McElroy's Run Impoundment
History of Construction

Allegheny Energy Supply Company, LLC
A FirstEnergy Company
Pleasants Power Station
Pleasants County, West Virginia

October 2016

Prepared for:
Allegheny Energy Supply Company, LLC
A FirstEnergy Company
800 Cabin Hill Drive
Greensburg, Pennsylvania 15601

Prepared by:
GAI Consultants, Inc.
Murrysville Office
4200 Triangle Lane
Export, Pennsylvania 15632-1358

Report Authors:

Trent I. Muraoka, P.E.
Project Engineer

Arica L. DiTullio, P.E.
Engineering Manager

Kent C. Cockley, P.E.
Engineering Director/Senior Associate

Table of Contents

1.0 Purpose

This Report, the Construction History of Pleasants Power Station McElroy's Run Impoundment, covers the following criteria listed in the Code of Federal Regulations (CFR) Coal Combustion Residuals (CCR) Rule 40 CFR 257.73(c)(1), to the extent feasible:

- name and size of the watershed within which the CCR unit is located;
- location map;
- material physical and engineering properties description for foundation and abutment and CCR unit;
- site preparation and construction methods for each zone;
- detailed drawings;
- description of the existing instrumentation;
- area capacity curves;
- spillway and diversion features description, capacities, and calculations;
- construction specifications and provisions for surveillance, maintenance, and repair; and
- any record or knowledge of structural instability.

2.0 Introduction

The Pleasants Power Station (Station) is a coal-fired electric generating station located near the community of Willow Island in Pleasants County, West Virginia (WV). The Station consists of two generating units, which are capable of producing 1,300 megawatts of electricity. CCRs generated at the Station are placed in the McElroy's Run CCR Surface Impoundment (Impoundment), which is located approximately one-half-mile east-southeast of the Station. The Impoundment location is shown on the United States Geological Survey (USGS) 7.5-Minute Topographic Quadrangle Map provided as Figure 1. According to the USGS, the Impoundment is located in the Little Muskingum-Middle Island Watershed (USGS Hydrologic Unit Code 05030201) and has an area of 1,800 square miles. The WV Department of Environmental Protection identifies the watershed as the Middle Ohio North.

The purpose of the Impoundment is to receive flue gas desulfurization (FGD) scrubber by-product generated at the Station, effluent from the recirculation system from Sedimentation Ponds No. 1 and 2 of the adjacent landfill and their underdrains, and waste materials collected primarily because of general house-cleaning maintenance and/or repair at the Pleasants Power Station. The National Pollutant Discharge Elimination System (NPDES) Water Pollution Control Permit (WV 0079171) authorizes discharge to the Ohio River in accordance with effluent limitations, monitoring requirements, and other conditions set forth in the permit. The McElroy's Run Dam Certificate of Approval was signed on February 7, 1978 (ID No. 07302).

3.0 Construction Summary of Impoundment and Embankment

The Impoundment embankment construction took place from 1979 through 1992, occurring over stages. The approximate dates of construction for each successive stage are depicted on Drawing 101-6514-196. The crest of the dam is at elevation (El.) 900 feet, with El. 887 feet as the permitted final level of CCR. The Impoundment area is approximately 253 acres. A clay blanket on the upstream slope and clay-filled cutoff trench along the upstream toe were constructed to serve as a low permeability barrier. The downstream end was constructed with compacted fly ash. A landfill facility was constructed on the downstream face of the embankment, which is now grass-covered. A blanket drain, consisting of sand or bottom ash, was installed between natural soil and embankment fill downstream of the cut-off keyway.

McElroy's Dam was constructed on native soils with a clay soil cut-off keyway installed through the soft broken claystone layer to the top of bedrock, an interbedded siltstone, sandstone, and claystone formation. Foundation soils in the valley of the McElroy's Dam embankment consist of alluvial and residual soils. These soils are clayey and cohesive, and thus are not susceptible to liquefaction. However, pockets of sandy soil exist within the site soils; Investigations performed by GAI Consultants, Inc. (GAI) indicate that the soil layer over the interbedded bedrock formation is thicker towards the abutments than at the midpoint of the dam. A blanket drain, consisting of sand or bottom ash, was installed between natural soil and embankment fill downstream of the cut-off keyway.

The physical and engineering properties of the foundation, abutment, and embankment materials of which the CCR unit is constructed are listed below.

Table 1

Physical and Engineering Properties of Foundation and Abutment Materials

Soil Description	Soil Unit Weights	Long Term Conditions	
		Effective Stress Parameters	
	γ moist (pcf)	Cohesion, C′ (psf)	Friction, ϕ′ (degrees)
Compacted Silty Clay	132.9	228	26.8
In-Situ Silty Clay to Clayey Silt and Rock Fragments	127.8	49	24.8
Soft Broken Claystone	135.0	1238	32
Interbedded Siltstone, Sandstone, and Claystone	-	-	-
Compacted Fly Ash	113.1	0	29.7
Bottom Ash Filter Blanket	110.0	0	35

Drawings in Appendix A show the plan view and the typical transverse and longitudinal section of the embankment, as well as the width of the embankment.

Five survey-monitoring points were installed in 1997 in the upstream slope of the embankment slightly below the crest near El. 900 feet. The monitoring points are used to measure horizontal movement and settlement of the embankment, and to determine if there is movement of the embankment over time. Piezometers are installed in the embankment to monitor the water level in the embankment.

Two perforated cross-valley foundation underdrain pipes were installed in a trench below the drainage blanket of the downstream slope of the Impoundment embankment as a part of construction. The drains were installed across the flat bottom of the valley about 100 feet upstream of the toe of the embankment. The two pipes meet near the center of the valley where they turn and extend to the current toe of the ash disposal landfill. The pipes collect any seepage that enters the drainage blanket, either through the embankment or from the subgrade below the Impoundment embankment. This water is transmitted to Sedimentation Pond No. 1.

The dam was constructed with two concrete discharge towers serving as the principal spillway. Current water levels in the Impoundment has made the use of Decant Tower 1 impractical. Decant Tower 1 was sealed such that no water enters the Tower. Decant Tower 2 is outfitted with an operational sluice gate at El. 885 feet, and a 24-inch square (former sluice gate) opening at El. 890 feet. Discharge from this structure is directed under the dam via a 36-inch-diameter concrete pipe that is approximately 3,600 feet long. Flow from the concrete pipe is conveyed to the principal spillway, with discharge directed to a channel that leads to McElroy's Run Creek. However, operational practices currently implemented at the Impoundment prevent discharge from principal spillway from occurring.

Currently, the primary discharge from the Impoundment is by use of a siphon. The siphon line is a 12-inch-diameter, high-density polyethylene pipe that can convey water to the Station for reuse, or discharge to the Ohio River. The maximum discharge of the siphon is 3,800 gallons per minute (GPM), but typically discharges at 1,800 GPM to maintain an adequate operating water elevation. The siphon flow can either be diverted to the plant for makeup water or discharged through a 14-inch pipeline to an NPDES-permitted Outfall. Design calculations for the siphon line area are attached as Attachment C. The siphon line is the primary operating mechanism for withdrawing water from the Impoundment to maintain the operational water elevation behind the dam.

An emergency spillway located near the west abutment serves the Impoundment. The spillway is concrete-lined and has an approach lined with stone rip-rap. The spillway outlet is protected with rip-rap. The spillway bottom width ranges from 20.25 to 20.5 feet with side slopes at 3H:1V or 6H:1V and with a crest El. of 893.5 feet. The spillway has a minimum depth of 6.5 feet and can convey an approximate maximum flow rate of 9,000 cubic feet per second (cfs), which is greater than the probable maximum flood (PMF) design storm of 100 cfs through the emergency spillway. A Stage-Storage curve was developed by GAI as part of a recent Capacity Estimate of the Impoundment (Attachment B). The Stage-Storage curve of the reservoir was based on 2015 Aerial Mapping.

FGD scrubber by-product is pumped to the Impoundment through two eight-inch-diameter slurry lines to a valve station near the west end of the Impoundment dam. The slurry can be discharged into the Impoundment from the valve station or directed into a mobile pipeline boom, for discharge at various locations in the Impoundment.

The Monitoring and Emergency Action Plan and Operations Plan, completed by FirstEnergy Corporation, revised October 2015, outlines the requirements for monitoring, inspection, and maintenance of the Impoundment.

Based on the information reviewed, there have been no identified safety issues for the McElroy's Embankment in the last 10 years.

FIGURE

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

The National Map
US Topo

WILLOW ISLAND QUADRANGLE
WEST VIRGINIA-OHIO
7.5-MINUTE SERIES

Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and 1 000-meter grid: Universal Transverse Mercator, Zone 17S
10 000-foot ticks: West Virginia Coordinate System of 1983 (north zone), Ohio Coordinate System of 1983 (south zone)

This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Imagery....................NAIP, August 2011
Roads....................HERE, ©2013
Roads within US Forest Service Lands..........FSTopo Data with limited Forest Service updates, 2013
Names....................GNIS, 2013
Hydrography..........National Hydrography Dataset, 2011
Contours..........National Elevation Dataset, 2004
Boundaries..........Multiple sources; see metadata file 1972 - 2013
Public Land Survey System..........BLM, 2013

UTM GRID AND 2014 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
8° 5′ 144 MILS
0° 12′ 4 MILS

U.S. National Grid
100,000-m Square ID MD
Grid Zone Designation 17S

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the National Geospatial Program US Topo Product Standard, 2011.
A metadata file associated with this product is draft version 0.6.16

QUADRANGLE LOCATION

ADJOINING QUADRANGLES
1 Marietta
2 Belmont
3 Raven Rock
4 Valley Mills
5 Schultz
6 Kanawha
7 Petroleum
8 Cairo

ROAD CLASSIFICATION

Expressway, Secondary Hwy, Ramp, Local Connector, Local Road, 4WD
Interstate Route, US Route, State Route
FS Primary Route, FS Passenger Route, FS High Clearance Route

Check with local Forest Service unit for current travel conditions and restrictions.

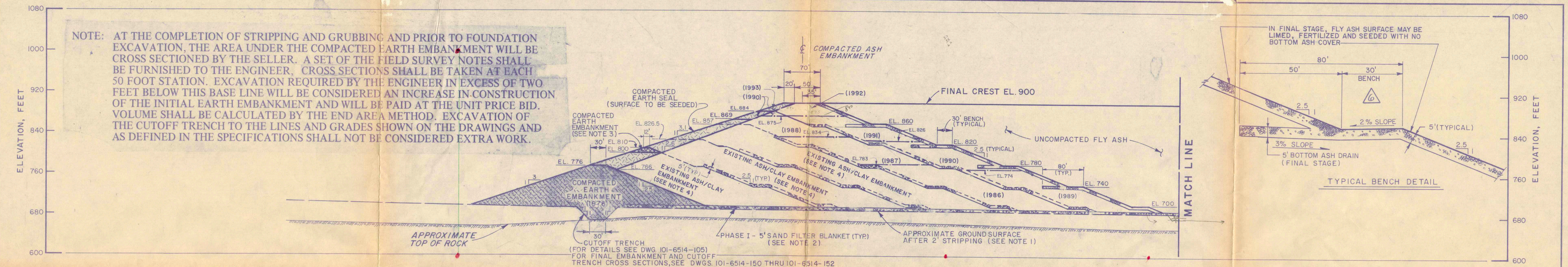
WILLOW ISLAND, WV-OH
2014

NSN. 7643016404391
NGA REF NO. USGSX24K49250

APPENDIX A
McElroy's Run Disposal Site Drawings

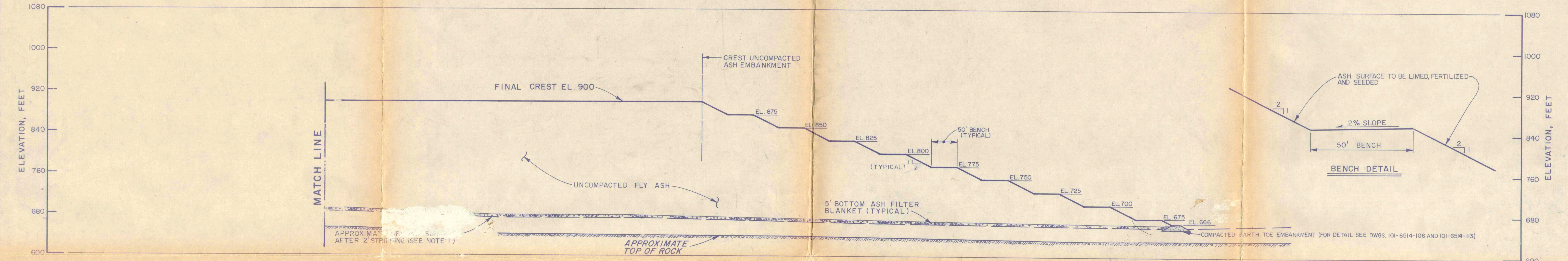
N
TRUE NORTH
PLANT NORTH
44°25'
DOWNSTREAM TOE OF COMPACTED ASH EMBANKMENT
36" ϕ CMP DIVERSION PIPE
PIPE INVERT EL. 688
30° DEFLECTION WITH ENCASEMENT PIPE INVERT EL. 686.3 (STA. 13+15)
36" X 36" Y WITH PLUG AND BLOCKING DURING FIRST STAGE CONSTRUCTION INV. EL. 684.0-ENCASED
30' WIDE BENCH @ EL. 700
30' WIDE BENCH @ EL. 740
30' WIDE BENCH @ EL. 780
30' WIDE BENCH @ EL. 820
30' WIDE BENCH @ 860
℄ 36" ϕ SPECIAL ORDER DECANT PIPE
℄ FINAL STAGE EMERGENCY SPILLWAY
50' WIDE ASH CREST @ EL. 900
20' WIDE EARTH CREST @ EL. 900
N72° 35' 34"W 2483.92'
AXIS OF ASH EMBANKMENT
LIMIT OF CLEARING, GRUBBING, AND STRIPPING FOR FIRST-YEAR COMPACTED ASH EMBANKMENT
AXIS OF INITIAL EARTH EMBANKMENT
APPROXIMATE LIMITS OF SPILLWAY INLET TO BE PAVED (SEE DWG. 101-6514-113)
SPILLWAY INVERT EL. 893.5
TOE OF ASH EMBANKMENT COMPACTED EARTH SEAL
DECANT TOWER NO. 2 PIPE INVERT EL. 796.5
DECANT TOWER NO. 1 PIPE INVERT EL. 714.5
CONCRETE ENCASEMENTS
FINAL FLOOD POOL EL. 896.7 (80% PROBABLE MAXIMUM PRECIPITATION)
MAXIMUM FINAL OPERATING POOL LEVEL EL. 893.0
MAXIMUM FINAL SLUDGE LEVEL EL. 887.0
ABANDONED WATER WELL-PUMPED DRY AND PLUGGED WITH CONCRETE
UPSTREAM TOE OF COMPACTED EARTH EMBANKMENT
PHASE I CONSTRUCTION DIVERSION INLET (SEE DWG. 101-6514-113) CONNECTION @ STA. 0+00 REMOVED, PLUGGED AND ENCASED AT COMPLETION OF PHASE I WORK
REFERENCE
ALLEGHENY POWER SERVICE CORPORATION DWG. 500-242 TITLED TOPOGRAPHIC MAP OF WILLOW ISLAND DATED: 7-23-73, SCALE: 1" = 200'
SCALE 80 0 80 160 FEET
LEGEND:
PERMANENT HORIZONTAL CONTROL MONUMENT LOCATED AND PLACED IN FIELD BY U.E. & C., 1977.
PHASE I CONSTRUCTION WITH AS-BUILT DETAILS
LIMIT OF PHASE I PLACEMENT OF SAND FILTER DRAINAGE BLANKET. ALL REQUIRED WORK IN AREA SHOWN NOT COMPLETED DURING PHASE I.
NOTES
1. FOR STRUCTURAL DETAILS OF DECANT TOWERS, SEE DWGS. 101-6514-109 AND 101-6514-110.
2. FOR STRUCTURAL DETAILS OF CLEARWELL, SEE DWG. 101-6514-112.
5. FOR LIMITS OF PHASE I CLEARING, SEE DRAWING 101-6514-101.
6. FOR REVISED SPILLWAY PLAN SEE DRAWINGS 101-6514-204 TO 101-6514-211.
D'APPOLONIA CONSULTING ENGINEERS, INC.
REVISED SPILLWAY
AS-BUILT DETAILS
CONSTRUCTION
PHASE I CONSTRUCTION LIMITS
ISSUE No. DATE DWN CHKD APP APP APP ISSUED FOR
SCALE AS SHOWN
ENGINEER STATE REG No.
PLEASANTS POWER STATION-UNITS NO. 1 & NO. 2
MONONGAHELA POWER COMPANY
THE POTOMAC EDISON COMPANY
WEST PENN POWER COMPANY
SLUDGE STABILIZATION FACILITY
McELROYS RUN DISPOSAL SITE
DETAILED PLAN OF COMPACTED ASH EMBANKMENT AND INITIAL EARTH EMBANKMENT
Dravo Lime COMPANY
APSC 506-103
DRAWING NUMBER 101-6514-103
REVISION 4

NOTE: AT THE COMPLETION OF STRIPPING AND GRUBBING AND PRIOR TO FOUNDATION EXCAVATION, THE AREA UNDER THE COMPACTED EARTH EMBANKMENT WILL BE CROSS SECTIONED BY THE SELLER. A SET OF THE FIELD SURVEY NOTES SHALL BE FURNISHED TO THE ENGINEER. CROSS SECTIONS SHALL BE TAKEN AT EACH 50 FOOT STATION. EXCAVATION REQUIRED BY THE ENGINEER IN EXCESS OF TWO FEET BELOW THIS BASE LINE WILL BE CONSIDERED AN INCREASE IN CONSTRUCTION OF THE INITIAL EARTH EMBANKMENT AND WILL BE PAID AT THE UNIT PRICE BID. VOLUME SHALL BE CALCULATED BY THE END AREA METHOD. EXCAVATION OF THE CUTOFF TRENCH TO THE LINES AND GRADES SHOWN ON THE DRAWINGS AND AS DEFINED IN THE SPECIFICATIONS SHALL NOT BE CONSIDERED EXTRA WORK.



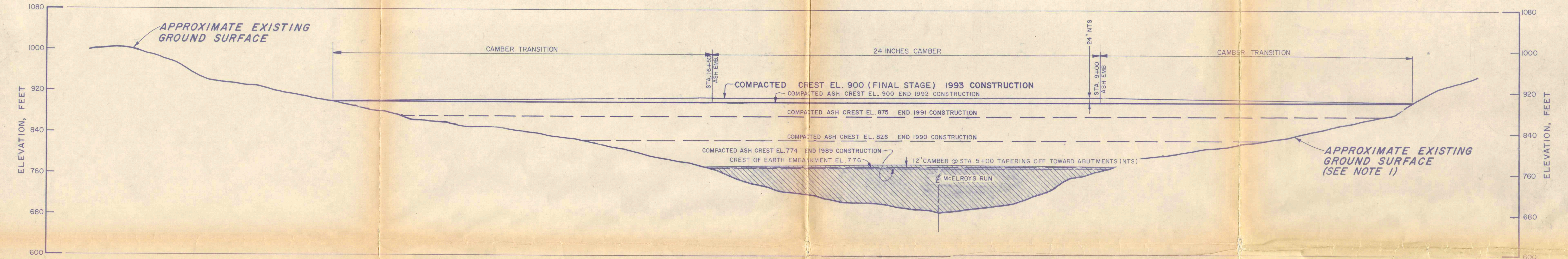
TYPICAL TRANSVERSE SECTION

SCALE 80 0 80 160 FEET



TYPICAL TRANSVERSE SECTION (CONTINUED)

SCALE 80 0 80 160 FEET



LONGITUDINAL SECTION ALONG AXIS OF FINAL STAGE COMPACTED ASH EMBANKMENT

SCALE 80 0 80 160 FEET

LEGEND

PHASE I CONSTRUCTION WITH AS-BUILT DETAILS

NOTE

1. THE DESIGN STRIPPING DEPTH UNDER THE EMBANKMENT IS 2 FEET. ACTUAL DEPTH OF UNSUITABLE MATERIAL TO BE REMOVED WILL BE AS DIRECTED BY THE ENGINEER.
2. THE AREA UNDER THE FIRST-YEAR COMPACTED ASH EMBANKMENT IS TO BE CLEARED, GRUBBED, AND STRIPPED DURING THE PHASE I CONSTRUCTION.
3. A COMPACTED EARTH DIKE SHALL BE CONSTRUCTED TO ELEVATION 810 ALONG THE UPSTREAM EDGE OF THE EARTH SEAL DURING THE BEGINING OF THE 1982 CONSTRUCTION SEASON TO PROVIDE THE DESIGN STORM IMPOUNDMENT CAPACITY. SIDE SLOPES OF THIS STRUCTURE SHALL BE 3.1:1 UPSTREAM AND 2.5:1 DOWNSTREAM. CONSTRUCTION MATERIAL SHALL BE THE SAME AS THAT USED FOR THE COMPACTED EARTH SEAL.
4. FOR AS-BUILT CONSTRUCTION PROGRESS BETWEEN 1979 AND 1985 SEE DRAWING 101-6514-196.

GAI CONSULTANTS, INC.
Engineers • Geologists • Planners Environmental Specialists
570 Beatty Rd. • Pittsburgh Monroeville, Pa. 15146
412-856-6400

PROJ. NO. 81-237
DWG. NO. 81-237-F14

D'APPOLONIA CONSULTING ENGINEERS, INC.
PROJ. NO. 76-204 DWG. NO. M 27

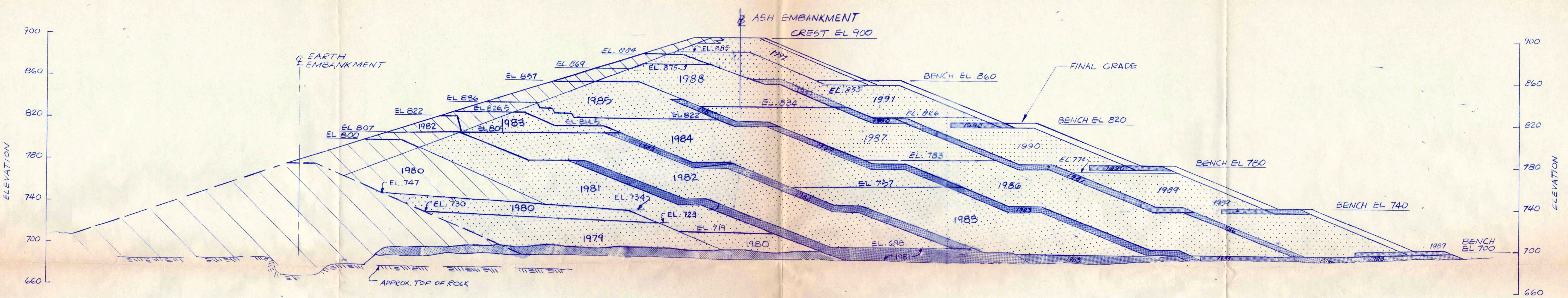
ISSUE No.	DATE	DWN	CHKD	APP	APP	APP	ISSUED FOR
7	2-5-91	NER	TRG				CONSTRUCTION SCHEDULE REVISION
6	2-21-90	NER	TRG	TDD			CONSTRUCTION SCHEDULE REVISION
5	6-18-86	GY	TDD	TDD			CONSTRUCTION SCHEDULE REVISION
4	7-16-81	RGN	awe	JHP			CONSTRUCTION SCHEDULE REVISION
3	2-22-79	ACS	awe	JHP			AS-BUILT DETAILS
2	1-30-78	DDS	JHP				CONSTRUCTION
1	12-27-77	G.J.G.	awe				PHASE I CONSTRUCTION LIMITS
	8-12-77	wfp	awe	JHP			

SCALE: AS SHOWN
ENGINEER STATE REG No.

PLEASANTS POWER STATION-UNITS NO. 1 & NO. 2
MONONGAHELA POWER COMPANY · THE POTOMAC EDISON COMPANY · WEST PENN POWER COMPANY

SLUDGE STABILIZATION FACILITY
McELROYS RUN DISPOSAL SITE
TRANSVERSE AND LONGITUDINAL SECTIONS OF EMBANKMENT

Dravo Lime Company
APSC 506-104
DRAWING NUMBER 101-6514-104
REVISION 7



TYPICAL TRANSVERSE SECTION

SCALE: 1" = 40'
40' 0 40' 80'

LEGEND

- APPROXIMATE TOP OF ROCK
- EXISTING GROUND SURFACE
- EARTH EMBANKMENT (PHASE I)
- PROPOSED GRADE
- SAND FILTER
- BOTTOM ASH
- CLAY
- FLY ASH

(7)

REFERENCE DRAWINGS:

1. APS DWG.NO.101-6514-104 REV.4 McELROYS RUN DISPOSAL SITE-TRANSVERSE AND LONGITUDINAL SECTIONS OF EMBANKMENT
2. UNNUMBERED DRAWING TITLED McELROY'S RUN EMBANKMENT, PLEASANTS POWER STATION, BY H. DESKINS, DATED 1-31-83.

GAI CONSULTANTS, INC.

PROJ. NO. 81-237

DWG. NO. 81-237-F13

ISSUE No	DATE	DWN	CHKD	APP	APP	APP	ISSUED FOR
7	2-8-93	G.Y.	TRG	TDD			AS-BUILT THRU DEC. 1992
6	1-15-92	G.Y.	TDD	TDD			AS-BUILT THRU DEC. 1991
5	2-6-91	REM	TRG	TRG			AS BUILT THRU DEC. 1990
4	2-21-90	NER	TRG	TDD			AS-BUILT THRU FEB. 1990
3	3-2-89	G.Y.	TRG	TDD			AS-BUILT THRU FEB. 1989
2	2-8-88	F.P.	TRG	TDD			AS BUILT THRU JAN. 1988
1	12-23-86	FP	TRG	TDD			AS BUILT THRU DEC. 1986
0	2-10-86	RAC	JAB	TDD			AS-BUILT THRU DECEMBER 1985

SCALE: AS SHOWN

ENGINEER STATE REG No.

OCT 31 1996

OCT 31 1996

PLEASANTS POWER STATION-UNITS NO. 1 & NO. 2

MONONGAHELA POWER COMPANY | THE POTOMAC EDISON COMPANY | WEST PENN POWER COMPANY

SLUDGE STABILIZATION FACILITY
McELROYS RUN DISPOSAL SITE
AS-BUILT CONSTRUCTION SEQUENCE

APSC 506-190

DRAWING NUMBER: 101-6514-196

REVISION: (7)

CONTROL MONUMENTS:

1. COORDINATES SHOWN ARE BASED ON THE WEST VIRGINIA STATE PLANE COORDINATE SYSTEM, NORTH ZONE NAD 83.

PROVIDED BY FIRSTENERGY			
MON.	NORTHING	EASTING	ELEV.
5*	320472.10	1467897.76	955.53
15*	320116.42	1467280.08	900.01
17*	319843.37	1466716.28	899.24

* HELD FOR SURVEY CONTROL

REFERENCE SURVEY DRAWINGS

C79508574 - HYDROGRAPHIC SURVEY JUNE 2015
C79508574 - HYDROGRAPHIC SURVEY NOV. 2013
C79506538 - BOTTOM CONTOURS OCT. 2009
C79503257 - CONTOUR PLAN JUNE 2004
C7950082 - CONTOUR PLAN NOV. 1999
C7950079 - CONTOUR PLAN
C7940006 - CONTOUR PLAN
C7940005 - CONTOUR PLAN
C7940004 - CONTOUR PLAN

LEGEND:

- EDGE OF WATER
- 900 CONTOURS
- EXISTING FE SURVEY CONTROL MONUMENT
- TREE LINE

NOTES:

1. COORDINATES AND ELEVATIONS ESTABLISHED BY GPS METHODS. HORIZONTAL DATUM IS NAD 83 SPC WV NORTH ZONE. VERTICAL DATUM IS NAVD OF 1988.
2. HYDROGRAPHIC SURVEY OF BOTTOM OF RESERVOIR TOPOGRAPHY WAS PERFORMED USING GPS VRS SURVEY METHODS COMBINED WITH AN OHMEX SONARMITE SINGLE BEAM ECHO SOUNDER.
3. BOTTOM OF RESERVOIR TOPOGRAPHY IS BASED ON SURVEY PERFORMED JUNE 1-5, 2015.
4. TOPOGRAPHY BEYOND LIMIT OF HYDROGRAPHIC SURVEY: AERIAL MAPPING PROVIDED BY FIRSTENERGY CORP. FROM KUCERA INTERNATIONAL, INC. PHOTOGRAPHY ON APRIL 11, 2015.
5. THE RESERVOIR VOLUME IS BASED ON ELEVATION 887.0 FEET. THE ELEVATION CONTOUR WAS GENERATED FROM THE AERIAL MAPPING REFERENCED IN NOTE 4.

SCALE: 1" = 200'
200 0 200 400

gai consultants

FUNCTIONAL LOCATION NO. ____________

Last .Net editor version: 1.1.2.0

THIS IS AN AutoCAD DRAWING - DO NOT MANUALLY REVISE

REVISION	DR	CHKD	APPD	DATE
PROJECT NUMBER				

REFERENCE DRAWINGS	
DWG. NO.	TITLE
GAI # C120987.00	2013 HYDROGRAPHIC SURVEY
VARIOUS	SEE REFERENCE DRAWING LIST ON THIS SHEET

INITIAL PROJECT #

ENGINEERING	DATE
DR JAF	11/26/2013
CHKD DJP	11/26/2013
APPD GER	11/26/2013
SCALE AS NOTED	

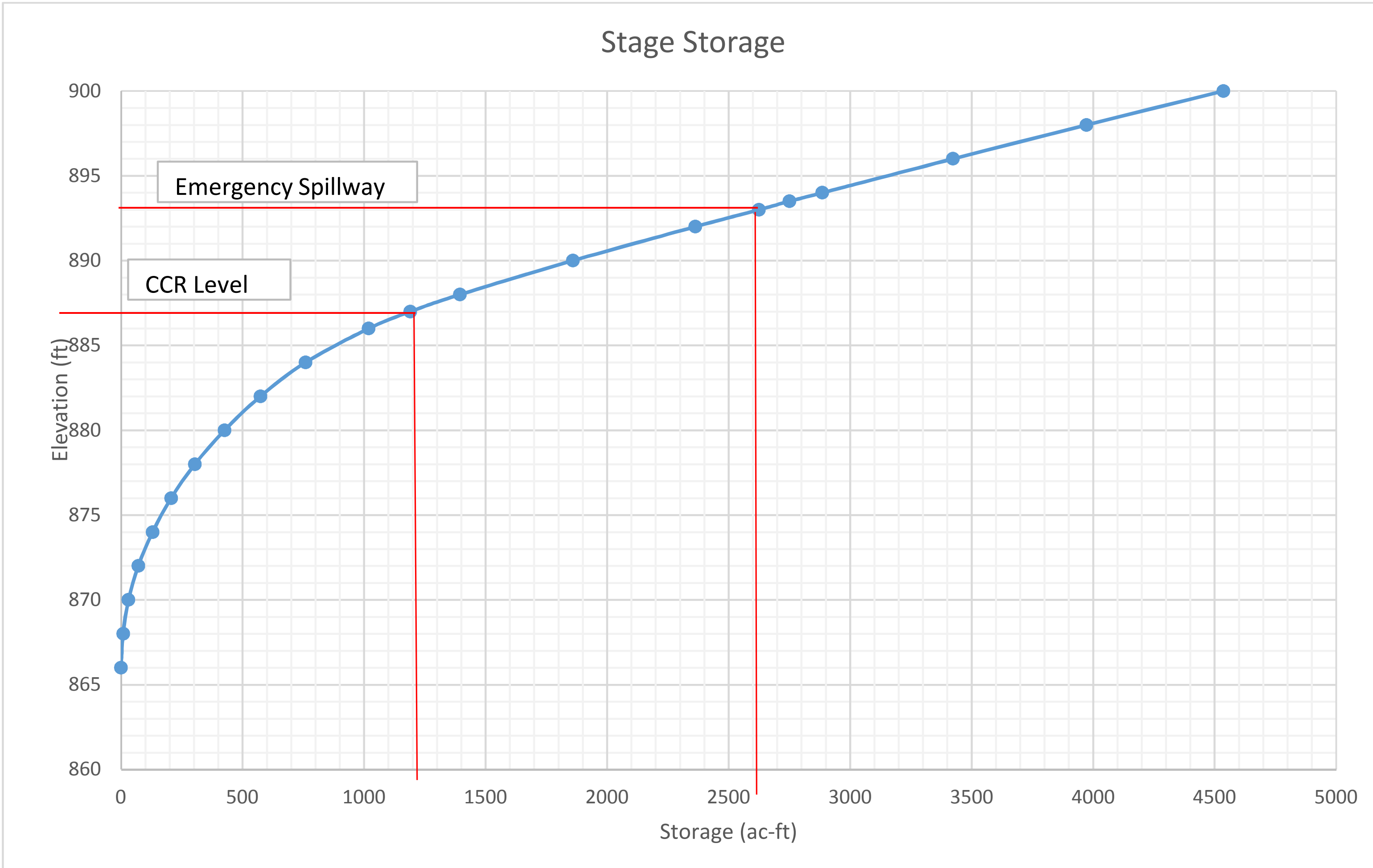
HYDROGRAPHIC SURVEY
McELROY'S RUN IMPOUNDMENT
PLEASANTS COUNTY, WEST VIRGINIA

FACILITY PLEASANTS UNIT COMMON

FirstEnergy GENERATION, LLC

DWG. NO. C7950XXXX REV. 2

APPENDIX B
Stage Storage Verification Calculation



Stage Storage
Emergency Spillway
CCR Level
Elevation (ft)
900
895
890
885
880
875
870
865
860
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Storage (ac-ft)

APPENDIX C
Design Calculations for Siphon Line

APPENDIX B

CALCULATIONS FOR THE
MINIMUM SIPHON HYDRAULIC CAPACITY

APPENDIX B

Table of Contents

I. SUMMARY OF PRECIPITATION DATA
Parkersburg WSO CI

TABLE 1 SUMMARY OF PRECIPITATION DATA - PARKERSBURG WSO

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1971	rainfall	2.43	3.62	1.31	1.22	3.82	3.09	5.20	4.04	4.59	1.38	2.26	1.73	**34.69**
	departure	-0.91	0.79	-2.22	-2.03	0.12	-1.18	1.09	0.26	1.88	-0.67	-0.10	-1.11	-4.08
	average	3.34	2.83	3.53	3.25	3.70	4.27	4.11	3.78	2.71	2.05	2.36	2.84	38.77
1972	rainfall	2.67	3.02	3.07	6.18	2.07	5.43	1.51	7.97	4.97	1.70	3.93	4.85	**47.37**
	departure	-0.67	0.19	-0.46	2.93	-1.63	1.16	-2.60	4.19	2.26	-0.35	1.57	2.01	8.60
	average	3.34	2.83	3.53	3.25	3.70	4.27	4.11	3.78	2.71	2.05	2.36	2.84	38.77
1973	rainfall	2.22	1.91	2.68	5.71	3.35	2.02	6.53	2.10	3.32	3.73	3.46	1.86	**38.89**
	departure	-1.12	-0.92	-0.85	2.46	-0.35	-2.25	2.42	-1.68	0.61	1.68	1.10	-0.98	0.12
	average	3.34	2.83	3.53	3.25	3.70	4.27	4.11	3.78	2.71	2.05	2.36	2.84	38.77
1974	rainfall	4.77	1.62	2.88	2.48	6.12	5.18	2.45	5.89	3.20	1.09	2.46	3.26	**41.40**
	departure	1.69	-1.15	-0.87	-0.97	2.56	1.17	-1.83	2.55	0.40	-1.02	-0.06	0.49	
	average	3.08	2.77	3.75	3.45	3.56	4.01	4.28	3.34	2.80	2.11	2.52	2.77	
1975	rainfall	2.77	3.77	4.63	4.39	5.01	2.33	2.35	4.42	5.42	4.12	2.59	3.71	**45.51**
	departure	-0.31	1.00	0.88	0.94	1.45	-1.68	-1.93	1.08	2.62	2.01	0.07	0.94	7.07
	average	3.08	2.77	3.75	3.45	3.56	4.01	4.28	3.34	2.80	2.11	2.52	2.77	38.44
1976	rainfall	2.54	2.17	2.81	0.96	2.77	4.52	6.50	1.94	2.81	5.02	0.34	1.39	**33.77**
	departure	-0.54	-0.60	-0.94	-2.49	-0.79	0.51	2.22	-1.40	0.01	2.91	-2.18	-1.38	-4.67
	average	3.08	2.77	3.75	3.45	3.56	4.01	4.28	3.34	2.80	2.11	2.52	2.77	38.44
1977	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1981	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1982	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

I. SUMMARY OF PRECIPITATION DATA
Parkersburg WSO CI

1983	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1984	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1985	rainfall	2.04	2.75	5.29	1.6	5.2	1.65	6.28	3.57	0.59	3.91	7.39	1.26	41.53
	departure		0.17	1.73	-1.77	1.71	-2.19	2.20	-0.01	-2.23	1.47	4.96	-1.46	
	average	2.04	2.58	3.56	3.37	3.49	3.84	4.08	3.58	2.82	2.44	2.43	2.72	41.53
1986	rainfall													
	departure													
	average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	rainfall	1.71	0.73	2.03	3.02	1.71	2.01	2.65	2.65	2.03	1.75	2.03	3.20	25.52
	departure	-1.15	-1.85	-1.53		-1.78	-1.83	-1.43	-0.93	-0.79	-0.69	-0.40	0.48	
	average	2.86	2.58	3.56	3.02	3.49	3.84	4.08	3.58	2.82	2.44	2.43	2.72	25.52
1988	rainfall	1.48	2.86	3.17	2.52	1.57	0.64	4.24	1.19	3.59	1.76	4.43	3.68	31.13
	departure		0.28	-0.39	-0.85	-1.92	-3.20	0.16	-2.39	0.77	-0.68	2.00	0.96	
	average	1.48	2.58	3.56	3.37	3.49	3.84	4.08	3.58	2.82	2.44	2.43	2.72	31.13
1989	rainfall	3.61	7.26	5.97	5.82	4.56	4.22	2.58	8.06	6.94	3.01	1.30	1.19	54.52
	departure	0.75		2.41	2.45	1.07	0.38	-1.50	4.48	4.12		-1.13		
	average	2.86	7.26	3.56	3.37	3.49	3.84	4.08	3.58	2.82	3.01	2.43	1.19	54.52
1990	rainfall	2.90	3.09	2.57	2.19	8.49	5.23	7.77	5.65	2.15	4.95	2.36	8.21	55.56
	departure	0.04	0.51	-0.99	-1.18	5.00	1.39	3.69	2.07	-0.67	2.51	-0.07	5.49	
	average	2.86	2.58	3.56	3.37	3.49	3.84	4.08	3.58	2.82	2.44	2.43	2.72	55.56
1991	rainfall	3.08	3.58	4.74	4.37	1.75	3.85	7.85	4.74	3.55	1.22	3.82	5.47	48.02
	departure	0.22	1.00	1.18	1.00	-1.74	0.01	3.77	1.16	0.73	-1.22	1.39	2.75	
	average	2.86	2.58	3.56	3.37	3.49	3.84	4.08	3.58	2.82	2.44	2.43	2.72	48.02
1992	rainfall	2.30	1.50	4.30	2.27	3.75	3.10	8.46	3.75	2.34	0.63	3.52	1.81	37.73
	departure	-0.56	-1.08	0.74	-1.10	0.26	-0.74	4.38	0.17	-0.48	-1.81			
	average	2.86	2.58	3.56	3.37	3.49	3.84	4.08	3.58	2.82	2.44	3.52	1.81	37.73
1993	rainfall	2.50	1.78	4.49	2.90	2.22	3.16	3.75	3.10	3.58	3.23	3.61	1.73	36.05
	departure	0.19	-0.70		-0.42	-1.53	-0.27	-0.46	-0.62	0.51	0.55	0.69	-1.19	
	average	2.31	2.48	4.49	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	36.05

I. SUMMARY OF PRECIPITATION DATA
Parkersburg WSO CI

1994	rainfall	5.11	3.51	5.98	5.54	3.71	3.15	7.79	4.60	3.38	0.66	2.40	2.75	48.58
	departure	0.00	1.03	2.43	2.22	-0.04	-0.28	3.58	0.88	0.31	-2.02	-0.52	-0.17	0.00
	average	5.11	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	48.58
1995	rainfall	4.38	2.29	1.57	2.21	8.99	4.84	1.06	4.71	2.42	4.60	2.69	2.50	**42.26**
	departure	0.00	-0.19	-1.98	-1.11	5.24	1.41	-3.15	0.99	-0.65	1.92	-0.23	0.00	0.00
	average	4.38	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.50	42.26
1996	rainfall	5.04	3.34	4.30	3.26	9.06	4.68	7.43	2.53	5.79	1.49	3.26	3.29	**53.47**
	departure	2.73	0.86	0.75	-0.06	5.31	1.25	3.22	-1.19	2.72	-1.19	0.34	0.37	15.11
	average	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36
1997	rainfall	2.23	1.48	9.42	2.16	3.80	6.82	5.29	5.70	1.84	1.19	1.91	2.10	**43.94**
	departure	-0.08	-1.00	5.87	-1.16	0.05	3.39	1.08	1.98	-1.23	-1.49	-1.01	0.00	0.00
	average	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.10	43.94
1998	rainfall	3.63	4.71	3.55	4.91	3.85	13.20	2.56	0.67	2.31	2.02	1.65	2.23	**45.29**
	departure	1.32	2.23	0.00	1.59	0.10	9.77	-1.65	-3.05	-0.76	-0.66	-1.27	-0.69	6.93
	average	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36
1999	rainfall	5.79	2.67	3.23	2.79	3.08	1.77	1.86	4.13	1.12	3.36	4.40	3.37	**37.57**
	departure	3.48	0.19	-0.32	-0.53	-0.67	-1.66	-2.35	0.41	-1.95	0.68	1.48	0.45	-0.79
	average	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36

Statistical analyses can be performed based on the Average Annual Precipitation, or on the individual Average Monthly Precipitation values.
Analysis based on the Average Annual Precipitation have a more direct correlation to exceedance probability, which is typically based on an annual basis.
Analysis based on the individual Average Monthly Precipitation values provide some insight in the variability of precipitation that may occur.

II. STATISTICAL ASSESSMENT, MONTHLY BASIS

A Statistical Analysis is performed on the monthly precipitation for comparative purposes only.
The standard deviation is computed for the Monthly Precipitation values, and monthly precipitation values equal to the Average Monthly Ppt plus a multiple of the standard deviation are computed.
The results will be compared to results on statistical analyses performed on annual precipitation.

TABLE 2 SUMMARY OF MONTHLY PRECIPITATION COMPARATIVE ANALYSES

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Monthly Values	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36
Standard Deviation of Monthly Values	1.21	1.38	1.81	1.58	2.27	2.59	2.41	1.93	1.56	1.43	1.44	1.65	
Average Monthly Precipitation + One Standard Deviation	3.52	3.86	5.36	4.90	6.02	6.02	6.62	5.65	4.63	4.11	4.36	4.57	59.63
Maximum Monthly Values	5.79	7.26	9.42	6.18	9.06	13.20	8.46	8.06	6.94	5.02	7.39	8.21	94.99
The Maximum Annual Rainfall Recorded is													55.56

III. STATISTICAL ASSESSMENT, ANNUAL BASIS

Year		Precipitation (inches)	Data Counter
1971		34.69	1
1972		47.37	1
1973		38.89	1
1974		41.4	1
1975		45.51	1
1976		33.77	1
1977	B&V study data	*36.03*	1
1978		*43.82*	1
1979		*43.92*	1
1980		*42.34*	1
1981		*35.65*	1
1982		*38.14*	1
1983		*50.57*	1
1984		*36.16*	1
1985		41.53	1
1986		*43.15*	1
1987		25.52	1
1988		31.13	1
1989		54.52	1
1990		55.56	1
1991		48.02	1
1992		37.73	1
1993		36.05	1
1994		48.58	1
1995		42.26	1
1996		53.47	1
1997		43.94	1
1998		45.29	1
1999		37.57	1

total precipitation, inches 1212.58

number of years with data 29

Average Annual Precipitation	**41.81**	inches	*Parkersburg WSO CI* supplemented with Black & Veatch data

Additional data is available for the Wood County Airport, as taken directly from "Scrubber Solids Pond Hydrologic Study Report", by Black & Veatch, Project 26287, February 1995. (noted in above table)

Average Annual Precipitation **41.06** **inches** *Wood County Airport*

Use Average Annual Precipitation =	**41.81**	inches	
Variance	48.54		
Standard Deviation	6.97		*computed as square root of variance*
	6.97		*spreadsheet built-in formula*

Sum of Average Monthly Ppt values	38.36	inches
Average Annual Precipitation	41.81	inches

Note the relatively large difference between these two values

Average Annual Precipitation	41.81	inches
Standard Deviation of Annual Precipitation	6.97	inches
Average Annual Ppt + 1 Standard Deviation	48.78	inches
Average Annual Ppt + 1-1/2 Standard Deviation	52.26	inches
Average Annual Ppt + 2 Standard Deviation	55.75	inches

Exceedance Probability Analysis

ASSUME Precipitation can be approximated as a Normal Distribution

Set Nz (Z) = Normal Function [(x - mean) / (standard deviation)]

The probability that the precipitation in a given year will be equalled or exceeded is expressed as 1 - Nz(Z)

Given Average Annual Precipitation 41.8131 inches
Standard Deviation 6.97 inches

parameter "x"	multiple of std dev	x	Z	Nz(Z)	1 - Nz(Z)	Probability of Exceedance
mean	0	41.81	0.00	0.5	0.5	50%
mean + std dev	1	48.78	1.00	0.8413	0.1587	16%
mean + 1.25 std dev	1.25	50.52	1.25	0.8997	0.1003	10%
mean + 1.5 std dev	1.5	52.26	1.50	0.9332	0.0668	7%
mean + 2 std dev	2	55.75	2.00	0.9773	0.0227	2%

obtain value from "Standard Normal Distribution Function" table, in Introduction to Probability Theory and Statistical Inference, H.J.Larson, (2nd ed), . Wiley & Sons, 1974

TABLE 3 ANNUAL PRECIPITATION ANALYSES

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Monthly Values	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36
Percentage of Average Monthly Ppt to Sum of Average Monthly Values	6.02%	6.47%	9.25%	8.65%	9.78%	8.94%	10.97%	9.70%	8.00%	6.99%	7.61%	7.61%	
Monthly Ppt Distribution of Average Annual Ppt	2.52	2.70	3.87	3.62	4.09	3.74	4.59	4.05	3.35	2.92	3.18	3.18	41.81
Monthly Ppt Distribution of Average Annual Ppt plus 1 Standard Deviation	2.94	3.15	4.51	4.22	4.77	4.36	5.35	4.73	3.90	3.41	3.71	3.71	48.78
Monthly Ppt Distribution of Average Annual Ppt plus 1-1/2 Standard Deviation	3.15	3.38	4.84	4.52	5.11	4.67	5.74	5.07	4.18	3.65	3.98	3.98	52.26
Monthly Ppt Distribution of Average Annual Ppt plus 2 Standard Deviation	3.36	3.60	5.16	4.82	5.45	4.98	6.12	5.41	4.46	3.89	4.24	4.24	55.75

IV. COMPARISON OF MONTHLY AVERAGE RAINFALL AMOUNTS, 1971 & 1999 CALENDAR YEARS, RAINFALL IN INCHES

1971	average	3.34	2.83	3.53	3.25	3.70	4.27	4.11	3.78	2.71	2.05	2.36	2.84	38.77
1999	average	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36
		-1.03	-0.35	0.02	0.07	0.05	-0.84	0.10	-0.06	0.36	0.63	0.56	0.08	-0.41

V. DEVELOPMENT OF "WET YEAR" MONTHLY PRECIPITATION DISTRIBUTION

The Maximum Annual Precipitation recorded (calendar basis) is 55.56 inches

The Average Annual Precipitation is 41.81 inches

Sum of Average Monthly Precipitation values 38.36 inches

The Average Annual Precipitation plus One Standard Deviation is 48.78 inches
This precipitation has been exceeded 4 times since 1971.

The Annual Precipitation for Average Monthly Ppt plus Monthly Standard Deviation is 59.63 inches
(year where the monthly ppt is equal to the average monthly value plus one standard deviation)

A "Wet Year" will be considered to be a Year in which the precipitation in any month is equal to the Average Monthly Precipitation plus 1 Standard Deviation.
This yields a probability of exceedance of about **16%**

TABLE 3 SUMMARY OF PRECIPITATION ANALYSES

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Monthly Ppt	2.31	2.48	3.55	3.32	3.75	3.43	4.21	3.72	3.07	2.68	2.92	2.92	38.36
Monthly Average Annual Ppt	2.52	2.70	3.87	3.62	4.09	3.74	4.59	4.05	3.35	2.92	3.18	3.18	41.81
Wet Year Ppt, 1 Std Dev, based on Monthly Average Annual Ppt	2.94	3.15	4.51	4.22	4.77	4.36	5.35	4.73	3.90	3.41	3.71	3.71	48.78
Wet Year Ppt, 1.5 Std Dev, based on Monthly Average Annual Ppt	3.15	3.38	4.84	4.52	5.11	4.67	5.74	5.07	4.18	3.65	3.98	3.98	52.26
Wet Year Ppt, 2 Std Dev, based on Monthly Average Annual Ppt	3.36	3.60	5.16	4.82	5.45	4.98	6.12	5.41	4.46	3.89	4.24	4.24	55.75

Evaporation

I. Available Evaporation Data

I.A. Clarksburg 1948 (8) to 1964 (9)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Average Value				3.11	3.90	4.44	4.90	3.85	2.47	1.69			24.36

I.B. Evaporation Maps, Weather Atlas of the United States, U.S. Department of Commerce, Environmental Data Service, June 1968.

I.B.1. Mean Annual Class A Pan Evaporation - Plate 1

Clarksburg area	40	
McElroy's Run site	45	

I.B.2. Mean Annual Lake Evaporation - Plate 2

Clarksburg area	30	inches
McElroy's Run site	34	inches

I.B.3. Mean Annual Class A Pan Coefficient - Plate 3

Clarksburg area	75	percent
McElroy's Run site	75	percent

I.B.4. Calculated Class A Pan Coefficient, from Class A Pan & Lake Evaporation

Clarksburg area	75	percent
McElroy's Run site	76	percent

I.B.5. Mean May-October Evaporation in Percent of Annual Evaporation - Plate 4

Clarksburg area	72	percent
McElroy's Run site	74	percent

Evaporation

II. Analyses and Correlations

Pan evaporation is usually not measured from late fall to late spring in the northern climes, due to freezing of the water.
However, some evaporation does occur during this period.
Given the above information from the Weather Atlas, one can adjust the Clarksburg data to fill in the remaining portion of the year, and then adjust again to correlate it to the McElroy's Run site.

II.A. Adjust Clarksburg data to get full year info

At Clarksburg area

The mean annual lake evaporation	30 inches	(Weather Atlas, Plate 2)
The May - October evaporation from the Clarksburg data is	21.25 inches	(Clarksburg data)
The Clarksburg data (Section I.A. above) is believed to be "lake" evaporation		
The proportion of the Clarksburg May - October evaporation to the Mean Annual Evaporation is then	71 percent	(calculation)
The Weather Atlas indicates that the proportion should be	72 percent	(Weather Atlas. Plate 1 & 2)

Use **72** percent in the water balance analyses.

Given that **72** percent of the Mean Annual (Pan or Lake) Evaporation occurs in the 6 month period May to October.
The remaining **28** percent of the Mean Annual (Pan or Lake) Evaporation would occur in the remaining 6 month period November to April.

For Lake Evaporation, the corresponding evaporation values would be

Mean Annual Lake Evaporation	30 inches	(Weather Atlas, Plate 2)
May to October	21.25 inches	(Clarksburg data)
November to April	8.75 inches	(calculation)
The Clarksburg data indicates that the monthly average for April is	3.11 inches	(Clarksburg data)
Therefore, Lake Evaporation from November to March would be	5.64 inches	(calculation)
Divide this amount evenly between the 5 months	1.13 inches/month	(calculation)

The resulting monthly distribution of lake evaporation for the Clarksburg area is therefore

Clarksburg area

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
1.13	1.13	1.13	3.11	3.90	4.44	4.90	3.85	2.47	1.69	1.13	1.13	30.00

Evaporation

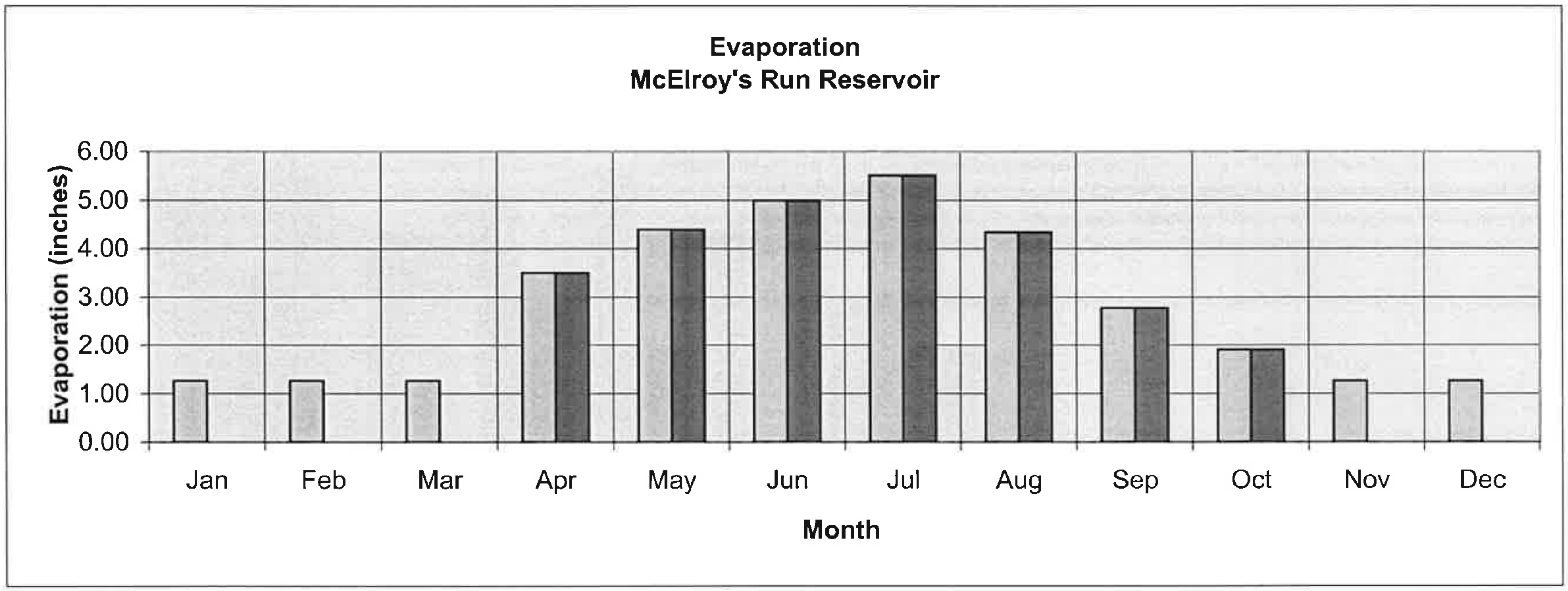
I.C. The Weather Atlas indicates that the ratio of evaporation at the McElroy's Run site to evaporation at the Clarksburg area is on the order of

pan evaporation	1.13	(Weather Atlas, Plate 1)
lake evaporation	1.13	(Weather Atlas, Plate 2)

Use **Ratio of McElroy's Evaporation to Clarksburg Evaporation = 1.13**

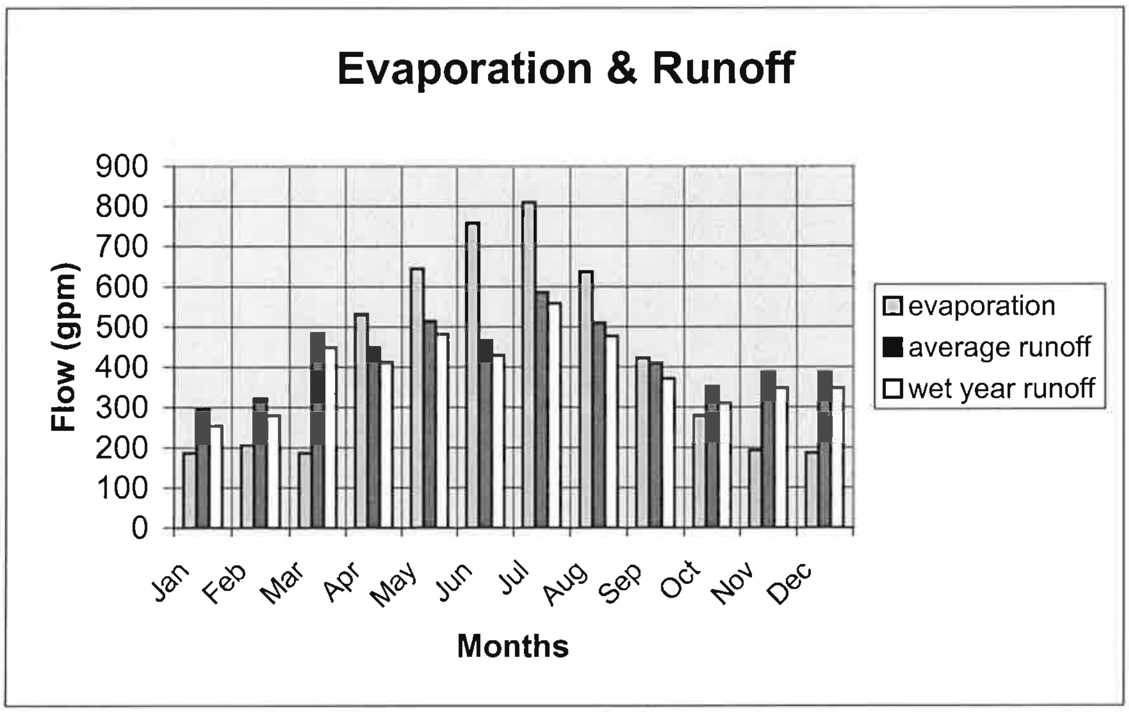
The Average Monthly distribution of lake evaporation at the McElroy's Run site is estimated as the Clarksburg monthly values multiplied by the above ratio.
The Below-Average Monthly distribution of lake evaporation assumes negligible evaporation occurs between November through March.

	McElroy's Run Site												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Average	1.27	1.27	1.27	3.50	4.39	5.00	5.51	4.33	2.78	1.90	1.27	1.27	33.75
Below-Average	0	0	0	3.50	4.39	5.00	5.51	4.33	2.78	1.90	0.00	0.00	27.41



Reservoir Normal Operating Pool Target Elevation 887 ft, msl
Surface Elevation of Reservoir at Target Elevation 241.5 acres

	Evaporation (inches)	Evaporation (gpm)	Average Runoff (inches)	Average Runoff (gpm)	Wet Year Runoff (inches)	Wet Year Runoff (inches)
Jan	1.27	186	2.01	296	1.73	254
Feb	1.27	206	2.19	321	1.90	279
Mar	1.27	186	3.29	483	3.05	449
Apr	3.50	531	3.05	448	2.80	411
May	4.39	644	3.50	514	3.28	481
Jun	5.00	758	3.16	465	2.92	429
Jul	5.51	810	3.98	585	3.80	558
Aug	4.33	636	3.47	509	3.24	477
Sep	2.78	422	2.79	410	2.53	371
Oct	1.90	279	2.39	351	2.11	310
Nov	1.27	193	2.64	387	2.36	347
Dec	1.27	186	2.64	387	2.36	347



KLC

Elevation - Area Measurements obtained using CADD of digitized 2000 Topo of the McElroy's Run Reservoir Area. Volume is computed using the Average End Area Method. Computed Volumes were checked against the Elevation-Storage Curve originally developed for the Reservoir by D'Appolonia, Inc., and good agreement (+/- 1-2 percent) was obtained. Therefore, these values are used in subsequent reservoir analyses in this spreadsheet.

Reservoir Water Level at Time of Aerial Mapping	***876.10***	ft, msl
Reported Reservoir Water Level (March 2001)	***880.5***	ft, msl
Reported Reservoir Water Level (November 2001)	***881.4***	ft, msl
Current Reservoir Water Level (December 2001)	***880.9***	ft, msl

TABLE 1

Reservoir Elevation (ft, msl)	Surface Area (ac)	Average Surface Area (sf)	Increm. Storage Volume (ac-ft)	Total Storage Volume (ac-ft)	Reservoir Elevation (ft,msl)
876.10	***160***			***14500***	*Ref. 2, Drawing 6056-F-211434*
		167	151		
877.00	175			14651	877.00
		182	182		
878.00	***190***			14833	878.00
		196	196		
879.00	202			15029	879.00
		208	208		
880.00	***214***			15237	880.00
		216	216		
881.00	218			15454	881.00
		220	220		
882.00	***223***			15674	882.00
		224	224		
883.00	226			15898	883.00
		228	228		
884.00	***230***			16127	884.00
		232	232		
885.00	234			16359	885.00
		236	236		
886.00	***238***			16595	886.00
		240	240		
887.00	241			16835	887.00
		243	243		
888.00	***245***			17078	888.00
		248	248		
889.00	250			17326	889.00
		253	253		
890.00	***255***			17578	890.00
		256	256		
891.00	258			17835	891.00
		259	259		
892.00	***260***			18094	892.00
		262	262		
893.00	263			18355	893.00
		264	264		
894.00	***266***			18620	894.00
		267	267		
895.00	268			18887	895.00
		270	270		
896.00	***271***			19157	896.00
		272	272		
897.00	274			19429	897.00
		275	275		
898.00	***276***			19704	898.00
		278	278		
899.00	279			19982	899.00
		280	280		
900.00	***282***			20263	900.00

Runoff

I. First Order Approximation of Monthly Runoff Volume

The SCS Soil Cover Complex Method is adopted to estimate monthly average runoff volumes to the resrevoir. This method is also used in the HELP model for the prediction of runoff. The method uses an initial abstraction parameter, which accounts for some minimum level losses (infiltration & interception) before the start of runoff.

For water balance methods using monthly rainfall, predicted runoff volumes using the SCS method are considered to be slightly conservative, because the computed initial abstraction is taken from the entire monthly rainfall, rather than only for those rainfall events which exceed the initial abstraction.

During the winter months, the volume of runoff may differ somewhat from the predicted values. The effective curve number may be increased because of the probability of frozen ground, which reduces infiltration. Precipitation may also occur as snowfall, whose fate depends upon temperature and relative humidity levels in addition to ground moisture conditions.

The scope of the analyses does not permit evaluation of long-term records of daily temperature, relative humidity, and precipitation values. Also, the availability of this information, both in quantity and in proximity to the McElroy's site, is limited. Therefore, monthly values of precipitation and evaporation are used, as this data would provide reasonable prediction of reservoir levels.

II. Data

II.A. **Reservoir Normal Operating Target Level 887 ft, msl**

II.B.1. Areas

Reservoir	241.5 acres	(Elevation 887 ft, msl)
Upland Areas	386.5 acres	
upland area, woods, fair condition	96.6 acres	
upland area, pasture, fair condition	289.9 acres	
subtotal, area upland of reservoir	628.0 acres	
Ash Disposal Area	204.0 acres	Solid Waste/NPDES Application (81-237-67, March 1997), Addendum II, Section 4, p. 6 of 17, 81-237-41
active disposal	30.4 acres	Solid Waste/NPDES Application (81-237-67, March 1997), Addendum II, Section 4, p. 6 of 17, 81-237-41
revegetated pile	114.0 acres	estimated, by trial & error to get composite CN
off-site areas	55.6 acres	estimated, by trial & error to get composite CN
pond	4.0 acres	estimated, by trial & error to get composite CN
total	832.0 acres	

II.B.2. Curve Numbers

reservoir	100
upland areas	
fair woods, HSG "B/C"	67
fair pasture, HSG "C"	79
ash disposal area	
active disposal	86
revegetated pile	74
off-site areas	68
pond	100

II.B.3. Composite Curve Numbers (see calcs by TRV, "Emergency Spillway, 2-13-92, in letter, GAI to APSC (H.McCullough), Project 81-237-41, April 14, 1992; and Solid Waste/NPDES Application (81-237-67, March 1997), Addendum II, Section 4, p. 6 of 17, 81-237-41

reservoir plus upland area	85	*rounded*
reservoir alone	100	*rounded*
upland areas alone	76	*rounded*
ash disposal area	74	*rounded*

II.B.4. S Factor

reservoir plus upland area	1.73	*using unrounded CN values*
reservoir alone	0.00	*using unrounded CN values*
upland areas alone	3.16	*using unrounded CN values*
ash disposal area	3.51	*using unrounded CN values*

II.B.5. Minimum Rainfall Resulting in Runoff

reservoir plus upland area	0.35	inch
reservoir alone	0	inch
upland areas alone	0.63	inch
ash disposal area	0.70	inch

Table 1
Summary of Monthly Average Runoff Volumes
Areas Draining to the Reservoir
Precipitation Records 1971-1999

Average Year Monthly Precipitation, Average Monthly Precipitation Values adjusted to obtain Average Annual Precipitation														
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
average annual monthly rainfall		2.52	2.70	3.87	3.62	4.09	3.74	4.59	4.05	3.35	2.92	3.18	3.18	41.81
predicted runoff, composite,CN=	85	1.21	1.36	2.36	2.14	2.56	2.25	3.01	2.53	1.90	1.54	1.76	1.76	24.37
predicted runoff, reservoir CN=	100	2.52	2.70	3.87	3.62	4.09	3.74	4.59	4.05	3.35	2.92	3.18	3.18	41.81
predicted runoff, upland CN=	76	0.71	0.82	1.64	1.45	1.81	1.54	2.20	1.78	1.25	0.96	1.14	1.14	16.44
predicted runoff, ash site CN=	74	0.62	0.73	1.50	1.32	1.66	1.41	2.04	1.64	1.14	0.86	1.03	1.03	14.96

for comparison purposes only, consider the following

Maximum Monthly Values	*5.79*	*7.26*	*9.42*	*6.18*	*9.06*	*13.20*	*8.46*	*8.06*	*6.94*	*5.02*	*7.39*	*8.21*	*94.99*

maximum annual total rainfall *55.56*

Wet Year Monthly Precipitation = Average Monthly Precipitation plus 1 Standard Deviation based on Annual Rainfall														
Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Predicted Monthly Precipitation		2.94	3.15	4.51	4.22	4.77	4.36	5.35	4.73	3.90	3.41	3.71	3.71	48.78
departure of adusted rainfall from average		0.42	0.45	0.64	0.60	0.68	0.62	0.76	0.68	0.56	0.49	0.53	0.53	
predicted runoff, composite,CN=	85	1.55	1.74	2.94	2.68	3.18	2.80	3.72	3.14	2.39	1.95	2.22	2.22	30.54
predicted runoff, reservoir CN=	100	2.94	3.15	4.51	4.22	4.77	4.36	5.35	4.73	3.90	3.41	3.71	3.71	48.78
predicted runoff, upland CN=	76	0.97	1.12	2.14	1.91	2.35	2.02	2.83	2.32	1.67	1.30	1.52	1.52	21.66
predicted runoff, ash site CN=	74	0.87	1.01	1.98	1.76	2.18	1.87	2.65	2.15	1.53	1.18	1.39	1.39	19.95

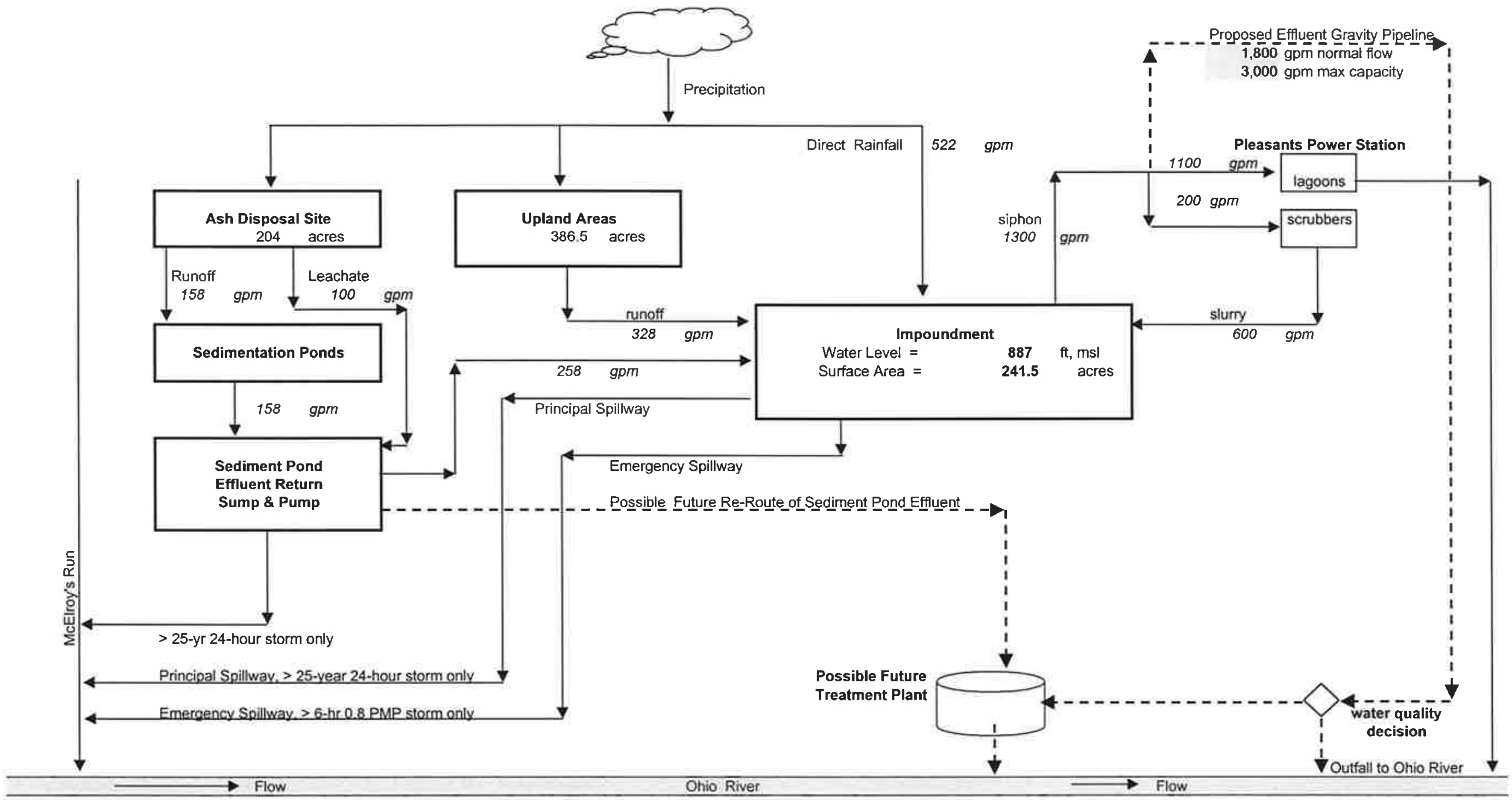
Very Wet Year Monthly Precipitation = Average Monthly Precipitation plus 1-1/2 Standard Deviation based on Annual Precipitation														
Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Predicted Monthly Precipitation		3.15	3.38	4.84	4.52	5.11	4.67	5.74	5.07	4.18	3.65	3.98	3.98	52.26
departure of adusted rainfall from average		0.63	0.68	0.97	0.90	1.02	0.93	1.15	1.01	0.84	0.73	0.80	0.80	
predicted runoff, composite,CN=	85	1.73	1.93	3.24	2.95	3.49	3.09	4.08	3.45	2.64	2.17	2.46	2.46	33.69
predicted runoff, reservoir CN=	100	3.15	3.38	4.84	4.52	5.11	4.67	5.74	5.07	4.18	3.65	3.98	3.98	52.26
predicted runoff, upland CN=	76	1.12	1.28	2.40	2.15	2.63	2.27	3.15	2.59	1.88	1.48	1.72	1.72	24.38
predicted runoff, ash site CN=	74	1.00	1.16	2.23	1.99	2.45	2.11	2.96	2.42	1.73	1.35	1.58	1.58	22.56

Runoff

Extremely Wet Year Monthly Precipitation = Average Monthly Precipitation plus 2 Standard Deviation based on Annual Precipitation														
Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Predicted Monthly Precipitation		3.36	3.60	5.16	4.82	5.45	4.98	6.12	5.41	4.46	3.89	4.24	4.24	55.75
departure of adusted rainfall from average		0.84	0.90	1.29	1.21	1.36	1.25	1.53	1.35	1.12	0.97	1.06	1.06	
predicted runoff, composite,CN=	85	1.91	2.13	3.54	3.23	3.81	3.38	4.44	3.77	2.90	2.38	2.70	2.70	36.87
predicted runoff, reservoir CN=	100	3.36	3.60	5.16	4.82	5.45	4.98	6.12	5.41	4.46	3.89	4.24	4.24	55.75
predicted runoff, upland CN=	76	1.26	1.44	2.67	2.39	2.91	2.52	3.48	2.87	2.10	1.66	1.93	1.93	27.16
predicted runoff, ash site CN=	74	1.14	1.31	2.49	2.23	2.73	2.35	3.28	2.69	1.94	1.52	1.78	1.78	25.25

FIGURE 2
WATER BALANCE FLOW DIAGRAM

proposed re-route of siphon



	indicates value obtained from another worksheet in this spreadsheet
	indicates required manual input of value by user
	indicates value obtained from Allegheny Energy Supply/Pleasants Power Station

DESIGN DATA	Average Year			90% Confidence	
	flow (gpm)	volume (ac-ft)		flow (gpm)	volume (ac-ft)
INFLOWS	**1708**	**2755**		**2077**	**3350**
Annual Precipitation in Reservoir	522	841		652	1052
Upland Runoff	328	530		487	785
Ash Disposal Site Runoff	158	254		238	384
Slurry Flows *	**600**	968		600	968
Ash Disposal Site Leachate	**100**	**161**		100	**161**
OUTFLOWS	**1721**	**2776**		**2077**	**3350**
Siphon Discharge ***	**1300**	2097		1735	2799
Mix Tank Siphon Withdrawal **	**200**	323		200	323
Average Evaporation	421	679		342	552

* Station Slurry Flow set at 600 gpm, based on review by Ray Kustra
** Mix Tank Siphon Withdrawal set at 200 gpm, estimate made by Ralph Curtiss & Ray Kustra
*** For the Average Year, the hydraulic capacity of the existing siphon is shown
For the 90% Confidence, the minimum hydraulic capacity of the improved siphon is shown.
Note: See Worksheet "reservoir_operation" for actual tracking of flows and volumes into and from the reservoir.

Outline of Analyses

Data Summary

Reservoir Normal Operating Level	*flowchart*
Station Slurry (Process) Flows, long-term average	*flowchart*
Gypsum Process/Mix Tank Withdrawal, est. long-term average	*flowchart*
Siphon, flow monitor measurement	*flowchart*
Net Siphon, considering Mix Tank operation	
Leachate Flows from Sediment Pond, ultimate development	*flowchart*
Reservoir Elevation-Area-Volume Rating Table	*elev_area_volume*

I. Average Year Analysis: Average Precipitation and Average Evaporation

Predict the response, on a monthly basis, of reservoir levels during an "Average Year".

I.A. Inflows (Average Monthly Precipitation & Design Estimates)	
I.A.1. Direct Precipitation onto Reservoir Area	*Rainfall_Parkersburg_WSO*
I.A.2. Runoff from Upland Area	*Runoff*
I.A.3. Runoff from Ash Site (Sediment Pond Effluent System)	*Runoff*
I.A.4. Slurry Flows	*flowchart*
I.A.5. Sediment Pond Base Flow	
I.B. Outflows	
I.B.1. Siphon Discharge (Current Capacity)	*Station measurement*
I.B.2. Evaporation (Average Monthly Evaporation, "Lake")	*Evaporation*
I.C. Mass Balance of Inflows and Outflows	*calc*
I.D. Summary of Analysis	
I.E. Conclusion	

II. Minimum Required Total Reservoir Discharge for an "Average" Year

What is the Minimum Total Reservoir Discharge Required to Maintain a Given Reservoir Level Over the Course of a Year with Average Precipitation and Average Evaporation?

- II.A. Estimated Minimum Discharge and Monthly Discharge Volume
- II.B. Mass Balance of Inflows and Outflows
- II.C. Summary of Analysis

III. Wet Year Analysis: Above-Average Precipitation with Below-Average Evaporation

Predict the response, on a monthly basis, of reservoir levels during a "Wet Year".

A "Wet Year" is defined here as a year in which the total annual precipitation has approximately a 15 percent probability of being exceeded.

A "Wet Year" is based on the Average Annual Precipitation plus One (1) Standard Deviation.

- III.A. Inflows
  - III.A.1. Direct Precipitation onto Reservoir Area
  - III.A.2. Runoff from Upland Areas
  - III.A.3. Runoff from Ash Site (Sediment Pond Effluent System)
  - III.A.4. Slurry Flows
  - III.A.5. Sediment Pond Base Flow

III. Wet Year Analysis: Above-Average Precipitation with Below-Average Evaporation (con't)

- III.B. Outflows
  - III.B.1. Siphon Discharge (Current Design Capacity)
  - III.B.2. Evaporation (Below-Average Monthly Evaporation ("Lake")
- III.C. Mass Balance of Inflows and Outflows
- III.D. Summary of Analysis

IV. Minimum Required Total Reservoir Discharge for a "Wet Year"

What is the Minimum Total Reservoir Discharge Required to Maintain a Given Reservoir Level Over the Course of a Year with Above-Average Precipitation and Below-Average Evaporation?

Above-Average Precipitation is Set as the Average Annual Precipitation plus One (1) Standard Deviation.

The Probability that a year would have a total precipitation greater than this precipitation is about 15%.

- IV.A. Estimated Minimum Discharge and Discharge Volume
- IV.B. Mass Balance of Inflows and Outflows
- IV.C. Summary of Analysis

V. Sensitivity Analysis # 1:

What Reservoir Level Would Result for a "Wet Year" if the Total Reservoir Discharge is Based on an "Average Year"?

- IV.A. Estimated Minimum Discharge and Discharge Volume
- IV.B. Mass Balance of Inflows and Outflows

VI. Very Wet Year Analysis: More-than-Above Average Precipitation with Below-Average Evaporation

What Reservoir Level would result for a "Very Wet Year" under Current Siphon Discharge Conditions?

A "Very Wet Year" is defined as a year in which the Annual Precipitation that occurs has a 10% or less probability of being exceeded.

The precipitation that would have a 10% or less probability of occurring corresponds approximately to the Average Annual Precipitation plus One-and-One-Half (1-1/2) Standard Deviation.

- VI.A. Inflows
  - VI.A.1. Direct Precipitation onto Reservoir Area
  - VI.A.2. Runoff from Upland Areas
  - VI.A.3. Runoff from Ash Site (Sediment Pond Effluent System)
  - VI.A.4. Slurry Flows
  - VI.A.5. Sediment Pond Base Flow
- VI.B. Outflows
  - VI.B.1. Siphon Discharge (Current Design Capacity)
  - VI.B.2. Evaporation (Below-Average Monthly Evaporation ("Lake")
- VI.C. Mass Balance of Inflows and Outflows
- VI.D. Estimated Minimum Discharge and Discharge Volume
- VI.E. Summary of Analysis

VII. Minimum Required Total Reservoir Discharge for a "Very Wet Year"

What is the Minimum Total Reservoir Discharge Required to Maintain a Given Reservoir Level Over the Course of a Year with More-Than-Above-Average Precipitation and Below-Average Evaporation?

The probability that this amount of precipitation would occur is approximately ten (10) percent or less.

- VII.A. Mass Balance of Inflows and Outflows
- VII.B. Estimated Minimum Discharge and Discharge Volume
- VII.C. Summary of Analysis

VIII. Minimum Total Reservoir Discharge for an "Extremely Wet Year"

What is the Minimum Total Reservoir Discharge to Maintain a Given Reservoir Level Over the Course of a Year with a Greatly-More-Than-Above-Average Precipitation and Below-Average Evaporation?

Greatly-More-Than-Above Precipitation is set as the Average Annual Precipitation plus Two (2) Standard Deviations (92% confidence). The Probability that a year would have a total precipitation greater than this precipitation is about 2%.

- VIII.A. Estimated Minimum Discharge and Discharge Volume
- VIII.B. Mass Balance of Inflows and Outflows
- VIII.C. Summary of Analysis

VIII. Compare Reservoir Range Fluctuations with Maximum Normal Pool Level for the Reservoir.

IX. Evaluate Fluctuation of the Reservoir during the Course of the Year Analyzed

X. Plot of Monthly Reservoir Elevation Performance for Selected Discharge Rates

Data Summary

			Worksheet Reference
Reservoir Normal Operating Level	**887.00**	**ft, msl**	*flowchart*
Station Slurry (Process) Flows, long-term average	**600**	**gpm**	*flowchart*
Gypsum Process/Mix Tank Withdrawal, est. long-term average	**200**	**gpm**	*flowchart*
Siphon, flow monitor measurement	**1100**	**gpm**	*flowchart*
Net Siphon, considering Mix Tank operation	**1300**	**gpm**	*calc*
Leachate Flows from Sediment Pond, ultimate development	**100**	**gpm**	*flowchart*

Reservoir Elevation-Area-Volume Rating Table *Elev_Area_Volume*

Reservoir Water Elevation-Storage Volume Rating Table

Water Elevation (ft, msl)	Storage Volume (ac-ft)	Surface Area (ac)	Water Elevation (ft, msl)
877.00	14651	175	877
878.00	14833	190	878
879.00	15029	202	879
880.00	15237	214	880
881.00	15454	218	881
882.00	15674	223	882
883.00	15898	226	883
884.00	16127	230	884
885.00	16359	234	885
886.00	16595	238	886
887.00	16835	241	887
888.00	17078	245	888
889.00	17326	250	889
890.00	17578	255	890
891.00	17835	258	891
892.00	18094	260	892
893.00	18355	263	893
894.00	18620	266	894
895.00	18887	268	895
896.00	19157	271	896
897.00	19429	274	897
898.00	19704	276	898
899.00	19982	279	899
900.00	20263	282	900

I. Average Year Analysis: Average Precipitation and Average Evaporation

Predict the response, on a monthly basis, of reservoir levels during an "Average Year".

NORMAL RESERVOIR OPERATING LEVEL	**887.00**	**ft, msl**	*flowchart*
AVERAGE ANNUAL PRECIPITATION	**41.81**	**inches**	*rainfall_parkersburg_wso*
PROBABILITY OF EXCEEDANCE	**50**	**percent**	

I.A. Inflows (Average Monthly Precipitation & Design Estimates)

I.A.1. Direct Precipitation onto Reservoir Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Values	2.52	2.70	3.87	3.62	4.09	3.74	4.59	4.05	3.35	2.92	3.18	3.18
Average Reservoir Area (acres) (reservoir level @ Normal Operating Level)	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
Inflow Volume (ac-ft)	50.67	54.40	77.87	72.83	82.26	75.24	92.35	81.60	67.34	58.79	64.05	64.05

Note: Average Monthly Values = long-term average of monthly average values of precipitation.

I.A.2. Runoff from Upland Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Values	0.71	0.82	1.64	1.45	1.81	1.54	2.20	1.78	1.25	0.96	1.14	1.14
Average Upland Area (acres)	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5
Inflow Volume (ac-ft)	22.72	26.43	52.80	46.77	58.17	49.63	70.89	57.35	40.42	31.00	36.72	36.72

I.A.3. Runoff from Ash Site (Sediment Pond Effluent System)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Values	0.62	0.73	1.50	1.32	1.66	1.41	2.04	1.64	1.14	0.86	1.03	1.03
Average Disposal Area (acres)	204	204	204	204	204	204	204	204	204	204	204	204
Inflow Volume (ac-ft)	10.51	12.34	25.52	22.48	28.23	23.93	34.70	27.82	19.30	14.60	17.45	17.45

NOTE: Runoff from the ash disposal site drains to the sediment ponds. Outflow from the ponds is directed to the Sediment Pond Effluent System lift station, and then pumped to the reservoir. The design capacity of the pumps (2 in operation, 1 in reserve) is about 1150 gpm.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Rainfall-Runoff Inflow Volume (ac-ft)	83.91	93.17	156.19	142.08	168.66	148.80	197.94	166.78	127.06	104.38	118.22	118.22

I.A.4. Slurry Flows ***(based on Station estimate, December 2001, revised November 2002)***

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	600	600	600	600	600	600	600	600	600	600	600	600
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Inflow Volume (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20

I. Average Year Analysis: Average Precipitation and Average Evaporation

I.A.5. Sediment Pond Base Flow ***(based on design predictions, ultimate pile development)***

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	100	100	100	100	100	100	100	100	100	100	100	100
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Inflow Volume (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70

I.B. Outflows

I.B.1. Siphon Discharge (Current Capacity)

Use the Net Siphon Discharge, which equals to measured siphon line flow less the Station withdrawal for mix tank uses

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Discharge Volume (ac-ft)	178.11	160.87	178.11	172.36	178.11	172.36	178.11	178.11	172.36	178.11	172.36	178.11

I.B.2. Evaporation (Average Monthly Evaporation, "Lake")

data provided by U.S. Army Corps of Engineers, Huntington District, WV, for Clarksburg WV, 1948-1964.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
evaporation (inches)	1.27	1.27	1.27	3.50	4.39	5.00	5.51	4.33	2.78	1.90	1.27	1.27
Reservoir Area (acres)	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
Evaporative Loss (ac-ft)	25.54	25.54	25.54	70.41	88.30	100.52	110.94	87.16	55.92	38.26	25.54	25.54

I.C. Mass Balance of Inflows and Outflows

I.C.1. Determination of Individual Component Volumes and Net Changes to Reservoir Volume

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I.C.1.a	**Inflows to Reservoir**	**179.81**	**179.80**	**252.10**	**234.89**	**264.56**	**241.61**	**293.84**	**262.68**	**219.87**	**200.29**	**211.03**	**214.12**
I.C.1.a.1	Direct Rainfall (ac-ft)	50.67	54.40	77.87	72.83	82.26	75.24	92.35	81.60	67.34	58.79	64.05	64.05
I.C.1.a.2	Upland Areas (ac-ft)	22.72	26.43	52.80	46.77	58.17	49.63	70.89	57.35	40.42	31.00	36.72	36.72
I.C.1.a.3	Ash Disposal Area (ac-ft)	10.51	12.34	25.52	22.48	28.23	23.93	34.70	27.82	19.30	14.60	17.45	17.45
I.C.1.a.4	Slurry Disposal (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20
I.C.1.a.5	Sediment Pond (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70
I.C.1.b	**Outflows from Reservoir**	**203.64**	**186.41**	**203.64**	**242.77**	**266.40**	**272.88**	**289.04**	**265.27**	**228.28**	**216.37**	**197.90**	**203.64**
I.C.1.b.1	Siphon (Net, ac-ft)	178.11	160.87	178.11	172.36	178.11	172.36	178.11	178.11	172.36	178.11	172.36	178.11
I.C.1.b.2	Evaporation (ac-ft)	25.54	25.54	25.54	70.41	88.30	100.52	110.94	87.16	55.92	38.26	25.54	25.54
I.C.1.c	Net Change in Reservoir Volume (ac-ft)	(23.84)	(6.61)	48.45	(7.88)	(1.84)	(31.27)	4.80	(2.59)	(8.41)	(16.08)	13.13	10.48

I. Average Year Analysis: Average Precipitation and Average Evaporation
I.C.2. Tracking Reservoir Elevations based on Net Changes in Reservoir Volume

BEGINNING NORMAL RESERVOIR OPERATING LEVEL ***887.00*** **ft, msl** **AS OF 1 JANUARY OF FIRST YEAR OF ANALYSIS**
Beginning Reservoir Volume at Normal Operating Water Level 16835 ac-ft

THEN AVERAGE PREDICTED RESERVOIR LEVEL AT THE END OF EACH SUCCEEDING MONTH WOULD BE AS GIVEN BELOW:

Monthly Tracking of Reservoir Volumes and Elevations

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	**887**	886.90	886.87	887.07	887.04	887.03	886.90	886.92	886.91	886.88	886.81	886.87
Reservoir Volume	**16,835**	16,811	16,804	16,853	16,845	16,843	16,812	16,817	16,814	16,806	16,790	16,803
At End of Month												
Net Change in Volume (ac-ft)	(23.84)	(6.61)	48.45	(7.88)	(1.84)	(31.27)	4.80	(2.59)	(8.41)	(16.08)	13.13	10.48
Reservoir Volume	16,811	16,804	16,853	16,845	16,843	16,812	16,817	16,814	16,806	16,790	16,803	16,813
Approx. Reservoir Water Level	886.90	886.87	887.07	887.04	887.03	886.90	886.92	886.91	886.88	886.81	886.87	**886.91**
low elevation of interpolation	886	886	887	887	887	886	886	886	886	886	886	886
high elevation of interpolation	887	887	888	888	888	887	887	887	887	887	887	887
low storage of interpolation	16595	16595	16835	16835	16835	16595	16595	16595	16595	16595	16595	16595
high storage of interpolation	16835	16835	17078	17078	17078	16835	16835	16835	16835	16835	16835	16835

I.D. Summary of Analysis

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	887.00	886.90	886.87	887.07	887.04	887.03	886.90	886.92	886.91	886.88	886.81	886.87
last of month reservoir level	886.90	886.87	887.07	887.04	887.03	886.90	886.92	886.91	886.88	886.81	886.87	886.91

Minimum Reservoir Level During the Year	886.81	ft, msl
Maximum Reservoir Level During the Year	887.07	ft, msl

I.E. Conclusion
The Existing Siphon, given its current operation, has sufficient capacity to prevent an net increase in reservoir level over the course of an average year.

II. Minimum Required Total Reservoir Discharge for an "Average" Year

Using the above information and procedure, estimate the total reservoir discharge rate needed to maintain, at year's end, a "no net increase' in reservoir water level.

II.A. Estimated Minimum Discharge and Monthly Discharge Volume

Trial & Error Solution: Assume a Reservoir Discharge Rate, compute resulting End-of-the-Year Reservoir Level, and compare to First-of-the-Year Reservoir Level.

First-of-the-Year Reservoir Level	887	**ft, msl**	*Assumed Starting Point for Analysis*
Required NET Total Reservoir Discharge Capacity	***1286***	**gpm**	*manually input this value until the "End-of-the-Year Reservoir Level" matches the "First-of-the-Year Reservoir Level"*
Average Monthly Discharged Volume	**170.50**	**ac-ft**	
End-of-the-Year Reservoir Level	**887.00**	**ft, msl**	*This value must equal the "First-of-the-Year Reservoir Level"*
Maximum Reservoir Level during the Year	**887.10**	**ft, msl**	

II.B. Mass Balance of Inflows and Outflows

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
II.A.	Inflows to Reservoir	**179.81**	**179.80**	**252.10**	**234.89**	**264.56**	**241.61**	**293.84**	**262.68**	**219.87**	**200.29**	**211.03**	**214.12**
II.A.1.	Reservoir (ac-ft)	50.67	54.40	77.87	72.83	82.26	75.24	92.35	81.60	67.34	58.79	64.05	64.05
II.A.2.	Upland Areas	22.72	26.43	52.80	46.77	58.17	49.63	70.89	57.35	40.42	31.00	36.72	36.72
II.A.3.	Ash Disposal Areas	10.51	12.34	25.52	22.48	28.23	23.93	34.70	27.82	19.30	14.60	17.45	17.45
II.A.4.	Slurry Disposal (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20
II.A.5	Sediment Pond (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70
II.B.	Outflows from Reservoir	**201.73**	**184.68**	**201.73**	**240.91**	**264.48**	**271.03**	**287.12**	**263.35**	**226.42**	**214.45**	**196.04**	**201.73**
II.B.1.	Reservoir Discharge (ac-ft)	176.19	159.14	176.19	170.50	176.19	170.50	176.19	176.19	170.50	176.19	170.50	176.19
II.B.2.	Evaporation (ac-ft)	25.54	25.54	25.54	70.41	88.30	100.52	110.94	87.16	55.92	38.26	25.54	25.54
Net Change in Reservoir Volume (ac-ft)		(21.92)	(4.88)	50.37	(6.02)	0.08	(29.42)	6.72	(0.67)	(6.55)	(14.16)	14.99	12.40

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	**887**	886.91	886.89	887.10	887.07	887.07	886.95	886.98	886.98	886.95	886.89	886.95
Reservoir Volume	16,835	16,813	16,808	16,859	16,853	16,853	16,823	16,830	16,829	16,823	16,809	16,824
At End of Month												
Net Change in Volume	-22	-5	50	-6	0	-29	7	-1	-7	-14	15	12
Reservoir Volume	16,813	16,808	16,859	16,853	16,853	16,823	16,830	16,829	16,823	16,809	16,824	16,836
Approx. Reservoir Water Level	886.91	886.89	887.10	887.07	887.07	886.95	886.98	886.98	886.95	886.89	886.95	**887.00**
low elevation of interpolation	886	886	887	887	887	886	886	886	886	886	886	887
high elevation of interpolation	887	887	888	888	888	887	887	887	887	887	887	888
low storage of interpolation	16595	16595	16835	16835	16835	16595	16595	16595	16595	16595	16595	16835
high storage of interpolation	16835	16835	17078	17078	17078	16835	16835	16835	16835	16835	16835	17078

II.C. Summary of Analysis

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	**887.00**	886.91	886.89	887.10	887.07	887.07	886.95	886.98	886.98	886.95	886.89	886.95
end of month reservoir level	886.91	886.89	887.10	887.07	887.07	886.95	886.98	886.98	886.95	886.89	886.95	**887.00**

Minimum Reservoir Level During the Year	886.89	ft, msl	*March*
Maximum Reservoir Level During the Year	887.10	ft, msl	*Apr*
Fluctuation in reservoir Level	0.21	ft	

III. Wet Year Analysis: Above-Average Precipitation with Below-Average Evaporation

Current Reservoir Discharge Capabilities

NORMAL RESERVOIR OPERATING LEVEL	**887**	**ft, msl**	*flowchart*
SIPHON DISCHARGE CAPACITY	**1300**	**gpm**	*capacity of existing siphon*
WET YEAR ANNUAL PRECIPITATION	**48.78**	**inches**	*rainfall_parkersburg_wso*
PROBABILITY OF EXCEEDANCE	**85**	**percent**	

III.A. Inflows

III.A.1. Direct Precipitation onto Reservoir Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adj. Maximum Monthly Rainfall	2.94	3.15	4.51	4.22	4.77	4.36	5.35	4.73	3.90	3.41	3.71	3.71
Average Reservoir Area (acres)	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
(reservoir level Normal Operating Level)												
Inflow Volume (ac-ft)	59.12	63.47	90.85	84.96	95.97	87.78	107.74	95.20	78.56	68.58	74.73	74.73

III.A.2. Runoff from Upland Areas

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adj. Maximum Monthly Runoff	0.97	1.12	2.14	1.91	2.35	2.02	2.83	2.32	1.67	1.30	1.52	1.52
Average Upland Area (acres)	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5
Inflow Volume (ac-ft)	31.35	36.07	68.97	61.52	75.57	65.06	91.14	74.57	53.64	41.84	49.02	49.02

III.A.3. Runoff from Ash Site (Sediment Pond Effluent System)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adj. Maximum Monthly Runoff	0.87	1.01	1.98	1.76	2.18	1.87	2.65	2.15	1.53	1.18	1.39	1.39
Average Disposal Area (acres)	204	204	204	204	204	204	204	204	204	204	204	204
Inflow Volume (ac-ft)	14.77	17.12	33.72	29.94	37.08	31.73	45.04	36.57	25.95	20.01	23.62	23.62

NOTE: Runoff from the ash disposal site drains to the sediment ponds. Outflow from the ponds is directed to the Sediment Pond Effluent System lift station, and then pumped to the reservoir. The design capacity of the pumps (2 in operation, 1 in reserve) is about 1150 gpm.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Rainfall-Runoff Inflow Volume (ac-ft)	105.23	116.66	193.53	176.42	208.62	184.57	243.92	206.34	158.15	130.43	147.36	147.36

III.A.4. Slurry Flows

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	600	600	600	600	600	600	600	600	600	600	600	600
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Inflow Volume (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20

III.A.5. Sediment Pond Base Flow

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	100	100	100	100	100	100	100	100	100	100	100	100
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inflow Volume (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70

III. Wet Year Analysis: Above-Average Precipitation with Below-Average Evaporation

III.B. Outflows

III.B.1. Siphon Discharge (Current Design Capacity)

Use the Net Siphon Discharge, which equals to measured siphon line flow less the Station withdrawal for mix tank uses

Net Siphon Discharge Capacity = 1300 gpm

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Discharge Volume (ac-ft)	178.11	160.87	178.11	172.36	178.11	172.36	178.11	178.11	172.36	178.11	172.36	178.11

III.B.2. Evaporation (Below-Average Monthly Evaporation ("Lake")
values based on data from U.S. Army Corps of Engineers, Huntington District, WV, for Clarksburg WV, 1948-1964.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
evaporation (inches)	0.00	0.00	0.00	3.50	4.39	5.00	5.51	4.33	2.78	1.90	0.00	0.00
Reservoir Area (acres)	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
Evaporative Loss (ac-ft)	0.00	0.00	0.00	70.41	88.30	100.52	110.94	87.16	55.92	38.26	0.00	0.00

III.C. Mass Balance of Inflows and Outflows

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
III.A.	Inflows to Reservoir	**201.13**	**203.28**	**289.44**	**269.23**	**304.52**	**277.38**	**339.82**	**302.25**	**250.96**	**226.33**	**240.17**	**243.27**
III.A.1.	Direct Rainfall (ac-ft)	59.12	63.47	90.85	84.96	95.97	87.78	107.74	95.20	78.56	68.58	74.73	74.73
III.A.2.a.	Upland Areas (ac-ft)	31.35	36.07	68.97	61.52	75.57	65.06	91.14	74.57	53.64	41.84	49.02	49.02
III.A.2.b	Ash Disposal Area (ac-ft)	14.77	17.12	33.72	29.94	37.08	31.73	45.04	36.57	25.95	20.01	23.62	23.62
III.A.3.	Slurry Disposal (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20
III.A.4	Sediment Pond (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70
III.B.	Outflows from Reservoir	**178.11**	**160.87**	**178.11**	**242.77**	**266.40**	**272.88**	**289.04**	**265.27**	**228.28**	**216.37**	**172.36**	**178.11**
III.B.1.	Siphon (Net, ac-ft)	178.11	160.87	178.11	172.36	178.11	172.36	178.11	178.11	172.36	178.11	172.36	178.11
III.B.2.	Evaporation (ac-ft)	0.00	0.00	0.00	70.41	88.30	100.52	110.94	87.16	55.92	38.26	0.00	0.00
	Net Change in Reservoir Volume (ac-ft)	23.03	42.41	111.33	26.46	38.12	4.50	50.78	36.98	22.68	9.97	67.81	65.16

BEGINNING NORMAL RESERVOIR OPERATING LEVEL **887** **ft, msl** **AS OF 1 JANUARY OF FIRST YEAR OF ANALYSIS**
Beginning Reservoir Volume at Normal Operating Water Level 16835 ac-ft

III. Wet Year Analysis: Above-Average Precipitation with Below-Average Evaporation

THEN AVERAGE PREDICTED RESERVOIR LEVEL AT THE END OF EACH SUCCEEDING MONTH WOULD BE

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	**887**	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77
Reservoir Volume	16,835	16,858	16,900	17,012	17,038	17,076	17,081	17,131	17,168	17,191	17,201	17,269
At End of Month												
Reservoir Volume	16,858	16,900	17,012	17,038	17,076	17,081	17,131	17,168	17,191	17,201	17,269	17,334
Approx. Reservoir Water Level	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77	**889.03**
low elevation of interpolation	887	887	887	887	887	888	888	888	888	888	888	889
high elevation of interpolation	888	888	888	888	888	889	889	889	889	889	889	890
low storage of interpolation	16835	16835	16835	16835	16835	17078	17078	17078	17078	17078	17078	17326
high storage of interpolation	17078	17078	17078	17078	17078	17326	17326	17326	17326	17326	17326	17578

III.D. Summary of Analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	**887.00**	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77
end of month reservoir level	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77	889.03
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Minimum Reservoir Level During the Year	887.00	ft, msl	*Jan*
Maximum Reservoir Level During the Year	889.03	ft, msl	*Dec*

The existing siphon cannot handle a "Wet Year".

IV. Minimum Required Total Reservoir Discharge for a "Wet Year"

What is the Minimum Total Reservoir Discharge Required to Maintain a Given Reservoir Level Over the Course of a Year with Above-Average Precipitation and Below-Average Evaporation?

Above-Average Precipitation is Set as the Average Annual Precipitation plus One (1) Standard Deviation.

The Probability that a year would have a total precipitation greater than this precipitation is about 15%.

Annual "Wet Year" Precipitation	**48.78**	**inches**
Probability of Exceedance	**16%**	
Number of Times Exceeded Since 1970	**3**	

IV.A. Estimated Minimum Discharge and Discharge Volume

Trial & Error Solution: Assume a Reservoir Discharge Rate, compute resulting End-of-the-Year Reservoir Level, and compare to First-of-the-Year Reservoir Level.

First-of-the-Year Reservoir Level	**887**	**ft, msl**	*Assumed Starting Point for Analysis*
Required NET Total Reservoir Discharge Capacity	***1610***	**gpm**	*manually input this value until the "End-of-the-Year Reservoir Level"*
Average Monthly Discharged Volume	**213.46**	**ac-ft**	
End-of-the-Year Reservoir Level	**887.00**	**ft, msl**	*This value must equal the "First-of-the-Year Reservoir Level"*
Maximum Reservoir Level during the Year	**887.22**	**ft, msl**	

IV.B. Mass Balance of Inflows and Outflows

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Inflows to Reservoir	**201.13**	**203.28**	**289.44**	**269.23**	**304.52**	**277.38**	**339.82**	**302.25**	**250.96**	**226.33**	**240.17**	**243.27**
IV.A.	Direct Rainfall (ac-ft)	59.12	63.47	90.85	84.96	95.97	87.78	107.74	95.20	78.56	68.58	74.73	74.73
IV.A.2	Upland Areas (ac-ft)	31.35	36.07	68.97	61.52	75.57	65.06	91.14	74.57	53.64	41.84	49.02	49.02
IV.A.2.a.	Ash Disposal Area (ac-ft)	14.77	17.12	33.72	29.94	37.08	31.73	45.04	36.57	25.95	20.01	23.62	23.62
IV.A.2.b.	Slurry Disposal (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20
IV.A.3.	Sediment Pond (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70
IV.A.4	Outflows from Reservoir	**220.58**	**199.23**	**220.58**	**283.87**	**308.87**	**313.98**	**331.51**	**307.74**	**269.38**	**258.84**	**213.46**	**220.58**
IV.B.	Siphon (Net, ac-ft)	220.58	199.23	220.58	213.46	220.58	213.46	220.58	220.58	213.46	220.58	213.46	220.58
IV.B.1.	Evaporation (ac-ft)	0.00	0.00	0.00	70.41	88.30	100.52	110.94	87.16	55.92	38.26	0.00	0.00
IV.B.2.													
	Net Change in Reservoir Volume (ac-ft)	(19.44)	4.05	68.86	(14.64)	(4.35)	(36.60)	8.31	(5.49)	(18.42)	(32.51)	26.71	22.69

NORMAL RESERVOIR OPERATING LEVEL	887	ft, msl	AS OF 31 DEC OF THE PRECEDING YEAR
Reservoir Volume at Assumed Reservoir Water Level	16835	ac-ft	

IV. Minimum Required Total Reservoir Discharge for a "Wet Year"

THEN THE PREDICTED RESERVOIR LEVEL AT THE END OF EACH SUCCEEDING MONTH WOULD BE AS GIVEN BELOW:

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	**887.00**	886.92	886.94	887.22	887.16	887.14	886.99	887.03	887.00	886.93	886.79	886.90
Reservoir Volume	16,835	16,815	16,819	16,888	16,874	16,869	16,833	16,841	16,836	16,817	16,785	16,811
At End of Month												
Net Change in Volume (ac-ft)	-19	4	69	-15	-4	-37	8	-5	-18	-33	27	23
Reservoir Volume	16,815	16,819	16,888	16,874	16,869	16,833	16,841	16,836	16,817	16,785	16,811	16,834
Approx. Reservoir Water Level	886.92	886.94	887.22	887.16	887.14	886.99	887.03	887.00	886.93	886.79	886.90	**887.00**
low elevation of interpolation	886	886	887	887	887	886	887	887	886	886	886	886
high elevation of interpolation	887	887	888	888	888	887	888	888	887	887	887	887
low storage of interpolation	16595	16595	16835	16835	16835	16595	16835	16835	16595	16595	16595	16595
high storage of interpolation	16835	16835	17078	17078	17078	16835	17078	17078	16835	16835	16835	16835

IV.C. Summary of Analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	887.00	886.92	886.94	887.22	887.16	887.14	886.99	887.03	887.00	886.93	886.79	886.90
end of month reservoir level	886.92	886.94	887.22	887.16	887.14	886.99	887.03	887.00	886.93	886.79	886.90	887.00
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Minimum Reservoir Level During the Year	886.79	ft, msl	*Jan*
Maximum Reservoir Level During the Year	887.22	ft, msl	***Dec***

V. Sensitivity Analysis # 1:

What Reservoir Level Would Result for a "Wet Year" if the Total Reservoir Discharge is Based on an "Average Year"?

NORMAL RESERVOIR OPERATING LEVEL 887 ft, msl

IV.A. Estimated Minimum Discharge and Discharge Volume

Trial & Error Solution: Assume a Reservoir Discharge Rate, compute resulting End-of-the-Year Reservoir Level, and compare to First-of-the-Year Reservoir Level.

First-of-the-Year Reservoir Level	887	ft, msl	
Required Reservoir Discharge for Average Year	***1286***	gpm	*II.A.*

IV.A. Estimated Minimum Discharge and Discharge Volume

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IV.A.	Inflows to Reservoir	**201.13**	**203.28**	**289.44**	**269.23**	**304.52**	**277.38**	**339.82**	**302.25**	**250.96**	**226.33**	**240.17**	**243.27**
IV.A.2	Direct Rainfall (ac-ft)	59.12	63.47	90.85	84.96	95.97	87.78	107.74	95.20	78.56	68.58	74.73	74.73
IV.A.2.a.	Upland Areas (ac-ft)	31.35	36.07	68.97	61.52	75.57	65.06	91.14	74.57	53.64	41.84	49.02	49.02
IV.A.2.b.	Ash Disposal Area (ac-ft)	14.77	17.12	33.72	29.94	37.08	31.73	45.04	36.57	25.95	20.01	23.62	23.62
IV.A.3.	Slurry Disposal (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20
IV.A.4	Sediment Pond (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70
IV.B.	Outflows from Reservoir	**176.19**	**159.14**	**176.19**	**240.91**	**264.48**	**271.03**	**287.12**	**263.35**	**226.42**	**214.45**	**170.50**	**176.19**
IV.B.1.	Siphon (Net, ac-ft)	176.19	159.14	176.19	170.50	176.19	170.50	176.19	176.19	170.50	176.19	170.50	176.19
IV.B.2.	Evaporation (ac-ft)	0.00	0.00	0.00	70.41	88.30	100.52	110.94	87.16	55.92	38.26	0.00	0.00
Net Change in Reservoir Volume (ac-ft)		24.95	44.14	113.25	28.32	40.04	6.36	52.70	38.89	24.53	11.88	69.67	67.08

BEGINNING NORMAL RESERVOIR OPERATING LEVEL	**887**	**ft, msl**	AS OF 1 JANUARY OF FIRST YEAR OF ANALYSIS
Beginning Reservoir Volume at Normal Operating Water Level	16835	ac-ft	

THEN THE PREDICTED RESERVOIR LEVEL AT THE END OF EACH SUCCEEDING MONTH WOULD BE AS GIVEN BELOW:

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	**887**	887.10	887.28	887.75	887.87	888.03	888.06	888.27	888.43	888.52	888.57	888.85
Reservoir Volume	16835	16860	16904	17017	17045	17086	17092	17145	17183	17208	17220	17290
At End of Month												
Net Change in Volume	25	44	113	28	40	6	53	39	25	12	70	67
Reservoir Volume	16860	16904	17017	17045	17086	17092	17145	17183	17208	17220	17290	17357
Approx. Reservoir Water Level	887.10	887.28	887.75	887.87	888.03	888.06	888.27	888.43	888.52	888.57	888.85	889.12
low elevation of interpolation	887	887	887	887	888	888	888	888	888	888	888	889
high elevation of interpolation	888	888	888	888	889	889	889	889	889	889	889	890
low storage of interpolation	16835	16835	16835	16835	17078	17078	17078	17078	17078	17078	17078	17326
high storage of interpolation	17078	17078	17078	17078	17326	17326	17326	17326	17326	17326	17326	17578
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	887.00	887.10	887.28	887.75	887.87	888.03	888.06	888.27	888.43	888.52	888.57	888.85
end of month reservoir level	887.10	887.28	887.75	887.87	888.03	888.06	888.27	888.43	888.52	888.57	888.85	889.12

VI. Very Wet Year Analysis: More-than-Above Average Precipitation with Below-Average Evaporation

What Reservoir Level would result for a "Very Wet Year" under Current Siphon Discharge Conditions?

A "Very Wet Year" is defined as a year in which the Annual Precipitation that occurs has a 10% or less probability of being exceeded.

The precipitation that would have a 10% or less probability of occurring corresponds approximately to the Average Annual Precipitation plus One-and-One-Half (1-1/2) Standard Deviation.

THIS IS THE PROPOSED DESIGN CONDITION

NORMAL RESERVOIR OPERATING LEVEL 887 ft, msl

VI.D. Estimated Minimum Discharge and Discharge Volume

VI.A.1. Direct Precipitation on the Reservoir

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adj. Maximum Monthly Rainfall	3.15	3.38	4.84	4.52	5.11	4.67	5.74	5.07	4.18	3.65	3.98	3.98
Average Reservoir Area (acres)	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
(reservoir level Normal Operating Level)												
Inflow Volume (ac-ft)	63.34	68.00	97.34	91.03	102.82	94.05	115.43	102.00	84.18	73.48	80.06	80.06

VI.A.2. Runoff from Upland Areas

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adj. Maximum Monthly Runoff	1.12	1.28	2.40	2.15	2.63	2.27	3.15	2.59	1.88	1.48	1.72	1.72
Average Upland Area (acres)	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5	386.5
Inflow Volume (ac-ft)	35.93	41.17	77.35	69.20	84.57	73.08	101.57	83.48	60.54	47.55	55.46	55.46

VI.A.3 Runoff from Ash Disposal Site (Sediment Pond Effluent System)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adj. Maximum Monthly Runoff	1.00	1.16	2.23	1.99	2.45	2.11	2.96	2.42	1.73	1.35	1.58	1.58
Average Disposal Area (acres)	204	204	204	204	204	204	204	204	204	204	204	204
Inflow Volume (ac-ft)	17.05	19.67	37.99	33.84	41.68	35.81	50.39	41.12	29.44	22.87	26.87	26.87

NOTE: Runoff from the ash disposal site drains to the sediment ponds. Outflow from the ponds is directed to the Sediment Pond Effluent System lift station, and then pumped to the reservoir. The design capacity of the pumps (2 in operation, 1 in reserve) is about 1150 gpm.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Rainfall-Runoff Inflow Volume (ac-ft)	116.32	128.84	212.68	194.07	229.07	202.94	267.39	226.60	174.16	143.90	162.40	162.40

VI.A.4 Slurry Flows

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	600	600	600	600	600	600	600	600	600	600	600	600
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Inflow Volume (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20

VI. Very Wet Year Analysis: More-than-Above Average Precipitation with Below-Average Evaporation

VI.A.5 Sediment Pond Underdrain Flows

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	100	100	100	100	100	100	100	100	100	100	100	100
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Inflow Volume (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70

VI.B. Outflows

VI.B.1 Siphon Discharge (Current Discharge Capacity)

Net Siphon Discharge Capacity = 1300 gpm 100 percent of the time

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly Value (gpm)	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
Percent of Time in Operation	100	100	100	100	100	100	100	100	100	100	100	100
Discharge Volume (ac-ft)	178.11	160.87	178.11	172.36	178.11	172.36	178.11	178.11	172.36	178.11	172.36	178.11

VI.B.2 Evaporation (Below-Average)

values based on data from U.S. Army Corps of Engineers, Huntington District, WV, for Clarksburg WV, 1948-1964.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
evaporation (inches)	0.00	0.00	0.00	3.50	4.39	5.00	5.51	4.33	2.78	1.90		
Reservoir Area (acres)	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
Evaporative Loss (ac-ft)	0.00	0.00	0.00	70.41	88.30	100.52	110.94	87.16	55.92	38.26	0.00	0.00

III.C. Mass Balance of Inflows and Outflows

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
III.A.	Inflows to Reservoir	212.22	215.46	308.59	286.88	324.98	295.75	363.30	322.51	266.97	239.80	255.20	258.30
III.A.1.	Direct Rainfall (ac-ft)	63.34	68.00	97.34	91.03	102.82	94.05	115.43	102.00	84.18	73.48	80.06	80.06
III.A.2.a.	Upland Areas (ac-ft)	35.93	41.17	77.35	69.20	84.57	73.08	101.57	83.48	60.54	47.55	55.46	55.46
III.A.2.b	Ash Disposal Area (ac-ft)	17.05	19.67	37.99	33.84	41.68	35.81	50.39	41.12	29.44	22.87	26.87	26.87
III.A.3.	Slurry Disposal (ac-ft)	82.20	74.25	82.20	79.55	82.20	79.55	82.20	82.20	79.55	82.20	79.55	82.20
III.A.4	Sediment Pond (ac-ft)	13.70	12.37	13.70	13.26	13.70	13.26	13.70	13.70	13.26	13.70	13.26	13.70
III.B.	Outflows from Reservoir	178.11	160.87	178.11	242.77	266.40	272.88	289.04	265.27	228.28	216.37	172.36	178.11
III.B.1.	Siphon (Net, ac-ft)	178.11	160.87	178.11	172.36	178.11	172.36	178.11	178.11	172.36	178.11	172.36	178.11
III.B.2.	Evaporation (ac-ft)	0.00	0.00	0.00	70.41	88.30	100.52	110.94	87.16	55.92	38.26	0.00	0.00
	Net Change in Reservoir Volume (ac-ft)	34.11	54.59	130.48	44.11	58.58	22.86	74.26	57.24	38.69	23.44	82.84	80.19

BEGINNING NORMAL RESERVOIR OPERATING LEVEL 887 ft, msl AS OF 1 JANUARY OF FIRST YEAR OF ANALYSIS
Beginning Reservoir Volume at Normal Operating Water Level 16835 ac-ft

VI. Very Wet Year Analysis: More-than-Above Average Precipitation with Below-Average Evaporation
THEN AVERAGE PREDICTED RESERVOIR LEVEL AT THE END OF EACH SUCCEEDING MONTH WOULD BE

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	887.00	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77
Reservoir Volume	16835	16858	16900	17012	17038	17076	17081	17131	17168	17191	17201	17269
At End of Month												
Net Change in Volume (ac-ft)	34	55	130	44	59	23	74	57	39	23	83	80
Reservoir Volume	16869	16912	17031	17056	17097	17099	17155	17189	17207	17215	17284	17349
Approx. Reservoir Water Level	887.14	887.32	887.81	887.91	888.07	888.08	888.31	888.45	888.52	888.55	888.83	889.09
low elevation of interpolation	887	887	887	887	888	888	888	888	888	888	888	889
high elevation of interpolation	888	888	888	888	889	889	889	889	889	889	889	890
low storage of interpolation	16835	16835	16835	16835	17078	17078	17078	17078	17078	17078	17078	17326
high storage of interpolation	17078	17078	17078	17078	17326	17326	17326	17326	17326	17326	17326	17578

III.D. Summary of Analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	887.00	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77
end of month reservoir level	887.14	887.32	887.81	887.91	888.07	888.08	888.31	888.45	888.52	888.55	888.83	889.09
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Minimum Reservoir Level During the Year	887.00	ft, msl	*Jan*
Maximum Reservoir Level During the Year	889.09	ft, msl	*Dec*

VII. Minimum Required Total Reservoir Discharge for a "Very Wet Year"

What is the Minimum Total Reservoir Discharge Required to Maintain a Given Reservoir Level Over the Course of a Year with More-Than-Above-Average Precipitation and Below-Average Evaporation?
The probability that this amount of precipitation would occur is approximately ten (10) percent or less.
THIS CASE IS THE BASIS FOR DESIGN OF THE IMPROVED SIPHON WITH THE EFFLUENT GRAVITY PIPELINE

VI.A. Estimated Minimum Siphon Discharge and Discharge Volume

Probability of Exceedance is	**7%**
Number of Times Exceeded Since 1970	**3**

Trial & Error Solution: Assume a Reservoir Discharge Rate, compute resulting End-of-the-Year Reservoir Level, and compare to First-of-the-Year Reservoir Level.

First-of-the-Year Reservoir Level	**887**	**ft, msl**	*Assumed Starting Point for Analysis*
Required NET Total Reservoir Discharge Capacity	***1735***	**gpm**	*manually input this value until the "End-of-the-Year Reservoir Level"*
Average Monthly Discharged Volume	**230.03**	**ac-ft**	
End-of-the-Year Reservoir Level	**887.00**	**ft, msl**	*This value must equal the "First-of-the-Year Reservoir Level"*
Maximum Reservoir Level during the Year	**887.19**	**ft, msl**	

IV.B. Mass Balance of Inflows and Outflows

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Inflows to Reservoir	**212.22**	**215.46**	**308.59**	**286.88**	**324.98**	**295.75**	**363.30**	**322.51**	**266.97**	**239.80**	**255.20**	**258.30**
IV.A.	Direct Rainfall (ac-ft)	**63.34**	**68.00**	**97.34**	**91.03**	**102.82**	**94.05**	**115.43**	**102.00**	**84.18**	**73.48**	**80.06**	**80.06**
IV.A.2	Upland Areas (ac-ft)	**35.93**	**41.17**	**77.35**	**69.20**	**84.57**	**73.08**	**101.57**	**83.48**	**60.54**	**47.55**	**55.46**	**55.46**
IV.A.2.a.	Ash Disposal Area (ac-ft)	**17.05**	**19.67**	**37.99**	**33.84**	**41.68**	**35.81**	**50.39**	**41.12**	**29.44**	**22.87**	**26.87**	**26.87**
IV.A.2.b.	Slurry Disposal (ac-ft)	**82.20**	**74.25**	**82.20**	**79.55**	**82.20**	**79.55**	**82.20**	**82.20**	**79.55**	**82.20**	**79.55**	**82.20**
IV.A.3.	Sediment Pond (ac-ft)	**13.70**	**12.37**	**13.70**	**13.26**	**13.70**	**13.26**	**13.70**	**13.70**	**13.26**	**13.70**	**13.26**	**13.70**
IV.A.4	Outflows from Reservoir	**237.70**	**214.70**	**237.70**	**300.45**	**326.00**	**330.56**	**348.64**	**324.87**	**285.96**	**275.96**	**230.03**	**237.70**
IV.B.	Siphon (Net, ac-ft)	**237.70**	**214.70**	**237.70**	**230.03**	**237.70**	**230.03**	**237.70**	**237.70**	**230.03**	**237.70**	**230.03**	**237.70**
IV.B.1.	Evaporation (ac-ft)	**0.00**	**0.00**	**0.00**	**70.41**	**88.30**	**100.52**	**110.94**	**87.16**	**55.92**	**38.26**	**0.00**	**0.00**
IV.B.2.	Net Change in Reservoir Volume (ac-ft)	**-25.48**	**0.76**	**70.88**	**-13.57**	**-1.02**	**-34.81**	**14.66**	**-2.36**	**-18.99**	**-36.16**	**25.17**	**20.60**

NORMAL RESERVOIR OPERATING LEVEL	887	ft, msl	AS OF 31 DEC OF THE PRECEDING YEAR
Reservoir Volume at Assumed Reservoir Water Level	16835	ac-ft	

VII. Minimum Required Total Reservoir Discharge for a "Very Wet Year"
THEN THE PREDICTED RESERVOIR LEVEL AT THE END OF EACH SUCCEEDING MONTH WOULD BE AS GIVEN BELOW:

Year 1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
At Start of Month												
Reservoir Water Level	**887**	886.89	886.90	887.19	887.13	887.13	886.99	887.05	887.04	886.96	886.81	886.91
Reservoir Volume	16,835	16,809	16,810	16,881	16,867	16,866	16,832	16,846	16,844	16,825	16,789	16,814
At End of Month												
Net Change in Volume (ac-ft)	-25	1	71	-14	-1	-35	15	-2	-19	-36	25	21
Reservoir Volume	16,809	16,810	16,881	16,867	16,866	16,832	16,846	16,844	16,825	16,789	16,814	16,834
Approx. Reservoir Water Level	886.89	886.90	887.19	887.13	887.13	886.99	887.05	887.04	886.96	886.81	886.91	**887.00**
low elevation of interpolation	886	886	887	887	887	886	887	887	886	886	886	886
high elevation of interpolation	887	887	888	888	888	887	888	888	887	887	887	887
low storage of interpolation	16595	16595	16835	16835	16835	16595	16835	16835	16595	16595	16595	16595
high storage of interpolation	16835	16835	17078	17078	17078	16835	17078	17078	16835	16835	16835	16835

IV.C. Summary of Analysis

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
first of month reservoir level	887.00	886.89	886.90	887.19	887.13	887.13	886.99	887.05	887.04	886.96	886.81	886.91
end of month reservoir level	886.89	886.90	887.19	887.13	887.13	886.99	887.05	887.04	886.96	886.81	886.91	887.00
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Minimum Reservoir Level During the Year	886.81	ft, msl	*Jan*
Maximum Reservoir Level During the Year	887.19	ft, msl	***Dec***

IX. Evaluate Fluctuation of the Reservoir during the Course of the Year Analyzed

Maximum Heights and Fluctuations of Reservoir Levels for Analyzed Conditions

Maximum Normal Pool Level in Reservoir	**888.45**	ft, msl	spreadsheet h&h.xls, worksheet reservoir_level.
Normal Operating Level in Reservoir	**887.00**	ft, msl	

Analyzed Condition	Total Reservoir Discharge (gpm)	Maximum Reservoir Level (ft, msl)	Annual Fluctuation in Reservoir Level (ft)
Average Year			
Current Siphon	1300	887.07	0.26
Minimum Required Reservoir Discharge	1286	887.10	0.21
Wet Year			
Current Siphon	1300	889.03	2.03
Minimum Required Reservoir Discharge	1610	887.22	0.43
Very Wet Year			
Current Siphon	1300	889.09	2.09
Minimum Required Reservoir Discharge	1735	887.19	0.38

X. Plot of Monthly Reservoir Elevation Performance for Selected Discharge Rates

Average Year, 1300 gpm siphon

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
887.00	886.90	886.87	887.07	887.04	887.03	886.90	886.92	886.91	886.88	886.81	886.87	886.91

Average Year, 1286 gpm siphon

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
887.00	886.91	886.89	887.10	887.07	887.07	886.95	886.98	886.98	886.95	886.89	886.95	887.00

Wet Year, 1300 gpm siphon

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
887.00	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77	889.03

Wet Year, 1610 gpm siphon

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
887.00	886.92	886.94	887.22	887.16	887.14	886.99	887.03	887.00	886.93	886.79	886.90	887.00

Very Wet Year 1300 gpm siphon

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
887.00	887.09	887.27	887.73	887.84	887.99	888.01	888.22	888.36	888.46	888.50	888.77	889.09

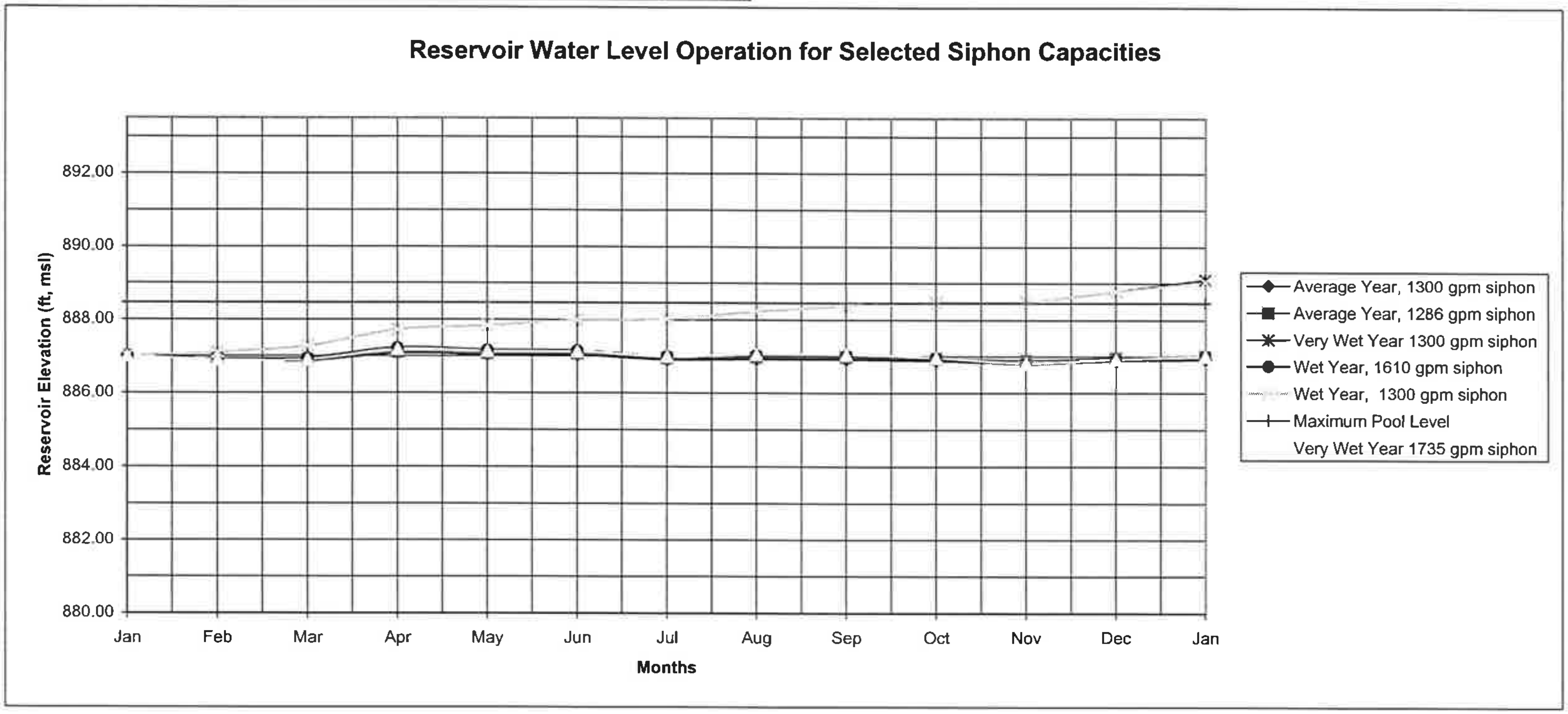
Very Wet Year 1735 gpm siphon

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
887.00	886.89	886.90	887.19	887.13	887.13	886.99	887.05	887.04	886.96	886.81	886.91	887.00

Maximum Pool Level

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
888.45	888.45	888.45	888.45	888.45	888.45	888.45	888.45	888.45	888.45	888.45	888.45	888.45

NORMAL RESERVOIR OPERATING LEVEL	887 ft, msl



Note: user must manually change custom footer to indicate Normal Operating Level of Reservoir.

APPENDIX C

CALCULATIONS FOR THE PROPOSED
IMPROVED SIPHON EFFLUENT GRAVITY PIPELINE DESIGN

APPENDIX C

Table of Contents

I. Objective

Design of a Proposed Pipeline, to convey water from the Reservoir to the Ohio River. The pipeline is to operate as a siphon, similar to the existing siphon pipeline. The pipeline would incorporate the hdpe pipe portion of the existing siphon line, with a new hdpe pipe installed from the downstream end of the existing pipe to a new outfall at the Ohio River. The outfall segment of the pipeline would be ductile iron pipe. The discharge of the pipeline may be either to the Ohio River or to a treatment plant, depending upon technical feasilibility and regulatory acceptance. The pipeline would operate as a siphon to the treatment plant, if one is required.

II. Design Parameters & Constraints

The siphon must be capable of handling, at a minimum, the design discharge withdrawal rate that has been determined for maintenance of the reservoir water level with the desired operating range.

The piping must be capable of withstanding the anticipated internal and surge pressures, to include potential water hammer pressures.

It is desired that the new siphon pipeline be designed and constructed so as to be positively-draining (no high or low spots in the line) except for the siphon crest. This may require passing surface drainage structures over or under the Proposed Pipeline, and/or the placement of fill over the pipeline for frost protection.

II. Geometry

Horizontal and vertical geometry of the Proposed New Siphon Pipeline is given on worksheet "geometry" of this spreadsheet file. The geometry is obtained from GAI Drawing 1999-170-51-F1003, dated 22 January 2002, by MAM. Revised 5 March 2002

III. Layout

Based on the geometry, alignment and the anticipated hydraulic features of the Proposed New Siphon Pipeline, a hydraulic schematic is developed, from which various hydraulic features of the pipeline can be identified and tabulated.

IV. Method of Analysis

The Energy Equation (Bernoulli Equation) is used to calculated headlosses in the proposed pipeline, and thereby estimate hydraulic capacity and pipe size. The Energy Equation is applied in a downstream direction, starting with the water level in the reservoir. The energy and hydraulic grade elevations at selected points along the pipeline are then computed. The hydraulic capacity of the pipeline is based on maintaining the hydraulic grade line above the crown of the pipeline, or above the river level, whichever is the more critical.

The hydraulic analysis is presented in worksheet "hyd_anal_*_*" in this spreadsheet file. "*" indicates either "des" (design) or "max" (maximum hydraulic capacity), and nominal pipe size "12" (12 inches) or "14" (14 inches).

V. Pipe Design

Based on the predicted hydraulic conditions, the class of pipe for the proposed pipeline is determined. Three conditions are analyzed. The first condition is when the valve is closed at the downstream end, and a static head exists in the pipeline. The second condition is when the pipeline is operating under design and under maximum flow conditions. The third condition is for waterhammer, assuming a valve is shut rapidly. The Class of pipe (SDR for hdpe, and pressure class for ductile iron) required to withstand the most critical of these conditions, if considered practical, is determined.

Under any scenario, controls should be placed on the rate at which flow control ("throttle") valves can operate, to reduce surge pressures and prevent water hammer.

Allegheny Energy Supply
Pleasants Power Station
McElroy's Run Disposal Facility

Reservoir Management Study
New Siphon Line Design
Worksheet "GEOMETRY"

GAI Project 1999-170-51
KLF 10Jan2002

Summary of Geometry
Proposed Siphon Pipeline

Point	Description	Northing	Easting	Length of Pipeline between Points (ft)	Stationing Hundreds (ft)	Stationing Ones (ft)	Length by Stationing (ft)	Ground Elevation (ft, msl)	Invert Elevation of pipe (ft, msl)	Computed Slope of Pipeline (ft/ft)
0	intake in reservoir	319500	1466700					881	877	
				702.14						0.0014
1	headwall connection at dam	319370	1466010					881	876	
				128.55						-0.0389
2	crest at siphon vault	319400	1465885					900	881	
				1054.34						0.0152
3	Pigcatcher Road slope break	319540	1464840					870	865	
				785.06						0.1847
4	Ash Haul Road slope break	319875	1464130					725	720	
				64.23						0.0654
5	PT-101 of new siphon route & connection w/ extg line	**319891.82**	**1464068.01**		**0**	**0**		718	715.80	
				54.63			54.63			0.1333
6	PT-102	**319932.00**	**1464031.00**		**0**	**54.63**		713	708.52	
				270.37			270.37			0.1912
7	PT-103	**320084.88**	**1463808.00**		**3**	**25.00**		662	656.82	
				200.05			201.05			0.1091
8	PT-104	**320198.00**	**1463643.00**		**5**	**26.05**		644	635.00	
				206.38			205.39			0.0120
9	PT-105	**320047.84**	**1463501.42**		**7**	**31.44**		641	632.52	
				274.70			274.70			0.0025
10	PT-106	**319985.00**	**1463234.00**		**10**	**6.14**		636	631.83	
				135.00			135.00			0.0024
11	PT-107	**319959.11**	**1463101.51**		**11**	**41.14**		637	631.50	
				99.77			98.95			0.0025
12	PT-108	**319926.89**	**1463007.09**		**12**	**40.09**		636	631.25	
				620.24			621.06			0.0025
13	PT-109	**320125.37**	**1462419.46**		**18**	**61.15**		626	629.70	
				200.26			200.26			0.0025
14	PT-110	**320119.64**	**1462219.28**		**20**	**61.41**		633	629.20	
				199.99			199.98			0.0025
15	PT-111	**320318.44**	**1462241.05**		**22**	**61.39**		636	628.70	
				185.07			185.07			0.0025
16	PT-112	**320503.44**	**1462246.05**		**24**	**46.46**		636	628.23	
	Route 2 Xing			139.94			139.94			0.0025
17	PT-113	**320623.44**	**1462174.05**		**25**	**86.40**		634	627.88	
				110.76			110.76			0.0043
18	PT-114	**320706.48**	**1462100.76**		**26**	**97.16**		634	627.40	
				198.12			198.11			0.0025
19	PT-115	**320841.48**	**1462245.76**		**28**	**95.27**		632	626.90	
				99.06			99.06			0.0273
20	PT-116	**320916.59**	**1462310.34**		**29**	**94.33**		630	624.20	
				159.85			159.85			0.0025
21	PT-117	**321025.40**	**1462427.44**		**31**	**54.18**		627	623.80	
				672.10			672.10			0.0025
22	PT-118 (bend at Eureka Road)	**321606.00**	**1462766.00**		**38**	**26.28**		631	622.12	
				161.79			161.79			0.0025
23	PT-119	**321766.00**	**1462742.00**		**39**	**88.07**		631	621.72	
				309.16			309.15			0.0025
24	PT-120	**322059.71**	**1462645.50**		**42**	**97.22**		634	620.94	
				212.59			212.60			0.0025
25	PT-121	**322259.29**	**1462572.27**		**45**	**9.82**		635	620.41	
				86.76			86.75			0.2007
26	PT-122	**322340.74**	**1462542.39**		**45**	**96.57**		605	603.00	
				275.23			275.43			0.0654
27	outfall in Ohio River	322600.00	1462450.00		**48**	**72**		585	585	
	total length of pipeline			7,331						

Summary of Pipeline Layout
Proposed Siphon Pipeline

Point	Description	Pipeline Segment	Type of Pipe (hdpe or duct. iron)	Length of Pipeline Segment (ft)	Entrance Condition	Exit Condition	# of Bends	# of Tees or Wyes	# of Shutoff Valves	# of Check Valves	# of Throttle Valves
0	intake in reservoir	**1**	**hdpe**	**702.14**	1	0	1	0	0	0	0
1	headwall connection at dam	**1**	**hdpe**	**128.55**	0	0	1	0	0	0	0
2	crest at siphon vault	**1**	**hdpe**	**1054.34**	0	0	4	0	0	0	0
3	Pigcatcher Road slope break	**1**	**hdpe**	**785.06**	0	0	1	0	0	0	0
4	Ash Haul Road slope break	**1**	**hdpe**	**64.23**	0	0	1	0	0	0	0
5	PT-101 of new siphon route & connection w/ extg line	**2**	**hdpe**	**54.63**	0	0	0	1	0	0	0
6	PT-102	**2**	**hdpe**	**270.37**	0	0	0	0	0	0	0
7	PT-103	**2**	**hdpe**	**200.05**	0	0	0	0	0	0	0
8	PT-104	**2**	**hdpe**	**206.38**	0	0	1	0	0	0	0
9	PT-105	**2**	**hdpe**	**274.70**	0	0	1	0	0	0	0
10	PT-106	**2**	**hdpe**	**135.00**	0	0	0	0	0	0	0
11	PT-107	**2**	**hdpe**	**99.77**	0	0	0	0	0	0	0
12	PT-108	**2**	**hdpe**	**620.24**	0	0	1	0	0	0	0
13	PT-109	**2**	**hdpe**	**200.26**	0	0	1	0	0	0	0
14	PT-110	**2**	**hdpe**	**199.99**	0	0	1	0	0	0	0
15	PT-111	**2**	**hdpe**	**185.07**	0	0	0	0	0	0	0
16	PT-112	**2**	**hdpe**	**139.94**	0	0	1	0	0	0	0
17	PT-113	**2**	**hdpe**	**110.76**	0	0	0	0	0	0	0
18	PT-114	**2**	**hdpe**	**198.12**	0	0	1	0	0	0	0
19	PT-115	**2**	**hdpe**	**99.06**	0	0	0	0	0	0	0
20	PT-116	**2**	**hdpe**	**159.85**	0	0	0	0	0	0	0
21	PT-117	**2**	**hdpe**	**672.10**	0	0	1	0	0	0	0
22	PT-118 (bend at Eureka Road)	**2**	**hdpe**	**161.79**	0	0	1	0	1	1	1
23	PT-119	**2**	**hdpe**	**309.16**	0	0	0	0	0	0	0
24	PT-120	**2**	**hdpe**	**212.59**	0	0	0	0	0	0	0
25	PT-121	**2**	**hdpe**	**86.76**	0	0	1	0	0	0	0
26	PT-122	**3**	**duct. iron**	**275.23**	0	1	1	0	0	0	0
27	outfall in Ohio River										
	subtotals				1	1	19	1	1	1	1

pipeline segment refers to (1) hdpe pipe portion of existing siphon line
(2) hdpe pipe portion of proposed new siphon line
(3) ductile iron pipe portion of proposed new siphon line

Headloss Coefficients for Pipeline, and various fittings

Sudden Expansions											
A1/A2	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
k	1	0.81	0.64	0.49	0.36	0.25	0.16	0.09	0.04	0.01	0

k is applied to the velocity head for the smaller diameter of the pipes (the A1 pipe) k v_1^2/2g

For entrance of a pipe into a reservoir or manhole, use 1

Sudden Contractions											
A2/A1	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
k	0.5	0.48	0.45	0.41	0.36	0.29	0.21	0.13	0.07	0.01	0

k is applied to the velocity head for the smaller diameter of the pipes (the A2 pipe) k v_2^2/2g

For exit from a manhole or pond to a pipe, use 0.5

Conical Diffusers						*Rouse, p. 421*
angle of cone	0	20	30	45	60	
k for D2/D1 = 1.5	0.2	0.4	0.7	1.05	1.2	
k for D2/D1 = 3	0.2	0.4	0.65	0.87	1.03	

k is applied to the square of the difference of the two velocities k (v_1 - v_2)^2/2g

Valves					*Rouse, p. 421*
Gate Valve					
% open	25	50	75	100	
k	24	5.6	1.15	0.19	

Check Valve (Swing), fully open 2.5

Bends, 90 degrees		*Rouse, p. 421*
standard sweep	0.9	
medium-sweep	0.75	
long-sweep	0.6	

Ductile Iron Pipe

from DIPRA, "Ductile Iron Pipe"

Nominal Diameter (inches)	Outside Diameter (inches)	Nominal Thickness and Inside Diameter (inches) for Selected Pressure Classes			
		PC = 350		PC = 300	
		t (inch)	ID (inch)	t (inch)	ID (inch)
3	3.96	0.25	3.46	---	---
4	4.8	0.25	4.3	---	---
6	6.9	0.25	6.4	---	---
8	9.05	0.25	8.55	---	---
10	11.1	0.26	10.58	---	---
12	13.2	0.28	12.64	---	---
14	15.3	0.31	14.68	0.3	14.7
16	17.4	0.34	16.72	0.32	16.76
18	19.5	0.36	18.78	0.34	18.82
20	21.6	0.38	20.84	0.36	20.88
24	25.8	0.43	24.94	0.4	25
30	32	0.49	31.02	0.45	31.1
36	38.3	0.56	37.18	0.51	37.28
42	44.5	0.63	43.24	0.57	43.36
48	50.8	0.7	49.4	0.64	49.52
54	57.56	0.79	55.98	0.72	56.12
60	61.61	0.83	59.95	0.76	60.09
64	65.67	0.87	63.93	0.8	64.07

Cone Sleeve Flow Chart Cv

Red Valve Control Valve manufacturer literature

		Valve Opening (% of Total Travel)									
Valve Size	Port Size	10	20	30	40	50	60	70	8	90	100
8	6	62	156	311	427	653	810	948	1055	1173	1300
10	6	33.8	59.2	127	220	363	482	549	609	659	710
10	8	140	315	648	834	1047	1222	1547	1732	1805	2010
12	8	85.9	153	317	709	904	1034	1202	1333	1531	1680
12	10	171	355	726	1418	1923	2407	2824	3101	3420	3800
14	10	155	328	616	983	1349	1773	2273	2524	2755	2928
14	12	250	520	1063	2077	2816	3525	4136	4541	5008	5565

Solution Procedure For Valve Sizing

ASSUME a pressure drop across the valve (psi) for each Flow Condition

Minimum Flow Condition	Q =	1200	gpm
Design Flow Condition	Q =	1700	gpm
Maximum Flow Condition	Q =	3200	gpm

Calculate the Cv values for each flow condition

For a Control Valve whose Valve Size is equal to or smaller than the line size,
Find the Port Size whose Cv range encompasses the computed Cv values
within 20% and 80% travel (manufacturer recommendation).

Calculate the Maximum Allowable Pressure Drop (psi)

Compare the Maximum Allowable Pressure Drop to the Assumed Pressure Drop.

KLF

If Assumed Pressure Drop is less than the Maximum Allowable Pressure Drop,
then cavitation will not occur.

Nominal Pipe Diameter	12	inches
Inside Pipe Diameter	10.43	inches

Flow Conditions

Minimum Flow Condition	1200	gpm
Design Flow Condition	1700	gpm
Maximum Flow Condition	3200	gpm

ASSUMED PRESSURE DROP

Minimum Flow Condition	5	psi
Design Flow Condition	7	psi
Maximum Flow Condition	10	psi

Calculate the Cv values for the Flow Conditions

Cv = Q sqrt (G / dP)

Cv	flow in gpm of 60 degree water through the valve with 1 psi pressure drop, at a stated upstream pressure
Q	flow (gpm)
G	specific gravity of fluid
dP	drop in pressure across valve (psi)

Q	dP	Cv
gpm	psi	
1200	5	537
1700	7	643
3200	10	1012

The Range of Computed Cv values is 537 to 1012

From the manufacturer's (Red Valve) literature, bracketing the above Cv values between 20% and 80% opening, the following Control Valve appears applicable.

Valve Size	10	10
Port Size	6	8
Cv @ 20%	59.2	315
Cv @ 80%	609	1732

Calculate the Maximum Allowable Pressure Drop

dP_allowable = FL^2 * (P1 + 14.7 - rc * Pv)

Kcf

FL	Pressure Recovery Factor			
P1	Inlet Pressure (psi)			
14.7	conversion factor from psig to psia			
rc	Critical Pressure Ratio, =		0.94	
Pv	Vapor Pressure at Flow Temperature			
	ASSUME Temperature = 80 degrees F (to provide cushion against cavitation)			
	0.5	psi		
FL	10 x 6 Cone Sleeve Control Valve			0.7
FL	10 x 8 Cone Sleeve Control Valve			0.6
P1	34.13	ft	Energy Grade Elevation - Invert of Pipe Elevation at Valve Location	
	15	psi		
rc	0.94			
Pv	0.5	psi		

dP_allowable = 14
10

because dP assumed > dP allowable, cavitation may result.

Assume a less drop in pressure across the valve

KLC

The energy at any point in the system can be predicted using the Energy Equation (the general form of Bernoulli's Equation), assuming sufficient information is known about the pipe and the flow conditions.
For this analysis, it is assumed that the pipeline will flow full throughout its entire length. This assumption will be verified, and subsequent modifications will be made as appropriate.

For this analysis, a downstream approach is used. Starting with a known water level in the reservoir, the energy losses in the pipeline are then calculated. By comparing the resulting energy grade and hydraulic grade elevations with the pipeline profile, confirmation that the pipe does indeed flow full can be determined. If, at any point along the pipeline alignment, the hydraulic grade line dips below the crown of the pipe,then the pipe size may not be adequate to convey the flow, and a larger pipe size should be selected.

If, for a Selected Pipe Size (Nominal Diameter) and Flow, the computed Hydraulic Grade Line is above the crown of the pipe everywhere along the pipe, and is above the ground elevation at Point 118, where the proposed Control Valve Vault is to be located, then the Selected Pipe Size will be considered to be adequate to convey the flow.

This Worksheet computes flow conditions for the Design Reservoir Withdrawal Discharge Rate, for a given Pipe Type and Size.
The cells indicated in PINK require USER INPUT for the selection of the Pipe Type, Size, and Class, and of the Flow.
The worksheet automatically calculates the inside diameter of HDPE pipe, given the provided information, for pipe of 10 inches Nominal Diameter or larger. Smaller pipe sizes result in a warning to the USER.
The inside diameter for ductile iron pipe is obtained from a lookup table in the Worksheet "REF_INFO".
Pipe Segments "1" and "2" are reserved for HDPE pipe only. Pipe Segment "3" is reserved for Ductile Iron Pipe.

General Design Data

Reservoir Water Level	**881.00**	**ft, msl**	as of December 2001
Ohio River Water Level			
Normal Pool Level	**602.00**	**ft, msl**	

Pipe Design Data

The proposed pipeline is divided into three (3) segments, corresponding to (1) the hdpe pipe portion of the existing siphon line; (2) the proposed new hdpe portion of the new siphon line; and (3) the proposed new ductile iron portion of the new siphon line.

	segment 1		segment 2		segment 3	
Type of Pipe	HDPE	*as-built*	HDPE	*proposed*	duct. iron	*Proposed*
Pipe Size, Nominal (inches)	12	*as-built*	12	*proposed*	12	*Proposed*
SDR or Class	17	*as-built*	11	*proposed*	350	*DIPRA info, ductile iron pipe*
Inside Diameter of Pipe (inches)	11.250	***calc, manufacturer info, Driscopipe***	10.432	*calc*	12.64	*DIPRA info, ductile iron pipe, look up from worksheet "ref_info"*
Design Flow (gpm)	1700	*reservoir design discharge*	1700	*reservoir design discharge*	1700	*reservoir design discharge*
Full Flow Pipe Area (sq ft)	0.69	*calc*	0.59	*calc*	0.87	*calc*
Full Flow Velocity (fps)	5.49	*calc*	6.38	*calc*	4.35	*calc*
Dynamic Viscosity (ft^2/s)	0.000017	*water at 40 degrees F*	0.000017	*water at 40 degrees F*	0.000017	*water at 40 degrees F*
Reynold's Number RE	3.03E+05	*calc*	3.26E+05	*calc*	2.69E+05	*calc*
pipe "k" factor	smooth	*Rouse,Engineering Hydraulics,p.405*	smooth	*Rouse,Engineering Hydraulics,p.405*	1.20E-03	*average for cast iron,Rouse, p.405*
pipe "D/k" factor	smooth	*Rouse,Engineering Hydraulics,p.405*	smooth	*Rouse,Engineering Hydraulics,p.405*	878	*calc*
Darcy-Weisbach Friction Factor "f"	0.015	*Rouse,Engineering Hydraulics,p.405*	0.015	*Rouse,Engineering Hydraulics,p.405*	0.022	*Rouse,Engineering Hydraulics,p.405*
Velocity Head (ft)	0.47	*calc*	0.63	*calc*	0.29	*calc*
		Rouse,Engineering Hydraulics,p.405, provided as sheet 1a				

Throttle Valve Design Data

The headloss for a throttle valve is dependent upon the "% open" setting of the vave and the valve's Cv value.
Cv is a measurement of the valve's capacity to pass flow with a one (1) foot drop in pressure.
For water, the equation for Cv is Cv = Q / sqrt(dP)

Q flow
dP drop in pressure

the drop in pressure would represent the headloss that occurs through the valve at the setting indicated.

The Cv values are obtained from manufacturer's literature.

For the tabulation below for Throttle Valve Headloss to function correctly, the User must specify pertinent data on the valve, to allow computation of the headloss through the valve.
This information must be provided for the Worksheet to accurately predict headlosses through the piping system.

Manufacturer of Valve	DeZunk		
Type of Valve	ball		
Size of Valve	10	inches	
Number of Valves (in Series)	1		
% Open Setting of Valve	50	*manufacturer's literature*	dummy value, use only to set Cv below
Cv of valve for % Open Setting	204	*manufacturer's literature*	GIVEN, from JLS (back calculated to get loss = 69.23 +/-)

NOTE:

Point	Description	Pipeline Segment	type of pipe	Energy Head (ft)	Length of Pipeline Segment	Friction Gradient (ft/ft)	Headlosses Pipe Friction (ft)	Entrance	Bends	Tees	Shutoff Valves	Throttle Valves	Check Valves	Exit	Total Headloss (ft)	Energy Head Elevation (ft, msl)	Hydraulic Grade Elevation (ft, msl)	Invert Elevation of Pipe (ft, msl)	Crown Elevation of Pipe (ft, msl)	Is Pipe Adequate to Pass Flow (y/n)
0	intake in reservoir			**881.00**												881.00	880.53	877	878.00	yes
		1	hdpe		702.14	0.007481	5.25	0.23	0.42	0.00	0.00	0.00	0.00	0.00	5.91					
1	headwall connection at dam			875.09												875.09	874.63	876	877.00	no
		1	hdpe		128.55	0.007481	0.96	0.00	0.42	0.00	0.00	0.00	0.00	0.00	1.38					
2	crest at siphon vault			873.71												873.71	873.24	881	882.00	no
		1	hdpe		1054.34	0.007481	7.89	0.00	1.68	0.00	0.00	0.00	0.00	0.00	9.57					
3	Pigcatcher Road slope break			864.14												864.14	863.67	865	866.00	no
		1	hdpe		785.06	0.007481	5.87	0.00	0.42	0.00	0.00	0.00	0.00	0.00	6.29					
4	Ash Haul Road slope break			857.85												857.85	857.38	720	721.00	yes
		1	hdpe		64.23	0.007481	0.48	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.90					
5	PT-101 of new siphon route & connection w/ extg line			856.94												856.94	856.31	715.8	716.80	yes
		2	hdpe		54.63	0.010912	0.60	0.00	0.00	0.57	0.00	0.00	0.00	0.00	1.17					
6	PT-102			855.78												855.78	855.15	708.52	709.52	yes
		2	hdpe		270.37	0.010912	2.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95					
7	PT-103			852.83												852.83	852.20	656.82	657.82	yes
		2	hdpe		200.05	0.010912	2.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.18					
8	PT-104			850.65												850.65	850.01	635	636.00	yes
		2	hdpe		206.38	0.010912	2.25	0.00	0.57	0.00	0.00	0.00	0.00	0.00	2.82					
9	PT-105			847.82												847.82	847.19	632.52	633.52	yes
		2	hdpe		274.70	0.010912	3.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	3.57					
10	PT-106			844.26												844.26	843.62	631.83	632.83	yes
		2	hdpe		135.00	0.010912	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47					
11	PT-107			842.78												842.78	842.15	631.5	632.50	yes
		2	hdpe		99.77	0.010912	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09					
12	PT-108			841.70												841.70	841.06	631.25	632.25	yes
		2	hdpe		620.24	0.010912	6.77	0.00	0.57	0.00	0.00	0.00	0.00	0.00	7.34					
13	PT-109			834.36												834.36	833.73	629.7	630.70	yes
		2	hdpe		200.26	0.010912	2.19	0.00	0.57	0.00	0.00	0.00	0.00	0.00	2.75					
14	PT-110			831.60												831.60	830.97	629.2	630.20	yes
		2	hdpe		199.99	0.010912	2.18	0.00	0.57	0.00	0.00	0.00	0.00	0.00	2.75					
15	PT-111			828.85												828.85	828.22	628.7	629.70	yes
		2	hdpe		185.07	0.010912	2.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02					
16	PT-112			826.83												826.83	826.20	628.23	629.23	yes
		2	hdpe		139.94	0.010912	1.53	0.00	0.57	0.00	0.00	0.00	0.00	0.00	2.10					
17	PT-113			824.74												824.74	824.10	627.88	628.88	yes
		2	hdpe		110.76	0.010912	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21					
18	PT-114			823.53												823.53	822.89	627.4	628.40	yes
		2	hdpe		198.12	0.010912	2.16	0.00	0.57	0.00	0.00	0.00	0.00	0.00	2.73					
19	PT-115			820.80												820.80	820.16	626.9	627.90	yes
		2	hdpe		99.06	0.010912	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.08					
20	PT-116			819.72												819.72	819.08	624.2	625.20	yes
		2	hdpe		159.85	0.010912	1.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74					
21	PT-117			817.97												817.97	817.34	623.8	624.80	yes
		2	hdpe		672.10	0.010912	7.33	0.00	0.57	0.00	0.00	0.00	0.00	0.00	7.90					
22	PT-118 (bend at Eureka Road)			810.07												810.07	809.43	622.12	623.12	yes
		2	hdpe		161.79	0.010912	1.77	0.00	0.57	0.00	0.12	69.44	1.17	0.00	73.07					
23	PT-119			737.00												737.00	736.37	621.72	622.72	yes
		2	hdpe		309.16	0.010912	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37					
24	PT-120			733.63												733.63	732.99	620.94	621.94	yes
		2	hdpe		212.59	0.010912	2.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.32					
25	PT-121			731.31												731.31	730.67	620.41	621.41	yes
		2	hdpe		86.76	0.010912	0.95	0.00	0.57	0.00	0.00	0.00	0.00	0.00	1.52					
26	PT-122			729.79												729.79	729.50	603	604.00	yes
		3	duct. iron		275.23	0.006128	1.69	0.00	0.26	0.00	0.00	0.00	0.00	0.29	2.24					
27	outfall in Ohio River			727.55												727.55	727.25	585	**602.00**	yes
	subtotal, headloss to Proposed Control Valve Vault						62.21	0.23	7.92	0.57	0.00	0.00	0.00	0.00	70.93					
	subtotal, headloss to Ohio River						72.30	0.23	9.32	0.57	0.12	69.44	1.17	0.29	153.45					

The energy at any point in the system can be predicted using the Energy Equation (the general form of Bernoulli's Equation), assuming sufficient information is known about the pipe and the flow conditions.
For this analysis, it is assumed that the pipeline will flow full throughout its entire length. This assumption will be verified, and subsequent modifications will be made as appropriate.

For this analysis, a downstream approach is used. Starting with a known water level in the reservoir, the energy losses in the pipeline are then calculated. By comparing the resulting energy grade and hydraulic grade elevations with the pipeline profile, confirmation that the pipe does indeed flow full can be determined. If, at any point along the pipeline alignment, the hydraulic grade line dips below the crown of the pipe,then the pipe size may not be adequate to convey the flow, and a larger pipe size should be selected.

If, for a Selected Pipe Size (Nominal Diameter) and Flow, the computed Hydraulic Grade Line is above the crown of the pipe everywhere along the pipe, and is above the ground elevation at Point 118, where the proposed Control Valve Vault is to be located, then the Selected Pipe Size will be considered to be adequate to convey the flow.

This Worksheet computes flow conditions for the Design Reservoir Withdrawal Discharge Rate, for a given Pipe Type and Size.
The cells indicated in PINK require USER INPUT for the selection of the Pipe Type, Size, and Class, and of the Flow.
The worksheet automatically calculates the inside diameter of HDPE pipe, given the provided information, for pipe of 10 inches Nominal Diameter or larger. Smaller pipe sizes result in a warning to the USER.
The inside diameter for ductile iron pipe is obtained from a lookup table in the Worksheet "REF_INFO".
Pipe Segments "1" and "2" are reserved for HDPE pipe only. Pipe Segment "3" is reserved for Ductile Iron Pipe.

General Design Data

Reservoir Water Level	881 ft, msl	as of December 2001
Ohio River Water Level		
Normal Pool Level	602 ft, msl	

Pipe Design Data

The proposed pipeline is divided into three (3) segments, corresponding to (1) the hdpe pipe portion of the existing siphon line; (2) the proposed new hdpe portion of the new siphon line; and (3) the proposed new ductile iron portion of the new siphon line.

	segment 1		segment 2		segment 3	
Type of Pipe	HDPE	*as-built*	HDPE	*proposed*	duct. iron	*Proposed*
Pipe Size, Nominal (inches)	12	*as-built*	12	*proposed*	12	*Proposed*
SDR or Class	17	*as-built*	11	*proposed*	350	*DIPRA info, ductile iron pipe*
Inside Diameter of Pipe (inches)	11.250	*calc, manufacturer info, Driscopipe*	10.432	*calc*	12.64	*DIPRA info, ductile iron pipe, look up from worksheet "ref_info"*
Design Flow (gpm)	3213	*maximum reservoir withdrawal discharge*	3213	*maximum reservoir withdrawal discharge*	3213	*reservoir design discharge*
Full Flow Pipe Area (sq ft)	0.69	*calc*	0.59	*calc*	0.87	*calc*
Full Flow Velocity (fps)	10.37	*calc*	12.06	*calc*	8.22	*calc*
Dynamic Viscosity (ft^2/s)	0.000017	*water at 40 degrees F*	0.000017	*water at 40 degrees F*	0.000017	*water at 40 degrees F*
Reynold's Number RE	5.72E+05	*calc*	6.17E+05	*calc*	5.09E+05	*calc*
pipe "k" factor	smooth	*Rouse,Engineering Hydraulics,p.405*	smooth	*Rouse,Engineering Hydraulics,p.405*	0.0012	*average for cast iron,Rouse, p.405*
pipe "D/k" factor	smooth	*Rouse,Engineering Hydraulics,p.405*	smooth	*Rouse,Engineering Hydraulics,p.405*	878	*calc*
Darcy-Weisbach Friction Factor "f"	0.013	*Rouse,Engineering Hydraulics,p.405*	0.013	*Rouse,Engineering Hydraulics,p.405*	0.021	*Rouse,Engineering Hydraulics,p.405*
Velocity Head (ft)	1.67	*calc*	2.26	*calc*	1.05	*calc*

Throttle Valve Design Data

The headloss for a throttle valve is dependent upon the "% open" setting of the vave and the valve's Cv value.
Cv is a measurement of the valve's capacity to pass flow with a one (1) foot drop in pressure.
For water, the equation for Cv is $Cv = Q / \mathrm{sqrt}(dP)$

Q flow
dP drop in pressure
the drop in pressure would represent the headloss that occurs through the valve at the setting indicated.

The Cv values are obtained from manufacturer's literature.

For the tabulation below for Throttle Valve Headloss to function correctly, the User must specify pertinent data on the valve, to allow computation of the headloss through the valve.
This information must be provided for the Worksheet to accurately predict headlosses through the piping system.

Manufacturer of Valve	DeZurik		
Type of Valve	ball		
Size of Valve	10	inches	
Number of Valves (in Series)	1		
% Open Setting of Valve	100	manufacturer's literature	
Cv of valve for % Open Setting	1972	manufacturer's literature	GIVEN, from JLS (back calculated to get 2.31 ft of headloss)

Point	Description	Pipeline Segment	type of pipe	Energy Head (ft)	Length of Pipeline Segment	Friction Gradient (ft/ft)	Headlosses								Total Headloss (ft)	Energy Head Elevation (ft, msl)	Hydraulic Grade Elevation (ft, msl)	Invert Elevation of Pipe (ft, msl)	Crown Elevation of Pipe (ft, msl)	Is Pipe Adequate to Pass Flow (y/n)
							Pipe Friction (ft)	Entrance	Bends	Tees	Shutoff Valves	Throttle Valves	Check Valves	Exit						
0	intake in reservoir			**881.00**												881.00	879.33	877	878.00	yes
		1	hdpe		702.14	0.02316	16.26	0.84	1.50	0.00	0.00	0.00	0.00	0.00	18.60					
1	headwall connection at dam			862.40												862.40	860.73	876	877.00	no
		1	hdpe		128.55	0.02316	2.98	0.00	1.50	0.00	0.00	0.00	0.00	0.00	4.48					
2	crest at siphon vault			857.92												857.92	856.25	881	882.00	no
		1	hdpe		1054.34	0.02316	24.42	0.00	6.01	0.00	0.00	0.00	0.00	0.00	30.43					
3	Pigcatcher Road slope break			827.49												827.49	825.82	865	866.00	no
		1	hdpe		785.06	0.02316	18.18	0.00	1.50	0.00	0.00	0.00	0.00	0.00	19.69					
4	Ash Haul Road slope break			807.80												807.80	806.13	720	721.00	yes
		1	hdpe		64.23	0.02316	1.49	0.00	1.50	0.00	0.00	0.00	0.00	0.00	2.99					
5	PT-101 of new siphon route & connection w/ extg line			804.81												804.81	802.55	715.8	716.80	yes
		2	hdpe		54.63	0.033783	1.85	0.00	0.00	2.03	0.00	0.00	0.00	0.00	3.88					
6	PT-102			800.93												800.93	798.68	708.52	709.52	yes
		2	hdpe		270.37	0.033783	9.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.13					
7	PT-103			791.80												791.80	789.54	656.82	657.82	yes
		2	hdpe		200.05	0.033783	6.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.76					
8	PT-104			785.04												785.04	782.78	635	636.00	yes
		2	hdpe		206.38	0.033783	6.97	0.00	2.03	0.00	0.00	0.00	0.00	0.00	9.01					
9	PT-105			776.04												776.04	773.78	632.52	633.52	yes
		2	hdpe		274.70	0.033783	9.28	0.00	2.03	0.00	0.00	0.00	0.00	0.00	11.31					
10	PT-106			764.72												764.72	762.46	631.83	632.83	yes
		2	hdpe		135.00	0.033783	4.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.56					
11	PT-107			760.16												760.16	757.90	631.5	632.50	yes
		2	hdpe		99.77	0.033783	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.37					
12	PT-108			756.79												756.79	754.53	631.25	632.25	yes
		2	hdpe		620.24	0.033783	20.95	0.00	2.03	0.00	0.00	0.00	0.00	0.00	22.99					
13	PT-109			733.80												733.80	731.55	629.7	630.70	yes
		2	hdpe		200.26	0.033783	6.77	0.00	2.03	0.00	0.00	0.00	0.00	0.00	8.80					
14	PT-110			725.01												725.01	722.75	629.2	630.20	yes
		2	hdpe		199.99	0.033783	6.76	0.00	2.03	0.00	0.00	0.00	0.00	0.00	8.79					
15	PT-111			716.22												716.22	713.96	628.7	629.70	yes
		2	hdpe		185.07	0.033783	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.25					
16	PT-112			709.96												709.96	707.71	628.23	629.23	yes
		2	hdpe		139.94	0.033783	4.73	0.00	2.03	0.00	0.00	0.00	0.00	0.00	6.76					
17	PT-113			703.20												703.20	700.94	627.88	628.88	yes
		2	hdpe		110.76	0.033783	3.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.74					
18	PT-114			699.46												699.46	697.20	627.4	628.40	yes
		2	hdpe		198.12	0.033783	6.69	0.00	2.03	0.00	0.00	0.00	0.00	0.00	8.73					
19	PT-115			690.74												690.74	688.48	626.9	627.90	yes
		2	hdpe		99.06	0.033783	3.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.35					
20	PT-116			687.39												687.39	685.13	624.2	625.20	yes
		2	hdpe		159.85	0.033783	5.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40					
21	PT-117			681.99												681.99	679.73	623.8	624.80	yes
		2	hdpe		672.10	0.033783	22.71	0.00	2.03	0.00	0.00	0.00	0.00	0.00	24.74					
22	PT-118 (bend at Eureka Road)			657.25												657.25	654.99	622.12	623.12	yes
		2	hdpe		161.79	0.033783	5.47	0.00	2.03	0.00	0.00	2.65	5.65	0.00	15.80					
23	PT-119			641.45												641.45	639.19	621.72	622.72	yes
		2	hdpe		309.16	0.033783	10.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.44					
24	PT-120			631.00												631.00	628.75	620.94	621.94	yes
		2	hdpe		212.59	0.033783	7.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.18					
25	PT-121			623.82												623.82	621.56	620.41	621.41	yes
		2	hdpe		86.76	0.033783	2.93	0.00	2.03	0.00	0.00	0.00	0.00	0.00	4.96					
26	PT-122			618.86												618.86	617.81	603	604.00	yes
		3	duct. iron		275.23	0.020895	5.75	0.00	0.94	0.00	0.00	0.00	0.00	1.05	7.74					
27	outfall in Ohio River			611.12												611.12	610.07	585	586.00	yes

subtotal, headloss to Proposed Control Valve Vault	192.59
subtotal, headloss to Ohio River	224.36

Objective: Determine the potential for waterhammer and/or surge, and design measures to mitigate or minimize adverse effects.

Surge occurs in a pipeline whenever a change in the momentum and inertia occurs.
Waterhammer is a surge that occurs due to a sudden change in these parameters.

Maximum surge pressures (waterhammer) would occur when

valve closure time <= 2 x length of pipeline / speed of the pressure wave

of tv <= 2 L / s

s is dependent upon properties of the fluid and the pipe

s = 12 * sqrt ((K * E) / ((w / g) * (E + (K * DR)))

s	speed of the pressure wave (fps)
K	bulk modulus of the liquid (psi)
E	Modulus of Elasticity of pipe material (psi)
DR	Dimenson Ratio
w	unit weight of the fluid (pcf)
g	acceleration constant (f/s^2)
	32.2 f/s^2)

The excess pressure realized during a rapid valve closure is

dP = w s dv / 144 g

dP	change in pressure (psi)
dv	change in velocity (fps) that occurs during the critical time 2 L / s

For the application at hand,
Consider the siphon is operating at its design flow and at its predicted maximum hydraulic capacity

Q =	1700	gpm	*design flow, worksheet "hyd_anal_des_12"*
Q =	3213	gpm	*maximum hydraulic capacity, worksheet "hyd_anal_max_12"*
K =	300,000	psi	*water*
E =	100,000	psi	*hdpe, short term stress*
DR =	17		*max SDR of the siphon pipe, worksheet "hyd_anal_des_12"*
w =	62.4	pcf	*water*
L =	7331	ft	*worksheet "geometry"*
v =	5.49	fps	*design flow, worksheet "hyd_anal_des_12"*
v =	10.37	fps	*maximum hydraulic capacity, worksheet "hyd_anal_max_12"*

s =	655	fps	*speed of the pressure wave through the pipe* *s is independent of the flow rate*
tv =	22	seconds	tv is independent of the flow rate

The maximum value of dv is when the fluid is brought to a standstill by the valve closing, such that

dv =	5.49	fps	*design flow conditions, when the fluid is brought to a standstill*
dv =	10.37	fps	*maximum hydraulic capacity conditions, fluid is brought to a standstill*

and therefore

dP =	48	psi	*waterhammer pressure, design flow conditions*
dP =	91	psi	*waterhammer pressure, maximum hydraulic capacity conditions*

Therefore, the occurrence of waterhammer could add 48 psi *design flow conditions*
91 psi *maximum hydraulic capacity conditions*
rating required for the pipe.

Pressure Rating of Pipe (12" Diameter DR 11)		160	psi
Maximum Operating Pressure in Line		93.4	psi
Location with Highest Operating Pressure		PT-104	
Pipe Invert Elevation at	PT-104	635	ft, msl
150% Operating Pressure at	PT-104	140.2	psi
Lowest Pipe Invert Elevation on Line		622.12	ft, msl
Location of Lowest (Invert Elevation) Point of Line		PT-118 (bend at Eureka Road)	
Operating Pressure in Line at	PT-118 (bend at Eureka Road)	81.4	psi
150% Operating Pressure at	PT-118 (bend at Eureka Road)	122.2	psi

Point	Description (Upper Siphon Pipeline)	Operating Pressure in Pipe (psi)	150% of Operating Pressure (psi)	Invert Elevation of pipe (ft, msl)	Is 150% of Operating Pressure Less Than Pipe's Pressure Rating?	Test Pressure if Pipe is Tested to a Minimum of 150% of Operating Pressure at any Point	% of Operating Pressure	Is the Test Pressure Less Than the Pipe's Pressure Rating?	Recommended Test Procedure: Test Pressure if Pipe is Tested to 150% of Operating Pressure at Lowest Point on Line	Recommended Test Procedure: % of Operating Pressure	VLOOKUP table columns	
5	PT-101 of new siphon route & connection w/ extg line	61.2	91.7	715.80	OK	105.2	172	OK	81.6	133	5	PT-101 of new siphon route & connection w/ extg line
6	PT-102	63.8	95.7	708.52	OK	108.3	170	OK	84.8	133	6	PT-102
7	PT-103	84.9	127.4	656.82	OK	130.7	154	OK	107.1	126	7	PT-103
8	PT-104	93.4	140.2	635.00	OK	140.2	150	OK	116.6	125	8	PT-104
9	PT-105	93.3	139.9	632.52	OK	141.2	151	OK	117.7	126	9	PT-105
10	PT-106	92.1	138.1	631.83	OK	141.5	154	OK	118.0	128	10	PT-106
11	PT-107	91.6	137.3	631.50	OK	141.7	155	OK	118.1	129	11	PT-107
12	PT-108	91.2	136.8	631.25	OK	141.8	155	OK	118.2	130	12	PT-108
13	PT-109	88.7	133.0	629.70	OK	142.5	161	OK	118.9	134	13	PT-109
14	PT-110	87.7	131.6	629.20	OK	142.7	163	OK	119.1	136	14	PT-110
15	PT-111	86.7	130.1	628.70	OK	142.9	165	OK	119.3	138	15	PT-111
16	PT-112	86.1	129.1	628.23	OK	143.1	166	OK	119.5	139	16	PT-112
17	PT-113	85.3	128.0	627.88	OK	143.3	168	OK	119.7	140	17	PT-113
18	PT-114	85.0	127.5	627.40	OK	143.5	169	OK	119.9	141	18	PT-114
19	PT-115	84.0	126.0	626.90	OK	143.7	171	OK	120.1	143	19	PT-115
20	PT-116	84.7	127.1	624.20	OK	144.8	171	OK	121.3	143	20	PT-116
21	PT-117	84.1	126.2	623.80	OK	145.0	172	OK	121.4	144	21	PT-117
22	PT-118 (bend at Eureka Road)	81.4	122.2	622.12	OK	145.7	179	OK	122.2	150	22	PT-118 (bend at Eureka Road)

Determine What Class of Pipe is Required for the New Siphon Line

REFERENCE manufacturer literature on DRISCOPIPE, 1000 Series

psi rating	51	64	80	100	128	160	200	267	267
DR of pipe	32.5	26	21	17	13.5	11	9	7	7
	26	21	17	13.5	11	9	7	7	0

Reservoir Water Level	881.00	ft, msl	
Ohio River Water Level			
Normal Pool Level	602.00	ft, msl	
Maximum Static Head in Pipe	279	ft	*neglecting losses*
Maximum Static Pressure in Pipe	121	psi	*neglecting losses*
Conversion Factor			

1 cf of water weighs 62.4 lbs
1 cf of water per sq in = 0.433 psi

Point	Description	Static Conditions: Invert Elevation of pipe (ft, msl)	Static Pressure in Pipe (ft)	Static Pressure in Pipe (psi)	Design Flow Conditions: Energy Head Elevation (ft, msl)	Operating Pressure Head in Pipe (ft)	Operating Pressure in Pipe (psi)	Water Hammer Pressure (psi)	Maximum Pressure in Pipe (psi)	Controlling Condition in Pipe	Minimum DR Rating of Pipe	Maximum Flow Conditions: Energy Head Elevation (ft, msl)	Operating Pressure Head in Pipe (ft)	Operating Pressure in Pipe (psi)	Water Hammer Pressure (psi)	Maximum Pressure in Pipe (psi)	Controlling Condition in Pipe	Minimum DR Rating of Pipe
0	intake in reservoir	877.00	4.00	2	881.00	4.00	0	48	48	Waterhammer	32.5	881.00	4.00	0	91	91	Waterhammer	17
1	headwall connection at dam	876.00	5.00	2	875.09	-0.91	0	48	48	Waterhammer	32.5	862.40	-13.60	-6	91	85	Waterhammer	17
2	crest at siphon vault	881.00	0.00	0	873.71	-7.29	-3	48	45	Waterhammer	32.5	857.92	-23.08	-10	91	81	Waterhammer	17
3	Pigcatcher Road slope break	865.00	16.00	7	864.14	-0.86	0	48	48	Waterhammer	32.5	827.49	-37.51	-16	91	75	Waterhammer	21
4	Ash Haul Road slope break	720.00	161.00	70	857.85	137.85	60	48	108	Waterhammer	13.5	807.80	87.80	38	91	129	Waterhammer	11
5	PT-101 of new siphon route & connection w/ extg line	715.80	165.20	72	856.94	141.14	61	48	110	Waterhammer	13.5	804.81	89.01	39	91	130	Waterhammer	11
6	PT-102	708.52	172.48	75	855.78	147.26	64	48	112	Waterhammer	13.5	800.93	92.41	40	91	131	Waterhammer	11
7	PT-103	656.82	224.18	97	852.83	196.01	85	48	133	Waterhammer	11	791.80	134.98	58	91	150	Waterhammer	11
8	PT-104	635.00	246.00	107	850.65	215.65	93	48	142	Waterhammer	11	785.04	150.04	65	91	156	Waterhammer	11
9	PT-105	632.52	248.48	108	847.82	215.30	93	48	142	Waterhammer	11	776.04	143.52	62	91	154	Waterhammer	11
10	PT-106	631.83	249.17	108	844.26	212.43	92	48	140	Waterhammer	11	764.72	132.89	58	91	149	Waterhammer	11
11	PT-107	631.50	249.50	108	842.78	211.28	92	48	140	Waterhammer	11	760.16	128.66	56	91	147	Waterhammer	11
12	PT-108	631.25	249.75	108	841.70	210.45	91	48	140	Waterhammer	11	756.79	125.54	54	91	146	Waterhammer	11
13	PT-109	629.70	251.30	109	834.36	204.66	89	48	137	Waterhammer	11	733.80	104.10	45	91	136	Waterhammer	11
14	PT-110	629.20	251.80	109	831.60	202.40	88	48	136	Waterhammer	11	725.01	95.81	42	91	133	Waterhammer	11
15	PT-111	628.70	252.30	109	828.85	200.15	87	48	135	Waterhammer	11	716.22	87.52	38	91	129	Waterhammer	11
16	PT-112	628.23	252.77	110	826.83	198.60	86	48	134	Waterhammer	11	709.96	81.73	35	91	127	Waterhammer	13.5
17	PT-113	627.88	253.12	110	824.74	196.86	85	48	134	Waterhammer	11	703.20	75.32	33	91	124	Waterhammer	13.5
18	PT-114	627.40	253.60	110	823.53	196.13	85	48	133	Waterhammer	11	699.46	72.06	31	91	123	Waterhammer	13.5
19	PT-115	626.90	254.10	110	820.80	193.90	84	48	132	Waterhammer	11	690.74	63.84	28	91	119	Waterhammer	13.5
20	PT-116	624.20	256.80	111	819.72	195.52	85	48	133	Waterhammer	11	687.39	63.19	27	91	119	Waterhammer	13.5
21	PT-117	623.80	257.20	111	817.97	194.17	84	48	132	Waterhammer	11	681.99	58.19	25	91	117	Waterhammer	13.5
22	PT-118 (bend at Eureka Road)	622.12	258.88	112	810.07	187.95	81	48	130	Waterhammer	11	657.25	35.13	15	91	107	Static	13.5
23	PT-119	621.72	259.28	112	737.00	115.28	50	48	112	Static	13.5	641.45	19.73	9	91	100	Static	17
24	PT-120	620.94	260.06	113	733.63	112.69	49	48	113	Static	13.5	631.00	10.06	4	91	96	Static	17
25	PT-121	620.41	260.59	113	731.31	110.90	48	48	113	Static	13.5	623.82	3.41	1	91	93	Static	17
26	PT-122	603.00	278.00	120	729.79	126.79	55	48	120	Static	13.5	618.86	15.86	7	91	98	Static	17
	MAXIMUM PRESSURE IN PIPE			120			93		142							156		