APPENDIX B
DESIGN EXAMPLES FOR SELECTED EROSION AND SEDIMENT CONTROL PRACTICES

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APPENDIX B
DESIGN EXAMPLES FOR SELECTED EROSION AND SEDIMENT CONTROL PRACTICES

Background

Standard details and drawings for temporary erosion and sediment control practices have been used since the early 1970's. Many of these details were developed by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS), now known as the Natural Resources Conservation Service (NRCS). These details were incorporated into many state design manuals. These practices included the following:

- Earth Dike
- Construction Ditch
- Perimeter Dike/Swale
- Flow Spreader
- Pipe Slope Drain
- Straw Bale Dike
- Silt Fence

What made the use of these details attractive was that they were sized based upon the drainage area, and no extensive engineering calculations were needed for design. For example, if we needed to design a construction ditch to control the runoff from 8 acres above a disturbed construction area by sloping the swale at 3 percent, we would look at page 3.4 and select Ditch B, with a channel treatment of seed and straw mulch. The Ditch B cross section is a 6-foot bottom width, 1-foot design depth, and 2:1 side slopes.

This selection process is independent of location in New York State as well as the design rainfall amount. As a result, individuals have often wondered what level of protection is actually being provided.

Site specific practice design depends on a number of variables. These include drainage area, hydrologic soil group, cover, topography, rainfall amount, and intensity or distribution.

The following design examples illustrate how these variables can be incorporated into site specific design process.

Determining Stormwater Runoff

Stormwater runoff volumes and peak discharges should be calculated using current hydrologic data. As noted in Section 1, the hydrologic data published by the Northeast Regional Climate Center (NRCC), provides updated rainfall values for a wide range on frequencies and durations on their website, http://precip.eas.cornell.edu/. These data combined with construction site runoff curve numbers are then used with appropriate software to calculate peak rates of runoff, runoff volumes, and flow durations.

A detailed example of this process is presented in the design example for Sediment Basin Design.

Runoff Control Practices Design Examples

This method of designing a practice or evaluating the performance of a proposed practice, is applicable to most of the temporary runoff practices. The first example evaluates the effectiveness of the construction ditch.

Example 1: Case 1 - Construction Ditch A

Given:

Drainage Area = 4.9 acres

Hydrologic Soil Group = C

Runoff Curve Number = 91 (C soil disturbed for construction)

Slope of Swale = 3%

Rainfall (P) = 2.5 inches (from NRCC) (This represents NY state's average 1-year, 24-hour storm)

Runoff (Q) = 1.6 inches (from TR55 RCN tables)

Time of Concentration for Runoff (T_c) = 6 minute (assumed 0.1 hour, the shortest allowed with TR-55)

From HydroCAD routing:

Q_p = 12.2 cfs

For Ditch A, the design cross-section shows a bottom width of 4 feet., design depth of 1 foot, and 2:1 side slopes.

Therefore, ditch area = 6 ft^2 for design depth

Compute velocity, $V = \frac{1.486}{n} \left(\frac{A}{Wp}\right)^{2/3} S^{1/2}$

Where:

n = 0.040 for vegetated channels

A = 6 sq. ft.

Wp = 8.2 ft. (wetted perimeter)

S = .03 ft/ft (slope)

Therefore, $V = \frac{1.486}{.04} \left(\frac{6}{8.2}\right)^{2/3} (.03)^{1/2}$

$= 5$ feet per second

Select the appropriate stabilization lining.

Since $Q = AV$, the ditch capacity is

$Q = (6\ ft^2)(5\ ft/sec) = 30$ cfs or more than twice required

Case 2—Construction Ditch B

Given:

Drainage Area = 10 acres
Hydrologic Soil Group = C
Runoff Curve Number = 91
Slope of Swale = 3%
Rainfall (P) = 2.5 inches

Runoff (Q) = 1.6 inches

Time of Concentration for Runoff (T_c) = 0.1

From HydroCAD routing:

$Q_p = 25$ cfs

For Ditch B, the design cross-section has a 6-foot bottom width, 1-foot depth, and 2:1 side slopes.

Therefore, the area = 8 ft^2

Computing velocity for a ditch slope of 3%,

$V = \frac{1.486}{.04} \left(\frac{8}{10.47}\right)^{2/3} (.03)^{1/2}$

$V = (37.15)(.836)(.173) = 5.37$ ft/sec

Since:

$Q = AV$, the ditch capacity is

$Q = (8\ ft^2)(5.37\ ft/sec) = 43$ cfs

Case 3 - This site is adjacent to a significant water body in Westchester County. We want to protect the site for the 2-year, 24-hour storm.

Given:

Drainage Area = 10 acres

Hydrologic Soil Group = D soils

Runoff Curve Number = 94, ("D" under construction)

Slope of Swale = 3%

Rainfall (P) = 3.5 inches (NRCC)

Runoff (Q) = 2.8 inches (TR55 RCN)

Assume Time of Concentration for Runoff (T_c) = 0.1 hour (most conservative value)

From HydroCAD routing:

Qp = 28.7 cfs

From Case 2, Ditch B, we know that the maximum capacity is 43 cfs with a velocity of 5.37 feet per second.

Our conclusions would indicate that Ditch B is adequate for capacity. The velocity is higher and thus a lining should be used to protect the ditch from erosion.

Sediment Storage Volume Design Procedure

Practices such as silt fence, straw bale dikes, earthen berms, and other slope interupters, are often used on slopes or near the toes of fill slopes to capture sediment laden runoff. These have failed many times in the field due to poor siting, improper installation, lack of maintenance, and little consideration of the proper use of the practice.

The following design example shows how careful we need to be in using these practices. We will look at the use of silt fence in the following typical situations.

Case 1 - At the toe of a 3:1 earthfill

Given:

Earthfill slope 30 feet high , slope length 95 feet

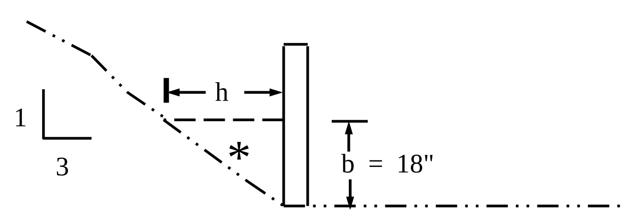
Hydrologic Soil Group—C

The Runoff Curve Number = 91 (bare soil)

Typically, the installed height of the silt fence is 30-36". The maximum design sediment depth behind the silt fence is 50% of its height, or 18" maximum.

For this case, the design sediment area is equal to:

A = 1/2bh



* Design sediment storage volume

A = 1/2 (1.5')(4-5') = 3.375 sq. ft. per linear foot

This equals 337.5 cubic feet per 100 feet of fence.

The actual slope surface is approximately 95 feet. For a rainfall of 1 inch on this site, the runoff equals 0.4 inches (TR55). The total volume of runoff would equal

$$\frac{0.4 \text{ inches}}{12 \text{ inches/ft}} \times 9500 \text{ sq. ft.} = 317 \text{ cu. ft.}$$

This example shows that the volume required for a 1-inch storm is barely provided, but the location of the fence provides no buffer for material that rolls down the slope nor room for maintenance. The fence should be located at least 10 feet from the toe of the slope.

Case 2- Determine level of protection for CASE 1 when fence is moved 10 feet from the toe of slope.

When the silt fence is moved 10' away from the 3:1 slope, the design area of storage equals,

337.5 sq. ft. + 1,500 sq. ft. = 1,837.5 cu.ft. per 100 feet of fence

Since this is the maximum runoff volume that can be controlled, the runoff depth equates to:

$$\frac{1{,}837.5 \text{ ft}^3}{9{,}500 \text{ ft}^2} = 0.193 \text{ feet} = 2.3 \text{ inches}$$

From TR55 for a runoff Q = 2.3 inches, with a Curve Number at 91, P, rainfall is found to be 3.2 inches.

Thus, this design configuration can manage to store the runoff from a 3.2 inch rainfall event.

This method can be used to evaluate the positioning of these sediment control practices on the contour to hold sediment close to its source. It allows a designer to evaluate an existing condition, or to select a specific level of protection higher than that which may be provided by the standard details.

Rock Outlet Protection Design Examples

(Refer to Rock Outlet Protection Standard on Page 3.40)

Example 1: Pipe Flow (full) with discharge to unconfined section.

Given: A circular conduit flowing full.

Q = 280 cfs, diam. = 66 in., tailwater (surface) is 2 ft. above pipe invert (minimum tailwater condition).

Find: Read d_{50} = 1.2 and apron length (L_a) = 38 ft.
Apron width = diam. + L_a = 5.5 + 38 = 43.5 ft.

Use: d_{50} = 15”, d_{max} = 22”, blanket thickness = 32”

Example 2: Box Flow (partial) with high tailwater

Given: A box conduit discharging under partial flow conditions. A concrete box 5.5 ft. x 10 ft. flowing 5.0 ft. deep,

Q = 600 cfs and tailwater surface is 5 ft. above invert (max. tailwater condition).

Since this is not full pipe and does not directly fit the nomograph assumptions of Figure 7B.13 substitute depth as the diameter, to find a discharge equal to full pipe flow for that diameter, in this case 60 inches.

Since, Q = AV and $A = \frac{\pi D^2}{4}$

First, compute the actual box culvert velocity for the given flow conditions:

V = (Q/A) = (600/(5) (10)) = 12 fps

Then determine the equivalent flow through a 5 foot diameter pipe using the same velocity as the box culvert as computed above:

$$Q = \frac{\pi D^2}{4} \times V = \frac{3.14\,(5 \text{ ft})^2}{4} \times 12 \text{ fps} = 236 \text{ cfs}$$

At the intersection of the curve d = 60 in. and Q = 236 cfs, read d_{50} = 0.4 ft.

Then reading the d = 60 in. curve, read apron length (L_a) = 40 ft.

Apron width, W = conduit width + (0.4)(L_a) = 10 + (0.4)(40) = 26 ft.

Example 3: Open Channel Flow with Discharge to Unconfined Section

Given: A trapezoidal concrete channel 5 ft. wide with 2:1 side slopes is flowing 2 ft. deep, Q = 180 cfs (velocity = 10 fps) and the tailwater surface downstream is 0.8 ft. (minimum tailwater condition).

Find: Using similar principles as Example 2, compute equivalent discharge for a 2 foot, using depth as a diameter, circular pipe flowing full at 10 feet per second.

Velocity:

$$Q = \frac{\pi\,(2 \text{ft})^2}{} \times 10 \text{ fps} = 31.4 \text{ cfs}$$

4

At intersection of the curve, d = 24 in. and Q = 32 cfs, read d_{50} = 0.6 ft.

Then reading the d = 24 in. curve, read apron length (L_a) = 20 ft.

Apron width, W = bottom width of channel + L_a = 5 + 20 = 25 ft.

Example 4: Pipe flow (partial) with discharge to a confined section

Given: A 48 in. pipe is discharging with a depth of 3 ft. Q = 100 cfs, and discharge velocity of 10 fps (established from partial flow analysis) to a confined trapezoidal channel with a 2 ft. bottom, 2:1 side slopes, n = .04, and grade of 0.6%.

Calculation of the downstream channel (by Manning's Equation) indicates a normal depth of 3.1 ft. and normal velocity of 3.9 fps.

Since the receiving channel is confined, the maximum tailwater condition controls.

Find: discharge using previous principles:

$$Q = \frac{\pi\,(3ft)^2}{4} \times 10 \text{ fps} = 71 \text{ cfs}$$

At the intersection of d = 36 in. and Q = 71 cfs, read d_{50} = 0.3 ft.

Reading the d = 36" curve, read apron length (L_a) = 30 ft.

Since the maximum flow depth in this reach is 3.1 ft., that is the minimum depth of riprap to be maintained for the entire length.

Flow Diffuser Design Examples

(Refer to Flow Diffuser on Page 3.16)

The stormwater runoff from a 3.5 acre drainage area is to be discharged offsite through a flow diffuser. The drainage area is upland meadow, pasture and access road. The 10 year, 24 hour rainfall is 3.5 inches. A peak rate of runoff of 8.8 cubic feet per second results from a curve number of 80 and a time of concentration of 6 minutes (0.10 hour), using the HydroCAD computer model. This flow is being diffused off the right of way to prevent excessive flows further down the access road corridor.

A. Determine the diffuser length:

Since the maximum flow rate from the diffuser onto the vegetated buffer area is 0.25 cfs, per linear foot of weir length, the diffuser length is:

$$W = \frac{Q_{10}}{Q_D} = \frac{8.8 \text{ cfs}}{0.25 \text{ cfs.ft}} = 35.2 \text{ ft}$$

B. Using the standard minimum diffuser cross-section dimensions, solve for the d_{50} rock size:

Assume: 1:1 side slopes, 2 ft top width, h = 1.0 ft, W = 36 ft for:

$$Q = \frac{(h^{2/3})\,(W)}{[L/D + 2.5\,L^2]^{0.5}}$$

Where:

h = ponding depth behind the diffuser

W = linear length of diffuser along centerline

L = average horizontal flow length through the diffuser perpendicular to the centerline

D = average stone diameter (ft.) in the structure

Try a D (d50) = 0.50 ft (6 inches), from typical cross section, L=3 ft, then,

$$Q = \frac{1^{2/3} \times 36}{[3/0.5 + 2.5 + (3)^2]^{0.5}} = \frac{36}{(17)^{0.5}} = \frac{36}{4.18}$$

Therefore, Q = 8.6 cfs, this approximates the 10 year discharge and the design is balanced.

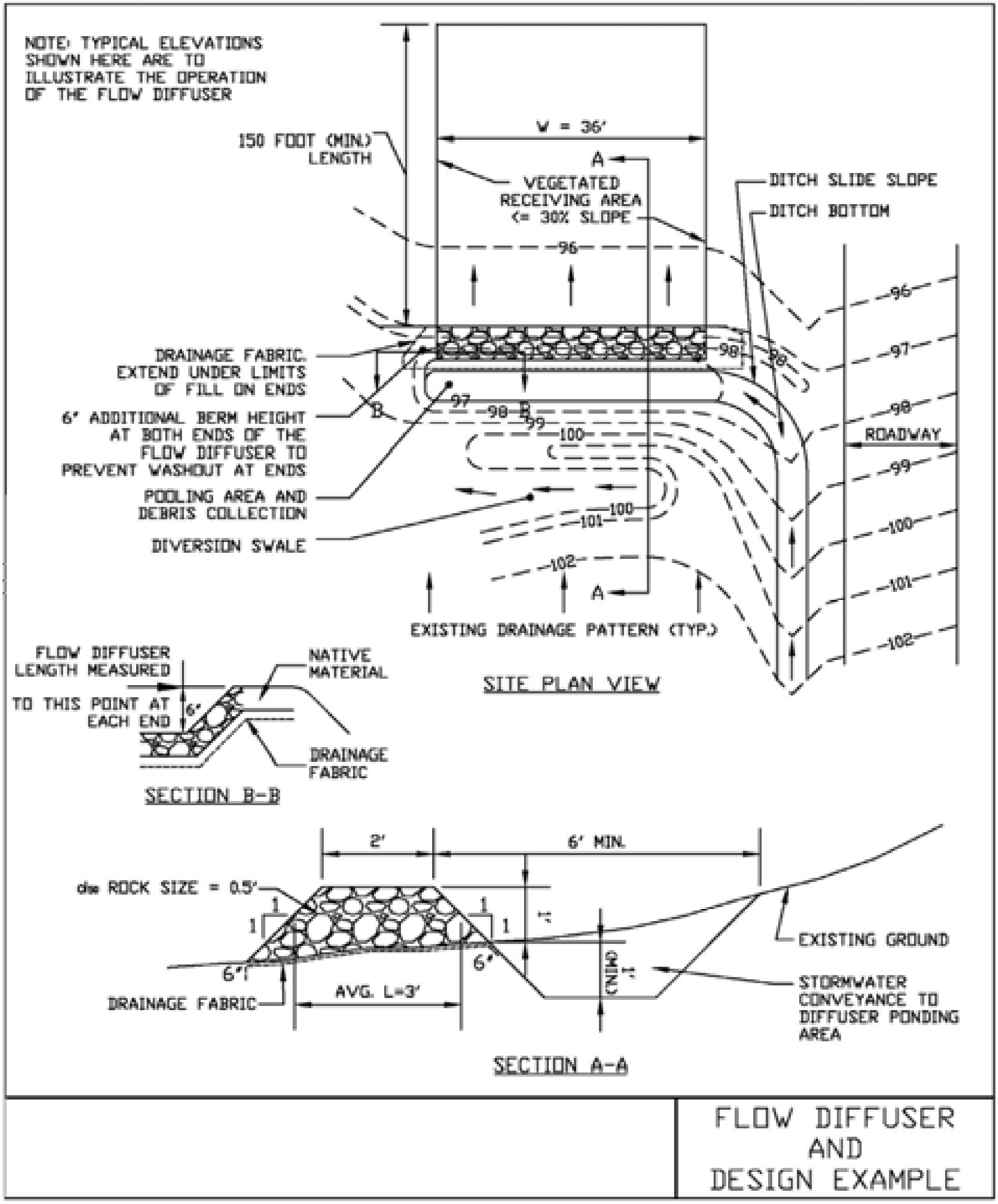
What if d_{50} is 0.75 ft. or 9 in.?, then:

$$Q = \frac{36}{[3/0.75 + 2.5 + (3)^2]^{0.5}} = \frac{36}{3.94} = 9.1 \text{ cfs}$$

And this flow exceeds the maximum allowable. Figure B.1 on page B.5 shows the dimensions and details for the final diffuser configuration.

Design Note: Changing the variables of height, side slope, rock size, and weir length, will result in a change of the diffuser discharge. All dimensions need to be balanced so the diffused flow does not exceed the maximum allowable of 0.25 cfs per linear foot of the diffuser. This practice can be modeled for storage requirements as a pond with a constant overflow rate.

Figure B.1
Flow Diffuser Design Example



CEDAR POINT SECTION 3
SEDIMENT BASIN DESIGN EXAMPLE

Cedar Point is a residential construction project in Cicero, Onondaga County, New York. Section 3 contains quarter acre lots with residential streets on approximately 20.4 acres. A sediment basin will be utilized as a component of the erosion and sediment control plan for this project. It will be located at the storm drainage outlet of the project (See Figure B.5). The drainage area to the basin is 14.9 acres.

The runoff curve number (RCN) used to calculate the stormwater runoff for design storms from this drainage area is based on the maximum disturbed construction condition. In this case it means bare soil for all the lot areas and impervious surface for the street area. This drainage area has 1.6 acres of paved roads and gutters; 6.4 acres of exposed soil in Hydrologic Soil Group (HSG) B; and 6.9 acres of exposed soil in HSG C. This results in a composite RCN of 90. Based on hydrologic data obtained from the Northeast Regional Climate Center (NRCC) and using the HydroCAD computer model, the peak discharge for the 10 year frequency storm is 39.2 cubic feet per second. See Figures B.2 to B.7 that show the development of the hydrology data. The steps to obtain this data are listed below:

1. Go to the NRCC website, http://precip.eas.cornell.edu/.
2. Select the tab Data and Products.
3. Use the Google Map to zoom into the project and double click.
4. From the Products list, select Extreme Precipitation Tables- Text/CSV.
5. At the bottom of the page, set smoothing to No, then click Submit.
6. Select Save when asked.
7. Set Save In to your HydroCAD IDF file or your HydroCAD projects folder.
8. Set the name for this file as NY-Cicero.hci.
9. Set the file format as "plain text".
10. Click save and close the NRCC site.

If you are using a different computer program, import the text files into that program in accordance with the programs protocols. These text files will be converted into rainfall distribution curves for each specific rainfall frequency.

11. Open HydroCAD and click on the calculator icon.
12. Click "Rainfall"
13. Click "Import Events from IDF"
14. Click "Create Mass Curves", then OK.
15. Click "Yes" on popup screen to replace the storm events, and accept.

This process imports rainfall values from the 1 year to the 500 year storm. This will be shown on the main screen when you toggle down the storm event window. Make sure when calculating Tc with HydroCAD that the NRCC 2 year storm value is used for the sheet flow calculation and not the older value. For our example, the 2 year rainfall is 2.37 inches and the 10 year rainfall is 3.39 inches.

The design results are shown on the following Temporary Sediment Basin Design Data Sheet. The instructions for the use of this form are shown on page 5.25.

The outlet for this sediment basin is a skimmer device. It is critical to size the orifice so that the appropriate detention time for dewatering is applied to maximize the basin efficiency. The Dewatering Device standard on page 5.10 sets the criteria for orifice sizing.

The Cedar Point Section 3 soils contain approximately 45 % fines (less than the #200 sieve size); therefore the storage volume drawdown time should be a minimum of 48 hours. The dewatering volume is calculated to be approximately 54,000 cubic feet. Therefore, from Figure 5.3 on page 5.11 of the Dewatering Device standard, enterthe bottom of the chart at 54,000 cubic feet. Travel vertically to the 2 day dewatering time line. Then read across to find the orifice diameter at approximately 4.5 inches.

The arm length for the skimmer is equal to the hypotenuse of a 45 degree right triangle using the full storage depth as the leg of the triangle (see Figure 5.4 on page 5-12). Our full storage depth is 8 feet. Therefore, the length of the skimmer arm is 8 feet x 1.414 = 11.3 feet. Use 12.0 feet for ease of field construction with a four foot flexible coupling to the bottom of the riser (see Figure B.13 on page B.18).

The design results are shown on the Temporary Sediment Basin Design Data Sheet, Figure B.9 on page B.14.

Figure B.2
NRCC Project Locator Map

Figure B.3
NRCC Sediment Basin Location

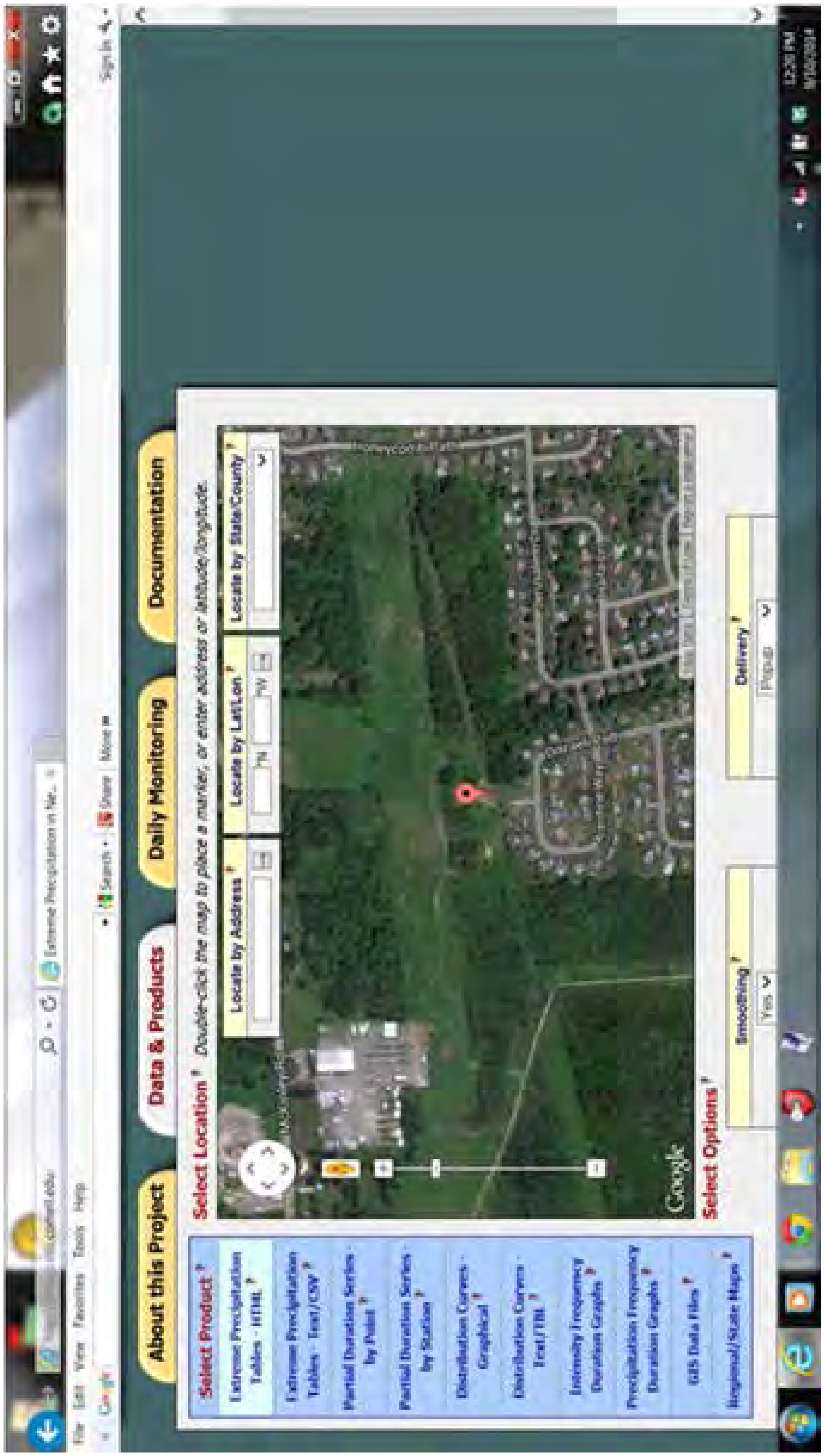


Figure B.4
Cedar Point Google Map Pre-Construction

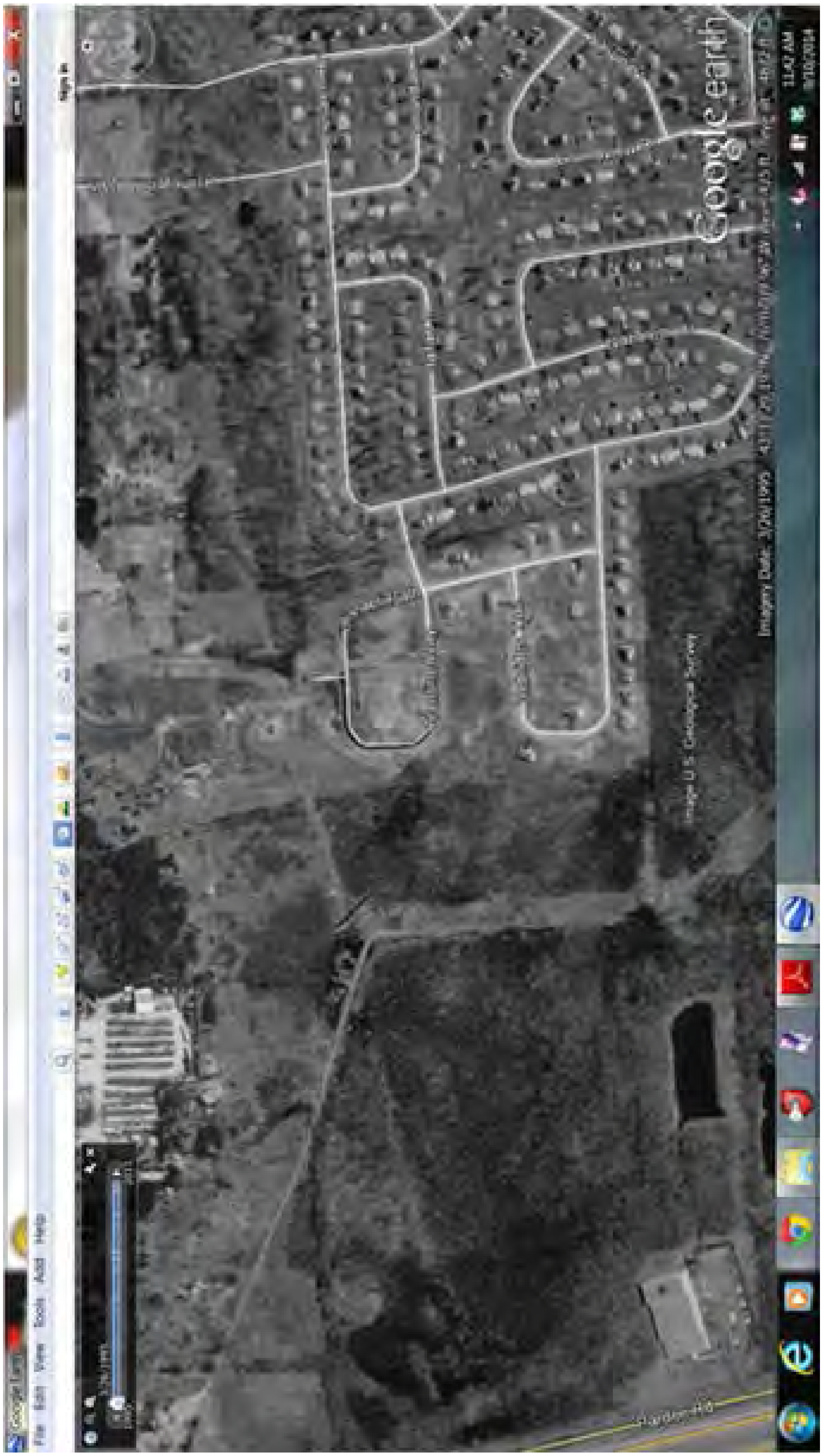


Figure B.5
Cedar Point Site Sediment Basin Photograph

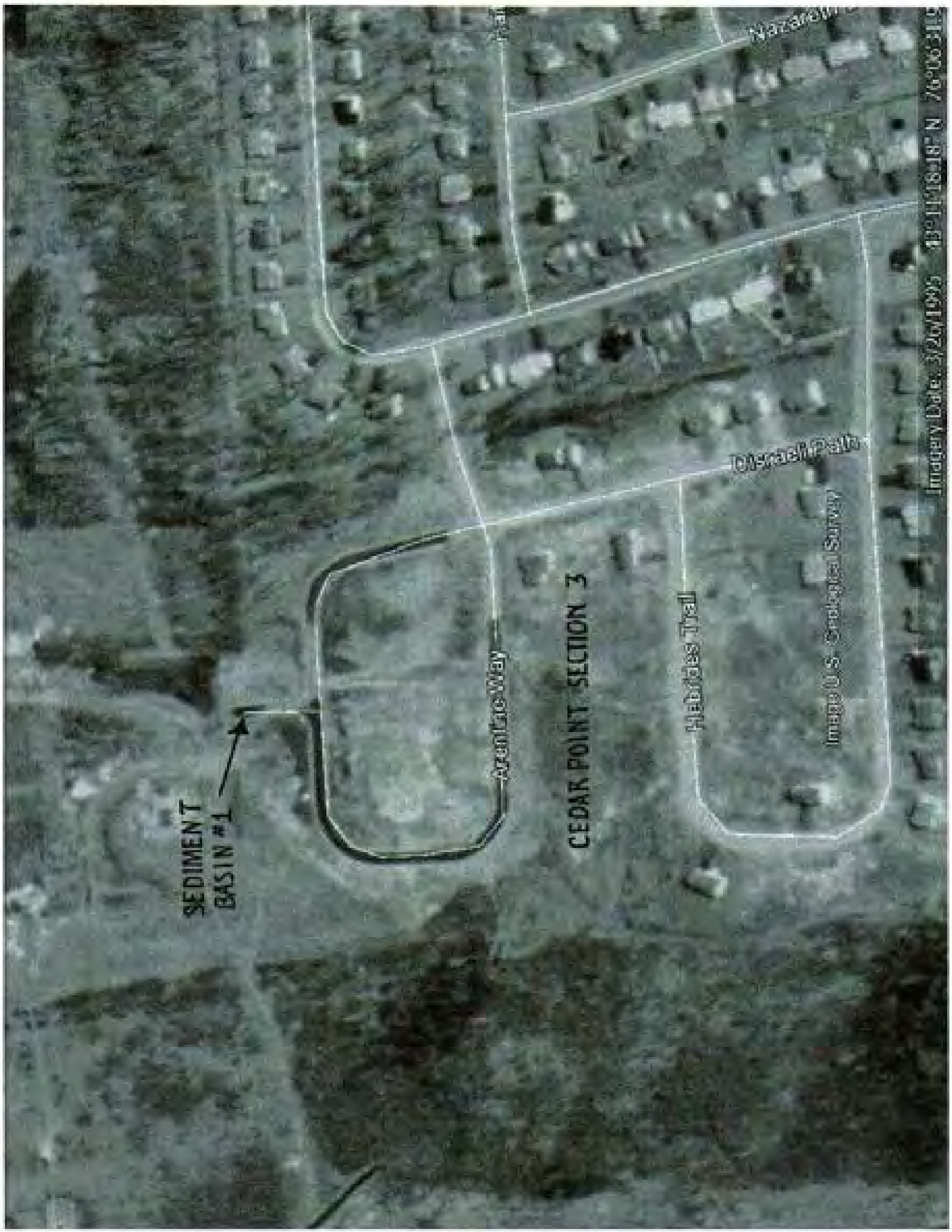


Figure B.6
NRCC Rainfall Text Table

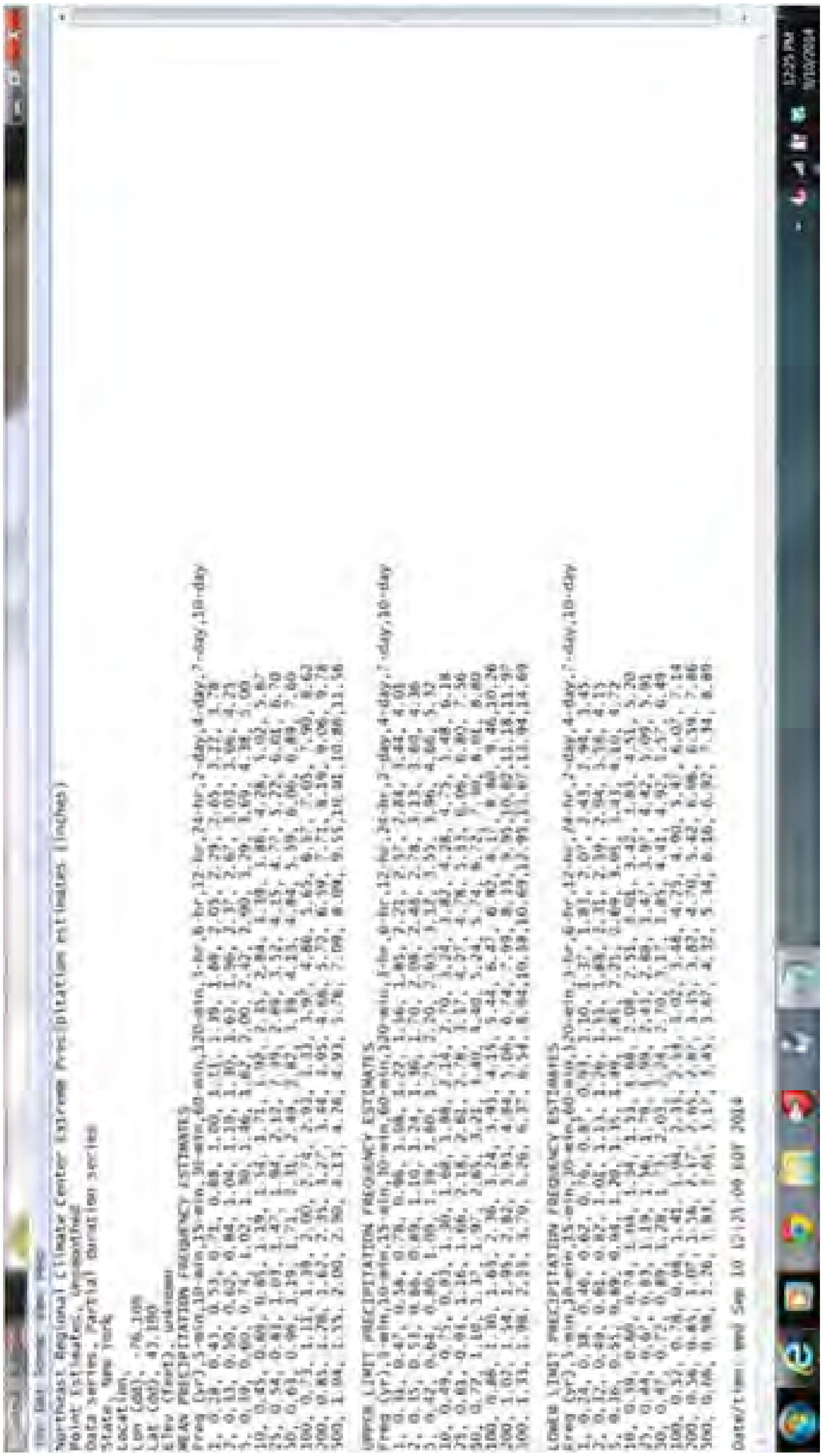


Figure B.7
HydroCAD Summary Sheet

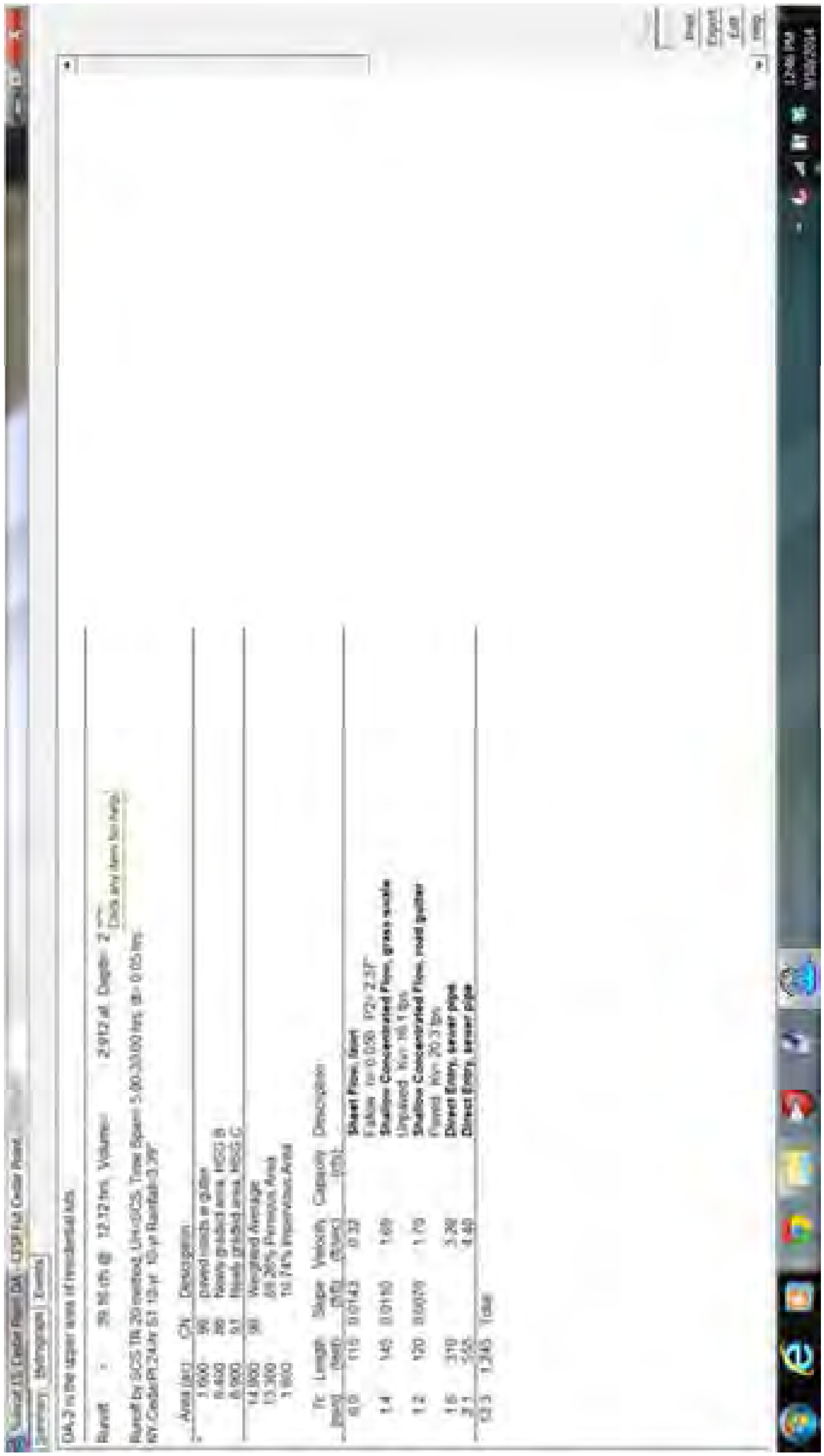


Figure B.8
Cedar Point Sediment Basin Stage - Storage Curve

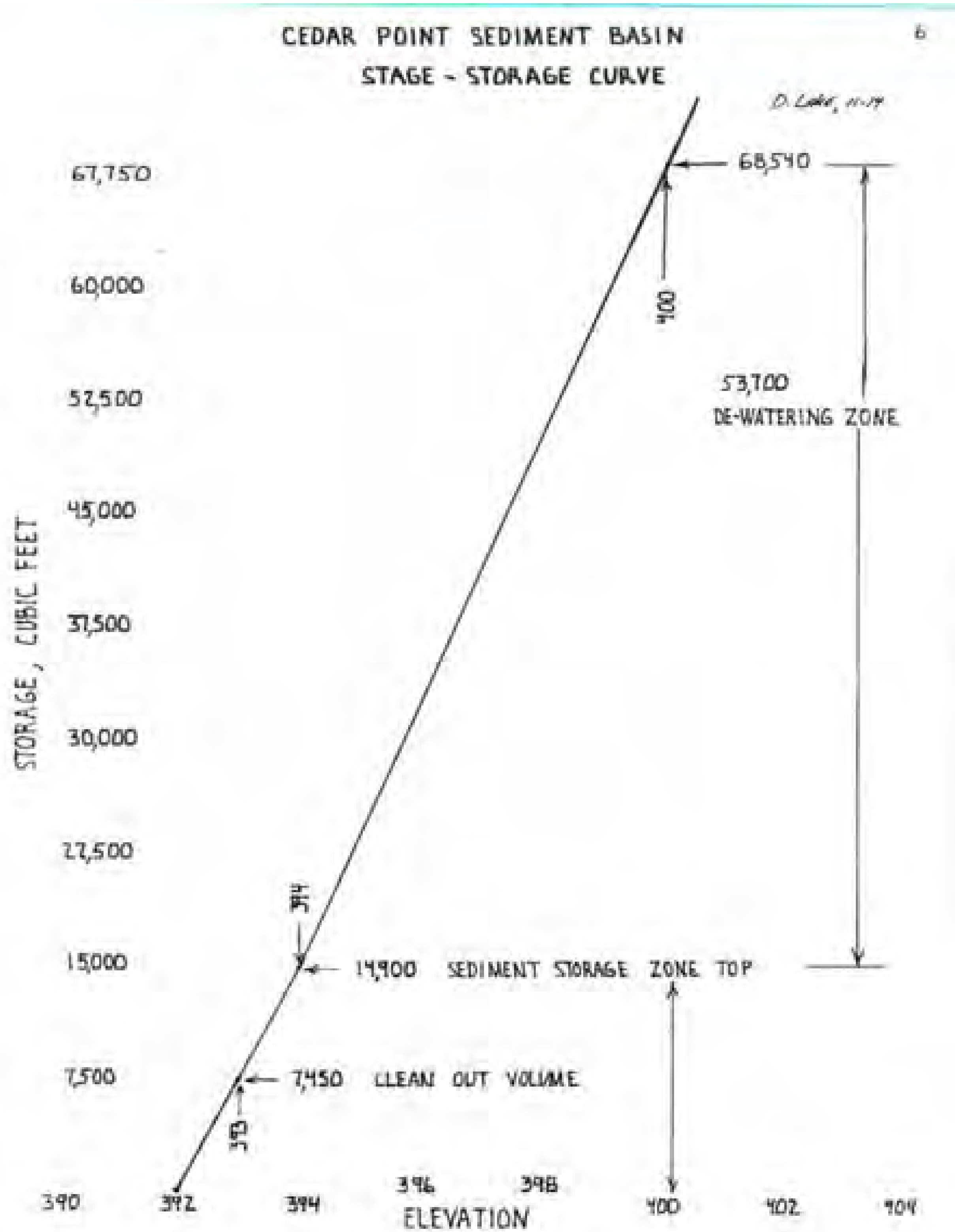


Figure B.9
Temporary Sediment Basin Design Data Sheet

TEMPORARY SEDIMENT BASIN DESIGN DATA SHEET

Computed by D. Lake Date ______ Checked by ______ Date ______
Project Cedar Point Section 3 Basin # 1
Location Cicero, NY Total Area draining to basin (≤50 Ac.) 14.9 Acres

BASIN SIZE DESIGN

1. Sediment storage zone volume = 1,000 cu. ft. x number of disturbed acres = 14900 cu. ft., Top of Zone Elev. 394.0
2. Dewatering zone volume = 3,600 cu. ft. x number of drainage area acres = 53640 cu. ft., Top of Zone Elev. 400.0
3. Length to width ratio = 3.4 : 1
4. A. Cleanout at 50% of sediment storage zone volume, Elev. 393.0
   B. Distance below top of riser 7.0 feet
5. Minimum surface area is larger of 0.01 $Q_{(10)}$ 0.39 or, 0.015 DA = 0.22 use 0.4 acres

DESIGN OF SPILLWAYS & ELEVATIONS

Runoff

6. $Q_{p(10)}$ = 39.2 cfs (Attach runoff computation sheets)

Pipe Spillway (Q_{ps})

7. Min. pipe spillway cap., Q_{ps} = 0.2 x 14.9 Drainage Area, acres = 3 cfs
   Note: If there is no emergency spillway, then required $Q_{ps} = Q_{p(10)}$ = — cfs.
8. H, head = 8 ft. Barrel length = 60 ft
9. Barrel: Diam. 12 inches; Q_{ps} = (Q) 9.1 x (cor.fac.) 1.04 = 9.5 cfs.
10. Riser: Diam. 21 inches; Length 7.5 ft.; h = 1.0 ft. Crest Elev. 400.0
11. Trash Rack: Diameter = 30 inches; H, height = 11 inches

Emergency Spillway Design

12. Emergency Spillway Flow, $Q_{es} = Q_p - Q_{ps}$ = 39.2 - 9.5 = 29.7 cfs.
13. Width 12 ft.; H_p 1.0 ft Crest elevation 401.0 ; Design High Water Elev. 402.0
    Entrance channel slope 2 % ; Top of Dam Elev. 403.0
    Exit channel slope 3 %

ANTI-SEEP COLLAR/SEEPAGE DIAPHRAGM DESIGN

Collars:

14. y = 7.5 ft.; z = 2.5 :1; pipe slope = 1 %, L_s = 51 ft.
    Use 2 collars, 4' - 9 inches square; projection = 1.8 ft.

Diaphragms:

#______ width______ ft. height ______ ft.

DEWATERING ORIFICE SIZING

(Determined from the Dewatering Device Standard)

15. Dewatering orifice diameter = 4.5 inches. Skimmer X or Riser ____ (check one)
16. Design dewatering time 2 days (Min. 2 days required)

Figure B.10
Temporary Sediment Basin Profile Detail

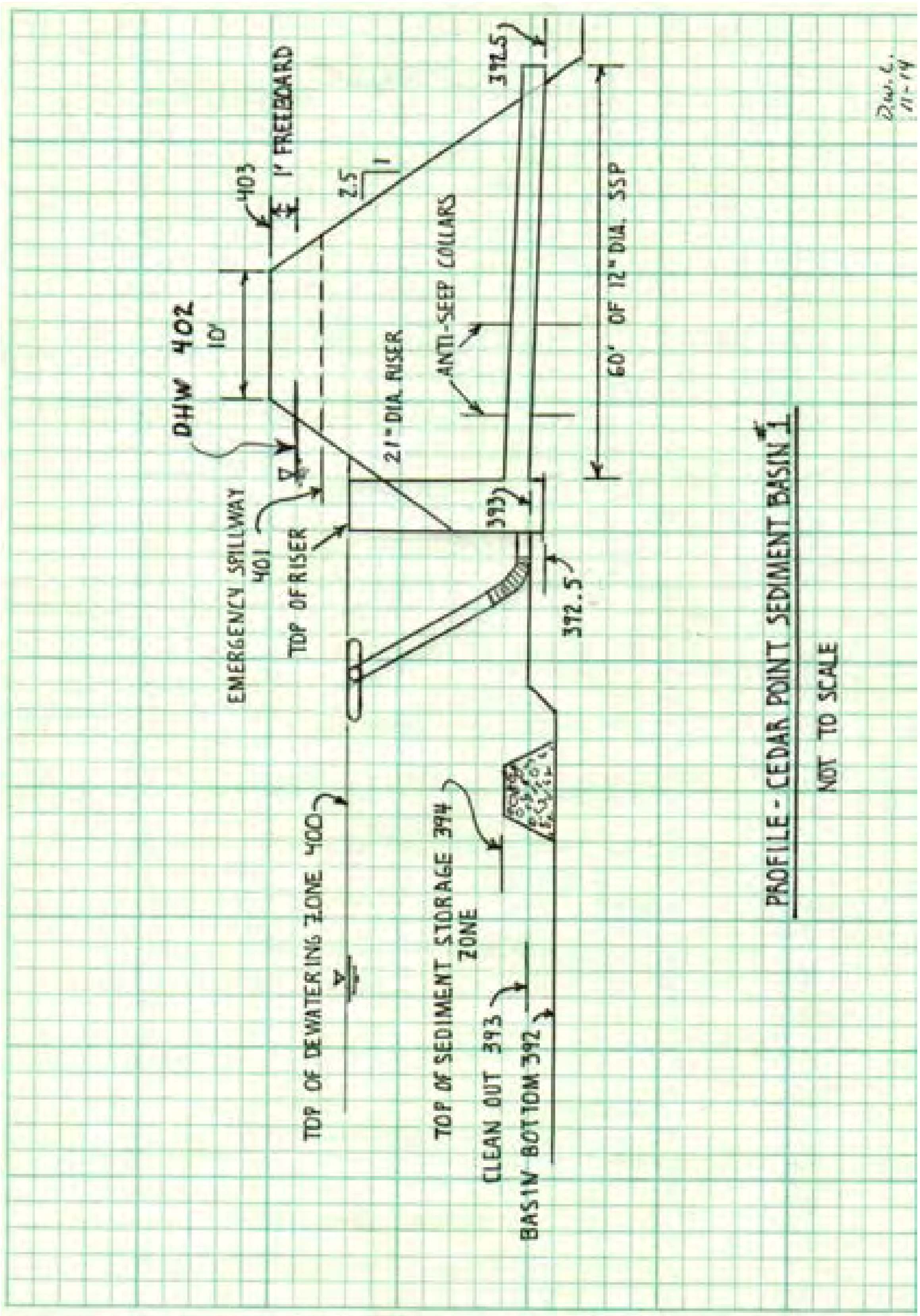


Figure B.11
Temporary Sediment Basin Spillway Detail

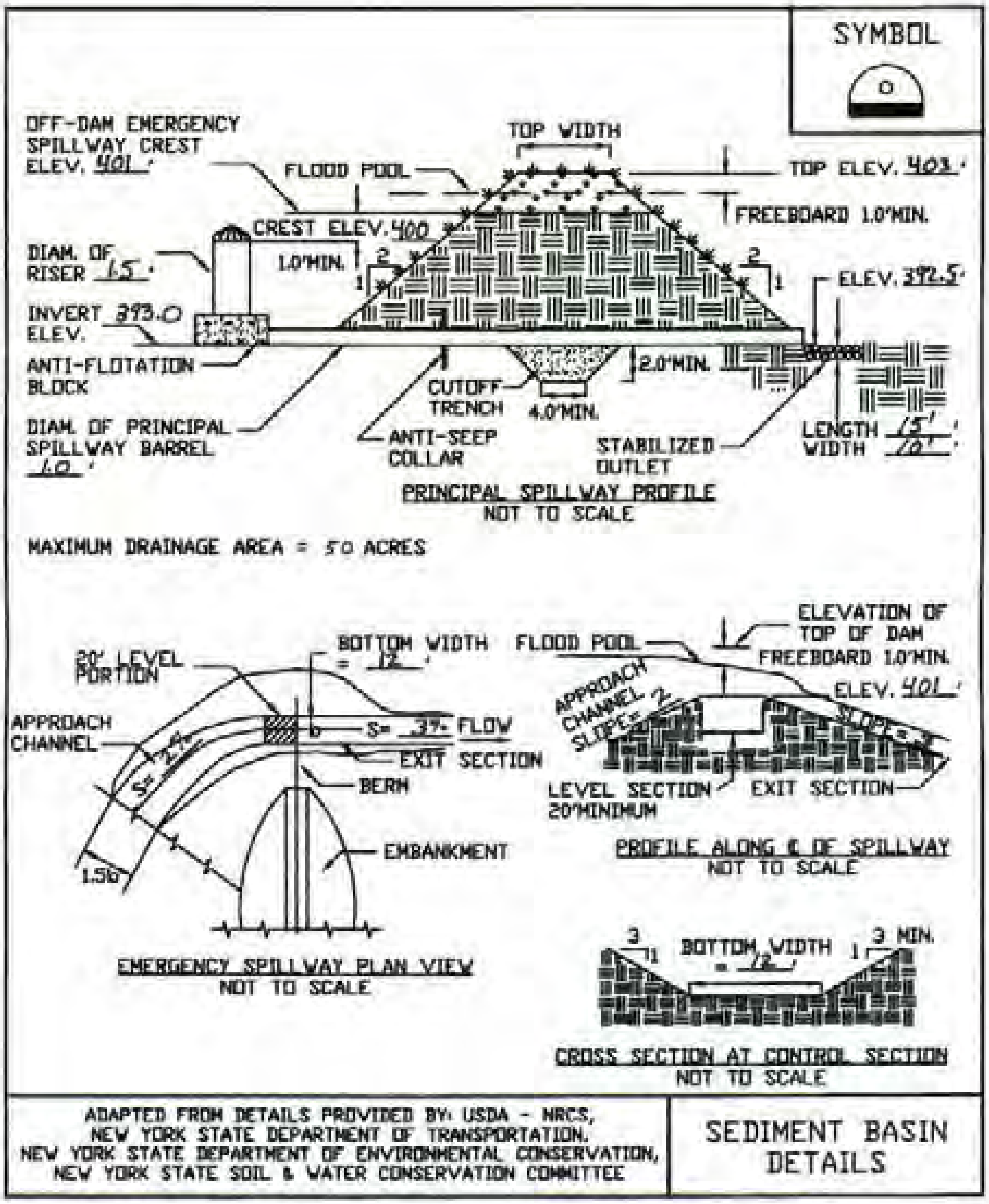


Figure B.12
Skimmer Orifice Design Chart

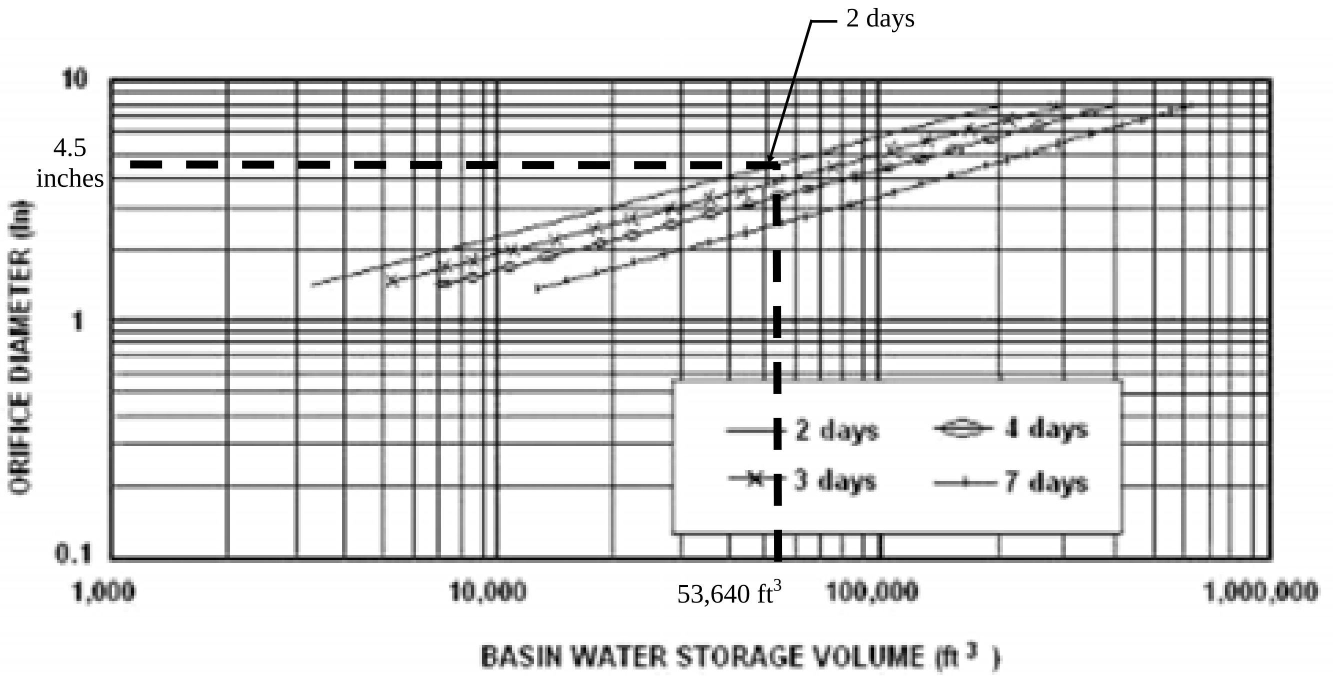
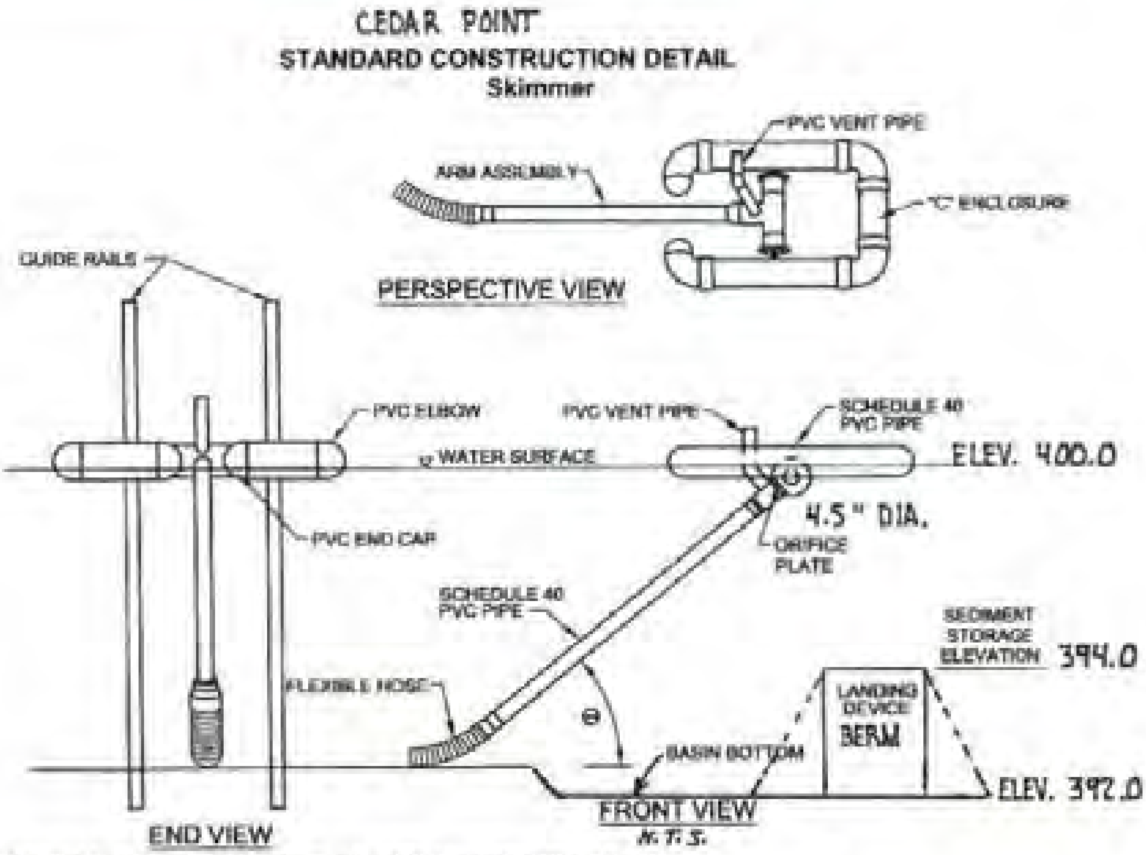


Figure B.13
Skimmer Dewatering Device Detail



Adapted from Penn State Agricultural and Biological fact Sheet F-253

NOTE: This table is intentionally blank and should be filled in by the plan preparer.

Basin No.	Water Surface Elevation (ft)	Arm Length (ft)	Arm Dia. (in)	Orifice Size* (in)	Top of Landing Device Elevation (ft)	Flexible Hose Length (in)	Flexible Hose Attachment Elevation (ft)
CP-1	400.0	12	6	4.5	394.0	48	393.0

* Must be equal to or less than arm diameter

A rope shall be attached to the skimmer arm to facilitate access to the skimmer once installed.

Skimmer shall be inspected weekly and after each runoff event.

Any malfunctioning skimmer shall be repaired or replaced within 24 hours of inspection.

Ice or sediment buildup around the principal spillway shall be removed so as to allow the skimmer to respond to fluctuating water elevations.

Sediment shall be removed from the basin when it reaches the level marked on the sediment clean-out stake or the top of the landing device.

A semi-circular landing zone may be substituted for the guide rails