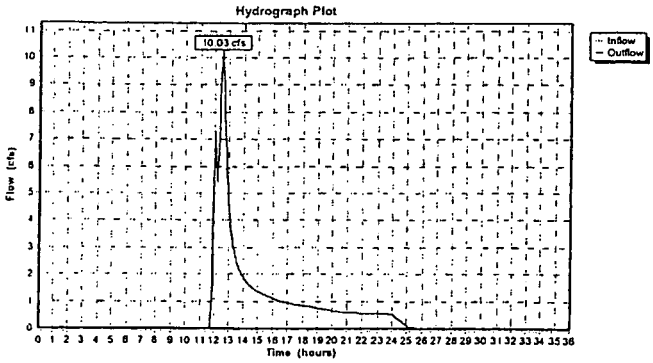
[65] Warning: Inlet elevation not specified

Inflow = 10.07 cfs @ 12.52 hrs, Volume= 1.605 af
Outflow = 10.03 cfs @ 12.53 hrs, Volume= 1.605 af, Atten= 0%, Lag= 0.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 1.0 min

Peak Depth= 1.08'
Capacity at bank full= 153.84 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 75.0' Slope= 0.0083 '/'
Side Slope Z-value= 3.0 '/'

Reach 20: east runon channel



Reach 21: east runon channel

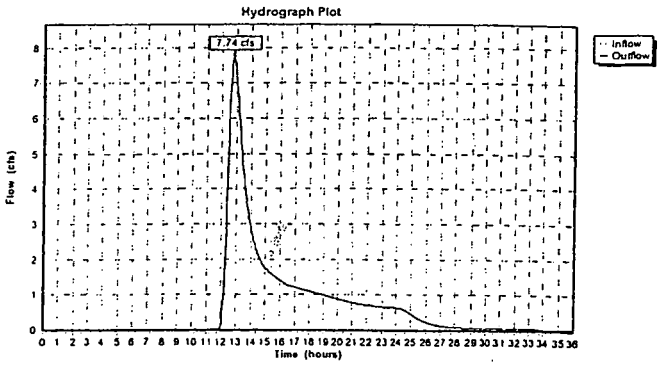
[65] Warning: Inlet elevation not specified

Inflow = 7.74 cfs @ 12.79 hrs, Volume= 1.817 af
Outflow = 7.74 cfs @ 12.80 hrs, Volume= 1.817 af, Atten= 0%, Lag= 0.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 1.0 min

Peak Depth= 0.94'
Capacity at bank full= 169.20 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 65.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 21: east runon channel



DBH 1/30/02 202/282

Reach 22: east runon channel

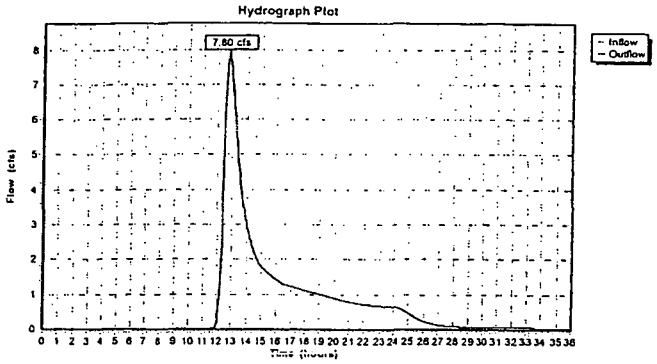
[65] Warning: Inlet elevation not specified

Inflow = 7.81 cfs @ 12.80 hrs, Volume= 1.844 af
Outflow = 7.80 cfs @ 12.83 hrs, Volume= 1.844 af, Atten= 0%, Lag= 2.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 2.8 min

Peak Depth= 0.95'
Capacity at bank full= 364.40 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 190.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 22: east runon channel



Reach 23: new CMP culverts

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

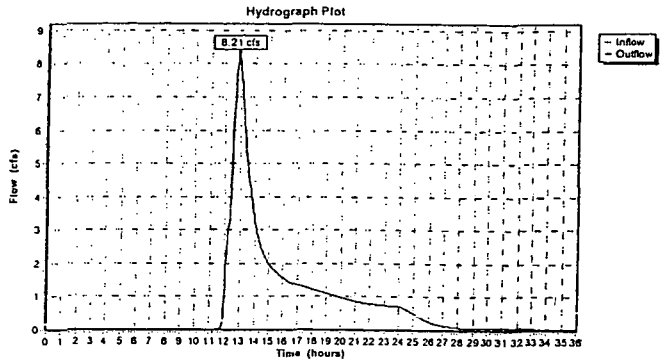
Inflow = 8.22 cfs @ 12.85 hrs, Volume= 2.042 af
Outflow = 8.21 cfs @ 12.87 hrs, Volume= 2.042 af, Atten= 0%, Lag= 0.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.2 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 1.3 min

4664

Peak Depth= 0.55'
Capacity at bank full= 473.85 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 95.0' Slope= 0.0060 '/'

Reach 23: new CMP culverts



Reach 24: runon channel

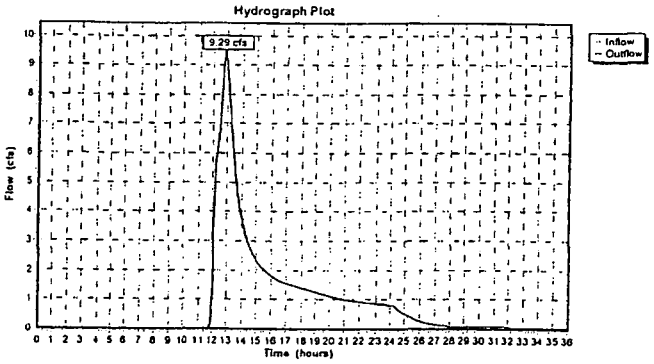
[65] Warning: Inlet elevation not specified

Inflow = 9.31 cfs @ 12.82 hrs, Volume= 2.398 af
Outflow = 9.29 cfs @ 12.86 hrs, Volume= 2.397 af, Atten= 0%, Lag= 2.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.2 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 3.9 min

Peak Depth= 0.43'
Capacity at bank full= 153.54 cfs
8.50' x 2.00' deep channel, n= 0.030 Length= 160.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 24: runon channel



Reach 25: new CMP arch

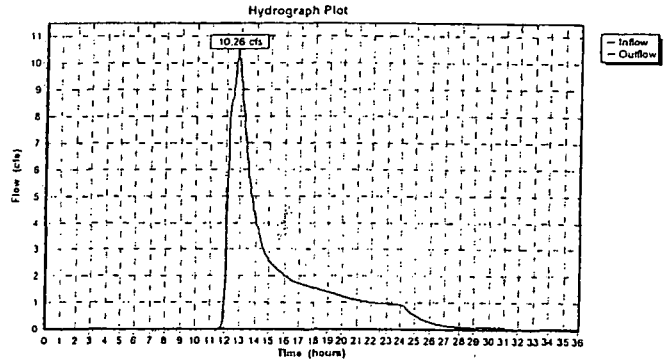
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 10.27 cfs @ 12.82 hrs, Volume= 2.694 af
Outflow = 10.26 cfs @ 12.83 hrs, Volume= 2.694 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.3 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 0.8 min

Peak Depth= 0.62'
Capacity at bank full= 453.67 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 60.0' Slope= 0.0055 '/'

Reach 25: new CMP arch



Reach 26: runon channel

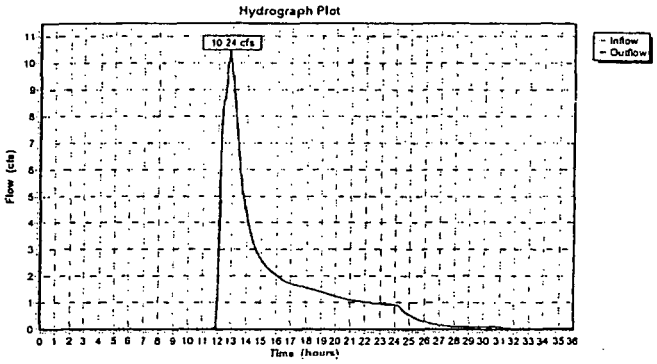
[65] Warning: Inlet elevation not specified

Inflow = 10.26 cfs @ 12.83 hrs, Volume= 2.694 af
Outflow = 10.24 cfs @ 12.88 hrs, Volume= 2.694 af, Atten= 0%, Lag= 3.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.8 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 4.6 min

Peak Depth= 1.11'
Capacity at bank full= 90.11 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 300.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 26: runon channel



UCP 30 JAN 02 DBM 1/30/02 203/282

Reach 27: new CMP arch

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

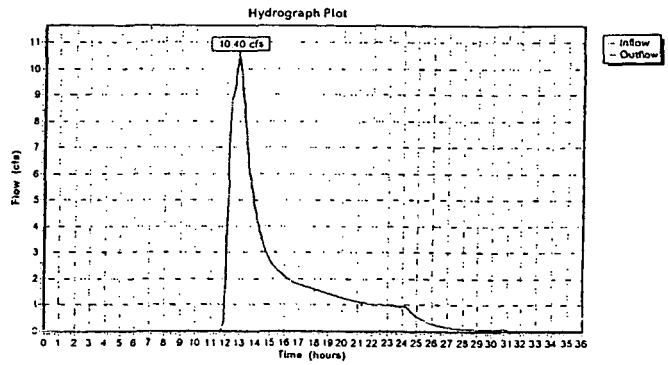
Inflow = 10.41 cfs @ 12.88 hrs, Volume= 2.795 af
Outflow = 10.40 cfs @ 12.89 hrs, Volume= 2.795 af, Atten= 0%, Lag= 1.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.3 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 1.4 min

4664

Peak Depth= 0.63'
Capacity at bank full= 455.55 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 110.0' Slope= 0.0055 '/'

Reach 27: new CMP arch



Reach 28: new CMP culverts

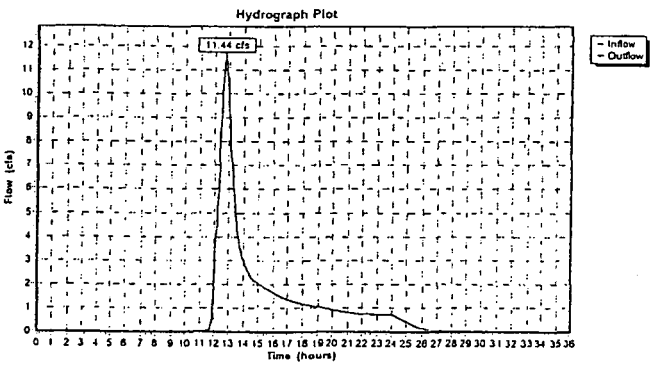
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 11.45 cfs @ 12.75 hrs, Volume= 2.214 af
Outflow = 11.44 cfs @ 12.76 hrs, Volume= 2.214 af, Atten= 0%, Lag= 0.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.2 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 1.0 min

Peak Depth= 0.69'
Capacity at bank full= 408.61 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 65.0' Slope= 0.0045 '/'

Reach 28: new CMP culverts



Reach 29: east runon channel

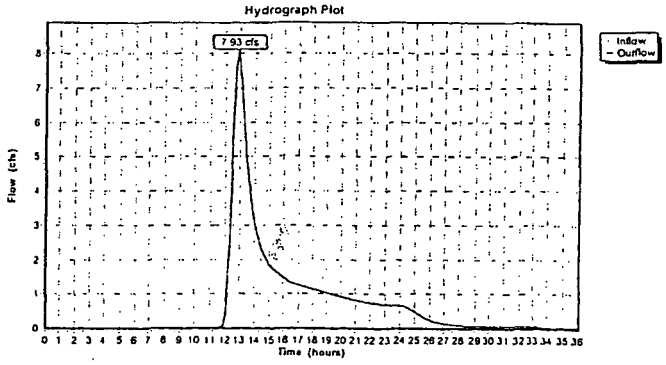
[65] Warning: Inlet elevation not specified

Inflow = 7.95 cfs @ 12.82 hrs, Volume= 1.904 af
Outflow = 7.93 cfs @ 12.86 hrs, Volume= 1.903 af, Atten= 0%, Lag= 2.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 3.4 min

Peak Depth= 0.95'
Capacity at bank full= 255.23 cfs
0.00' x 3.50' deep channel, n= 0.030 Length= 230.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 29: east runon channel



Reach 30: east runon channel

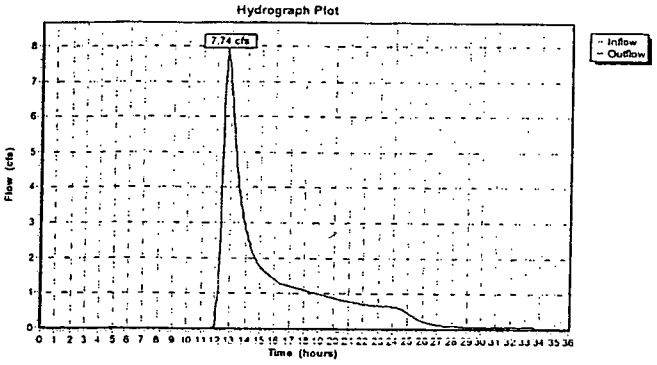
[65] Warning: Inlet elevation not specified

'nflow = 7.74 cfs @ 12.78 hrs, Volume= 1.817 af
utflow = 7.74 cfs @ 12.79 hrs, Volume= 1.817 af, Atten= 0%, Lag= 0.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.1 fps, Avg. Travel Time= 0.4 min

Peak Depth= 0.94'
Capacity at bank full= 104.05 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 30.0' Slope= 0.0100 '/'
Side Slope Z-value= 3.0 '/'

Reach 30: east runon channel



DCP 30 JAN 02
DBM 1/30/02
204/282

Reach 31: culvert

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

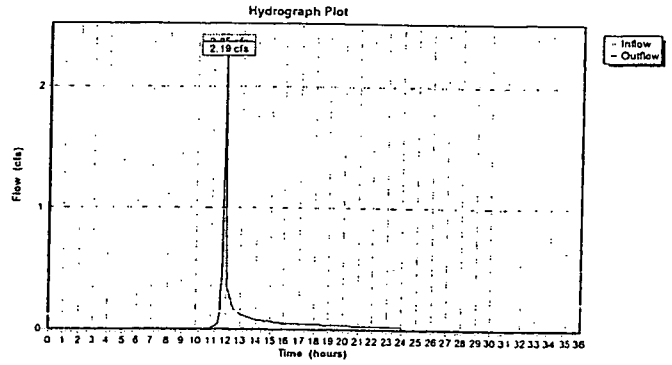
Inflow = 2.25 cfs @ 11.91 hrs, Volume= 0.096 af
Outflow = 2.19 cfs @ 11.93 hrs, Volume= 0.096 af, Atten= 2%, Lag= 0.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.5 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 0.9 min

- 4664

Peak Depth= 0.21'
Capacity at bank full= 946.99 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.013 Length= 80.0' Slope= 0.0125 '/'

Reach 31: culvert



Pond 1P: (new node)

Inflow = 11.25 cfs @ 12.51 hrs, Volume= 1.850 af
Outflow = 7.74 cfs @ 12.78 hrs, Volume= 1.817 af, Atten= 31%, Lag= 16.0 min
Primary = 7.74 cfs @ 12.78 hrs, Volume= 1.817 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

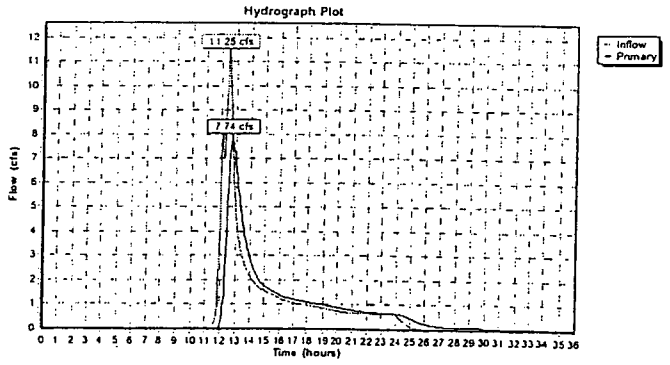
Starting Elev= 592.00' Storage= 0.691 af
Peak Elev= 592.98' Storage= 1.082 af (0.391 af above starting storage)
Plug-Flow detention time= 348.7 min calculated for 1.124 af (61% of inflow)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
589.30	0.186	0.000	0.000	0.186
590.00	0.210	0.139	0.139	0.211
591.00	0.278	0.243	0.382	0.279
592.00	0.342	0.309	0.691	0.344
593.00	0.463	0.401	1.092	0.465
594.00	0.624	0.542	1.634	0.627

Primary OutFlow (Free Discharge)
└─1=Special (user-defined)

#	Routing	Invert	Outlet Devices
1	Primary	592.00'	Special (user-defined)
			Head (feet) 0.00 0.01 0.18 0.51 1.01 1.34 1.67 2.00
			Disch. (cfs) 0.00 0.00 0.08 1.33 8.21 17.57 31.73 51.47

Pond 1P: (new node)



Pond 2P: (new node)

Inflow	=	12.06 cfs @	12.53 hrs, Volume=	1.919 af	
Outflow	=	10.72 cfs @	12.69 hrs, Volume=	1.919 af,	Atten= 11%, Lag= 9.5 min
Primary	=	10.72 cfs @	12.69 hrs, Volume=	1.919 af	

outing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

Starting Elev= 588.00' Storage= 1.282 af
Peak Elev= 588.47' Storage= 1.509 af (0.227 af above starting storage)
Plug-Flow detention time= 460.6 min calculated for 0.636 af (33% of inflow)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
584.30	0.260	0.000	0.000	0.260
585.00	0.286	0.191	0.191	0.287
586.00	0.328	0.307	0.498	0.330
587.00	0.397	0.362	0.860	0.400
588.00	0.448	0.422	1.282	0.452
589.00	0.519	0.483	1.765	0.524
590.00	0.647	0.582	2.347	0.652

Primary OutFlow (Free Discharge)
└1=Special (user-defined)

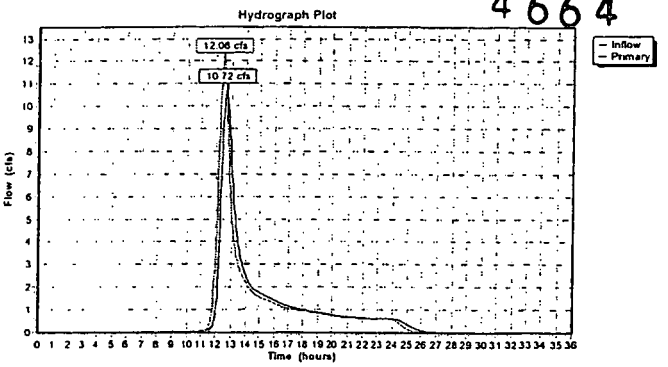
#	Routing	Invert	Outlet Devices
1	Primary	588.00'	Special (user-defined)
			Head (feet) 0.00 0.01 0.18 0.51 1.01 1.34 1.67 2.00
			Disch. (cfs) 0.00 0.02 1.97 11.93 39.57 66.41 100.28 141.52

OBM 1/30/02

205/282

Pond 2P: (new node)

4664



Pond 3P: Borrow Area Basin

Inflow	=	31.84 cfs @	11.90 hrs, Volume=	8.141 af	
Outflow	=	0.00 cfs @	0.00 hrs, Volume=	0.000 af,	Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

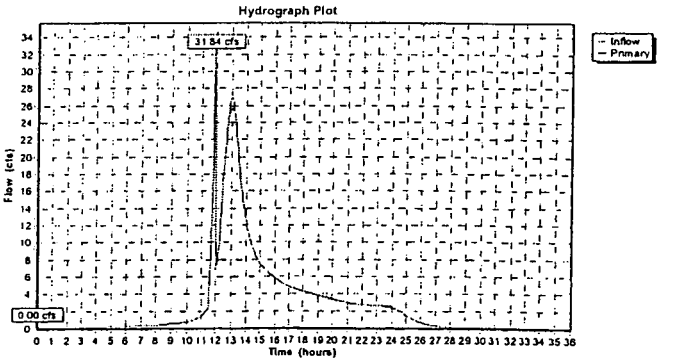
Peak Elev= 571.23' Storage= 8.141 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.00	6.391	0.000	0.000	6.391
571.00	6.687	6.538	6.538	6.690
572.00	7.017	6.851	13.390	7.023
573.00	7.290	7.153	20.543	7.300
574.00	7.613	7.451	27.994	7.626
575.00	7.921	7.766	35.760	7.938

Primary OutFlow (Free Discharge)
├2=Culvert
│└1=Orifice/Grate
└3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.30'	48.0" Horiz. Orifice/Grate X 2.00 Limited to weir flow C= 0.600
2	Primary	569.80'	48.0" x 200.0' long Culvert X 2.00 Ke= 0.700
			Outlet Invert= 569.00' S= 0.0040 '/' n= 0.024 Cc= 0.900
3	Primary	578.00'	20.0' long Broad-Crested Rectangular Weir
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Pond 3P: Borrow Area Basin



DCP 30 JAN 02

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: _____ Date: _____

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

EAST OSDF POST-DEVELOPMENT DESIGN SCENARIO
25-YEAR, 24-HOUR STORM EVENT

Pond 3P: Borrow Area Basin

4664

Inflow	=	151.60 cfs @	12.62 hrs,	Volume=	27.127 af
Outflow	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af, Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.05 hrs

Peak Elev= 573.88' Storage= 27.127 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.00	6.391	0.000	0.000	6.391
571.00	6.687	6.538	6.538	6.690
572.00	7.017	6.851	13.390	7.023
573.00	7.290	7.153	20.543	7.300
574.00	7.613	7.451	27.994	7.626
575.00	7.921	7.766	35.760	7.938

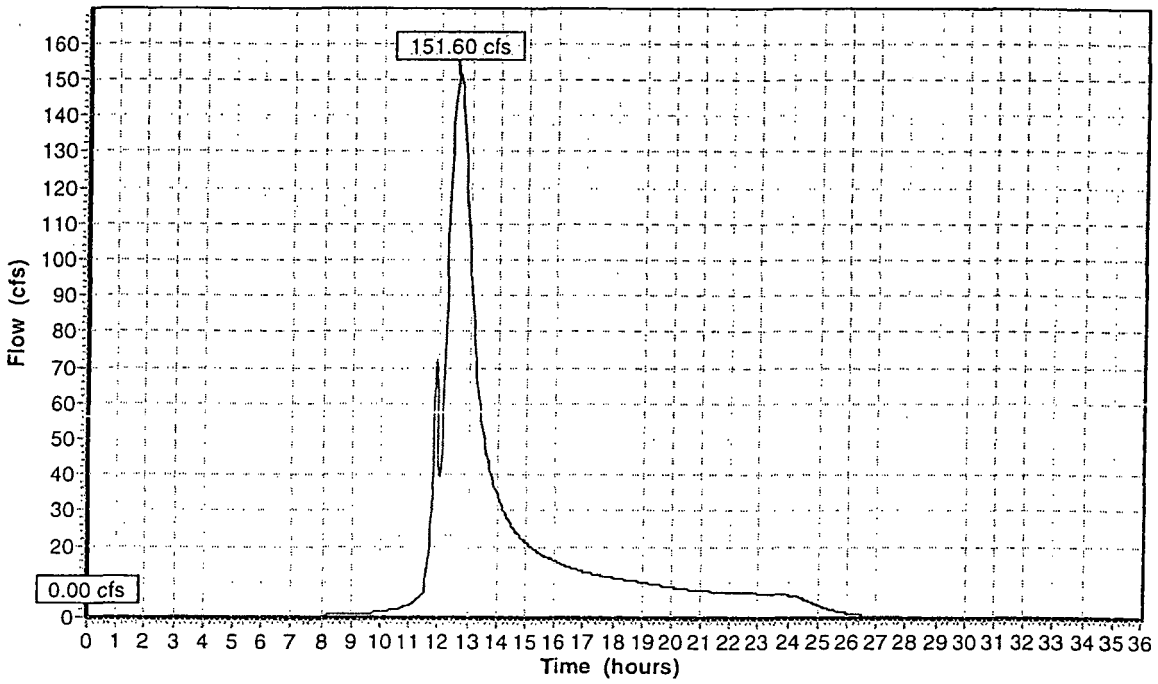
Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.30'	**48.0" Horiz. Orifice/Grate X 2.00** Limited to weir flow C= 0.600
2	Primary	569.80'	**48.0" x 200.0' long Culvert X 2.00** Ke= 0.700
			Outlet Invert= 569.00' S= 0.0040 '/' n= 0.024 Cc= 0.900
3	Primary	578.00'	**20.0' long Broad-Crested Rectangular Weir**
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Pond 3P: Borrow Area Basin

- 4664

Hydrograph Plot



Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DGP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

- 4664

ATTACHMENT C-1D

HydroCAD™ OUTPUT REPORTS

WEST OSDF POST-DEVELOPMENT DESIGN SCENARIO

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DGP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

WEST OSDF POST-DEVELOPMENT DESIGN SCENARIO
2-YEAR, 24-HOUR STORM EVENT

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=2.55"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover
Tc=18.3 min CN=74 Area=2.730 ac Runoff= 1.80 cfs 0.144 af

Subcatchment B: vegetated final cover
Tc=19.3 min CN=74 Area=5.342 ac Runoff= 3.41 cfs 0.281 af

Subcatchment C: vegetated final cover
Tc=19.3 min CN=74 Area=5.399 ac Runoff= 3.45 cfs 0.284 af

Subcatchment D: vegetated final cover
Tc=19.3 min CN=74 Area=5.530 ac Runoff= 3.53 cfs 0.291 af

Subcatchment E: vegetated final cover
Tc=19.7 min CN=74 Area=4.807 ac Runoff= 3.03 cfs 0.253 af

Subcatchment F: vegetated final cover/open space
Tc=12.5 min CN=74 Area=1.640 ac Runoff= 1.34 cfs 0.087 af

Subcatchment G: vegetated final cover/open space
Tc=21.4 min CN=74 Area=3.637 ac Runoff= 2.18 cfs 0.191 af

Subcatchment H: open space with good grass cover
Tc=30.5 min CN=74 Area=0.797 ac Runoff= 0.37 cfs 0.042 af

Subcatchment I: open space with good grass cover
Tc=25.0 min CN=74 Area=0.512 ac Runoff= 0.28 cfs 0.027 af

Subcatchment J: open space with good grass cover
Tc=9.1 min CN=74 Area=1.452 ac Runoff= 1.36 cfs 0.077 af

Subcatchment K: open space with good grass cover
Tc=16.4 min CN=79 Area=0.765 ac Runoff= 0.79 cfs 0.055 af

Subcatchment L: open space with good grass cover
Tc=17.7 min CN=74 Area=1.277 ac Runoff= 0.86 cfs 0.067 af

Subcatchment M: open space with good grass cover
Tc=5.3 min CN=79 Area=0.964 ac Runoff= 1.48 cfs 0.070 af

Subcatchment N: open space with good grass cover
Tc=15.2 min CN=74 Area=1.043 ac Runoff= 0.77 cfs 0.055 af

Subcatchment O: direct runon to pond
Tc=1.0 min CN=98 Area=2.252 ac Runoff= 8.94 cfs 0.435 af

DBM 1/30/02

Subcatchment P: open space with good grass cover
Tc=7.6 min CN=74 Area=0.943 ac Runoff= 0.94 cfs 0.050 af

Reach 1: west channel
Inflow= 1.80 cfs 0.144 af
Length= 400.0' Max Vel= 1.6 fps Capacity= 223.61 cfs Outflow= 1.65 cfs 0.143 af

Reach 2: west channel
Inflow= 4.70 cfs 0.424 af
Length= 400.0' Max Vel= 2.1 fps Capacity= 223.61 cfs Outflow= 4.53 cfs 0.422 af

Reach 3: west channel
Inflow= 7.23 cfs 0.707 af
Length= 400.0' Max Vel= 2.3 fps Capacity= 223.61 cfs Outflow= 7.07 cfs 0.704 af

Reach 4: west channel
Inflow= 9.40 cfs 0.995 af
Length= 90.0' Max Vel= 2.5 fps Capacity= 224.44 cfs Outflow= 9.34 cfs 0.994 af

Reach 5: culvert
Inflow= 9.34 cfs 0.994 af
Length= 100.0' Max Vel= 2.9 fps Capacity= 397.33 cfs Outflow= 9.30 cfs 0.993 af

Reach 6: west channel
Inflow= 9.30 cfs 0.993 af
Length= 380.0' Max Vel= 2.5 fps Capacity= 337.31 cfs Outflow= 9.14 cfs 0.990 af

Reach 7: west channel
Inflow= 10.66 cfs 1.243 af
Length= 550.0' Max Vel= 2.8 fps Capacity= 315.77 cfs Outflow= 10.47 cfs 1.237 af

Reach 8: west channel
Inflow= 12.89 cfs 1.715 af
Length= 280.0' Max Vel= 3.0 fps Capacity= 315.58 cfs Outflow= 12.81 cfs 1.711 af

Reach 9: culvert
Inflow= 0.79 cfs 0.055 af
Length= 200.0' Max Vel= 2.3 fps Capacity= 43.05 cfs Outflow= 0.77 cfs 0.055 af

Reach 10: access road diversion channel
Length= 260.0' Max Vel= 0.0 fps Capacity= 32.43 cfs Outflow= 0.00 cfs 0.000 af

Reach 11: access road diversion channel
Inflow= 1.34 cfs 0.087 af
Length= 310.0' Max Vel= 1.6 fps Capacity= 84.62 cfs Outflow= 1.23 cfs 0.086 af

Reach 12: culvert
Inflow= 4.73 cfs 0.401 af
Length= 116.0' Max Vel= 4.9 fps Capacity= 1,112.19 cfs Outflow= 4.67 cfs 0.401 af

Reach 13: culvert
Inflow= 0.86 cfs 0.067 af
Length= 65.0' Max Vel= 2.8 fps Capacity= 1,040.04 cfs Outflow= 0.85 cfs 0.067 af

Reach 14: culvert
Inflow= 1.48 cfs 0.070 af
Length= 112.0' Max Vel= 2.8 fps Capacity= 822.56 cfs Outflow= 1.43 cfs 0.070 af

Pond 1P: Sedimentation Basin 2
Peak Storage= 2.388 af Inflow= 14.18 cfs 2.389 af
Primary= 0.00 cfs 0.000 af Outflow= 0.00 cfs 0.000 af

- 4664

Runoff Area = 39.090 ac Volume = 2.411 af Average Depth = 0.74"

Subcatchment A: vegetated final cover

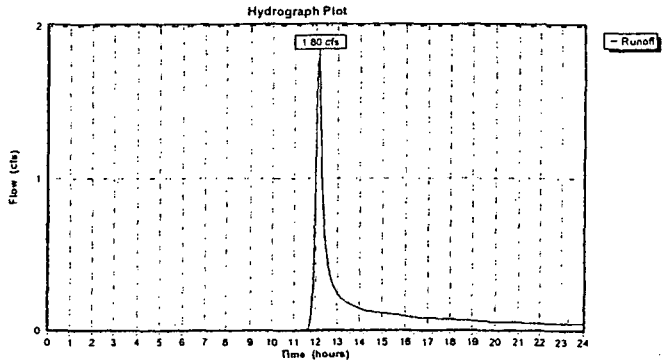
Runoff = 1.80 cfs @ 12.13 hrs, Volume= 0.144 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
2.730	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.7	180	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
18.3	670	Total			

Subcatchment A: vegetated final cover



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Subcatchment B: vegetated final cover

Runoff = 3.41 cfs @ 12.14 hrs, Volume= 0.281 af

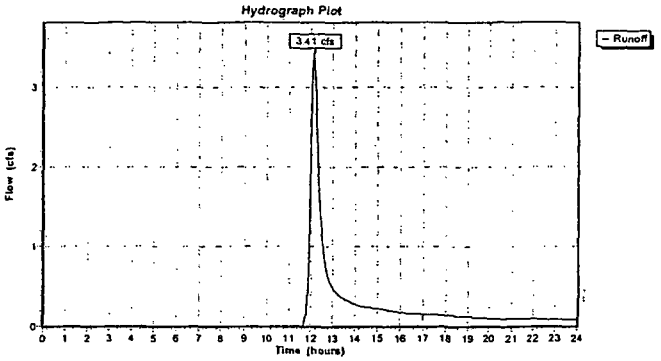
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.342	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	200	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
0.8	200	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
19.3	950	Total			

DBH 1/30/02

Subcatchment B: vegetated final cover



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Subcatchment C: vegetated final cover

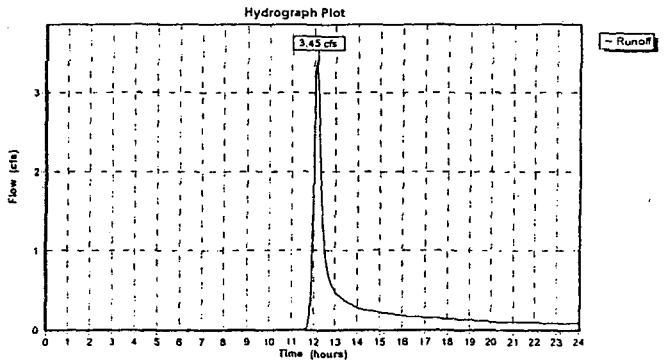
Runoff = 3.45 cfs @ 12.14 hrs, Volume= 0.284 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.399	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	200	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
0.8	195	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
19.3	945	Total			

Subcatchment C: vegetated final cover



Subcatchment D: vegetated final cover

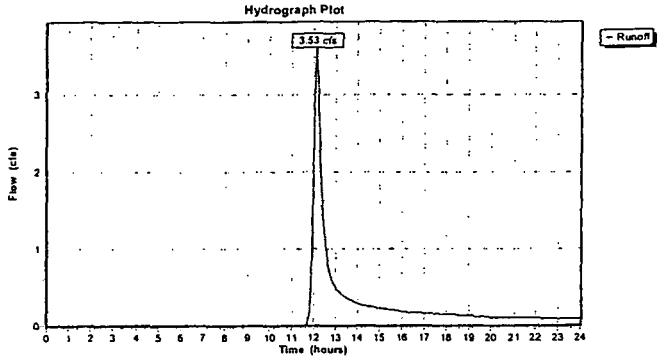
Runoff = 3.53 cfs @ 12.14 hrs, Volume= 0.291 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
5.530	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	205	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
0.8	195	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
19.3	950	Total			

Subcatchment D: vegetated final cover



4664

Subcatchment E: vegetated final cover

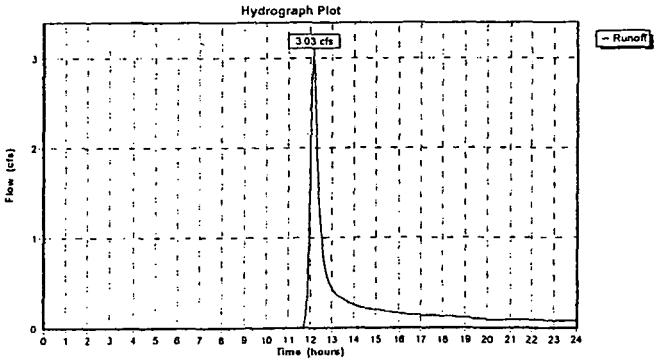
Runoff = 3.03 cfs @ 12.15 hrs, Volume= 0.253 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
4.807	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	205	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	190	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 3.0 & 6.0 '/' n= 0.030
0.1	60	0.0100	15.0	423.51	Circular Channel (pipe), Diam= 72.0" Area= 28.3 sf Perim= 18.8' r= 1.50' n= 0.013
1.2	305	0.0075	4.2	75.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 6.0 & 3.0 '/' n= 0.030
19.7	1,060	Total			

Subcatchment E: vegetated final cover



Subcatchment F: vegetated final cover/open space

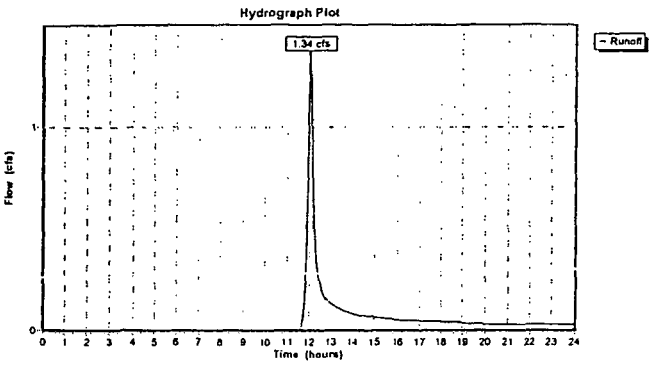
Runoff = 1.34 cfs @ 12.06 hrs, Volume= 0.087 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.640	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
11.1	300	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	135	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.4	50	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.7	185	0.0133	4.6	41.54	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.50' Z= 3.0 & 5.0 '/' n= 0.030
12.5	670	Total			

Subcatchment F: vegetated final cover/open space



DBM 1/30/02 214/202

Subcatchment G: vegetated final cover/open space

Runoff = 2.18 cfs @ 12.17 hrs, Volume= 0.191 af

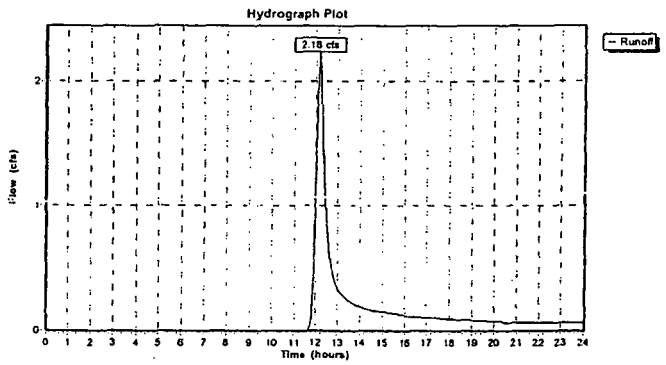
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
3.637	74	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
11.1	230	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.3	20	0.1700	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	110	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.9	450	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.5	130	0.0066	4.6	114.26	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.50' Z= 3.0 & 5.0 '/' n= 0.030
21.4	990	Total			

Subcatchment G: vegetated final cover/open space



Subcatchment H: open space with good grass cover

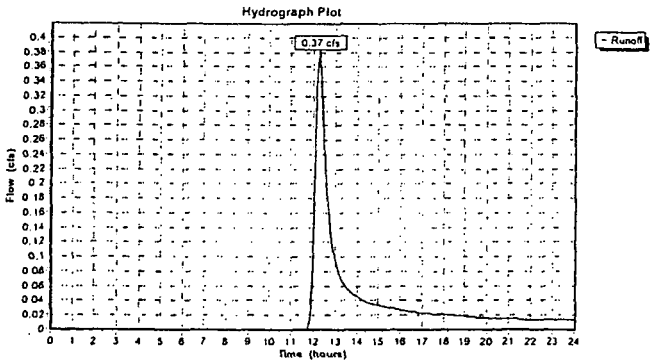
Runoff = 0.37 cfs @ 12.29 hrs, Volume= 0.042 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.797	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
30.1	300	0.0141	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	50	0.0141	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
30.5	350	Total			

Subcatchment H: open space with good grass cover



Subcatchment I: open space with good grass cover

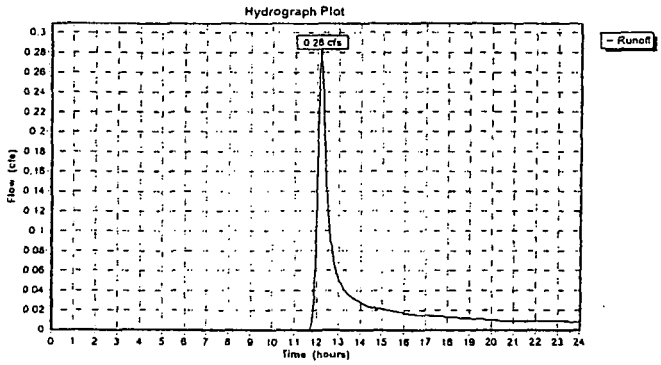
Runoff = 0.28 cfs @ 12.21 hrs, Volume= 0.027 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.512	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
24.8	300	0.0230	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	30	0.0230	2.4		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
25.0	330	Total			

Subcatchment I: open space with good grass cover



Subcatchment J: open space with good grass cover

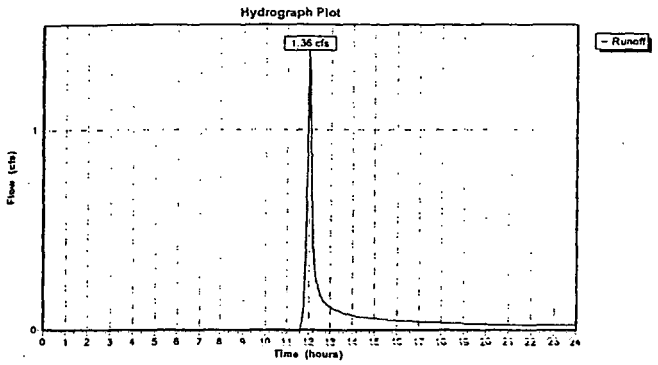
Runoff = 1.36 cfs @ 12.02 hrs, Volume= 0.077 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.452	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1	110	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.0	350	0.0075	6.0	221.03	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.50' Z= 3.0 '/' n= 0.030
9.1	460	Total			

Subcatchment J: open space with good grass cover



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Subcatchment K: open space with good grass cover

Runoff = 0.79 cfs @ 12.10 hrs, Volume= 0.055 af

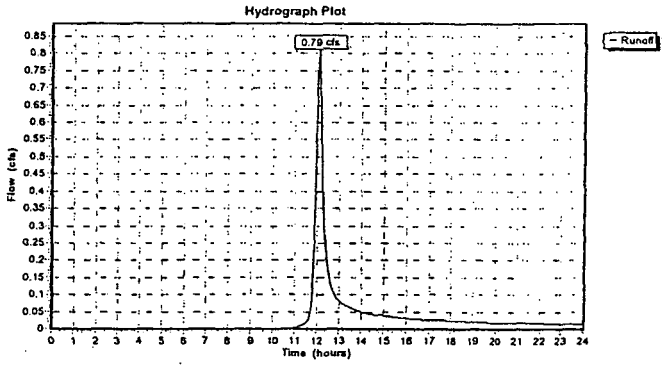
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.765	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
16.4	220	0.0347	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

- 4664

Subcatchment K: open space with good grass cover



Subcatchment L: open space with good grass cover

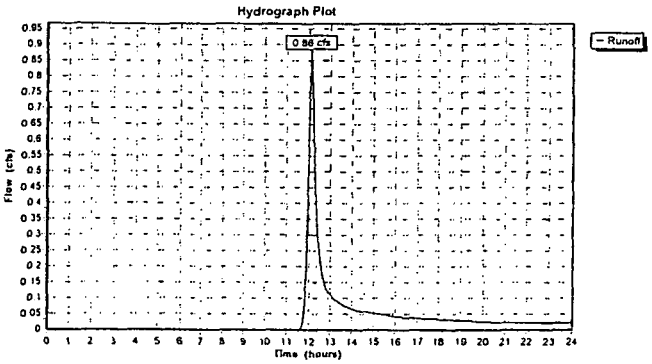
Runoff = 0.86 cfs @ 12.12 hrs, Volume= 0.067 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.277	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
17.7	220	0.0285	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment L: open space with good grass cover



Subcatchment M: open space with good grass cover

[49] Hint: Tc<2dt may require smaller dt

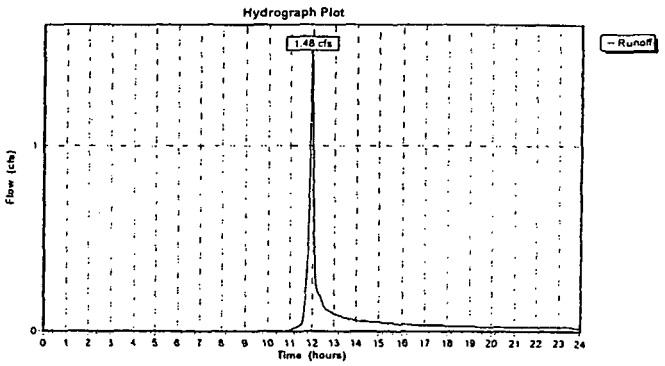
Runoff = 1.48 cfs @ 11.97 hrs, Volume= 0.070 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.964	79	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.0	390	0.0110	6.6	177.46	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.00' Z= 3.0 '/' n= 0.030
5.3	440	Total			

Subcatchment M: open space with good grass cover



Subcatchment N: open space with good grass cover

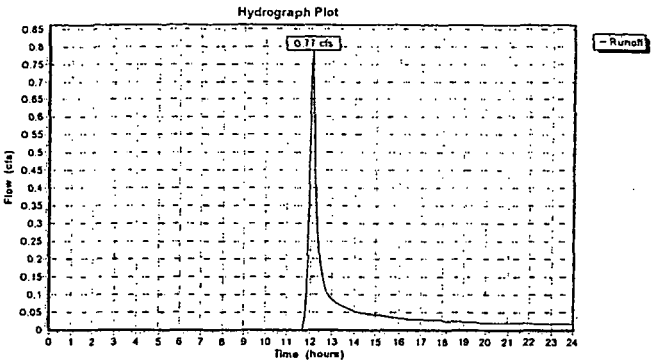
Runoff = 0.77 cfs @ 12.09 hrs, Volume= 0.055 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
1.043	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.2	170	0.0250	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment N: open space with good grass cover



DGP 30 JAN 02 216/282
DBM 1/30/02

Subcatchment O: direct runon to pond

[49] Hint: Tc<2dt may require smaller dt

Runoff = 8.94 cfs @ 11.90 hrs, Volume= 0.435 af

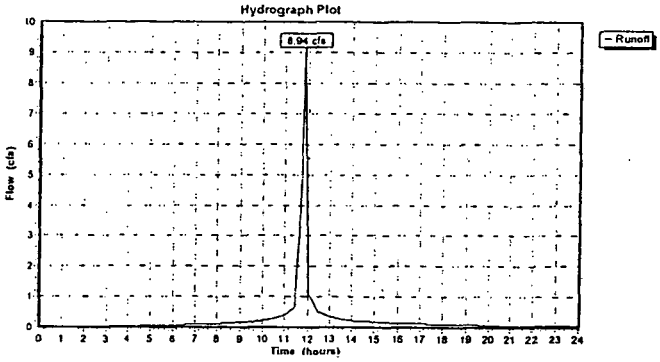
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
2.252	98	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.0					Direct Entry,

– 4664

Subcatchment O: direct runon to pond



Subcatchment P: open space with good grass cover

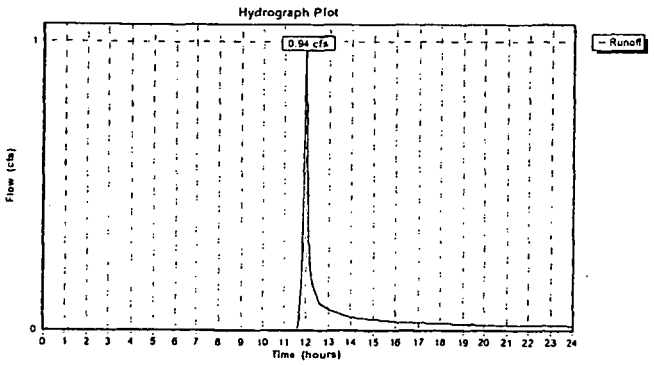
Runoff = 0.94 cfs @ 12.00 hrs, Volume= 0.050 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=2.55"

Area (ac)	CN	Description
0.943	74	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.7	235	0.0075	6.0	221.03	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.50' Z= 3.0 '/' n= 0.030
7.6	325	Total			

Subcatchment P: open space with good grass cover



Reach 1: west channel

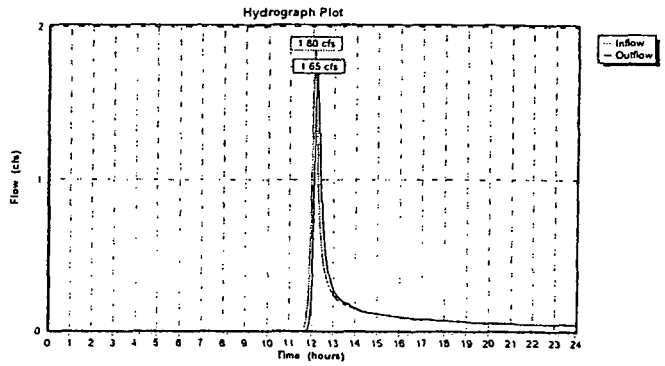
[65] Warning: Inlet elevation not specified

Inflow = 1.80 cfs @ 12.13 hrs, Volume= 0.144 af
Outflow = 1.65 cfs @ 12.26 hrs, Volume= 0.143 af, Atten= 8%, Lag= 7.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.6 fps, Min. Travel Time= 4.1 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 8.4 min

Peak Depth= 0.48'
Capacity at bank full= 223.61 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 400.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 1: west channel



Reach 2: west channel

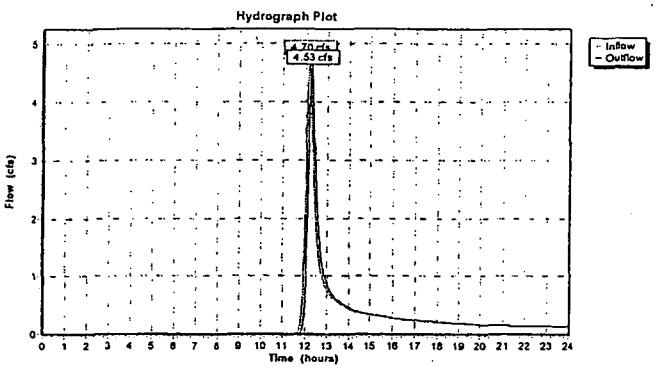
[65] Warning: Inlet elevation not specified

Inflow = 4.70 cfs @ 12.18 hrs, Volume= 0.424 af
Outflow = 4.53 cfs @ 12.28 hrs, Volume= 0.422 af, Atten= 4%, Lag= 5.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.1 fps, Min. Travel Time= 3.2 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 6.4 min

Peak Depth= 0.70'
Capacity at bank full= 223.61 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 400.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 2: west channel



DGP 30 JAN 02 211 / 282
DBM 1/30/02

Reach 3: west channel

[65] Warning: Inlet elevation not specified

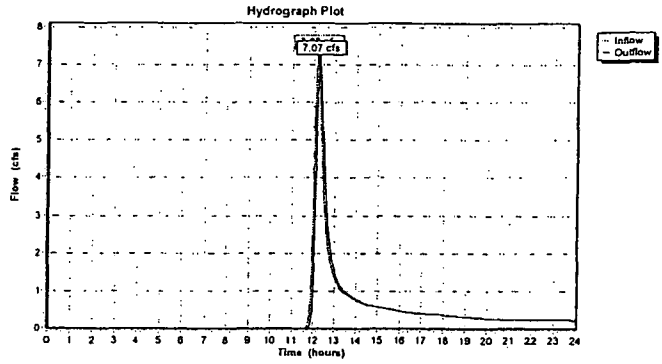
Inflow = 7.23 cfs @ 12.22 hrs, Volume= 0.707 af
Outflow = 7.07 cfs @ 12.31 hrs, Volume= 0.704 af, Atten= 2%, Lag= 5.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.3 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 5.7 min

4664

Peak Depth= 0.82'
Capacity at bank full= 223.61 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 400.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 3: west channel



Reach 4: west channel

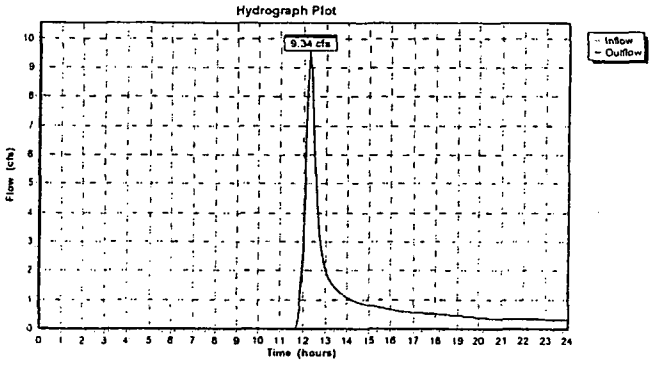
[65] Warning: Inlet elevation not specified

Inflow = 9.40 cfs @ 12.27 hrs, Volume= 0.995 af
Outflow = 9.34 cfs @ 12.29 hrs, Volume= 0.994 af, Atten= 1%, Lag= 1.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.5 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 1.2 min

Peak Depth= 0.91'
Capacity at bank full= 224.44 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 90.0' Slope= 0.0076 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 4: west channel



Reach 5: culvert

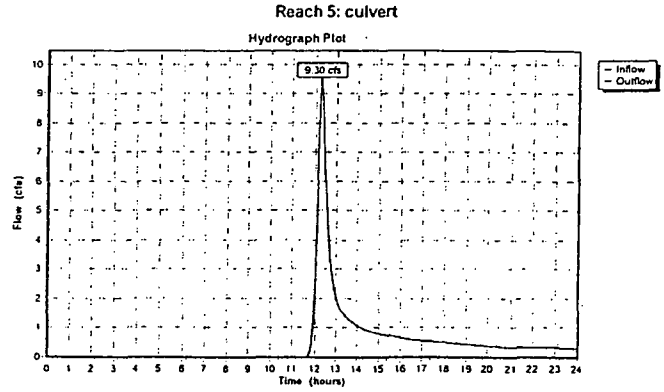
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 9.34 cfs @ 12.29 hrs, Volume= 0.994 af
Outflow = 9.30 cfs @ 12.31 hrs, Volume= 0.993 af, Atten= 0%, Lag= 1.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 0.6 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 1.3 min

Peak Depth= 0.63'
Capacity at bank full= 397.33 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.024 Length= 100.0' Slope= 0.0075 '/'

Reach 5: culvert



Reach 6: west channel

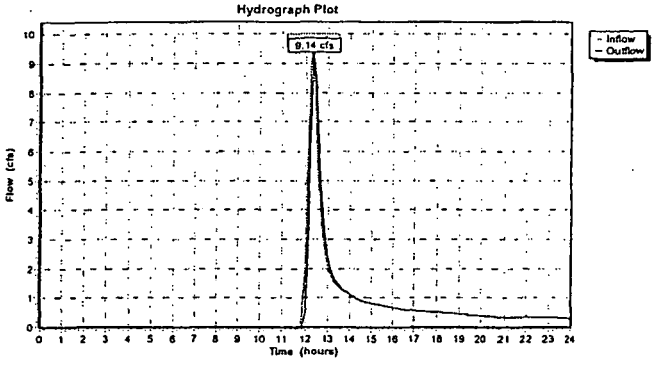
[65] Warning: Inlet elevation not specified

Inflow = 9.30 cfs @ 12.31 hrs, Volume= 0.993 af
Outflow = 9.14 cfs @ 12.38 hrs, Volume= 0.990 af, Atten= 2%, Lag= 4.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.5 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 4.9 min

Peak Depth= 0.91'
Capacity at bank full= 337.31 cfs
0.00' x 3.50' deep channel, n= 0.030 Length= 380.0' Slope= 0.0075 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 6: west channel



DGP 30 JAN 02 DBM 1/30/02 210/282

Reach 7: west channel

[65] Warning: Inlet elevation not specified

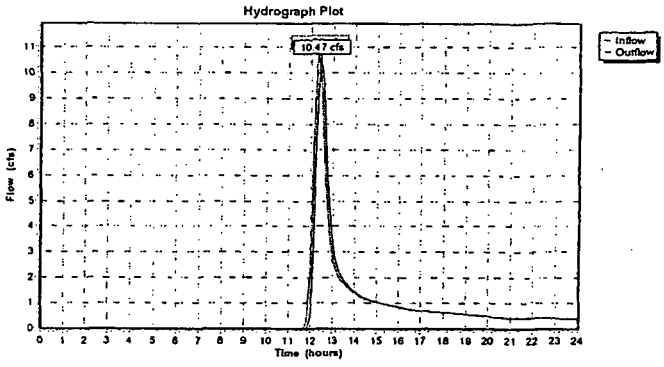
Inflow = 10.66 cfs @ 12.36 hrs, Volume= 1.243 af
Outflow = 10.47 cfs @ 12.45 hrs, Volume= 1.237 af, Atten= 2%, Lag= 5.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.8 fps, Min. Travel Time= 3.3 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 6.2 min

4664

Peak Depth= 1.12'
Capacity at bank full= 315.77 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 550.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 7: west channel



Reach 8: west channel

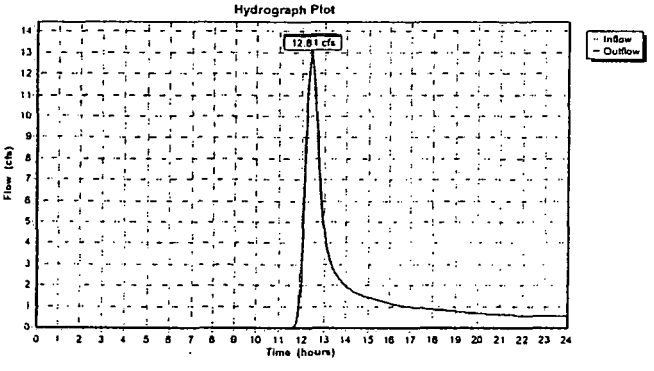
[65] Warning: Inlet elevation not specified

Inflow = 12.89 cfs @ 12.41 hrs, Volume= 1.715 af
Outflow = 12.81 cfs @ 12.46 hrs, Volume= 1.711 af, Atten= 1%, Lag= 2.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.0 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 3.0 min

Peak Depth= 1.20'
Capacity at bank full= 315.58 cfs
0.00' x 4.00' deep channel, n= 0.030 Length= 280.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 '/'

Reach 8: west channel



Reach 9: culvert

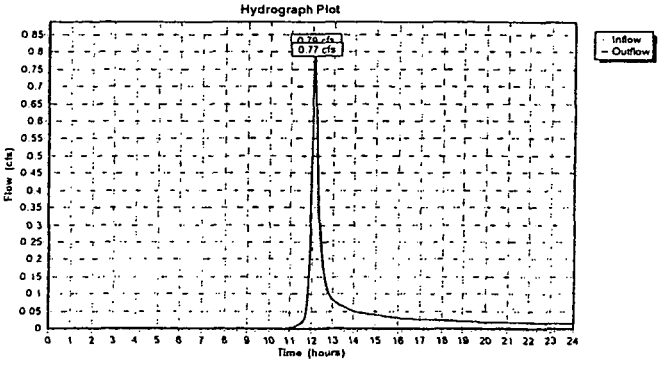
[65] Warning: Inlet elevation not specified

Inflow = 0.79 cfs @ 12.10 hrs, Volume= 0.055 af
Outflow = 0.77 cfs @ 12.14 hrs, Volume= 0.055 af, Atten= 3%, Lag= 2.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.3 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 3.2 min

Peak Depth= 0.33'
Capacity at bank full= 43.05 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 200.0' Slope= 0.0261 '/'
Side Slope Z-value= 3.0 '/'

Reach 9: culvert



Reach 10: access road diversion channel

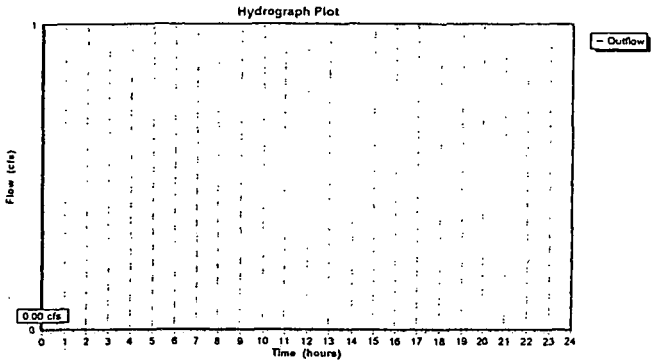
[43] Hint: Has no inflow (Outflow=Zero)

Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.0 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.0 fps, Avg. Travel Time= 0.0 min

Peak Depth= 0.00'
Capacity at bank full= 32.43 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 260.0' Slope= 0.0148 '/'
Side Slope Z-value= 3.0 '/'

Reach 10: access road diversion channel



DCP 30 JAN 02 DBM 1/30/02 417/282

Reach 11: access road diversion channel

[65] Warning: Inlet elevation not specified

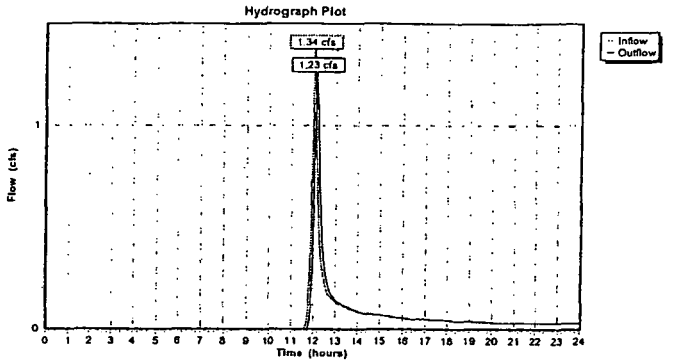
Inflow = 1.34 cfs @ 12.06 hrs, Volume= 0.087 af
Outflow = 1.23 cfs @ 12.16 hrs, Volume= 0.086 af, Atten= 8%, Lag= 5.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.6 fps, Min. Travel Time= 3.3 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 7.2 min

4664

Peak Depth= 0.51'
Capacity at bank full= 84.62 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 310.0' Slope= 0.0066 '/'
Side Slope Z-value= 3.0 '/'

Reach 11: access road diversion channel



Reach 12: culvert

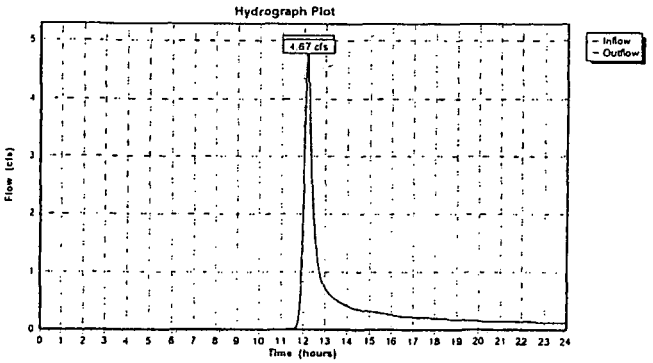
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 4.73 cfs @ 12.17 hrs, Volume= 0.401 af
Outflow = 4.67 cfs @ 12.18 hrs, Volume= 0.401 af, Atten= 1%, Lag= 0.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.9 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 2.1 fps, Avg. Travel Time= 0.9 min

Peak Depth= 0.28'
Capacity at bank full= 1,112.19 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.013 Length= 116.0' Slope= 0.0172 '/'

Reach 12: culvert



Reach 13: culvert

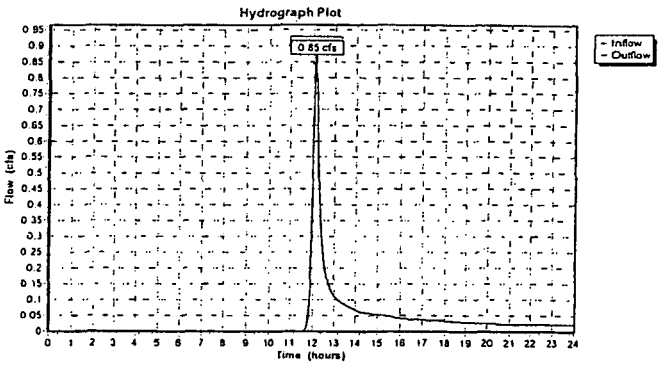
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 0.86 cfs @ 12.12 hrs, Volume= 0.067 af
Outflow = 0.85 cfs @ 12.13 hrs, Volume= 0.067 af, Atten= 1%, Lag= 0.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.8 fps, Min. Travel Time= 0.4 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 0.6 min

Peak Depth= 0.13'
Capacity at bank full= 1,040.04 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.013 Length= 65.0' Slope= 0.0151 '/'

Reach 13: culvert



Reach 14: culvert

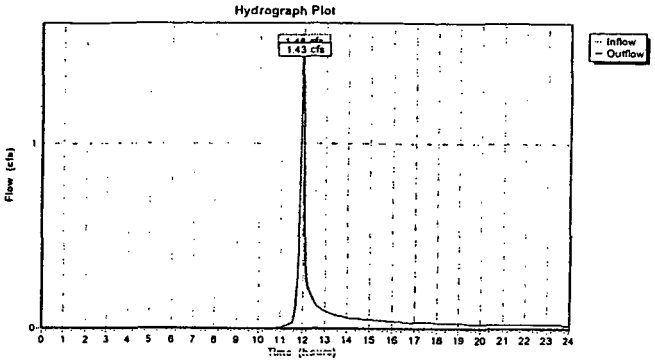
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow	=	1.48 cfs @	11.97 hrs,	Volume=	0.070 af
Outflow	=	1.43 cfs @	11.99 hrs,	Volume=	0.070 af, Atten= 3%, Lag= 1.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.8 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 1.4 min

Peak Depth= 0.19'
Capacity at bank full= 822.56 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.024 Length= 112.0' Slope= 0.0321 '/'

Reach 14: culvert



DCP 30 JAN 02

4664

Pond 1P: Sedimentation Basin 2

Inflow	=	14.18 cfs @	12.44 hrs,	Volume=	2.389 af
Outflow	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af, Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs,	Volume=	0.000 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

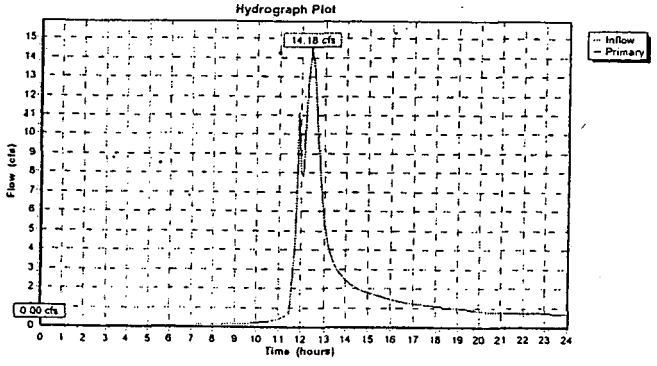
Peak Elev= 572.05' Storage= 2.388 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.50	1.460	0.000	0.000	1.460
571.00	1.512	0.743	0.743	1.513
572.00	1.614	1.563	2.306	1.617
573.00	1.713	1.663	3.969	1.719
574.00	1.819	1.766	5.735	1.827
575.00	1.917	1.868	7.602	1.928
576.00	2.026	1.971	9.574	2.039
577.00	2.162	2.094	11.667	2.177

Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.50'	48.0" Horiz. Orifice/Grate Limited to weir flow C= 0.600
2	Primary	570.78'	36.0" x 680.0' long Culvert Ke= 0.700
			Outlet Invert= 563.30' S= 0.0110 '/' n= 0.024 Cc= 0.900
3	Primary	576.00'	20.0' long Broad-Crested Rectangular Weir
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Pond 1P: Sedimentation Basin 2



Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

WEST OSDF POST-DEVELOPMENT DESIGN SCENARIO 25-YEAR, 24-HOUR STORM EVENT

Pond 1P: Sedimentation Basin 2

- 4664

Inflow	=	62.13 cfs @	12.30 hrs, Volume=	7.355 af	
Outflow	=	0.00 cfs @	0.00 hrs, Volume=	0.000 af,	Atten= 100%, Lag= 0.0 min
Primary	=	0.00 cfs @	0.00 hrs, Volume=	0.000 af	

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Peak Elev= 574.87' Storage= 7.351 af
Plug-Flow detention time= (not calculated)
Storage and wetted areas determined by Conic sections

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)	Wet.Area (acres)
570.50	1.460	0.000	0.000	1.460
571.00	1.512	0.743	0.743	1.513
572.00	1.614	1.563	2.306	1.617
573.00	1.713	1.663	3.969	1.719
574.00	1.819	1.766	5.735	1.827
575.00	1.917	1.868	7.602	1.928
576.00	2.026	1.971	9.574	2.039
577.00	2.162	2.094	11.667	2.177

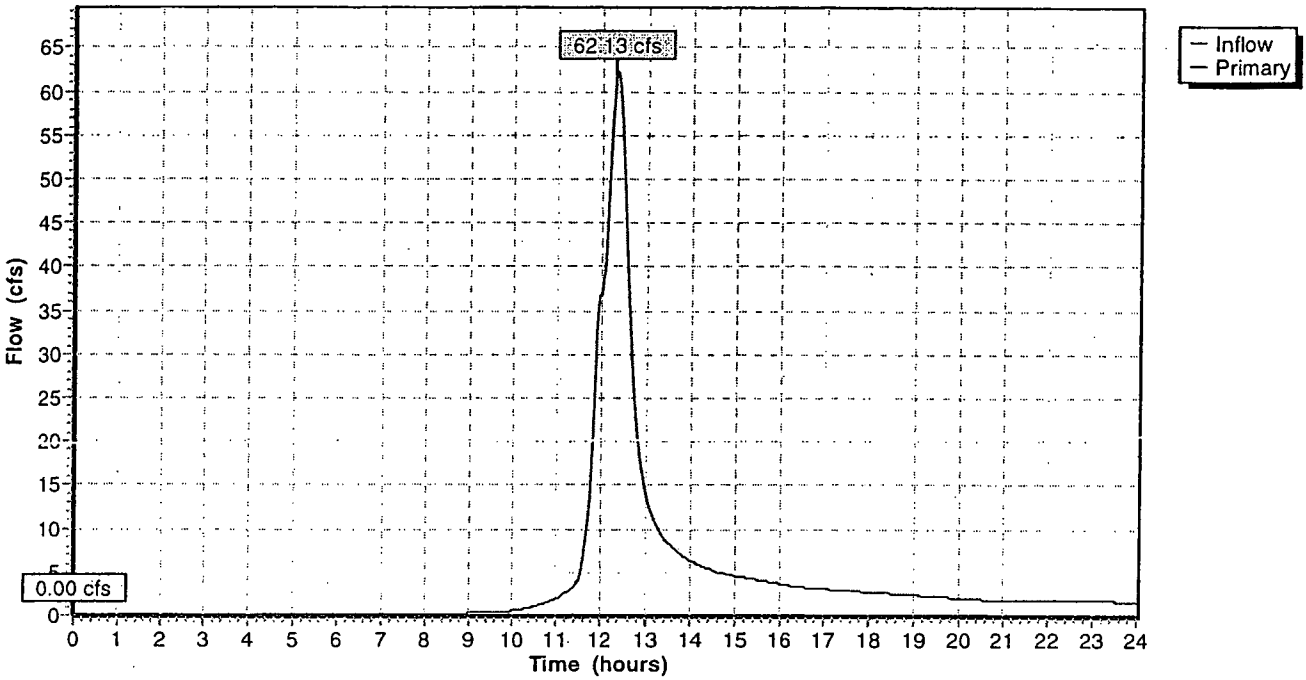
Primary OutFlow (Free Discharge)
- 2=Culvert
  - 1=Orifice/Grate
- 3=Broad-Crested Rectangular Weir

#	Routing	Invert	Outlet Devices
1	Device 2	575.50'	**48.0" Horiz. Orifice/Grate** Limited to weir flow C= 0.600
2	Primary	570.78'	**36.0" x 680.0' long Culvert** Ke= 0.700
			Outlet Invert= 563.30' S= 0.0110 '/' n= 0.024 Cc= 0.900
3	Primary	576.00'	**20.0' long Broad-Crested Rectangular Weir**
			Head (feet) 0.50 1.00 1.50 2.00 2.50 3.00 4.00 5.00
			Coef. (English) 3.00 3.00 3.00 3.00 3.00 3.00 3.00 3.00

Pond 1P: Sedimentation Basin 2

4664

Hydrograph Plot



4664

ATTACHMENT C-1E

HydroCAD™ OUTPUT REPORTS

DESIGN CASE "A"

- 4664

DESIGN CASE "A"

25-YEAR, 24-HOUR STORM EVENT

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=4.70"
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: liner runout
Tc=3.4 min CN=89 Area=1.927 ac Runoff= 12.05 cfs 0.559 af

Subcatchment B: construction laydown
Tc=32.9 min CN=82 Area=0.880 ac Runoff= 2.02 cfs 0.205 af

Subcatchment C: construction laydown
Tc=25.9 min CN=82 Area=0.711 ac Runoff= 1.90 cfs 0.166 af

Subcatchment D: construction laydown
Tc=30.7 min CN=82 Area=0.654 ac Runoff= 1.57 cfs 0.152 af

Subcatchment E: construction laydown
Tc=30.8 min CN=82 Area=1.287 ac Runoff= 3.08 cfs 0.299 af

Subcatchment F: construction laydown
Tc=28.3 min CN=82 Area=0.336 ac Runoff= 0.85 cfs 0.078 af

Subcatchment G: construction laydown
Tc=9.8 min CN=82 Area=1.858 ac Runoff= 7.91 cfs 0.435 af

Subcatchment H: construction laydown/pavement
Tc=19.1 min CN=92 Area=0.650 ac Runoff= 2.68 cfs 0.205 af

Reach 1: existing culvert Inflow= 2.02 cfs 0.205 af
Length= 80.0' Max Vel= 2.7 fps Capacity= 677.07 cfs Outflow= 2.01 cfs 0.204 af

Reach 2: channel Inflow= 2.01 cfs 0.204 af
Length= 330.0' Max Vel= 2.1 fps Capacity= 352.90 cfs Outflow= 1.99 cfs 0.204 af

Reach 3: existing culverts Inflow= 8.41 cfs 0.638 af
Length= 55.0' Max Vel= 4.6 fps Capacity= 813.23 cfs Outflow= 8.33 cfs 0.638 af

Reach 4: existing culverts Inflow= 1.90 cfs 0.166 af
Length= 60.0' Max Vel= 4.7 fps Capacity= 1,557.22 cfs Outflow= 1.89 cfs 0.166 af

Reach 5: channel Inflow= 12.05 cfs 0.559 af
Length= 170.0' Max Vel= 2.1 fps Capacity= 60.78 cfs Outflow= 10.91 cfs 0.559 af

Reach 6: channel Inflow= 11.74 cfs 0.724 af
Length= 230.0' Max Vel= 1.8 fps Capacity= 12.79 cfs Outflow= 11.05 cfs 0.723 af

Reach 7: channel Inflow= 20.18 cfs 1.513 af
Length= 185.0' Max Vel= 4.3 fps Capacity= 138.21 cfs Outflow= 19.74 cfs 1.512 af

Reach 8: new culverts Inflow= 24.73 cfs 2.095 af
Length= 49.0' Max Vel= 5.5 fps Capacity= 647.72 cfs Outflow= 24.61 cfs 2.094 af

Runoff Area = 8.303 ac Volume = 2.099 af Average Depth = 3.03"

4664

Subcatchment A: liner runout

[49] Hint: Tc<2dt may require smaller dt

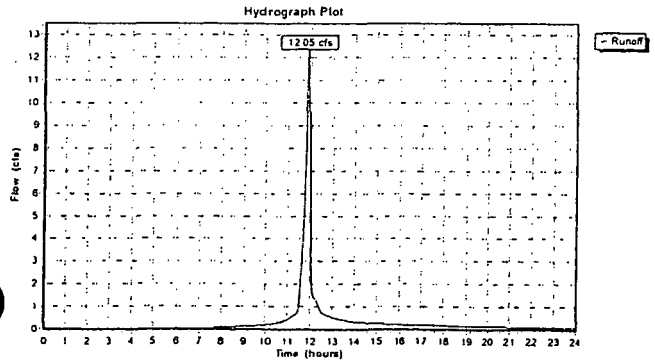
Runoff = 12.05 cfs @ 11.94 hrs, Volume= 0.559 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.927	89	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.0	8	0.6660	3.0		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.3	18	0.0215	0.9		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
0.2	31	0.2500	2.7		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
1.2	90	0.0222	1.3		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
1.7	590	0.0100	5.7	949.93	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.50' Z= 3.0 & 50.0 '/' n= 0.030
3.4	737	Total			

Subcatchment A: liner runout



Subcatchment B: construction laydown

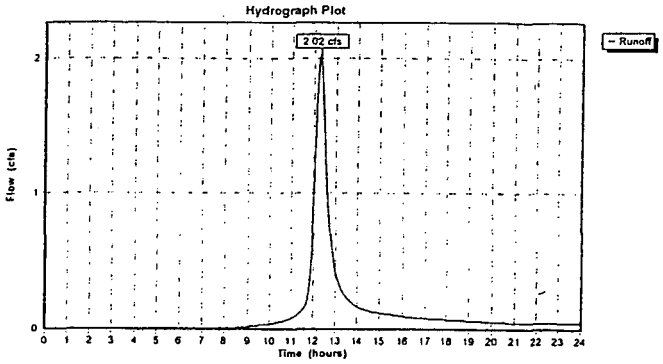
Runoff = 2.02 cfs @ 12.28 hrs, Volume= 0.205 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.880	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
31.6	300	0.0125	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.3	145	0.0125	1.8		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
32.9	445	Total			

Subcatchment B: construction laydown



Subcatchment C: construction laydown

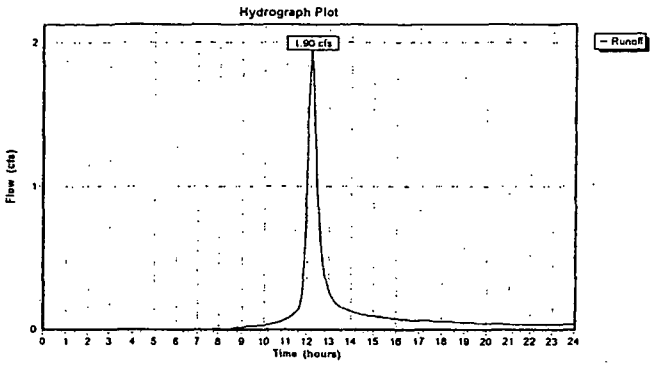
Runoff = 1.90 cfs @ 12.19 hrs, Volume= 0.166 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.711	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
25.9	260	0.0154	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment C: construction laydown



Subcatchment D: construction laydown

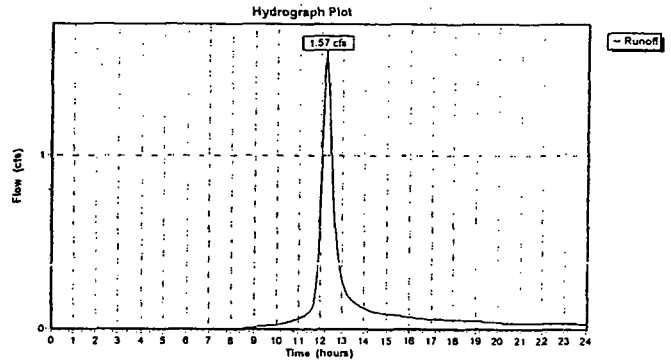
Runoff = 1.57 cfs @ 12.25 hrs, Volume= 0.152 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.654	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.6	85	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
23.4	215	0.0136	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	30	0.0136	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.4	60	0.0050	2.8	18.84	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.50' Z= 3.0 '/' n= 0.030
30.7	390	Total			

Subcatchment D: construction laydown



Subcatchment E: construction laydown

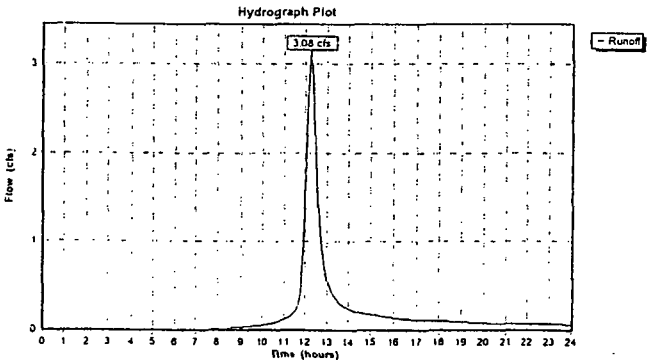
Runoff = 3.08 cfs @ 12.25 hrs, Volume= 0.299 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.287	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
30.8	300	0.0133	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"

Subcatchment E: construction laydown



Subcatchment F: construction laydown

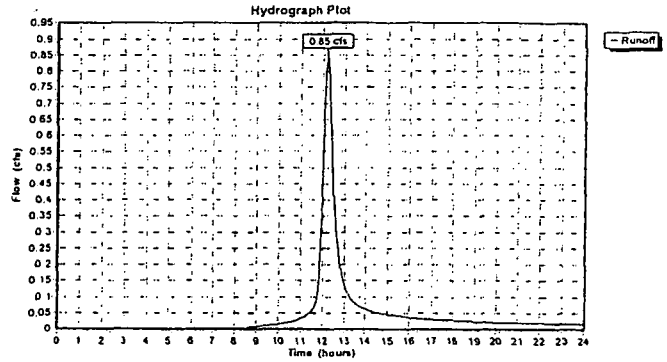
Runoff = 0.85 cfs @ 12.22 hrs, Volume= 0.078 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.336	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	20	0.3750	2.9		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
5.0	60	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
4.3	55	0.0600	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
17.7	165	0.0161	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
1.2	150	0.0161	2.0		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
28.3	450	Total			

Subcatchment F: construction laydown



Subcatchment G: construction laydown

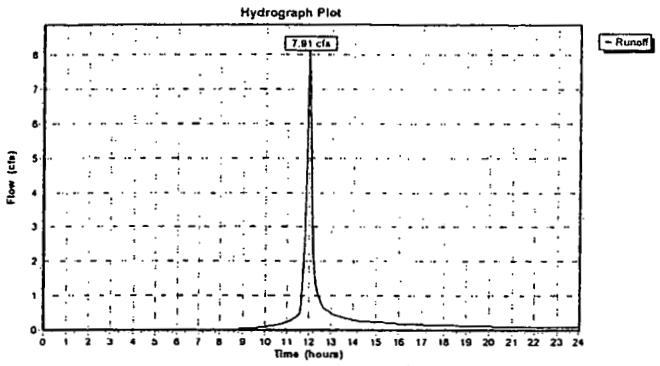
Runoff = 7.91 cfs @ 12.01 hrs, Volume= 0.435 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
1.858	82	

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.9	85	0.0235	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.9	330	0.0150	6.0	119.69	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.00' Z= 4.0 & 6.0 '/' n= 0.030
9.8	415	Total			

Subcatchment G: construction laydown



DGP 30 JAN 02
DBM 1/30/02

Subcatchment H: construction laydown/pavement

Runoff = 2.68 cfs @ 12.11 hrs, Volume= 0.205 af

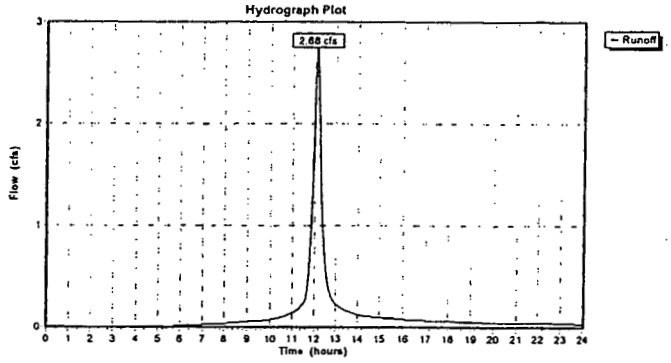
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.70"

Area (ac)	CN	Description
0.650	92	

- 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.1	165	0.0182	1.3		Sheet Flow, Smooth surfaces n= 0.011 P2= 2.60"
17.0	115	0.0087	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
19.1	280	Total			

Subcatchment H: construction laydown/pavement



Reach 1: existing culvert

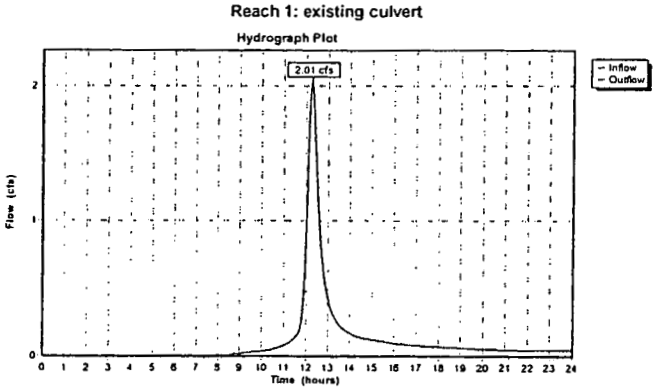
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

Inflow = 2.02 cfs @ 12.28 hrs, Volume= 0.205 af
Outflow = 2.01 cfs @ 12.29 hrs, Volume= 0.204 af, Atten= 0%, Lag= 1.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.7 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 1.1 min

Peak Depth= 0.24'
Capacity at bank full= 677.07 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.018 Length= 80.0' Slope= 0.0123 '/'

Reach 1: existing culvert



Reach 2: channel

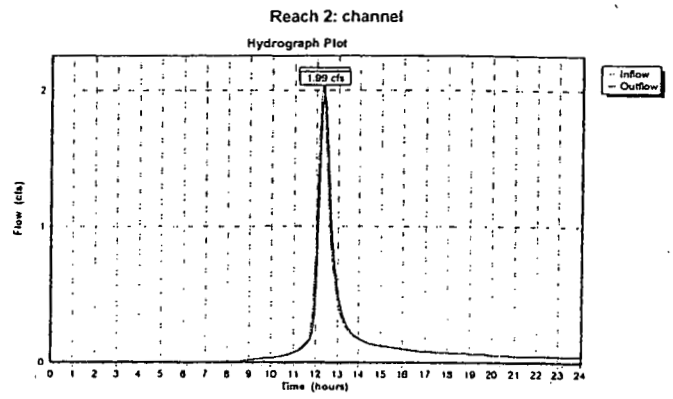
[65] Warning: Inlet elevation not specified

Inflow = 2.01 cfs @ 12.29 hrs, Volume= 0.204 af
Outflow = 1.99 cfs @ 12.37 hrs, Volume= 0.204 af, Atten= 1%, Lag= 4.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.1 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 1.0 fps, Avg. Travel Time= 5.8 min

Peak Depth= 0.43'
Capacity at bank full= 352.90 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 330.0' Slope= 0.0150 '/'
Side Slope Z-value= 4.0 6.0 '/'

Reach 2: channel



Reach 3: existing culverts

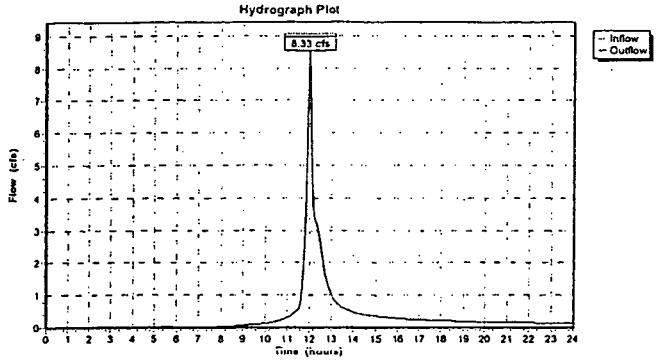
[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

flow	=	8.41 cfs @	12.02 hrs,	Volume=	0.638 af
utflow	=	8.33 cfs @	12.02 hrs,	Volume=	0.638 af, Atten= 1%, Lag= 0.4 min

outing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.6 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 0.5 min

Peak Depth= 0.43'
Capacity at bank full= 813.23 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 55.0' Slope= 0.0055 '/'

Reach 3: existing culverts



Reach 4: existing culverts

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

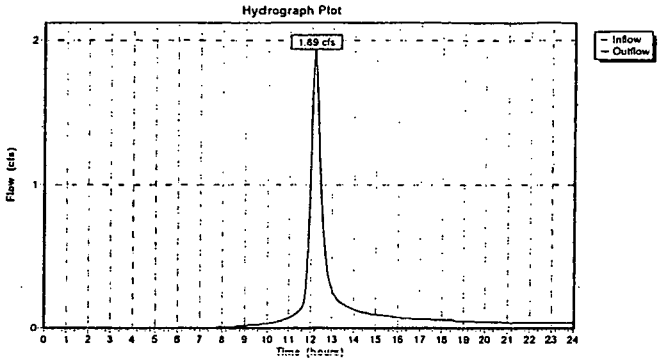
Inflow	=	1.90 cfs @	12.19 hrs,	Volume=	0.166 af
Outflow	=	1.89 cfs @	12.20 hrs,	Volume=	0.166 af, Atten= 0%, Lag= 0.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.7 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.5 fps, Avg. Travel Time= 0.4 min

- 4664

Peak Depth= 0.16'
Capacity at bank full= 1,557.22 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.010 Length= 60.0' Slope= 0.0200 '/'

Reach 4: existing culverts



Reach 5: channel

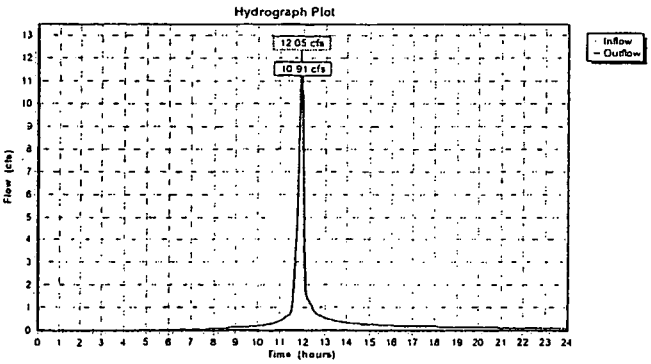
[65] Warning: Inlet elevation not specified

Inflow	=	12.05 cfs @	11.94 hrs,	Volume=	0.559 af
Outflow	=	10.91 cfs @	11.97 hrs,	Volume=	0.559 af, Atten= 10%, Lag= 2.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.1 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 3.8 min

Peak Depth= 1.34'
Capacity at bank full= 60.78 cfs
0.00' x 2.50' deep channel, n= 0.030 Length= 170.0' Slope= 0.0034 '/'
Side Slope Z-value= 3.0 '/'

Reach 5: channel



Reach 6: channel

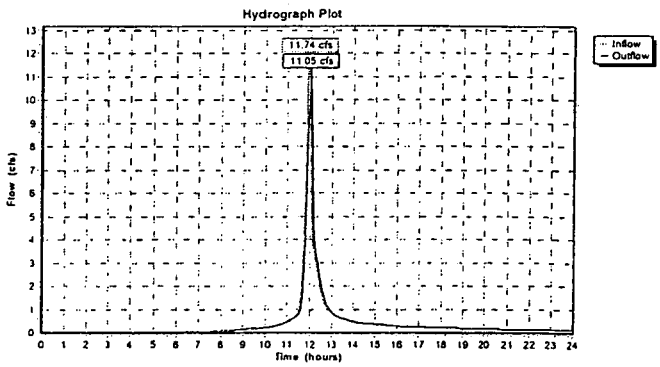
[65] Warning: Inlet elevation not specified

Inflow	=	11.74 cfs @	11.97 hrs,	Volume=	0.724 af
Outflow	=	11.05 cfs @	12.03 hrs,	Volume=	0.723 af, Atten= 6%, Lag= 3.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.8 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 5.6 min

Peak Depth= 1.44'
Capacity at bank full= 12.79 cfs
0.00' x 1.50' deep channel, n= 0.030 Length= 230.0' Slope= 0.0023 '/'
Side Slope Z-value= 3.0 '/'

Reach 6: channel



Reach 7: channel

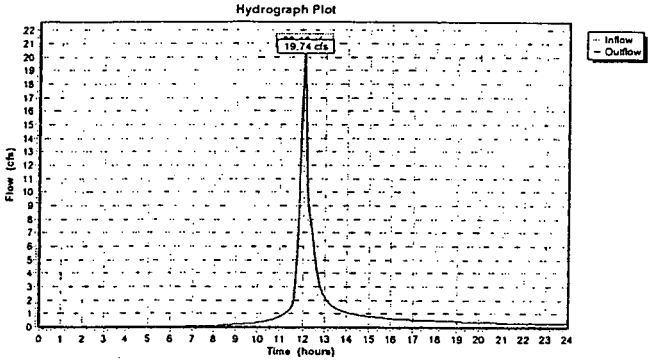
[65] Warning: Inlet elevation not specified

Inflow = 20.18 cfs @ 12.03 hrs, Volume= 1.513 af
Outflow = 19.74 cfs @ 12.05 hrs, Volume= 1.512 af, Atten= 2%, Lag= 1.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.3 fps, Min. Travel Time= 0.7 min
Avg. Velocity = 1.6 fps, Avg. Travel Time= 1.9 min

Peak Depth= 0.97'
Capacity at bank full= 138.21 cfs
0.00' x 2.00' deep channel, n= 0.030 Length= 185.0' Slope= 0.0200 '/'
Side Slope Z-value= 4.0 6.0 '/'

Reach 7: channel



DBM 1/30/02 2501200
DEP 30JAN02

Reach 8: new culverts

[52] Hint: Inlet conditions not evaluated
[65] Warning: Inlet elevation not specified

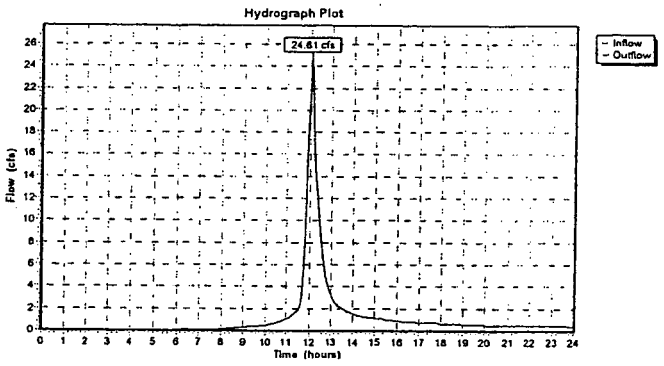
Inflow = 24.73 cfs @ 12.06 hrs, Volume= 2.095 af
Outflow = 24.61 cfs @ 12.07 hrs, Volume= 2.094 af, Atten= 0%, Lag= 0.2 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.5 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 1.8 fps, Avg. Travel Time= 0.4 min

Peak Depth= 0.80'
Capacity at bank full= 647.72 cfs
A factor of 2.00 has been applied to the supplied storage and discharge data
72.0" Diameter Pipe n= 0.017 Length= 49.0' Slope= 0.0100 '/'

= 4664

Reach 8: new culverts



- 4664

ATTACHMENT C-2

WEIGHTED CURVE NUMBER CALCULATIONS

DBM 1/30/02 232/282
DGP 30JAN02

- 4664

RESULTS FOR THE CALCULATION OF WEIGHTED CN
East OSDF Construction Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	1.96	100%	B/C	vegetated final cover	83	83
B	1.18	100%	B/C	vegetated final cover	83	83
C	5.21	100%	B/C	vegetated final cover	83	83
D	5.13	100%	B/C	vegetated final cover	83	83
E	5.09	100%	B/C	vegetated final cover	83	83
F	5.05	100%	B/C	vegetated final cover	83	83
G	5.31	100%	B/C	unvegetated final cover	89	89
H	3.49	100%	B/C	unvegetated final cover	89	89
I	1.69	100%	C	construction laydown	82	82
J	2.65	10% 90%	B C	construction laydown construction laydown	74 82	81
K	4.14	50% 50%	B C	construction laydown construction laydown	74 82	78
L	1.68	30% 70%	B C	runon north of borrow area runon north of borrow area	69 79	76
M	1.00	100%	C	runon north of borrow area	79	79
N	7.82	100%	N/A	direct runon to pond	98	98
O	1.32	100%	C	runon north of borrow area	79	79
P	5.24	45% 55%	B C	runon north of borrow area runon north of borrow area	69 79	75
Q	7.70	70% 30%	B C	runon north of borrow area runon north of borrow area	69 79	72
R	2.61	55% 45%	B C	runon north of borrow area runon north of borrow area	69 79	74
S	0.40	10% 90%	B C	runon north of borrow area runon north of borrow area	69 79	78
T	0.42	100%	N/A	direct runon to pond	98	98
U	4.15	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72
V	0.27	100%	N/A	direct runon to pond	98	98
W	10.59	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72
X	11.85	80% 20%	B C	runon east of OSDF runon east of OSDF	69 79	71
Y	6.52	60% 40%	B C	runon east of OSDF runon east of OSDF	69 79	73
Z	1.61	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72
AA	2.71	55% 45%	B C	runon east of OSDF runon east of OSDF	69 79	74
BB	0.76	100%	C	runon east of OSDF	79	79
CC	0.12	100%	C	runon east of OSDF	79	79
DD	0.54	100%	B/C	unvegetated final cover	89	89
EE	0.93	20% 80%	B C	runon north of borrow area runon north of borrow area	69 79	77
FF	3.09	100%	B/C	unvegetated final cover	89	89
GG	1.98	55% 45%	B C	construction laydown construction laydown	74 82	78
HH	0.55	100%	C	runon north of borrow area	79	79
II	1.67	50% 50%	B C	runon area to borrow area runon area to borrow area	61 74	68
JJ	0.91	93% 7%	B C	runon area to borrow area runon area to borrow area	61 74	62
KK	5.89	80% 20%	B C	runon area to borrow area runon area to borrow area	61 74	64
LL	7.05	100%	B	runoff	61	61
MM	1.94	100%	B	runoff	61	61
NN	1.27	60% 40%	B C	runoff runoff	61 74	66
OO	0.40	65% 35%	B C	runon area to borrow area runon area to borrow area	61 74	66
PP	40.96	80% 20%	B C	vegetated borrow are vegetated borrow are	61 74	64

N/A - Not Applicable

233/282
DGP 30JAN02
DBM 1/30/02
- 4664

RESULTS FOR THE CALCULATION OF WEIGHTED CN
West OSDF Construction Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	2.73	100%	B/C	vegetated final cover	83	83
B	5.34	100%	B/C	vegetated final cover	83	83
C	5.40	100%	B/C	vegetated final cover	83	83
D	5.53	100%	B/C	unvegetated final cover	89	89
E	4.81	100%	B/C	unvegetated final cover	89	89
F	1.64	60% 40%	B/C C	unvegetated final cover construction laydown	89 82	86
G	3.64	40% 60%	B/C C	unvegetated final cover construction laydown	89 82	85
H	0.80	100%	C	construction laydown	82	82
I	0.51	100%	C	construction laydown	82	82
J	1.45	100%	C	construction laydown	82	82
K	0.77	100%	C	runon north of borrow area	79	79
L	1.28	100%	C	construction laydown	82	82
M	0.96	100%	C	runon north of borrow area	79	79
N	1.04	100%	C	construction laydown	82	82
O	2.25	100%	N/A	direct runon to pond	98	98
P	0.94	100%	C	construction laydown	82	82

N/A - Not Applicable

234/282
DBM 1/30/02
DGP 30 JAN 02

4664

RESULTS FOR THE CALCULATION OF WEIGHTED CN
East OSDF Post Development Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	1.96	100%	B/C	vegetated final cover	74	74
B	1.18	100%	B/C	vegetated final cover	74	74
C	5.21	100%	B/C	vegetated final cover	74	74
D	5.13	100%	B/C	vegetated final cover	74	74
E	5.09	100%	B/C	vegetated final cover	74	74
F	5.05	100%	B/C	vegetated final cover	74	74
G	5.31	100%	B/C	vegetated final cover	74	74
H	3.49	100%	B/C	vegetated final cover	74	74
I	1.69	100%	C	grass area	74	74
J	2.65	10% 90%	B C	grass area grass area	61 74	73
K	4.14	50% 50%	B C	grass area grass area	61 74	68
L	1.68	30% 70%	B C	runon north of borrow area runon north of borrow area	69 79	76
M	1.00	100%	C	runon north of borrow area	79	79
N	7.82	100%	N/A	direct runon to pond	98	98
O	1.32	100%	C	runon north of borrow area	79	79
P	5.24	45% 55%	B C	runon north of borrow area runon north of borrow area	69 79	75
Q	7.70	70% 30%	B C	runon north of borrow area runon north of borrow area	69 79	72
R	2.61	55% 45%	B C	runon north of borrow area runon north of borrow area	69 79	74
S	0.40	10% 90%	B C	runon north of borrow area runon north of borrow area	69 79	78
T	0.42	100%	N/A	direct runon to pond	98	98
U	4.15	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72
V	0.27	100%	N/A	direct runon to pond	98	98
W	10.59	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72
X	11.85	80% 20%	B C	runon east of OSDF runon east of OSDF	69 79	71
Y	6.52	60% 40%	B C	runon east of OSDF runon east of OSDF	69 79	73
Z	1.61	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72
AA	2.71	55% 45%	B C	runon east of OSDF runon east of OSDF	69 79	74
BB	0.76	100%	C	runon east of OSDF	79	79
CC	0.12	100%	C	runon east of OSDF	79	79
DD	0.54	100%	B/C	vegetated final cover	74	74
EE	0.93	20% 80%	B C	runon north of borrow area runon north of borrow area	69 79	77
FF	3.09	100%	B/C	vegetated final cover	74	74
GG	1.98	55% 45%	B C	grass area grass area	61 74	67
HH	0.55	100%	C	runon north of borrow area	79	79
II	1.67	50% 50%	B C	runon area to borrow area runon area to borrow area	61 74	68
JJ	0.91	93% 7%	B C	runon area to borrow area runon area to borrow area	61 74	62
KK	5.89	80% 20%	B C	runon area to borrow area runon area to borrow area	61 74	64
LL	7.05	100%	B	borrow area runoff	61	61
MM	1.94	100%	B	borrow area runoff	61	61
NN	1.27	60% 40%	B C	borrow area runoff borrow area runoff	61 74	66
OO	0.40	65% 35%	B C	runon area to borrow area runon area to borrow area	61 74	66
PP	40.96	80% 20%	B C	vegetated borrow area vegetated borrow area	61 74	64

N/A - Not Applicable

235/282
DGP 30 JAN 02
DBM 1/30/02
- 4664

RESULTS FOR THE CALCULATION OF WEIGHTED CN
West OSDF Post Development Design Scenario

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	2.73	100%	B/C	vegetated final cover	74	74
B	5.34	100%	B/C	vegetated final cover	74	74
C	5.40	100%	B/C	vegetated final cover	74	74
D	5.53	100%	B/C	vegetated final cover	74	74
E	4.81	100%	B/C	vegetated final cover	74	74
F	1.64	60% 40%	B/C C	vegetated final cover grass area	74 74	74
G	3.64	40% 60%	B/C B/C	vegetated final cover grass area	74 74	74
H	0.80	100%	C	grass area	74	74
I	0.51	100%	C	grass area	74	74
J	1.45	100%	C	grass area	74	74
K	0.77	100%	C	runon north of borrow area	79	79
L	1.28	100%	C	grass area	74	74
M	0.96	100%	C	runon north of borrow area	79	79
N	1.04	100%	C	grass area	74	74
O	2.25	100%	N/A	direct runon to pond	98	98
P	0.94	100%	C	grass area	74	74

N/A - Not Applicable

2360/282
DBM 1/30/02
DGP 30 JAN 02

RESULTS FOR THE CALCULATION OF WEIGHTED CN
Design Case "A"

- 4664

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN
A	1.93	100%	B/C	liner runout	89	89
B	0.88	100%	C	construction laydown	82	82
C	0.71	100%	C	construction laydown	82	82
D	0.65	100%	C	construction laydown	82	82
E	1.29	100%	C	construction laydown	82	82
F	0.34	100%	C	construction laydown	82	82
G	1.86	100%	C	construction laydown	82	82
H	0.65	60% 40%	C C	pavement construction laydown	98 82	92

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF PHASE V Project/Proposal No.:GQ1342 Task No.:17

- 4664

EXAMPLE CALCULATION FOR WEIGHTED CURVE NUMBER OF SUBCATCHMENT J OF THE EAST OSDF CONSTRUCTION-PHASE DESIGN SCENARIO

PURPOSE

The computation below illustrates the method for calculating a composite curve number (CN) for a subcatchment area comprising more than one CN. This CN value is used as one of the input parameters in the computer program "HydroCAD" for computing runoff.

CALCULATION PROCEDURE

The composite CN for a subcatchment area comprising more than one CN is calculated by summing the products of each CN multiplied by its percentage of the total area.

DATA VERIFICATION

The table below lists the CN's for subcatchment area J of the East OSDF Construction-Phase Design Scenario grouped according to Hydrological Soil Group (HSG), the contributing percentage of the total area for subcatchment area J, and land use.

HSG	Percent of Area %	Land Use Description	CN
B	10	Disturbed Area-Construction Support Zone	74
C	90	Disturbed Area-Construction Support Zone	82

CALCULATIONS

Weighted CN = (74)(0.10)+(82)(0.90)

= **81**

- 4664

ATTACHMENT C-3

TABULATED ANALYSIS RESULTS FOR CHANNELS

OSDF CONSTRUCTION/FILLING PERIOD CONDITIONS
SUMMARY OF CHANNEL ANALYSIS RESULTS

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node	HydroCAD Q[4] (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth[5] Y (ft)	Estimated Q[5] (cfs)	Channel Freeboard[7] (ft)	Peak Flow Velocity (fps)	Lining Type[6]
7	new	E OSDF	vee	4.0	1.00%	0.030	0	6	3	2P - T - I - DD	67.02	14.74	16.73	0.88	1.81	67.29	2.2	4.56	grass
8	new	E OSDF	trapezoidal	4.5	0.46%	0.030	10	3	3	8	65.98	19.33	18.66	1.04	1.37	66.66	3.1	3.45	grass
9	new	E OSDF	trapezoidal	3.5	0.45%	0.030	10	3	3	9	65.95	19.33	18.66	1.04	1.37	65.93	2.1	3.41	grass
10	new	E OSDF	trapezoidal	2.0	0.45%	0.030	10	3	3	11 - GG	74.69	21.18	19.30	1.10	1.47	75.10	0.5	3.55	grass
12	new	E OSDF	trapezoidal	2.0	0.45%	0.030	10	3	3	12 + HH	77.15	21.56	19.42	1.11	1.49	77.01	0.5	3.57	grass
13	new	E OSDF	trapezoidal	2.0	0.45%	0.030	20	3	3	13	142.34	37.04	29.55	1.25	1.51	143.48	0.5	3.87	grass
18	new	E OSDF	vee	3.0	1.00%	0.030	0	3	3	19	38.43	8.77	10.81	0.81	1.71	37.89	1.3	4.32	grass
19	new	E OSDF	vee	3.0	0.90%	0.030	0	3	3	20	43.35	10.05	11.57	0.87	1.83	43.07	1.2	4.29	grass
20	new	E OSDF	vee	3.0	0.83%	0.030	0	3	3	1P - U - V	43.26	10.49	11.83	0.89	1.87	43.82	1.1	4.18	grass
30	new	E OSDF	vee	2.5	1.00%	0.030	0	3	3	30	45.98	10.05	11.57	0.87	1.83	45.40	0.7	4.52	grass
21	new	E OSDF	vee	3.0	1.00%	0.030	0	3	3	22	46.33	10.27	11.70	0.88	1.85	46.74	1.2	4.55	grass
22	new	E OSDF	vee	4.0	1.00%	0.030	0	3	3	29	47.10	10.27	11.70	0.88	1.85	46.74	2.2	4.55	grass
29	new	E OSDF	vee	3.5	1.00%	0.030	0	3	3	23	48.76	10.49	11.83	0.89	1.87	48.10	1.6	4.58	grass
24	new	E OSDF	trapezoidal	2.0	0.75%	0.030	8.5	3	3	24	57.16	14.36	16.03	0.90	1.19	57.43	0.8	4.00	grass
26	new	E OSDF	vee	2.5	0.75%	0.030	0	3	3	27	64.98	14.52	13.91	1.04	2.20	64.26	0.3	4.43	grass
7	new	W OSDF	vee	4	0.75%	0.030	0	3	3	8 - 12	66.37	14.92	14.10	1.06	2.23	66.62	1.8	4.47	grass
8	new	W OSDF	vee	4	0.75%	0.030	0	3	3	8 + P	97.09	19.81	16.25	1.22	2.57	97.27	1.4	4.91	grass
9	existing	W OSDF	vee	1.5	2.61%	0.030	0	3	3	9 + H + 1	5.21	1.35	4.24	0.32	0.67	5.03	0.8	3.47	grass
10	new	W OSDF	vee	1.5	1.48%	0.030	0	3	3	10 + F	9.68	2.71	6.01	0.45	0.95	9.61	0.6	3.55	grass
11	new	W OSDF	vee	2.5	0.66%	0.030	0	3	3	11 + G	27.01	7.97	10.31	0.77	1.63	27.09	0.9	3.40	grass
2	existing	DC A	vee	3.0	1.50%	0.030	0	4	6	1 + G	8.82	2.81	7.65	0.37	0.75	8.77	2.3	3.12	grass
5	new	DC A	vee	2.5	0.34%	0.030	0	3	3	5	12.05	5.63	8.66	0.65	1.37	12.16	1.1	2.16	grass
6	new	DC A	vee	2.5	0.23%	0.030	0	3	3	6 + D	12.43	6.66	9.42	0.71	1.49	12.53	1.0	1.88	grass
7	existing	DC A	vee	2.0	2.00%	0.030	0	4	6	7 + E	21.87	5.10	10.36	0.49	1.01	22.41	1.0	4.39	grass

E OSDF = East OSDF Construction-Phase Design Scenario
W OSDF = West OSDF Construction-Phase Design Scenario
DC A = Design Case "A"

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from the Drawings.
4. Peak inflow rates calculated by HydroCAD for each reach. See attachment C-1.
5. Calculated flow rates using an iterative procedure and compared with flow from HydroCAD.
6. Maximum permissible velocity for grass lined channels is 5 fps.
7. Calculated as the difference between minimum available flow depth and peak flow depth.

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DCP 30JAN02
DBM 1/30/02

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OSDF POST DEVELOPMENT PERIOD CONDITIONS
SUMMARY OF CHANNEL ANALYSIS RESULTS

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations								
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node[3]	HydroCAD Q[4] (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth[5] Y (ft)	Estimated Q[5] (cfs)	Channel Freeboard[7] (ft)	Peak Flow Velocity (fps)	Sufficient to Minimize Sedimentation?	Lining Type[6]
1	existing	E OSDF PD	vee	5	0.45%	0.030	0	6	4	2	4.96	2.81	7.65	0.37	0.75	4.81	4.25	1.71	Is adressed in a separate calculation package presented for Phase V.	grass
2	existing	E OSDF PD	vee	6.5	0.45%	0.030	0	3	5	3	7.06	3.61	7.85	0.46	0.95	7.17	5.55	1.98		grass
3	new	E OSDF PD	vee	7.4	0.50%	0.030	0	3	4	4	8.67	3.86	7.65	0.50	1.05	8.59	6.35	2.22		grass
4	new	E OSDF PD	vee	6.5	0.50%	0.030	0	3	4	5	9.97	4.31	8.09	0.53	1.11	9.96	5.39	2.31		grass
5	new	E OSDF PD	vee	3	0.50%	0.030	0	3	6	6	11.07	4.96	9.71	0.51	1.05	11.14	1.95	2.24		grass
6	new	E OSDF PD	vee	3	1.00%	0.030	0	3	6	7	11.66	3.89	8.60	0.45	0.93	11.39	2.07	2.93		grass
7	new	E OSDF PD	vee	4.0	1.00%	0.030	0	6	3	2P - T - I - DD	11.63	3.89	8.60	0.45	0.93	11.39	3.07	2.93		grass
8	new	E OSDF PD	trapezoidal	4.5	0.45%	0.030	10	3	3	8	10.72	5.62	13.10	0.43	0.49	10.65	4.01	1.89		grass
9	new	E OSDF PD	trapezoidal	3.5	0.45%	0.030	10	3	3	9	10.71	5.62	13.10	0.43	0.49	10.65	3.01	1.89		grass
10	new	E OSDF PD	trapezoidal	2.0	0.45%	0.030	10	3	3	11 - GG	11.65	5.88	13.23	0.44	0.51	11.41	1.49	1.94		grass
12	new	E OSDF PD	trapezoidal	2.0	0.45%	0.030	10	3	3	12 + HH	11.86	6.14	13.35	0.46	0.53	12.19	1.47	1.99		grass
13	new	E OSDF PD	trapezoidal	2.0	0.45%	0.030	20	3	3	13	22.38	10.98	23.23	0.47	0.51	22.20	1.49	2.02		grass
14	existing	E OSDF PD	vee	1.5	0.40%	0.030	0	3	5	15	1.04	0.88	3.88	0.23	0.47	1.03	1.03	1.17		grass
15	existing	E OSDF PD	vee	2.0	0.63%	0.030	0	3	5	16	2.68	1.49	5.04	0.30	0.61	2.60	1.39	1.75		grass
16	existing	E OSDF PD	vee	3.4	0.74%	0.030	0	2.5	5	17	3.20	1.58	5.06	0.31	0.65	3.12	2.75	1.97		grass
17	existing	E OSDF PD	vee	3.5	1.25%	0.030	0	4	5	18	5.48	2.02	5.18	0.33	0.67	5.32	2.83	2.63		grass
18	new	E OSDF PD	vee	3.0	1.00%	0.030	0	3	3	19	9.08	3.06	5.39	0.48	1.01	9.30	1.99	3.04		grass
19	new	E OSDF PD	vee	3.0	0.90%	0.030	0	3	3	20	10.07	3.43	5.77	0.51	1.07	10.30	1.93	3.00		grass
20	new	E OSDF PD	vee	3.0	0.83%	0.030	0	3	3	1P - U - V	10.03	3.43	5.77	0.51	1.07	9.89	1.93	2.88		grass
30	new	E OSDF PD	vee	2.5	1.00%	0.030	0	3	3	30	7.74	2.71	5.01	0.45	0.95	7.90	1.55	2.92		grass
21	new	E OSDF PD	vee	3.0	1.00%	0.030	0	3	3	22	7.81	2.71	5.01	0.45	0.95	7.90	2.05	2.92		grass
22	new	E OSDF PD	vee	4.0	1.00%	0.030	0	3	3	29	7.95	2.71	5.01	0.45	0.95	7.90	3.05	2.92		grass
29	new	E OSDF PD	vee	3.5	1.00%	0.030	0	3	3	23	8.22	2.82	5.13	0.46	0.97	8.35	2.53	2.96		grass
24	new	E OSDF PD	trapezoidal	2.0	0.75%	0.030	8.5	3	3	24	9.31	4.21	11.22	0.38	0.43	9.42	1.57	2.24		grass
26	new	E OSDF PD	vee	2.5	0.75%	0.030	0	3	3	27	10.41	3.70	7.02	0.53	1.11	10.36	1.39	2.80		grass
1	new	W OSDF PD	vee	3	0.75%	0.030	0	3	6	2	4.70	2.27	5.56	0.35	0.71	4.80	2.29	2.12	Intenionally left blank.	grass
2	new	W OSDF PD	vee	3	0.75%	0.030	0	3	6	3	7.23	3.10	7.67	0.40	0.83	7.28	2.17	2.35		grass
3	new	W OSDF PD	vee	3	0.75%	0.030	0	3	6	4	9.40	3.73	3.41	0.44	0.91	9.31	2.09	2.50		grass
4	new	W OSDF PD	vee	3	0.76%	0.030	0	3	6	5	9.34	3.73	3.41	0.44	0.91	9.37	2.09	2.52		grass
6	new	W OSDF PD	vee	3.5	0.75%	0.030	0	3	6	7	10.66	4.06	3.78	0.46	0.95	10.44	2.55	2.57		grass
7	new	W OSDF PD	vee	4	0.75%	0.030	0	3	3	8 - 12	10.67	3.83	7.15	0.54	1.13	10.87	2.87	2.84		grass
8	new	W OSDF PD	vee	4	0.75%	0.030	0	3	3	8 + P	13.07	4.39	7.65	0.57	1.21	13.05	2.79	2.97		grass
9	new	W OSDF PD	vee	1.5	2.61%	0.030	0	3	3	9 + H + I	1.27	0.46	2.47	0.18	0.39	1.19	1.11	2.60		grass
10	new	W OSDF PD	vee	1.5	1.48%	0.030	0	3	3	10 + F	1.34	0.61	2.85	0.21	0.45	1.31	1.05	2.16		grass
11	new	W OSDF PD	vee	2.5	0.66%	0.030	0	3	3	11 + G	3.20	1.60	4.62	0.35	0.73	3.18	1.77	1.99		grass

E OSDF PD= East OSDF Post Development Design Scenario
W OSDF PD= West OSDF Post Development Design Scenario

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from the Drawings.
3. N/A indicates that there is not specific HydroCAD node associated with the particular channel.
4. Peak flow rates calculated by HydroCAD for each reach. See attachment C-1.
5. Calculated flow rates using an iterative procedure and compared with flow from HydroCAD.
6. Maximum permissible velocity for grass lined channels is 5 fps.
7. Calculated as the difference between minimum available flow depth and peak flow depth.

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DGP 30JAN02
DBM 1/30/02

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Written by: DBM DBM 1/30/02 Date: 01/12/09 (YY MM DD) Reviewed by: DGP Date: 02/01/30 (YY MM DD)

Client: Fernald Project: OSDF Phase V Project/Proposal No.: GO1342 Task No.: 17

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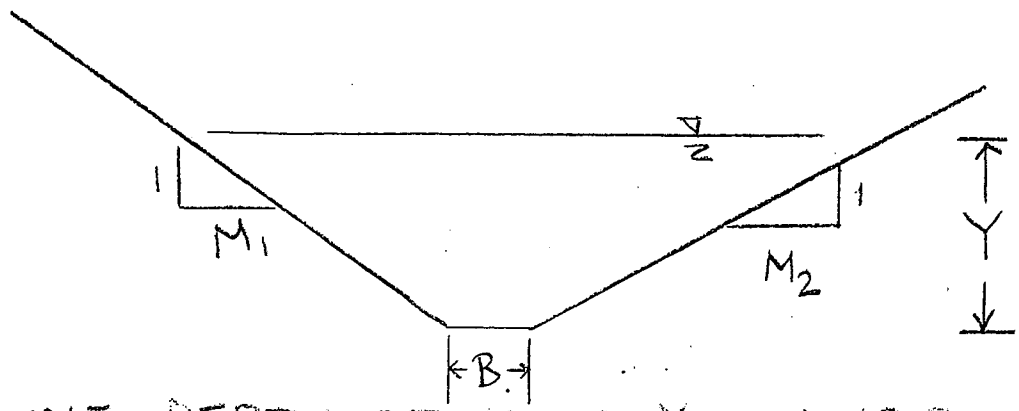
EXAMPLE CALCULATION FOR ANALYSIS OF CHANNEL 12 - EAST OSDF DESIGN SCENARIO

PEAK DISCHARGE (25 year 24 hour STORM)	Q_{max} = 77.15 cfs
BASE WIDTH	B = 10 ft
LEFT SIDE SLOPE	M_1 = 3H:1V
RIGHT SIDE SLOPE	M_2 = 3H:1V
MANNING'S ROUGHNESS COEFFICIENT	n = 0.030
LONGITUDINAL CHANNEL SLOPE	S_o = 0.0045 ft/ft

CHANNEL GEOMETRY (NOT TO SCALE)



ASSUME DEPTH OF FLOW, Y = 1.49 ft

AREA OF FLOW

$$A = \frac{1}{2} Y (2B + (M_1 Y + M_2 Y))$$

$$= YB + M_1 \frac{Y^2}{2} + M_2 \frac{Y^2}{2}$$

$$= 1.49(10) + 3\left(\frac{1.49^2}{2}\right) + 3\left(\frac{1.49^2}{2}\right)$$

$$= 21.5603$$

$$= \underline{\underline{21.56 \text{ ft}^2}}$$

Written by: DBM DBM 1/30/22 Date: 01/12/09 (YY MM DD) Reviewed by: DCP Date: 02/01/09 (YY MM DD)

Client: Fernald Project: OSDF Phase V Project/Proposal No.: GO1342 Task No.: 17

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WETTED PERIMETER

$$P = B + \sqrt{Y^2 + (M_1 Y)^2} + \sqrt{Y^2 + (M_2 Y)^2}$$

$$= 10 + \sqrt{1.49^2 + (3 * 1.49)^2} + \sqrt{1.49^2 + (3 * 1.49)^2}$$

$$= 10 + 4.71179 + 4.71179$$

$$= 19.42358$$

$$= \underline{19.42 \text{ ft}}$$

HYDRAULIC RADIUS

$$R = A / P$$

$$= 21.56 / 19.42$$

$$= \underline{1.11 \text{ ft}}$$

AVERAGE VELOCITY

$$V = Q/A = \frac{1}{A}\left(\frac{1.49}{n} * A * R^{2/3} * S_o^{1/2}\right) = \frac{1.49}{n} * R^{2/3} * S_o^{1/2}$$

$$= \frac{1.49}{0.030} * (1.11)^{2/3} * (0.0045)^{1/2}$$

$$= \underline{3.57 \text{ ft/s}}$$

DISCHARGE VERIFICATION

$$Q_{max} = A * V$$

$$= 21.56 * 3.57$$

$$= \underline{76.97 \text{ cfs}}$$

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ATTACHMENT C-4A

CulvertMaster® OUTPUT REPORTS FOR CULVERTS

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DGP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

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CulvertMaster® OUTPUT REPORTS FOR CULVERTS

EAST OSDF DESIGN SCENARIO

245/282
DEP 30 JAN 02
DBM 1/30/02

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Culvert Designer/Analyzer Report
east node 11

Peak Discharge Method: User-Specified			
Design Discharge	76.91 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	583.84 ft	Invert Downstream	583.57 ft
Length	60.00 ft	Slope	0.004500 ft/ft
Drop	0.27 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	587.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	585.06 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	3-27 inch Circular	76.91 cfs	586.71 ft	

Culvert Designer/Analyzer Report
east node 11

246/282
DGP 30 JAN 02
DBM 1/30/02

4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	587.50 ft	Storm Event	Design
Computed Headwater Elev	586.71 ft	Discharge	76.91 cfs
Headwater Depth/Height	1.27	Tailwater Elevation	585.06 ft
Inlet Control HW Elev.	586.71 ft	Control Type	Inlet Control
Outlet Control HW Elev.	586.70 ft		

Grades			
Upstream Invert	583.84 ft	Downstream Invert	583.57 ft
Length	60.00 ft	Constructed Slope	0.004500 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	1.75 ft
Slope Type	Steep	Normal Depth	1.75 ft
Flow Regime	Supercritical	Critical Depth	1.77 ft
Velocity Downstream	7.73 ft/s	Critical Slope	0.004397 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.010
Section Material	HDPE (Smooth Interior)	Span	2.25 ft
Section Size	27 inch	Rise	2.25 ft
Number Sections	3		

Outlet Control Properties			
Outlet Control HW Elev.	586.70 ft	Upstream Velocity Head	0.91 ft
Ke	0.20	Entrance Loss	0.18 ft

Inlet Control Properties			
Inlet Control HW Elev.	586.71 ft	Flow Control	Submerged
Inlet Type	Groove end projecting	Area Full	11.9 ft²
K	0.00450	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	3
C	0.03170	Equation Form	1
Y	0.69000		

000366

Culvert Designer/Analyzer Report
east node 23

247/282
DCP 30JAN02
DBM 1/30/02

-- 4664

Peak Discharge Method: User-Specified			
Design Discharge	48.76 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	586.32 ft	Invert Downstream	585.78 ft
Length	92.00 ft	Slope	0.005870 ft/ft
Drop	0.54 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	590.00 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	587.01 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	2-36 inch Circular	48.76 cfs	589.02 ft	

000367

Culvert Designer/Analyzer Report
east node 23

248 /282

DEP 30 JAN 02
DBM 1/30/02

-- 4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	590.00 ft	Storm Event	Design
Computed Headwater Elev	589.02 ft	Discharge	48.76 cfs
Headwater Depth/Height	0.90	Tailwater Elevation	587.01 ft
Inlet Control HW Elev.	588.83 ft	Control Type	Outlet Control
Outlet Control HW Elev.	589.02 ft		

Grades			
Upstream Invert	586.32 ft	Downstream Invert	585.78 ft
Length	92.00 ft	Constructed Slope	0.005870 ft/ft

Hydraulic Profile			
Profile	M2	Depth, Downstream	1.59 ft
Slope Type	Mild	Normal Depth	1.78 ft
Flow Regime	Subcritical	Critical Depth	1.59 ft
Velocity Downstream	6.40 ft/s	Critical Slope	0.008394 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.018
Section Material	CMP	Span	3.00 ft
Section Size	36 inch	Rise	3.00 ft
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	589.02 ft	Upstream Velocity Head	0.48 ft
Ke	0.90	Entrance Loss	0.44 ft

Inlet Control Properties			
Inlet Control HW Elev.	588.83 ft	Flow Control	N/A
Inlet Type	Projecting	Area Full	14.1 ft^2
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

000368

Culvert Designer/Analyzer Report
east node 25

249 / 282
DGP 30JAN02
DBM 1/30/02

-- 4664

Peak Discharge Method: User-Specified			
Design Discharge	64.23 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	584.85 ft	Invert Downstream	584.53 ft
Length	53.00 ft	Slope	0.006038 ft/ft
Drop	0.32 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	588.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	586.73 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	2-42 x 29 inch Arch	64.23 cfs	587.71 ft	

000369

250 /282
DGP 30 JAN 02
DBM 1/30/02

- 4664

Culvert Designer/Analyzer Report
east node 25

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	588.50	ft	Storm Event	Design	
Computed Headwater Elev	587.71	ft	Discharge	64.23	cfs
Headwater Depth/Height	1.18		Tailwater Elevation	586.73	ft
Inlet Control HW Elev.	587.52	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	587.71	ft			

Grades					
Upstream Invert	584.85	ft	Downstream Invert	584.53	ft
Length	53.00	ft	Constructed Slope	0.006038	ft/ft

Hydraulic Profile					
Profile	M1		Depth, Downstream	2.20	ft
Slope Type	Mild		Normal Depth	1.78	ft
Flow Regime	Subcritical		Critical Depth	1.48	ft
Velocity Downstream	4.93	ft/s	Critical Slope	0.009283	ft/ft

Section					
Section Shape	Arch		Mannings Coefficient	0.018	
Section Material	Steel and Aluminum Var CR		Span	3.50	ft
Section Size	42 x 29 inch		Rise	2.42	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	587.71	ft	Upstream Velocity Head	0.40	ft
Ke	0.90		Entrance Loss	0.36	ft

Inlet Control Properties					
Inlet Control HW Elev.	587.52	ft	Flow Control	N/A	
Inlet Type	Thin wall projecting		Area Full	13.0	ft^2
K	0.03400		HDS 5 Chart	34	
M	1.50000		HDS 5 Scale	3	
C	0.04960		Equation Form	1	
Y	0.57000				

000370

Culvert Designer/Analyzer Report
east node 27

251/282
DGP 30JAN02
DBM 1/30/02

--4664

Peak Discharge Method: User-Specified			
Design Discharge	64.98 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	582.80 ft	Invert Downstream	582.36 ft
Length	106.00 ft	Slope	0.004151 ft/ft
Drop	0.44 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	587.00 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	583.88 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	2-42 x 29 inch Arch	64.98 cfs	585.63 ft	

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Culvert Designer/Analyzer Report
east node 27

252/282
DGP 30JAN02
DBM 1/30/02

4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	587.00	ft	Storm Event	Design	
Computed Headwater Elev:	585.63	ft	Discharge	64.98	cfs
Headwater Depth/Height	1.17		Tailwater Elevation	583.88	ft
Inlet Control HW Elev.	585.50	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	585.63	ft			

Grades					
Upstream Invert	582.80	ft	Downstream Invert	582.36	ft
Length	106.00	ft	Constructed Slope	0.004151	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	1.52	ft
Slope Type	Mild		Normal Depth	N/A	ft
Flow Regime	Subcritical		Critical Depth	1.49	ft
Velocity Downstream	6.78	ft/s	Critical Slope	0.009342	ft/ft

Section					
Section Shape	Arch		Mannings Coefficient	0.018	
Section Material	Steel and Aluminum Var CR		Span	3.50	ft
Section Size	42 x 29 inch		Rise	2.42	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	585.63	ft	Upstream Velocity Head	0.44	ft
Ke	0.90		Entrance Loss	0.40	ft

Inlet Control Properties					
Inlet Control HW Elev.	585.50	ft	Flow Control	N/A	
Inlet Type	Thin wall projecting		Area Full	13.0	ft^2
K	0.03400		HDS 5 Chart	34	
M	1.50000		HDS 5 Scale	3	
C	0.04960		Equation Form	1	
Y	0.57000				

000372

253/282
DGP 30 JAN 02
DBM 1/30/02

4664

Culvert Designer/Analyzer Report
east node 28

Peak Discharge Method: User-Specified			
Design Discharge	70.77 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	586.95 ft	Invert Downstream	586.53 ft
Length	92.00 ft	Slope	0.004565 ft/ft
Drop	0.42 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	590.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	588.04 ft

Name	Description	Discharge	HW Elev.	Velocity
x Triai-i	2-49 x 33 inch Arch	70.77 cfs	589.52 ft	

000373

Culvert Designer/Analyzer Report
east node 28

254/282
DCP 30JAN02
DBM 1/30/02
- 4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	590.50	ft	Storm Event	Design	
Computed Headwater Elev	589.52	ft	Discharge	70.77	cfs
Headwater Depth/Height	0.93		Tailwater Elevation	588.04	ft
Inlet Control HW Elev.	589.30	ft	Control Type	Outlet Control	
Outlet Control HW Elev.	589.52	ft			

Grades					
Upstream Invert	586.95	ft	Downstream Invert	586.53	ft
Length	92.00	ft	Constructed Slope	0.004565	ft/ft

Hydraulic Profile					
Profile	M2		Depth, Downstream	1.51	ft
Slope Type	Mild		Normal Depth	1.88	ft
Flow Regime	Subcritical		Critical Depth	1.46	ft
Velocity Downstream	6.42	ft/s	Critical Slope	0.008797	ft/ft

Section					
Section Shape	Arch		Mannings Coefficient	0.019	
Section Material	Steel and Aluminum Var CR		Span	4.08	ft
Section Size	49 x 33 inch		Rise	2.75	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	589.52	ft	Upstream Velocity Head	0.44	ft
Ke	0.70		Entrance Loss	0.31	ft

Inlet Control Properties					
Inlet Control HW Elev.	589.30	ft	Flow Control	Unsubmerged	
Inlet Type	Mitered to slope (arch)		Area Full	17.8	ft^2
K	0.03000		HDS 5 Chart	34	
M	1.00000		HDS 5 Scale	2	
C	0.04630		Equation Form	1	
Y	0.75000				

000374

Culvert Designer/Analyzer Report
east node 31

255 / 282
DCP 30JAN02
DBM 1/30/02

-- 4664

Peak Discharge Method: User-Specified			
Design Discharge	6.54 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	584.00 ft	Invert Downstream	583.00 ft
Length	80.00 ft	Slope	0.012500 ft/ft
Drop	1.00 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	588.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	584.51 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	1-27 inch Circular	6.54 cfs	585.49 ft	

000375

Culvert Designer/Analyzer Report
east node 31

250/282
DGP 30 JAN 02
DBM 1/30/02

-- 4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	588.50	ft	Storm Event	Design	
Computed Headwater Elev	585.49	ft	Discharge	6.54	cfs
Headwater Depth/Height	0.66		Tailwater Elevation	584.51	ft
Inlet Control HW Elev.	585.20	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	585.49	ft			

Grades					
Upstream Invert	584.00	ft	Downstream Invert	583.00	ft
Length	80.00	ft	Constructed Slope	0.012500	ft/ft

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	1.51	ft
Slope Type	Steep		Normal Depth	0.64	ft
Flow Regime	N/A		Critical Depth	0.87	ft
Velocity Downstream	2.31	ft/s	Critical Slope	0.003722	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.012	
Section Material	HDPE (Smooth Interior)		Span	2.25	ft
Section Size	27 inch		Rise	2.25	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	585.49	ft	Upstream Velocity Head	0.33	ft
Ke	0.90		Entrance Loss	0.29	ft

Inlet Control Properties					
Inlet Control HW Elev.	585.20	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	4.0	ft^2
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

000376

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

4664

CulvertMaster® OUTPUT REPORTS FOR CULVERTS

WEST OSDF SCENARIO

258/282
DGP 30JAN02
DBM 1/30/02
- 4664

Culvert Designer/Analyzer Report
west node 5 design

Peak Discharge Method: User-Specified			
Design Discharge	44.48 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	580.68 ft	Invert Downstream	579.98 ft
Length	95.00 ft	Slope	0.007368 ft/ft
Drop	0.70 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	585.00 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	582.50 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	1-42 inch Circular	44.48 cfs	584.32 ft	

259 / 282
DGP 30JAN02
DBM 1/30/02

- 4664

Culvert Designer/Analyzer Report
west node 5 design

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	585.00 ft	Storm Event	Design
Computed Headwater Elev:	584.32 ft	Discharge	44.48 cfs
Headwater Depth/Height	1.04	Tailwater Elevation	582.50 ft
Inlet Control HW Elev.	584.08 ft	Control Type	Outlet Control
Outlet Control HW Elev.	584.32 ft		

Grades			
Upstream Invert	580.68 ft	Downstream Invert	579.98 ft
Length	95.00 ft	Constructed Slope	0.007368 ft/ft

Hydraulic Profile			
Profile	M1	Depth, Downstream	2.52 ft
Slope Type	Mild	Normal Depth	2.18 ft
Flow Regime	Subcritical	Critical Depth	2.08 ft
Velocity Downstream	6.00 ft/s	Critical Slope	0.008555 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.018
Section Material	CMP	Span	3.50 ft
Section Size	42 inch	Rise	3.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	584.32 ft	Upstream Velocity Head	0.75 ft
Ke	0.90	Entrance Loss	0.68 ft

Inlet Control Properties			
Inlet Control HW Elev.	584.08 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	9.6 ft^2
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

000379

Culvert Designer/Analyzer Report
west node 12 design

260/282
DGP 3054N02
DBM 1/30/02

4664

Peak Discharge Method: User-Specified			
Design Discharge	30.11 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	577.05 ft	Invert Downstream	576.00 ft
Length	115.00 ft	Slope	0.009130 ft/ft
Drop	1.05 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	581.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	578.57 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	1-30 inch Circular	30.11 cfs	580.87 ft	

000380

Culvert Designer/Analyzer Report
west node 12 design

261 /282
DGP 30 JAN 02
DBM 1/30/02

- 4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	581.50 ft	Storm Event	Design
Computed Headwater Elev	580.87 ft	Discharge	30.11 cfs
Headwater Depth/Height	1.53	Tailwater Elevation	578.57 ft
Inlet Control HW Elev.	580.50 ft	Control Type	Outlet Control
Outlet Control HW Elev.	580.87 ft		

Grades			
Upstream Invert	577.05 ft	Downstream Invert	576.00 ft
Length	115.00 ft	Constructed Slope	0.009130 ft/ft

Hydraulic Profile			
Profile	PressureProfile	Depth, Downstream	2.57 ft
Slope Type	N/A	Normal Depth	2.24 ft
Flow Regime	N/A	Critical Depth	1.87 ft
Velocity Downstream	6.13 ft/s	Critical Slope	0.012490 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.018
Section Material	CMP	Span	2.50 ft
Section Size	30 inch	Rise	2.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	580.87 ft	Upstream Velocity Head	0.58 ft
Ke	0.90	Entrance Loss	0.53 ft

Inlet Control Properties			
Inlet Control HW Elev.	580.50 ft	Flow Control	Transition
Inlet Type	Projecting	Area Full	4.9 ft^2
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

000381

Culvert Designer/Analyzer Report
west node 13 design

262 /282
DGP 30 JAN 02
DBM 1/30/02
-- 4664

Peak Discharge Method: User-Specified			
Design Discharge	4.24 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	579.80 ft	Invert Downstream	579.00 ft
Length	65.00 ft	Slope	0.012308 ft/ft
Drop	0.80 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	581.80 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	579.50 ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-15 inch Circular	4.24 cfs	581.08 ft	

000382

Culvert Designer/Analyzer Report
west node 13 design

263/282
DCP 30 JAN 02
DBM 1/30/02

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	581.80	ft	Storm Event	Design	
Computed Headwater Elev	581.08	ft	Discharge	4.24	cfs
Headwater Depth/Height	1.02		Tailwater Elevation	579.50	ft
Inlet Control HW Elev.	581.05	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	581.08	ft			

Grades					
Upstream Invert	579.80	ft	Downstream Invert	579.00	ft
Length	65.00	ft	Constructed Slope	0.012308	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.69	ft
Slope Type	Steep		Normal Depth	0.69	ft
Flow Regime	Supercritical		Critical Depth	0.83	ft
Velocity Downstream	6.08	ft/s	Critical Slope	0.007000	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.25	ft
Section Size	15 inch		Rise	1.25	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	581.08	ft	Upstream Velocity Head	0.37	ft
Ke	0.20		Entrance Loss	0.07	ft

Inlet Control Properties					
Inlet Control HW Elev.	581.05	ft	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	1.2	ft^2
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

000383

Culvert Designer/Analyzer Report
west node 14 design

264/282
DEP 30 JAN 02
DBM 1/30/02

- 4664

Peak Discharge Method: User-Specified			
Design Discharge	4.33 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	578.60 ft	Invert Downstream	575.00 ft
Length	112.00 ft	Slope	0.032143 ft/ft
Drop	3.60 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	582.20 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	576.00 ft

Name	Description	Discharge	HW Elev.	Velocity
x Triai-i	1-50 x 31 inch Arch	4.33 cfs	579.38 ft	

000384

265/282
DGP 30 JAN 02
DBM 1/30/02

- 4664

Culvert Designer/Analyzer Report
west node 14 design

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	582.20 ft	Storm Event	Design
Computed Headwater Elev	579.38 ft	Discharge	4.33 cfs
Headwater Depth/Height	0.30	Tailwater Elevation	576.00 ft
Inlet Control HW Elev.	579.20 ft	Control Type	Entrance Control
Outlet Control HW Elev.	579.38 ft		

Grades			
Upstream Invert	578.60 ft	Downstream Invert	575.00 ft
Length	112.00 ft	Constructed Slope	0.032143 ft/ft

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.00 ft
Slope Type	Steep	Normal Depth	0.37 ft
Flow Regime	N/A	Critical Depth	0.46 ft
Velocity Downstream	1.24 ft/s	Critical Slope	0.012841 ft/ft

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Corrugations Historic	Span	4.17 ft
Section Size	50 x 31 inch	Rise	2.58 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	579.38 ft	Upstream Velocity Head	0.17 ft
Ke	0.90	Entrance Loss	0.15 ft

Inlet Control Properties			
Inlet Control HW Elev.	579.20 ft	Flow Control	N/A
Inlet Type	CR structural plate, projecting	Area Full	8.4 ft²
K	0.03000	HDS 5 Chart	35
M	1.50000	HDS 5 Scale	1
C	0.04960	Equation Form	1
Y	0.57000		

000385

Written by: Dana Mehlman (DBM) DBM Date: 1/29/2002 Reviewed by: DCP Date: 30 JAN 02

Client: Fluor Fernald, Inc. Project: OSDF Phase V Project No.: GQ1342 Task No.: 17

-- 4664

CulvertMaster® OUTPUT REPORTS FOR CULVERTS

DESIGN CASE "A"

267/282
DCP 30JAN02
DBM 1/30/02

Culvert Designer/Analyzer Report
reach 1

-- 4664

Peak Discharge Method: User-Specified			
Design Discharge	2.02 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	587.35 ft	Invert Downstream	586.37 ft
Length	80.00 ft	Slope	0.012250 ft/ft
Drop	0.98 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	590.00 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	586.80 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	1-18.0 x 11.0 inch Arch	2.02 cfs	588.03 ft	

000387

Culvert Designer/Analyzer Report
reach 1

268 / 282
DGP 30 JAN 02
DBM 1/30/02

-- 4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	590.00 ft	Storm Event	Design
Computed Headwater Elev	588.03 ft	Discharge	2.02 cfs
Headwater Depth/Height	0.75	Tailwater Elevation	586.80 ft
Inlet Control HW Elev.	587.97 ft	Control Type	Entrance Control
Outlet Control HW Elev.	588.03 ft		

Grades			
Upstream Invert	587.35 ft	Downstream Invert	586.37 ft
Length	80.00 ft	Constructed Slope	0.012250 ft/ft

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.43 ft
Slope Type	Steep	Normal Depth	0.35 ft
Flow Regime	N/A	Critical Depth	0.41 ft
Velocity Downstream	3.25 ft/s	Critical Slope	0.007284 ft/ft

Section			
Section Shape	Arch	Mannings Coefficient	0.018
Section Material	Concrete	Span	1.50 ft
Section Size	18.0 x 11.0 inch	Rise	0.92 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	588.03 ft	Upstream Velocity Head	0.18 ft
Ke	0.50	Entrance Loss	0.09 ft

Inlet Control Properties			
Inlet Control HW Elev.	587.97 ft	Flow Control	N/A
Inlet Typ	Square edge w/headwall (arch)	Area Full	1.1 ft²
K	0.00980	HDS 5 Chart	0
M	2.00000	HDS 5 Scale	0
C	0.03980	Equation Form	1
Y	0.67000		

000388

Culvert Designer/Analyzer Report
reach 3

269 / 282
DKP 3 JAN 02
DBM 1/30/02

- 4664

Peak Discharge Method: User-Specified			
Design Discharge	8.41 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	581.60 ft	Invert Downstream	581.30 ft
Length	55.00 ft	Slope	0.005455 ft/ft
Drop	0.30 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	585.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	582.27 ft

Name	Description	Discharge	HW Elev.	Velocity
x Trial-1	2-18 inch Circular	8.41 cfs	582.76 ft	

000389

Culvert Designer/Analyzer Report
reach 3

270/282
DEP 30JAN02
DBM 1/30/02

-- 4664

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	585.50 ft	Storm Event	Design
Computed Headwater Elev	582.76 ft	Discharge	8.41 cfs
Headwater Depth/Height	0.77	Tailwater Elevation	582.27 ft
Inlet Control HW Elev.	582.70 ft	Control Type	Entrance Control
Outlet Control HW Elev.	582.76 ft		

Grades			
Upstream Invert	581.60 ft	Downstream Invert	581.30 ft
Length	55.00 ft	Constructed Slope	0.005455 ft/ft

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.97 ft
Slope Type	Steep	Normal Depth	0.68 ft
Flow Regime	N/A	Critical Depth	0.79 ft
Velocity Downstream	3.48 ft/s	Critical Slope	0.003243 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.010
Section Material	HDPE (Smooth Interior)	Span	1.50 ft
Section Size	18 inch	Rise	1.50 ft
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	582.76 ft	Upstream Velocity Head	0.31 ft
Ke	0.20	Entrance Loss	0.06 ft

Inlet Control Properties			
Inlet Control HW Elev.	582.70 ft	Flow Control	N/A
Inlet Type	Groove end w/headwall	Area Full	3.5 ft²
K	0.00180	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	2
C	0.02920	Equation Form	1
Y	0.74000		

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271 /282
DCP 30 JAN 02
DBM 1/30/02

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Culvert Designer/Analyzer Report
reach 4

Peak Discharge Method: User-Specified			
Design Discharge	1.90 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	582.70 ft	Invert Downstream	581.50 ft
Length	60.00 ft	Slope	0.020000 ft/ft
Drop	1.20 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	587.00 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	582.94 ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-18 inch Circular	1.90 cfs	583.45 ft	

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Culvert Designer/Analyzer Report
reach 4

272/282
DGP 31 JAN 02
DBM 1/30/02

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	587.00	ft	Storm Event	Design	
Computed Headwater Elev	583.45	ft	Discharge	1.90	cfs
Headwater Depth/Height	0.50		Tailwater Elevation	582.94	ft
Inlet Control HW Elev.	583.40	ft	Control Type	Entrance Control	
Outlet Control HW Elev.	583.45	ft			

Grades					
Upstream Invert	582.70	ft	Downstream Invert	581.50	ft
Length	60.00	ft	Constructed Slope	0.020000	ft/ft

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	1.44	ft
Slope Type	Steep		Normal Depth	0.32	ft
Flow Regime	N/A		Critical Depth	0.52	ft
Velocity Downstream	1.09	ft/s	Critical Slope	0.002919	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.010	
Section Material	HDPE (Smooth Interior)		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	583.45	ft	Upstream Velocity Head	0.19	ft
Ke	0.20		Entrance Loss	0.04	ft

Inlet Control Properties					
Inlet Control HW Elev.	583.40	ft	Flow Control	N/A	
Inlet Type	Groove end w/headwall		Area Full	1.8	ft^2
K	0.00180		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	2	
C	0.02920		Equation Form	1	
Y	0.74000				

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Culvert Designer/Analyzer Report
reach 8

273/282
DGP 30JAN02
DBM 1/30/02
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Peak Discharge Method: User-Specified			
Design Discharge	24.73 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	579.33 ft	Invert Downstream	578.84 ft
Length	49.00 ft	Slope	0.010000 ft/ft
Drop	0.49 ft		

Headwater Model: Maximum Allowable HW	
Headwater Elevation	582.50 ft

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	579.84 ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	2-30 inch Circular	24.73 cfs	581.38 ft	

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Culvert Designer/Analyzer Report
reach 8

274/282
DOP 30 JAN 02
DBM 1/30/02

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Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	582.50 ft	Storm Event	Design
Computed Headwater Elev	581.38 ft	Discharge	24.73 cfs
Headwater Depth/Height	0.82	Tailwater Elevation	579.84 ft
Inlet Control HW Elev.	581.13 ft	Control Type	Entrance Control
Outlet Control HW Elev.	581.38 ft		

Grades			
Upstream Invert	579.33 ft	Downstream Invert	578.84 ft
Length	49.00 ft	Constructed Slope	0.010000 ft/ft

Hydraulic Profile			
Profile	S2	Depth, Downstream	1.09 ft
Slope Type	Steep	Normal Depth	1.09 ft
Flow Regime	Supercritical	Critical Depth	1.18 ft
Velocity Downstream	6.01 ft/s	Critical Slope	0.007567 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.017
Section Material	CMP	Span	2.50 ft
Section Size	30 inch	Rise	2.50 ft
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	581.38 ft	Upstream Velocity Head	0.46 ft
Ke	0.90	Entrance Loss	0.41 ft

Inlet Control Properties			
Inlet Control HW Elev.	581.13 ft	Flow Control	N/A
Inlet Type	Projecting	Area Full	9.8 ft^2
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

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ATTACHMENT C-4B

TABULATED ANALYSIS RESULTS FOR CULVERTS

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DCP 30JAN02
DBM 1/30/02

OSDF CONSTRUCTION/FILLING PERIOD CONDITIONS
SUMMARY OF CULVERT ANALYSES RESULTS

CULVERT IDENTIFICATION			PHYSICAL CHARACTERISTICS OF CULVERT						CULVERT PROFILE				CULVERTMASTER® MODELING CHARACTERISTICS			HYDRAULIC CAPACITY					STRUCTURAL CAPACITY (6)				OUTLET PROTECTION (6)				
Culvert Name	Status (1)	Design Scenario	Material - Type	Entrance Loss Coefficient (Ke)	Manning's n	Entrance Configuration (2)	Number of Culverts - Diameter	Approximate Length (ft)	Inlet Invert Elevation (ft MSL)	Outlet Invert Elevation (ft MSL)	Slope ft/ft	Overtopping Elevation (7) (ft MSL)	Entrance Configuration(3)	Entrance Loss Coefficient (Ke)	Number of Culverts - Diameter (3)	HydroCad Node / Peak Flow Rate (cfs)	Tailwater Elevation (ft MSL)	Calculated Headwater Depth - Inlet Control (4) (ft MSL)	Calculated Headwater Depth Outlet Control (4) (ft MSL)	Calculated Freeboard (ft)	Available Cover (ft)	Design Traffic Type	Minimum Required Cover (ft)	Structurally Stable	Outlet Velocity (ft/s)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	d_{50} (in)	Thickness (in)
11a	reconfigured	E OSDF	HDPE	0.2	0.010	Projecting	2 - 27 inch	60	583.84	583.57	0.0045	587.50	Groove - Projecting	0.2	3 - 27 inch	11 / 76.91	585.06	586.71	586.70	0.8	3.41	Off-Highway	3	yes	7.7	5	10	6	12
11b	reconfigured	E OSDF	RCP	0.2	0.013	Projecting	1 - 30 inch	60																					
23	new	E OSDF	Helical CMP	0.9	0.018	Projecting	2 - 36 inch	92	586.32	585.78	0.0059	590.00	Projecting	0.9	2 - 36 inch	23 / 48.76	587.01	588.83	589.02	1.0	2.04	On-Highway	2	yes	6.4	6	12	6	12
25	new	E OSDF	Helical CMP - Arch	0.9	0.018	Projecting	2 - 42 x 29 inch	53	584.85	584.53	0.0060	588.50	Thin Wall Projecting	0.9	2 - 42 x 29 inch	25 / 64.23	586.73	587.52	587.71	0.8	3.23	On-Highway	2	yes	4.9	0	0	0	0
27	new	E OSDF	Helical CMP - Arch	0.9	0.018	Projecting	2 - 42 x 29 inch	106	582.80	582.36	0.0042	587.00	Thin Wall Projecting	0.9	2 - 42 x 29 inch	27 / 64.98	583.88	585.50	585.63	1.4	3.78	Off-Highway	3	yes	6.8	6	12	6	12
28	new - temporary	E OSDF	Helical CMP - Arch	0.7	0.019	Mitered to Slope	2 - 49 x 33 inch	92	586.95	586.53	0.0046	590.50	Mitered to Slope	0.7	2 - 49 x 33 inch	28 / 70.77	588.04	589.30	589.52	1.0	3.05	Off-Highway	3	yes	6.4	6	12	6	12
31	existing	E OSDF	HDPE	0.9	0.012	Projecting	1 - 27 inch	80	584.00	583.00	0.0125	588.50	Projecting	0.9	1 - 27 inch	31 / 6.54	584.51	585.20	585.49	3.0	-	-	-	-	2.3	-	-	-	-
5	new - temporary	W OSDF	Helical CMP	0.9	0.019	Projecting	1 - 42 inch	95	580.68	579.98	0.0074	585.00	Projecting	0.9	1 - 42 inch	5 / 44.48	582.50	584.08	584.32	0.7	4.57	Off-Highway	3	yes	6.0	7	14	6	12
12	new	W OSDF	Helical CMP	0.9	0.018	Projecting	1 - 30 inch	115	577.05	576.00	0.0091	581.50	Projecting	0.9	1 - 30 inch	12 / 30.11	578.57	580.5	580.87	0.6	6.13	On-Highway	2	yes	6.1	5	10	6	12
13	existing	W OSDF	RCP	0.2	0.013	Groove End Projecting	1 - 15 inch	65	579.80	579.00	0.0123	581.80	Groove End Projecting	0.2	1 - 15 inch	13 / 4.24	579.50	581.05	581.08	0.7	-	-	-	-	6.1	-	-	-	-
14	existing	W OSDF	CMP	0.9	0.024	Projecting	1 - 50 x 31 inch	112	578.60	575.00	0.0321	582.20	Projecting	0.9	1 - 50 x 31 inch	14 / 4.33	576.00	579.20	579.38	2.8	-	-	-	-	1.2	-	-	-	-
1	existing - temporary	DC A	CMPA - Arch	0.5	0.018	Flared End Section	1 - 13 x 17 inch	80	587.35	586.37	0.0123	590.00	Headwall	0.5	1 - 11 x 18 inch	1 / 2.02	586.80	587.97	588.03	2.0	-	-	-	-	3.3	-	-	-	-
3	existing - temporary	DC A	PVC	0.2	0.010	Concrete Headwall	2 - 18 inch	55	581.60	581.30	0.0055	585.50	Groove Headwall	0.2	2 - 18 inch	3 / 8.41	582.27	582.70	582.76	2.7	-	-	-	-	3.5	-	-	-	-
4	existing - temporary	DC A	PVC	0.2	0.010	Concrete Headwall	2 - 18 inch	60	582.70	581.50	0.0200	587.00	Groove Headwall	0.2	2 - 18 inch	4 / 1.90	582.94	583.4	583.45	3.5	-	-	-	-	1.1	-	-	-	-
8	new - temporary	DC A	Helical CMP	0.9	0.017	Projecting	2 - 30 inch	49	579.33	578.84	0.0100	582.50	Projecting	0.9	2 - 30 inch	8 / 24.73	579.84	581.13	581.38	1.1	2.32	On-Highway	2	yes	6.0	5	10	6	12

- E OSDF = East OSDF Construction-Phase Design Scenario
- W OSDF = West OSDF Construction-Phase Design Scenario
- DC A = Design Case "A"
- N/A = Not Applicable
- d_{50} = Average particle diameter

Notes
(1) New indicates a new culvert to be installed.
(2) Entrance configuration assumed.
(3) Dimensions and entrance configurations used in the Culvertmaster software package were selected to match existing culvert characteristics as closely as possible.
(4) Headwater depths calculated using Culvertmaster software package. Summary output presented for each culvert in Attachment C-4A.
(5) Grading is provided in the Construction Drawings
(6) Neither structural capacity nor outlet protection are evaluated for existing culverts.

=-4664 277/282
DGP 30JAN02
DBM 1/30/02

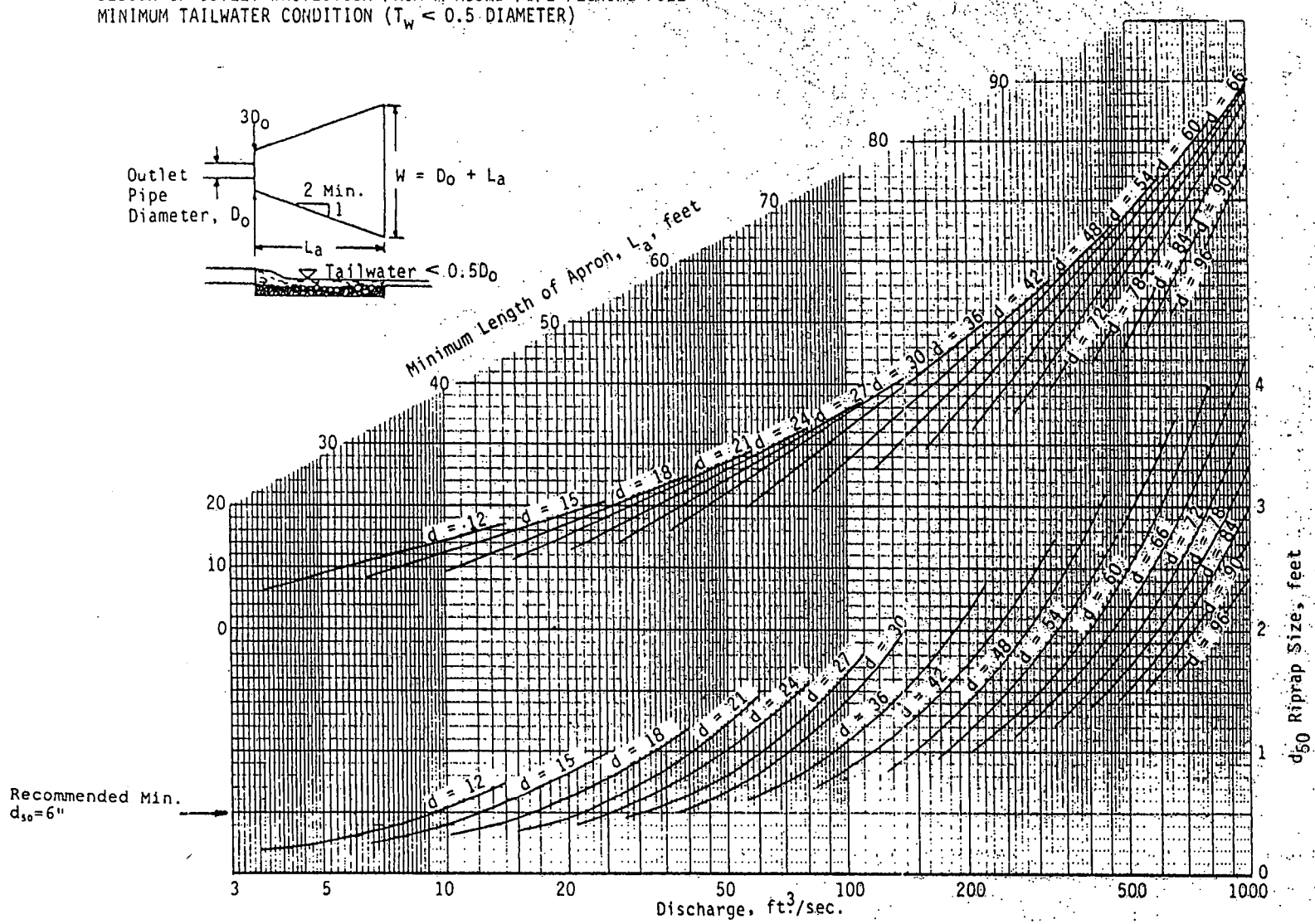
OSDF CONSTRUCTION/FILLING PERIOD CONDITIONS
SUMMARY OF CULVERT RIP RAP ANALYSES RESULTS

CULVERT IDENTIFICATION			PHYSICAL CHARACTERISTICS OF CULVERT				OUTLET PROTECTION									
									Temporary Protection		Permanent Protection		DCP Minimum Apron Length			
Culvert Name	Status [1]	Design Scenario	Material - Type	Manning's n	Number of Culverts - Diameter	Approximate Length (ft)	HydroCad Node / Peak Flow Rate (cfs)	Outlet Velocity (ft/s)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	Riprap Length at Inlet (ft)	Riprap Length at Outlet (ft)	d_{50} (in)	Thickness (in)
11a	reconfigured	E OSDF	HDPE	0.010	2 - 27 inch	60	11 / 48.5	7.7	-	-	4	8	4.5	9	6	12
11b	reconfigured	E OSDF	RCP	0.013	1 - 30 inch	60	11 / 27.5	7.7	-	-	4	8	5	10	6	12
23	new	E OSDF	Helical CMP	0.018	2 - 36 inch	92	23 / 48.76	6.4	-	-	4	8	6	12	6	12
25	new	E OSDF	Helical CMP - Arch	0.018	2 - 42 x 29 inch	53	25 / 64.23	4.9	-	-	none recommended		6	12	6	12
27	new	E OSDF	Helical CMP - Arch	0.018	2 - 42 x 29 inch	106	27 / 64.98	6.8	-	-	4	8	6	12	6	12
28	new - temporary	E OSDF	Helical CMP - Arch	0.020	2 - 49 x 33 inch	92	28 / 70.77	6.4	3	5	-	-	6	12	6	12
31	existing	E OSDF	HDPE	0.012	1 - 27 inch	80	31 / 6.54	2.3	-	-	-	-	-	-	-	-
5	new - temporary	W OSDF	Helical CMP	0.018	1 - 42 inch	95	5 / 44.48	6.0	4.5	9	-	-	7	14	6	12
12	new	W OSDF	Helical CMP	0.018	1 - 30 inch	115	12 / 30.11	6.1	-	-	4	8	5	10	6	12
13	existing	W OSDF	RCP	0.013	1 - 15 inch	65	13 / 4.24	6.1	-	-	-	-	-	-	-	-
14	existing	W OSDF	CMP	0.024	1 - 50 x 31 inch	112	14 / 4.33	1.2	-	-	-	-	-	-	-	-
1	existing - temporary	DC A	CMPA - Arch	0.018	1 - 13 x 17 inch	80	1 / 2.02	3.3	-	-	-	-	-	-	-	-
3	existing - temporary	DC A	PVC	0.010	2 - 18 inch	55	3 / 8.41	3.5	-	-	-	-	-	-	-	-
4	existing - temporary	DC A	PVC	0.010	2 - 18 inch	60	4 / 1.90	1.1	-	-	-	-	-	-	-	-
8	new - temporary	DC A	Helical CMP	0.017	2 - 30 inch	49	8 / 24.73	6.0	4	8	-	-	5	10	6	12

- E OSDF = East OSDF Construction-Phase Design Scenario
- W OSDF = West OSDF Construction-Phase Design Scenario
- DC A = Design Case "A"
- N/A = Not Applicable
- d_{50} = Average particle diameter

1992

DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MINIMUM TAILWATER CONDITION (T_w < 0.5 DIAMETER)



Source: USDA-SCS

Plate 3.18-3

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278/282
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279 / 282
DGP 30JAN02
DBM 1/30/02

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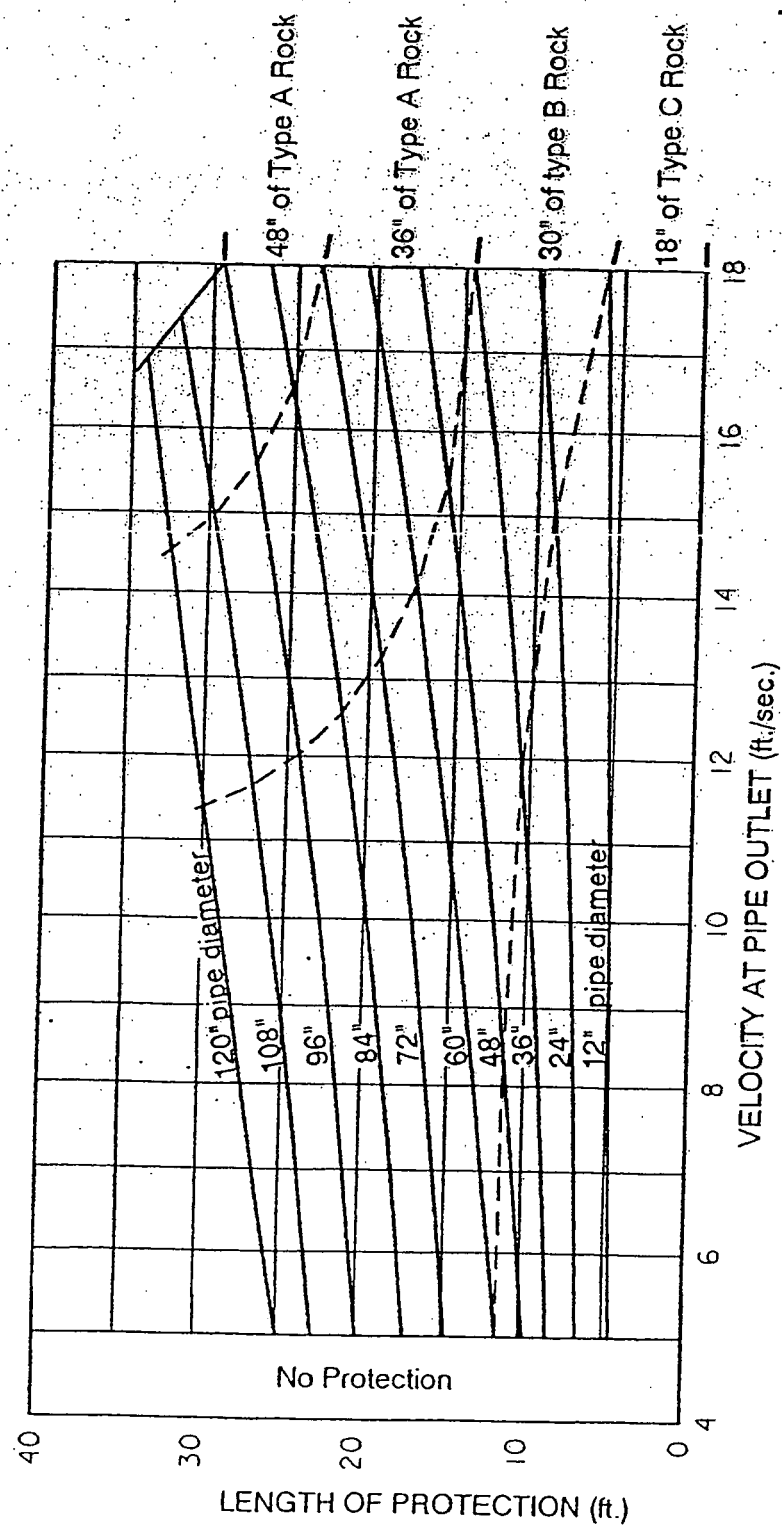

Source: ODOT Location and Design Manual, 1992

Figure 2-3 Outlet protection length

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ATTACHMENT C-5

TABULATED ANALYSIS RESULTS FOR BASIN OUTLET STRUCTURES

ITEM		BORROW AREA BASIN		
		DESCRIPTION	PARAMETER VALUE IN UNITS SHOWN	
PRINCIPAL SPILLWAY	Riser Pipe	Existing Twin 48" CMP	ELEVATION (ft MSL)	575.3
	Outlet Pipe	Existing Twin 48" CMP		569.8
EMERGENCY SPILLWAY		20' long rectangular		578.0
EMBANKMENT		Cut to existing ground		579.0
AVAILABLE STORAGE VOLUME (TO RISER INLET)		To primary spillway riser pipe inlet	VOLUME (acre-ft)	35.8
SUBCATCHMENT		Total Upstream Drainage Area	AREA (acres)	174.86

BORROW AREA BASIN ROUTING RESULTS

DESIGN PARAMETER	Value
25-YEAR 24-HOUR PEAK WATER ELEVATION (ft MSL)	574.29
REQUIRED STORAGE VOLUME BASED ON DRAINAGE AREA (acre-ft)	7.2

Notes

1. Minimum Sedimentation Basin volume of 35.8 acre-ft exceeds disturbed area-based volume of 7.2 acre
2. A freeboard greater than 1 ft of maintained for the 25-year, 24-hour storm ever
3. Calculation for volume based on drainage area
   (1800 cf) x (174.86 acres of upstream drainage area) x (1 year/cleanout) = 314,748 cf/cleanc

281/282
DGP 30 JAN 02
DBM 1/30/02

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ITEM		OSDF SEDIMENTATION BASIN 2		
		DESCRIPTION	PARAMETER VALUE IN UNITS SHOWN	
PRINCIPAL SPILLWAY	Riser Pipe	48"	ELEVATION (ft MSL)	575.5
	Outlet Pipe	New 36" CMP pipe/72" x 44" CMP pipe arch bulkhead eccentric reducer coupled to existing 72" x 44" CMP pipe arch		570.8
EMERGENCY SPILLWAY		20 ' long rectangular		576.0
EMBANKMENT		Cut to existing ground surface		577.0
AVAILABLE STORAGE VOLUME (TO RISER INLET)		To primary spillway riser pipe inlet	VOLUME (acre-ft)	8.6
SUBCATCHMENT		Total Upstream Drainage Area	AREA (acres)	39.09

Notes

1. Minimum Sedimentation Basin volume of 8.6 acre-ft exceeds disturbed area-based volume of 4.886 acre-ft.
   Minimum Sedimentation Basin volume of 8.6 acre-ft exceeds the 10-year, 24-hour runoff volume of 8.42 acre-ft
2. Flow does not enter emergency spillway for the 25-year, 24-hour storm event.
3. A freeboard of 1 ft is maintained for the 100-yr, 24-hour storm event.
4. Calculation for volume based on drainage area.
   (0.125 acre-ft/acre-year) x (39.09 acres of upstream drainage area) x (1 year/cleanout) = 4.886 acre-ft/cleanout

OSDF SEDIMENTATION BASIN 2 ROUTING RESULTS

DESIGN PARAMETER	Value
10-YEAR 24-HOUR RUNOFF VOLUME (acre-ft)	8.41
25-YEAR 24-HOUR PEAK WATER ELEVATION (ft MSL)	575.66
100-YEAR 24-HOUR PEAK WATER ELEVATION (ft MSL)	575.84
REQUIRED STORAGE VOLUME BASED ON DRAINAGE AREA (acre ft)	4.886

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282/282
DBM 1/30/02
DOP 30 JAN 02

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Section 13.3

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13.3 OSDF PHASE V, EAST 2000-YEAR DRAINAGE CHANNEL EVALUATION

COMPUTATION COVER SHEET

- 4664

SUBJECT OF COMPUTATIONS OSDF PHASE V, EAST 2000-YEAR DRAINAGE CHANNEL EVALUATION

Computations By:
(Cognizant Engineer)

Signature Dana Beth Mehlman — Date 25 January 200

Printed Name and Title: Dana Beth Mehlman, Staff Engineer

Assumptions and Procedures Checked By:
(Checker)

Signature [signature] — Date 30 JAN. 2002

Printed Name and Title: Daniel G. Pass, Project Engineer

Computations Checked by:

Signature [signature] — Date 30 Jan 02

Printed Name and Title: Ganesh Gopalakrishnan, Project Engineer

Computations Backchecked by:
(Cognizant Engineer)

Signature Dana Beth Mehlman — Date 30 January 200

Printed Name and Title: Dana Beth Mehlman, Staff Engineer

Approved by:
(DTL)

Signature [signature] — Date 30 JAN 2002

Printed Name and Title: Daniel G. Pass, Project Engineer

Approved by:
(TETL)

Signature [signature] — Date 30 Jan 2002

Printed Name and Title: J.F. Beech, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	SUBMITTAL TO FF/DOE/EPA	30JAN02	DGP for DBM	DGP	JFB

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ADDENDUM TO SECTION 13.1

(ADDED TO REVISION 1 PACKAGE)

The 2000-year drainage channel aligned along the east perimeter of the OSDF was originally designed to convey runoff from the east slope of the OSDF final cover system and runon from east of the OSDF. This channel was designed to include a 1% overbank between the 25-year channel and the Emergency Access Road (formerly the Rerouted North Entrance Road), to accommodate these flows. Further analyses (presented in this addendum) show that a portion of the runon from the 2000-year storm event is diverted by the road embankment and thus does not enter the channel. Additionally, the geometry of a segment of the channel differs from the original design by not including a 1% overbank.

This addendum is prepared to evaluate the adequacy of the East 2000-year channel considering the diversion of runon by the Emergency Access Road and the existing and as-designed geometry of the channel. For Cells 1 to 3, the channel geometry used in the evaluation is consistent with a recent aerial topographic plan, which does not reflect a 1% overbank. For Cell 4, the channel geometry used in the evaluation is consistent with OSDF Phase IV construction drawings, which does not include a 1% overbank. For Cells 5 to 7; the channel geometry used in the evaluation is consistent with OSDF Phase V construction drawings and the originally designed 1% overbank. Calculation procedures and input data are similar to that used in Section 13.1. This addendum is presented as Section 13.3 of the OSDF Final Design Calculation Package and is entitled "OSDF Phase V, East 2000-Year Drainage Channel Evaluation". Section 13.3 is presented in Volume VII of the OSDF Final Design Calculation Package.

OSDF PHASE V, EAST 2000-YEAR DRAINAGE CHANNEL EVALUATION

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EXECUTIVE SUMMARY

PURPOSE OF ANALYSES

The 2000-year drainage channel aligned along the east perimeter of the OSDF (2000-year channel) was originally designed to convey runoff from the east slope of the OSDF final cover system and runon from east of the OSDF, for the 2000-year 24-hour storm event. This channel was previously evaluated as part of Calculation Section 13.1.

For the evaluation presented in Calculation Section 13.1, the channel geometry was consistent with the OSDF Final Design Package, which included a 1% overbank between the East 25-year runoff channel (25-year channel) and the Emergency Access Road (formerly the Rerouted North Entrance Road). The final channel geometry East of Cells 1 to 4 will differ from the OSDF Final Design Package by not incorporating a 1% overbank. Furthermore, analyses presented herein indicate that runon south of Cell 4 is expected to be diverted by the Emergency Access Road (road) embankment and thus not enter the 2000-year channel. Runon along and north of Cell 4 is considered to enter the 2000-year channel due to the presence of a culvert and berm crossing the runon channel at the southeast corner of Cell 4.

The purpose of this calculation is to revaluate the adequacy of the 2000-year channel using a channel geometry that exists along Cells 1 to 3 and is expected to exist (with the completion of Phases IV and V construction) along Cells 4 to 7, to convey runoff from the 2000-year 24-hour storm event with a minimum 0.5 ft freeboard.

METHOD OF ANALYSES

Analysis methods and input data, not specific to channel geometry, are consistent with that used in the OSDF Final Design calculation package "Stormwater Runon/Runoff and Drainage Control Structures" (i.e., Calculation Section 13.1).

Cross-sectional geometry for the 2000-year channel along Cells 1 to 3 was obtained from a topographic map prepared after construction of this segment of the channel. This channel segment exists and was constructed without the 1% overbank. Cross-sectional geometry for the 2000-year channel along Cell 4 was obtained from OSDF Phase IV Final Certified-For-Construction drawings (Phase IV drawings). The channel segment along Cell 4 is yet to be constructed; Phase IV drawings show this segment to be constructed without a 1% overbank. Cross-sectional geometry for the 2000-year channel along Cells 5, 6, and 7 was obtained from OSDF Phase V Certified-For-Construction drawings (Phase V drawings).

RESULTS AND CONCLUSIONS

The results of the analyses performed indicate that freeboard for the 2000-year channel will equal or exceed 0.5 ft (measured vertically from the subgrade of the Monitoring Access which is located at the approximate terminal end of the final cover system) for peak flows from the 2000-year 24-hour storm event. Based on the above, the 2000-year channel as constructed for Cells 1 to 3 and to be constructed for Cells 4 to 7 is expected to convey the 2000-year 24-hour event without adversely impacting the On-Site Disposal Facility (OSDF) final cover system.

4664

OSDF PHASE V, EAST 2000-YEAR DRAINAGE CHANNEL EVALUATION

TABLE OF CONTENTS

EXECUTIVE SUMMARY
TABLE OF CONTENTS
PROCEDURES
INTRODUCTION AND PURPOSE 4
DESIGN CRITERIA 4
DESIGN SCENARIOS 4
SOFTWARE 5
HYDROLOGIC ANALYSES 5
HYDRAULIC ANALYSES 5
ATTACHMENTS
A-1 – LAYOUT OF 2000-YEAR STORM DESIGN SCENARIOS 6
A-2 – NODAL NETWORK DIAGRAM 8

DATA VERIFICATION
INTRODUCTION 10
HYDROLOGIC ANALYSES 10
HYDRAULIC ANALYSES 11
ATTACHMENTS
B-1 – SUBCATCHMENT AREA AND WEIGHTED CURVE NUMBER DATA 12
B-2 – DATA FOR CALUCLATION OF TIME OF CONCENTRATION 14
B-3 – CHANNEL ANALYSIS INPUT DATA 18

CALCULATIONS
INTRODUCTION 22
HYDROLOGIC ANALYSES 22
HYDRAULIC ANALYSES 22
RESULTS AND CONCLUSIONS 23
ATTACHMENTS
C-1A – HydroCAD™ OUTPUT REPORTS, 2000 YEAR STORM DESIGN SCENARIO – LIGHT VEGETATION 25
C-1B – HydroCAD™ OUTPUT REPORTS, 2000 YEAR STORM DESIGN SCENARIO – MODERATE VEGETATION 34
C-1C – HydroCAD™ OUTPUT REPORTS, 2000 YEAR STORM DESIGN SCENARIO – HEAVY VEGETATION 43
C-2 – WEIGHTED CURVE NUMBER CALCULATIONS 52
C-3 – TABULATED CHANNEL ANALYSIS RESULTS 54
C-4 – GRAPHICAL CHANNEL ANALYSIS RESULTS 58

OSDF PHASE V, EAST 2000-YEAR DRAINAGE CHANNEL EVALUATION

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PROCEDURES

INTRODUCTION AND PURPOSE

The 2000-year drainage channel aligned along the east perimeter of the OSDF (2000-year channel) was originally designed to convey runoff from the east slope of the OSDF final cover system and runon from east of the OSDF, for the 2000-year 24-hour storm event. This channel was previously evaluated as part of Calculation Section 13.1.

For the evaluation presented in Calculation Section 13.1, the OSDF Final Design Package which included a 1% overbank between the East 25-year runoff channel (25-year channel) and the Emergency Access Road (formerly the Rerouted North Entrance Road). The final channel geometry East of Cells 1 to 4 will differ from the OSDF Final Design Package by not incorporating a 1% overbank. Furthermore, analyses presented herein indicate that runon downstream of Cell 4 is be expected to be diverted by the Emergency Access Road (road) embankment and thus not enter the 2000-year channel. Runon along and north of Cell 4 is considered to enter the 2000-year channel due to the presence of a culvert and berm crossing the runon channel at the southeast corner of Cell 4.

The purpose of this calculation is to revaluate the adequacy of the 2000-year channel using a channel geometry that exists along Cells 1 to 3 and is expected to exist (with the completion of Phases IV and V construction) along Cells 4 to 7, to convey runoff from the 2000-year 24-hour storm event with a minimum 0.5 ft freeboard.

DESIGN CRITERIA

The design criteria for this calculation are consistent with that used in Calculation Section 13.1.

DESIGN SCENARIOS

As in the OSDF Final Design Package [GeoSyntec, 1997], three independent scenarios were

analyzed for the 2000-year channel. These three scenarios model differing vegetative conditions to reflect different time periods after the closure of the facility. The scenarios are identified as follows: 2000-Year Storm Design Scenario-Light Vegetation, 2000-Year Storm Design Scenario-Moderate Vegetation, and 2000-Year Storm Design Scenario-Heavy Vegetation.

Layout for 2000-Year Design Scenarios

The layout of the East Perimeter of the OSDF for the 2000-year design scenarios is consistent with existing conditions and future modifications shown on Phase IV and Phase V drawings (Phases yet to be constructed). Runon along and north of Cell 4 is considered to enter the 2000-year channel due to the presence of a culvert and berm crossing the runon channel at the southeast corner of Cell 4. The capacity of the Emergency Access Road (road) embankment to divert runon downstream of Cell 4 for the 2000-year storm event (thus preventing the runon from entering the 2000-year channel) is evaluated. A schematic drawing showing the layout of the East Perimeter of the OSDF for the purpose of hydrologic calculations is included as Attachment A-1.

SOFTWARE

The software (i.e. HydroCad™) and analysis methods employed for this calculation is consistent with that used in Calculation Section 13.1.

HYDROLOGIC ANALYSES

Procedures used for hydrologic analyses are consistent with that used in Calculation Section 13.1, updated to reflect the expected long-term geometry of the 2000-year drainage channel and the configuration of the Emergency Access Road embankment.

HYDRAULIC ANALYSES

Procedures for hydraulic analyses are consistent with that used in Calculation Section 13.1, updated to include the 1% overbank (where expected to be present along the channel alignment), the geometry of the Emergency Access Road embankment, and the adjacent runon diversion area.

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ATTACHMENT A-1

LAYOUT OF 2000-YEAR STORM DESIGN SCENARIOS

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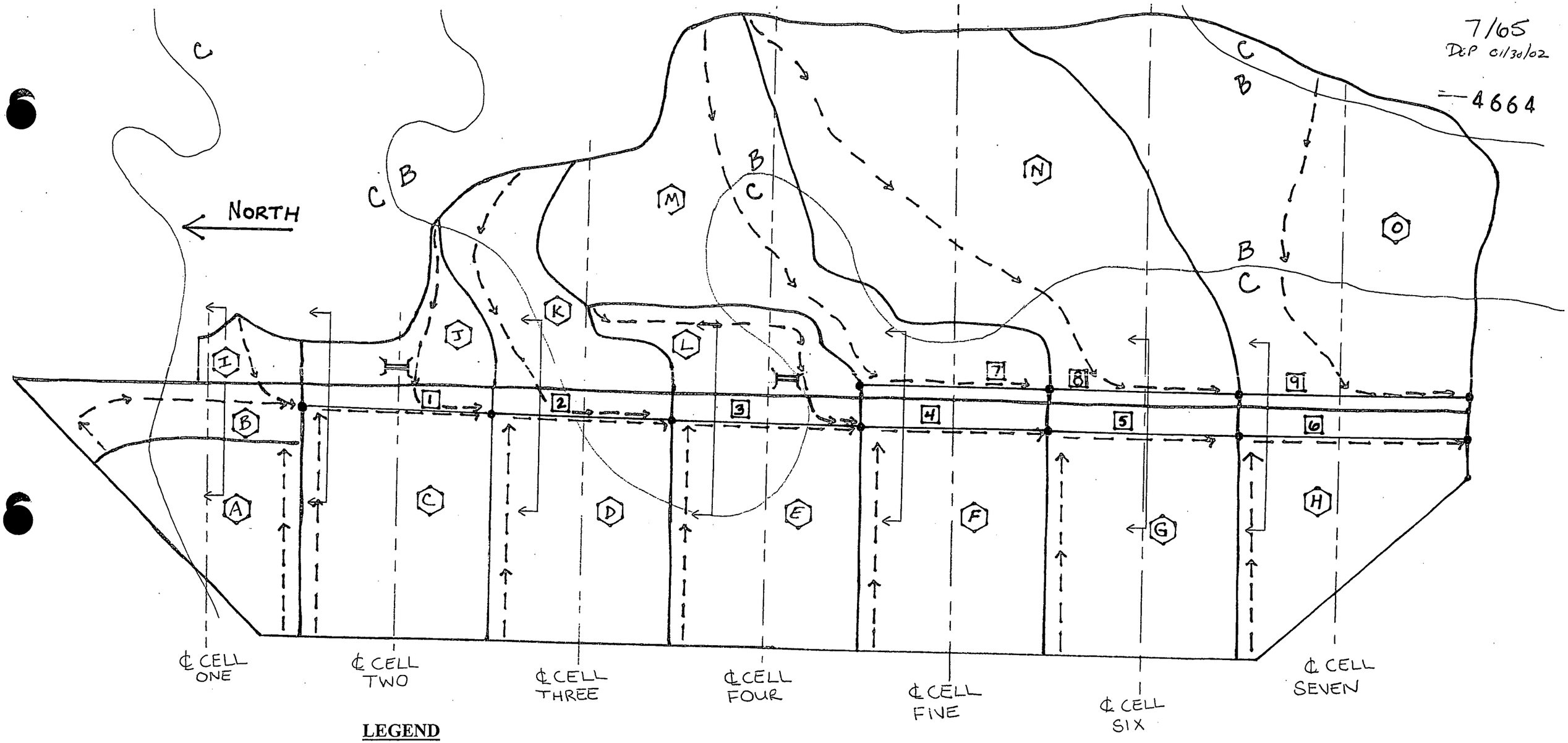

LEGEND

- SUBCATCHMENT LABEL
- REACH LABEL
- REACH ALIGNMENT
- FLOW PATH
- CULVERT
- CENTERLINE OF CELL
- LOCATION OF CROSS-SECTION
- B / C DELINEATION OF HSG B & C AREAS

NOTE: CENTERLINES OF CELLS AND LOCATIONS OF CROSS SECTIONS ARE SHOWN FOR INFORMATION PURPOSE ONLY.

Phase V
2000 Year Storm Design Scenario
Scale 1" = 200'
0 200

000413

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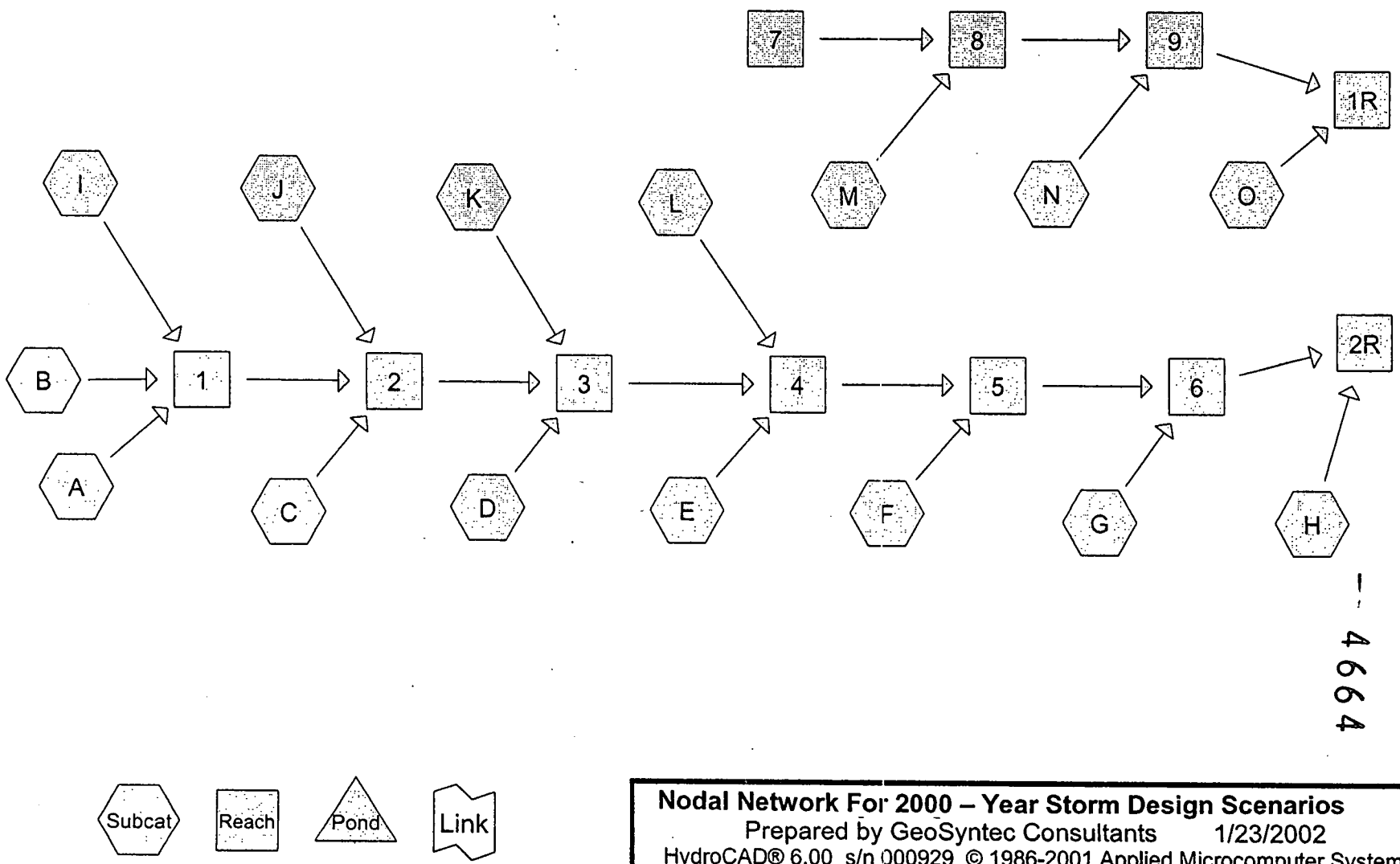
ATTACHMENT A-2

NODAL NETWORK DIAGRAM



Nodal Network For 2000 – Year Storm Design Scenarios
Prepared by GeoSyntec Consultants 1/23/2002
HydroCAD® 6.00 s/n 000929 © 1986-2001 Applied Microcomputer Systems

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OSDF PHASE V, EAST-2000 YEAR DRAINAGE CHANNEL

DATA VERIFICATION

INTRODUCTION

As described in the Procedures Section, the purpose of this calculation is to revaluate the adequacy of the 2000-year channel, using the channel geometry that exists along Cells 1 to 3 and is expected to exist (with the completion of Phases IV and V construction) along Cells 4 to 7, to convey runoff from the 2000-year 24-hour storm event with a minimum 0.5 ft freeboard. This section (Data Verification) presents the selection of parameters used to perform analyses in the Calculations Section of this calculation package.

HYDROLOGIC ANALYSES

For the three 2000 Year Storm Design Scenarios, the relationships of subcatchments and reaches are shown by the nodal network diagram presented in Attachment A-2.

Rainfall Distribution

The rainfall distribution used for this calculation is consistent with Calculation Section 13.1 (i.e., an SCS Type II Rainfall Distribution used for the Fernald site location).

Rainfall Depth

The rainfall depths used for this calculation is consistent with Calculation Section 13.1 (i.e., a rainfall depth of 13.0 inches is used for the 2000-year storm event).

Runoff curve numbers

The runoff curve numbers used for this calculation are consistent with Calculation Section 12.5, "OSDF Phase V, Surface-Water Management System Design and Post-Closure Hydrology", adjusted to an antecedent moisture condition (AMC) of III. Subcatchment

characteristics including total area and data for calculation of weighted CN are tabulated in Attachment B-1. Data includes the percentage of subcatchment area for combinations of HSG, CN, and a land use description for each subcatchment. Land use description is selected to be consistent with conditions expected for the post-closure period.

Subcatchment Time of Concentration

Subcatchment characteristics for calculation of time of concentration are tabulated in Attachment B-2. Parameters include those for sheet, shallow concentrated, and channel flow. As in Calculation Section 13.1, three different scenarios are analyzed. Different combinations of Manning's number, for both sheet and channel flow, are selected for each design scenario. These parameters are presented below and are consistent with those used in Calculation Section 13.1:

2000-Year Storm Design Scenario	Manning's n for Sheet Flow	Manning's n for Channel Flow
Light Vegetation	0.150	0.030
Moderate Vegetation	0.240	0.030
Heavy Vegetation	0.240	0.100

HYDRAULIC ANALYSES

Geometric characteristics (i.e., sideslopes, width, and longitudinal slope) for the channel segment along Cells 1 – 3 were established from site topography from the January 2000 flyover (existing topography). Geometric characteristics for the channel along Cell 4 were established from the Phase IV Certified-For-Construction drawings. Geometric characteristics for the channel along Cells 5 – 7 were established from the Phase V Certified-For-Construction drawings. As described above, the Manning's n value will vary between scenarios. For the Light Vegetation, Moderate Vegetation and Heavy Vegetation 2000 Year Storm Design Scenarios, the Manning's n values are 0.030, 0.030, and 0.100, respectively. Data for channel segments are presented in Attachment B-3.

4664

ATTACHMENT B-1

SUBCATCHMENT AREA AND WEIGHTED CURVE NUMBER DATA

SUBCATCHMENT AREA AND HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF WEIGHTED CN
2000 YEAR STORM DESIGN SCENARIOS

Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN AMC = 2	Weighted CN AMC = 2	Weighted CN AMC = 3
A	2.60	100%	B/C	vegetated final cover	98	Intentionally left blank. Is adressed in the calculation section	Intentionally left blank. Is adressed in the calculation section.
B	1.64	100%	B/C	vegetated final cover	98		
C	4.96	100%	B/C	vegetated final cover	98		
D	4.75	100%	B/C	vegetated final cover	98		
E	4.95	100%	B/C	vegetated final cover	98		
F	4.81	100%	B/C	vegetated final cover	98		
G	4.95	100%	B/C	vegetated final cover	98		
H	3.92	100%	B/C	vegetated final cover	98		
I	0.53	100%	C	runon east of OSDF	79		
J	1.24	100%	C	runon east of OSDF	79		
K	2.62	65% 35%	B C	runon east of OSDF runon east of OSDF	69 79		
L	1.78	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79		
M	7.23	60% 40%	B C	runon east of OSDF runon east of OSDF	69 79		
N	11.66	75% 25%	B C	runon east of OSDF runon east of OSDF	69 79		
O	10.94	65% 35%	B C	runon east of OSDF runon east of OSDF	69 79		

N/A - Not Applicable

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ATTACHMENT B-2

DATA FOR CALCULATION OF TIME OF CONCENTRATION

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HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
2000 YEAR STORM DESIGN SCENARIO - LIGHT VEGETATION

2-year, 24-hr Design Rainfall Depth, P_{2-24} = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW			SHALLOW CONCENTRATED FLOW			CHANNEL FLOW 1						CHANNEL FLOW 2					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	190	unpaved	0.1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	vegetated final cover	90	grass: short	0.150	0.0750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	130	0	2.03	6.0, 6.0	0.030	0.0250	320	0	2.03	4.0, 6.0	0.030	0.0075
C	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	190	unpaved	0.1700	-	-	-	370	0	2.33	6.0, 4.0	0.030	0.0035	-	-	-	-	-	-
D	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	180	unpaved	0.1700	-	-	-	200	0	2.86	6.0, 5.0	0.030	0.0083	150	0	2.86	6.0, 4.0	0.030	0.0045
E	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	170	unpaved	0.1700	-	-	-	50	0	3.32	6.0, 4.0	0.030	0.0045	320	0	3.32	6.0, 3.0	0.030	0.0105
F	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	175	unpaved	0.1700	-	-	-	360	0	3.68	4.0, 6.0	0.030	0.0050	-	-	-	-	-	-
G	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	175	unpaved	0.1700	-	-	-	370	0	3.86	3.0, 6.0	0.030	0.0050	-	-	-	-	-	-
H	vegetated final cover	90	grass: short	0.150	0.0500	60	grass: short	0.150	0.1000	150	grass: short	0.150	0.1700	175	unpaved	0.1700	-	-	-	440	0	3.86	3.0, 6.0	0.030	0.0050	-	-	-	-	-	-
I	runon east of OSDF	210	grass: short	0.150	0.0050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55	0	2.03	4.0, 6.0	0.030	0.0075	-	-	-	-	-	-
J	runon east of OSDF	300	grass: short	0.150	0.0158	-	-	-	-	-	-	-	-	100	unpaved	0.0158	-	-	-	150	0	2.33	6.0, 4.0	0.030	0.0035	-	-	-	-	-	-
K	runon east of OSDF	300	grass: short	0.150	0.0070	-	-	-	-	-	-	-	-	290	unpaved	0.0200	-	-	-	250	0	2.86	6.0, 4.0	0.030	0.0045	-	-	-	-	-	-
L	runon east of OSDF	300	grass: short	0.150	0.0250	-	-	-	-	-	-	-	-	140	unpaved	0.0250	170	unpaved	0.0375	90	0	3.32	6.0, 3.0	0.030	0.0105	-	-	-	-	-	-
M	runon east of OSDF	300	grass: short	0.150	0.0100	-	-	-	-	-	-	-	-	350	unpaved	0.0139	180	unpaved	0.0167	360	0	0.82	4.0, 3.0	0.030	0.0125	-	-	-	-	-	-
N	runon east of OSDF	300	grass: short	0.150	0.0198	-	-	-	-	-	-	-	-	770	unpaved	0.0198	-	-	-	395	0	1.17	58.0, 3.0	0.030	0.0100	-	-	-	-	-	-
O	runon east of OSDF	300	grass: short	0.150	0.0200	-	-	-	-	-	-	-	-	420	unpaved	0.0200	-	-	-	250	0	1.17	60.0, 3.0	0.030	0.0100	-	-	-	-	-	-

B attach 2000/B2 light

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HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
2000 YEAR STORM DESIGN SCENARIO - MODERATE VEGETATION

2-year, 24-hr Design Rainfall Depth, P_{2-24} = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW			SHALLOW CONCENTRATED FLOW			CHANNEL FLOW 1						CHANNEL FLOW 2					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	190	unpaved	0.1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	vegetated final cover	90	grass: dense	0.240	0.0750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	130	0	1.90	6.0, 6.0	0.030	0.0250	320	0	1.90	4.0, 6.0	0.030	0.0075
C	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	190	unpaved	0.1700	-	-	-	370	0	2.15	6.0, 4.0	0.030	0.0035	-	-	-	-	-	-
D	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	180	unpaved	0.1700	-	-	-	200	0	2.65	6.0, 5.0	0.030	0.0083	150	0	2.65	6.0, 4.0	0.030	0.0045
E	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	170	unpaved	0.1700	-	-	-	50	0	3.10	6.0, 4.0	0.030	0.0045	320	0	3.10	6.0, 3.0	0.030	0.0105
F	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	175	unpaved	0.1700	-	-	-	360	0	3.45	4.0, 6.0	0.030	0.0050	-	-	-	-	-	-
G	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	175	unpaved	0.1700	-	-	-	370	0	3.64	3.0, 6.0	0.030	0.0050	-	-	-	-	-	-
H	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	175	unpaved	0.1700	-	-	-	440	0	3.64	3.0, 6.0	0.030	0.0050	-	-	-	-	-	-
I	runon east of OSDF	210	grass: dense	0.240	0.0050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55	0	1.90	4.0, 6.0	0.030	0.0075	-	-	-	-	-	-
J	runon east of OSDF	300	grass: dense	0.240	0.0158	-	-	-	-	-	-	-	-	100	unpaved	0.0158	-	-	-	150	0	2.15	6.0, 4.0	0.030	0.0035	-	-	-	-	-	-
K	runon east of OSDF	300	grass: dense	0.240	0.0070	-	-	-	-	-	-	-	-	290	unpaved	0.0200	-	-	-	250	0	2.65	6.0, 4.0	0.030	0.0045	-	-	-	-	-	-
L	runon east of OSDF	300	grass: dense	0.240	0.0250	-	-	-	-	-	-	-	-	140	unpaved	0.0250	170	unpaved	0.0375	90	0	3.10	6.0, 3.0	0.030	0.0105	-	-	-	-	-	-
M	runon east of OSDF	300	grass: dense	0.240	0.0100	-	-	-	-	-	-	-	-	350	unpaved	0.0139	180	unpaved	0.0167	360	0	0.75	4.0, 3.0	0.030	0.0125	-	-	-	-	-	-
N	runon east of OSDF	300	grass: dense	0.240	0.0198	-	-	-	-	-	-	-	-	770	unpaved	0.0198	-	-	-	395	0	1.08	58.0, 3.0	0.030	0.0100	-	-	-	-	-	-
O	runon east of OSDF	300	grass: dense	0.240	0.0200	-	-	-	-	-	-	-	-	420	unpaved	0.0200	-	-	-	250	0	1.08	60.0, 3.0	0.030	0.0100	-	-	-	-	-	-

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HYDROCAD™ INPUT PARAMETERS FOR THE CALCULATION OF TIME OF CONCENTRATION
2000 YEAR STORM DESIGN SCENARIO - HEAVY VEGETATION

2-year, 24-hr Design Rainfall Depth, $P_{2,24}$ = 2.60 inches

SUBCATCHMENT LABEL AND DESCRIPTION		SHEET FLOW 1				SHEET FLOW 2				SHEET FLOW 3				SHALLOW CONCENTRATED FLOW			SHALLOW CONCENTRATED FLOW			CHANNEL FLOW 1						CHANNEL FLOW 2					
No.	Description	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Manning's n	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Surface Description	Land Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)	Flow Length (ft)	Bottom Width (ft)	Flow Depth (ft)	Sideslopes (ft/ft)	Manning's n	Longitudinal Slope (ft/ft)
A	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	190	unpaved	0.1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B	vegetated final cover	90	grass: dense	0.240	0.0750	-	-	-	-	-	-	-	-	-	-	-	-	-	-	130	0	2.91	6.0, 6.0	0.100	0.0250	320	0	2.91	4.0, 6.0	0.100	0.0075
C	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	190	unpaved	0.1700	-	-	-	370	0	3.32	6.0, 4.0	0.100	0.0035	-	-	-	-	-	-
D	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	180	unpaved	0.1700	-	-	-	200	0	4.03	6.0, 5.0	0.100	0.0083	150	0	4.03	6.0, 4.0	0.100	0.0045
E	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	170	unpaved	0.1700	-	-	-	50	0	4.59	6.0, 4.0	0.100	0.0045	320	0	4.59	6.0, 3.0	0.100	0.0105
F	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	175	unpaved	0.1700	-	-	-	360	0	5.00	4.0, 6.0	0.100	0.0050	-	-	-	-	-	-
G	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	175	unpaved	0.1700	-	-	-	370	0	5.15	3.0, 6.0	0.100	0.0050	-	-	-	-	-	-
H	vegetated final cover	90	grass: dense	0.240	0.0500	60	grass: dense	0.240	0.1000	150	grass: dense	0.240	0.1700	175	unpaved	0.1700	-	-	-	440	0	5.15	3.0, 6.0	0.100	0.0050	-	-	-	-	-	-
I	runon east of OSDF	210	grass: dense	0.240	0.0050	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55	0	2.91	4.0, 6.0	0.100	0.0075	-	-	-	-	-	-
J	runon east of OSDF	300	grass: dense	0.240	0.0158	-	-	-	-	-	-	-	-	100	unpaved	0.0158	-	-	-	150	0	3.32	6.0, 4.0	0.100	0.0035	-	-	-	-	-	-
K	runon east of OSDF	300	grass: dense	0.240	0.0070	-	-	-	-	-	-	-	-	290	unpaved	0.0200	-	-	-	250	0	4.03	6.0, 4.0	0.100	0.0045	-	-	-	-	-	-
L	runon east of OSDF	300	grass: dense	0.240	0.0250	-	-	-	-	-	-	-	-	140	unpaved	0.0250	170	unpaved	0.0375	90	0	4.59	6.0, 3.0	0.100	0.0105	-	-	-	-	-	-
M	runon east of OSDF	300	grass: dense	0.240	0.0100	-	-	-	-	-	-	-	-	350	unpaved	0.0139	180	unpaved	0.0167	360	0	1.16	4.0, 3.0	0.100	0.0125	-	-	-	-	-	-
N	runon east of OSDF	300	grass: dense	0.240	0.0198	-	-	-	-	-	-	-	-	770	unpaved	0.0198	-	-	-	395	0	1.63	58.0, 3.0	0.100	0.0100	-	-	-	-	-	-
O	runon east of OSDF	300	grass: dense	0.240	0.0200	-	-	-	-	-	-	-	-	420	unpaved	0.0200	-	-	-	250	0	1.63	60.0, 3.0	0.100	0.0100	-	-	-	-	-	-

4664

ATTACHMENT B-3

CHANNEL ANALYSIS INPUT DATA

2000 YEAR STORM DESIGN SCENARIO - LIGHT VEGETATION
SUMMARY OF CHANNEL INPUT DATA

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node [3]	HydroCAD Q (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth Y (ft)	Estimated Q (cfs)	Channel Freeboard (ft)	Peak Flow Velocity (fps)	Lining Type
subcatchment B	existing	2000 DS	vee	11.90	0.35%	0.030	0	6	4	1									
reach 1	existing	2000 DS	vee	10.90	0.35%	0.030	0	6	4	2									
reach 2	existing	2000 DS	vee	7.73	0.45%	0.030	0	6	5	3									
reach 3	new [4]	2000 DS	vee	6.76	0.45%	0.030	0	6	3	4	Intentionally left blank. Is addressed in the calculation section.								
reach 4	new	2000 DS	vee	7.25	0.50%	0.030	0	6	4	5									
reach 5	new	2000 DS	vee	5.88	0.50%	0.030	0	6	3	6									
reach 6	new	2000 DS	vee	5.76	0.50%	0.030	0	6	3	2R									
reach 7	new	2000 DS	vee	3.60	1.25%	0.030	0	4	3	8									
reach 8	new	2000 DS	vee	3.51	1.00%	0.030	0	58	3	9									
reach 9	new	2000 DS	vee	3.50	1.00%	0.030	0	60	3	1R									

2000 DS = 2000 Year Storm Design Scenario

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from existing topographic information and construction drawings.
3. N/A indicates that there is not specific HydroCAD node associated with the particular channel.
4. This channel will be constructed as part of Phase IV project.

000425

4664

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19/65

2000 YEAR STORM DESIGN SCENARIO - MODERATE VEGETATION
SUMMARY OF CHANNEL INPUT DATA

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node[3]	HydroCAD Q (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth Y (ft)	Estimated Q (cfs)	Channel Freeboard (ft)	Peak Flow Velocity (fps)	Lining Type
subcatchment B	existing	2000 DS	vee	11.90	0.35%	0.030	0	6	4	1									
reach 1	existing	2000 DS	vee	10.90	0.35%	0.030	0	6	4	2									
reach 2	existing	2000 DS	vee	7.73	0.45%	0.030	0	6	5	3									
reach 3	new[4]	2000 DS	vee	6.76	0.45%	0.030	0	6	3	4									
reach 4	new	2000 DS	vee	7.25	0.50%	0.030	0	6	4	5	Intentionally left blank. Is addressed in the calculation section.								
reach 5	new	2000 DS	vee	5.88	0.50%	0.030	0	6	3	6									
reach 6	new	2000 DS	vee	5.76	0.50%	0.030	0	6	3	2R									
reach 7	new	2000 DS	vee	3.60	1.25%	0.030	0	4	3	8									
reach 8	new	2000 DS	vee	3.51	1.00%	0.030	0	58	3	9									
reach 9	new	2000 DS	vee	3.50	1.00%	0.030	0	60	3	1R									

2000 DS = 2000 Year Storm Design Scenario

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from existing topographic information and construction drawings.
3. N/A indicates that there is not specific HydroCAD node associated with the particular channel.
4. This channel will be constructed as part of Phase IV project.

DLP 01/30/02
20/65
- 4664

000426

2000 YEAR STORM DESIGN SCENARIO - HEAVY VEGETATION
SUMMARY OF CHANNEL INPUT DATA

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node [3]	HydroCAD Q (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth Y (ft)	Estimated Q (cfs)	Channel Freeboard (ft)	Peak Flow Velocity (fps)	Lining Type
subcatchment B	existing	2000 DS	vee	11.90	0.35%	0.100	0	6	4	1									
reach 1	existing	2000 DS	vee	10.90	0.35%	0.100	0	6	4	2									
reach 2	existing	2000 DS	vee	7.73	0.45%	0.100	0	6	5	3									
reach 3	new [4]	2000 DS	vee	6.76	0.45%	0.100	0	6	3	4	Intentionally left blank. Is addressed in the calculation section.								
reach 4	new	2000 DS	vee	7.25	0.50%	0.100	0	6	4	5									
reach 5	new	2000 DS	vee	5.88	0.50%	0.100	0	6	3	6									
reach 6	new	2000 DS	vee	5.76	0.50%	0.100	0	6	3	2R									
reach 7	new	2000 DS	vee	3.60	1.25%	0.100	0	4	3	8									
reach 8	new	2000 DS	vee	3.51	1.00%	0.100	0	58	3	9									
reach 9	new	2000 DS	vee	3.50	1.00%	0.100	0	60	3	1R									

2000 DS = 2000 Year Storm Design Scenario

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from existing topographic information and construction drawings.
3. N/A indicates that there is not specific HydroCAD node associated with the particular channel.
4. This channel will be constructed as part of Phase IV project.

000427

B attach 2000/B3 heavy

4664

21/65

OSDF PHASE V, EAST 2000-YEAR DRAINAGE CHANNEL EVALUATION

CALCULATIONS

INTRODUCTION

As described in the Procedures Section, the purpose of this calculation is to revaluate the adequacy of the 2000-year channel, using the channel geometry that exists along Cells 1 to 3 and is expected to exist (with the completion of Phases IV and V construction) along Cells 4 to 7, to convey runoff from the 2000-year 24-hour storm event with a minimum 0.5 ft freeboard. This section (Calculations) presents calculations based on procedures and data presented in the Procedures and Data Verification Sections of this calculation package.

HYDROLOGIC ANALYSES

Hydrologic analyses are completed for the three 2000-Year Storm Design Scenarios, nodal networks are prepared, and HydroCAD™ runs are performed for the 2000-year, 24-hour storm event. HydroCAD™ output reports for these runs are presented in Attachment C-1A, C-1B, and C-1C for the Light Vegetation, Moderate Vegetation, and Heavy Vegetation 2000-Year Design Scenarios, respectively. The primary calculation parameter obtained from the HydroCAD™ output reports for use in this evaluation is 2000-year, 24-hour peak flow rate.

Weighted runoff curve numbers are calculated using a spreadsheet. Results are presented in Attachment C-2. The calculated weighted runoff curve numbers are directly input into HydroCAD™.

HYDRAULIC ANALYSES

A cross-section was selected for each cell for evaluation of freeboard using the peak flow rate from each of the three design scenarios. These cross-sections are shown in Attachment C-3. Freeboard is measured vertically between the level of the Monitoring Access subgrade and water level calculated using Manning's equation for 2000-year, 24-hour peak flow rates. Calculations for freeboard were performed using a computer spreadsheet. Spreadsheets for each design scenario are presented in Attachment C-3.

For incorporation into Manning's equation, the geometry of the 2000-year channel was modeled to be V-shaped. Since the configurations of the channels are non-uniform, calculation results (for the design scenario with the greatest flow depths, the heavy vegetation scenario for all cells) are presented on cross-sections for each cell in Attachment C-4.

RESULTS AND CONCLUSIONS

In all cases, the V-shaped flow area modeled using Manning's equation exceeds the actual available flow area.

Results of the analyses performed indicate that freeboard for the 2000-year channel will equal or exceed 0.5 ft (measured vertically from the subgrade of the Monitoring Access which is located at the approximate terminal end of the final cover system) for peak 2000-year 24-hour storm event. Based on the above, the 2000-year channel as constructed for Cells 1 to 3 and to be constructed for Cells 4 to 7 is expected to convey the 2000-year 24-hour event without adversely impacting the On-Site Disposal Facility (OSDF) final cover system.

4664

ATTACHMENT C-1

HydroCAD™ OUTPUT REPORTS

- 4664

ATTACHMENT C-1A

2000-YEAR STORM DESIGN SCENARIO – LIGHT VEGETATION
2000-YEAR, 24-HOUR STORM EVENT

Rec'd 01/30/02 26/60

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=13.00" (AMC=3)
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover
Tc=17.6 min CN=99 Area=2.601 ac Runoff= 33.78 cfs 2.784 af

Subcatchment B: vegetated final cover
Tc=7.4 min CN=99 Area=1.637 ac Runoff= 28.68 cfs 1.755 af

Subcatchment C: vegetated final cover
Tc=19.5 min CN=99 Area=4.960 ac Runoff= 61.28 cfs 5.307 af

Subcatchment D: vegetated final cover
Tc=18.8 min CN=99 Area=4.746 ac Runoff= 59.75 cfs 5.079 af

Subcatchment E: vegetated final cover
Tc=18.5 min CN=99 Area=4.946 ac Runoff= 62.74 cfs 5.293 af

Subcatchment F: vegetated final cover
Tc=18.7 min CN=99 Area=4.814 ac Runoff= 60.76 cfs 5.152 af

Subcatchment G: vegetated final cover
Tc=18.7 min CN=99 Area=4.946 ac Runoff= 62.42 cfs 5.293 af

Subcatchment H: vegetated final cover
Tc=18.9 min CN=99 Area=3.921 ac Runoff= 49.23 cfs 4.196 af

Subcatchment I: runon east of OSDF
Tc=13.8 min CN=91 Area=0.530 ac Runoff= 7.53 cfs 0.524 af

Subcatchment J: runon east of OSDF
Tc=30.4 min CN=91 Area=1.242 ac Runoff= 11.67 cfs 1.223 af

Subcatchment K: runon east of OSDF
Tc=42.9 min CN=87 Area=2.623 ac Runoff= 19.22 cfs 2.464 af

Subcatchment L: runon east of OSDF
Tc=25.9 min CN=86 Area=1.779 ac Runoff= 17.88 cfs 1.657 af

Subcatchment M: runon east of OSDF
Tc=41.0 min CN=87 Area=7.234 ac Runoff= 54.76 cfs 6.798 af

Subcatchment N: runon east of OSDF
Tc=33.9 min CN=86 Area=11.664 ac Runoff= 99.51 cfs 10.848 af

Subcatchment O: runon east of OSDF
Tc=30.5 min CN=87 Area=10.935 ac Runoff= 100.32 cfs 10.297 af

Reach 1: runoff channel — Inflow= 63.06 cfs 5.063 af
Length= 405.0' Max Vel= 2.9 fps Capacity= 2,565.53 cfs Outflow= 60.44 cfs 5.054 af

Reach 1R: (new node) — Inflow= 232.74 cfs 27.897 af
Outflow= 232.74 cfs 27.897 af

Reach 2: runoff channel — Inflow= 130.82 cfs 11.584 af
Length= 385.0' Max Vel= 4.3 fps Capacity= 2,054.66 cfs Outflow= 127.94 cfs 11.571 af

Reach 2R: (new node) — Inflow= 387.27 cfs 40.587 af
Outflow= 387.27 cfs 40.587 af

Reach 3: runoff channel — Inflow= 197.81 cfs 19.114 af
Length= 405.0' Max Vel= 5.4 fps Capacity= 1,590.57 cfs Outflow= 194.33 cfs 19.096 af

Reach 4: runoff channel — Inflow= 268.74 cfs 26.046 af
Length= 395.0' Max Vel= 4.8 fps Capacity= 1,377.52 cfs Outflow= 264.25 cfs 26.019 af

Reach 5: runoff channel — Inflow= 314.75 cfs 31.170 af
Length= 405.0' Max Vel= 5.2 fps Capacity= 840.15 cfs Outflow= 310.52 cfs 31.140 af

Reach 6: runoff channel — Inflow= 358.63 cfs 36.432 af
Length= 475.0' Max Vel= 5.3 fps Capacity= 800.53 cfs Outflow= 353.44 cfs 36.392 af

Reach 7: east runon ditch
Length= 395.0' Max Vel= 0.0 fps Capacity= 242.98 cfs Outflow= 0.00 cfs 0.000 af

Reach 8: east runon ditch — Inflow= 54.76 cfs 6.798 af
Length= 405.0' Max Vel= 2.7 fps Capacity= 1,794.23 cfs Outflow= 54.22 cfs 6.785 af

Reach 9: east runon ditch — Inflow= 146.94 cfs 17.632 af
Length= 475.0' Max Vel= 3.4 fps Capacity= 1,836.80 cfs Outflow= 145.53 cfs 17.600 af

Runoff Area = 68.578 ac Volume = 68.670 af Average Depth = 12.02"

- 4664

Subcatchment A: vegetated final cover

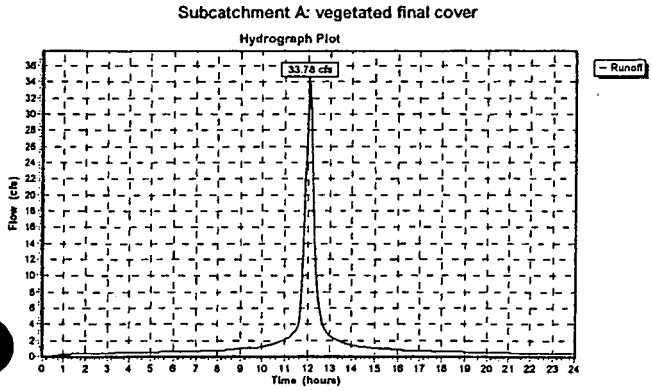
Runoff = 33.78 cfs @ 12.09 hrs, Volume= 2.784 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
2.601	98	
2.601	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
17.6	490	Total			

Subcatchment A: vegetated final cover



Subcatchment B: vegetated final cover

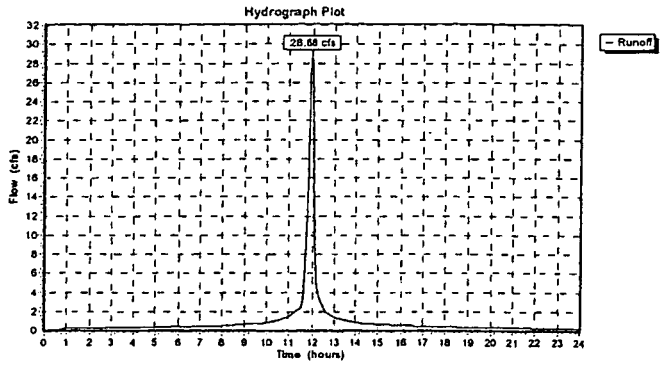
Runoff = 28.68 cfs @ 11.98 hrs, Volume= 1.755 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.637	98	
1.637	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.9	90	0.0750	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.3	130	0.0250	7.8	193.80	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.03' Z= 6.0 '/' n= 0.030
1.2	320	0.0075	4.3	88.06	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.03' Z= 4.0 & 6.0 '/' n= 0.030
7.4	540	Total			

Subcatchment B: vegetated final cover



000432

DEP 01/30/02 27/65

Subcatchment C: vegetated final cover

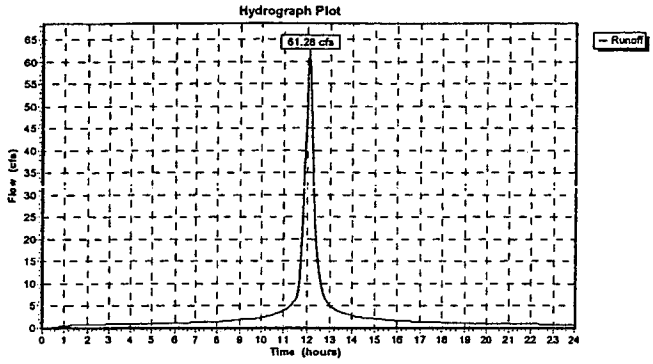
Runoff = 61.28 cfs @ 12.11 hrs, Volume= 5.307 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
pe II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.960	98	
4.960	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.9	370	0.0035	3.2	86.88	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.33' Z= 6.0 & 4.0 '/' n= 0.030
19.5	860	Total			

Subcatchment C: vegetated final cover



Subcatchment D: vegetated final cover

Runoff = 59.75 cfs @ 12.10 hrs, Volume= 5.079 af

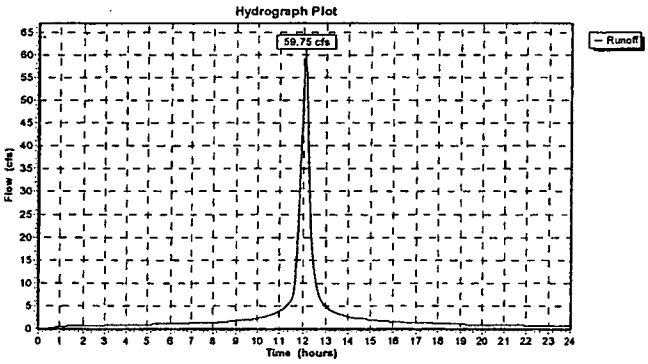
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

4664

Area (ac)	CN	Description
4.746	98	
4.746	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.5	180	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.6	200	0.0083	5.7	254.88	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.86' Z= 6.0 & 5.0 '/' n= 0.030
0.6	150	0.0045	4.2	170.16	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.86' Z= 6.0 & 4.0 '/' n= 0.030
18.8	830	Total			

Subcatchment D: vegetated final cover



Subcatchment E: vegetated final cover

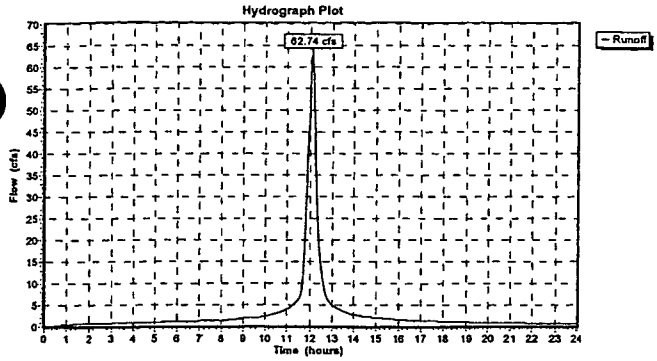
Runoff = 62.74 cfs @ 12.10 hrs, Volume= 5.293 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.946	98	
4.946	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.2	50	0.0045	4.6	253.27	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.32' Z= 6.0 & 4.0 '/' n= 0.030
0.8	320	0.0105	7.0	346.69	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.32' Z= 6.0 & 3.0 '/' n= 0.030
18.5	840	Total			

Subcatchment E: vegetated final cover



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Subcatchment F: vegetated final cover

Runoff = 60.75 cfs @ 12.10 hrs, Volume= 5.152 af

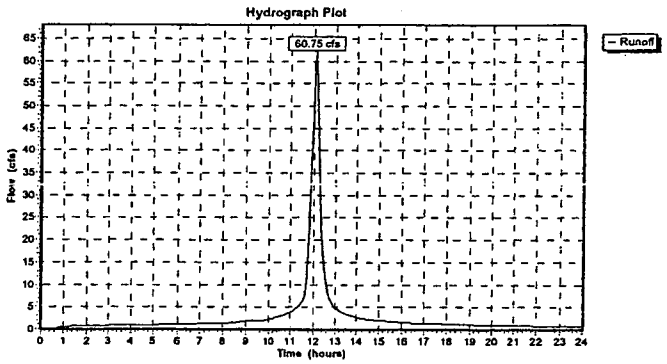
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.814	98	
4.814	98	Weighted Average, Adjusted for AMC = 99

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	360	0.0050	5.2	351.31	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.68' Z= 4.0 & 6.0 '/' n= 0.030
18.7	835	Total			

Subcatchment F: vegetated final cover



Subcatchment G: vegetated final cover

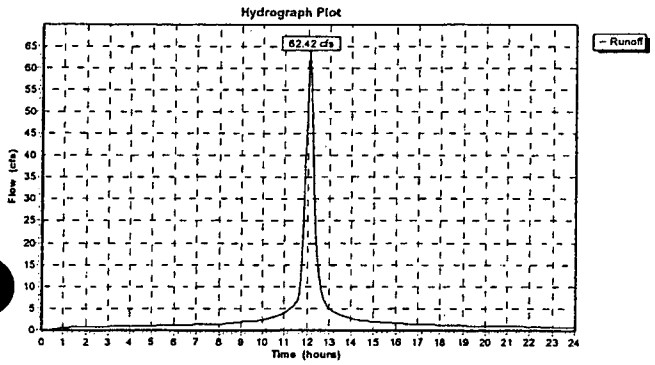
Runoff = 62.42 cfs @ 12.10 hrs, Volume= 5.293 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.946	98	
4.946	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	370	0.0050	5.3	357.57	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.86' Z= 3.0 & 6.0 '/' n= 0.030
18.7	845	Total			

Subcatchment G: vegetated final cover



Subcatchment H: vegetated final cover

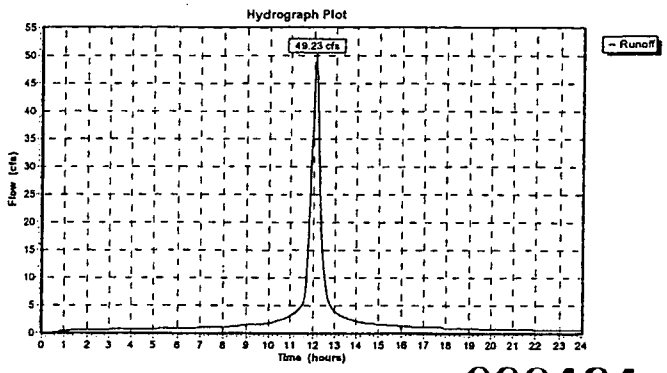
Runoff = 49.23 cfs @ 12.10 hrs, Volume= 4.196 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
3.921	98	
3.921	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	90	0.0500	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.8	60	0.1000	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
6.4	150	0.1700	0.4		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.4	440	0.0050	5.3	357.57	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.86' Z= 3.0 & 6.0 '/' n= 0.030
18.9	915	Total			

Subcatchment H: vegetated final cover



Subcatchment I: runon east of OSDF

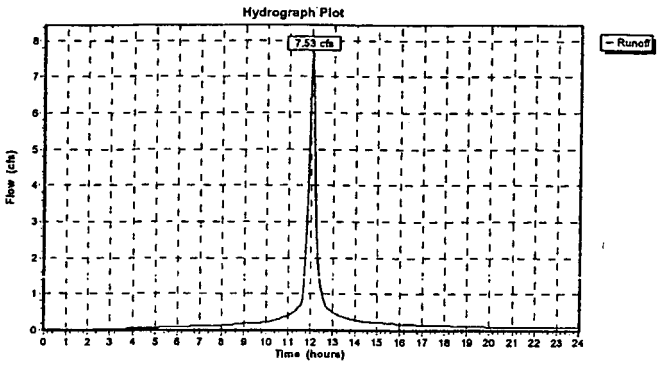
Runoff = 7.53 cfs @ 12.05 hrs, Volume= 0.524 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
0.530	79	
0.530	79	Weighted Average, Adjusted for AMC = 91

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.6	210	0.0500	0.3		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.2	55	0.0075	4.3	88.06	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.03' Z= 4.0 & 6.0 '/' n= 0.030
13.8	265	Total			

Subcatchment I: runon east of OSDF



Dec 01/30/02 29/65

Subcatchment J: runon east of OSDF

Runoff = 11.67 cfs @ 12.23 hrs, Volume= 1.223 af

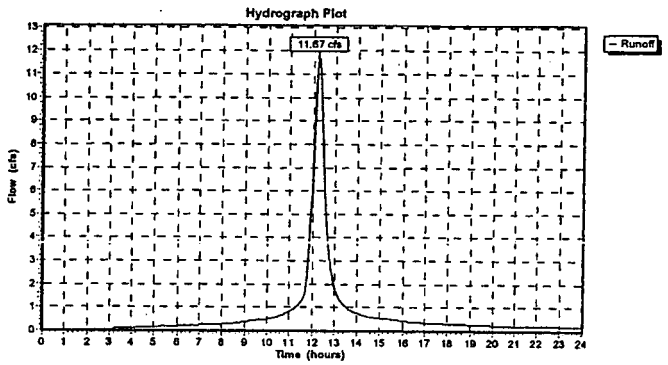
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.242	79	
1.242	79	Weighted Average, Adjusted for AMC = 91

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
28.8	300	0.0158	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.8	100	0.0158	2.0		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	150	0.0035	3.2	86.88	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.33' Z= 6.0 & 4.0 '/' n= 0.030
30.4	550	Total			

Subcatchment J: runon east of OSDF



Subcatchment K: runon east of OSDF

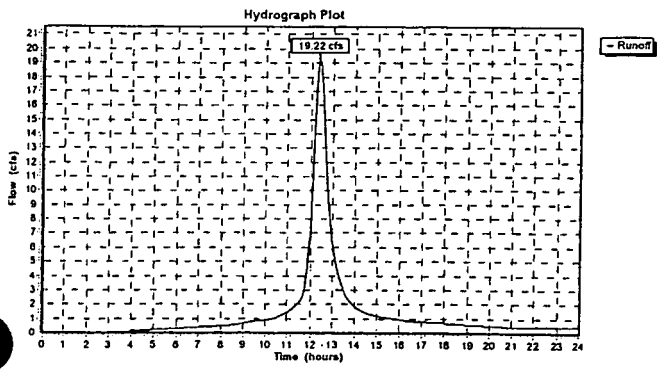
Runoff = 19.22 cfs @ 12.38 hrs, Volume= 2.464 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
2.623	73	
2.623	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
39.8	300	0.0070	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
2.1	290	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.0	250	0.0045	4.2	170.16	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.86' Z= 6.0 & 4.0 '/' n= 0.030
42.9	840	Total			

Subcatchment K: runon east of OSDF



Subcatchment L: runon east of OSDF

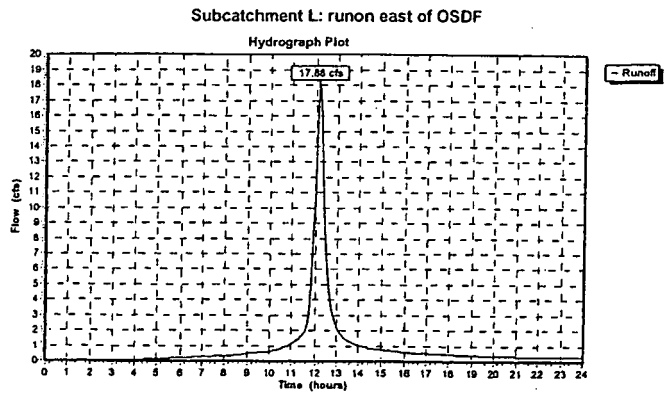
Runoff = 17.88 cfs @ 12.18 hrs, Volume= 1.657 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.779	72	
1.779	72	Weighted Average, Adjusted for AMC = 86

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
23.9	300	0.0250	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
0.9	140	0.0250	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.9	170	0.0375	3.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.2	90	0.0105	7.0	346.69	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.32' Z= 6.0 & 3.0 '/' n= 0.030
25.9	700	Total			

Subcatchment L: runon east of OSDF



Subcatchment M: runon east of OSDF

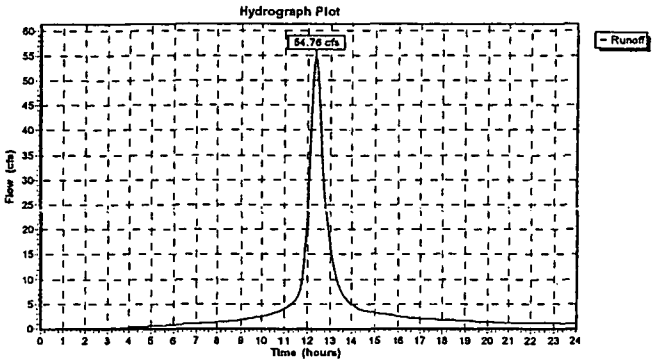
Runoff = 54.76 cfs @ 12.36 hrs, Volume= 6.798 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
7.234	73	
7.234	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
34.5	300	0.0100	0.1		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.1	350	0.0139	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.4	180	0.0167	2.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.0	360	0.0125	3.0	7.00	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=0.82' Z= 4.0 & 3.0 '/' n= 0.030
41.0	1,190	Total			

Subcatchment M: runon east of OSDF



Subcatchment N: runon east of OSDF

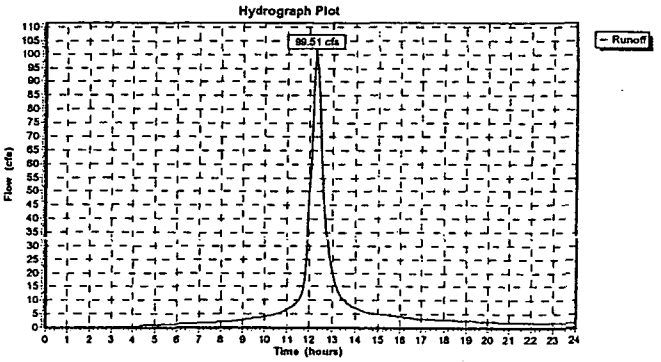
Runoff = 99.51 cfs @ 12.27 hrs, Volume= 10.848 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
11.664	72	
11.664	72	Weighted Average, Adjusted for AMC = 86

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.3	300	0.0198	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
5.7	770	0.0198	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.9	395	0.0100	3.5	144.39	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.17' Z= 58.0 & 3.0 '/' n= 0.030
33.9	1,465	Total			

Subcatchment N: runon east of OSDF



Subcatchment O: runon east of OSDF

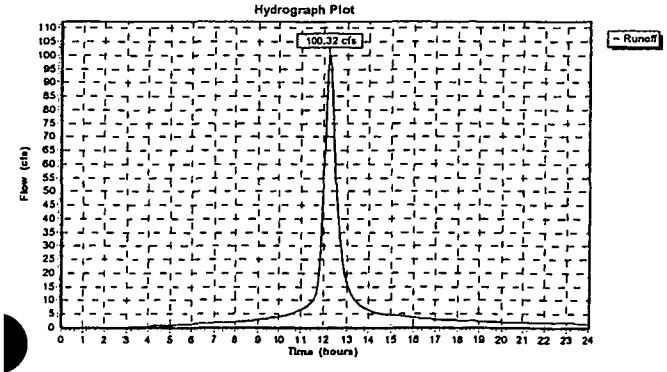
Runoff = 100.32 cfs @ 12.24 hrs, Volume= 10.297 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
10.935	73	
10.935	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
26.2	300	0.0200	0.2		Sheet Flow, Grass: Short n= 0.150 P2= 2.60"
3.1	420	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	250	0.0100	3.5	149.13	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.17' Z= 60.0 & 3.0 '/' n= 0.030
30.5	970	Total			

Subcatchment O: runon east of OSDF



Reach 1: runoff channel

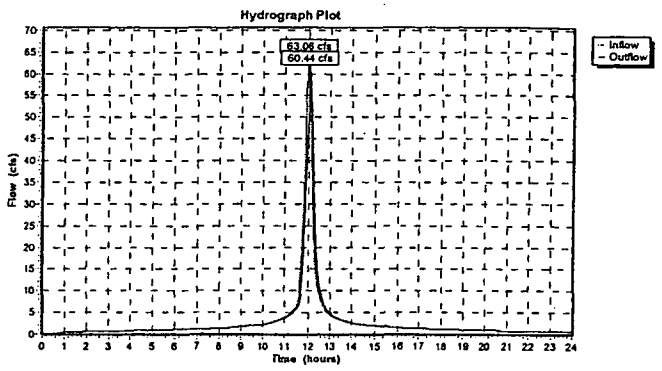
[65] Warning: Inlet elevation not specified

Inflow = 63.06 cfs @ 12.02 hrs, Volume= 5.063 af
Outflow = 60.44 cfs @ 12.09 hrs, Volume= 5.054 af, Atten= 4%, Lag= 4.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.9 fps, Min. Travel Time= 2.3 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 5.9 min

Peak Depth= 2.04'
Capacity at bank full= 2,565.53 cfs
0.00' x 8.29' deep channel, n= 0.030 Length= 405.0' Slope= 0.0035 '/'
Side Slope Z-value= 6.0 4.0 '/'

Reach 1: runoff channel



DCP 01/30/02 31/65

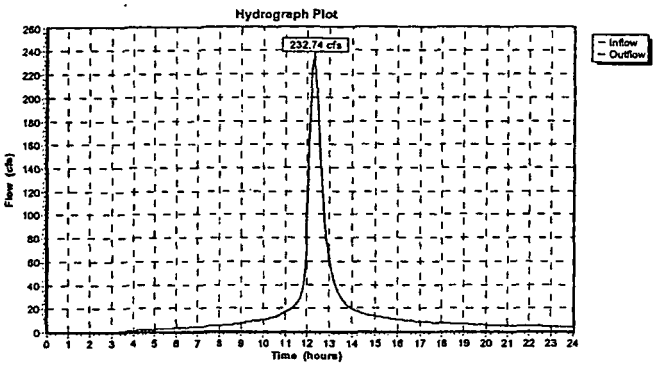
Reach 1R: (new node)

[40] Hint: Not Described (Outflow=Inflow)

Inflow = 232.74 cfs @ 12.32 hrs, Volume= 27.897 af
Outflow = 232.74 cfs @ 12.32 hrs, Volume= 27.897 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Reach 1R: (new node)



Reach 2: runoff channel

[65] Warning: Inlet elevation not specified

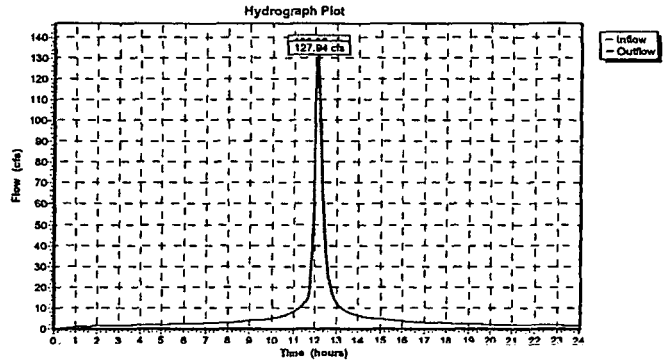
Inflow = 130.82 cfs @ 12.10 hrs, Volume= 11.584 af
Outflow = 127.94 cfs @ 12.15 hrs, Volume= 11.571 af, Atten= 2%, Lag= 2.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.3 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 3.7 min

4664

Peak Depth= 2.33'
Capacity at bank full= 2,054.66 cfs
0.00' x 6.57' deep channel, n= 0.030 Length= 385.0' Slope= 0.0064 '/'
Side Slope Z-value= 6.0 5.0 '/'

Reach 2: runoff channel



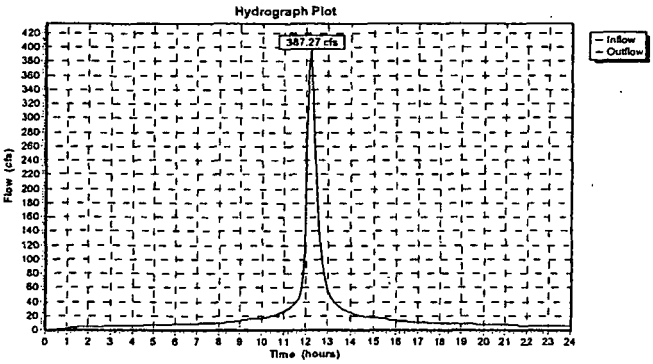
Reach 2R: (new node)

[40] Hint: Not Described (Outflow=Inflow)

Inflow = 387.27 cfs @ 12.23 hrs, Volume= 40.587 af
Outflow = 387.27 cfs @ 12.23 hrs, Volume= 40.587 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Reach 2R: (new node)



Reach 3: runoff channel

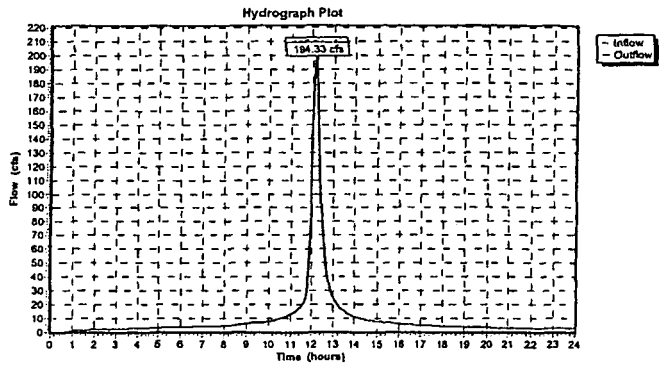
[65] Warning: Inlet elevation not specified

Inflow = 197.81 cfs @ 12.14 hrs, Volume= 19.114 af
Outflow = 194.33 cfs @ 12.18 hrs, Volume= 19.096 af, Atten= 2%, Lag= 2.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.4 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 2.2 fps, Avg. Travel Time= 3.1 min

Peak Depth= 2.86'
Capacity at bank full= 1,590.57 cfs
0.00' x 6.26' deep channel, n= 0.030 Length= 405.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 3: runoff channel



DCP 01/30/02 32/165

Reach 4: runoff channel

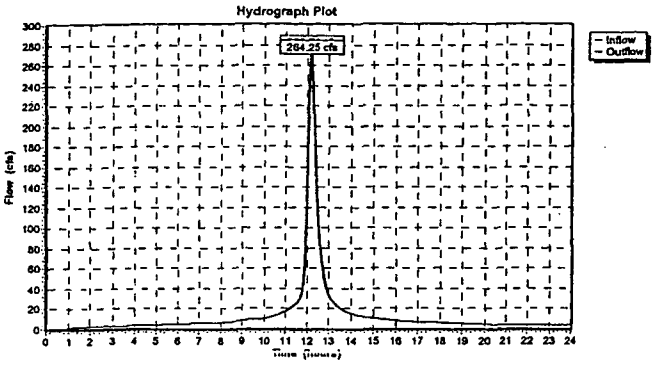
[65] Warning: Inlet elevation not specified

Inflow = 268.74 cfs @ 12.16 hrs, Volume= 26.046 af
Outflow = 264.25 cfs @ 12.20 hrs, Volume= 26.019 af, Atten= 2%, Lag= 2.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.8 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 2.0 fps, Avg. Travel Time= 3.3 min

Peak Depth= 3.32'
Capacity at bank full= 1,377.52 cfs
0.00' x 6.14' deep channel, n= 0.030 Length= 395.0' Slope= 0.0050 '/'
Side Slope Z-value= 4.0 6.0 '/'

Reach 4: runoff channel



Reach 5: runoff channel

[65] Warning: Inlet elevation not specified

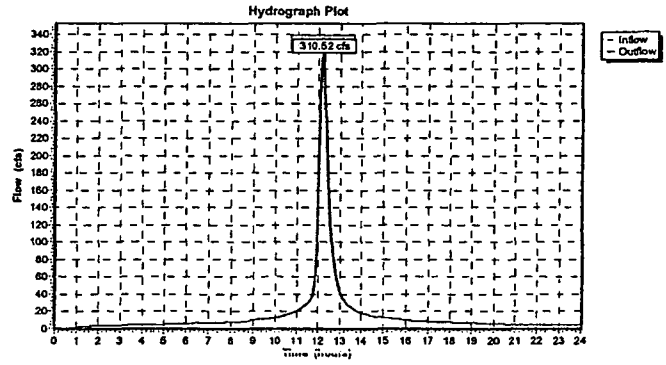
Inflow = 314.75 cfs @ 12.18 hrs, Volume= 31.170 af
Outflow = 310.52 cfs @ 12.22 hrs, Volume= 31.140 af, Atten= 1%, Lag= 2.4 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.2 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 2.1 fps, Avg. Travel Time= 3.2 min

4664

Peak Depth= 3.68'
Capacity at bank full= 840.15 cfs
0.00' x 5.32' deep channel, n= 0.030 Length= 405.0' Slope= 0.0050 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 5: runoff channel



Reach 6: runoff channel

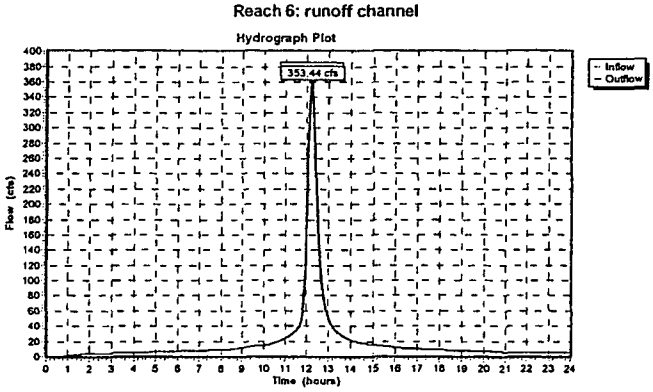
[65] Warning: Inlet elevation not specified

Inflow = 358.63 cfs @ 12.20 hrs, Volume= 36.432 af
Outflow = 353.44 cfs @ 12.25 hrs, Volume= 36.392 af, Atten= 1%, Lag= 2.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.3 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 2.2 fps, Avg. Travel Time= 3.6 min

Peak Depth= 3.86'
Capacity at bank full= 800.53 cfs
0.00' x 5.22' deep channel, n= 0.030 Length= 475.0' Slope= 0.0050 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 6: runoff channel



Reach 7: east runon ditch

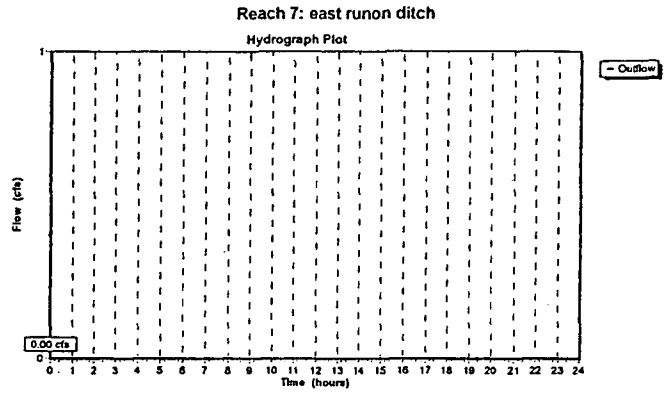
[43] Hint: Has no inflow (Outflow=Zero)

Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.0 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.0 fps, Avg. Travel Time= 0.0 min

Peak Depth= 0.00'
Capacity at bank full= 242.98 cfs
0.00' x 3.10' deep channel, n= 0.030 Length= 395.0' Slope= 0.0125 '/'
Side Slope Z-value= 4.0 3.0 '/'

Reach 7: east runon ditch



Reach 8: east runon ditch

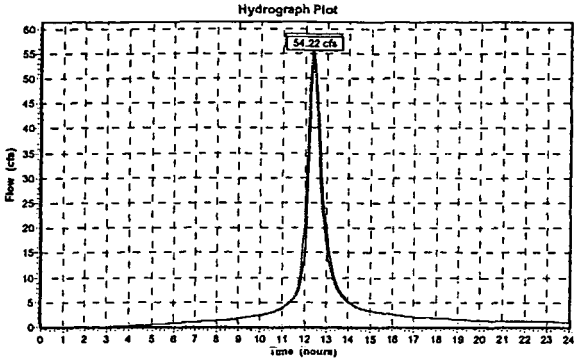
[65] Warning: Inlet elevation not specified

Inflow = 54.76 cfs @ 12.36 hrs, Volume= 6.798 af
Outflow = 54.22 cfs @ 12.43 hrs, Volume= 6.785 af, Atten= 1%, Lag= 4.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.7 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 5.8 min

Peak Depth= 0.81'
Capacity at bank full= 1,794.23 cfs
0.00' x 3.01' deep channel, n= 0.030 Length= 405.0' Slope= 0.0100 '/'
Side Slope Z-value= 58.0 3.0 '/'

Reach 8: east runon ditch



[redacted]

Reach 9: east runon ditch

[65] Warning: Inlet elevation not specified

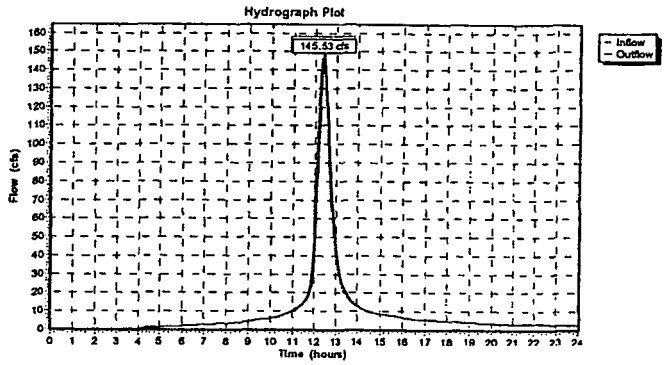
Inflow = 146.94 cfs @ 12.32 hrs, Volume= 17.632 af
Outflow = 145.53 cfs @ 12.40 hrs, Volume= 17.600 af, Atten= 1%, Lag= 4.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.4 fps, Min. Travel Time= 2.3 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 5.4 min

4664

Peak Depth= 1.16'
Capacity at bank full= 1,836.80 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 475.0' Slope= 0.0100 '/'
Side Slope Z-value= 60.0 3.0 '/'

Reach 9: east runon ditch



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ATTACHMENT C-1B

2000-YEAR STORM DESIGN SCENARIO – MODERATE VEGETATION
2000-YEAR, 24-HOUR STORM EVENT

Pl 01/30/02 35/65

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=13.00" (AMC=3)
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover
Tc=25.4 min CN=99 Area=2.601 ac Runoff= 27.84 cfs 2.780 af

Subcatchment B: vegetated final cover
Tc=10.2 min CN=99 Area=1.637 ac Runoff= 26.31 cfs 1.754 af

Subcatchment C: vegetated final cover
Tc=27.4 min CN=99 Area=4.960 ac Runoff= 50.80 cfs 5.300 af

Subcatchment D: vegetated final cover
Tc=26.6 min CN=99 Area=4.746 ac Runoff= 49.42 cfs 5.072 af

Subcatchment E: vegetated final cover
Tc=26.3 min CN=99 Area=4.946 ac Runoff= 51.86 cfs 5.286 af

Subcatchment F: vegetated final cover
Tc=26.5 min CN=99 Area=4.814 ac Runoff= 50.19 cfs 5.145 af

Subcatchment G: vegetated final cover
Tc=26.5 min CN=99 Area=4.946 ac Runoff= 51.56 cfs 5.286 af

Subcatchment H: vegetated final cover
Tc=26.7 min CN=99 Area=3.921 ac Runoff= 40.76 cfs 4.190 af

Subcatchment I: runon east of OSDF
Tc=20.1 min CN=91 Area=0.530 ac Runoff= 6.32 cfs 0.523 af

Subcatchment J: runon east of OSDF
Tc=43.5 min CN=91 Area=1.242 ac Runoff= 9.25 cfs 1.220 af

Subcatchment K: runon east of OSDF
Tc=61.2 min CN=87 Area=2.623 ac Runoff= 15.02 cfs 2.455 af

Subcatchment L: runon east of OSDF
Tc=36.9 min CN=86 Area=1.779 ac Runoff= 14.33 cfs 1.654 af

Subcatchment M: runon east of OSDF
Tc=56.9 min CN=87 Area=7.234 ac Runoff= 43.54 cfs 6.776 af

Subcatchment N: runon east of OSDF
Tc=46.0 min CN=86 Area=11.664 ac Runoff= 81.08 cfs 10.821 af

Subcatchment O: runon east of OSDF
Tc=42.5 min CN=87 Area=10.935 ac Runoff= 80.77 cfs 10.273 af

Reach 1: runoff channel — Inflow= 51.86 cfs 5.058 af
Length= 405.0' Max Vel= 2.8 fps Capacity= 2,565.53 cfs Outflow= 50.22 cfs 5.049 af

Reach 1R: (new node) — Inflow= 191.30 cfs 27.823 af
Outflow= 191.30 cfs 27.823 af

Reach 2: runoff channel — Inflow= 105.97 cfs 11.569 af
Length= 385.0' Max Vel= 4.1 fps Capacity= 2,054.66 cfs Outflow= 104.75 cfs 11.555 af

Reach 2R: (new node) — Inflow= 336.36 cfs 40.522 af
Outflow= 336.36 cfs 40.522 af

Reach 3: runoff channel — Inflow= 161.89 cfs 19.082 af
Length= 405.0' Max Vel= 5.1 fps Capacity= 1,590.57 cfs Outflow= 160.23 cfs 19.063 af

Reach 4: runoff channel — Inflow= 223.04 cfs 26.003 af
Length= 395.0' Max Vel= 4.6 fps Capacity= 1,377.52 cfs Outflow= 220.62 cfs 25.975 af

Reach 5: runoff channel — Inflow= 266.17 cfs 31.120 af
Length= 405.0' Max Vel= 4.9 fps Capacity= 840.15 cfs Outflow= 263.47 cfs 31.088 af

Reach 6: runoff channel — Inflow= 307.30 cfs 36.374 af
Length= 475.0' Max Vel= 5.1 fps Capacity= 800.53 cfs Outflow= 304.05 cfs 36.332 af

Reach 7: east runon ditch
Length= 395.0' Max Vel= 0.0 fps Capacity= 242.98 cfs Outflow= 0.00 cfs 0.000 af

Reach 8: east runon ditch — Inflow= 43.54 cfs 6.776 af
Length= 405.0' Max Vel= 2.6 fps Capacity= 1,794.23 cfs Outflow= 43.33 cfs 6.762 af

Reach 9: east runon ditch — Inflow= 118.98 cfs 17.584 af
Length= 475.0' Max Vel= 3.3 fps Capacity= 1,836.80 cfs Outflow= 118.35 cfs 17.551 af

Runoff Area = 68.578 ac Volume = 68.534 af Average Depth = 11.99"

4664

Subcatchment A: vegetated final cover

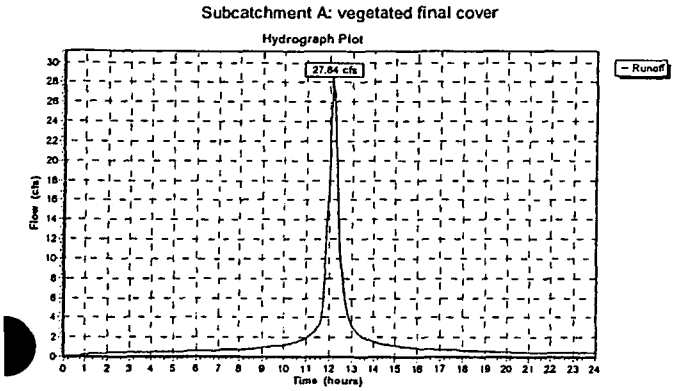
Runoff = 27.84 cfs @ 12.17 hrs, Volume= 2.780 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
2.601	98	
2.601	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
25.4	490	Total			

Subcatchment A: vegetated final cover



Subcatchment B: vegetated final cover

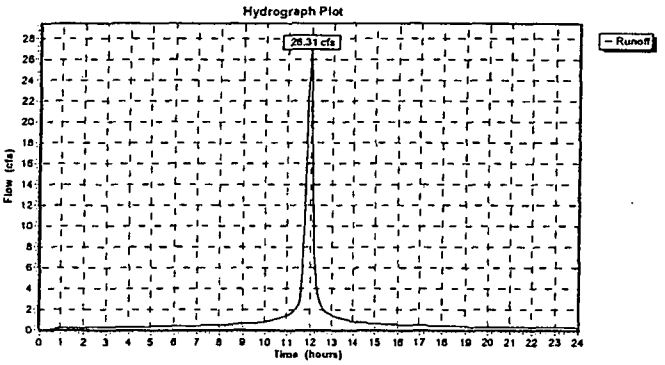
Runoff = 26.31 cfs @ 12.01 hrs, Volume= 1.754 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.637	98	
1.637	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	90	0.0750	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.3	130	0.0250	7.5	162.45	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.90' Z= 6.0 '/' n= 0.030
1.3	320	0.0075	4.1	73.82	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.90' Z= 4.0 & 6.0 '/' n= 0.030
10.2	540	Total			

Subcatchment B: vegetated final cover



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DCP 01/30/02 36/65

Subcatchment C: vegetated final cover

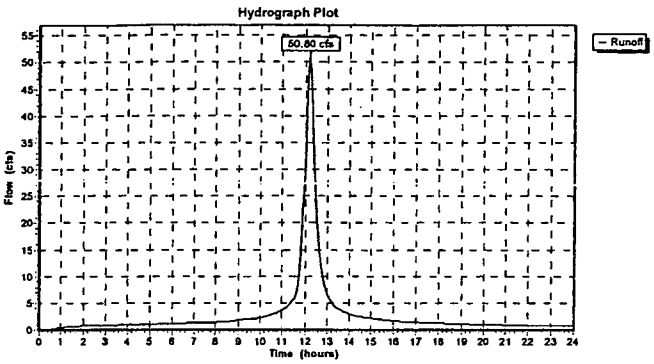
Runoff = 50.80 cfs @ 12.20 hrs, Volume= 5.300 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.960	98	
4.960	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.0	370	0.0035	3.0	70.12	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.15' Z= 6.0 & 4.0 '/' n= 0.030
27.4	860	Total			

Subcatchment C: vegetated final cover



Subcatchment D: vegetated final cover

Runoff = 49.42 cfs @ 12.19 hrs, Volume= 5.072 af

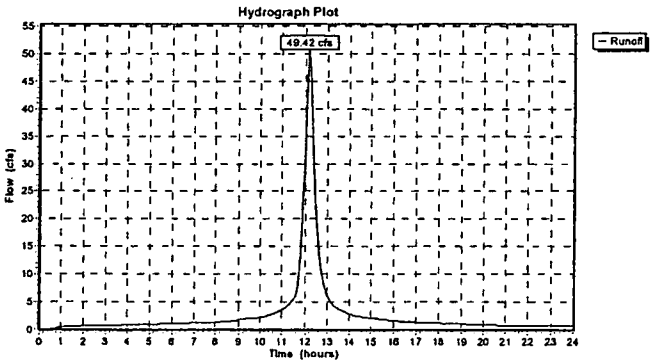
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.746	98	
4.746	98	Weighted Average, Adjusted for AMC = 99

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.5	180	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.6	200	0.0083	5.4	207.98	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.65' Z= 6.0 & 5.0 '/' n= 0.030
0.6	150	0.0045	4.0	138.85	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.65' Z= 6.0 & 4.0 '/' n= 0.030
26.6	830	Total			

Subcatchment D: vegetated final cover



Subcatchment E: vegetated final cover

Runoff = 51.86 cfs @ 12.18 hrs, Volume= 5.286 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.946	98	
4.946	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.2	50	0.0045	4.4	210.95	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.10' Z= 6.0 & 4.0 '/' n= 0.030
0.8	320	0.0105	6.7	288.76	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.10' Z= 6.0 & 3.0 '/' n= 0.030
26.3	840	Total			

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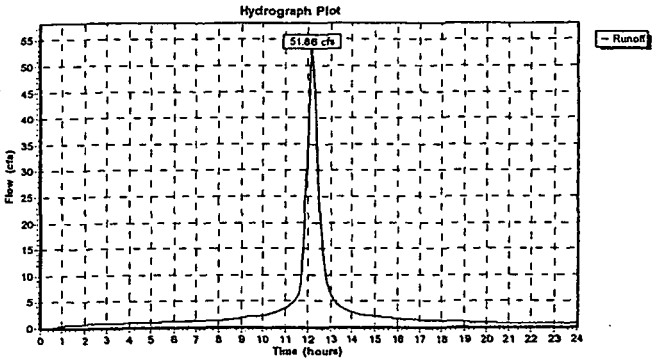
Subcatchment E: vegetated final cover



Subcatchment F: vegetated final cover

Runoff = 50.19 cfs @ 12.19 hrs, Volume= 5.145 af

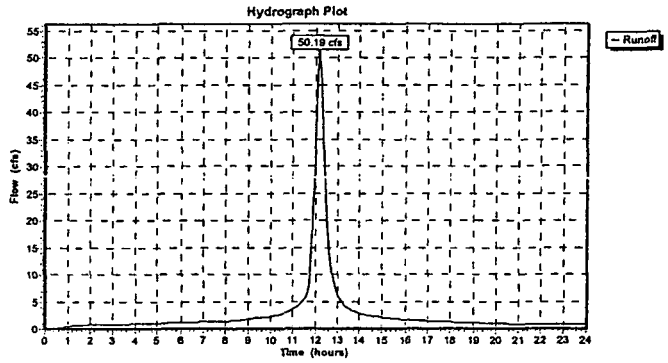
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.814	98	
4.814	98	Weighted Average, Adjusted for AMC = 99

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	360	0.0050	5.0	295.77	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.45' Z= 4.0 & 6.0 '/' n= 0.030
26.5	835	Total			

Subcatchment F: vegetated final cover



Subcatchment G: vegetated final cover

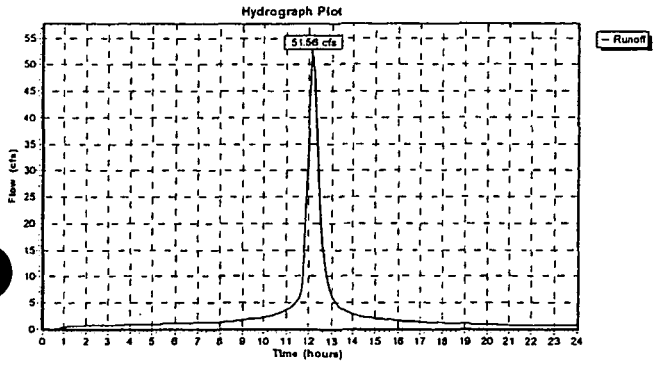
Runoff = 51.56 cfs @ 12.19 hrs, Volume= 5.286 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.946	98	
4.946	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.2	370	0.0050	5.1	305.77	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.64' Z= 3.0 & 6.0 '/' n= 0.030
26.5	845	Total			

Subcatchment G: vegetated final cover



Subcatchment H: vegetated final cover

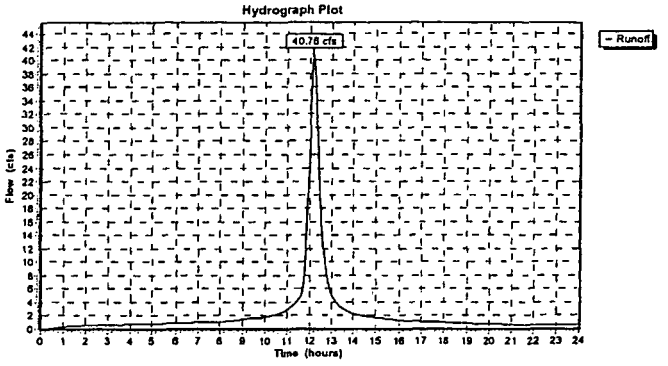
Runoff = 40.76 cfs @ 12.19 hrs, Volume= 4.190 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
3.921	98	
3.921	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.4	440	0.0050	5.1	305.77	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.64' Z= 3.0 & 6.0 '/' n= 0.030
26.7	915	Total			

Subcatchment H: vegetated final cover



Subcatchment I: runon east of OSDF

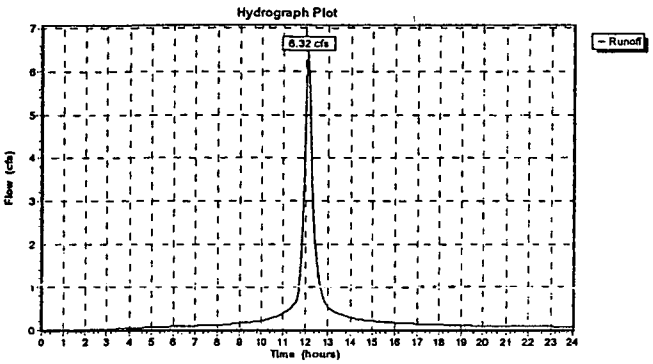
Runoff = 6.32 cfs @ 12.12 hrs, Volume= 0.523 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
0.530	79	
0.530	79	Weighted Average, Adjusted for AMC = 91

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
19.9	210	0.0500	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.2	55	0.0075	4.1	73.82	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.90' Z= 4.0 & 6.0 '/' n= 0.030
20.1	265	Total			

Subcatchment I: runon east of OSDF



DCP 01/30/02 38/165

Subcatchment J: runon east of OSDF

Runoff = 9.25 cfs @ 12.39 hrs, Volume= 1.220 af

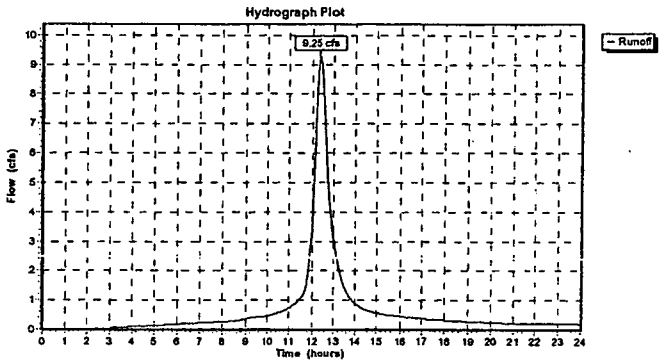
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.242	79	
1.242	79	Weighted Average, Adjusted for AMC = 91

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
41.9	300	0.0158	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.8	100	0.0158	2.0		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.8	150	0.0035	3.0	70.12	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.15' Z= 6.0 & 4.0 '/' n= 0.030
43.5	550	Total			

Subcatchment J: runon east of OSDF



Subcatchment K: runon east of OSDF

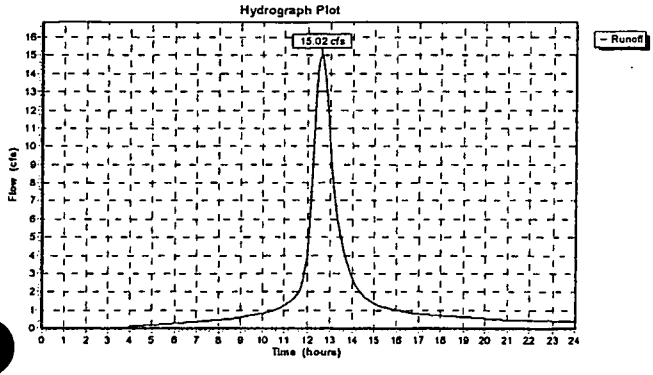
Runoff = 15.02 cfs @ 12.60 hrs, Volume= 2.455 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
2.623	73	
2.623	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
58.0	300	0.0070	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
2.1	290	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.1	250	0.0045	4.0	138.85	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.65' Z= 6.0 & 4.0 '/' n= 0.030
61.2	840	Total			

Subcatchment K: runon east of OSDF



Subcatchment L: runon east of OSDF

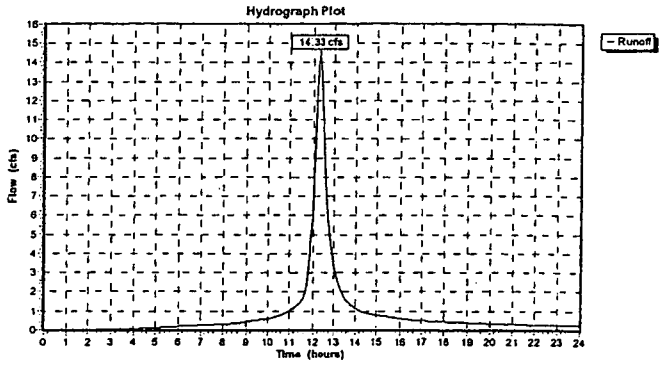
Runoff = 14.33 cfs @ 12.31 hrs, Volume= 1.654 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.779	72	
1.779	72	Weighted Average, Adjusted for AMC = 86

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
34.9	300	0.0250	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.9	140	0.0250	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.9	170	0.0375	3.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.2	90	0.0105	6.7	288.76	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.10' Z= 6.0 & 3.0 '/' n= 0.030
36.9	700	Total			

Subcatchment L: runon east of OSDF



Subcatchment M: runon east of OSDF

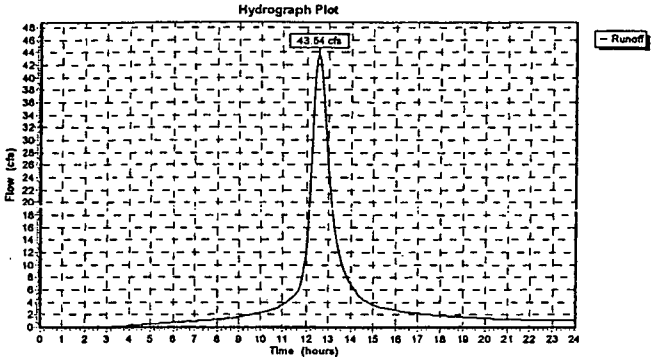
Runoff = 43.54 cfs @ 12.56 hrs, Volume= 6.776 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
7.234	73	
7.234	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
50.3	300	0.0100	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
3.1	350	0.0139	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.4	180	0.0167	2.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.1	360	0.0125	2.8	5.52	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=0.75' Z= 4.0 & 3.0 '/' n= 0.030
56.9	1,190	Total			

Subcatchment M: runon east of OSDF



DLI DEP 01/30/02 39/65

Subcatchment N: runon east of OSDF

Runoff = 81.08 cfs @ 12.42 hrs, Volume= 10.821 af

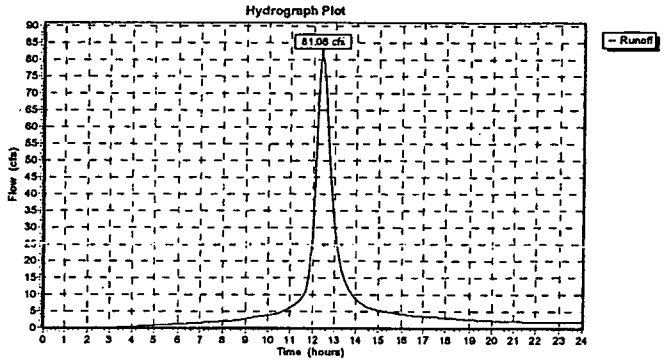
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
11.664	72	
11.664	72	Weighted Average, Adjusted for AMC = 86

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.3	300	0.0198	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.7	770	0.0198	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.0	395	0.0100	3.3	116.64	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.08' Z= 58.0 & 3.0 '/' n= 0.030
46.0	1,465	Total			

Subcatchment N: runon east of OSDF



Subcatchment O: runon east of OSDF

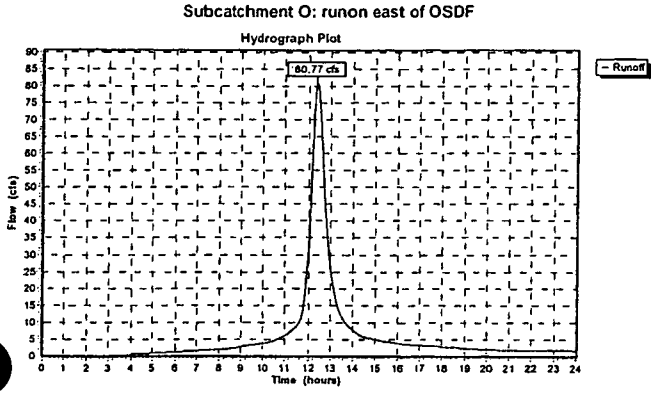
Runoff = 80.77 cfs @ 12.38 hrs, Volume= 10.273 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
10.935	73	
10.935	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.1	300	0.0200	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
3.1	420	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.3	250	0.0100	3.3	120.47	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.08' Z= 60.0 & 3.0 '/' n= 0.030
42.5	970	Total			

Subcatchment O: runon east of OSDF



Reach 1: runoff channel

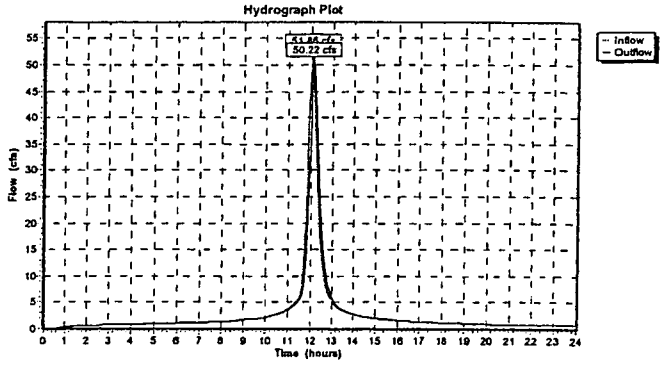
[65] Warning: Inlet elevation not specified

Inflow = 51.86 cfs @ 12.05 hrs, Volume= 5.058 af
Outflow = 50.22 cfs @ 12.13 hrs, Volume= 5.049 af, Atten= 3%, Lag= 4.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.8 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 5.8 min

Peak Depth= 1.90'
Capacity at bank full= 2,565.53 cfs
0.00' x 8.29' deep channel, n= 0.030 Length= 405.0' Slope= 0.0035 '/'
Side Slope Z-value= 6.0 4.0 '/'

Reach 1: runoff channel



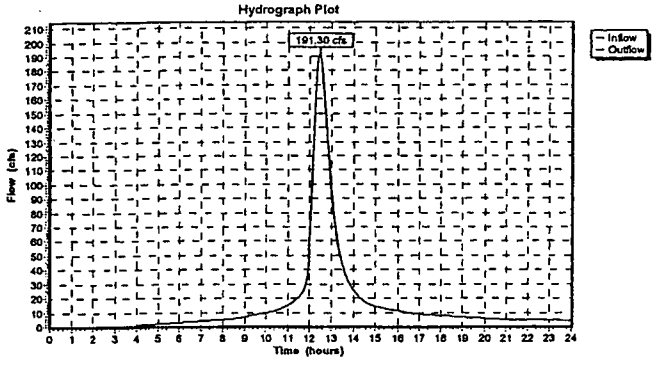
Reach 1R: (new node)

[40] Hint: Not Described (Outflow=Inflow)

Inflow = 191.30 cfs @ 12.48 hrs, Volume= 27.823 af
Outflow = 191.30 cfs @ 12.48 hrs, Volume= 27.823 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Reach 1R: (new node)



DCP 01/30/02 40/65

Reach 2: runoff channel

[65] Warning: Inlet elevation not specified

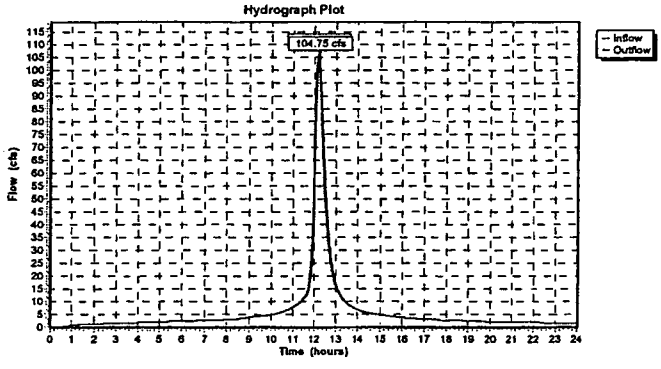
Inflow = 105.97 cfs @ 12.17 hrs, Volume= 11.569 af
Outflow = 104.75 cfs @ 12.22 hrs, Volume= 11.555 af, Atten= 1%, Lag= 3.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.1 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 1.7 fps, Avg. Travel Time= 3.7 min

4664

Peak Depth= 2.16'
Capacity at bank full= 2,054.66 cfs
0.00' x 6.57' deep channel, n= 0.030 Length= 385.0' Slope= 0.0064 '/'
Side Slope Z-value= 6.0 5.0 '/'

Reach 2: runoff channel



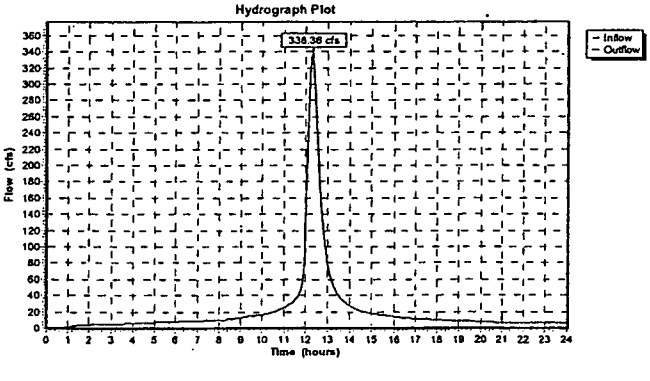
Reach 2R: (new node)

[40] Hint: Not Described (Outflow=Inflow)

Inflow = 336.36 cfs @ 12.32 hrs, Volume= 40.522 af
Outflow = 336.36 cfs @ 12.32 hrs, Volume= 40.522 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Reach 2R: (new node)



Reach 3: runoff channel

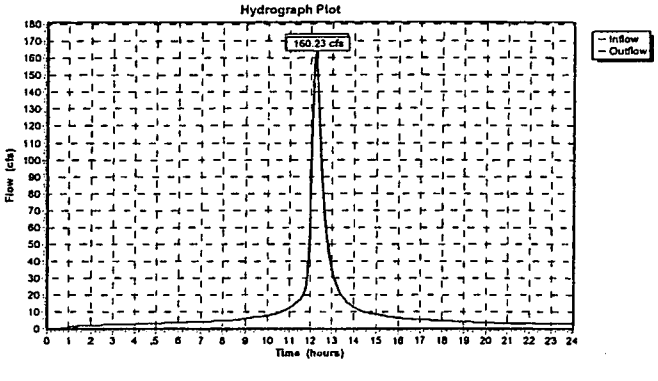
[65] Warning: Inlet elevation not specified

Inflow = 161.89 cfs @ 12.22 hrs, Volume= 19.082 af
Outflow = 160.23 cfs @ 12.26 hrs, Volume= 19.063 af, Atten= 1%, Lag= 2.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.1 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 2.2 fps, Avg. Travel Time= 3.1 min

Peak Depth= 2.65'
Capacity at bank full= 1,590.57 cfs
0.00' x 6.26' deep channel, n= 0.030 Length= 405.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 3: runoff channel



DCP 01/30/02 41/65

Reach 4: runoff channel

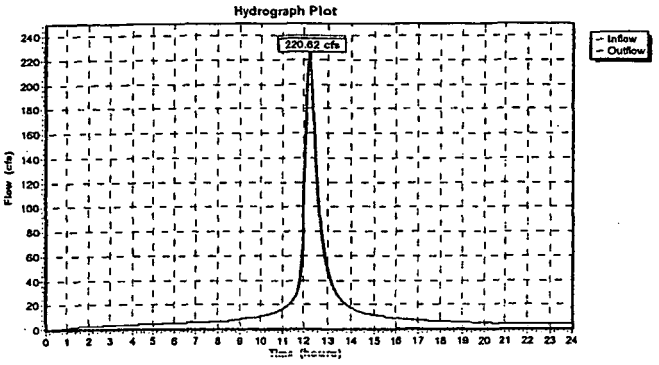
[65] Warning: Inlet elevation not specified

Inflow = 223.04 cfs @ 12.24 hrs, Volume= 26.003 af
Outflow = 220.62 cfs @ 12.29 hrs, Volume= 25.975 af, Atten= 1%, Lag= 2.6 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.6 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 2.0 fps, Avg. Travel Time= 3.3 min

Peak Depth= 3.10'
Capacity at bank full= 1,377.52 cfs
0.00' x 6.14' deep channel, n= 0.030 Length= 395.0' Slope= 0.0050 '/'
Side Slope Z-value= 4.0 6.0 '/'

Reach 4: runoff channel



Reach 5: runoff channel

[65] Warning: Inlet elevation not specified

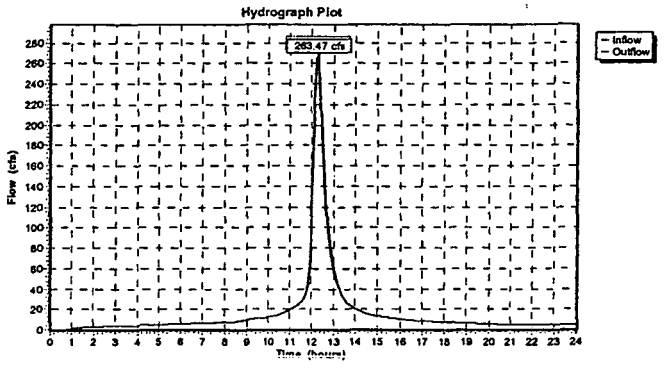
Inflow = 266.17 cfs @ 12.27 hrs, Volume= 31.120 af
Outflow = 263.47 cfs @ 12.31 hrs, Volume= 31.088 af, Atten= 1%, Lag= 2.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 4.9 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 2.1 fps, Avg. Travel Time= 3.2 min

4664

Peak Depth= 3.45'
Capacity at bank full= 840.15 cfs
0.00' x 5.32' deep channel, n= 0.030 Length= 405.0' Slope= 0.0050 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 5: runoff channel



Reach 6: runoff channel

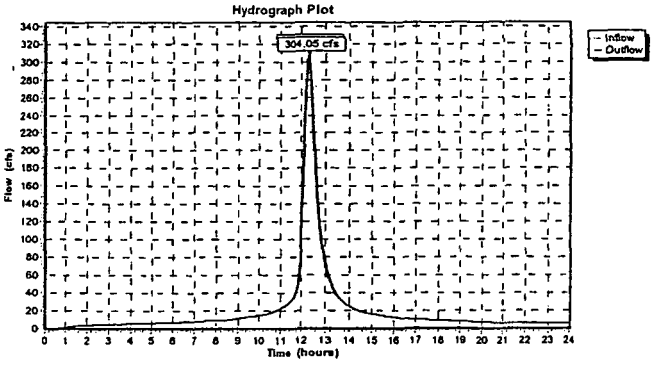
[65] Warning: Inlet elevation not specified

Inflow = 307.30 cfs @ 12.29 hrs, Volume= 36.374 af
Outflow = 304.05 cfs @ 12.34 hrs, Volume= 36.332 af, Atten= 1%, Lag= 2.8 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 5.1 fps, Min. Travel Time= 1.5 min
Avg. Velocity = 2.2 fps, Avg. Travel Time= 3.6 min

Peak Depth= 3.64'
Capacity at bank full= 800.53 cfs
0.00' x 5.22' deep channel, n= 0.030 Length= 475.0' Slope= 0.0050 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 6: runoff channel



Reach 7: east runon ditch

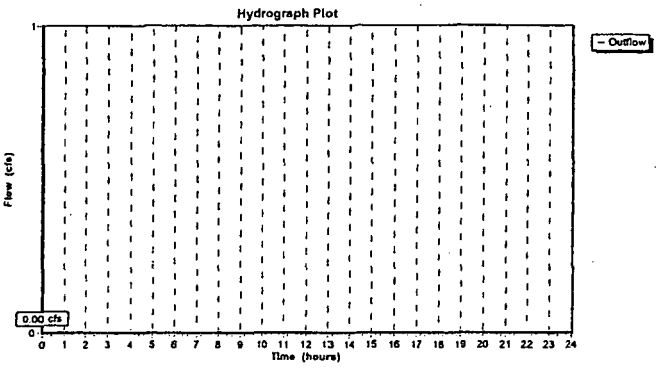
[43] Hint: Has no inflow (Outflow=Zero)

Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.0 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.0 fps, Avg. Travel Time= 0.0 min

Peak Depth= 0.00'
Capacity at bank full= 242.98 cfs
0.00' x 3.10' deep channel, n= 0.030 Length= 395.0' Slope= 0.0125 '/'
Side Slope Z-value= 4.0 3.0 '/'

Reach 7: east runon ditch



Reach 8: east runon ditch

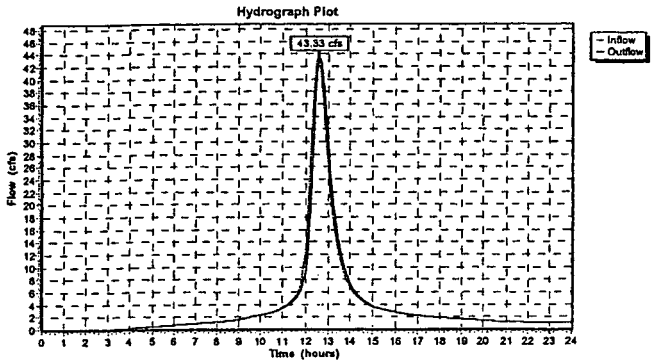
[65] Warning: Inlet elevation not specified

Inflow	=	43.54 cfs @	12.56 hrs,	Volume=	6.776 af
Outflow	=	43.33 cfs @	12.64 hrs,	Volume=	6.762 af, Atten= 0%, Lag= 4.6 min

outing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.6 fps, Min. Travel Time= 2.6 min
Avg. Velocity = 1.2 fps, Avg. Travel Time= 5.8 min

Peak Depth= 0.75'
Capacity at bank full= 1,794.23 cfs
0.00' x 3.01' deep channel, n= 0.030 Length= 405.0' Slope= 0.0100 '/'
Side Slope Z-value= 58.0 3.0 '/'

Reach 8: east runon ditch



Reach 9: east runon ditch

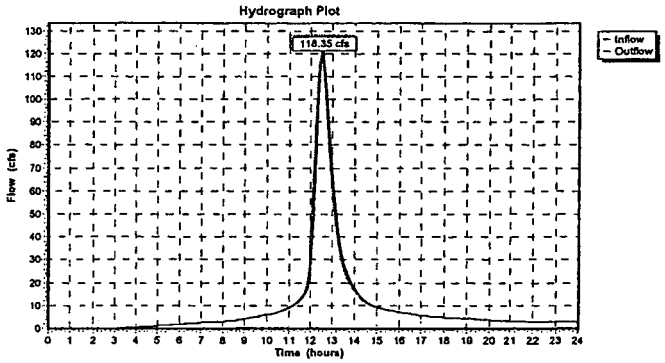
[65] Warning: Inlet elevation not specified

Inflow	=	118.98 cfs @	12.49 hrs,	Volume=	17.584 af
Outflow	=	118.35 cfs @	12.56 hrs,	Volume=	17.551 af, Atten= 1%, Lag= 4.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.3 fps, Min. Travel Time= 2.4 min
Avg. Velocity = 1.5 fps, Avg. Travel Time= 5.4 min

Peak Depth= 1.07'
Capacity at bank full= 1,836.80 cfs
0.00' x 3.00' deep channel, n= 0.030 Length= 475.0' Slope= 0.0100 '/'
Side Slope Z-value= 60.0 3.0 '/'

Reach 9: east runon ditch



4664

ATTACHMENT C-1C

2000-YEAR STORM DESIGN SCENARIO – HEAVY VEGETATION
2000-YEAR, 24-HOUR STORM EVENT

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Type II 24-hr Rainfall=13.00" (AMC=3)
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment A: vegetated final cover
Tc=25.4 min CN=99 Area=2.601 ac Runoff= 27.84 cfs 2.780 af

Subcatchment B: vegetated final cover
Tc=12.6 min CN=99 Area=1.637 ac Runoff= 24.52 cfs 1.754 af

Subcatchment C: vegetated final cover
Tc=30.5 min CN=99 Area=4.960 ac Runoff= 47.56 cfs 5.297 af

Subcatchment D: vegetated final cover
Tc=28.6 min CN=99 Area=4.746 ac Runoff= 47.30 cfs 5.070 af

Subcatchment E: vegetated final cover
Tc=27.8 min CN=99 Area=4.946 ac Runoff= 50.23 cfs 5.284 af

Subcatchment F: vegetated final cover
Tc=28.4 min CN=99 Area=4.814 ac Runoff= 48.29 cfs 5.143 af

Subcatchment G: vegetated final cover
Tc=28.5 min CN=99 Area=4.946 ac Runoff= 49.47 cfs 5.284 af

Subcatchment H: vegetated final cover
Tc=29.1 min CN=99 Area=3.921 ac Runoff= 38.71 cfs 4.188 af

Subcatchment I: runon east of OSDF
Tc=20.5 min CN=91 Area=0.530 ac Runoff= 6.25 cfs 0.523 af

Subcatchment J: runon east of OSDF
Tc=44.8 min CN=91 Area=1.242 ac Runoff= 9.07 cfs 1.220 af

Subcatchment K: runon east of OSDF
Tc=62.8 min CN=87 Area=2.623 ac Runoff= 14.73 cfs 2.454 af

Subcatchment L: runon east of OSDF
Tc=37.3 min CN=86 Area=1.779 ac Runoff= 14.24 cfs 1.653 af

Subcatchment M: runon east of OSDF
Tc=60.1 min CN=87 Area=7.234 ac Runoff= 41.87 cfs 6.772 af

Subcatchment N: runon east of OSDF
Tc=49.1 min CN=86 Area=11.664 ac Runoff= 77.35 cfs 10.815 af

Subcatchment O: runon east of OSDF
Tc=44.4 min CN=87 Area=10.935 ac Runoff= 78.37 cfs 10.269 af

DGH 01/30/02 44/65

Reach 1: runoff channel — Inflow= 52.69 cfs 5.057 af
Length= 405.0' Max Vel= 1.1 fps Capacity= 769.66 cfs Outflow= 48.15 cfs 5.034 af

Reach 1R: (new node) — Inflow= 163.07 cfs 27.738 af
Outflow= 163.07 cfs 27.738 af

— 4664

Reach 2: runoff channel — Inflow= 103.31 cfs 11.551 af
Length= 385.0' Max Vel= 1.6 fps Capacity= 616.40 cfs Outflow= 99.82 cfs 11.518 af

Reach 2R: (new node) — Inflow= 242.52 cfs 40.293 af
Outflow= 242.52 cfs 40.293 af

Reach 3: runoff channel — Inflow= 148.97 cfs 19.042 af
Length= 405.0' Max Vel= 2.0 fps Capacity= 477.17 cfs Outflow= 146.28 cfs 18.995 af

Reach 4: runoff channel — Inflow= 191.49 cfs 25.933 af
Length= 395.0' Max Vel= 1.8 fps Capacity= 413.26 cfs Outflow= 188.22 cfs 25.864 af

Reach 5: runoff channel — Inflow= 213.67 cfs 31.007 af
Length= 405.0' Max Vel= 1.9 fps Capacity= 252.05 cfs Outflow= 211.12 cfs 30.927 af

Reach 6: runoff channel — Inflow= 232.12 cfs 36.211 af
Length= 475.0' Max Vel= 1.9 fps Capacity= 240.16 cfs Outflow= 229.30 cfs 36.105 af

Reach 7: east runon ditch
Length= 395.0' Max Vel= 0.0 fps Capacity= 72.89 cfs Outflow= 0.00 cfs 0.000 af

Reach 8: east runon ditch — Inflow= 41.87 cfs 6.772 af
Length= 405.0' Max Vel= 1.0 fps Capacity= 538.27 cfs Outflow= 40.84 cfs 6.737 af

Reach 9: east runon ditch — Inflow= 107.40 cfs 17.552 af
Length= 475.0' Max Vel= 1.3 fps Capacity= 551.04 cfs Outflow= 105.39 cfs 17.469 af

Runoff Area = 68.578 ac Volume = 68.505 af Average Depth = 11.99"

Subcatchment A: vegetated final cover

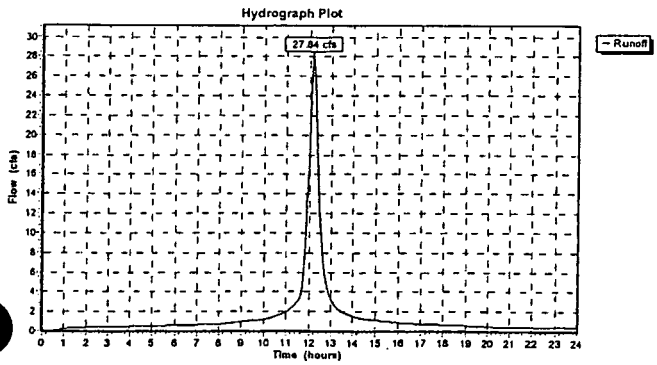
Runoff = 27.84 cfs @ 12.17 hrs, Volume= 2.780 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
2.601	98	
2.601	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
25.4	490	Total			

Subcatchment A: vegetated final cover



Subcatchment B: vegetated final cover

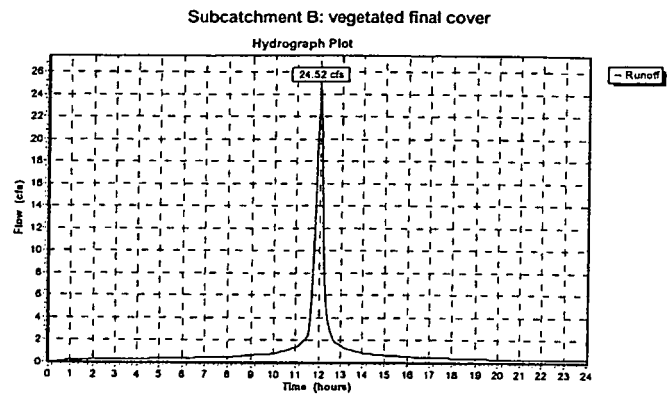
Runoff = 24.52 cfs @ 12.04 hrs, Volume= 1.754 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.637	98	
1.637	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.6	90	0.0750	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.7	130	0.0250	3.0	151.89	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.91' Z= 6.0 '/' n= 0.100
3.3	320	0.0075	1.6	69.02	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.91' Z= 4.0 & 6.0 '/' n= 0.100
12.6	540	Total			

Subcatchment B: vegetated final cover



Subcatchment C: vegetated final cover

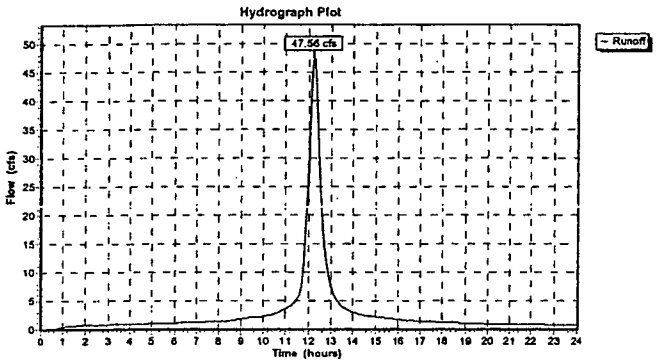
Runoff = 47.56 cfs @ 12.23 hrs, Volume= 5.297 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.960	98	
4.960	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.5	190	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
5.1	370	0.0035	1.2	67.01	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.32' Z= 6.0 & 4.0 '/' n= 0.100
30.5	860	Total			

Subcatchment C: vegetated final cover



DCP 01/30/02 TJ/LCS

Subcatchment D: vegetated final cover

Runoff = 47.30 cfs @ 12.21 hrs, Volume= 5.070 af

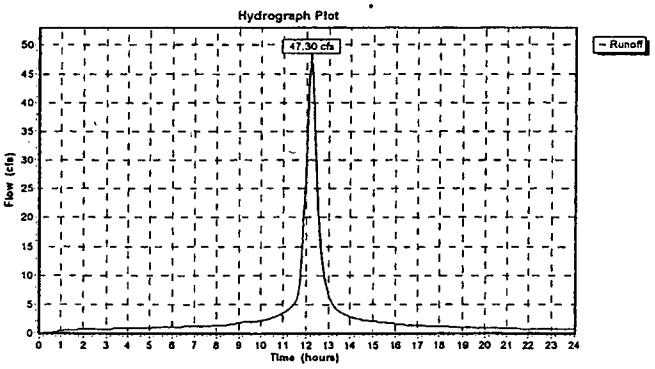
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

4664

Area (ac)	CN	Description
4.746	98	
4.746	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.5	180	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.6	200	0.0083	2.1	190.82	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.03' Z= 6.0 & 5.0 '/' n= 0.100
1.6	150	0.0045	1.6	127.40	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.03' Z= 6.0 & 4.0 '/' n= 0.100
28.6	830	Total			

Subcatchment D: vegetated final cover



Subcatchment E: vegetated final cover

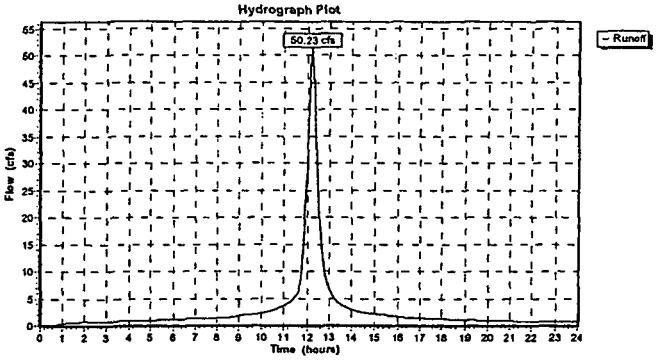
Runoff = 50.23 cfs @ 12.20 hrs, Volume= 5.284 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.946	98	
4.946	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	170	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.5	50	0.0045	1.7	180.24	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.59' Z= 6.0 & 4.0 '/' n= 0.100
2.0	320	0.0105	2.6	246.72	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.59' Z= 6.0 & 3.0 '/' n= 0.100
27.8	840	Total			

Subcatchment E: vegetated final cover



Dec 1 01/30/02 46/65

Subcatchment F: vegetated final cover

Runoff = 48.29 cfs @ 12.21 hrs, Volume= 5.143 af

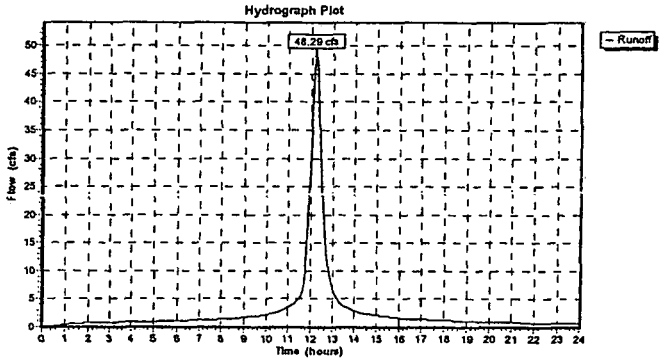
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.814	98	
4.814	98	Weighted Average, Adjusted for AMC = 99

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.1	360	0.0050	1.9	238.68	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=5.00' Z= 4.0 & 6.0 '/' n= 0.100
28.4	835	Total			

Subcatchment F: vegetated final cover



Subcatchment G: vegetated final cover

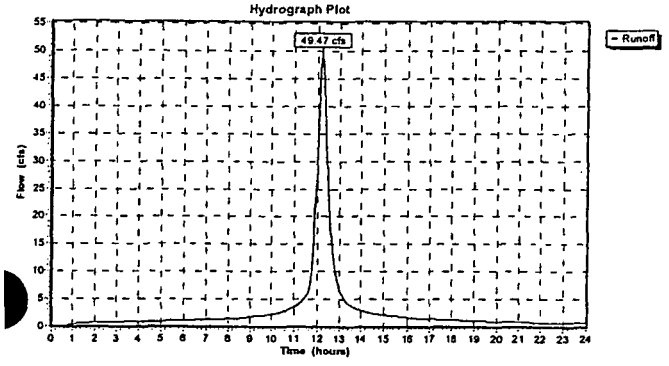
Runoff = 49.47 cfs @ 12.21 hrs, Volume= 5.284 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
4.946	98	
4.946	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.2	370	0.0050	1.9	231.42	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=5.15' Z= 3.0 & 6.0 '/' n= 0.100
28.5	845	Total			

Subcatchment G: vegetated final cover



Subcatchment H: vegetated final cover

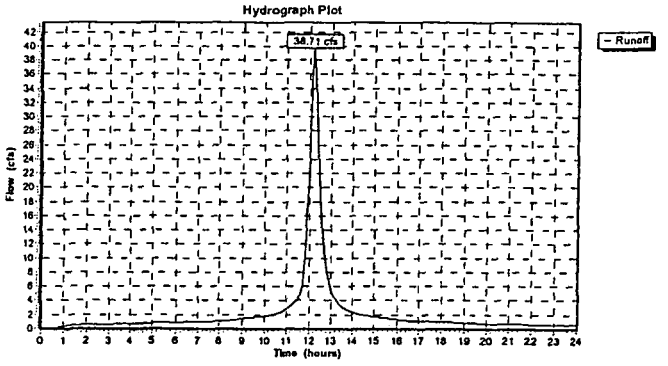
Runoff = 38.71 cfs @ 12.22 hrs, Volume= 4.188 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
3.921	98	
3.921	98	Weighted Average, Adjusted for AMC = 99

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	90	0.0500	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.5	60	0.1000	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
9.3	150	0.1700	0.3		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.4	175	0.1700	6.6		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.8	440	0.0050	1.9	231.42	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=5.15' Z= 3.0 & 6.0 '/' n= 0.100
29.1	915	Total			

Subcatchment H: vegetated final cover



Subcatchment I: runon east of OSDF

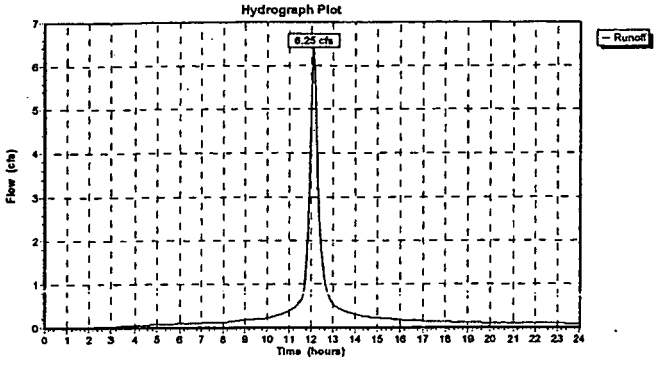
Runoff = 6.25 cfs @ 12.12 hrs, Volume= 0.523 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
0.530	79	
0.530	79	Weighted Average, Adjusted for AMC = 91

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
19.9	210	0.0500	0.2		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.6	55	0.0075	1.6	69.02	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=2.91' Z= 4.0 & 6.0 '/' n= 0.100
20.5	265	Total			

Subcatchment I: runon east of OSDF



VCI 01/30/02 T 1160

Subcatchment J: runon east of OSDF

Runoff = 9.07 cfs @ 12.40 hrs, Volume= 1.220 af

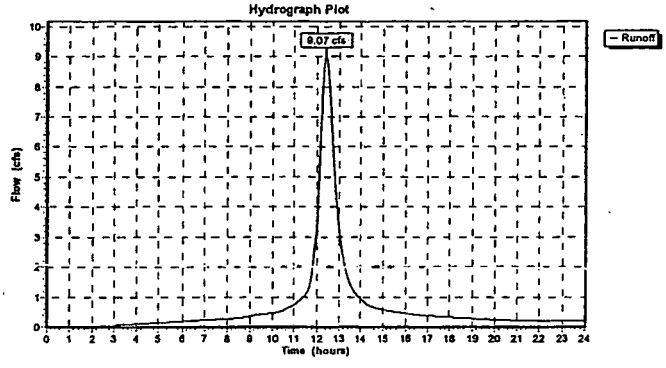
Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.242	79	
1.242	79	Weighted Average, Adjusted for AMC = 91

4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
41.9	300	0.0158	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.8	100	0.0158	2.0		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.1	150	0.0035	1.2	67.01	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=3.32' Z= 6.0 & 4.0 '/' n= 0.100
44.8	550	Total			

Subcatchment J: runon east of OSDF



Subcatchment K: runon east of OSDF

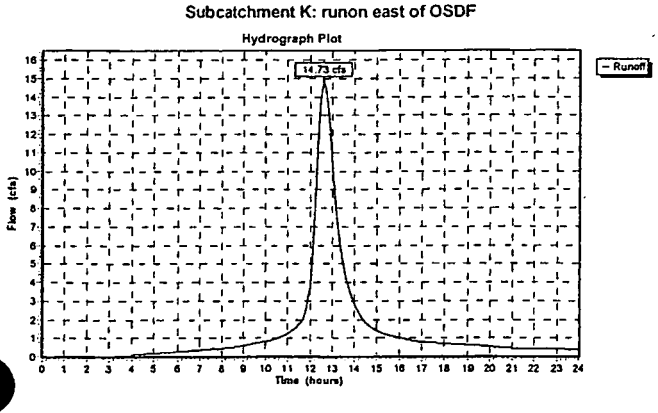
Runoff = 14.73 cfs @ 12.63 hrs, Volume= 2.454 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
2.623	73	
2.623	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
58.0	300	0.0070	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
2.1	290	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
2.7	250	0.0045	1.6	127.40	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.03' Z= 6.0 & 4.0 '/' n= 0.100
62.8	840	Total			

Subcatchment K: runon east of OSDF



Subcatchment L: runon east of OSDF

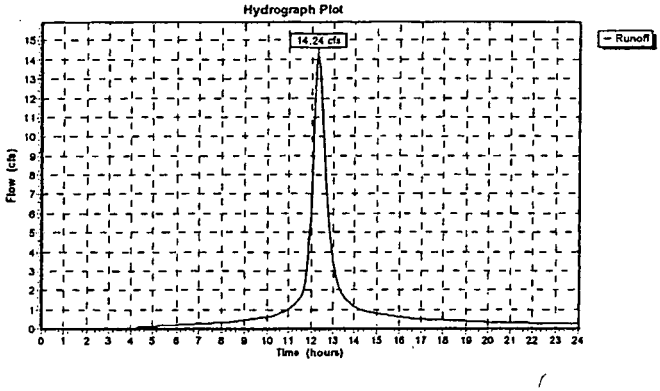
Runoff = 14.24 cfs @ 12.31 hrs, Volume= 1.653 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
1.779	72	
1.779	72	Weighted Average, Adjusted for AMC = 86

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
34.9	300	0.0250	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
0.9	140	0.0250	2.5		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.9	170	0.0375	3.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
0.6	90	0.0105	2.6	246.72	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=4.59' Z= 6.0 & 3.0 '/' n= 0.100
37.3	700	Total			

Subcatchment L: runon east of OSDF



Subcatchment M: runon east of OSDF

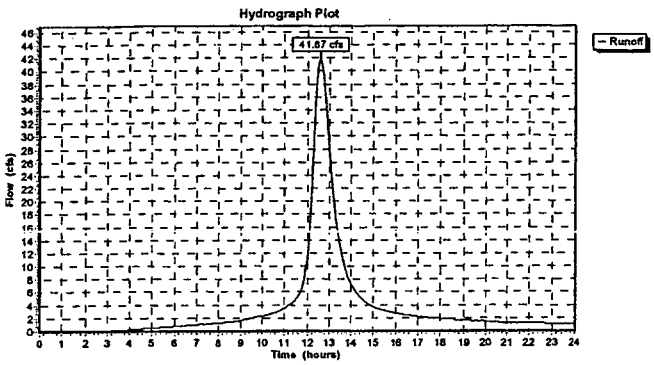
Runoff = 41.87 cfs @ 12.60 hrs, Volume= 6.772 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
7.234	73	
7.234	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
50.3	300	0.0100	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
3.1	350	0.0139	1.9		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
1.4	180	0.0167	2.1		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
5.3	360	0.0125	1.1	5.30	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.16' Z= 4.0 & 3.0 '/' n= 0.100
60.1	1,190	Total			

Subcatchment M: runon east of OSDF



DGP 01/30/02 48/65

Subcatchment N: runon east of OSDF

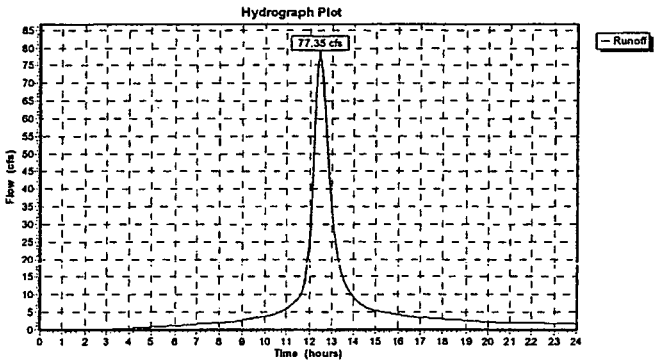
Runoff = 77.35 cfs @ 12.46 hrs, Volume= 10.815 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
11.664	72	
11.664	72	Weighted Average, Adjusted for AMC = 86 — 4664

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.3	300	0.0198	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
5.7	770	0.0198	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
5.1	395	0.0100	1.3	104.87	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.63' Z= 58.0 & 3.0 '/' n= 0.100
49.1	1,465	Total			

Subcatchment N: runon east of OSDF



Subcatchment O: runon east of OSDF

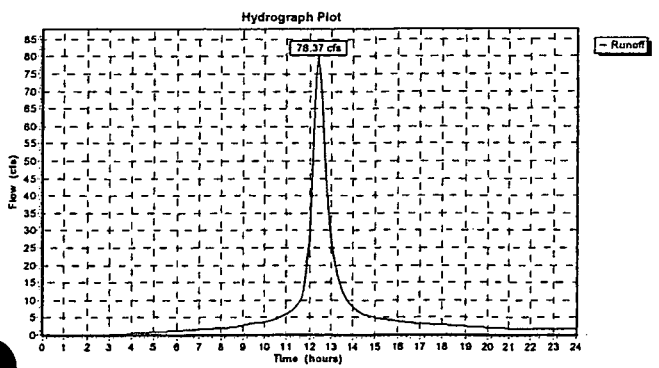
Runoff = 78.37 cfs @ 12.40 hrs, Volume= 10.269 af

Runoff by SCS TR-20 method, UH=SCS, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=13.00" (AMC=3)

Area (ac)	CN	Description
10.935	73	
10.935	73	Weighted Average, Adjusted for AMC = 87

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
38.1	300	0.0200	0.1		Sheet Flow, Grass: Dense n= 0.240 P2= 2.60"
3.1	420	0.0200	2.3		Shallow Concentrated Flow, Unpaved Kv= 16.1 fps
3.2	250	0.0100	1.3	108.32	Trap/Vee/Rect Channel Flow, Bot.W=0.00' D=1.63' Z= 60.0 & 3.0 '/' n= 0.100
44.4	970	Total			

Subcatchment O: runon east of OSDF



Reach 1: runoff channel

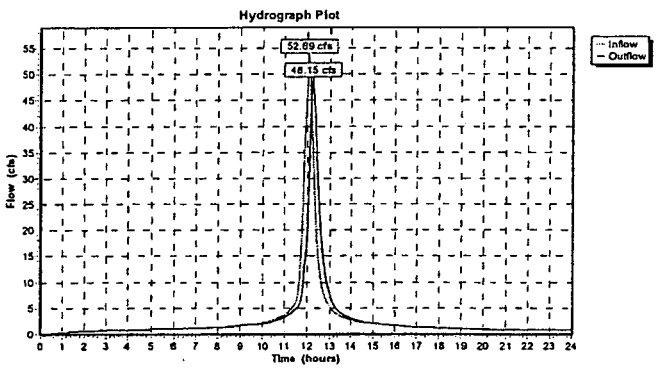
[65] Warning: Inlet elevation not specified

Inflow = 52.69 cfs @ 12.08 hrs, Volume= 5.057 af
Outflow = 48.15 cfs @ 12.26 hrs, Volume= 5.034 af, Atten= 9%, Lag= 10.7 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.1 fps, Min. Travel Time= 6.0 min
Avg. Velocity = 0.5 fps, Avg. Travel Time= 14.5 min

Peak Depth= 2.93'
Capacity at bank full= 769.66 cfs
0.00' x 8.29' deep channel, n= 0.100 Length= 405.0' Slope= 0.0035 '/'
Side Slope Z-value= 6.0 4.0 '/'

Reach 1: runoff channel



Reach 1R: (new node)

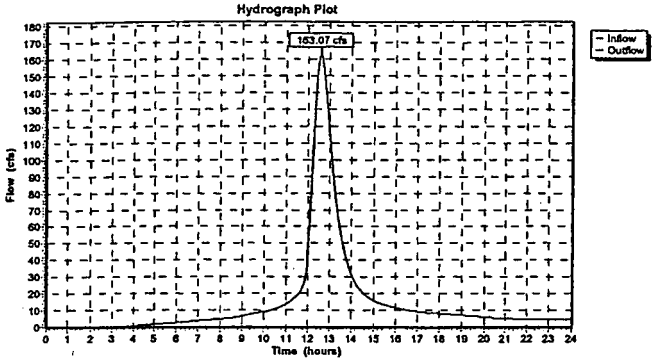
[40] Hint: Not Described (Outflow=Inflow)

'nflow = 163.07 cfs @ 12.60 hrs, Volume= 27.738 af
'tflow = 163.07 cfs @ 12.60 hrs, Volume= 27.738 af, Atten= 0%, Lag= 0.0 min

.uting by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Reach 1R: (new node)

Hydrograph Plot



DG.P 01/30/02 49/65

Reach 2: runoff channel

[65] Warning: Inlet elevation not specified

Inflow = 103.31 cfs @ 12.26 hrs, Volume= 11.551 af
Outflow = 99.82 cfs @ 12.37 hrs, Volume= 11.518 af, Atten= 3%, Lag= 7.0 min

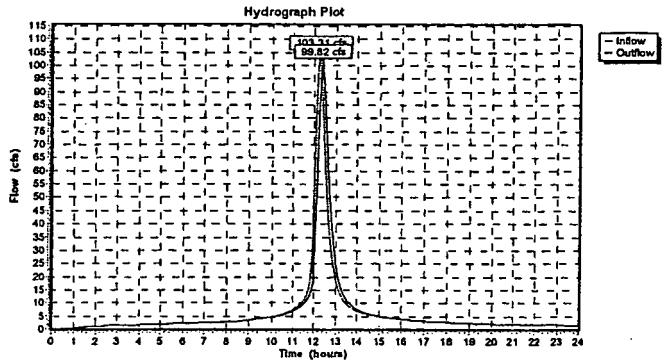
Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.6 fps, Min. Travel Time= 3.9 min
Avg. Velocity = 0.7 fps, Avg. Travel Time= 9.2 min

-- 4664

Peak Depth= 3.33'
Capacity at bank full= 616.40 cfs
0.00' x 6.57' deep channel, n= 0.100 Length= 385.0' Slope= 0.0064 '/'
Side Slope Z-value= 6.0 5.0 '/'

Reach 2: runoff channel

Hydrograph Plot



Reach 2R: (new node)

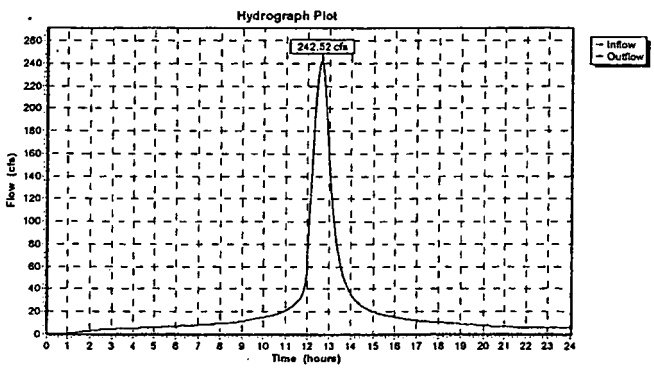
[40] Hint: Not Described (Outflow=Inflow)

Inflow = 242.52 cfs @ 12.63 hrs, Volume= 40.293 af
Outflow = 242.52 cfs @ 12.63 hrs, Volume= 40.293 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Reach 2R: (new node)

Hydrograph Plot



Reach 3: runoff channel

[65] Warning: Inlet elevation not specified

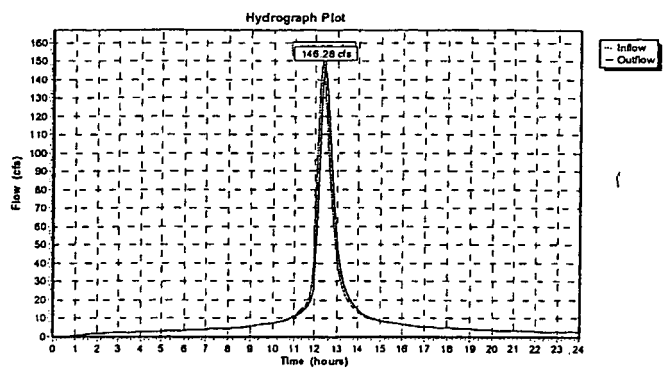
Inflow = 148.97 cfs @ 12.34 hrs, Volume= 19.042 af
Outflow = 146.28 cfs @ 12.44 hrs, Volume= 18.995 af, Atten= 2%, Lag= 6.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 2.0 fps, Min. Travel Time= 3.4 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 7.7 min

Peak Depth= 4.02'
Capacity at bank full= 477.17 cfs
0.00' x 6.26' deep channel, n= 0.100 Length= 405.0' Slope= 0.0075 '/'
Side Slope Z-value= 3.0 6.0 '/'

Reach 3: runoff channel

Hydrograph Plot



Reach 4: runoff channel

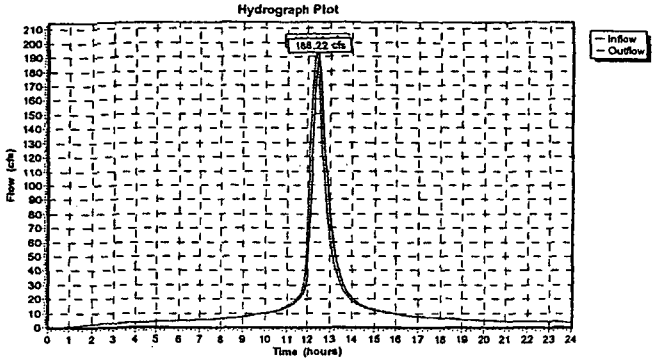
[65] Warning: Inlet elevation not specified

Inflow = 191.49 cfs @ 12.39 hrs, Volume= 25.933 af
Outflow = 188.22 cfs @ 12.50 hrs, Volume= 25.864 af, Atten= 2%, Lag= 6.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.8 fps, Min. Travel Time= 3.7 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 8.3 min

Peak Depth= 4.58'
Capacity at bank full= 413.26 cfs
0.00' x 6.14' deep channel, n= 0.100 Length= 395.0' Slope= 0.0050 '/'
Side Slope Z-value= 4.0 6.0 '/'

Reach 4: runoff channel



DGP 01/30/02 — 50/65

Reach 5: runoff channel

[65] Warning: Inlet elevation not specified

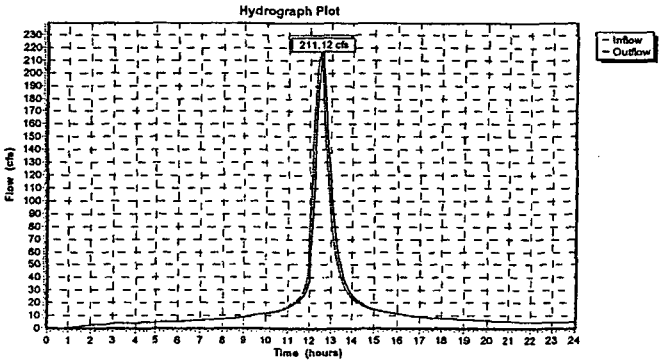
Inflow = 213.67 cfs @ 12.46 hrs, Volume= 31.007 af
Outflow = 211.12 cfs @ 12.57 hrs, Volume= 30.927 af, Atten= 1%, Lag= 6.3 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.9 fps, Min. Travel Time= 3.6 min
Avg. Velocity = 0.8 fps, Avg. Travel Time= 7.9 min

— 4664

Peak Depth= 4.98'
Capacity at bank full= 252.05 cfs
0.00' x 5.32' deep channel, n= 0.100 Length= 405.0' Slope= 0.0050 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 5: runoff channel



Reach 6: runoff channel

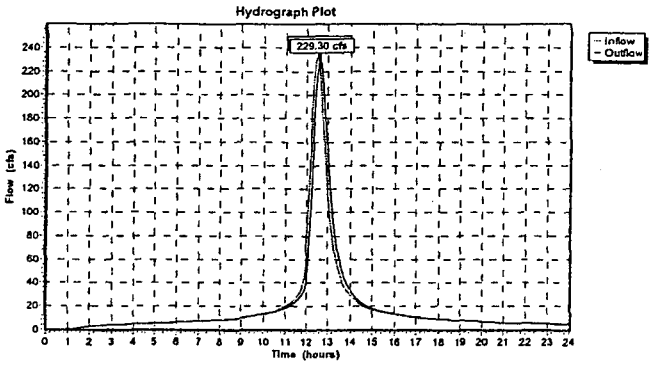
[65] Warning: Inlet elevation not specified

Inflow = 232.12 cfs @ 12.53 hrs, Volume= 36.211 af
Outflow = 229.30 cfs @ 12.65 hrs, Volume= 36.105 af, Atten= 1%, Lag= 7.1 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.9 fps, Min. Travel Time= 4.1 min
Avg. Velocity = 0.9 fps, Avg. Travel Time= 8.9 min

Peak Depth= 5.13'
Capacity at bank full= 240.16 cfs
0.00' x 5.22' deep channel, n= 0.100 Length= 475.0' Slope= 0.0050 '/'
Side Slope Z-value= 6.0 3.0 '/'

Reach 6: runoff channel



Reach 7: east runon ditch

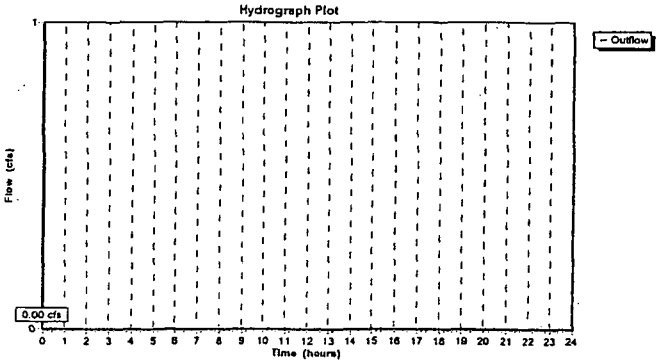
[43] Hint: Has no inflow (Outflow=Zero)

Outflow = 0.00 cfs @ 0.00 hrs, Volume= 0.000 af

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 0.0 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 0.0 fps, Avg. Travel Time= 0.0 min

Peak Depth= 0.00'
Capacity at bank full= 72.89 cfs
0.00' x 3.10' deep channel, n= 0.100 Length= 395.0' Slope= 0.0125 '/'
Side Slope Z-value= 4.0 3.0 '/'

Reach 7: east runon ditch



Reach 8: east runon ditch

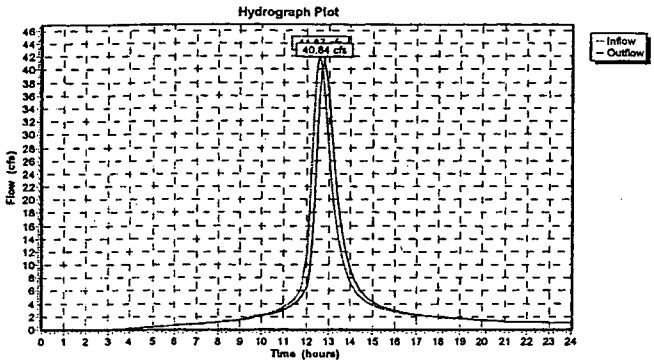
[65] Warning: Inlet elevation not specified

Inflow	=	41.87 cfs @	12.60 hrs,	Volume=	6.772 af
Outflow	=	40.84 cfs @	12.80 hrs,	Volume=	6.737 af, Atten= 2%, Lag= 11.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.0 fps, Min. Travel Time= 6.6 min
Avg. Velocity = 0.5 fps, Avg. Travel Time= 14.3 min

Peak Depth= 1.14'
Capacity at bank full= 538.27 cfs
0.00' x 3.01' deep channel, n= 0.100 Length= 405.0' Slope= 0.0100 '/'
Side Slope Z-value= 58.0 3.0 '/'

Reach 8: east runon ditch



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Reach 9: east runon ditch

[65] Warning: Inlet elevation not specified

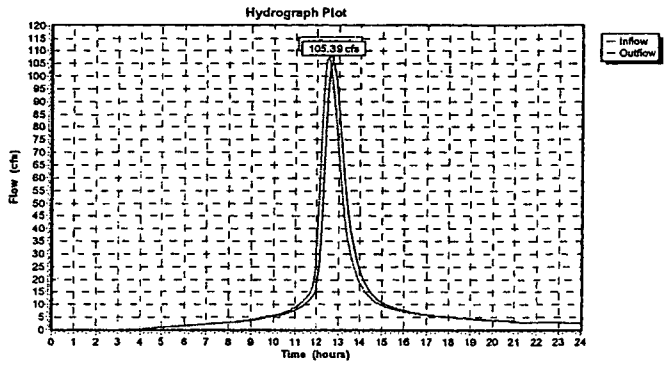
Inflow	=	107.40 cfs @	12.57 hrs,	Volume=	17.552 af
Outflow	=	105.39 cfs @	12.75 hrs,	Volume=	17.469 af, Atten= 2%, Lag= 10.9 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.3 fps, Min. Travel Time= 6.2 min
Avg. Velocity = 0.6 fps, Avg. Travel Time= 13.3 min

– 4664

Peak Depth= 1.61'
Capacity at bank full= 551.04 cfs
0.00' x 3.00' deep channel, n= 0.100 Length= 475.0' Slope= 0.0100 '/'
Side Slope Z-value= 60.0 3.0 '/'

Reach 9: east runon ditch



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ATTACHMENT C-2

WEIGHTED CURVE NUMBER CALCULATIONS

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53/65

RESULTS FOR THE CALCULATION OF WEIGHTED CN
2000 YEAR STORM DESIGN SCENARIOS

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Subcatchment Label	Area (acres)	Percent of Total Area %	HSG	Land Use Description	CN	Weighted CN AMC = 2	Weighted CN AMC = 3
A	2.60	100%	B/C	vegetated final cover	98	98	99
B	1.64	100%	B/C	vegetated final cover	98	98	99
C	4.96	100%	B/C	vegetated final cover	98	98	99
D	4.75	100%	B/C	vegetated final cover	98	98	99
E	4.95	100%	B/C	vegetated final cover	98	98	99
F	4.81	100%	B/C	vegetated final cover	98	98	99
G	4.95	100%	B/C	vegetated final cover	98	98	99
H	3.92	100%	B/C	vegetated final cover	98	98	99
I	0.53	100%	C	runon east of OSDF	79	79	91
J	1.24	100%	C	runon east of OSDF	79	79	91
K	2.62	65% 35%	B C	runon east of OSDF runon east of OSDF	69 79	73	87
L	1.78	70% 30%	B C	runon east of OSDF runon east of OSDF	69 79	72	86
M	7.23	60% 40%	B C	runon east of OSDF runon east of OSDF	69 79	73	87
N	11.66	75% 25%	B C	runon east of OSDF runon east of OSDF	69 79	72	86
O	10.94	65% 35%	B C	runon east of OSDF runon east of OSDF	69 79	73	87

N/A - Not Applicable

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ATTACHMENT C-3

TABULATED CHANNEL ANALYSIS RESULTS

2000 YEAR STORM DESIGN SCENARIO - LIGHT VEGETATION
SUMMARY OF CHANNEL ANALYSIS RESULTS

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node	HydroCAD Q[3] (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth[5] Y (ft)	Estimated Q[5] (cfs)	Channel Freeboard[4] (ft)	Peak Flow Velocity (fps)	Lining Type[6]
subcatchment B	existing	2000 DS	vee	11.90	0.35%	0.030	0	6	4	1	63.06	21.42	21.13	1.01	2.07	63.54	9.8	2.98	riprap
reach 1	existing	2000 DS	vee	10.90	0.35%	0.030	0	6	4	2	130.82	36.72	27.66	1.33	2.71	130.35	8.2	3.6	riprap
reach 2	existing	2000 DS	vee	7.73	0.45%	0.030	0	6	5	3	197.81	46.57	32.54	1.43	2.91	197.11	4.8	4.2	riprap
reach 3	new	2000 DS	vee	6.76	0.45%	0.030	0	6	3	4	268.74	56.39	32.73	1.72	3.54	270.09	3.2	4.8	riprap
reach 4	new	2000 DS	vee	7.25	0.50%	0.030	0	6	4	5	314.75	62.30	36.03	1.73	3.53	315.32	3.7	5.1	riprap
reach 5	new	2000 DS	vee	5.88	0.50%	0.030	0	6	3	6	358.63	67.40	35.78	1.88	3.87	361.09	2.0	5.4	riprap
reach 6	new	2000 DS	vee	5.76	0.50%	0.030	0	6	3	2R	387.27	70.92	36.70	1.93	3.97	386.52	1.8	5.5	riprap
reach 7	new	2000 DS	vee	3.60	1.25%	0.030	0	4	3	8	54.76	10.97	12.90	0.85	1.77	54.65	1.8	5.0	grass
reach 8	new	2000 DS	vee	3.51	1.00%	0.030	0	58	3	9	146.94	41.75	71.57	0.58	1.17	144.75	2.3	3.5	grass
reach 9	new	2000 DS	vee	3.50	1.00%	0.030	0	60	3	1R	232.74	60.86	87.81	0.69	1.39	236.71	2.1	3.9	grass

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from existing topographic information and Construction Drawings.
3. Peak flow rates calculated by HydroCAD for each reach. See attachment C-1.
4. Calculated as the difference between minimum channel depth and peak flow depth.
5. Calculated flow rates using Manning's equation.
6. Maximum permissible velocity for grass lined channels is 5 fps.
   Maximum permissible velocity for riprap lined channels is 12 fps.
7. Calculated as the difference between minimum available flow depth and peak flow depth.

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2000 YEAR STORM DESIGN SCENARIO - MODERATE VEGETATION
SUMMARY OF CHANNEL ANALYSIS RESULTS

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node	HydroCAD Q[3] (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth[5] Y (ft)	Estimated Q[5] (cfs)	Channel Freeboard[4] (ft)	Peak Flow Velocity (fps)	Lining Type[6]
subcatchment B	existing	2000 DS	vee	11.90	0.35%	0.030	0	6	4	1	51.86	18.24	19.49	0.94	1.91	51.27	10.0	2.81	
reach 1	existing	2000 DS	vee	10.90	0.35%	0.030	0	6	4	2	105.97	31.25	25.51	1.22	2.50	105.12	8.4	3.4	riprap
reach 2	existing	2000 DS	vee	7.73	0.45%	0.030	0	6	5	3	161.89	40.09	30.19	1.33	2.70	161.42	5.0	4.0	riprap
reach 3	new	2000 DS	vee	6.76	0.45%	0.030	0	6	3	4	223.04	48.71	30.42	1.60	3.29	222.17	3.5	4.6	riprap
reach 4	new	2000 DS	vee	7.25	0.50%	0.030	0	6	4	5	266.17	55.11	33.88	1.63	3.32	267.74	3.9	4.8	riprap
reach 5	new	2000 DS	vee	5.88	0.50%	0.030	0	6	3	6	307.30	59.62	33.65	1.77	3.64	306.66	2.2	5.2	riprap
reach 6	new	2000 DS	vee	5.76	0.50%	0.030	0	6	3	2R	336.36	63.62	34.76	1.83	3.76	334.36	2.0	5.3	riprap
reach 7	new	2000 DS	vee	3.60	1.25%	0.030	0	4	3	8	43.54	9.19	11.80	0.78	1.62	43.15	2.0	4.7	grass
reach 8	new	2000 DS	vee	3.51	1.00%	0.030	0	58	3	9	118.98	35.58	66.06	0.54	1.08	116.93	2.4	3.3	grass
reach 9	new	2000 DS	vee	3.50	1.00%	0.030	0	60	3	1R	191.30	51.61	80.86	0.64	1.29	189.99	2.2	3.7	grass

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from existing topographic information and Construction Drawings.
3. Peak flow rates calculated by HydroCAD for each reach. See attachment C-1.
4. Calculated as the difference between minimum channel depth and peak flow depth.
5. Calculated flow rates using Manning's equation.
6. Maximum permissible velocity for grass lined channels is 5 fps.
   Maximum permissible velocity for riprap lined channels is 12 fps.
7. Calculated as the difference between minimum available flow depth and peak flow depth.

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56/65

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2000 YEAR STORM DESIGN SCENARIO - HEAVY VEGETATION
SUMMARY OF CHANNEL ANALYSIS RESULTS

Channel Identification			Channel Characteristics							Hydrologic Calculations		Hydraulic Calculations							
Channel Name[1]	Status	Design Scenario	Section Shape	Minimum Channel Depth (ft)	Longitudinal Slope[2] (%)	Manning n	Bottom Width B (ft)	Side Slope M_1:1	Side Slope M_2:1	HydroCAD Node	HydroCAD Q[3] (cfs)	Area of Flow A (sq ft)	Perimeter P (ft)	Hydraulic Radius, R (ft)	Peak Flow Depth[5] Y (ft)	Estimated Q[5] (cfs)	Channel Freeboard[4] (ft)	Peak Flow Velocity (fps)	Lining Type[6]
subcatchment B	existing	2000 DS	vee	11.90	0.35%	0.100	0	6	4	1	52.69	18.62	19.70	0.95	1.93	52.72	10.0	2.83	
reach 1	existing	2000 DS	vee	10.90	0.35%	0.100	0	6	4	2	103.31	76.05	39.80	1.91	3.90	103.25	7.0	1.4	riprap
reach 2	existing	2000 DS	vee	7.73	0.45%	0.100	0	6	5	3	148.97	93.36	46.07	2.03	4.12	149.47	3.6	1.6	riprap
reach 3	new	2000 DS	vee	6.76	0.45%	0.100	0	6	3	4	191.49	107.60	45.21	2.38	4.89	191.79	1.9	1.8	riprap
reach 4	new	2000 DS	vee	7.25	0.50%	0.100	0	6	4	5	213.67	114.72	48.89	2.35	4.79	213.50	2.5	1.9	riprap
reach 5	new	2000 DS	vee	5.88	0.50%	0.100	0	6	3	6	232.12	119.35	47.61	2.51	5.15	232.12	0.7	1.9	riprap
reach 6	new	2000 DS	vee	5.76	0.50%	0.100	0	6	3	2R	242.52	123.09	48.35	2.55	5.23	241.86	0.5	2.0	riprap
reach 7	new	2000 DS	vee	3.60	1.25%	0.100	0	4	3	8	41.87	22.05	18.29	1.21	2.51	41.62	1.1	1.9	grass
reach 8	new	2000 DS	vee	3.51	1.00%	0.100	0	58	3	9	107.40	83.04	100.93	0.82	1.65	108.62	1.9	1.3	grass
reach 9	new	2000 DS	vee	3.50	1.00%	0.100	0	60	3	1R	163.07	112.52	119.39	0.94	1.89	161.16	1.6	1.4	grass

Notes:
1. Channels are named after the corresponding subcatchment or reach.
2. Longitudinal slopes taken from existing topographic information and Construction Drawings.
3. Peak flow rates calculated by HydroCAD for each reach. See attachment C-1.
4. Calculated as the difference between minimum channel depth and peak flow depth.
5. Calculated flow rates using Manning's equation.
6. Maximum permissible velocity for grass lined channels is 5 fps.
   Maximum permissible velocity for riprap lined channels is 12 fps.
7. Calculated as the difference between minimum available flow depth and peak flow depth.

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ATTACHMENT C-4

GRAPHICAL CHANNEL ANALYSIS RESULTS

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59/65

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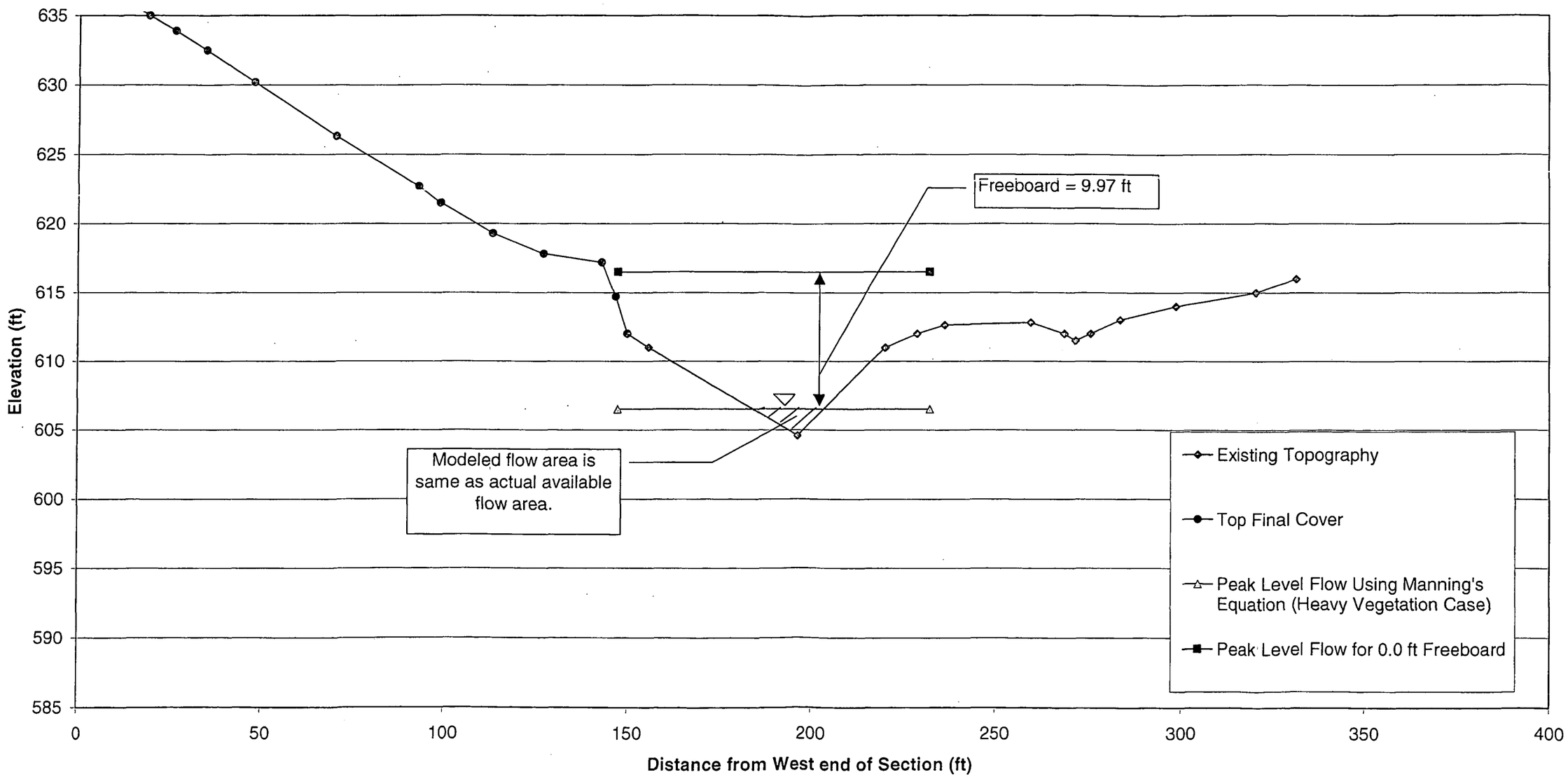
Analysis Cross-Section for Channel Segment Along Cell 1 (subcatchment B)
Coordinates for West End of Section: N 482904 E 1351478
Maximum Peak Flow Rate for Cell: Q = 52.7 cfs



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60/65
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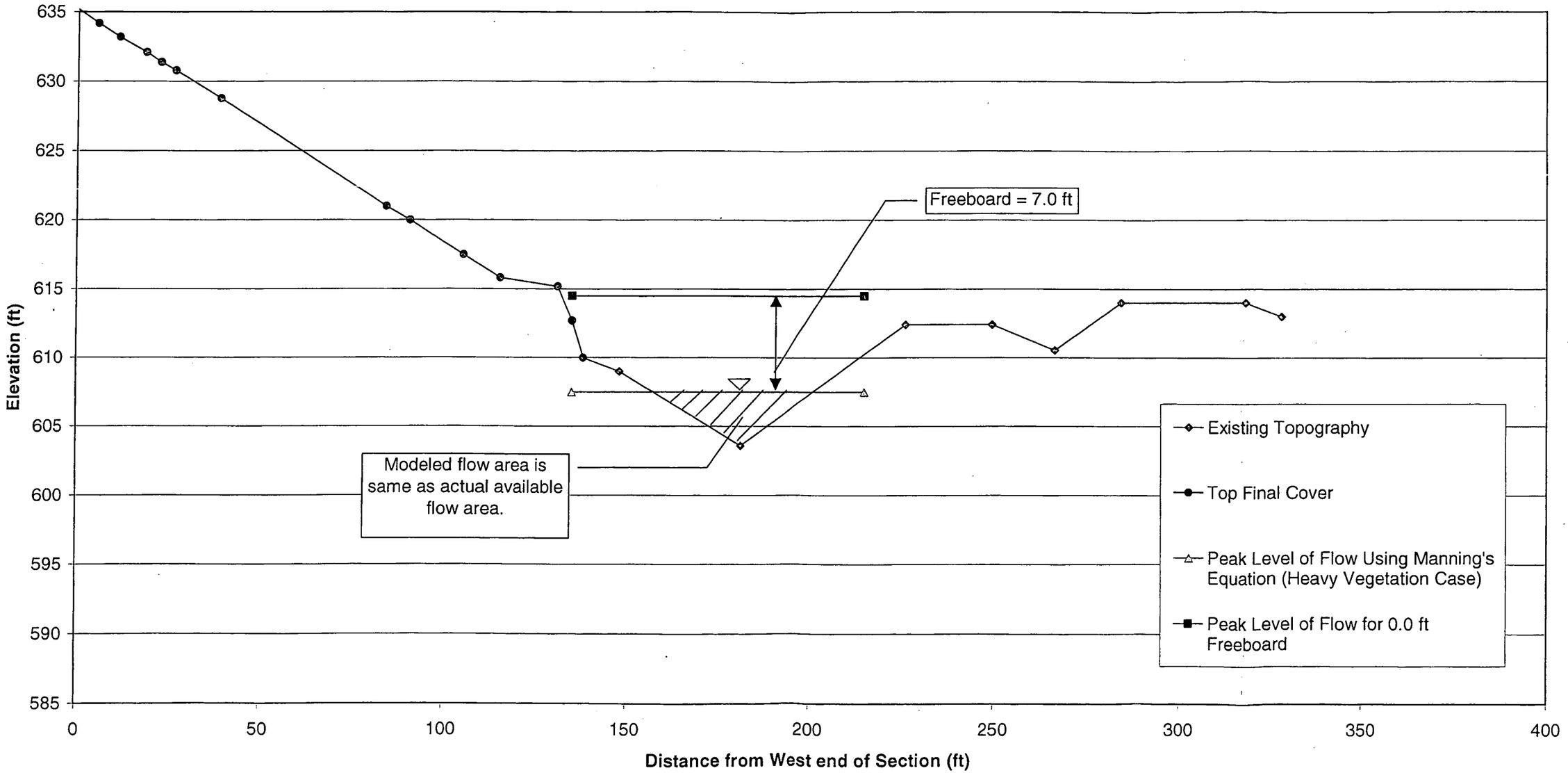
Analysis Cross-Section for Channel Segment Along Cell 2 (corresponds with Reach 1)
Coordinates for West End of Section: N 482693 E 1351484
Maximum Peak Flow Rate for Cell: Q = 103.3 cfs



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DGP 01/30/02

61/65
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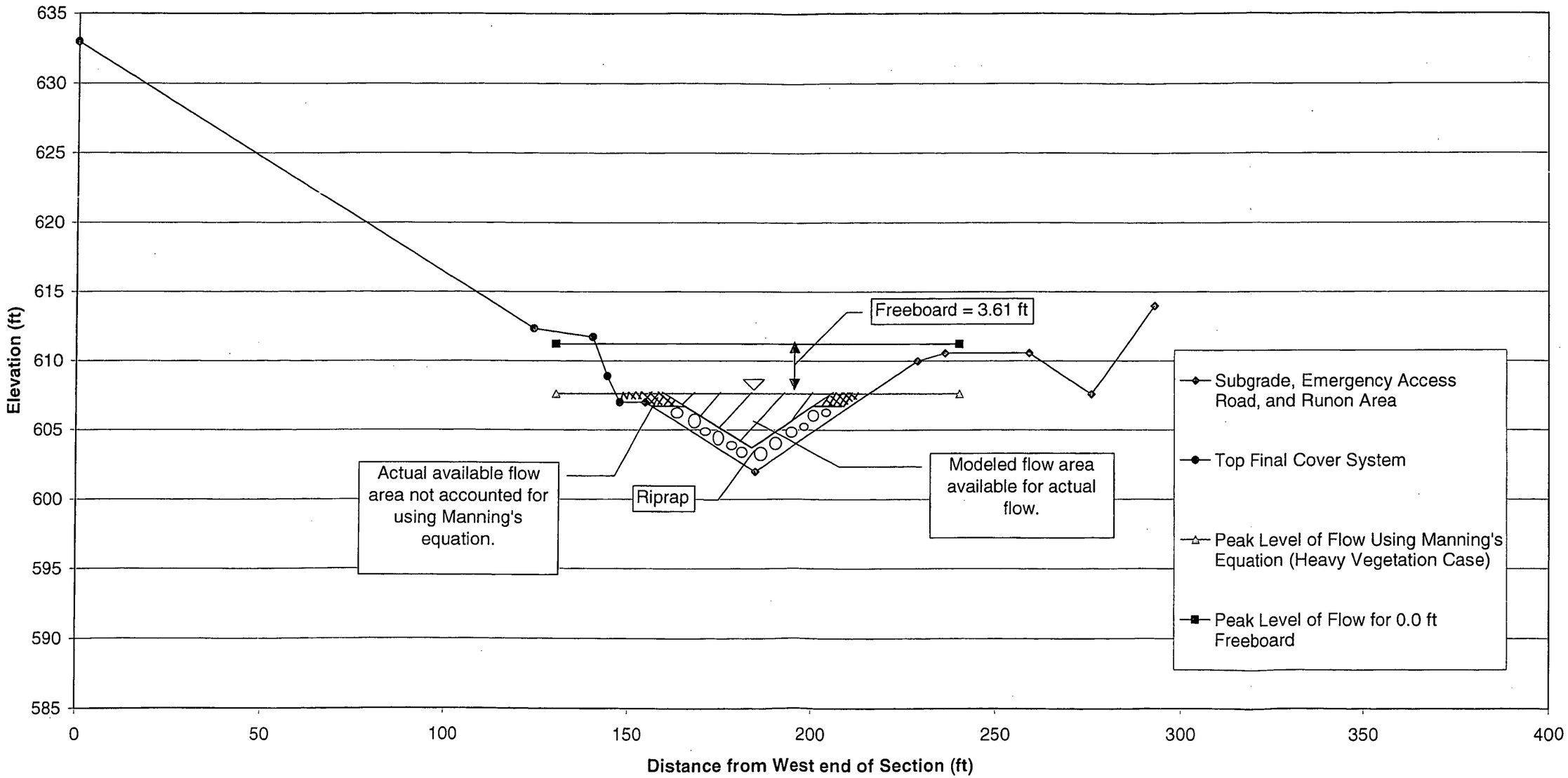
Analysis Cross-Section for Channel Segment Along Cell 3 (corresponds with Reach 2)
Coordinates for West End of Section: N 482231 E 1351470
Maximum Peak Flow Rate for Cell: Q = 149.0 cfs



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62/65

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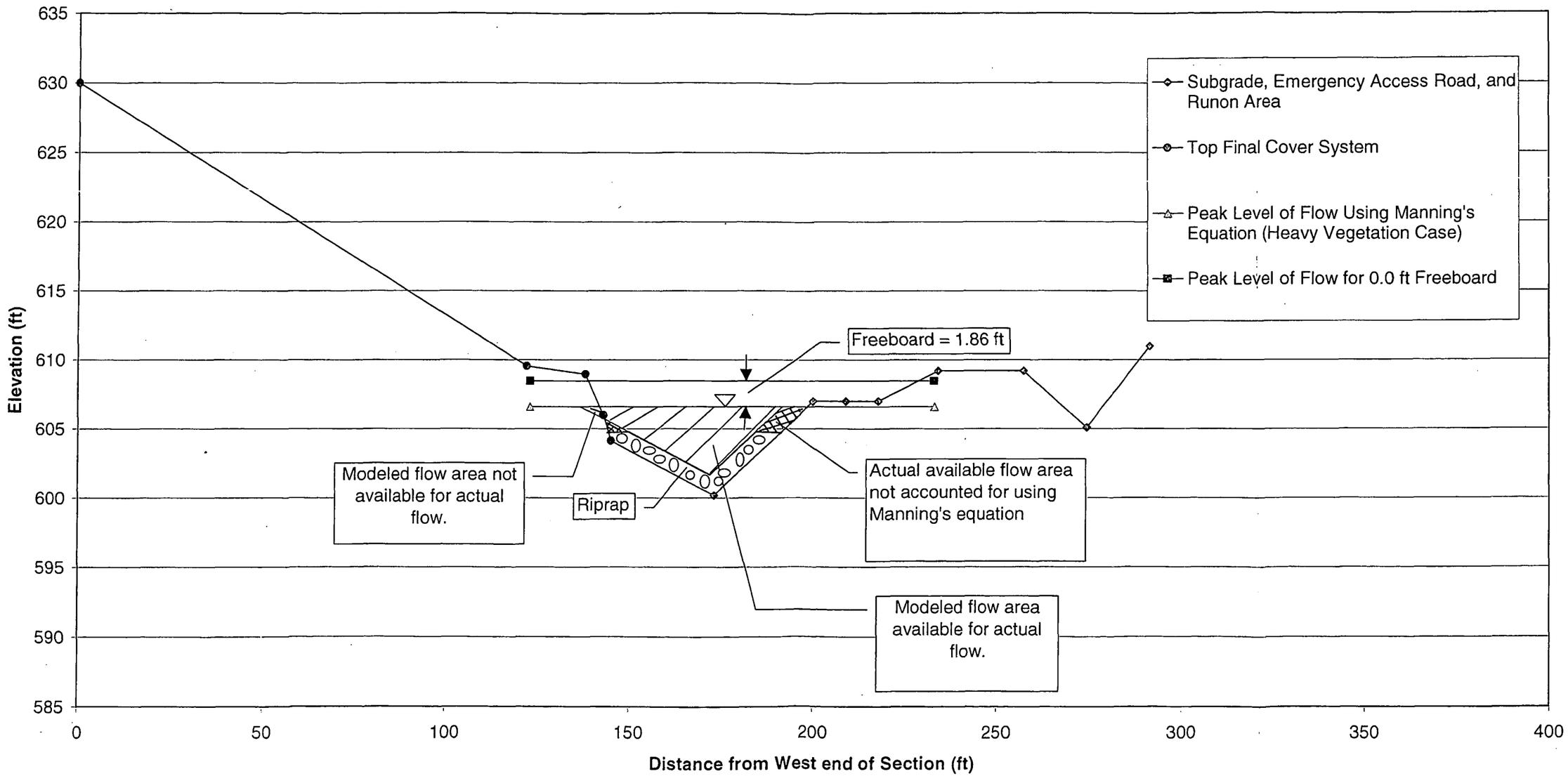
Analysis Cross-Section for Channel Segment Along Cell 4 (corresponds with Reach 3)
Coordinates for West End of Section: N 481859 E 1351467
Maximum Peak Flow Rate for Cell: Q = 191.5 cfs



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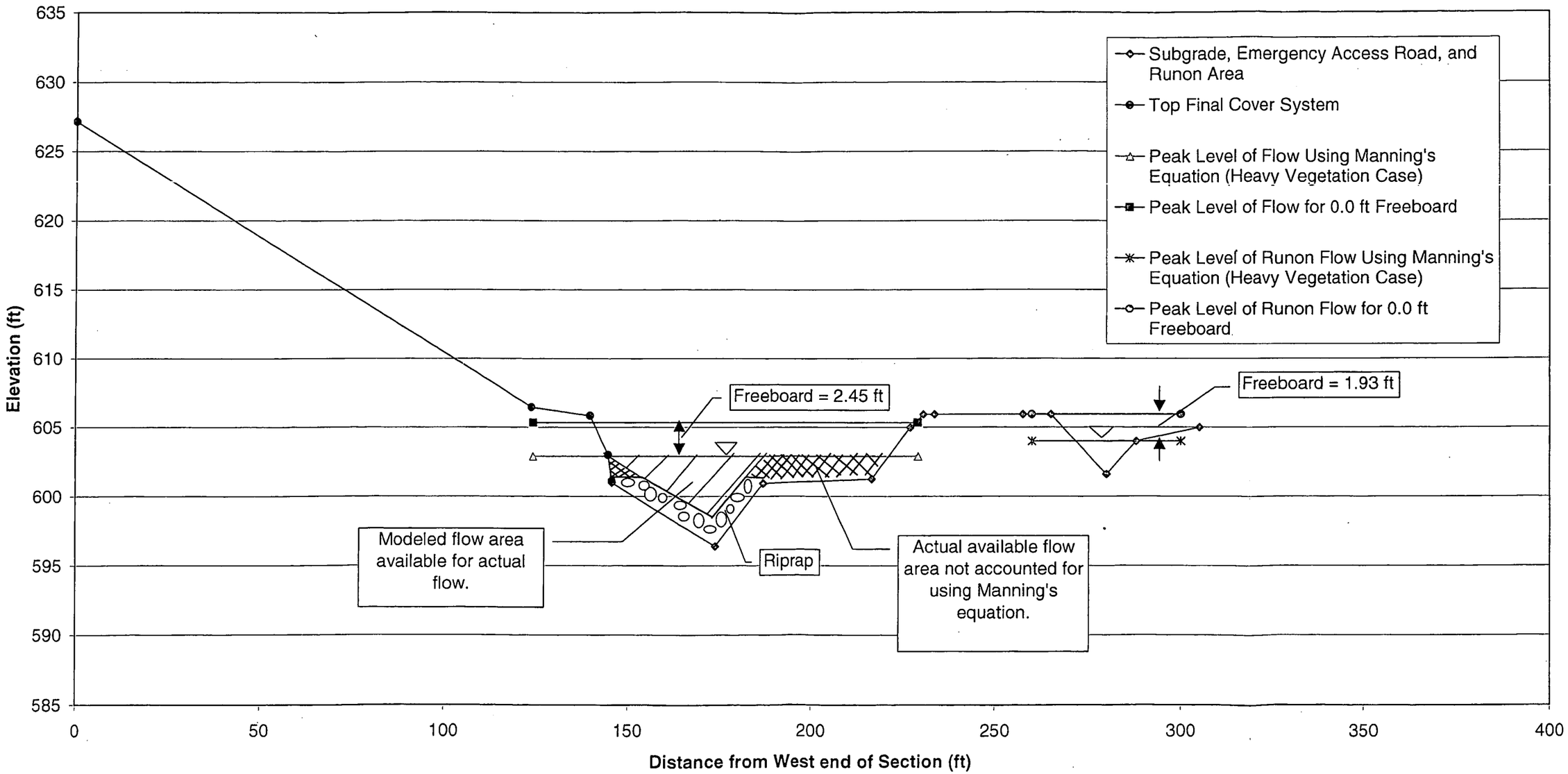
63/65
- 4664

Analysis Cross-Section for Channel Segment Along Cell 5 (corresponds with Reach 4)
Coordinates for West End of Section: N 481450 E 1351461
Maximum Peak Flow Rate for Cell: Q = 213.7 cfs



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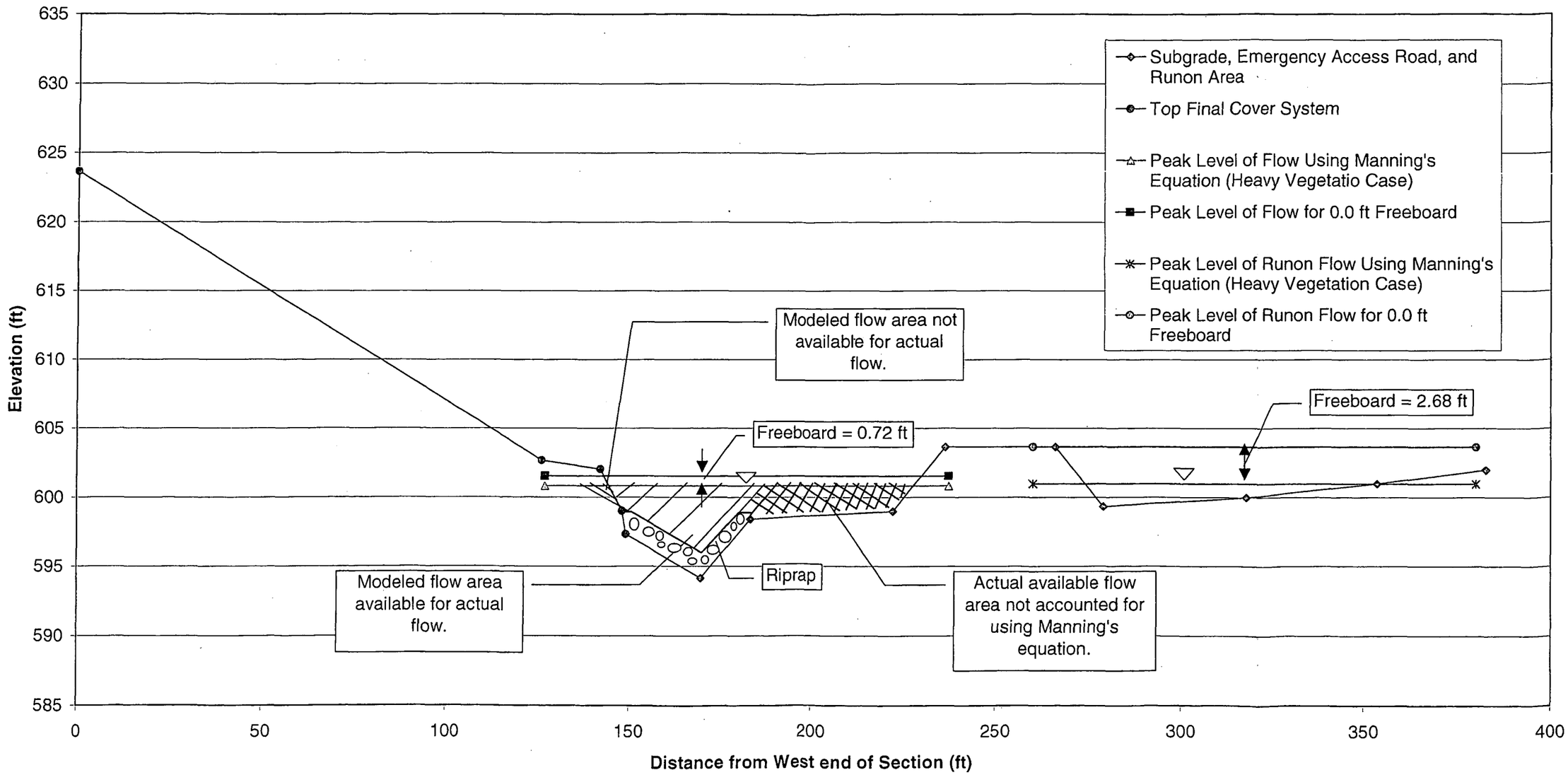
64/65

4664

Analysis Cross-Section for Channel Segment Clong Cell 6 (corresponds with Reach 5)
Coordinates for West End of Section: N 480941 E 1351453
Maximum Peak Flow Rate for Cell: Q = 232.1 cfs



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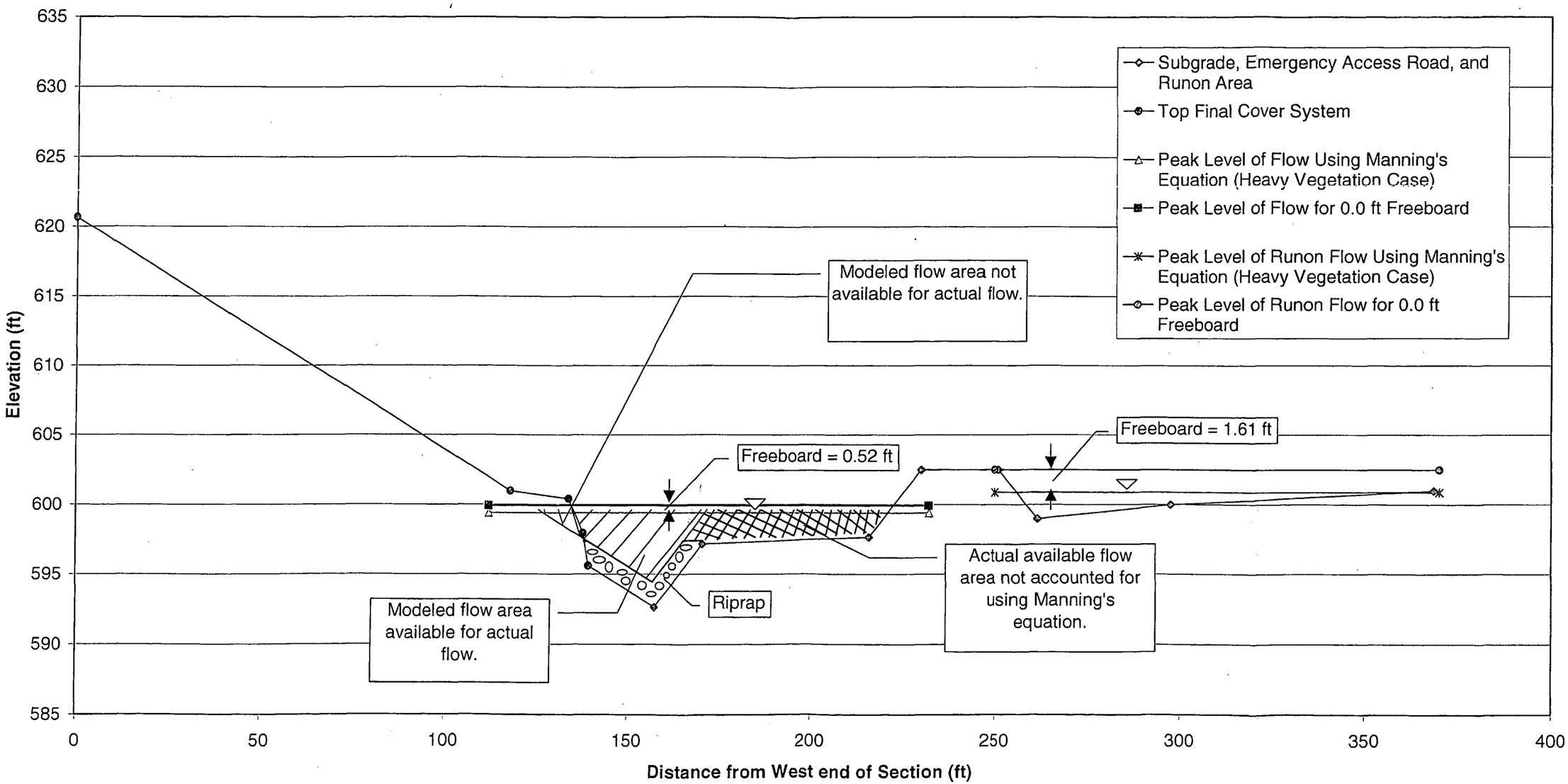
65/65

4664

Analysis Cross-Section for Channel Segment Along Cell 7 (corresponds with Reach 6)
Coordinates for West End of Section: N 480696 E 1351458
Maximum Peak Flow Rate for Cell: Q = 242.5 cfs



Section 13.4

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13.4 SEDIMENTATION EVALUATION OF PERMANENT DRAINAGE CHANNELS FOR HIGH-FREQUENCY DESIGN STORMS

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COMPUTATION COVER SHEET

SUBJECT OF COMPUTATIONS **SEDIMENTATION EVALUATION OF PERMANENT DRAINAGE CHANNELS FOR HIGH FREQUENCY STORM EVENTS**

Computations By:
(Cognizant Engineer)

Signature _____ Date: 25 Jan '02

Printed Name and Title: Ganesh Gopalakrishnan, P.E., Project Engineer

Assumptions and Procedures Checked By:
(Checker)

Signature _____ Date: 25 JAN 02

Printed Name and Title: Daniel G. Pass, P.E., Project Engineer

Computations Checked by:

Signature Dana Beth Mehlman Date: 29 Jan 2002

Printed Name and Title: Dana Beth Mehlman, Staff Engineer

Computations Backchecked by:
(Cognizant Engineer)

Signature _____ Date: 25 Jan 02

Printed Name and Title: Ganesh Gopalakrishnan, P.E., Project Engineer

Approved by:
(DTL)

Signature _____ Date: 25 JAN 02

Printed Name and Title: Daniel G. Pass, P.E., Project Engineer

Approved by:
(TETL)

Signature _____ Date: 29 JAN 2002

Printed Name and Title: J.F. Beech, Principal

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
0	SUBMITTAL TO EF/DOE/EPA	29 JAN 01	GG	DGP	DGP JFB

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Written by: Ganesh Gopalakrishnan (GG) Date: 1/25/2002 Reviewed by: Daniel G. Pass (DGP) Date: 1/25/20

Client: Fernald Project: Fernald OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.2 4

SEDIMENTATION EVALUATION OF PERMANENT DRAINAGE CHANNELS FOR HIGH-FREQUENCY STORM EVENTS

PURPOSE

The purpose of this package is to present an evaluation of the capacity of permanent channels associated with the Fernald On-Site Disposal Facility (OSDF) to resist accumulation of eroded sediments during high-frequency storm events (i.e., a low flow scenario). The 2-year 24-hour design storm event is considered for this evaluation. The hydrologic analysis results necessary to establish flows for the 2-year 24-hour design storm event were obtained from the calculation package titled "Phase V Surface-Water Management System Design and Post-Closure Hydrology".

APPROACH

The approach adopted in this package is to calculate a "maximum particle-size" corresponding to flow characteristics (i.e., velocity or tractive stress) in each drainage channel that will not be stable in the bed of the drainage channel. This implies that all sediment particle sizes smaller than the calculated maximum particle-size will be subject to movement (hereinafter referred to as "incipient motion") in the direction of flow for the conditions analyzed. The calculated maximum particle-size is compared to a site-specific envelope of laboratory particle-size distribution, which represents the range of particle sizes comprising surficial soils along permanent channel alignments and within the OSDF borrow area. For the purpose of this evaluation, permanent drainage channels are considered to be drainage channels within and south of the OSDF area expected to be in place at the end of Phase V construction.

METHODOLOGY

Three methods are used to evaluate the maximum particle-size expected to be subject to incipient motion under flow conditions considered for each drainage channel. Two methods correlate the flow velocity in the channel to a maximum particle-size (that is subject to incipient motion), and one method correlates the tractive stress in the channel to a maximum particle-size.

- **Method 1: Shield's Method [Vanoni, 1977].** The Shield's method provides a correlation between the shear stress in the channel and a maximum particle diameter subject to incipient motion. The Shield's Diagram used with this method is provided in Figure 1. As shown in Figure 1, the shear stress is expressed in terms of a dimensionless shear stress; and the particle diameter is expressed in terms of the Reynolds Number for flow at the boundary of the particle. For computational purposes, Shield's Diagram may be represented using the equation [USACE, 1995]

provided in Figure 2. Figure 2 also provides a graph for this equation relating particle diameter directly to the dimensionless shear (also called the Shield's Parameter). For calculations performed herein, the equation provided in Figure 2 is solved to obtain a maximum particle diameter, which will be subject to incipient motion due to the calculated tractive stress in the drainage channel.

- **Method 2: Hjulstrom's Curve [Hjulstrom, 1935].** This method relates the mean velocity in the channel and the particle diameter to one of three phases: erosion; sedimentation; and transportation. Figure 3 provides the Hjulstrom's Curve. A straight line boundary is provided between transportation and sedimentation phases. For calculations performed herein, an equation for this straight line is used to obtain a maximum particle diameter which will be subject to transportation (considered for the purposes of this calculation to correspond to incipient motion) due to the calculated velocity in the drainage channel.

- **Method 3: Mavis & Laushey Relationship [Vanoni, 1977].** Similar to Method 2 described above, this method provides a straight line boundary between transportation and sedimentation phases by relating the mean velocity in the channel and the particle diameter. Figure 4 provides this relationship. Similarly to Method 2, an equation for this straight line is used to obtain a maximum particle diameter which will be subject to incipient motion due to the calculated velocity in the drainage channel.

CALCULATIONS

- **Critical Particle Diameter.** Table 1 presents spreadsheet calculations for critical (i.e., maximum) particle diameter based on the Methods 1, 2, and 3 described above.

- **Particle-Size Distribution Curve.** An envelope of particle-size distribution for surficial soil samples collected and tested as part of the 1996 Test Pad Program is presented in Figure 5. This envelope presents the range of particles that are expected to be present along permanent drainage channels. The envelope was developed from particle-size distribution curves presented in the report "On-Site Disposal Facility Test Pad Program Final Report" [GeoSyntec, 1997]. These particle-size distribution curves are presented as Figure 6. Test samples are identified in the report as upper horizon brown till which comprises the surficial soil layer for the OSDF and borrow areas. A statistical comparison of particle-size diameters from the testing of 42 upper horizon brown till samples (obtained from locations distributed across the OSDF and borrow areas) and the Figure 5 envelope shows a consistency between the two sets of data.

RESULTS AND CONCLUSIONS

Calculation results presented on Table 1 show maximum particle sizes from the three methods to range from 3.9 mm to greater than 30mm. The minimum of the calculated maximum particle sizes for each method ranges from 3.9 mm to 5.9 mm. This range is shown plotted against the site-specific envelope of laboratory particle-size distribution on Figure 5. The minimum of this range (i.e., 3.9 mm) corresponds to 92% finer by weight on the minimum curve (See Figure 5). Based on this comparison, approximately 90% of the soil particles that form the bed of permanent drainage channels are expected to be resistant to significant sedimentation from the high-frequency storm event considered.

Based on the results presented above, permanent drainage channels are expected to exhibit a low potential for sedimentation after closure of the OSDF.

REFERENCES

GeoSyntec Consultants, "*On-Site Disposal Facility Test Pad program Final Report*", Volumes I to III, Fernald Environmental Management Project. DOE Fernald Area Office, Fernald, Ohio, 1997.

Hjulstrom, F., *The Morphological Activity of Rivers as Illustrated by River Fyris*, Bulletin of the Geological Institute, Uppasala, Vol. 25, Chapter 3., 1935.

USACE, *Sedimentation Investigation of Rivers and Reservoirs, Chapter 7: Sediment Transport Mechanics*, U.S. Army Corps of Engineers, Engineering Manual EM1110-2-4000, Washington D.C, 1975.

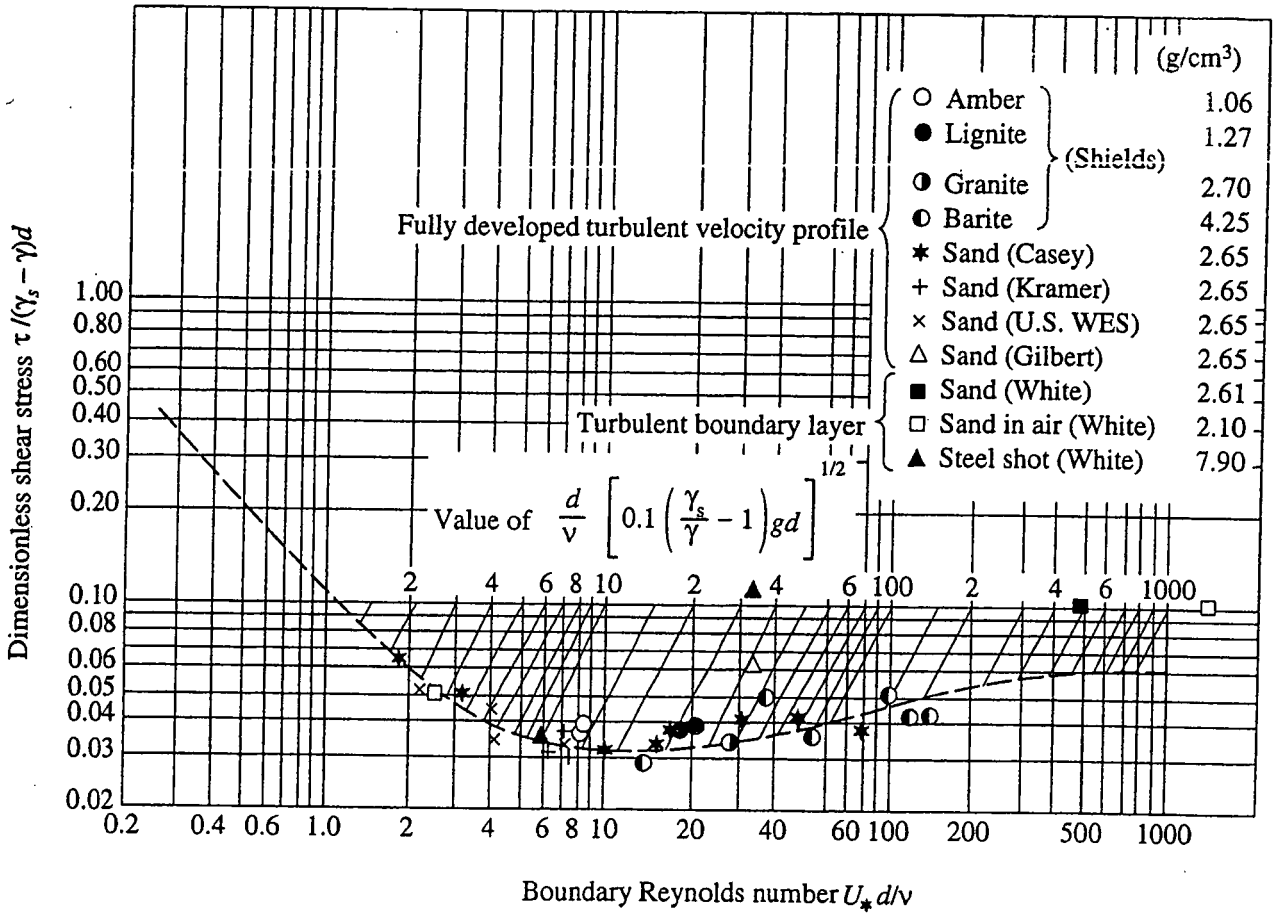
Vanoni, V.A., *Sedimentation Engineering*, ASCE Task Committee for the preparation of the Manual on Sedimentation of the Sedimentation Committee of the Hydraulics Division, 1975 (Reprinted 1977).

FIGURE 1

SHIELD'S DIAGRAM

Written by: GG Date: 01/12/18 (YY/MM/DD) Reviewed by: DCP Date: 02/01/25 (YY/MM/DD)

Client: FERNALD Project: OSDF PHASE V Project/Proposal No.: GQ1342 Task No.: 17.4



SHIELD'S DIAGRAM

FIGURE 2

SHIELD'S DIAGRAM – COMPUTATIONAL METHOD

4664 7/21

GG 1-28-02 DLP 01/25/02

$$\tau* = 0.22\,\beta + 0.06 \times 10^{-7.7\beta}$$

$$\beta = \left(\frac{1}{\nu} \sqrt{\left(\frac{\gamma_s - \gamma}{\gamma}\right) g d^3} \right)^{-0.6}$$

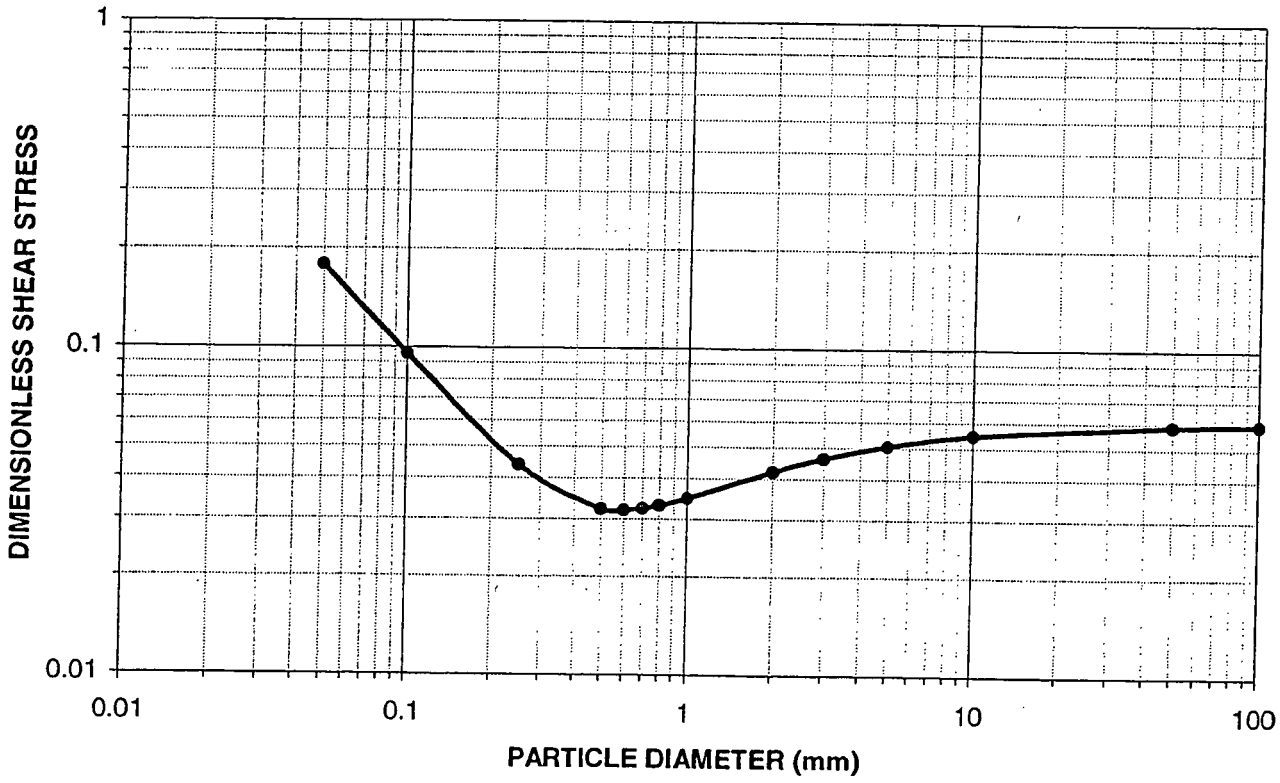
γ_s = particle specific weight

γ = fluid specific weight

ν = kinematic viscosity of the fluid

g = acceleration of gravity

d = particle diameter



Written by: Ganesh Gopalakrishnan (GG) Date: 1/25/2002 Reviewed by: Daniel G. Pass (DGP) Date: 01/25/02

Client: Fernald Project: Fernald OSDF Phase V Project/Proposal No.: GQ1342 Task No.: 17.4

4664

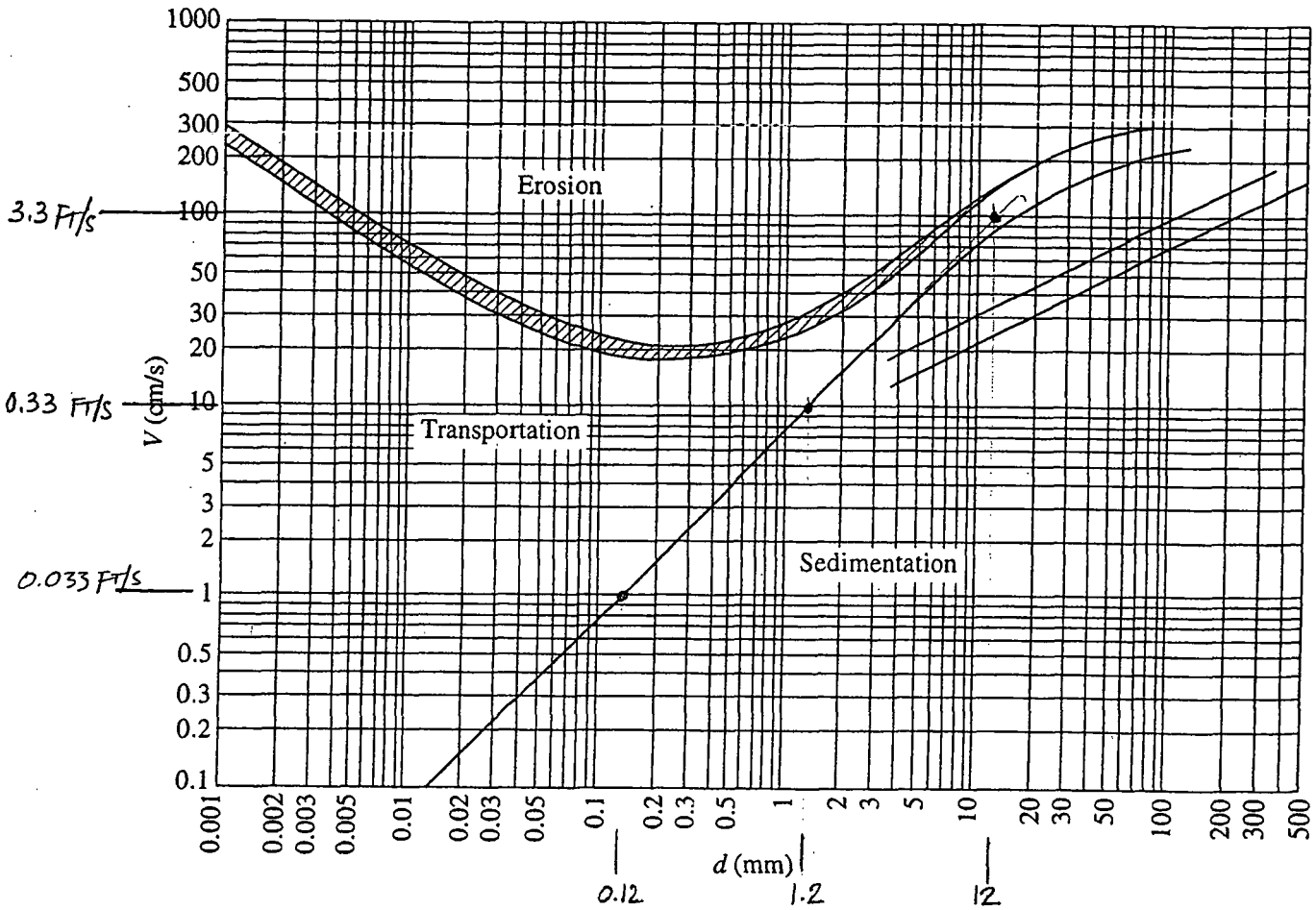
FIGURE 3

HJULSTROM'S CURVE

Written by: GG Date: 01/12/18 (YY/MM/DD) Reviewed by: DCP Date: 02/01/25 (YY/MM/DD)

Client: FERNALD Project: OSDF PHASE V Project/Proposal No.: GQ1342 Task No.: 17.4

4664



HJULSTROM'S CURVE

4664

FIGURE 4

MAVIS & LAUSHEY RELATIONSHIP

Written by: GG Date: 01/12/18 (YY/MM/DD) Reviewed by: DGP Date: 02/01/25 (YY/MM/DD)

Client: FERNALD Project: DSDF PHASE V Project/Proposal No.: GQ1342 Task No.: 17.X4

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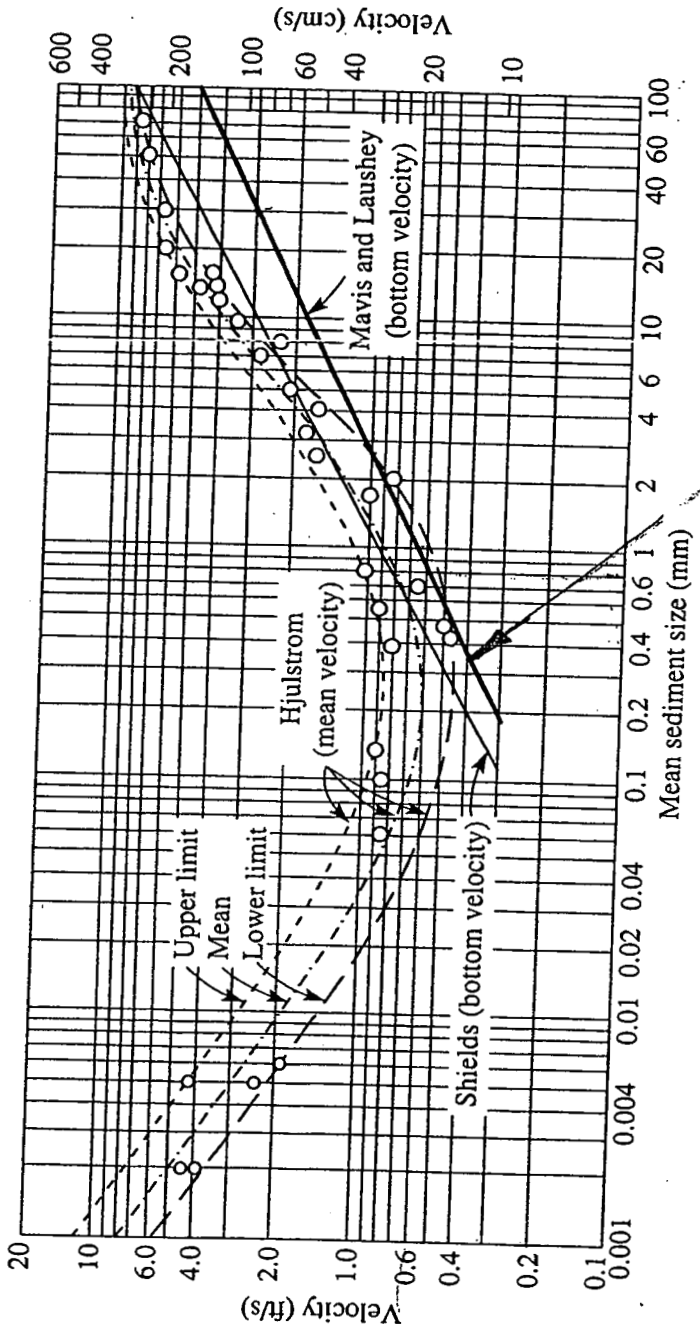
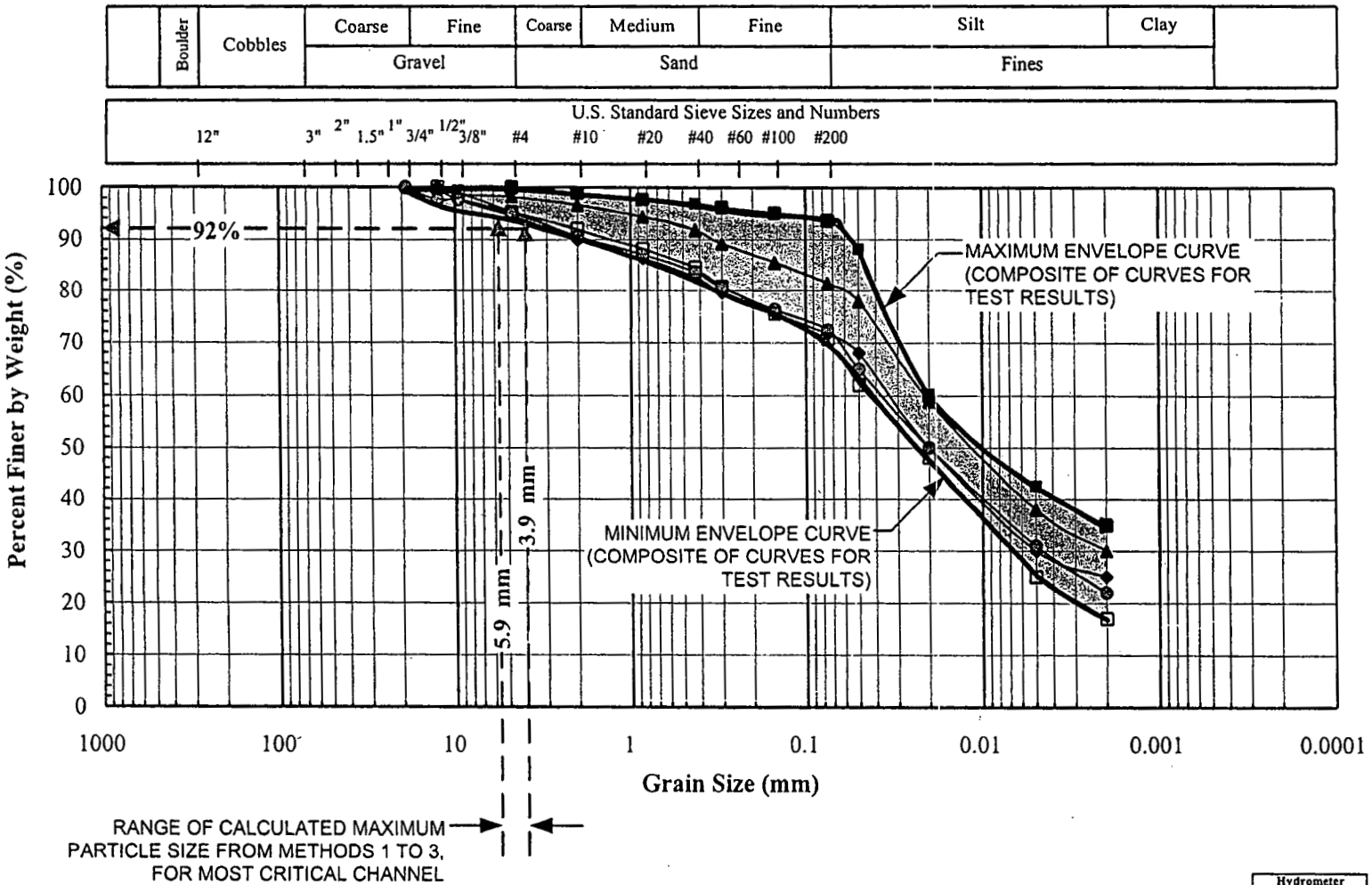


MAVIS-LAUSHEY RELATIONSHIP

FIGURE 5

SITE-SPECIFIC ENVELOPE OF PARTICLE-SIZE DISTRIBUTION

SITE-SPECIFIC ENVELOPE OF PARTICLE SIZE DISTRIBUTION



Hydrometer Particle Diameter (mm)
0.050
0.020
0.005
0.002
0.001

Sieve No.	Size (mm)
2"	50
1.5"	37.5
1"	25
3/4"	19
1/2"	12.5
3/8"	9.5
#4	4.75
#8	2.36
#10	2.00
#20	0.850
#40	0.425
#50	0.300
#60	0.250
#100	0.150
#200	0.075

NOTE: Grain Size Distribution Curves Obtained from "Test Pad Program Final Report" for 5 Upper Horizon Brown Till Samples.

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FIGURE NO. 5
PROJECT NO. GQ1342-17.2
DOCUMENT NO.
FILE NO. 000487

GH DCP 1-25-02 01/25/02

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4664

FIGURE 6

PARTICLE-SIZE DISTRIBUTION CURVES FOR UPPER HORIZON BROWN TILL

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FERNALD ON-SITE DISPOSAL FACILITY

PARTICLE SIZE DISTRIBUTION AND SOIL CLASSIFICATION TEST RESULTS

(ASTM D 422 & ASTM D 2487)

PROJECT: FERNALD ON-SITE DISPOSAL FACILITY

LOCATION: FERNALD, OHIO

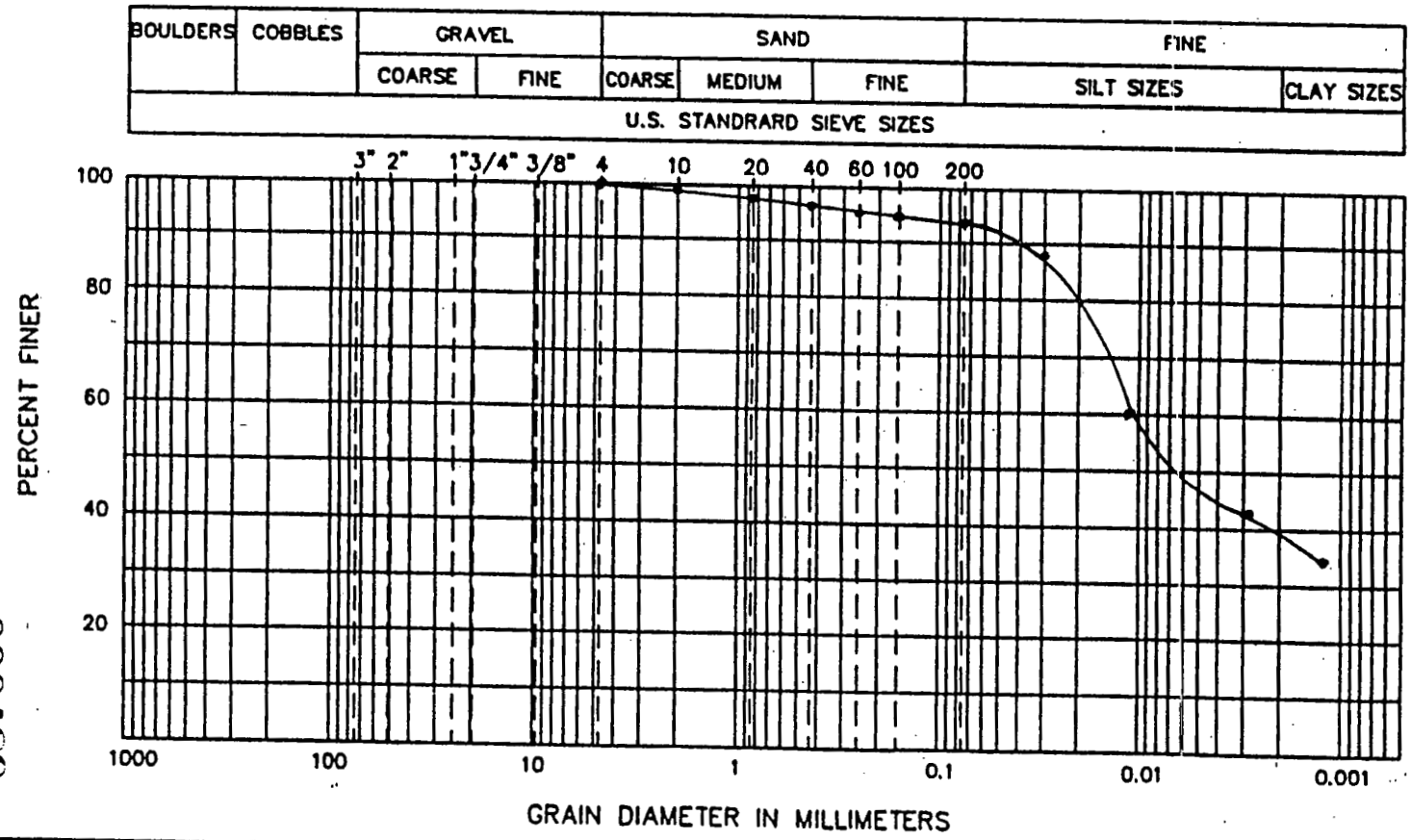
DESCRIPTION: TEST PAD CONST.

SOURCE: ON-SITE BORROW MATERIAL TYPE: UPPER HOR. Br. TILL

PROJECT NO.: GE 3900 TASK NO.: 5.3

DATE: 11 day JUNE month 1996 year

SAMPLE NO.: UH-01 QA ID: NM



CURVE COEFFICIENTS

(C_u) —

(C_c) —

ATTERBERG LIMITS

(LL) 55

(PL) 22

(PI) 33

SIEVE RESULTS

SIEVE SIZE	% FINER
3-in.	
2-in.	
1 1/2-in.	
1-in.	
3/4-in.	
1/2-in.	
3/8-in.	
NO. 4	100
NO. 10	98.9
NO. 20	97.7
NO. 40	96.9
NO. 60	96.1
NO. 100	95.0
NO. 200	93.6

GG 1-25-02

1> (2)

DGP 08/25/02

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000489

SOIL CLASSIFICATION (ASTM D 2487): BROWN — FAT CLAY (CH)

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GeoSyntec Consultants

FERMCO Fernald Environmental Restoration Management Corporation

FERNALD ON-SITE DISPOSAL FACILITY

PARTICLE SIZE DISTRIBUTION AND SOIL CLASSIFICATION TEST RESULTS

(ASTM D 422 & ASTM D 2487)

PROJECT: FERNALD ON-SITE DISPOSAL FACILITY

LOCATION: FERNALD, OHIO

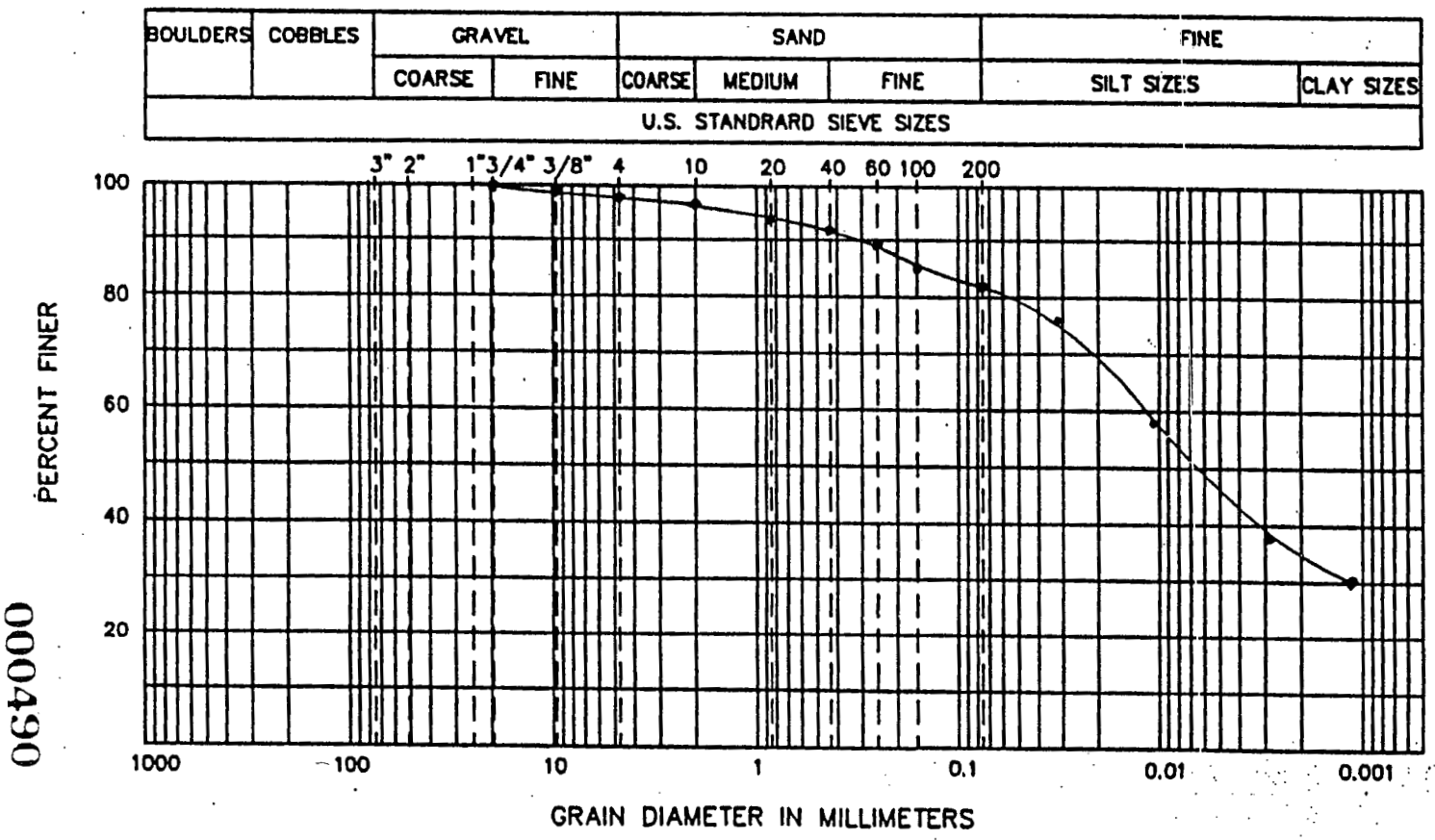
PROJECT NO.: GE 3900 TASK NO.: 5.3

DESCRIPTION: TEST PAD CONSTRUCTION

DATE: 19 day JUNE month 1996 year

SOURCE: ON-SITE BORROW 1'-2' MATERIAL TYPE: UPPER HORIZON BR. TILL

SAMPLE NO.: UH-04 QA ID: NM



000490

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CURVE COEFFICIENTS

(C_u) —

(C_c) —

ATTERBERG LIMITS

(LL) 49

(PL) 22

(PI) 27

SIEVE RESULTS

SIEVE SIZE	% FINER
3-in.	
2-in.	
1 1/2-in.	
1-in.	
3/4-in.	
1/2-in.	100
3/8-in.	98.7
NO. 4	98.2
NO. 10	96.6
NO. 20	94.3
NO. 40	91.8
NO. 60	89.1
NO. 100	85.4
NO. 200	81.5

SOIL CLASSIFICATION (ASTM D 2487): BROWN & GRAY - LEAN CLAY (CL) w/ SOME SAND & TR. of gvl

16/21 DCP 01/25/02

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FERMCO Fernald Environmental Restoration Management Corporation

FERNALD ON-SITE DISPOSAL FACILITY

PARTICLE SIZE DISTRIBUTION AND SOIL CLASSIFICATION TEST RESULTS (ASTM D 422 & ASTM D 2487)

PROJECT: FERNALD ON-SITE DISPOSAL FACILITY

LOCATION: FERNALD, OHIO

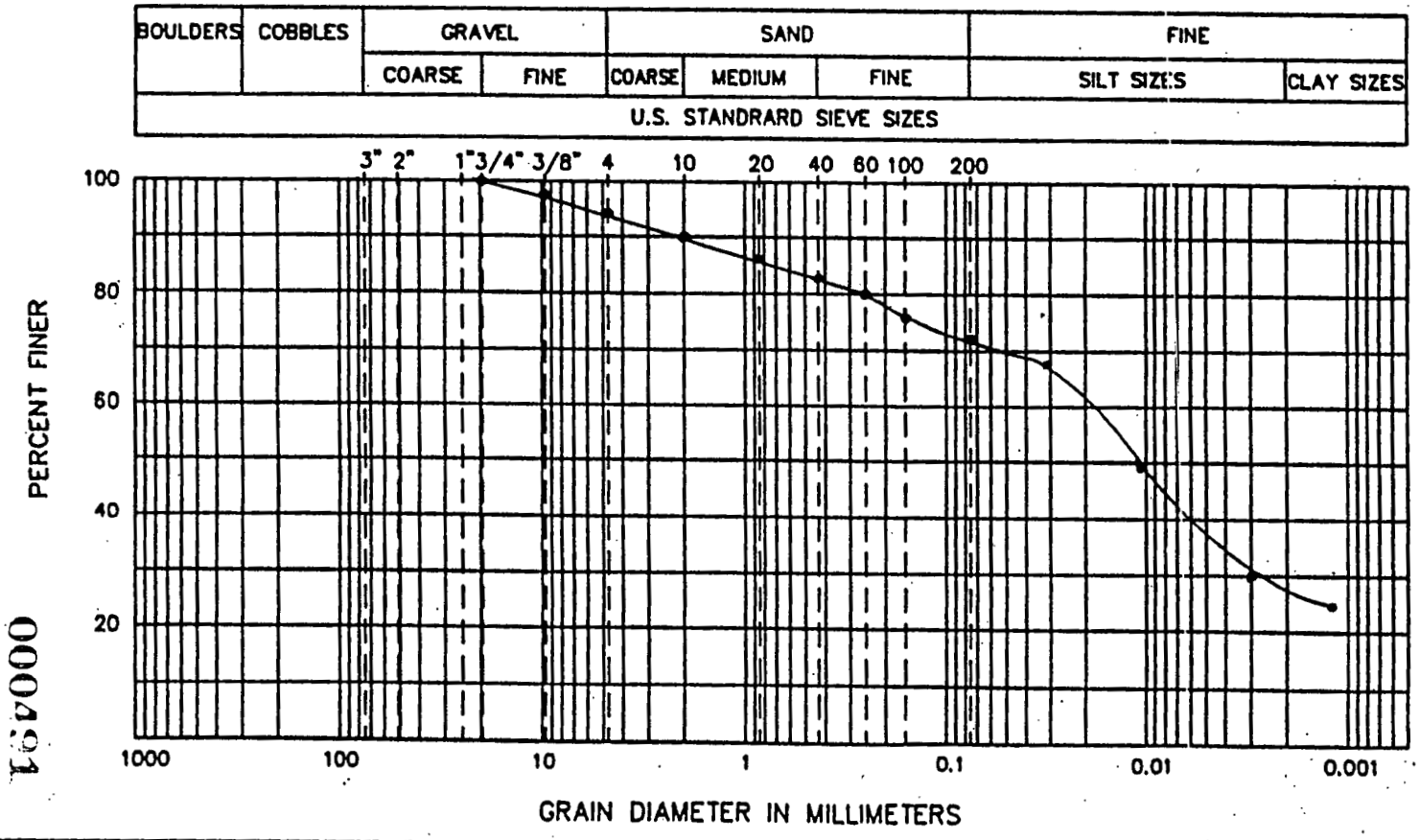
PROJECT NO.: GE3900 TASK NO.: 5.3

DESCRIPTION: TEST PAD CONSTRUCTION

DATE: 19 day JUNE month 1996 year

SOURCE: ON-SITE BORROW 2'-3' MATERIAL TYPE: UPPER HORIZON BR. TILL

SAMPLE NO.: UH-05 QA ID: NM



000491

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CURVE COEFFICIENTS

(C_u) —

(C_c) —

ATTERBERG LIMITS

(LL) 36

(PL) 19

(PI) 17

SIEVE RESULTS

SIEVE SIZE	% FINER
3-in.	
2-in.	
1 1/2-in.	
1-in.	
3/4-in.	
1/2-in.	100
3/8-in.	97.6
NO. 4	94.4
NO. 10	89.8
NO. 20	86.1
NO. 40	82.6
NO. 60	79.6
NO. 100	75.6
NO. 200	71.6

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SOIL CLASSIFICATION (ASTM D 2487): BROWN & GRAY — LEAN CLAY (CL) W/ SOME SAND & GVL.

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SHEET NO. 3 of 3

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FERNALD ON-SITE DISPOSAL FACILITY

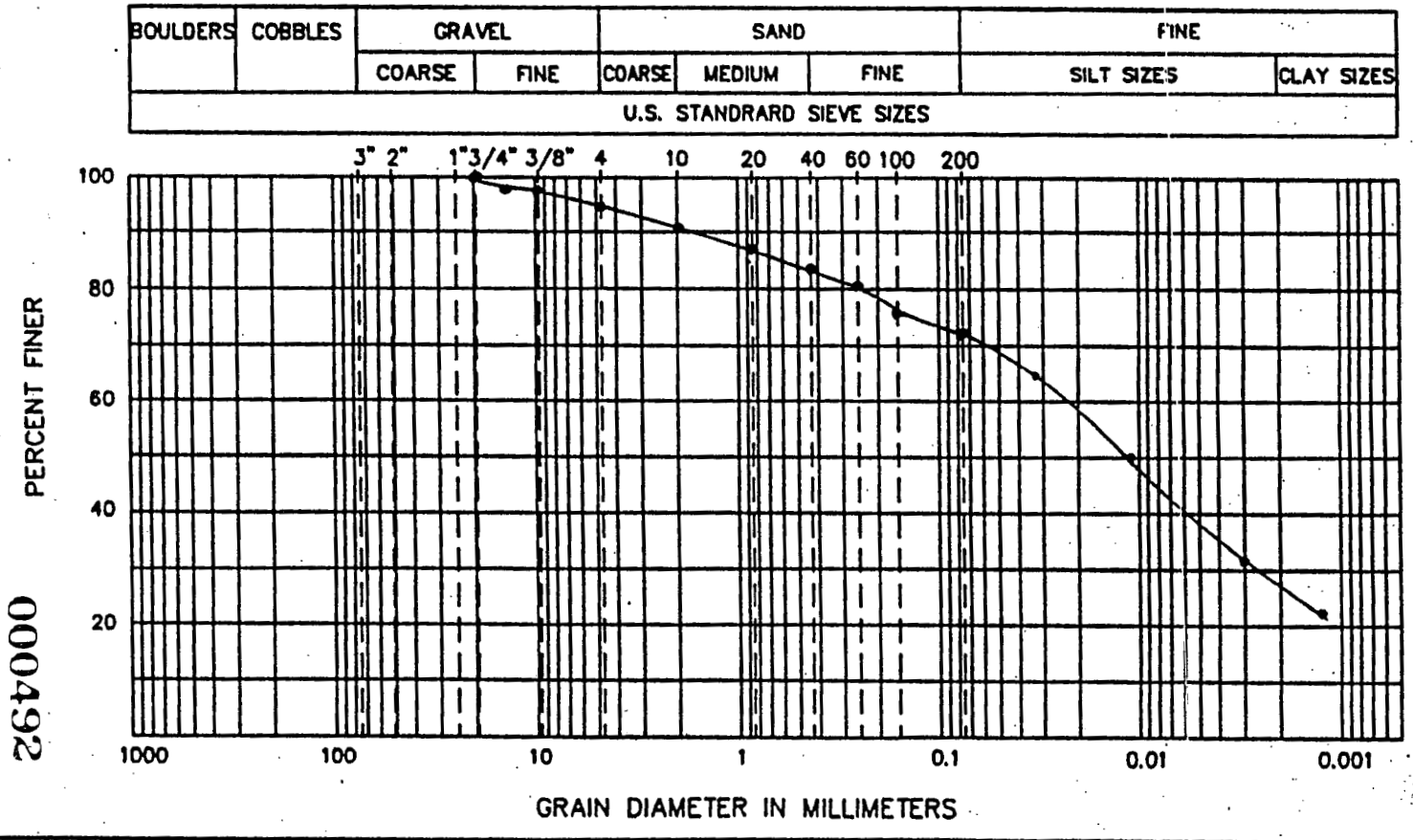
PARTICLE SIZE DISTRIBUTION AND SOIL CLASSIFICATION TEST RESULTS (ASTM D 422 & ASTM D 2487)

PROJECT: FERNALD ON-SITE DISPOSAL FACILITY

LOCATION: FERNALD, OHIO PROJECT NO.: GE3900 TASK NO.: 5.3

DESCRIPTION: TEST PAD CONSTRUCTION DATE: 19 day JUNE month 1996 year

SOURCE: ON-SITE BORROW 3'-4' MATERIAL TYPE: UPPER HORIZON BR. TILL SAMPLE NO.: UH-06 QA ID: NM



CURVE COEFFICIENTS

(C_u) —

(C_c) —

ATTERBERG LIMITS

(LL) 32

(PL) 18

(PI) 14

SIEVE RESULTS

SIEVE SIZE	% FINER
3-in.	
2-in.	
1 1/2-in.	
1-in.	
3/4-in.	100
1/2-in.	97.6
3/8-in.	97.6
NO. 4	95.0
NO. 10	90.6
NO. 20	86.9
NO. 40	83.5
NO. 60	80.5
NO. 100	76.4
NO. 200	72.4

SOIL CLASSIFICATION (ASTM D 2487): BROWN & GRAY — SANDY LEAN CLAY (CL) w/ some Gravel

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GG/1-25-02 18/21 PCP 01/25/02

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FERMCO Restoration Management Corporation

FERNALD ON-SITE DISPOSAL FACILITY

PARTICLE SIZE DISTRIBUTION AND SOIL CLASSIFICATION TEST RESULTS

(ASTM D 422 & ASTM D 2487)

PROJECT: FERNALD ON-SITE DISPOSAL FACILITY

LOCATION: FERNALD, OHIO

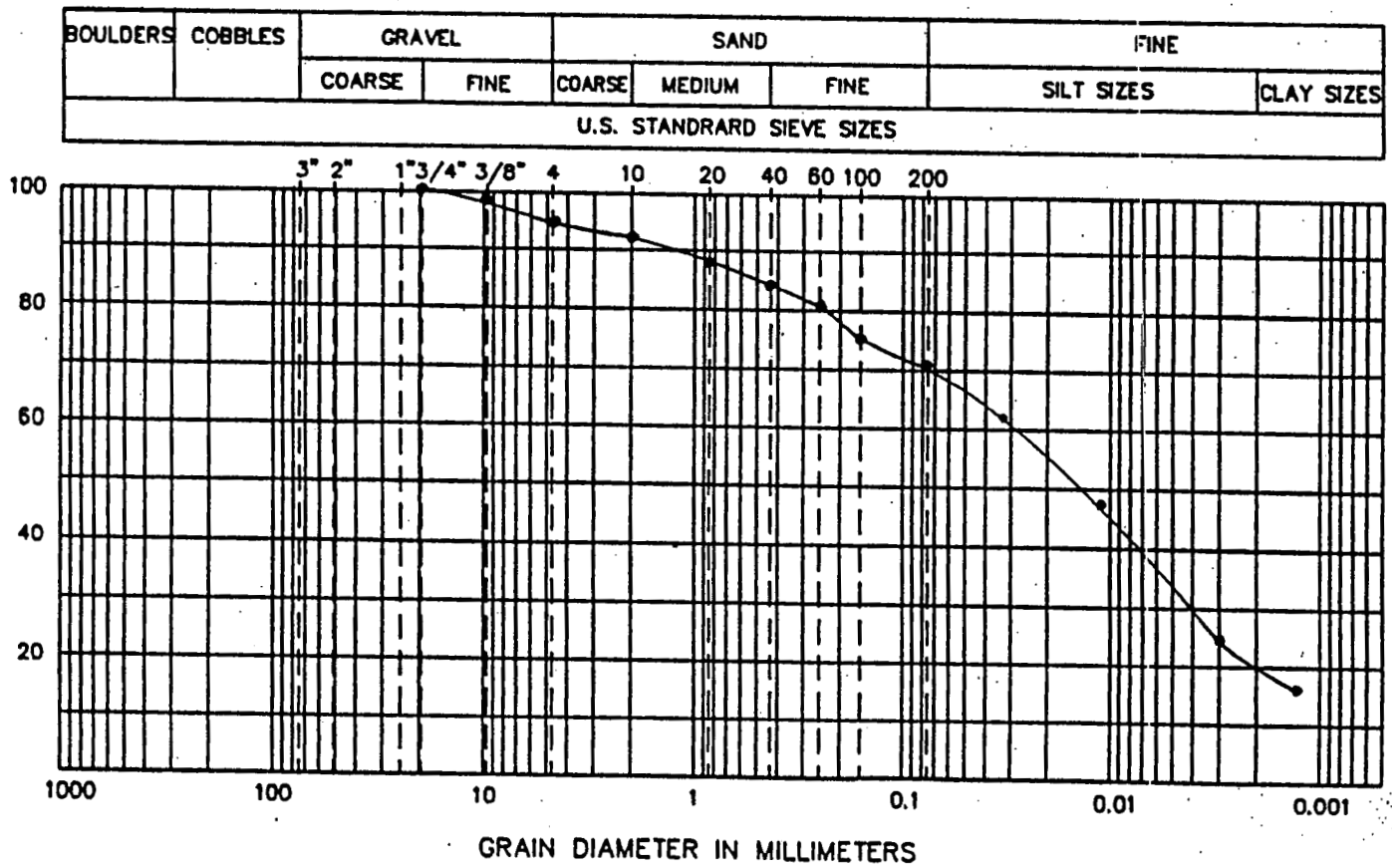
PROJECT NO.: GE 3900 TASK NO.: 5.3

DESCRIPTION: TEST PAD CONSTRUCTION

DATE: 19 day JUNE month 1996 year

SOURCE: ON-SITE BORROW 4'-5' MATERIAL TYPE: UPPER HORIZON BR TILL

SAMPLE NO.: UH-07 QA ID: NM



000493

4664

CURVE COEFFICIENTS

(C_u) —

(C_c) —

ATTERBERG LIMITS

(LL) 28

(PL) 17

(PI) 11

SIEVE RESULTS

SIEVE SIZE	% FINER
3-in.	
2-in.	
1 1/2-in.	
1-in.	
3/4-in.	
1/2-in.	100
3/8-in.	99.1
NO. 4	95.2
NO. 10	91.9
NO. 20	88.1
NO. 40	84.4
NO. 60	80.8
NO. 100	75.6
NO. 200	70.6

GTG 1-23-02 19/21 DCP 08/25/0

SOIL CLASSIFICATION (ASTM D 2487): BROWN & GRAY - SANDY LEAN CLAY (CL) W/ SOME GRAVEL

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SHEET NO. 3 OF 3

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TABLE 1

SPREADSHEET COMPUTATIONS

21/21 YCT 01/25/02 GG 1-25-02 DBM 1-29-2002

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TABLE 1

CALCULATIONS FOR SEDIMENTATION IN DRANAGE CHANNELS
FERNALD OSDF, PHASE V DESIGN

Input Parameters for Shield's Method

Water Temperature =	68	deg F
Kinematic Viscosity of Fluid =	1.08E-05	ft2/s
Particle Specific Weight =	165	psf
Unit Weight of Fluid =	62.4	psf

CHANNEL PROPERTIES									CALCULATED HYDRAULIC PROPERTIES								SHIELD'S METHOD					HJULSTROM's METHOD	MAVIS & LAUSHLEY
Location	Channel ID	Status	Peak 2-yr 24-hr Discharge	Bottom Width	Left Side Slope	Right Side Slope	Manning's Roughness	Channel Slope	Depth of Flow	Area of Flow	Wetted Perimeter	Hydraulic Radius	Slope	Average Velocity	Flow Rate (Check)	Average Tractive Stress	Critical Particle Diameter		Shield's Computational Parameter	Dimensionless Shield's Parameter	Dimensionless Shear Stress	Critical Particle Diameter	Critical Particle Diameter
			Q	B	Z1	Z2	n	So	Y	A	P	R=A/P		V	Q=AV	t_o	d	d	β		2.000	d	d
			cfs	ft	H:1V	H:1V		ft/ft	ft	ft^2	ft	ft	ft/ft	ft/s	ft^3/s	lb/ft^2	mm	ft				mm	mm
East	1	existing	5.0	0.0	6.0	4.0	0.030	0.0045	0.75	2.81	7.65	0.37	0.0045	1.71	4.8	0.103	5.92	1.94E-02	1.10E-02	5.18E-02	5.17E-02	6.21	8.881
East	2	existing	7.1	0.0	3.0	5.0	0.030	0.0045	0.95	3.61	7.85	0.46	0.0045	1.98	7.2	0.129	7.17	2.35E-02	9.28E-03	5.29E-02	5.35E-02	7.22	12.348
East	3	proposed	8.7	0.0	3.0	4.0	0.030	0.0050	1.05	3.86	7.65	0.50	0.0050	2.22	8.6	0.157	8.67	2.85E-02	7.82E-03	5.40E-02	5.39E-02	8.09	15.875
East	4	proposed	10.0	0.0	3.0	4.0	0.030	0.0050	1.11	4.31	8.09	0.53	0.0050	2.31	10.0	0.166	9.13	2.99E-02	7.47E-03	5.42E-02	5.42E-02	8.40	17.224
East	5	proposed	11.1	0.0	3.0	6.0	0.030	0.0050	1.05	4.96	9.71	0.51	0.0050	2.24	11.1	0.159	8.69	2.85E-02	7.80E-03	5.40E-02	5.45E-02	8.16	16.183
East	6	proposed	11.7	0.0	3.0	6.0	0.030	0.0100	0.93	3.89	8.60	0.45	0.0100	2.93	11.4	0.282	14.95	4.90E-02	4.79E-03	5.62E-02	5.61E-02	10.64	29.029
East	7	proposed	11.6	0.0	6.0	3.0	0.030	0.0100	0.93	3.89	8.60	0.45	0.0100	2.93	11.4	0.282	14.95	4.90E-02	4.79E-03	5.62E-02	5.61E-02	10.64	29.029
East	8	proposed	10.7	10.0	3.0	3.0	0.030	0.0045	0.49	5.62	13.10	0.43	0.0045	1.89	10.6	0.120	6.80	2.23E-02	9.73E-03	5.26E-02	5.26E-02	6.89	11.150
East	9	proposed	10.7	10.0	3.0	3.0	0.030	0.0045	0.49	5.62	13.10	0.43	0.0045	1.89	10.6	0.120	6.80	2.23E-02	9.73E-03	5.26E-02	5.26E-02	6.89	11.150
East	10	proposed	11.7	10.0	3.0	3.0	0.030	0.0045	0.51	5.88	13.23	0.44	0.0045	1.94	11.4	0.125	7.02	2.30E-02	9.46E-03	5.28E-02	5.28E-02	7.06	11.748
East	12	proposed	11.9	10.0	3.0	3.0	0.030	0.0045	0.53	6.14	13.35	0.46	0.0045	1.99	12.2	0.129	7.13	2.34E-02	9.32E-03	5.29E-02	5.38E-02	7.22	12.351
East	13	proposed	22.4	20.0	3.0	3.0	0.030	0.0045	0.51	10.98	23.23	0.47	0.0045	2.02	22.2	0.133	7.42	2.44E-02	9.00E-03	5.31E-02	5.31E-02	7.35	12.855
East	14	existing	1.0	0.0	3.0	5.0	0.030	0.0040	0.47	0.88	3.88	0.23	0.0040	1.17	1.0	0.057	3.53	1.16E-02	1.75E-02	4.78E-02	4.77E-02	4.26	3.863
East	15	existing	2.7	0.0	3.0	5.0	0.030	0.0063	0.61	1.49	5.04	0.30	0.0063	1.75	2.6	0.116	6.58	2.16E-02	1.00E-02	5.24E-02	5.24E-02	6.36	9.333
East	16	existing	3.2	0.0	2.5	5.0	0.030	0.0074	0.65	1.58	5.06	0.31	0.0074	1.97	3.1	0.144	8.01	2.63E-02	8.40E-03	5.35E-02	5.35E-02	7.16	12.122
East	17	existing	5.5	0.0	4.0	5.0	0.030	0.0125	0.67	2.02	6.18	0.33	0.0125	2.63	5.3	0.255	13.58	4.45E-02	5.23E-03	5.58E-02	5.58E-02	9.58	23.017
East	18	proposed	9.1	0.0	3.0	3.0	0.030	0.0100	1.01	3.06	6.39	0.48	0.0100	3.04	9.3	0.299	15.62	5.12E-02	4.61E-03	5.63E-02	5.69E-02	11.06	31.547
East	19	proposed	10.1	0.0	3.0	3.0	0.030	0.0090	1.07	3.43	6.77	0.51	0.0090	3.00	10.3	0.285	14.94	4.90E-02	4.80E-03	5.62E-02	5.67E-02	10.90	30.578
East	20	proposed	10.0	0.0	3.0	3.0	0.030	0.0083	1.07	3.43	6.77	0.51	0.0083	2.88	9.9	0.264	14.02	4.60E-02	5.08E-03	5.60E-02	5.59E-02	10.49	28.084
East	30	proposed	7.7	0.0	3.0	3.0	0.030	0.0100	0.95	2.71	6.01	0.45	0.0100	2.92	7.9	0.281	14.73	4.83E-02	4.86E-03	5.61E-02	5.67E-02	10.61	28.836
East	21	proposed	7.8	0.0	3.0	3.0	0.030	0.0100	0.95	2.71	6.01	0.45	0.0100	2.92	7.9	0.281	14.73	4.83E-02	4.86E-03	5.61E-02	5.67E-02	10.61	28.836
East	22	proposed	8.0	0.0	3.0	3.0	0.030	0.0100	0.95	2.71	6.01	0.45	0.0100	2.92	7.9	0.281	14.89	4.88E-02	4.81E-03	5.62E-02	5.61E-02	10.61	28.836
East	29	proposed	8.2	0.0	3.0	3.0	0.030	0.0100	0.97	2.82	6.13	0.46	0.0100	2.96	8.4	0.287	15.03	4.93E-02	4.77E-03	5.62E-02	5.68E-02	10.76	29.731
East	24	proposed	9.3	8.5	3.0	3.0	0.030	0.0075	0.43	4.21	11.22	0.38	0.0075	2.24	9.4	0.176	9.41	3.09E-02	7.27E-03	5.43E-02	5.55E-02	8.13	16.063
East	26	proposed	10.4	0.0	3.0	3.0	0.030	0.0075	1.11	3.70	7.02	0.53	0.0075	2.80	10.4	0.246	13.15	4.31E-02	5.38E-03	5.57E-02	5.57E-02	10.20	26.406
West	1	proposed	4.7	0.0	3.0	6.0	0.030	0.0075	0.71	2.27	6.56	0.35	0.0075	2.12	4.8	0.162	8.77	2.88E-02	7.74E-03	5.40E-02	5.48E-02	7.70	14.237
West	2	proposed	7.2	0.0	3.0	6.0	0.030	0.0075	0.83	3.10	7.67	0.40	0.0075	2.35	7.3	0.189	10.15	3.33E-02	6.79E-03	5.47E-02	5.54E-02	8.55	17.903
West	3	proposed	9.4	0.0	3.0	6.0	0.030	0.0075	0.91	3.73	8.41	0.44	0.0075	2.50	9.3	0.207	11.19	3.67E-02	6.22E-03	5.51E-02	5.51E-02	9.09	20.491
West	4	proposed	9.3	0.0	3.0	6.0	0.030	0.0076	0.91	3.73	8.41	0.44	0.0076	2.52	9.4	0.210	11.20	3.67E-02	6.22E-03	5.51E-02	5.57E-02	9.15	20.792
West	6	proposed	10.7	0.0	3.0	6.0	0.030	0.0075	0.95	4.06	8.78	0.46	0.0075	2.57	10.4	0.216	11.64	3.82E-02	6.00E-03	5.53E-02	5.53E-02	9.35	21.826
West	7	proposed	10.7	0.0	3.0	3.0	0.030	0.0075	1.13	3.83	7.15	0.54	0.0075	2.84	10.9	0.251	13.25	4.35E-02	5.34E-03	5.58E-02	5.63E-02	10.32	27.107
West	8	proposed	13.1	0.0	3.0	3.0	0.030	0.0075	1.21	4.39	7.65	0.57	0.0075	2.97	13.0	0.269	14.26	4.68E-02	5.00E-03	5.60E-02	5.60E-02	10.80	29.969
West	9	proposed	1.3	0.0	3.0	3.0	0.030	0.0261	0.39	0.46	2.47	0.18	0.0261	2.60	1.2	0.301	15.88	5.21E-02	4.54E-03	5.64E-02	5.63E-02	9.46	22.413
West	10	proposed	1.3	0.0	3.0	3.0	0.030	0.0148	0.45	0.61	2.85	0.21	0.0148	2.15	1.3	0.196	10.64	3.49E-02	6.51E-03	5.49E-02	5.49E-02	7.83	14.773
West	11	proposed	3.2	0.0	3.0	3.0	0.030	0.0066	0.73	1.60	4.62	0.35	0.0066	1.99	3.2	0.143	7.92	2.60E-02	8.48E-03	5.35E-02	5.35E-02	7.23	12.405

000495