ENVIRONMENTAL • GEOTECHNICAL
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RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

TYPE III RESTRICTED WASTE LANDFILL
IPL PETERSBURG GENERATING STATION
6925 NORTH STATE ROAD 57
PETERSBURG, INDIANA 47567

ATC PROJECT NO. 170LF00266

OCTOBER 7, 2016

PREPARED FOR:

INDIANAPOLIS POWER & LIGHT COMPANY
6925 NORTH STATE ROAD 57
PETERSBURG, INDIANA 47567
ATTENTION: MR. ERWIN A. LEIDOLF

ATC
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October 7, 2016

Mr. Erwin A. Leidolf
Senior Scientist
Indianapolis Power & Light Company
6925 North State Road 57
Petersburg, IN 47567

Re: **Run-on and Run-off Controls System Plan**
Type III Restricted Waste Landfill
IPL Petersburg Generating Station Landfill
Petersburg, IN 47567
ATC Project No. 170LF00266

Dear Mr. Leidolf:

ATC Group Services LLC (ATC) is pleased to present the following Run-On Run-Off Control System (ROROCS) Plan for the Indianapolis Power & Light Company (IPL) Petersburg Generating Station Type III Restricted Waste Landfill located at 6925 North State Road 57, Petersburg, IN 47567.

As required by 40 CFR 257.81, the owner or operator of a coal combustion residuals (CCR) landfill must design, construct, operate, and maintain:

1. A run-on control system to prevent flow onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm; and
2. A run-off control system from the active portion of the CCR unit to collect and control at least the water volume resulting from a 24-hour, 25-year storm.

Contained here within is a summary report which demonstrates that the Petersburg Landfill design measures are compliant with the CCR Rule. We appreciate the opportunity to assist you with this project. If you have any questions concerning information contained in this letter, please do not hesitate to call the undersigned at 317.849.4990.

Sincerely,
ATC Group Services LLC

Charles Dewes, E.I., CFM
Project Engineer

Donald Bryenton, P.E.
Principal Engineer

DONALD LEE BRYENTON
REGISTERED
No 17277
STATE OF INDIANA
PROFESSIONAL ENGINEER

David Stelzer, PhD., P.E.
Senior Project Engineer

Executive Summary

The IPL Petersburg Generating Station Landfill located at 6925 North State Road 57 in Petersburg, IN 47567, received a Solid Waste Land Disposal Facility Permit from Indiana Department of Environmental Management (IDEM) in 1983. The IDEM approved plans for this facility include a number of erosion control and runoff measures to contain design storm flow. Additional grading measures prevent run-on flow from entering the site.

The CCR Rule requires that all stormwater drainage structures, including channels, culverts, pipe systems, and detention basins be designed to convey the 25-year, 24-hour storm event. This report documents that the engineering structures for run-off and run-on control have been sized appropriately.

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Appendices

1 Introduction

This Run-On and Run-Off Control System (ROROCS) Plan was prepared for the existing IPL Petersburg Generating Station Type III Restricted Waste Landfill in accordance with 40 CFR 257.81 (Run-on and run-off controls for CCR landfills). This ROROCS Plan documents that the facility control systems have been designed and constructed to meet the CCR Rule following specified engineering calculations for the 24-hour, 25-year design storm. This ROROCS Plan must be placed in the facility's operating record as required by 40 CFR 257.105(g)(3).

2 Regulatory Requirements

2.1 Federal CCR Rule

As required by 40 CFR 257.81, the owner or operator of a coal combustion residuals (CCR) landfill must design, construct, operate, and maintain:

1. A run-on control system to prevent flow onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm; and

2. A run-off control system from the active portion of the CCR unit to collect and control at least the water volume resulting from a 24-hour, 25-year storm.

Additional requirements of the CCR Rule state that the ROROCS Plan must be updated and submitted once every five years as long as the landfill continues to be active.

The permit application reviewed and approved by IDEM includes sedimentation and erosion control systems that meet these requirements.

2.2 Preamble to the Federal CCR Rule

The preamble to the federal CCR Rule provides additional description regarding the intent of the requirements. Regarding run-off control, the following quotation from the preamble is relevant.

> *The owner or operator must design, construct, operate, and maintain the CCR landfill in such a way that any runoff generated from at least a 24-hour, 25-year storm must be collected through hydraulic structures, such as drainage ditches, toe drains, swales, or other means, and controlled so as to not adversely affect the condition of the CCR landfill. EPA has promulgated these requirements to minimize the detention time of run-off on the CCR landfill and minimize infiltration into the CCR landfill, to dissipate storm water run-off velocity, and to minimize erosion of CCR landfill slopes. An additional concern with run-off from CCR landfills is the water quality of the run-off, which may collect suspended solids from the landfill slopes.*

A description of run-on and run-off control systems is included in the following sections of this report.

3 Design Methodology

3.1 Design Storm

The 24-hour, 25-year design storm is the mandatory protection standard for run-on and run-off control systems. The 25-year design storm rainfall amount was derived from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 data for Pike County, Indiana. The storm generates approximately 5.5 inches of precipitation for this location. The rainfall hyetograph for this storm event is included in Appendix A. All run-on and run-off control systems were designed for this capacity.

3.2 Rainfall Abstractions

Losses in rainfall volume are accounted for in abstractions (losses). The SCS Method was applied to calculate the correct curve number for the land use and soil types of the site. This curve number was then applied to calculate the losses and the actual runoff. SCS equations are below:

$S = 1000/CN - 10$ [Equation 1]

$I_a = 0.2*S$ [Equation 2]

Where:
S = potential maximum retention after runoff begins (in.);
CN = curve number; and
I_a = initial abstraction (in.)

The initial abstraction is a function of the land use conditions as represented by the composite curve number for the tributary drainage area. For example, the initial abstraction for run-off from CCR material having a curve number of 79 is calculated as follows:

$I_a = 200/79 - 2 = 0.53$ *inches*

3.3 Runoff and Routing Methodology

The EPA SWMM program Version 5.1 was used to generate the runoff flow, velocities, and flow depths for a typical set of run-on / run-off control measures under the highest drainage area loading situation. The EPA SWMM Model was developed by the Water Supply and Water Resources Division of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory with assistance from the consulting firm of CDM Inc. under a Cooperative Research and Development Agreement (CRADA). The SWMM program emulates the NRCS TR55 Model. The infiltration calculations used SCS Curve Number method. The routing procedure used was the Kinematic Wave method for Unsteady Flow following a Type II SCS Unit Hydrograph. All erosion control measures were linked to drainage channels and reservoir areas using the EPA SWMM program. The simulation results are included in Appendix C.

4 Run-On Control

4.1 Topography

The site of the Petersburg Landfill is located directly adjacent to the White River at the Pike-Knox County border. The surrounding area is mostly flat with some rolling hills to the north and east of the landfill with the landfill itself as the highest feature. The landfill is protected from run-on flow by a perimeter road on the east and also by natural drainage relief. Runoff from higher topographic peaks routes around the landfill perimeter to join the White River.

4.2 Perimeter Railroad Embankment

The landfill is surrounded by a railroad embankment on the north and west sides. The railroad embankment height varies between 5 and 10 feet above natural grade. The railroad embankment is higher than the 100-Year Elevation of the White River. This prevents run-on flow from the White River entering the landfill (see Appendix B).

5 Run-Off Control

5.1 Erosion Control Measures

A series of diversion berms exist on the sloping faces of the developed portion of the landfill to gently direct runoff flow through the conveyance system. Additional berms will be added to the perimeter slopes as the remainder of the landfill is placed in operation. These berms prevent disturbance of the CCR materials during the design storm event. Terrace berms that are approximately twenty-four (24') feet wide convey flow to riprap downchutes. Terrace berms and downchute channels have adequate height to contain the calculated flow depth of the design storm.

5.2 Flow Conveyance and Capture Measures

Flow from diversion (terrace) berms is directed into riprap downchutes which feed into the perimeter ditch system. The encircling landfill ditch system is divided into several reaches. Some reaches flow to the (existing) Northwest and West Sedimentation Basins which will handle both the interim and final cover run-off flows. The West Sedimentation Basin outlets to an NPDES outfall area. Other perimeter ditch reaches will flow to the (future development) East Sedimentation Pond which will primarily handle final cover run-off flow. Future landfill development, ash pond closures, and other activities of the IPL Petersburg Generating Station which are unforeseen at this time may influence the planning and layout of run-on and run-off control measures. This plan will continue to be updated as future development occurs.

6 Conclusions

As required by 40 CFR 257.81, the IPL Petersburg Type III Restricted Waste Landfill run-on control system is designed to prevent flow onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm, and the IPL Petersburg Type III Restricted Waste Landfill run-off control system is designed to collect and control at least the water volume resulting from a 24-hour, 25-year storm.

Appendices

Appendix A: Storm Water Control Plan Overview

Appendix B: Calculations for Run-On Control System

Section 1: Run-On Control System Summary

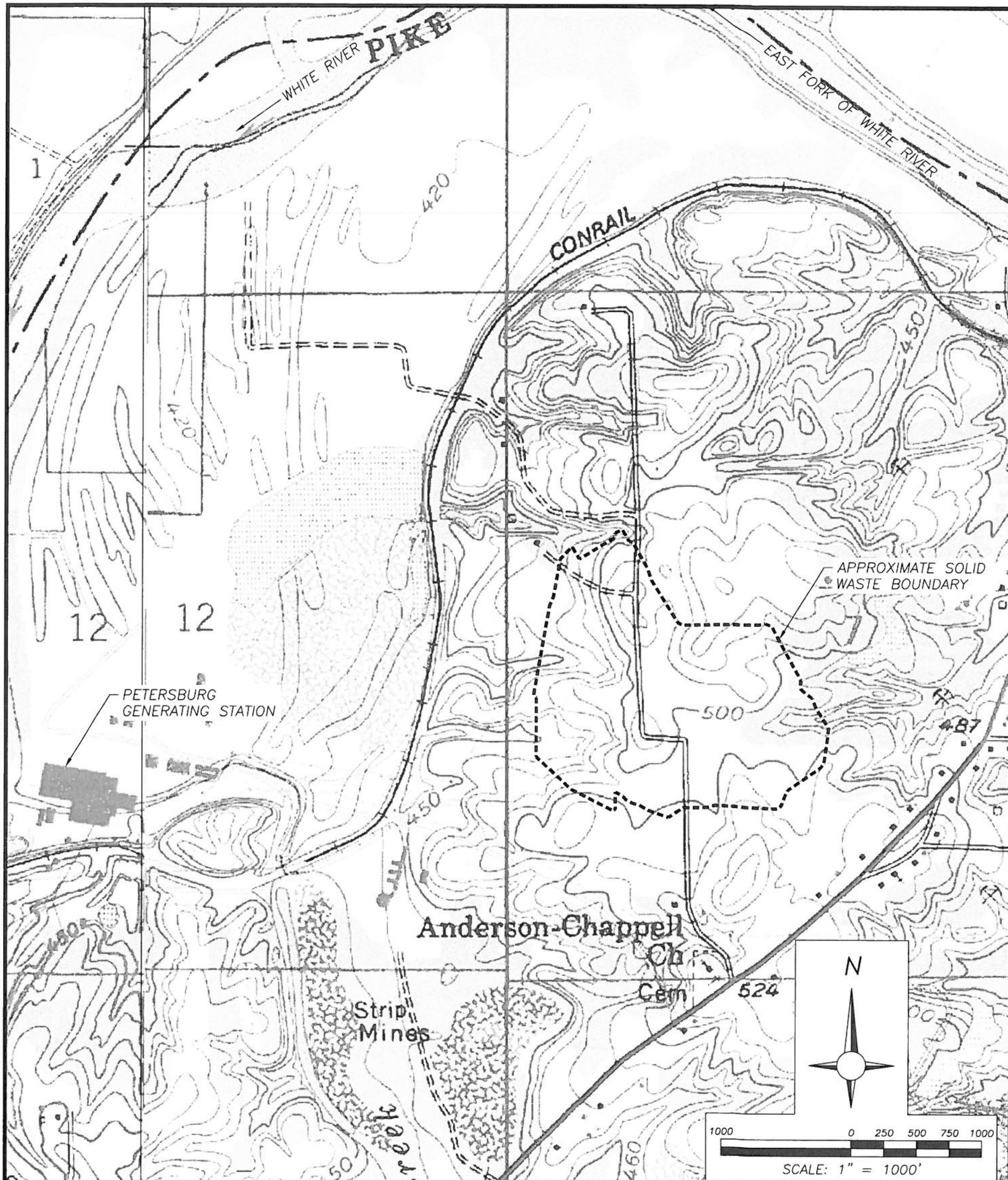
Appendix C: Calculations for Run-Off Control System

Run-Off Control System Interim and Final Cover Conditions Summary

Appendix D: References

Appendix E: Surface Water Control and Design Plan Sheets

Appendix A: Storm Water Control Plan Overview

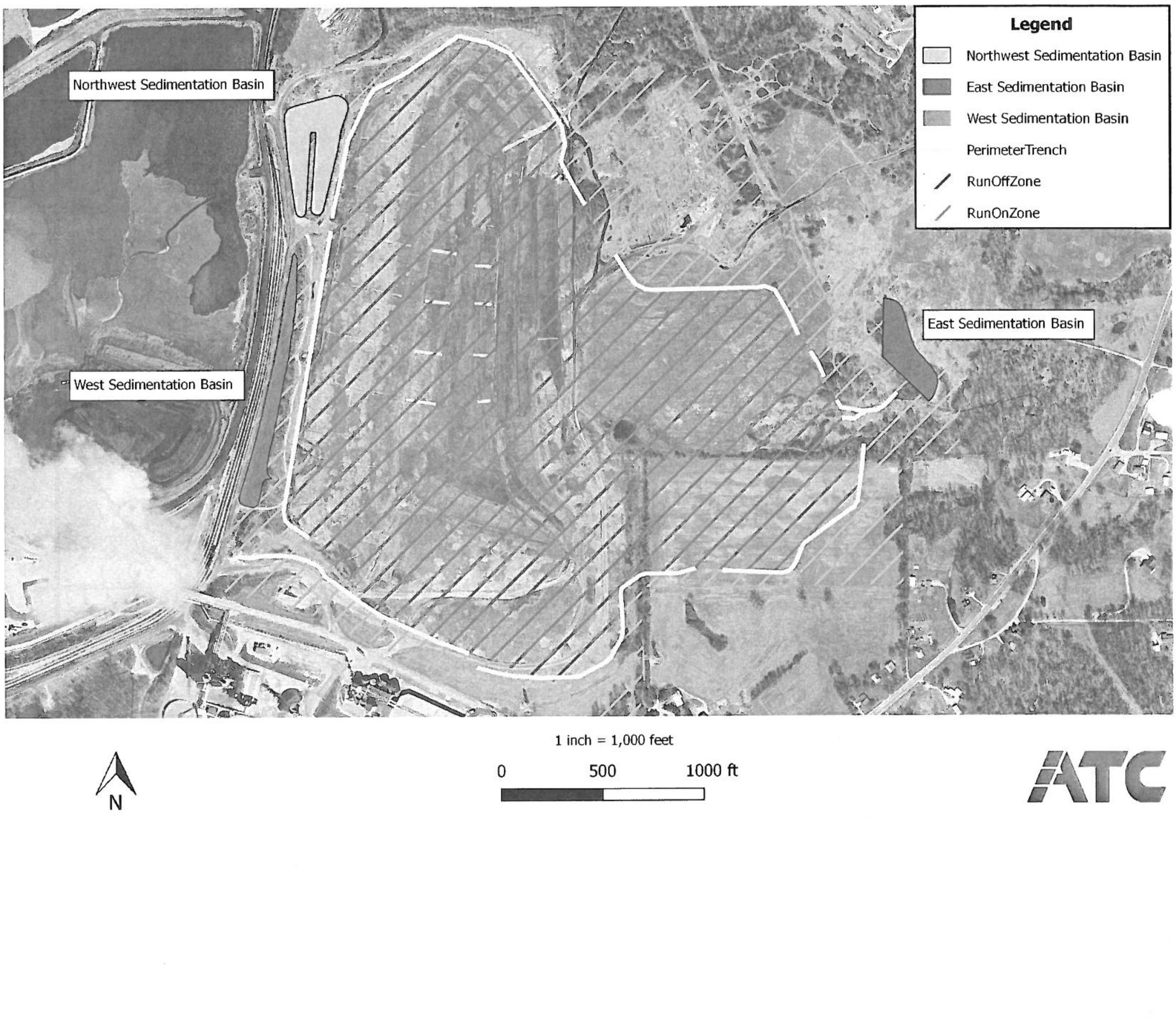


H:\2016\IPL\PETERSBURG\170LF00274\CCR POST CLOSE\174LF00274-PGS-LANDFILL LIMITS.DWG, SITE

VICINITY MAP

IPL PETERSBURG GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL
PETERSBURG, INDIANA

Project Number: 170LF00274		Drn. By: WS
Drawing File: SEE LOWER LEFT		Ckd. By: CD
Date: 9/16	Scale: AS SHOWN	App'd By:
ATC		Figure: 1


Legend
Northwest Sedimentation Basin
East Sedimentation Basin
West Sedimentation Basin
PerimeterTrench
RunOffZone
RunOnZone
Northwest Sedimentation Basin
West Sedimentation Basin
East Sedimentation Basin
1 inch = 1,000 feet
0
500
1000 ft
N
ATC

FLOW CONTROL STRUCTURE CONVEYANCE TABLE

FLOW CONTROL STRUCTURE	FLOW TYPE CONVEYED
Perimeter Channels	Run-On & Run-Off
Riprap Downchutes	Run-Off
Terrace Berms	Run-Off
Outlets to Retention Basins	Run-On & Run-Off
Retention Basins	Run-On & Run-Off

Appendix B: Calculations for Run-On Control System

Run-On Control System Summary

Run-On Control System

The objective of this calculation is to demonstrate that the perimeter stormwater controls for the IPL Petersburg Type III Restricted Waste Landfill have capacity to control run-on flow from the 24-hour, 25-year storm. According to EPA, run-on is defined as

"...Any liquid that drains over land onto any part of a CCR landfill or any lateral expansion of a CCR landfill. In surface water hydrology, run-on is a quantity of surface run-off, or excess rain, snowmelt, or other sources of water, which flows from an upstream catchment area onto a specific downstream location."

Although perimeter ditches and retention pond systems handle *both* run-on and run-off flow, the hydraulic capacities of these structures will be evaluated under this run-on section since the structures are located in the run-on producing zone of the landfill and adjoining area.

CALCULATION METHOD:

The capacity of the perimeter stormwater controls will be evaluated using the SCS method and Manning's equation.

DEFINITION OF VARIABLES

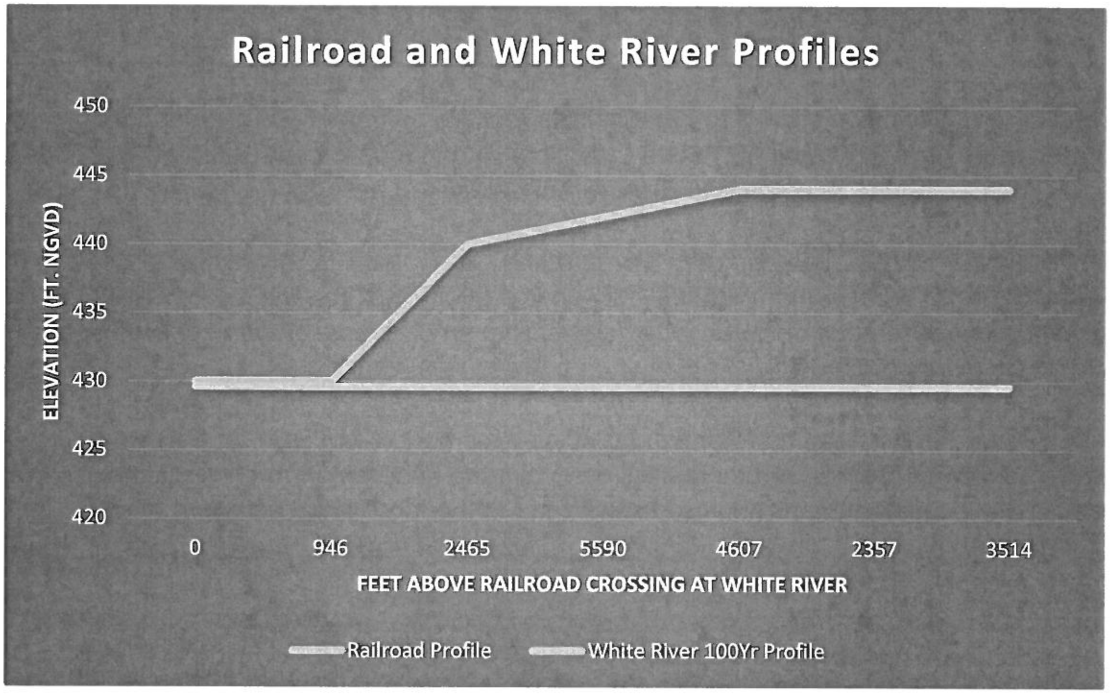
A = area;
CN = curve number;
Q = flow;
S = Channel Sideslope

CALCULATIONS

1.0 Perimeter Road

Drainage from the watersheds surrounding the Petersburg Landfill flows away from the landfill. Two principal watersheds which are UNT Lick Creek and UNT White River are shown on USGS Streamstats maps as dividing the landfill area in half with the landfill area as the highest local feature. This demonstrates that the landfill benefits from natural drainage relief and is protected from run-on flow of these smaller watersheds.

Further run-on flow protection from the larger White River watershed is provided by haul roads and the adjoining railroad embankment to the west of the landfill. The 100-year elevation of the White River was determined using Indiana Floodplain Information Portal (INFIP) as approximately 429.6 feet. A plot of the railroad embankment height versus the 100-year elevation of the White River is shown in the following figure:



At all locations along the elevation profile, the railroad embankment height is higher than the 100-year flood elevation. Therefore the landfill is insularly protected from run-on flow of the White River.

2.0 Perimeter Stormwater Channels

According to design plans perimeter ditches have 6.67'-foot channel bottoms with 3H:1V sideslopes. Perimeter ditches drain to sedimentation basins that are described in the following section.

The largest drainage area to any perimeter ditch segment was determined to be approximately 6 acres. EPA SWMM modeling results with max flow to a typical perimeter stormwater channel and capacity from manning's equation are summarized below:

EPA SWMM Max Flow (cfs)	Ditch Bottom (ft.)	Side Slope (xH:1V)	Ditch Height (ft.)	Capacity Channel (cfs)	Capacity> Max Flow?
31.64	6.67	3:1	4	394.7	YES

The ditch capacity is sufficient to handle stormwater flow from the landfill and adjacent areas.

3.0 Ponds

The combined run-on and run-off flow from the Petersburg Landfill is handled by a series of retention basins to the west of the landfill during the interim conditions. The west retention basins are the Northwest Sedimentation Basin and the West Sedimentation Basin. The Northwest Sedimentation Basin outlets to the West Sedimentation Basin before treatment and discharge to an NPDES outfall area.

For the final cover conditions an East Sedimentation Pond will add additional storage capacity. The storage volumes of individual basins were calculated and their approximate Stage-Storage curves are attached to this appendix for reference.

Combined storage available in the East, West, and Northwest Sedimentation basins is sufficient to handle the 25-year storm volume from the landfill and adjacent contributing areas during both interim and final cover conditions.

DISCUSSION:

The perimeter stormwater controls for the Petersburg Type III Restricted Waste Landfill have capacity to control both run-on and non-contact water run-off for the 24-Hour, 25-Year storm.

REFERENCES:

1. EPA SWMM v. 5.1 by Water Resources Division of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory with assistance from the consulting firm of CDM, Inc.
2. StreamStats in Indiana. U.S. Geological Survey. <http://streamstats.usgs.gov/>.
3. United States Department of Agriculture, "Urban Hydrology for Small Watersheds", Technical Release 55, June 1986.
4. NOAA Atlas 14, Volume 2, Version 3. "Precipitation Frequency Data Server". G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M. Yekta, and D. Riley.
5. Indiana Floodplain Information Portal (INFIP). <http://dnrmaps.dnr.in.gov/appsphp/fdms/>.

Natural Resources Conservation Service
United States Department of Agriculture

Trapezoidal Channel Section

Participant: Indianapolis Power & Light Co.
Location: Petersburg
County: County, Indiana
Designer:
Date: 09/30/2016

Checker: C.P.D.
Date: 09/28/16

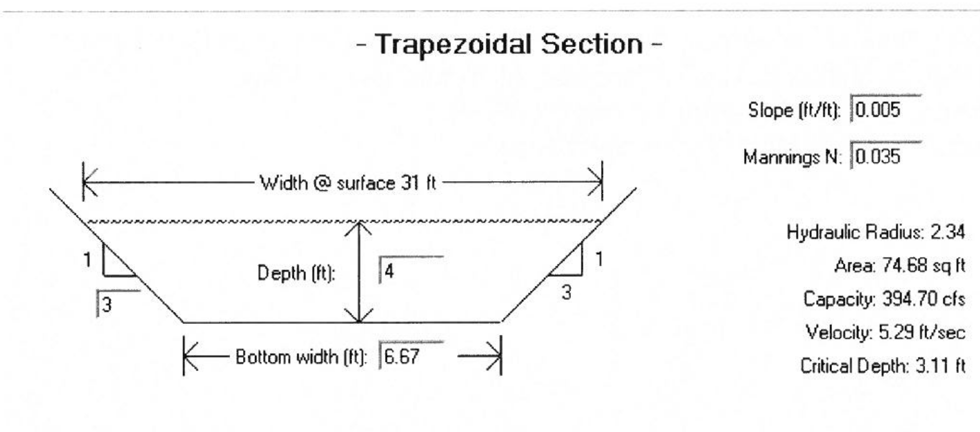
Hydraulics Formula, Version 2.2.1

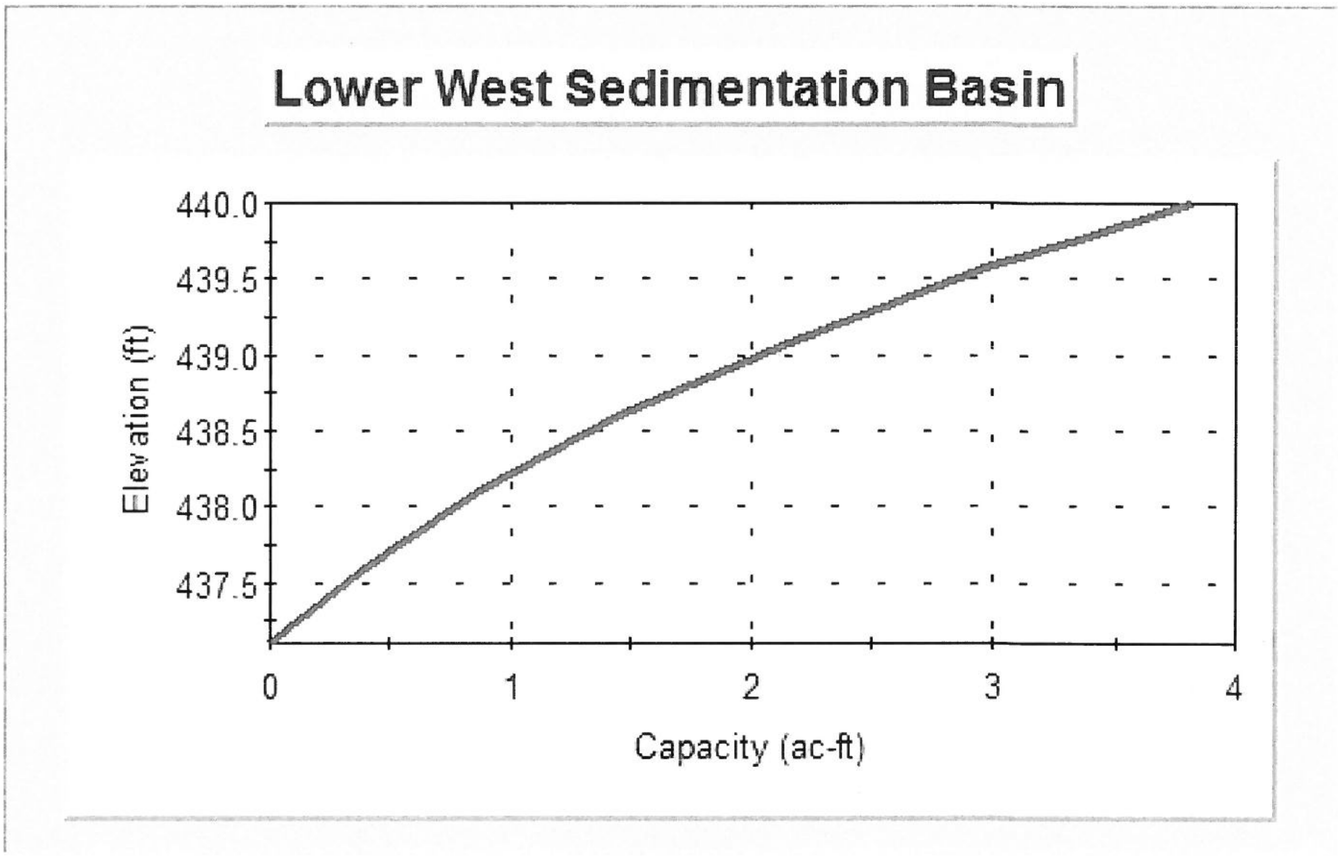
Perimeter Ditch

Slope: 0.005 ft/ft
'n' value: 0.035

Hydraulic Radius: 2.34
Area: 74.68 sq ft
Velocity: 5.29 ft/sec
Capacity: 394.70 cfs

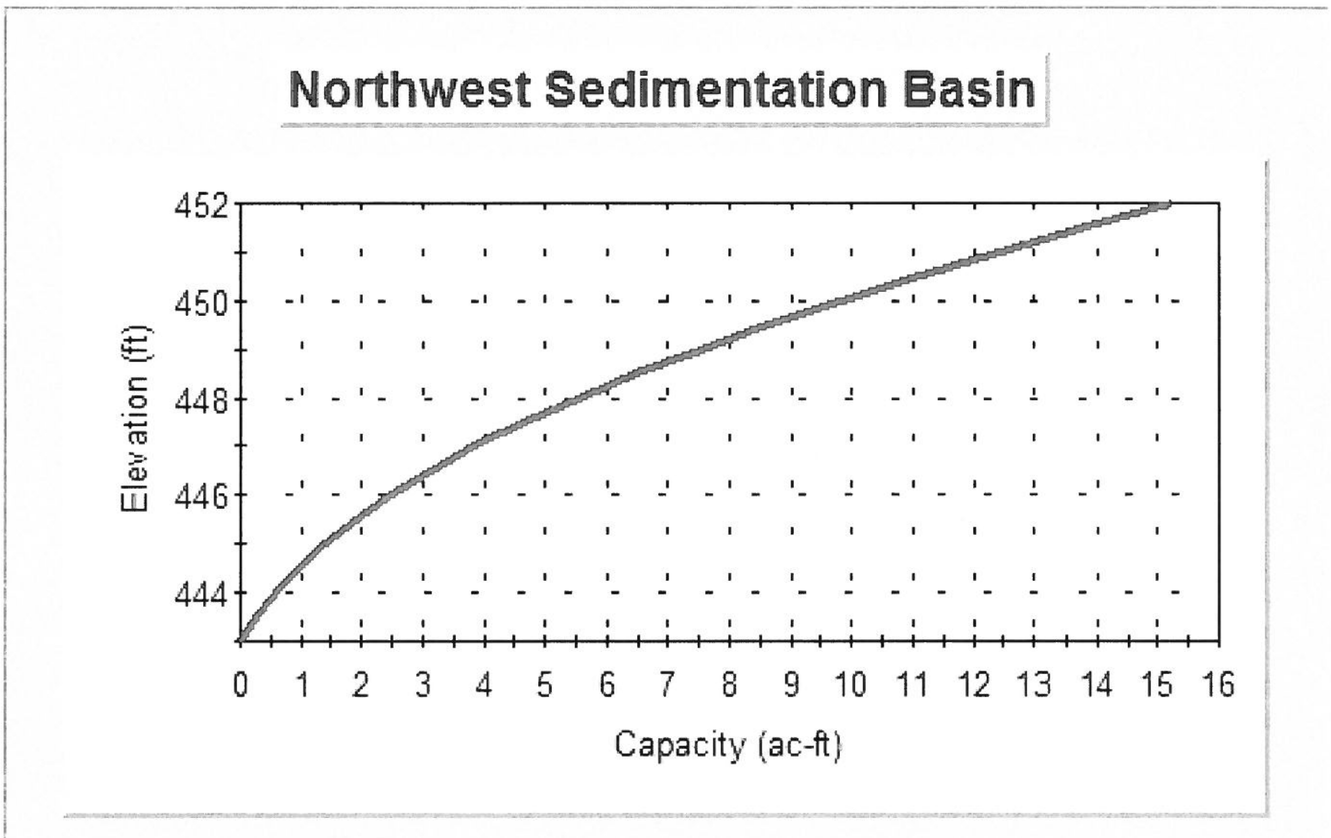
Sideslope: 3:1
Bottom Width: 6.67 ft
Depth of Flow: 4 ft.
Width @ surface 31 ft





Structure # 1

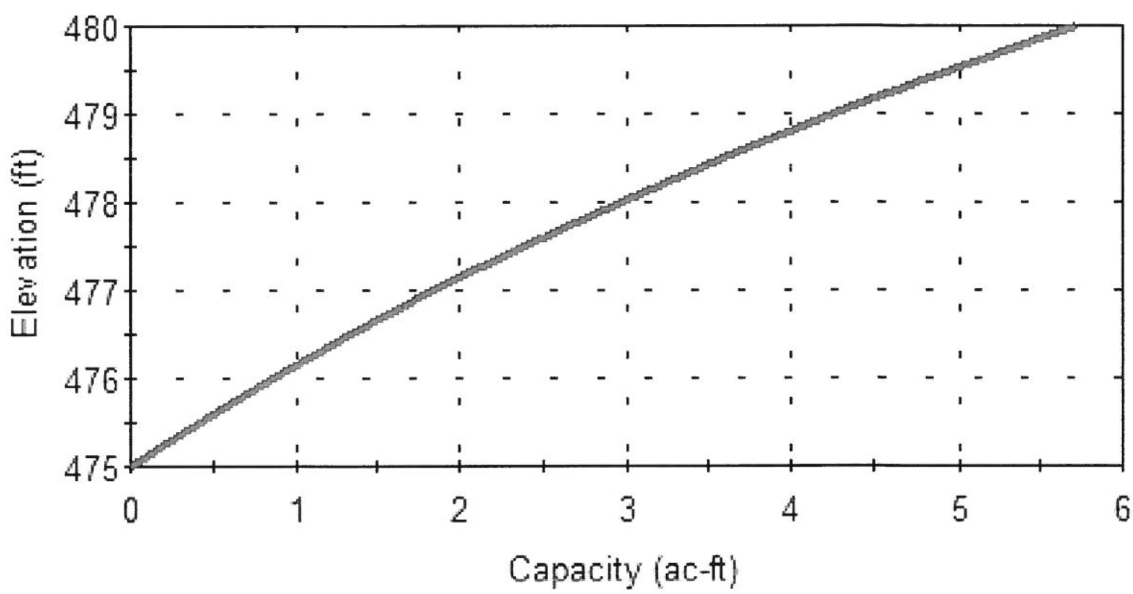
	Elevation (ft)	Area (ac)	Capacity (ac-ft)
▶	437.10	0.740	0.000
	438.00	0.990	0.776
	439.00	1.530	2.026
	440.00	2.060	3.814
*			



Structure # 1

Elevation (ft)	Area (ac)	Capacity (ac-ft)
443.00	0.500	0.000
444.00	0.700	0.597
445.00	0.940	1.414
446.00	1.220	2.491
447.00	1.520	3.858
448.00	1.840	5.536
449.00	2.150	7.529
450.00	2.470	9.837
451.00	2.790	12.465
452.00	2.790	15.255

East Sedimentation Basin



Structure # 1

Elevation (ft)	Area (ac)	Capacity (ac-ft)
475.00	0.820	0.000
476.00	0.910	0.865
477.00	1.050	1.844
478.00	1.210	2.973
479.00	1.370	4.262
480.00	1.540	5.716

Appendix C: Calculations for Run-Off Control System

Run-Off Control System Interim and Final Cover Conditions Summary

Run-Off Control System Interim and Final Cover Conditions Summary

The objective of this calculation is to evaluate the size of run-off control measures within the IPL Petersburg Type III Restricted Waste Landfill to provide capacity to control non-contract water run-off for the 24-Hour, 25-Year storm during interim and final cover conditions.

CALCULATION METHOD

The amount of rainfall for the 24-Hour, 25-Year storm event was taken from NOAA Atlas 14, Volume 2 [Ref. 4]. For the Petersburg, Indiana region, Atlas 14 yields a rainfall amount of approximately 5.5 inches.

Terrace-style diversion berm and riprap downchute designs were evaluated using EPA SWMM v. 5.1 modeling software [Ref. 1]. The EPA SWMM software uses the Soil Conservation Service (SCS) TR-55 [Ref. 3], Curve Number method for calculating runoff.

To demonstrate capacity of the interim and final cover storm water measures, a typical stormwater run-off control unit consisting of a downchute and adjoining terrace berms was modelled. The modelling simulation is for the stormwater run-off control unit of the Final Cover Grading Plan with the largest drainage area (highest loading condition). Deductive logic applies the calculated results from the highest loading condition to all other units with lesser loading conditions.

DEFINITION OF VARIABLES

A = area;
CN = curve number;
Q = flow;
S = Channel Sideslope

CALCULATIONS

1.0 Routing Procedure

After placement of the CCR to achieve a consistent grade across the landfill footprint, the landfill final closure area will be covered in protective soil and a vegetative layer. Several levels of terraces will be graded to act as diversion berms. Terraces will be spaced approximately sixty (60) feet apart from one another and will have a width of approximately twenty-four (24) feet. Individual terraces will convey run-off flow from the vegetated landfill cover areas to riprap downchute channels.

2.0 Hydraulic Performance of a Typical Terrace Diversion Berm

According to design plans terraces are 24 feet wide (topwidth) with 1.2-foot channel bottoms. Terrace berm channels are graded with a channel slope of 0.4% and drain to riprap downchutes.

The largest drainage area to any final cover terrace will be limited to approximately 0.6 acres. Flow to terraces of a typical stormwater run-off control unit are summarized in Table 1 below:

Table 1 – Terrace Berm Capacity

SWMM ID	Channel Slope {S}	Terrace Side Slope	Terrace Height (ft.)	Flow {Q} (cfs)	Flow Height (ft.)	Freeboard Inches
11	0.40%	3H:1V & 2%	0.5	1.5	0.21	3.48
12	0.40%	3H:1V & 2%	0.5	1.61	0.24	3.12
13	0.40%	3H:1V & 2%	0.5	1.75	0.27	2.76
14	0.40%	3H:1V & 2%	0.5	1.83	0.28	2.64
15	0.40%	3H:1V & 2%	0.5	1.9	0.29	2.52
16	0.40%	3H:1V & 2%	0.5	1.66	0.25	3
17	0.40%	3H:1V & 2%	0.5	1.61	0.23	3.24
18	0.40%	3H:1V & 2%	0.5	1.56	0.23	3.24
19	0.40%	3H:1V & 2%	0.5	1.53	0.21	3.48
20	0.40%	3H:1V & 2%	0.5	1.43	0.21	3.48
21	0.40%	3H:1V & 2%	0.5	2.16	0.3	2.4
22	0.40%	3H:1V & 2%	0.5	2.21	0.3	2.4
23	0.40%	3H:1V & 2%	0.5	2.26	0.3	2.4
24	0.40%	3H:1V & 2%	0.5	2.15	0.3	2.4
25	0.40%	3H:1V & 2%	0.5	2.41	0.31	2.28
26	0.40%	3H:1V & 2%	0.5	2.45	0.31	2.28
27	0.40%	3H:1V & 2%	0.5	2.49	0.31	2.28
28	0.40%	3H:1V & 2%	0.5	1.57	0.23	3.24
29	0.40%	3H:1V & 2%	0.5	1.45	0.2	3.6
30	0.40%	3H:1V & 2%	0.5	1.37	0.18	3.84

All terrace berms have positive freeboard indicating that sufficient design capacity exists.

3.0 Hydraulic Performance of a Typical Riprap Downchute

The trapezoidal riprap downchute channels have a 4-foot bottom width with 3H:1V sideslopes and 1 foot depth. All flows and velocities for a typical downchute under maximum loading were calculated using the EPA SWMM program [Ref. 1]. The resulting height of flow and capacity (freeboard) calculations are shown in Table 2 below:

Table 2 – Downchute Channel Capacity

SWMM ID	Channel Slope	Terrace Side Slope	Downchute Height (ft.)	Flow {Q} (cfs)	Flow Height (ft.)	Freeboard Inches
1	0.33	3H:1V	1	3.04	0.14	10.32
2	0.33	3H:1V	1	6.51	0.21	9.48
3	0.33	3H:1V	1	10.51	0.28	8.64
4	0.33	3H:1V	1	14.48	0.32	8.16
5	0.33	3H:1V	1	18.78	0.36	7.68
6	0.33	3H:1V	1	22.61	0.4	7.2
7	0.33	3H:1V	1	26.26	0.44	6.72
8	0.33	3H:1V	1	28.48	0.45	6.6
9	0.33	3H:1V	1	30.2	0.47	6.36
10	0.33	3H:1V	1	31.64	0.47	6.36

All channels have positive freeboard indicating that sufficient capacity exists.

DISCUSSION:

Run-off control measures for the IPL Petersburg Type III Restricted Waste Landfill have capacity to control non-contact water run-off for the 24-Hour, 25-Year storm event during interim and final cover conditions.

REFERENCES:

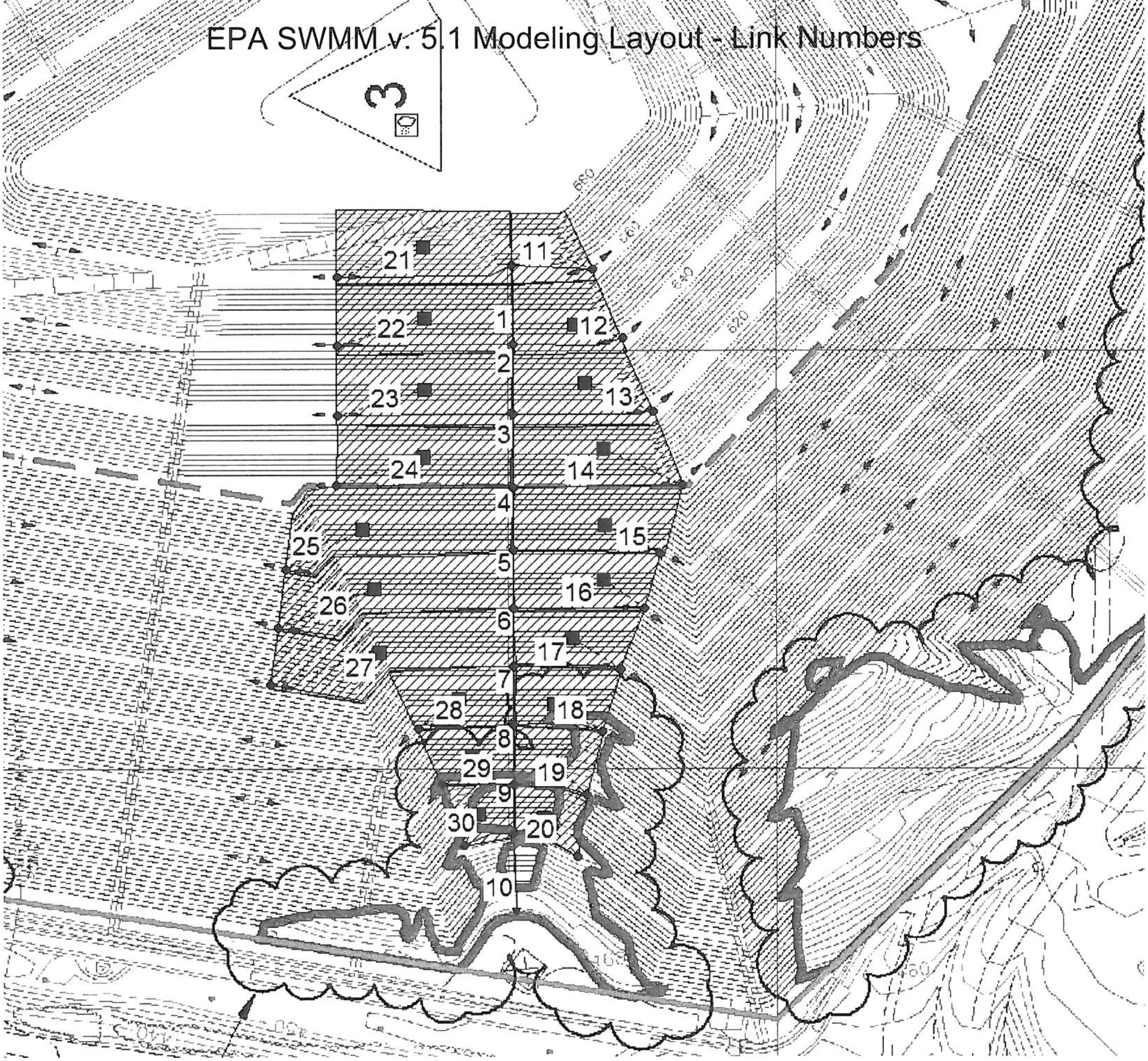
1. EPA SWMM v. 5.1 by Water Resources Division of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory with assistance from the consulting firm of CDM, Inc.
2. StreamStats in Indiana. U.S. Geological Survey. <http://streamstats.usgs.gov/>.
3. United States Department of Agriculture, “Urban Hydrology for Small Watersheds”, Technical Release 55, June 1986.
4. NOAA Atlas 14, Volume 2, Version 3. “Precipitation Frequency Data Server”. G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M. Yekta, and D. Riley.
5. Indiana Floodplain Information Portal (INFIP). <http://dnrmaps.dnr.in.gov/appsphp/fdms/>.

Appendix D: References

REFERENCE NO.	DESCRIPTION
1	EPA SWMM Modeling
2	USGS Streamstats – Drainage Areas
3	USDA TR-55
4	NOAA Atlas 14 Rainfall
5	INFIP Report

Reference 1: EPA SWMM Modeling

EPA SWMM v. 5.1 Modeling Layout - Link Numbers



EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)

IPL Petersburg Landfill - Downchute Routing Max Drainage Area 25Yr, 24Hr Storm

****
Element Count
****
Number of rain gages 1
Number of subcatchments ... 20
Number of nodes 31
Number of links 30
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
1	25Year24Hour	CUMULATIVE	6 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outle
32	0.16	93.60	0.00	33.0000	1	3
33	0.23	131.20	0.00	33.0000	1	4
34	0.32	165.10	0.00	33.0000	1	5
35	0.34	205.30	0.00	33.0000	1	6
36	0.35	178.70	0.00	33.0000	1	7
37	0.26	156.00	0.00	33.0000	1	8
38	0.22	130.60	0.00	33.0000	1	15
39	0.20	112.50	0.00	33.0000	1	16
40	0.17	102.00	0.00	33.0000	1	20
41	0.16	78.90	0.00	33.0000	1	21
42	0.11	65.70	0.00	33.0000	1	31
43	0.15	81.50	0.00	33.0000	1	30
44	0.21	114.30	0.00	33.0000	1	29
45	0.48	306.50	0.00	33.0000	1	28
46	0.47	297.30	0.00	33.0000	1	27
47	0.46	282.70	0.00	33.0000	1	26
48	0.40	210.90	0.00	33.0000	1	25
49	0.42	209.10	0.00	33.0000	1	24
50	0.41	205.80	0.00	33.0000	1	23
51	0.40	209.70	0.00	33.0000	1	22

IPL Petersburg Landfill - Downchute Routing Max Drainage Area 25Yr, 24Hr Storm

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
1	JUNCTION	660.00	1.00	0.0	
3	JUNCTION	660.37	1.00	0.0	
4	JUNCTION	640.52	1.00	0.0	
5	JUNCTION	620.66	1.00	0.0	
6	JUNCTION	600.82	1.00	0.0	
7	JUNCTION	580.71	1.00	0.0	
8	JUNCTION	560.62	1.00	0.0	
9	JUNCTION	640.00	1.00	0.0	
10	JUNCTION	620.00	1.00	0.0	
11	JUNCTION	600.00	1.00	0.0	
12	JUNCTION	580.00	1.00	0.0	
13	JUNCTION	560.00	1.00	0.0	
14	JUNCTION	540.00	1.00	0.0	
15	JUNCTION	540.52	1.00	0.0	
16	JUNCTION	520.45	1.00	0.0	
17	JUNCTION	520.00	1.00	0.0	
18	JUNCTION	500.00	1.00	0.0	
19	JUNCTION	480.00	1.00	0.0	
20	JUNCTION	500.41	1.00	0.0	
21	JUNCTION	480.32	1.00	0.0	
22	JUNCTION	660.82	1.00	0.0	
23	JUNCTION	640.82	1.00	0.0	
24	JUNCTION	620.84	1.00	0.0	
25	JUNCTION	600.84	1.00	0.0	
26	JUNCTION	581.13	1.00	0.0	
27	JUNCTION	561.19	1.00	0.0	
28	JUNCTION	541.23	1.00	0.0	
29	JUNCTION	520.46	1.00	0.0	
30	JUNCTION	500.33	1.00	0.0	
31	JUNCTION	480.26	1.00	0.0	
2	OUTFALL	460.00	1.00	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roug
1	1	9	CONDUIT	89.4	22.9531	0
2	9	10	CONDUIT	91.2	22.4770	0
3	10	11	CONDUIT	85.9	23.9408	0
4	11	12	CONDUIT	73.3	28.3613	0
5	12	13	CONDUIT	70.6	29.5386	0
6	13	14	CONDUIT	70.6	29.5386	0
7	14	17	CONDUIT	70.6	29.5386	0
8	17	18	CONDUIT	67.1	31.2256	0
9	18	19	CONDUIT	68.9	30.3337	0

10	19	2	CONDUIT	61.7	34.2650	0
11	3	1	CONDUIT	93.6	0.3953	0
12	4	9	CONDUIT	131.2	0.3963	0
13	5	10	CONDUIT	165.1	0.3998	0
14	6	11	CONDUIT	205.3	0.3994	0
15	7	12	CONDUIT	178.7	0.3973	0
16	8	13	CONDUIT	156.0	0.3974	0
17	15	14	CONDUIT	130.6	0.3982	0
18	16	17	CONDUIT	112.5	0.4000	0
19	20	18	CONDUIT	102.0	0.4020	0
20	21	19	CONDUIT	78.9	0.4056	0
21	22	1	CONDUIT	205.0	0.4000	0
22	23	9	CONDUIT	205.8	0.3984	0
23	24	10	CONDUIT	209.1	0.4017	0
24	25	11	CONDUIT	210.9	0.3983	0
25	26	12	CONDUIT	282.7	0.3997	0
26	27	13	CONDUIT	297.3	0.4003	0
27	28	14	CONDUIT	306.5	0.4013	0
28	29	17	CONDUIT	114.3	0.4025	0
29	30	18	CONDUIT	81.5	0.4049	0
30	31	19	CONDUIT	65.7	0.3957	0

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
1	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	109.89
2	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	108.74
3	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	112.23
4	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	122.15
5	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	124.66
6	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	124.66
7	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	124.66
8	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	128.17
9	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	126.33
10	TRAPEZOIDAL	1.00	7.00	0.68	10.00	1	134.26
11	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.86
12	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.87
13	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.90
14	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.90
15	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.88
16	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.88
17	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.89
18	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.90
19	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.92
20	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.96
21	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.90
22	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.89
23	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.92
24	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.89

25	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.90
26	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.91
27	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.92
28	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.93
29	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.95
30	TRAPEZOIDAL	0.50	7.22	0.26	27.70	1	7.86

```
*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... KINWAVE
Starting Date ............ APR-08-2016 00:00:00
Ending Date .............. APR-09-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:06:00
Wet Time Step ............ 00:06:00
Dry Time Step ............ 00:06:00
Routing Time Step ........ 30.00 sec


**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......         2.755         5.584
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........         0.888         1.801
Surface Runoff ...........         1.841         3.731
Final Storage ............         0.028         0.057
Continuity Error (%) .....        -0.096


**************************        Volume        Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
```

```
Wet Weather Inflow .......        1.839         0.599
Groundwater Inflow .......        0.000         0.000
RDII Inflow ..............        0.000         0.000
External Inflow ..........        0.000         0.000
External Outflow .........        1.954         0.637
Flooding Loss ............        0.007         0.002
Evaporation Loss .........        0.000         0.000
Exfiltration Loss ........        0.000         0.000
Initial Stored Volume ....        0.122         0.040
Final Stored Volume ......        0.008         0.003
Continuity Error (%) .....       -0.355


********************************
Highest Flow Instability Indexes
********************************
All links are stable.


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.04
Percent Not Converging      :     0.00


***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal
32	5.58	0.00	0.00	1.80	3.73	0.02
33	5.58	0.00	0.00	1.80	3.73	0.02
34	5.58	0.00	0.00	1.80	3.73	0.03
35	5.58	0.00	0.00	1.80	3.73	0.03
36	5.58	0.00	0.00	1.80	3.73	0.04
37	5.58	0.00	0.00	1.80	3.73	0.03
38	5.58	0.00	0.00	1.80	3.73	0.02
39	5.58	0.00	0.00	1.80	3.73	0.02
40	5.58	0.00	0.00	1.80	3.73	0.02
41	5.58	0.00	0.00	1.80	3.73	0.02
42	5.58	0.00	0.00	1.80	3.73	0.01
43	5.58	0.00	0.00	1.80	3.73	0.02
44	5.58	0.00	0.00	1.80	3.73	0.02
45	5.58	0.00	0.00	1.80	3.73	0.05

46	5.58	0.00	0.00	1.80	3.73	0.05
47	5.58	0.00	0.00	1.80	3.73	0.05
48	5.58	0.00	0.00	1.80	3.73	0.04
49	5.58	0.00	0.00	1.80	3.73	0.04
50	5.58	0.00	0.00	1.80	3.73	0.04
51	5.58	0.00	0.00	1.80	3.73	0.04

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min	Reported Max Depth Feet
1	JUNCTION	0.05	1.00	661.00	0 00:00	0.29
3	JUNCTION	0.03	0.21	660.58	0 12:00	0.21
4	JUNCTION	0.03	0.25	640.77	0 12:00	0.24
5	JUNCTION	0.04	0.28	620.94	0 12:00	0.28
6	JUNCTION	0.04	0.29	601.11	0 12:00	0.29
7	JUNCTION	0.04	0.29	581.00	0 12:00	0.29
8	JUNCTION	0.04	0.26	560.88	0 12:00	0.26
9	JUNCTION	0.05	1.00	641.00	0 00:00	0.30
10	JUNCTION	0.05	1.00	621.00	0 00:00	0.30
11	JUNCTION	0.05	1.00	601.00	0 00:00	0.31
12	JUNCTION	0.05	1.00	581.00	0 00:00	0.35
13	JUNCTION	0.05	1.00	561.00	0 00:00	0.39
14	JUNCTION	0.05	1.00	541.00	0 00:00	0.43
15	JUNCTION	0.03	0.24	540.76	0 12:00	0.24
16	JUNCTION	0.03	0.23	520.68	0 12:00	0.23
17	JUNCTION	0.04	1.00	521.00	0 00:00	0.44
18	JUNCTION	0.05	1.00	501.00	0 00:00	0.46
19	JUNCTION	0.05	1.00	481.00	0 00:00	0.46
20	JUNCTION	0.03	0.22	500.63	0 12:00	0.22
21	JUNCTION	0.03	0.21	480.53	0 12:00	0.21
22	JUNCTION	0.04	0.31	661.13	0 12:00	0.30
23	JUNCTION	0.05	0.31	641.13	0 12:00	0.31
24	JUNCTION	0.05	0.32	621.16	0 12:00	0.31
25	JUNCTION	0.04	0.31	601.15	0 12:00	0.30
26	JUNCTION	0.05	0.33	581.46	0 12:00	0.32
27	JUNCTION	0.05	0.33	561.52	0 12:00	0.32
28	JUNCTION	0.05	0.33	541.56	0 12:00	0.33
29	JUNCTION	0.03	0.24	520.70	0 12:00	0.23
30	JUNCTION	0.03	0.21	500.54	0 12:00	0.20
31	JUNCTION	0.02	0.18	480.44	0 12:00	0.18
2	OUTFALL	0.04	0.47	460.47	0 12:04	0.46

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
1	JUNCTION	0.00	3.22	0 00:00	0	0.0602
3	JUNCTION	0.94	0.94	0 12:00	0.0162	0.0162
4	JUNCTION	1.35	1.35	0 12:00	0.0233	0.0233
5	JUNCTION	1.88	1.88	0 12:00	0.0324	0.0324
6	JUNCTION	2.00	2.00	0 12:00	0.0344	0.0344
7	JUNCTION	2.06	2.06	0 12:00	0.0354	0.0354
8	JUNCTION	1.53	1.53	0 12:00	0.0263	0.0263
9	JUNCTION	0.00	6.51	0 12:03	0	0.129
10	JUNCTION	0.00	10.52	0 12:03	0	0.208
11	JUNCTION	0.00	14.49	0 12:03	0	0.288
12	JUNCTION	0.00	18.77	0 12:04	0	0.375
13	JUNCTION	0.00	22.61	0 12:04	0	0.454
14	JUNCTION	0.00	26.27	0 12:04	0	0.529
15	JUNCTION	1.29	1.29	0 12:00	0.0223	0.0223
16	JUNCTION	1.18	1.18	0 12:00	0.0202	0.0202
17	JUNCTION	0.00	28.48	0 12:04	0	0.573
18	JUNCTION	0.00	30.20	0 12:04	0	0.608
19	JUNCTION	0.00	31.64	0 12:04	0	0.637
20	JUNCTION	1.00	1.00	0 12:00	0.0172	0.0172
21	JUNCTION	0.94	0.94	0 12:00	0.0162	0.0162
22	JUNCTION	2.35	2.35	0 12:00	0.0405	0.0405
23	JUNCTION	2.41	2.41	0 12:00	0.0415	0.0415
24	JUNCTION	2.47	2.47	0 12:00	0.0425	0.0425
25	JUNCTION	2.35	2.35	0 12:00	0.0405	0.0405
26	JUNCTION	2.70	2.70	0 12:00	0.0466	0.0466
27	JUNCTION	2.76	2.76	0 12:00	0.0476	0.0476
28	JUNCTION	2.82	2.82	0 12:00	0.0486	0.0486
29	JUNCTION	1.23	1.23	0 12:00	0.0213	0.0213
30	JUNCTION	0.88	0.88	0 12:00	0.0152	0.0152
31	JUNCTION	0.65	0.65	0 12:00	0.0111	0.0111
2	OUTFALL	0.00	31.64	0 12:04	0	0.637

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Feet	Min. Depth Below Rim Feet
1	JUNCTION	24.00	1.000	0.000
3	JUNCTION	24.00	0.214	0.786
4	JUNCTION	24.00	0.248	0.752

5	JUNCTION	24.00	0.283	0.717
6	JUNCTION	24.00	0.290	0.710
7	JUNCTION	24.00	0.294	0.706
8	JUNCTION	24.00	0.261	0.739
9	JUNCTION	24.00	1.000	0.000
10	JUNCTION	24.00	1.000	0.000
11	JUNCTION	24.00	1.000	0.000
12	JUNCTION	24.00	1.000	0.000
13	JUNCTION	24.00	1.000	0.000
14	JUNCTION	24.00	1.000	0.000
15	JUNCTION	24.00	0.244	0.756
16	JUNCTION	24.00	0.234	0.766
17	JUNCTION	24.00	1.000	0.000
18	JUNCTION	24.00	1.000	0.000
19	JUNCTION	24.00	1.000	0.000
20	JUNCTION	24.00	0.219	0.781
21	JUNCTION	24.00	0.213	0.787
22	JUNCTION	24.00	0.310	0.690
23	JUNCTION	24.00	0.313	0.687
24	JUNCTION	24.00	0.315	0.685
25	JUNCTION	24.00	0.310	0.690
26	JUNCTION	24.00	0.327	0.673
27	JUNCTION	24.00	0.330	0.670
28	JUNCTION	24.00	0.333	0.667
29	JUNCTION	24.00	0.238	0.762
30	JUNCTION	24.00	0.208	0.792
31	JUNCTION	24.00	0.183	0.817

****
Node Flooding Summary
****

Flooding refers to all water that overflows a node, whether it ponds or not.

Node	Hours Flooded	Maximum Rate CFS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 gal	Maximum Ponded Volume 1000 ft3
1	0.01	0.50	0 00:00	0.000	0.000
9	0.01	1.00	0 00:00	0.000	0.000
10	0.01	1.00	0 00:00	0.000	0.000
11	0.01	1.00	0 00:00	0.000	0.000
12	0.01	1.00	0 00:00	0.000	0.000
13	0.01	1.00	0 00:00	0.000	0.000
14	0.01	1.00	0 00:00	0.000	0.000
17	0.01	1.00	0 00:00	0.000	0.000
18	0.01	1.00	0 00:00	0.000	0.000
19	0.01	1.00	0 00:00	0.000	0.000

****

Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CFS	Max Flow CFS	Total Volume 10^6 gal
2	85.38	1.15	31.64	0.637
System	85.38	1.15	31.64	0.637

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
1	CONDUIT	3.04	0	12:03	5.40	0.03	0.14
2	CONDUIT	6.51	0	12:03	6.55	0.06	0.21
3	CONDUIT	10.51	0	12:03	7.86	0.09	0.28
4	CONDUIT	14.48	0	12:04	9.24	0.12	0.32
5	CONDUIT	18.78	0	12:04	10.18	0.15	0.36
6	CONDUIT	22.61	0	12:04	10.80	0.18	0.40
7	CONDUIT	26.26	0	12:04	11.31	0.21	0.44
8	CONDUIT	28.48	0	12:04	11.82	0.22	0.45
9	CONDUIT	30.20	0	12:04	11.92	0.24	0.47
10	CONDUIT	31.64	0	12:04	12.61	0.24	0.47
11	CONDUIT	1.50	0	00:00	2.50	0.19	0.42
12	CONDUIT	1.61	0	00:00	2.55	0.20	0.48
13	CONDUIT	1.75	0	12:03	2.59	0.22	0.55
14	CONDUIT	1.83	0	12:04	2.61	0.23	0.56
15	CONDUIT	1.90	0	12:03	2.60	0.24	0.57
16	CONDUIT	1.66	0	00:00	2.58	0.21	0.50
17	CONDUIT	1.61	0	00:00	2.56	0.20	0.47
18	CONDUIT	1.56	0	00:00	2.54	0.20	0.46
19	CONDUIT	1.53	0	00:00	2.53	0.19	0.43
20	CONDUIT	1.43	0	00:00	2.49	0.18	0.42
21	CONDUIT	2.16	0	12:03	2.62	0.27	0.60
22	CONDUIT	2.21	0	12:03	2.61	0.28	0.60
23	CONDUIT	2.26	0	12:03	2.62	0.29	0.61
24	CONDUIT	2.15	0	12:04	2.61	0.27	0.60
25	CONDUIT	2.41	0	12:04	2.64	0.30	0.62
26	CONDUIT	2.45	0	12:05	2.65	0.31	0.62
27	CONDUIT	2.49	0	12:05	2.65	0.31	0.63
28	CONDUIT	1.57	0	00:00	2.55	0.20	0.46
29	CONDUIT	1.45	0	00:00	2.49	0.18	0.41
30	CONDUIT	1.37	0	00:00	2.43	0.17	0.36

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*************************
Conduit Surcharge Summary
*************************

No conduits were surcharged.


Analysis begun on:  Wed Sep 28 14:38:59 2016
Analysis ended on:  Wed Sep 28 14:38:59 2016
Total elapsed time: < 1 sec
```

IPL Petersburg Landfill - Downchute Routing Max Drainage Area 25Yr, 24Hr Storm

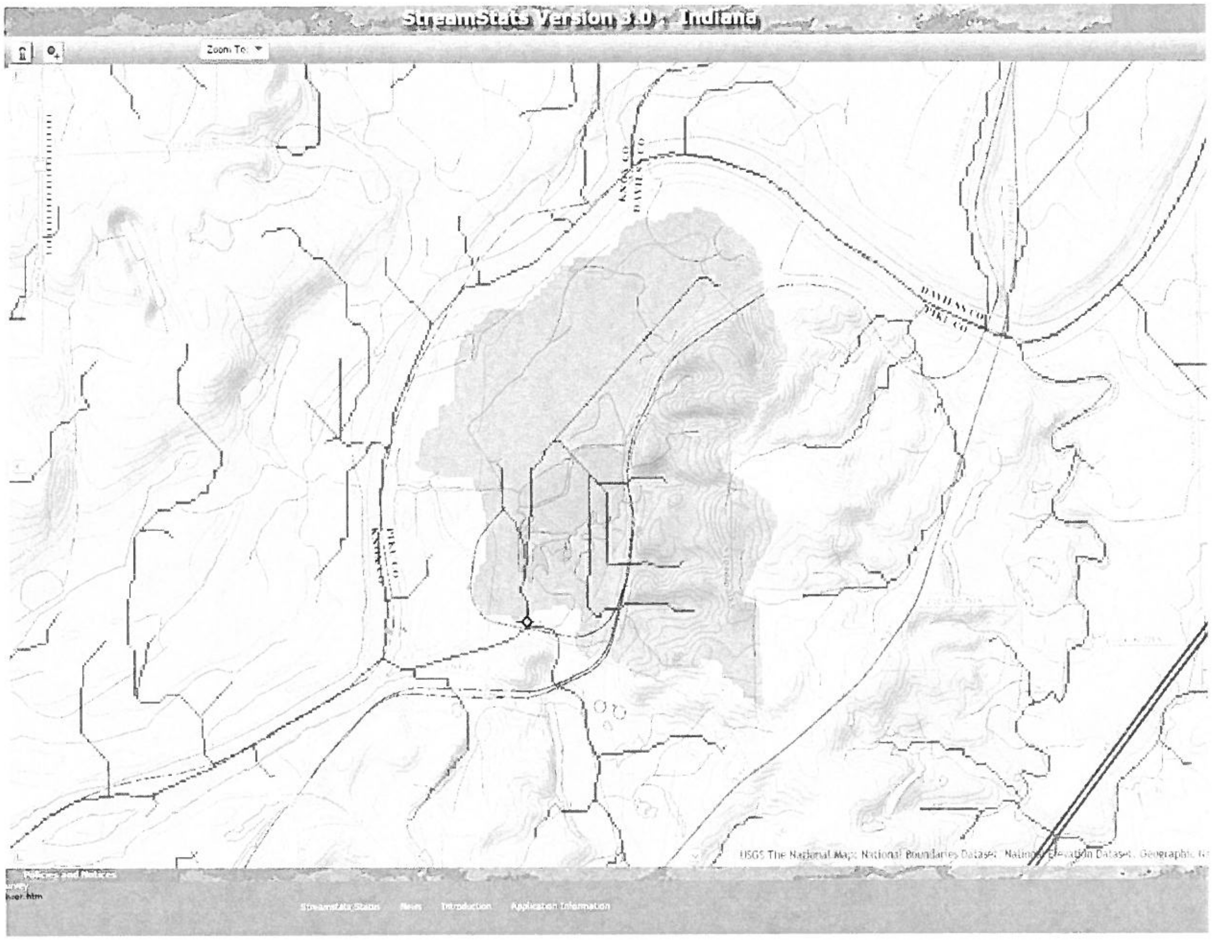
Link Flow Summary

Link	Type	Maximum |Flow| CFS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| ft/sec	Max / Full Flow	Max / Full Depth
1	CONDUIT	3.04	0	12:03	5.40	0.03	0.14
2	CONDUIT	6.51	0	12:03	6.55	0.06	0.21
3	CONDUIT	10.51	0	12:03	7.86	0.09	0.28
4	CONDUIT	14.48	0	12:04	9.24	0.12	0.32
5	CONDUIT	18.78	0	12:04	10.18	0.15	0.36
6	CONDUIT	22.61	0	12:04	10.80	0.18	0.40
7	CONDUIT	26.26	0	12:04	11.31	0.21	0.44
8	CONDUIT	28.48	0	12:04	11.82	0.22	0.45
9	CONDUIT	30.20	0	12:04	11.92	0.24	0.47
10	CONDUIT	31.64	0	12:04	12.61	0.24	0.47
11	CONDUIT	1.50	0	00:00	2.50	0.19	0.42
12	CONDUIT	1.61	0	00:00	2.55	0.20	0.48
13	CONDUIT	1.75	0	12:03	2.59	0.22	0.55
14	CONDUIT	1.83	0	12:04	2.61	0.23	0.56

IPL Petersburg Landfill - Downchute Routing Max Drainage Area 25Yr, 24Hr Storm

Link	Type	Maximum |Flow| CFS	Day of Maximum Flow	Hour of Maximum Flow	Maximum |Velocity| ft/sec	Max / Full Flow	Max / Full Depth
15	CONDUIT	1.90	0	12:03	2.60	0.24	0.57
16	CONDUIT	1.66	0	00:00	2.58	0.21	0.50
17	CONDUIT	1.61	0	00:00	2.56	0.20	0.47
18	CONDUIT	1.56	0	00:00	2.54	0.20	0.46
19	CONDUIT	1.53	0	00:00	2.53	0.19	0.43
20	CONDUIT	1.43	0	00:00	2.49	0.18	0.42
21	CONDUIT	2.16	0	12:03	2.62	0.27	0.60
22	CONDUIT	2.21	0	12:03	2.61	0.28	0.60
23	CONDUIT	2.26	0	12:03	2.62	0.29	0.61
24	CONDUIT	2.15	0	12:04	2.61	0.27	0.60
25	CONDUIT	2.41	0	12:04	2.64	0.30	0.62
26	CONDUIT	2.45	0	12:05	2.65	0.31	0.62
27	CONDUIT	2.49	0	12:05	2.65	0.31	0.63
28	CONDUIT	1.57	0	00:00	2.55	0.20	0.46
29	CONDUIT	1.45	0	00:00	2.49	0.18	0.41
30	CONDUIT	1.37	0	00:00	2.43	0.17	0.36

Reference 2: USGS Streamstats Drainage Areas


StreamStats Version 3.0 - Indiana
Zoom To
KNOX CO
DAVIESS CO
PIKE CO
USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic
Policies and Notices
StreamStats Status
News
Introduction
Application Information


StreamStats Version 3.0 : Indiana
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DAVIESS CO
PIKE CO
PIKE CO
KNOX CO
USGS The National Map: National Boundaries Dataset, National Elev
Streamstats Status
News
Introduction
Application Information

Reference 3: USDA TR-55 Calculations

USDA

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Conservation
Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

TR-55

Chapter 2 Estimating Runoff

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{[eq. 2-1]}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 2-2 into equation 2-1 gives:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{[eq. 2-3]}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

Figure 2-1 and table 2-1 solve equations 2-3 and 2-4 for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 2-2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in table 2-2 (*a* to *d*) represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 2-2 assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Appendix A defines the four groups and provides a list of most of the soils in the United States and their group classification. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced. Therefore, a method based on soil texture is given in appendix A for determining the HSG classification for disturbed soils.

Manning's equation is:

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n} \quad \text{[eq. 3-4]}$$

where:

V = average velocity (ft/s)
r = hydraulic radius (ft) and is equal to a/p_w
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of the hydraulic grade line (channel slope, ft/ft)
n = Manning's roughness coefficient for open channel flow.

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation 3-4, T_t for the channel segment can be estimated using equation 3-1.

Reservoirs or lakes

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed as zero.

Limitations

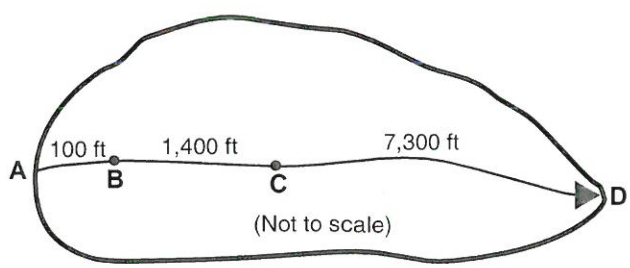
- Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation 3-3 was developed for use with the four standard rainfall intensity-duration relationships.
- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.
- The minimum T_c used in TR-55 is 0.1 hour.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR-55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outflow through the culvert.

Example 3-1

The sketch below shows a watershed in Dyer County, northwestern Tennessee. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:

Segment AB: Sheet flow; dense grass; slope (s) = 0.01 ft/ft; and length (L) = 100 ft. Segment BC: Shallow concentrated flow; unpaved; s = 0.01 ft/ft; and L = 1,400 ft. Segment CD: Channel flow; Manning's n = .05; flow area (a) = 27 ft^2; wetted perimeter (p_w) = 28.2 ft; s = 0.005 ft/ft; and L = 7,300 ft.

See figure 3-2 for the computations made on worksheet 3.



Reference 4: NOAA Atlas 14 Rainfall

NOAA Atlas 14, Volume 2, Version 3
Location name: Petersburg, Indiana, USA*
Latitude: 38.5303°, Longitude: -87.2396°
Elevation: 561.3 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.394 (0.362-0.431)	0.467 (0.429-0.511)	0.554 (0.509-0.606)	0.624 (0.570-0.681)	0.713 (0.649-0.777)	0.783 (0.710-0.852)	0.851 (0.768-0.926)	0.923 (0.827-1.00)	1.02 (0.906-1.11)	1.09 (0.964-1.19)
10-min	0.613 (0.563-0.669)	0.729 (0.670-0.798)	0.861 (0.791-0.941)	0.963 (0.880-1.05)	1.09 (0.993-1.19)	1.19 (1.08-1.29)	1.28 (1.16-1.39)	1.38 (1.24-1.50)	1.50 (1.33-1.63)	1.59 (1.40-1.73)
15-min	0.751 (0.690-0.820)	0.891 (0.819-0.976)	1.06 (0.971-1.16)	1.19 (1.08-1.29)	1.35 (1.23-1.47)	1.47 (1.33-1.60)	1.59 (1.44-1.73)	1.71 (1.54-1.86)	1.87 (1.66-2.03)	1.98 (1.75-2.16)
30-min	0.993 (0.913-1.08)	1.19 (1.10-1.31)	1.45 (1.33-1.58)	1.65 (1.50-1.79)	1.90 (1.73-2.07)	2.10 (1.90-2.29)	2.30 (2.07-2.50)	2.50 (2.24-2.72)	2.77 (2.46-3.01)	2.97 (2.63-3.24)
60-min	1.21 (1.11-1.32)	1.46 (1.34-1.60)	1.82 (1.67-1.99)	2.09 (1.91-2.28)	2.47 (2.25-2.69)	2.77 (2.51-3.01)	3.07 (2.77-3.34)	3.39 (3.04-3.69)	3.83 (3.40-4.17)	4.18 (3.69-4.55)
2-hr	1.45 (1.32-1.58)	1.75 (1.60-1.92)	2.20 (2.01-2.40)	2.55 (2.33-2.78)	3.04 (2.76-3.31)	3.44 (3.10-3.74)	3.85 (3.46-4.19)	4.29 (3.84-4.67)	4.90 (4.35-5.33)	5.38 (4.75-5.86)
3-hr	1.54 (1.42-1.68)	1.86 (1.71-2.04)	2.34 (2.14-2.55)	2.73 (2.49-2.97)	3.27 (2.97-3.56)	3.72 (3.36-4.04)	4.19 (3.77-4.55)	4.69 (4.19-5.09)	5.40 (4.78-5.85)	5.98 (5.25-6.48)
6-hr	1.87 (1.72-2.05)	2.25 (2.07-2.47)	2.82 (2.58-3.09)	3.28 (3.00-3.59)	3.94 (3.58-4.30)	4.48 (4.05-4.88)	5.05 (4.54-5.50)	5.66 (5.05-6.15)	6.52 (5.76-7.09)	7.22 (6.32-7.85)
12-hr	2.21 (2.04-2.42)	2.67 (2.45-2.92)	3.31 (3.04-3.62)	3.84 (3.51-4.18)	4.58 (4.17-4.98)	5.18 (4.71-5.63)	5.81 (5.26-6.31)	6.48 (5.83-7.04)	7.42 (6.61-8.06)	8.17 (7.23-8.88)
24-hr	2.63 (2.46-2.83)	3.17 (2.96-3.40)	3.95 (3.68-4.24)	4.58 (4.26-4.92)	5.49 (5.05-5.93)	6.24 (5.68-6.79)	7.04 (6.32-7.73)	7.89 (6.98-8.78)	9.12 (7.86-10.4)	10.1 (8.54-11.7)
2-day	3.14 (2.93-3.37)	3.77 (3.51-4.05)	4.66 (4.33-5.01)	5.39 (4.99-5.81)	6.43 (5.88-7.00)	7.29 (6.60-8.00)	8.20 (7.32-9.13)	9.18 (8.04-10.4)	10.6 (9.02-12.3)	11.7 (9.77-14.0)
3-day	3.36 (3.13-3.60)	4.03 (3.75-4.33)	4.97 (4.62-5.35)	5.75 (5.33-6.20)	6.85 (6.27-7.45)	7.76 (7.03-8.51)	8.72 (7.79-9.70)	9.75 (8.56-11.0)	11.2 (9.60-13.0)	12.4 (10.4-14.7)
4-day	3.58 (3.33-3.84)	4.29 (4.00-4.61)	5.29 (4.92-5.69)	6.11 (5.66-6.59)	7.28 (6.67-7.91)	8.23 (7.47-9.03)	9.25 (8.27-10.3)	10.3 (9.09-11.6)	11.9 (10.2-13.7)	13.1 (11.0-15.5)
7-day	4.18 (3.90-4.48)	5.00 (4.67-5.37)	6.14 (5.70-6.61)	7.06 (6.53-7.64)	8.37 (7.65-9.13)	9.44 (8.54-10.4)	10.6 (9.44-11.8)	11.8 (10.3-13.4)	13.5 (11.5-15.8)	14.9 (12.4-17.8)
10-day	4.73 (4.43-5.07)	5.66 (5.30-6.07)	6.93 (6.46-7.45)	7.96 (7.38-8.59)	9.40 (8.62-10.2)	10.6 (9.59-11.6)	11.8 (10.6-13.1)	13.1 (11.5-14.8)	14.9 (12.8-17.3)	16.4 (13.8-19.5)
20-day	6.51 (6.12-6.92)	7.74 (7.28-8.24)	9.28 (8.70-9.89)	10.5 (9.79-11.2)	12.2 (11.3-13.1)	13.4 (12.3-14.6)	14.8 (13.4-16.2)	16.1 (14.4-17.9)	17.9 (15.8-20.4)	19.3 (16.8-22.4)
30-day	8.02 (7.57-8.49)	9.47 (8.95-10.0)	11.2 (10.5-11.9)	12.5 (11.7-13.3)	14.3 (13.3-15.3)	15.7 (14.5-16.9)	17.0 (15.6-18.6)	18.4 (16.7-20.3)	20.2 (18.0-22.8)	21.6 (19.0-24.8)
45-day	10.1 (9.54-10.7)	11.9 (11.2-12.6)	13.9 (13.1-14.7)	15.5 (14.5-16.4)	17.5 (16.4-18.7)	19.1 (17.7-20.5)	20.6 (19.0-22.4)	22.2 (20.2-24.3)	24.2 (21.7-26.9)	25.7 (22.8-29.1)
60-day	12.0 (11.4-12.7)	14.1 (13.4-14.9)	16.5 (15.6-17.4)	18.2 (17.2-19.3)	20.5 (19.2-21.8)	22.3 (20.7-23.8)	23.9 (22.1-25.8)	25.6 (23.4-27.9)	27.7 (25.0-30.6)	29.2 (26.1-32.7)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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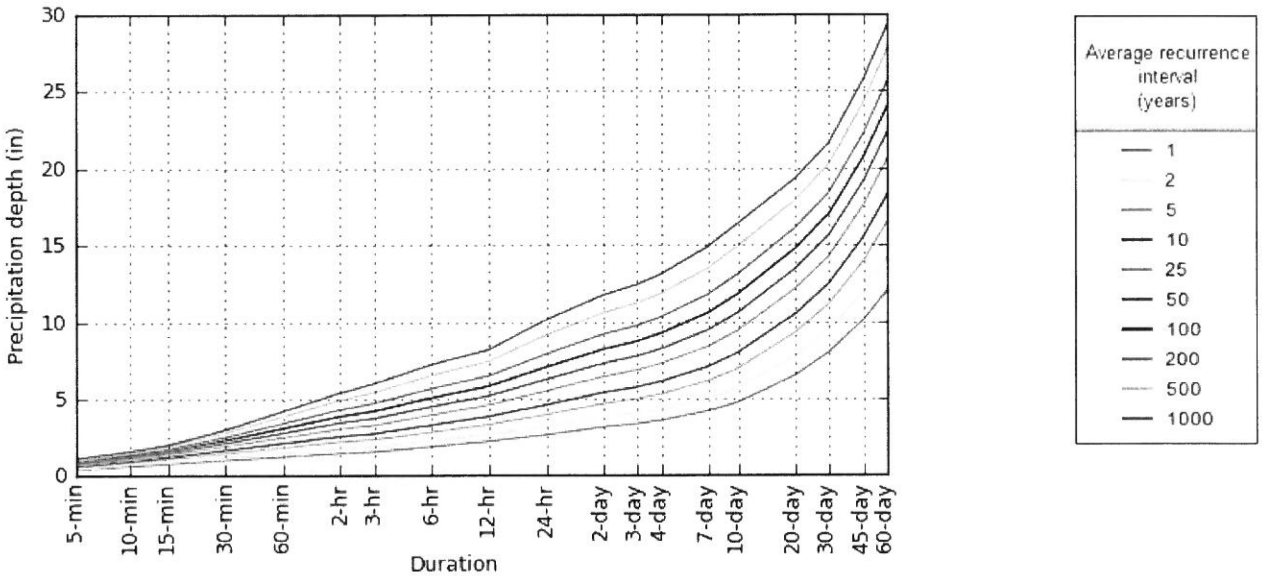
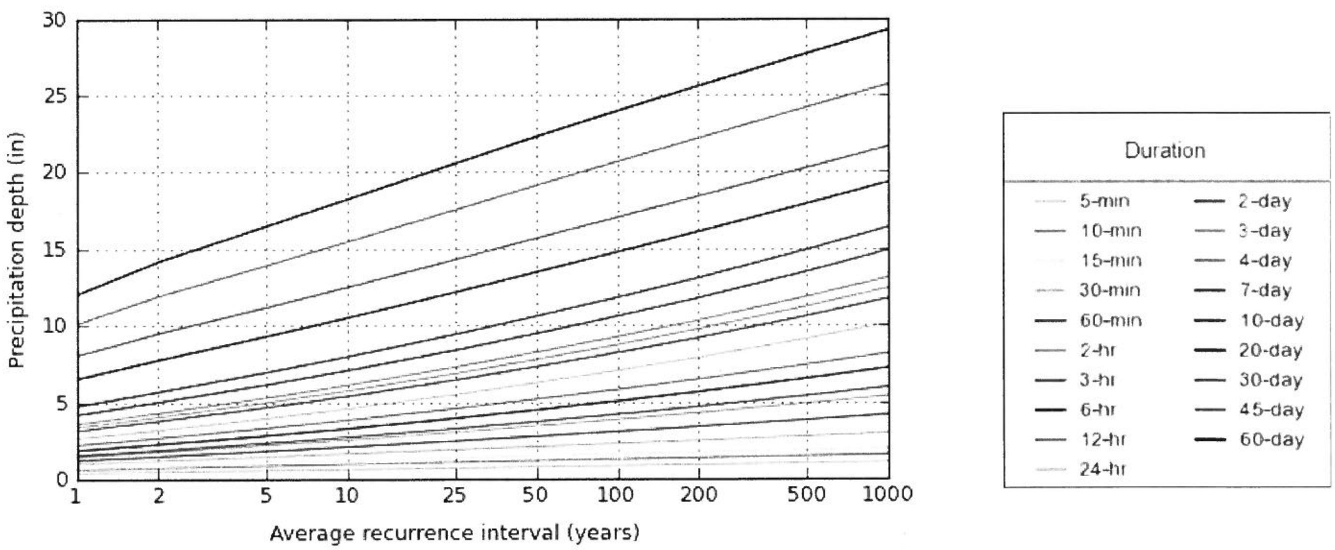
PF graphical

PDS-based depth-duration-frequency (DDF) curves
Latitude: 38.5303°, Longitude: -87.2396°





NOAA Atlas 14, Volume 2, Version 3 Created (GMT): Wed Sep 28 19:33:34 2016

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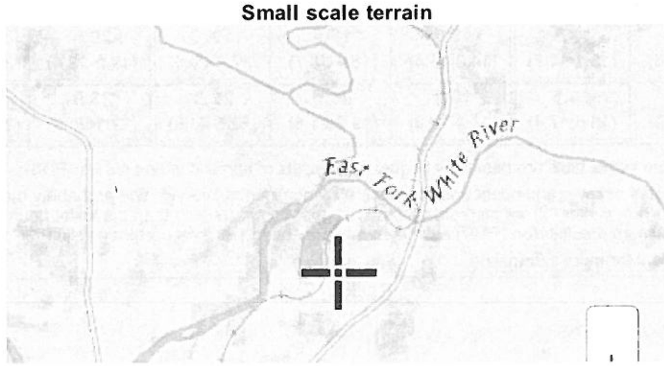
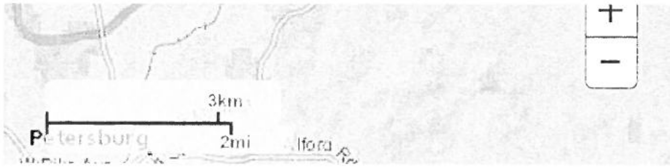
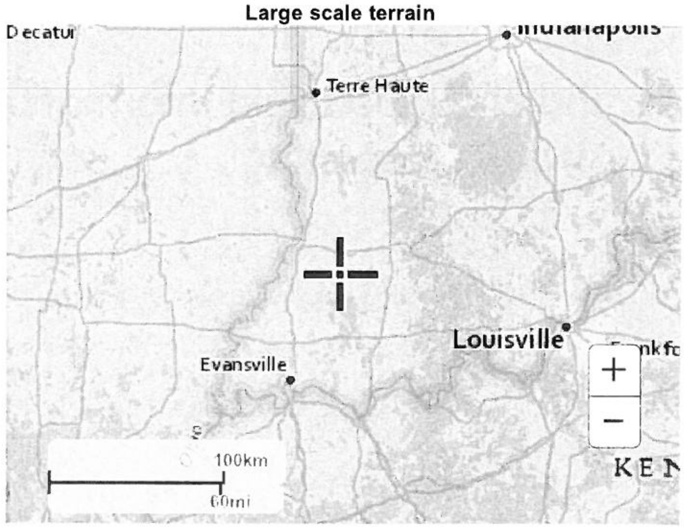
Maps & aerials

Small scale terrain

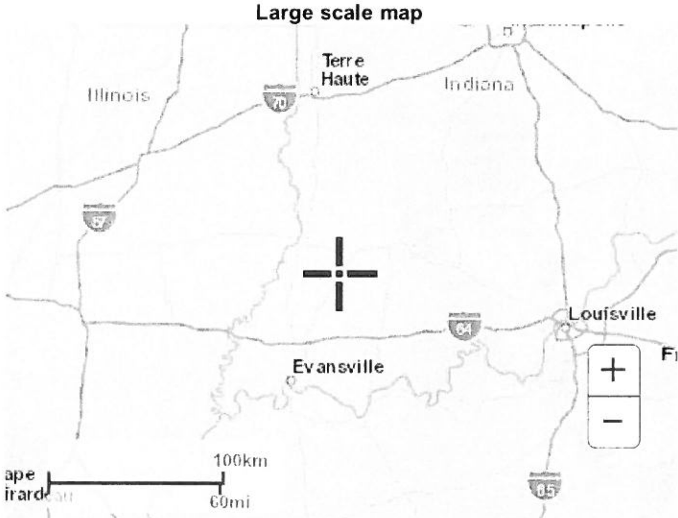




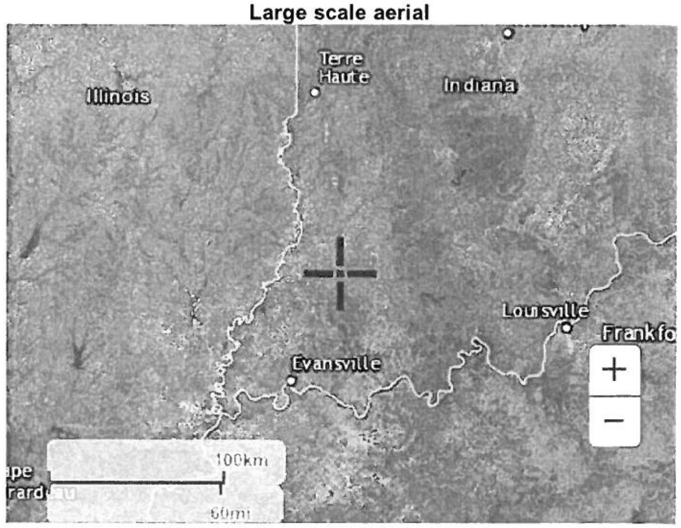
Large scale terrain



Large scale map



Large scale aerial



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Reference 5: Indiana Floodplain Information Portal (INFIP) Report

Indiana Floodplain Information Portal Report

Point of Interest

Effective Flood Zone:
A
Preliminary Flood Zone:
N/A
Best Available Flood Zone:
A
Approximate Flood Elevation:
429.6ft NAVD88
Source:
Zone A Model Delineation
Nearest Stream:
WHITE RIVER

Map Legend

Point of Interest
Nearest Point on Stream

Effective Flood Zone

- 0.2% Annual Chance Flood Hazard
- 1% Annual Chance Flood Hazard - Zone A (Approximate Study)
- 1% Annual Chance Flood Hazard - Zone AE (Detailed Study)
- 1% Annual Chance Flood Hazard - Floodway
- 1% Annual Chance Flood Hazard - Zone AH
- 1% Annual Chance Flood Hazard - Zone AO
- Zone X - Protected by Levee

Site Map with Effective Flood Zone

Approximate scale 1:24,000

Disclaimer

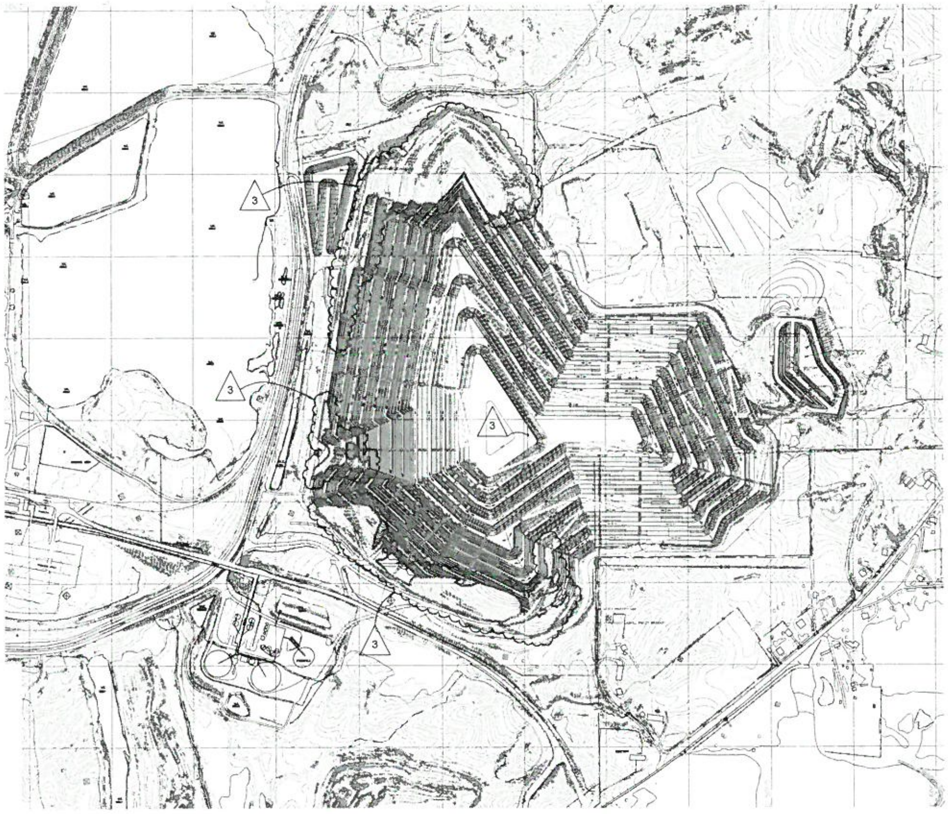
This data is a digital representation of the former paper Flood Insurance Rate Maps (FIRMs) for counties that have completed the Map Modernization Initiative. The data on counties derived from the official FEMA digital products (DFIRM) represent official FEMA designations of the Special Flood Hazard Areas. This data can be used for official National Flood Insurance Program (NFIP) purposes in accordance with the FEMA Mitigation Directorate Policy document tiled "Use of Digital Flood Hazard Data" dated November 29, 2007. For the non-modernized counties, the Effective is enhanced by the addition of the floodplain data from digitized paper copies of the FIRMs and the information should be considered advisory only. For these non-modernized counties, the paper maps are the official FEMA documents for regulatory and insurance purposes. Once the NFHL is official, the Effective is updated with the newly published information. For the status of counties published by FEMA please see http://www.floodmaps.fema.gov/NFHL/status.shtml.

Generated on Thursday September 29th 2016 at 10:21:25am

Appendix E: Surface Water Control and Design Plan Sheets

SHEET NO.	DESCRIPTION
*IPL 008-00-6-Y-D-42AF	Final Cover Conditions - Surface Water Control Plan
*Detail 1-1	Terrace Channel Design
*Detail 5-5	Riprap Downchute Channel Design
*Detail 6-6	Downchute Channel Profile

*Plan sheets from previously approved Indiana Department of Environmental Management (IDEM) Restricted Waste Type III Landfill application



NORTH

LEGEND

Landfill Facility Boundary
195.4 Acres

Solid Waste Boundary – Expansion Area (1996)
74.0 Acres

APPROVED

SCALE: 1"=200'

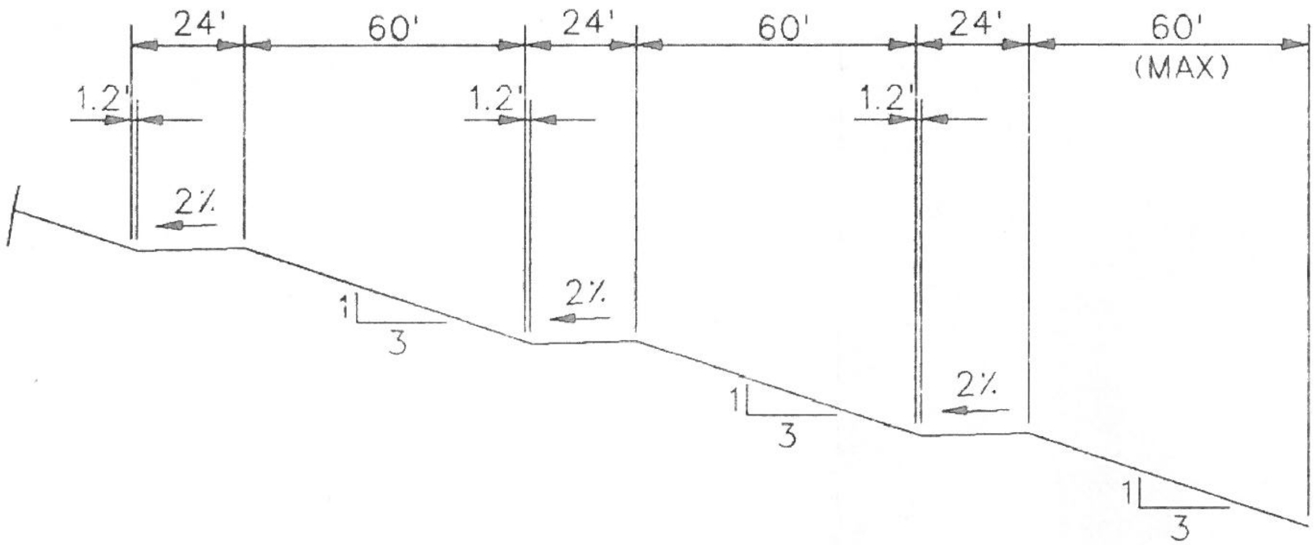
ORIGINAL ISSUE

S & W DWG NO. C2176.L4-EY-26-2

PETERSBURG GENERATING STATION
INDIANAPOLIS POWER & LIGHT COMPANY
JOB NO. 92-35092C

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASS.

DRAWING NUMBER

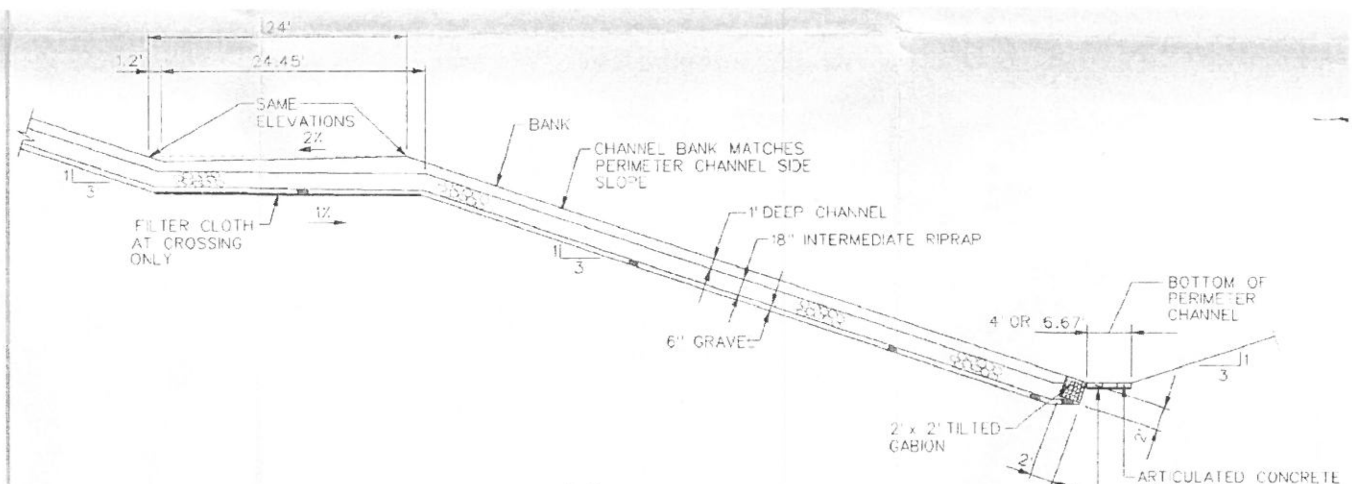


1-1
SCALE: 1"=40'

IPL PETERSBURG GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL

DETAIL 1-1 FROM IPL DRAWING NO. 008-00-6-Y-D-42AG
BY STONE & WEBSTER ENGINEERING CORPORATION

Project Number: 170LF00266		Drn. By: WS
Drawing File: SEE LOWER LEFT		Ckd. By: CD
Date: 9/16	Scale: AS SHOWN	App'd By:
ATC		Figure: 1



5-5
(B-3)
SCALE: 1"=8'

IPL PETERSBURG GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL
DETAIL 5-5 FROM IPL DRAWING NO. 008-00-6-Y-D-42AG
BY STONE & WEBSTER ENGINEERING CORPORATION

Project Number: 170LF00266	Drn. By: WS
Drawing File: SEE LOWER LEFT	Ckd. By: CD
ATC	App'd By:
	Ckd. Date:
Date: 9/16	
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Figure: 2	

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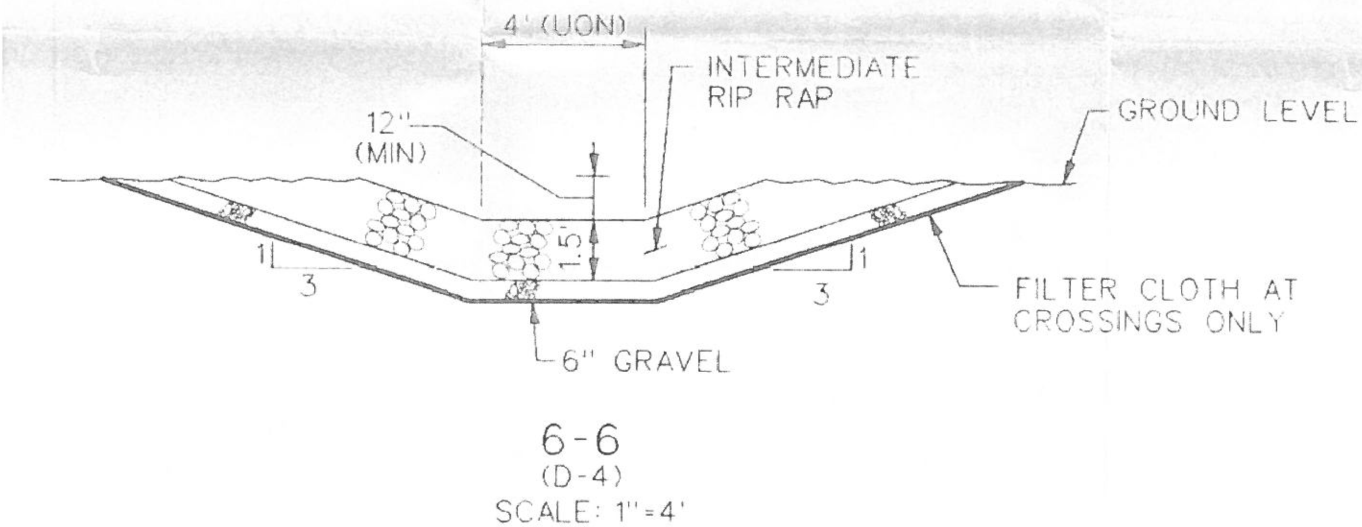

H:\2016\IPL\IPL ROROCS PLAN (170LF00266)\170LF00266-DETAILS-SCAN.DWG, DETAIL 6-6

IPL PETERSBURG GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL

DETAIL 6-6 FROM IPL DRAWING NO. 008-00-6-Y-D-42AG
BY STONE & WEBSTER ENGINEERING CORPORATION

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ATC		Figure: 3