RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

MUSCATINE POWER AND WATER
Muscatine County, Iowa
Coal Combustion Residue Landfill

Updated October 17, 2021

Prepared For:
Muscatine Power and Water

Prepared By:
HRGreen

RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN
COAL COMBUSTION RESIDUE LANDFILL
§257.81(c)

PERMIT NO. 70-SDP-06-82P

Muscatine Power and Water
3205 Cedar Street
Muscatine, IA 52761

Updated October 17, 2021

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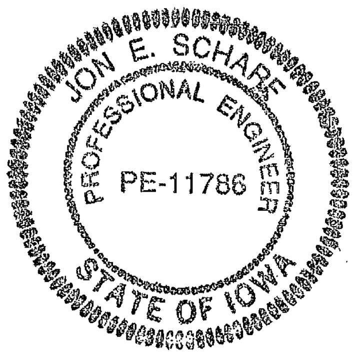
HRGreen

CERTIFICATION



I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

Date: 10/17/2021

Name: Jon E. Scharf

License Number: 11786

My renewal date is: 12/31/2021

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Entire Bound Document

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1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Muscatine Power and Water (MP&W) operates a coal fired power station in Muscatine Iowa having a generating nameplate capacity of 293.55 MW. Coal combustion residual (CCR) that is not beneficially used is disposed of in their landfill located approximately 10 miles west of the power station near the town of Letts, IA (Figure 1). The CCR includes a mixture of gypsum, fly ash, bottom ash, and slag materials. The landfill was placed into operation in December 1985 and is under sole control of MP&W.

The overall designated landfill development area includes four phases encompassing approximately 34 acres (Figure 2). Management of CCR at this landfill site is regulated under permits issued by the Iowa Department of Natural Resources (IDNR).

The United States Environmental Protection Agency (USEPA) published the final federal rule for the management of coal combustion residuals (CCR) on April 17, 2015. The purpose of this document is to comply with subpart §257.81of the CCR rule which requires that the Owner or Operator of a CCR landfill prepare a written initial run-on and run-off control system plan (Plan) no later than October 17, 2016. The Plan must be amended whenever there is a change in conditions that would substantially affect the written plan in effect. In addition, the rule requires that a periodic run-on and run-off control system plan be prepared at a frequency no longer than every five years. The deadline for completing a subsequent plan is based on the date of completing the previous plan. According to the rule, a Plan is considered complete when it has been placed in the facility's operating record as required by §257.105(g)(3). Both the initial and subsequent periodic plans must be certified by a qualified professional engineer stating that the plans meet the requirements of the rule.

MP&W placed the initial Run-On and Run-off Control System Plan in the facility's operating record on October 17, 2016. The periodic updated Plan (this document) was prepared within five years of the last Plan and was placed in the facility's operating record on October 17, 2021.

1.2 RELATED PERMITS

In addition to the federal provisions of Part §257 *Standards for Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments,* Muscatine Power and Water's CCR Landfill is currently subject to the following permits administered by the Iowa Department of Natural Resources:

- Iowa Department of Natural Resources Sanitary Disposal Project Permit, Permit Number 70-SDP-06-82P, Expiration date 8/10/2030
- Iowa Department of Natural Resources NPDES Permit, Iowa Permit Number 7000109, Issued 1/19/2010, Expiration Date 1/18/2015 (application was submitted on time per requirements; renewed permit pending)

1.3 RECORD KEEPING

This Run-On and Run-Off Control System Plan is subject to the requirements of §257.81(d), requiring compliance with the recordkeeping requirements specified in §257.105(g) for placement in the facility's operating record. Corresponding requirements include regulatory notifications specified in §257.106(g), and internet posting specified in §257.107(g).

Each document subject to these requirements must be retained for at least five years following the date of each occurrence, measurement, maintenance, corrective action, report, record, or study. Any required documentation must be readily retrievable for submittal to the State Director, if requested.

1.3.1 Notification

In accordance with §257.106(d), the State Director must be notified within 30 days of placing information in the facility operating record and on the Owner/Operator's publicly accessible internet site. Unless directed otherwise by IDNR staff, official notification should be sent to:

Mick Leat
Land Quality
Iowa Department of Natural Resources
502 East 9th Street
Des Moines, IA 50319-0034

1.3.2 Website

As required, MP&W maintains a publicly accessible Internet site which contains pertinent information from the facility operating record as specified in subparagraphs §257.107(e)–(j). In part, this includes this Run-on and Run-off Control Plan, amendments, and periodic plans all as described in Section 1.3. The materials to be forwarded to the CCR Web site must be posted within 30 days of placing the pertinent information in the facility operation record.

The publicly accessible internet site for Muscatine Power and Water is:
https://www.mpw.org/utilities/ccr-rule

2.0 DESIGN PLAN

2.1 DESIGN CRITERIA

In accordance with §257.81, the storm water management system must be designed, constructed and operated to maintain:

(1) A run-on control system to prevent flow onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm; and
(2) A run-off control system from the active portion of the CCR unit to collect and control at least the water volume resulting from a 24-hour, 25-year storm. In addition, any run-off from the active portion of the CCR unit must be handled in accordance with the surface water requirements under § 257.3-3. That is, any discharge of run-off shall not be in violation of the requirements of the National Pollutant Discharge Elimination System (NPDES) under the Clean Water Act.

2.2 LANDFILL DEVELOPMENT AND STORM WATER CONTROL

Landfill development and associated storm water control are illustrated on the attached Figures. Figures 3 shows existing site topography and hydrologic conditions along with the proposed development sequence, in order of Phase I on the east side through Phase IV to the west. At this time, development and active filling of CCR is permitted only in Phases I and II. Figure 4 shows development of the landfill at the point of full build-out; after all four phases are fully filled and covered. This figure is from the original 1991 design drawings by Green Environmental Services(1) and is slightly modified to illustrate future hydrologic conditions for this report.

Development of Phase I and the overall site perimeter site drainage system began in 1985. Development of the Phase II began in 2012. In 2020, MP&W completed a site improvement project that addressed storm water management, sedimentation, and general site operations. This construction project included additional final cover, storm water conveyance, site roads and other features as addressed in the project construction drawings(4).

At this time, the remaining CCR fill capacity of Phases I and II is nearly 300,000 cubic yards. This capacity is expected to provide for several decades of operations before future expansion into Phases III and IV would be considered.

2.3 RUN-ON CONTROL

Surface water run-on to active areas of the landfill site is prevented by engineered means (i.e. embankments and ditches) and by the natural topography. Refer to Figures 2 and 3 showing the landfill site with current topographic contours.

Surface water enters the site via an intermittent stream that originates on neighboring agricultural land in the SE¼ of Section 16. The stream enters the site near the northeast corner of the inactive, final covered and vegetated portion of the Phase I fill area. The stream is then routed through a constructed bypass ditch (> 10 feet deep) which diverts collected off-site and on-site non-fill surface drainage along the north and west perimeters of the landfill and Sediment Run-off Control Pond before it converges back into the original stream bed location about 500 feet southwest of the landfill.

Run-on is further prevented on the east side of the landfill by drainage ditches along the base of the covered landfill slope. South of the landfill there is a constructed ditch that directs storm water westerly and away from the landfill to the primary southerly drainage in this area.

2.4 RUN-OFF CONTROL

2.4.1 General Development

Run-off from portions of Phases I and II that have received final landfill cover is routed around the perimeter of the landfill to the main discharge outfall on the south end of the site. All other run-off within the current and future landfill boundaries is conveyed to the landfill Sediment Run-off Control Pond.

Storm water volumes to this pond will be highest and therefore “worst case” in the early stages of the landfill development. As shown on Figure 3, the catchment to the Sediment Run-off Control Pond includes most of the landfill except for approximately 10.9 acres of completed slope along the north and east sides of Phase I which has received approved final cover. Run-off volume to the pond will decrease as portions of the landfill reach design grades. Once final cover is constructed over completed slopes, more of the storm water will be diverted away from the Sediment Run-off Control Pond to the drainages north and south of the landfill.

The sediment run-off pond functions as a retention pond. Water is held in the pond until such time the landfill operator initiates a siphon control to lower the pond depth. Landfill operations records since 2011 indicate that the maximum range in pond levels have been from 705 feet to 714 feet. For purposes of this analysis, this range is said to be the “normal” operating range for the basin. Calculations verifying that the normal operating range of the retention pond results in sufficient capacity to retain the run-off volume generated by a 25 year, 24 hour storm event are included in Appendix A. This analysis was conservative for the purpose of verifying compliance with §257.8. Considering that the emergency spillway is approximately 9 feet above the high end of the normal operating range, the basin appears to be sufficiently sized to contain multiple large storm events if necessary.

2.4.2 Phase I & II Run-off

Phases I and II (22.7 acres) are currently permitted and under development. Phases III and IV are designated for future development. Run-off originating from the Phase I&II area is managed in different ways depending on whether it has been in contact with CCR materials or not. The site improvement project that was completed in 2020, along with operational changes at the time, were implemented with the goal to minimize storm water contact with the CCR.

At this time, the operational status of Phases I and II is broken down in three distinct areas as shown on Figure 3 and summarized as follows:

- Final Covered Area: 10.9 acres (Phase I)
- Current Active Operations Area: 5.2 acres (Phase I & II)
- Current Temporary Soil Covered Area: 6.6 acres (Phase I & II)

Hydrologic analysis was completed for the above conditions using HydroCAD and XPSWMM hydrology software. Each of these conditions were studied using the SCS Type II, 25-year, 24 hour storm event. Based on Atlas 14 rainfall data for Muscatine, this size storm event consists of a rainfall depth of 5.63 inches. The results of the analyses are as follows:

1. Run-off from Final Cover

   Design for the 2020 landfill improvement project(4) included installation of additional final cover in Phase I&II, along with associated berms, ditches, culverts, and storm water let-down structures. In summary, run-off from upper portions of the landfill slope is conveyed in ditches to collection ponds located both on and off of the landfill. The collected run-off at each pond is routed through a let-down structure to lower elevations in the system.

   For verification of the conveyance structure design, an ultimate buildout scenario (maximum slopes and height) for the Phase I&II area was divided into four catchment areas. Three of these catchments drained directly to the three ponds that included let-down structures. The remaining catchment area was for analysis of storm water backup (ponding) at an intermediate culvert located upstream of one of the let-down structures.

   A HydroCAD model was developed to route the catchment areas to the associated ponds to verify that 24" CMP let-down structures would be sufficient to drain the ponds as graded, and to verify that a 30 inch diameter outlet culvert would not be overtopped. In addition, analysis was conducted on the berms and ditches as detailed in the project plan set(4). Each berm or ditch was assessed to ensure the flows being conveyed would not overtop the berm or enter the roadway.

   A HydroCAD model report is included in Appendix B. Exhibit 1 in Appendix B displays the catchment areas and summarizes results of the analysis. The analyses indicate that the three letdown ponds and outlet culvert sufficiently serve their respective drainage areas with no additional grading required. When built as designed, flows resulting from the design storm event will be sufficiently contained within the ditches and berms.

2. Run-off from the Active Operation Area

   In the active operation area where CCR contact water (run-off originating on CCR) is generated, the run-off is routed to landfill surface "chimney" drains and directed via piping to a clay lined forebay of the site Sediment Run-off Control Pond. For sedimentation control, discharge from the forebay to the Sediment Run-off Control Pond is through a level-controlled structure. Currently there are four chimney drains to accommodate drainage of this area. The network of contact water drains and piping system is intended to be expanded vertically and horizontally as the operational area is developed.

   The design of the chimney drains and hydrologic condition at the time of construction were modeled in HydroCAD to evaluate their effectiveness and to assess the depth of ponding during a 25 year storm event. A HydroCAD model report for this condition is included in Appendix C.

   Based on the 2020 project design drawings, the HydroCAD analysis indicated that storm water from a 25 year event would pond up to a depth of 1.9 feet within the active operation area. Under this scenario, there would be approximately three feet of elevation available above the ponding level before the west berm would be over-topped. Since placement of CCR is on-going, drainage conditions within the operational area are not static and will change over time. The landfill operator must assess conditions and grade the CCR to provide sufficient ponding capacity and add additional drains as needed to accommodate run-off within this area.

3. <u>Run-off from Temporary Covered Area</u>
   A significant portion of Phase I&II does not have final cover and is not intended to receive additional CCR within a reasonable period of time (several years). To prevent excess generation of CCR contact water and to minimize erosion, this area was temporarily covered with soil and seeded. Currently, this non-contact run-off is routed to the west, to the Sediment Run-off Control pond. As this temporary covered area transitions to active CCR filling in the future, the run-off will be diverted to the sediment run-off pond forebay as described above. Based on projected rate of CCR fill at this landfill, the current temporary covered area (as shown on Figure 3) will likely remain in that status for the next decade.

   Drainage analysis on the temporary covered area was completed based on design involving three Hickenbottom intake risers draining to a single outlet culvert. XPSWMM hydrology software was used to model the system to identify the maximum ponding elevation at the inlets during the 25 year storm event. The resulting ponding depth at the inlets were up to 1.4 feet. Based on this condition, there would be approximately two feet of elevation available above the maximum ponding level before the west berm would be over-topped.

2.4.3 Post Development Run-off

As the landfill reaches final design grades and final cover is applied, less storm water will be routed to the Sediment Run-off Control Pond while more is routed to the north bypass ditch or south drainage. As shown on Figure 4, the catchment to the run-off pond after closure of the entire landfill (Phases I through IV) is about 40 percent of the catchment area in early landfill development conditions. Since this pond was designed for high runoff volumes expected in the early development period, its design during post development is considered conservative.

Upon completion of final cover, storm water from completed side-slopes of landfill will be conveyed to constructed let-down structures to the bottom of the slopes. The let-down structures convey run-off from the completed upper slopes to the current perimeter by-pass ditch to the north, ditches to the south, and to the sediment run-off pond to the west.

Surface drainage calculations for the let-down structures were prepared with the original 1991 landfill design documents[2], copies of which are included in Appendix D. As indicated on the documents, the calculations are based on rainfall intensity from a 100 year storm event and therefore considered conservative for the required 24 hour 25 year storm.

2.5 NPDES

MP&W is authorized under NPDES permit #7000109 to discharge storm water run-off from the Sediment Run-off Control Pond and water discharge from two groundwater cut-off drains, as shown on Figure 2.

The water level in the Sediment Run-off Control Pond is controlled by MP&W staff by operation of a siphon outlet over the pond berm to the south. The discharge flows southward and combines with flows from the original stream, perimeter bypass ditch, and storm water routed off of landfill final cover and landfill perimeter catchment. All combined storm water flows south to a ponding area (aka “farm pond”) where it discharges at its overflow point, corresponding to the NPDES permit’s outfall #001. Quarterly monitoring and annual reporting are completed by MP&W in accordance with its permit.

3.0 REFERENCES

(1) Green Environmental Services, Inc., “Muscatine Power and Water Coal Combustion Residue Landfill”, Drawing Set, 19 Sheets, Nov. 1991.

(2) Green Environmental Services, Inc., “Supporting Documentations for Muscatine Power and Water Coal Combustion Residue Landfill”, Report, Nov. 1991.

(3) Muscatine Power and Water, Letter w/ attachments to IDNR, “Response to September 10, 2009 Letter MP&W CCR Landfill Renewal Application”, December 17, 2009.

(4) HR Green, Inc., “CCR Landfill Cover Improvements” Muscatine Power and Water, Drawing Set, 15 Sheets, April 3, 2019.

FIGURES

Figure 1

LOCATION MAP

CCR Landfill
Muscatine Power and Water

Legend

Property Line (Approx.)

Landfill Development Area

0 500 Feet

Projected Coordinate System:
NAD 1983 StatePlane Iowa_South

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Figure 2

SITE MAP

CCR Landfill
Muscatine Power and Water

Legend

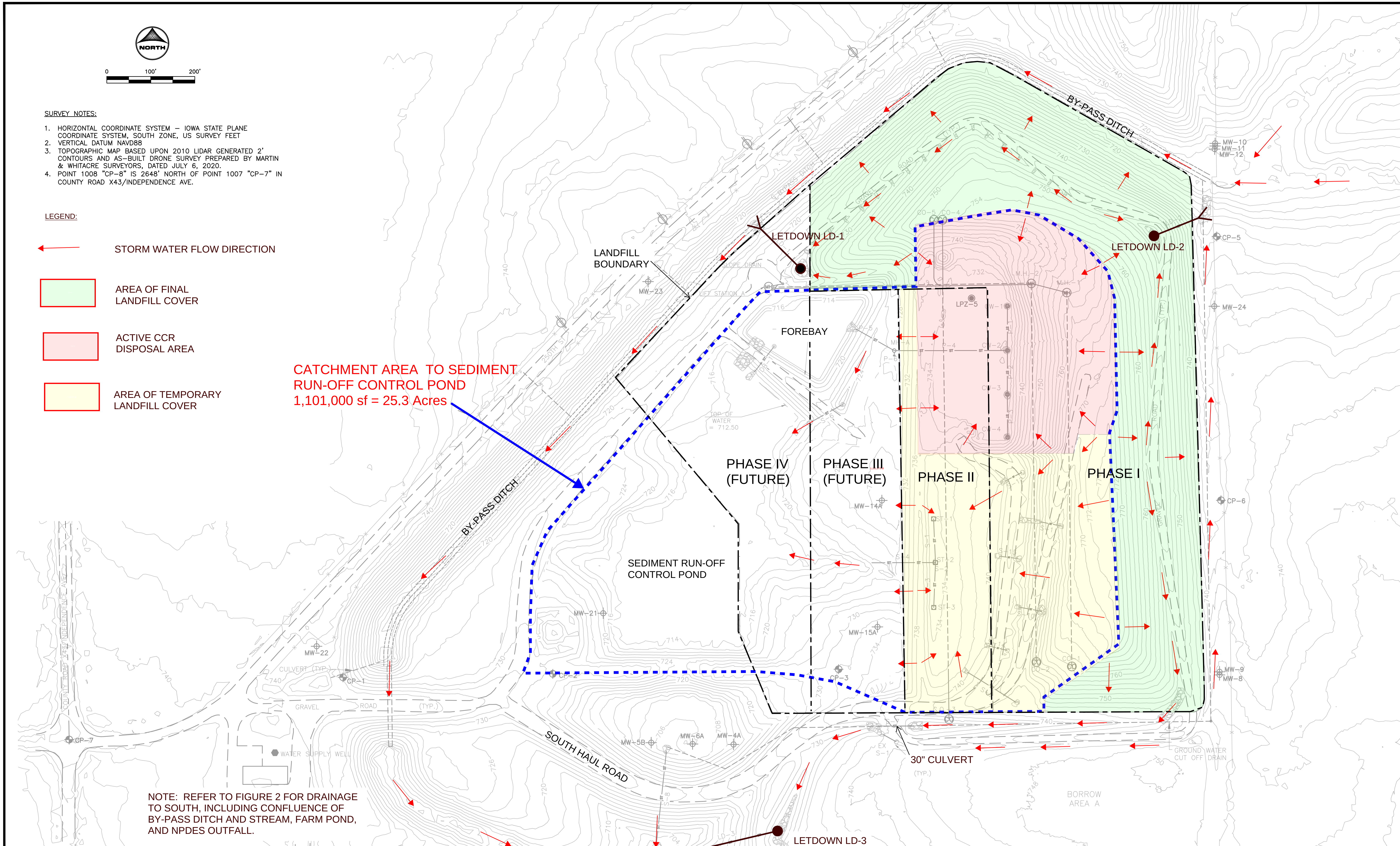
- Monitoring Wells
- Surface Water Points
- Landfill Piezometers
- Water Supply Well
- Groundwater Cut-Off Drain
- Phase Boundaries
- Landfill Development Area
- Property Line (Approx.)

0 300 Feet

Projected Coordinate System:
NAD 1983 StatePlane Iowa_South

HRGreen

PLOT: 10/7/2021 FILE: J:\2021\211368\RPT\Figures\Figure2-SiteMap-MP&Wlandfill.mxd



Xrefs: xgt-1-dh01; x-v-Aerial; xcx-Cont; xcx-Base

DRAWN BY: JJC JOB DATE: 2020
APPROVED: JES JOB NUMBER: 10100095.21
CAD DATE: 11/16/2020 5:09:09 PM
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NO.	DATE	BY	REVISION DESCRIPTION

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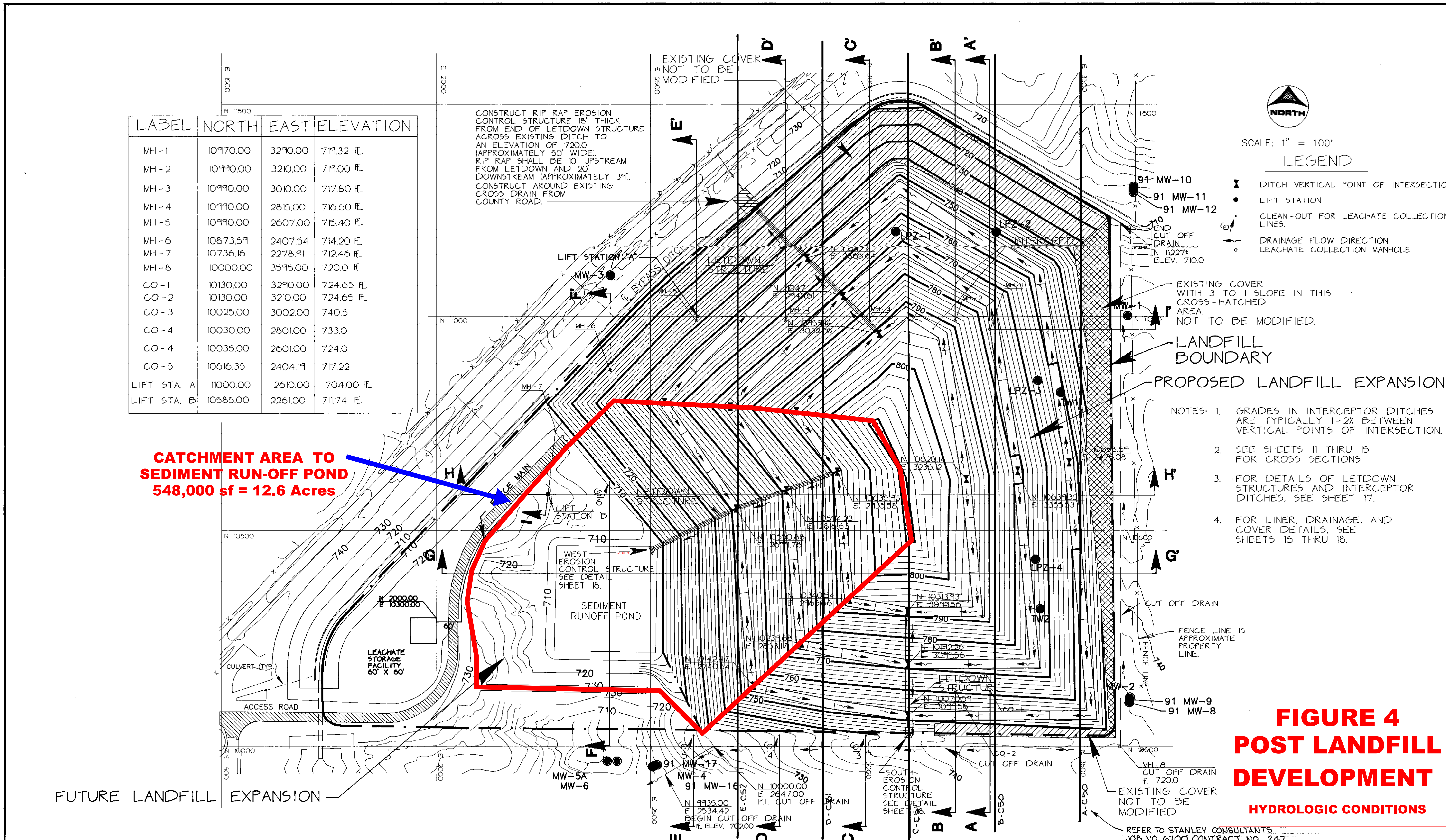
LANDFILL DEVELOPMENT PLAN
MUSCATINE POWER & WATER
MUSCATINE, IOWA

CIVIL
EXISTING SITE CONDITIONS

SHEET NO.
FIGURE 3



LABEL	NORTH	EAST	ELEVATION
MH-1	10970.00	3290.00	719.32 FL
MH-2	10990.00	3210.00	719.00 FL
MH-3	10990.00	3010.00	717.80 FL
MH-4	10990.00	2815.00	716.60 FL
MH-5	10990.00	2607.00	715.40 FL
MH-6	10873.59	2407.54	714.20 FL
MH-7	10736.16	2278.91	712.46 FL
MH-8	10000.00	3595.00	720.0 FL
CO-1	10130.00	3290.00	724.65 FL
CO-2	10130.00	3210.00	724.65 FL
CO-3	10025.00	3002.00	740.5
CO-4	10030.00	2801.00	733.0
CO-4	10035.00	2601.00	724.0
CO-5	10616.35	2404.19	717.22
LIFT STA. A	11000.00	2610.00	704.00 FL
LIFT STA. B	10585.00	2261.00	711.74 FL

FIGURE 4
POST LANDFILL DEVELOPMENT
HYDROLOGIC CONDITIONS

DRAWN: JEG/CAD/CASE1 SURVEYED:
APPROVED: FIELD BOOK NO.
DATE: NOVEMBER 15, 1991 JOB NO. 705910

NO.	DATE	BY	REVISION DESCRIPTION
1	11/19/91	JEG	XSEC I: NUMBER NOTES: EXTEND XSEC F: LIFT STA. A/B
2	11-19-96	EBL	ADDED SECTIONS A - THRU D

GREEN ENVIRONMENTAL SERVICES, INC.

MUSCATINE POWER AND WATER
CCR LANDFILL
1991

PROPOSED FINAL CONTOURS

SHEET NO.

DLF0001E D1-E(A)

HRGreen

APPENDIX A

SEDIMENT RUNOFF CONTROL BASIN CAPACITY CALCULATIONS

Project MPBW
Run-on Run-off Control Plan
Calc's for Sediment Runoff basin Capacity verification

HRGreen

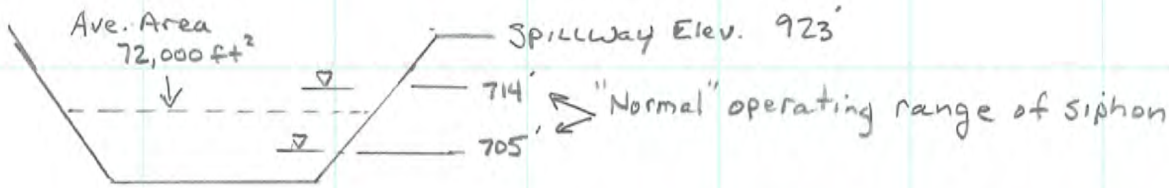
Sheet No. 1 of 5
Job No. 10100095.03
By JES Date 10/4/16
Checked ______ Date ______

Determine volume of run-off to sediment run-off basin. Maximum catchment is the current condition (32.8 acres). The catchment area will reduce as final cover is applied to completed areas and run off is directed off the landfill (not to the sediment runoff basin).

From worksheets 25yr, 24hr storm: 5.62"
Runoff (TR55) 4.4"

Volume of runoff to sediment runoff basin

$$4.4'' \left(\frac{1\,ft}{12''}\right) 32.8\ acre\ \frac{43560\,ft^2}{1\,acre} = 523{,}882\ ft^3$$



Runoff basin normal operating volume

$72{,}000\ ft^2 \times 9\ ft = 648{,}000\ ft^3$

Basin: $648{,}000\,ft^3 >$ Runoff $524{,}000\ ft^3$

Conclusion: The above analysis conservatively shows that basin is large enough to contain a 25yr, 24hr storm. This neglects additional basin capacity from the normal high operating level (elev. 914') to the spillway (923'). This also neglects additional storage capacity north of basin (prior to development of phase IV).

Worksheet 2: Runoff curve number and runoff

Project MP&W CCR LANDFILL	By JES	Date 10/4/2016
Location Muscatine, IA	Checked	Date

Check one: ☒ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN [1/] Figure 2-3	CN [1/] Figure 2-4	Area ☒ acres ☐ mi^2 ☐ %	Product of CN x area
D	Landfill condition most similar to TR-55 Table 2-2c Pasture, range. Hydrologic condition: Poor	89			32.8	2919
				Totals ➡	32.8	2919

[1/] Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{2919}{32.8} = 89$; Use CN ➡ 89

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr	25		
Rainfall, P (24-hour) SUDAS 2B-2 2015	in	5.62		
Runoff, Q (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	in	4.4		

Table 2B-2.10: Section 9 - Southeast Iowa
Rainfall Depth and Intensity for Various Return Periods

	Return Period															
	1 year		*2 year*		*5 year*		*10 year*		*25 year*		*50 year*		*100 year*		*500 year*	
Duration	*D*	*I*	*D*	*I*	*D*	*I*	*D*	*I*	*D*	*I*	*D*	*I*	*D*	*I*	*D*	*I*
5 min	0.38	4.57	0.44	5.33	0.54	6.58	0.64	7.68	0.76	9.22	0.87	10.4	0.97	11.7	1.24	14.8
10 min	0.55	3.34	0.65	3.9	0.80	4.82	0.93	5.62	1.12	6.76	1.27	7.66	1.43	8.60	1.81	10.8
15 min	0.68	2.72	0.79	3.17	0.98	3.93	1.14	4.57	1.37	5.49	1.55	6.23	1.74	6.98	2.21	8.85
30 min	0.95	1.9	1.11	2.22	1.38	2.76	1.61	3.22	1.94	3.88	2.20	4.40	2.46	4.93	3.12	6.25
1 hr	1.23	1.23	1.43	1.43	1.78	1.78	2.09	2.09	2.54	2.54	2.90	2.90	3.28	3.28	4.24	4.24
2 hr	1.51	0.75	1.76	0.88	2.19	1.09	2.58	1.29	3.14	1.57	3.61	1.80	4.10	2.05	5.35	2.67
3 hr	1.68	0.56	1.96	0.65	2.45	0.81	2.89	0.96	3.54	1.18	4.08	1.36	4.66	1.55	6.15	2.05
6 hr	1.99	0.33	2.32	0.38	2.91	0.48	3.44	0.57	4.25	0.70	4.92	0.82	5.63	0.93	7.50	1.25
12 hr	2.31	0.19	2.71	0.22	3.41	0.28	4.03	0.33	4.96	0.41	5.74	0.47	6.56	0.54	8.68	0.72
24 hr	2.68	0.11	3.12	0.13	3.90	0.16	4.59	0.19	5.62	0.23	6.46	0.26	7.35	0.30	9.64	0.40
48 hr	3.12	0.06	3.58	0.07	4.39	0.09	5.11	0.10	6.18	0.12	7.06	0.14	7.98	0.16	10.3	0.21
3 day	3.41	0.04	3.9	0.05	4.73	0.06	5.47	0.07	6.56	0.09	7.45	0.10	8.39	0.11	10.7	0.14
4 day	3.66	0.03	4.16	0.04	5.02	0.05	5.78	0.06	6.88	0.07	7.78	0.08	8.72	0.09	11.0	0.11
7 day	4.33	0.02	4.87	0.02	5.79	0.03	6.59	0.03	7.72	0.04	8.63	0.05	9.57	0.05	11.8	0.07
10 day	4.95	0.02	5.54	0.02	6.54	0.02	7.38	0.03	8.57	0.03	9.51	0.03	10.4	0.04	12.8	0.05

D = Total depth of rainfall for given storm duration (inches)
I = Rainfall intensity for given storm duration (inches/hour)

C. References

Perica, et. al. *NOAA Atlas 14: Precipitation-Frequency Atlas of the United States, Volume 8 Version 2.0: Midwestern States*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, & National Weather Service. 2013. http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume8.pdf

Huff & Angel. *Bulletin 71: Rainfall Frequency Atlas of the Midwest.* Midwestern Climate Center, Illinois State Water Survey. 1992.

Table 2-2c Runoff curve numbers for other agricultural lands [1/]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2/]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3/]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4/]	48	65	73
Woods—grass combination (orchard or tree farm). [5/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6/]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4/]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.

2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

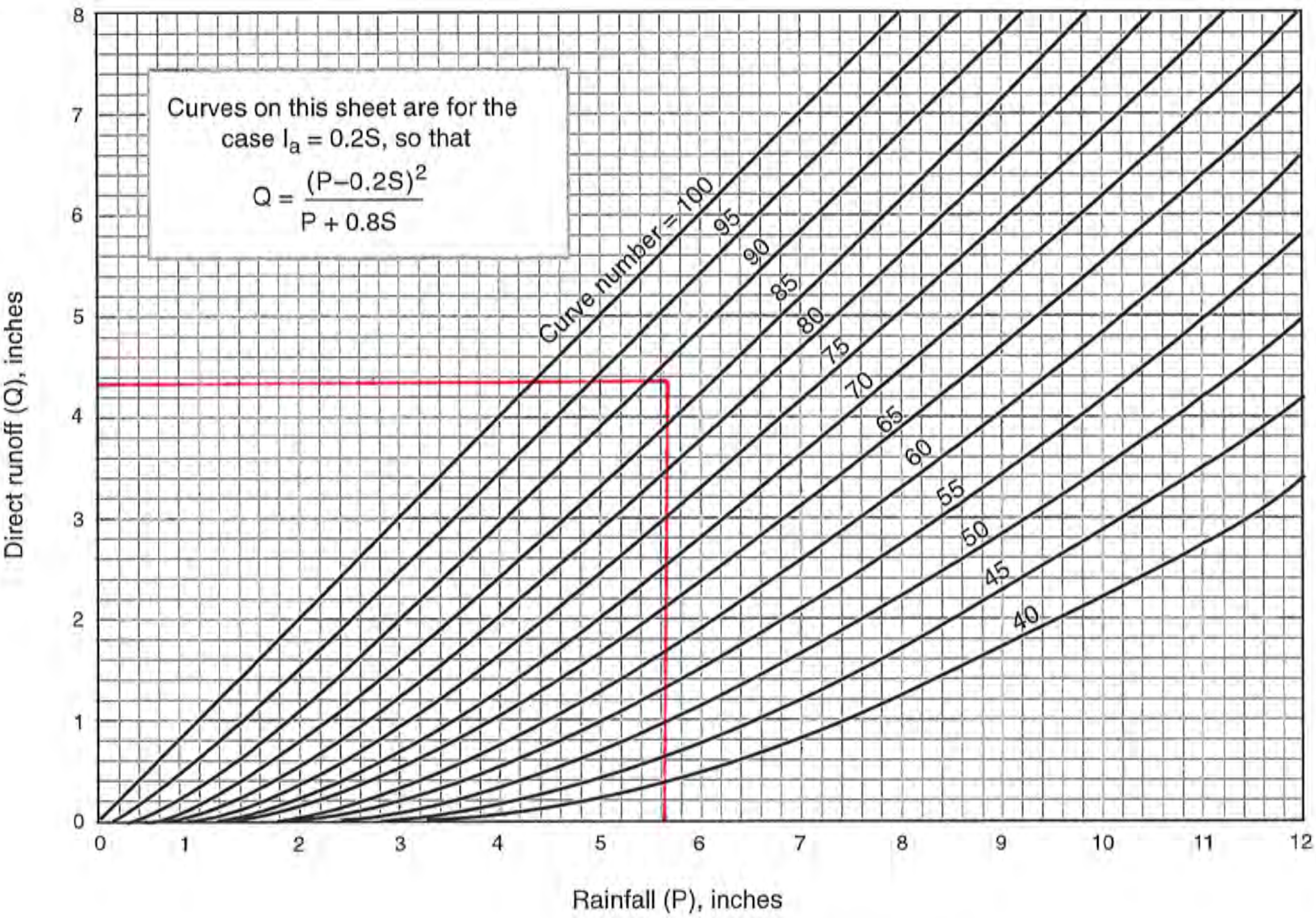
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use CN = 30 for runoff computations.

5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Figure 2-1 Solution of runoff equation.



Cover type

Table 2-2 addresses most cover types, such as vegetation, bare soil, and impervious surfaces. There are a number of methods for determining cover type. The most common are field reconnaissance, aerial photographs, and land use maps.

Treatment

Treatment is a cover type modifier (used only in table 2-2b) to describe the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced or no tillage.

Hydrologic condition

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant and residue cover on sample areas. *Good* hydrologic condition indicates that the soil usually has a low runoff potential for that specific hydrologic soil group, cover type, and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are (a) canopy or density of lawns, crops, or other vegetative areas; (b) amount of year-round cover; (c) amount of grass or close-seeded legumes in rotations; (d) percent of residue cover; and (e) degree of surface roughness.

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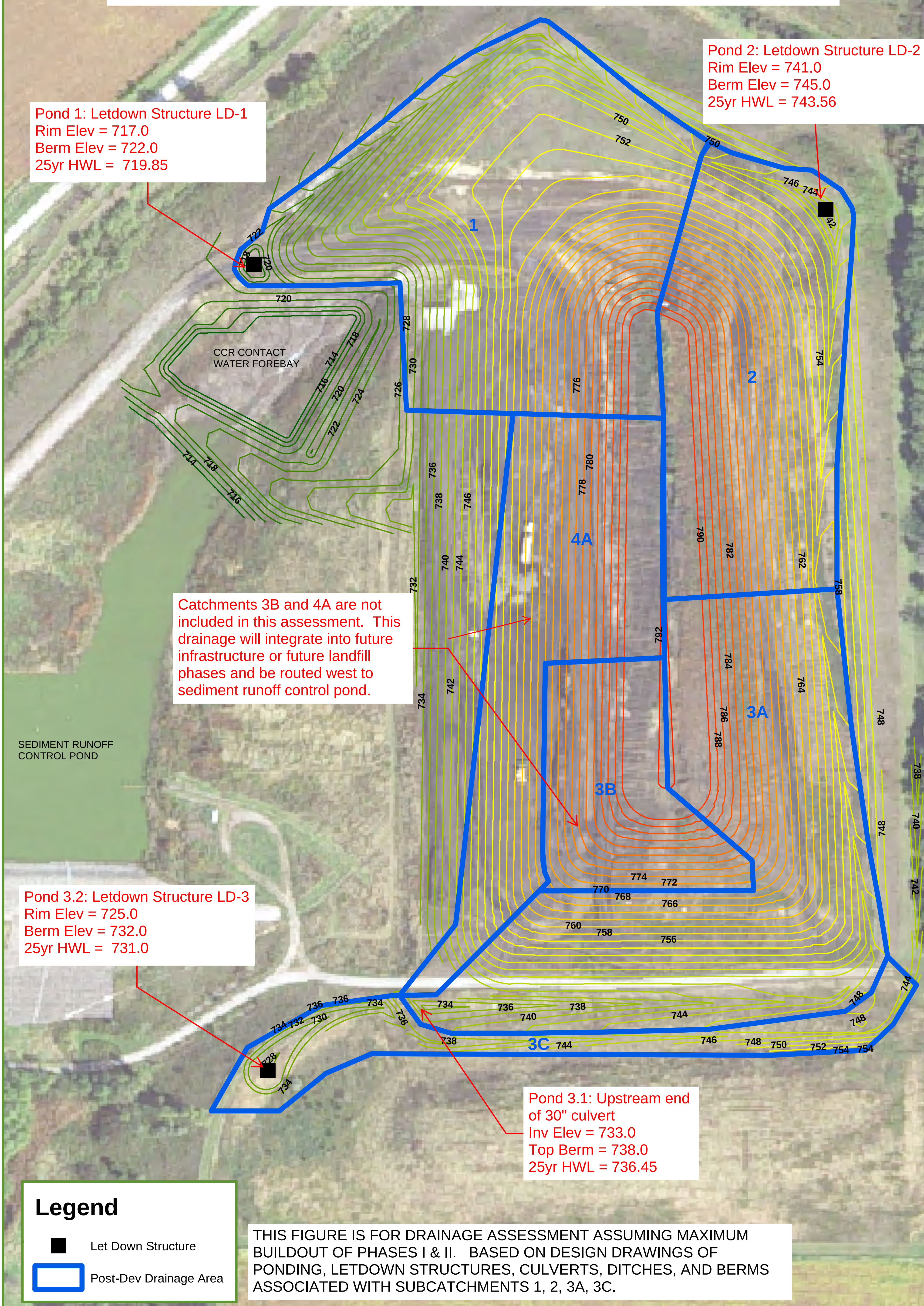
APPENDIX B

PHASE I&II FINAL BUILDOUT CONDITION HYDROCAD ANALYSIS

EXHIBIT 1 - CATCHMENT AND PONDING DIAGRAM



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PHASE I & II POST DEVELOPMENT DRAINAGE ASSESSMENT

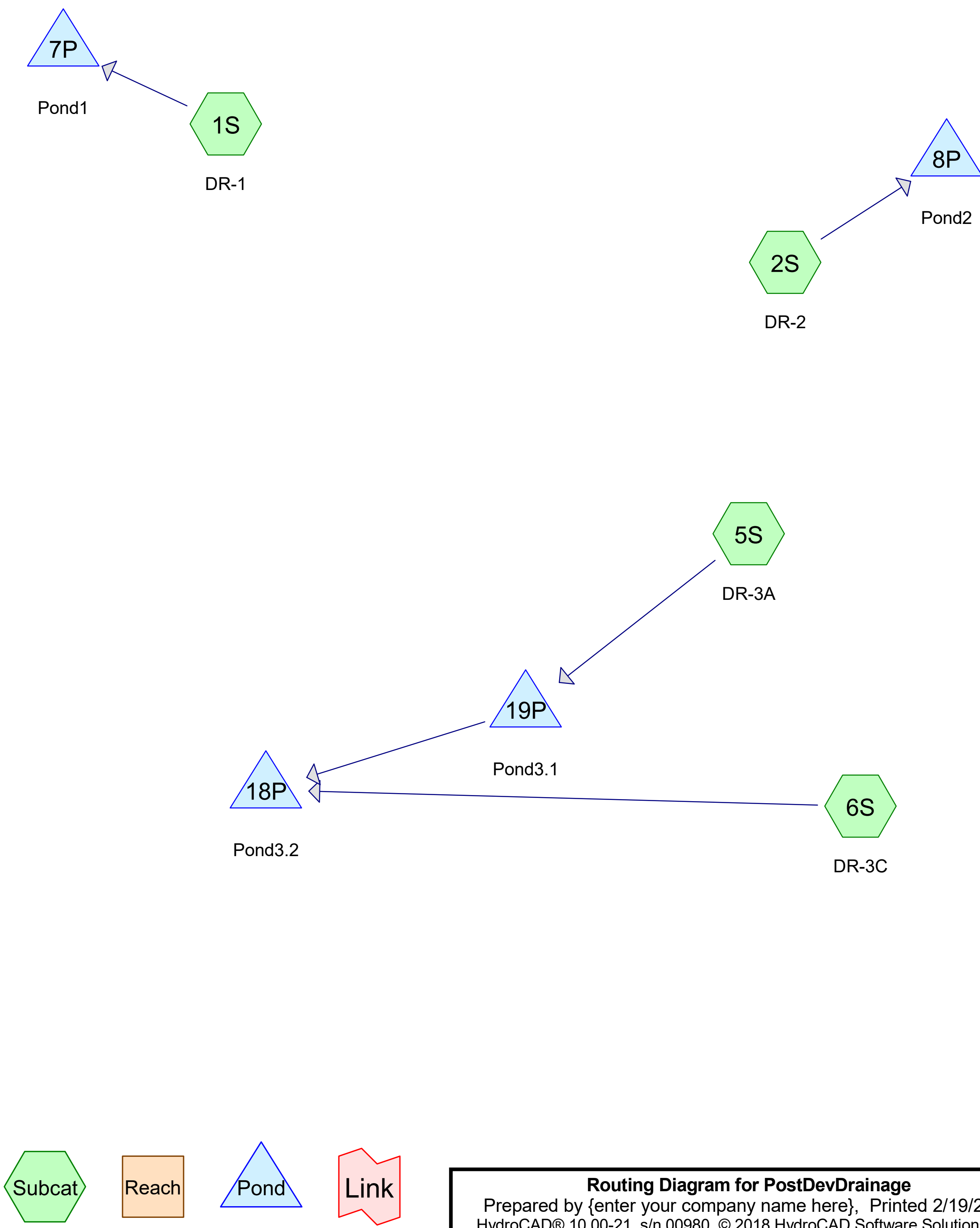
MUSCATINE POWER AND WATER CCR LANDFILL

N W E S

0 125 250 Feet

1 inch = 125 feet

HRG PLOT: 1:28:03 PM 2/12/2019 BY: cduntem FILE: \\hrgcrnas\data\10100095.06\GIS\MXD\Aerial11x17P.mxd



Routing Diagram for PostDevDrainage
Prepared by {enter your company name here}, Printed 2/19/2019

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
13.130	84	(1S, 2S, 5S, 6S)
13.130	**84**	**TOTAL AREA**

Pipe Listing (selected nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	19P	734.00	733.00	100.0	0.0100	0.013	30.0	0.0	0.0

Time span=3.00-62.00 hrs, dt=0.05 hrs, 1181 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 1S: DR-1 Runoff Area=3.780 ac 0.00% Impervious Runoff Depth=3.85"
CATCHMENT OF LET DOWN STRUCTURE LD-1 Tc=7.7 min CN=84 Runoff=23.31 cfs 1.213 af

Subcatchment 2S: DR-2 Runoff Area=3.390 ac 0.00% Impervious Runoff Depth=3.85"
CATCHMENT OF LET DOWN STRUCTURE LD-2 Tc=8.1 min CN=84 Runoff=20.65 cfs 1.088 af

Subcatchment 5S: DR-3A Runoff Area=4.750 ac 0.00% Impervious Runoff Depth=3.85"
CATCHMENT UPSTREAM OF 30" CULVERT AND LD-3 Tc=12.4 min CN=84 Runoff=25.11 cfs 1.525 af

Subcatchment 6S: DR-3C Runoff Area=1.210 ac 0.00% Impervious Runoff Depth=3.85"
ADDITIONAL CATCHMENT OF LET DOWN STRUCTURE LD-3 Tc=20.2 min CN=84 Runoff=5.08 cfs 0.388 af

Pond 7P: Pond1 Peak Elev=719.85' Storage=2,156 cf Inflow=23.31 cfs 1.213 af
POND FOR LET DOWN STRUCTURE LD-1 Outflow=20.63 cfs 1.213 af

Pond 8P: Pond2 Peak Elev=743.56' Storage=1,358 cf Inflow=20.65 cfs 1.088 af
POND FOR LET DOWN STRUCTURE LD-2 Outflow=18.92 cfs 1.088 af

Pond 18P: Pond3.2 Peak Elev=730.32' Storage=4,883 cf Inflow=27.91 cfs 1.913 af
POND FOR LET DOWN STRUCTURE LD-3 Outflow=23.05 cfs 1.913 af

Pond 19P: Pond3.1 Peak Elev=736.45' Storage=3,092 cf Inflow=25.11 cfs 1.525 af
DITCH PONDING AT 30" CULVERT lvert n=0.013 L=100.0' S=0.0100 '/' Outflow=23.00 cfs 1.525 af

Total Runoff Area = 13.130 ac Runoff Volume = 4.214 af Average Runoff Depth = 3.85"
100.00% Pervious = 13.130 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1S: DR-1

CATCHMENT OF LET DOWN STRUCTURE LD-1

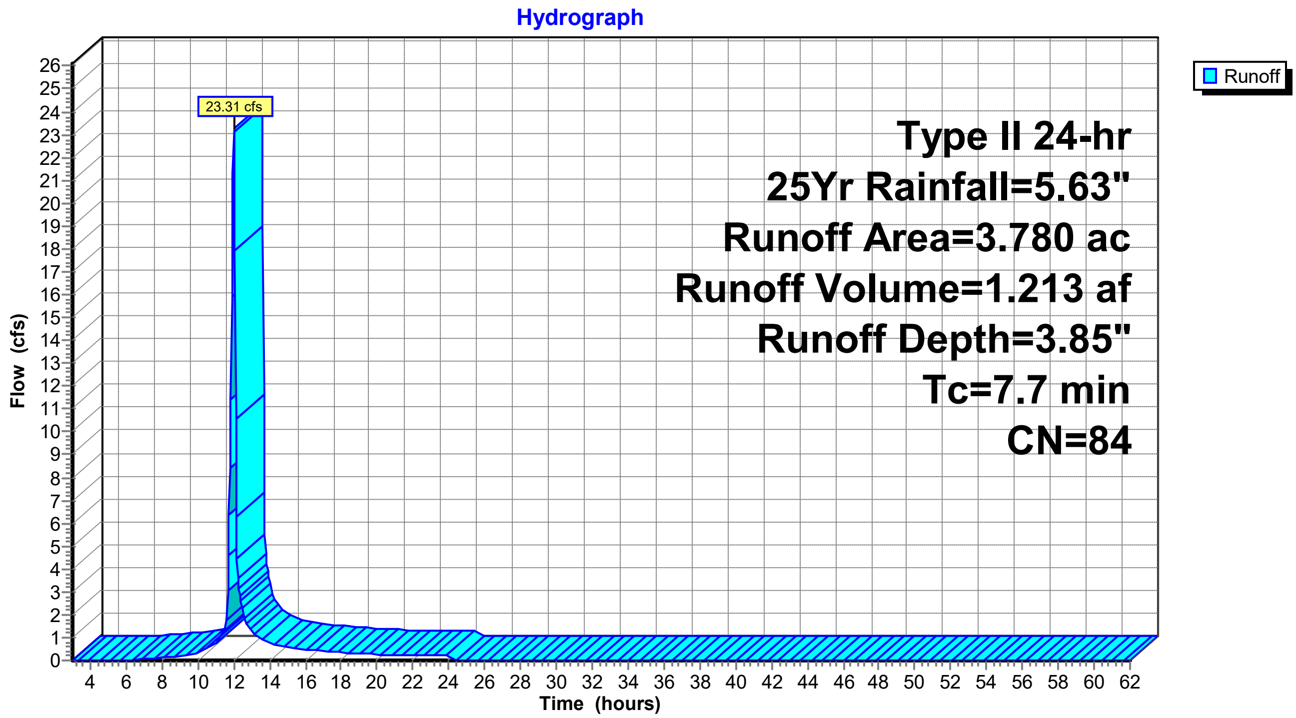
Runoff = 23.31 cfs @ 11.99 hrs, Volume= 1.213 af, Depth= 3.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Type II 24-hr 25Yr Rainfall=5.63"

	Area (ac)	CN	Description
*	3.780	84	
	3.780		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.7					**Direct Entry,**

Subcatchment 1S: DR-1



Summary for Subcatchment 2S: DR-2

CATCHMENT OF LET DOWN STRUCTURE LD-2

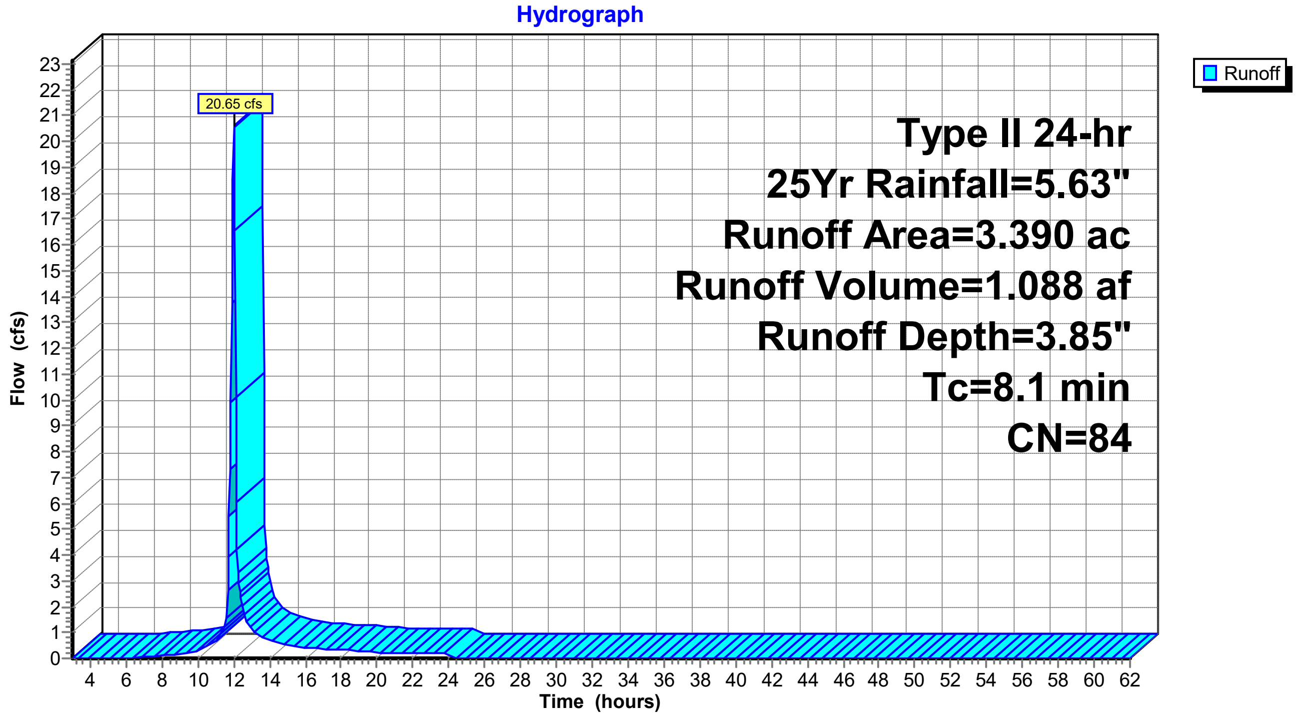
Runoff = 20.65 cfs @ 11.99 hrs, Volume= 1.088 af, Depth= 3.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Type II 24-hr 25Yr Rainfall=5.63"

	Area (ac)	CN	Description
*	3.390	84	
	3.390		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.1					**Direct Entry,**

Subcatchment 2S: DR-2



Summary for Subcatchment 5S: DR-3A CATCHMENT OF 30" CULVERT

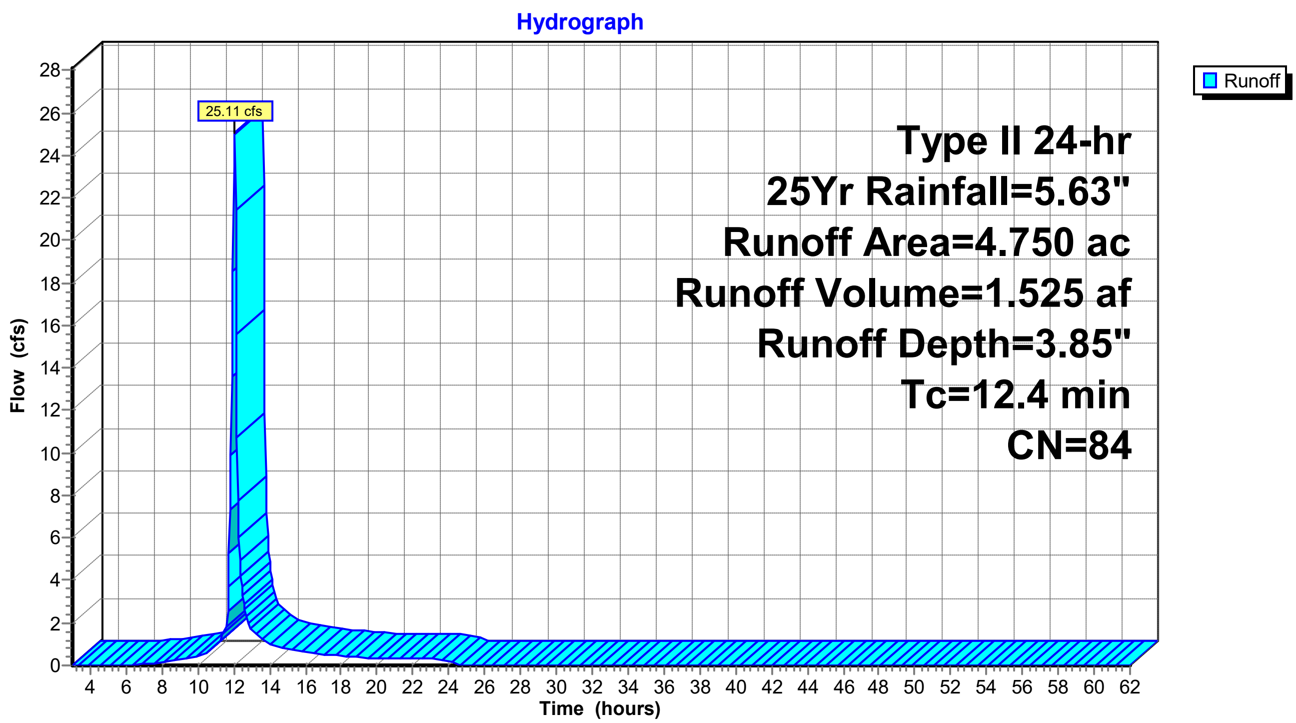
Runoff = 25.11 cfs @ 12.04 hrs, Volume= 1.525 af, Depth= 3.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Type II 24-hr 25Yr Rainfall=5.63"

	Area (ac)	CN	Description
*	4.750	84	
	4.750		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.4					**Direct Entry,**

Subcatchment 5S: DR-3A



Summary for Subcatchment 6S: DR-3C

ADDITIONAL CATCHMENT SOUTH OF SERVICE ROAD TO LD-3

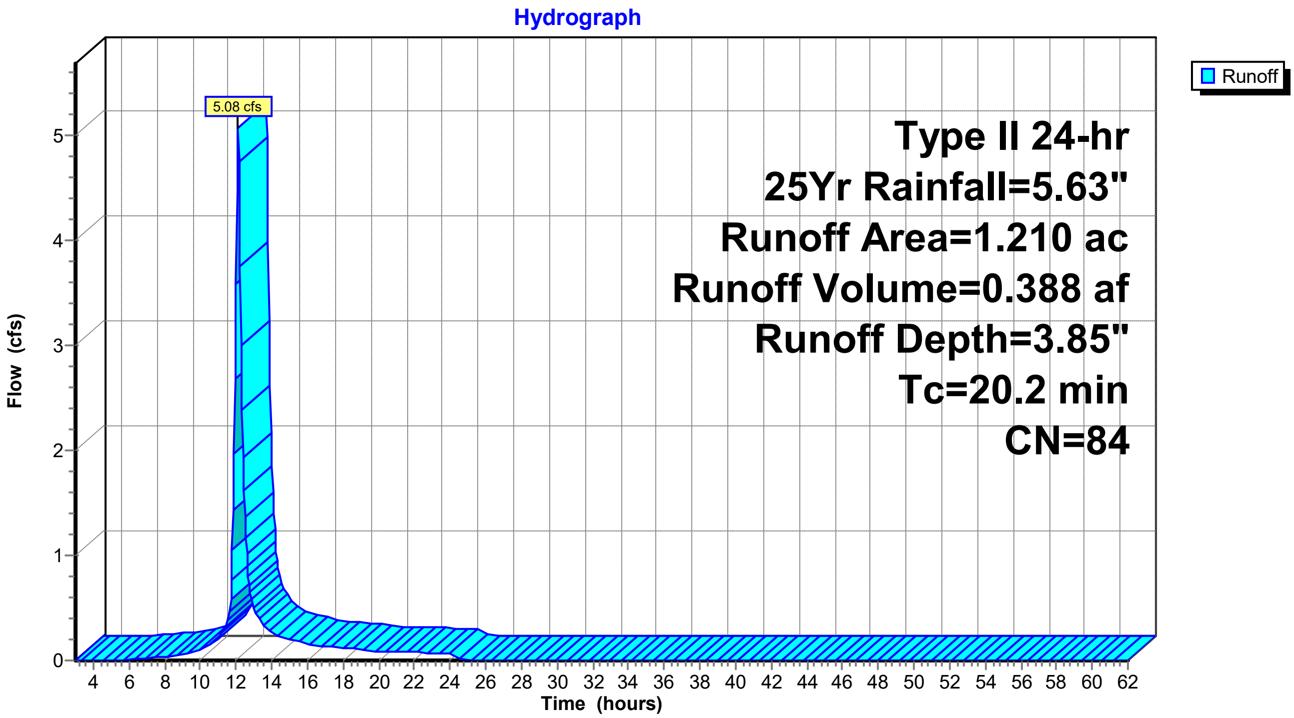
Runoff = 5.08 cfs @ 12.12 hrs, Volume= 0.388 af, Depth= 3.85"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Type II 24-hr 25Yr Rainfall=5.63"

	Area (ac)	CN	Description
*	1.210	84	
	1.210		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.2					**Direct Entry,**

Subcatchment 6S: DR-3C



Summary for Pond 7P: Pond1

PONDING AT 24" LETDOWN STRUCTURE LD-1

Inflow Area = 3.780 ac, 0.00% Impervious, Inflow Depth = 3.85" for 25Yr event
Inflow = 23.31 cfs @ 11.99 hrs, Volume= 1.213 af
Outflow = 20.63 cfs @ 12.03 hrs, Volume= 1.213 af, Atten= 12%, Lag= 2.4 min
Primary = 20.63 cfs @ 12.03 hrs, Volume= 1.213 af

Routing by Dyn-Stor-Ind method, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Peak Elev= 719.85' @ 12.03 hrs Surf.Area= 1,523 sf Storage= 2,156 cf

Plug-Flow detention time= 1.8 min calculated for 1.212 af (100% of inflow)
Center-of-Mass det. time= 1.8 min (806.2 - 804.4)

Volume	Invert	Avail.Storage	Storage Description
#1	718.00'	7,295 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

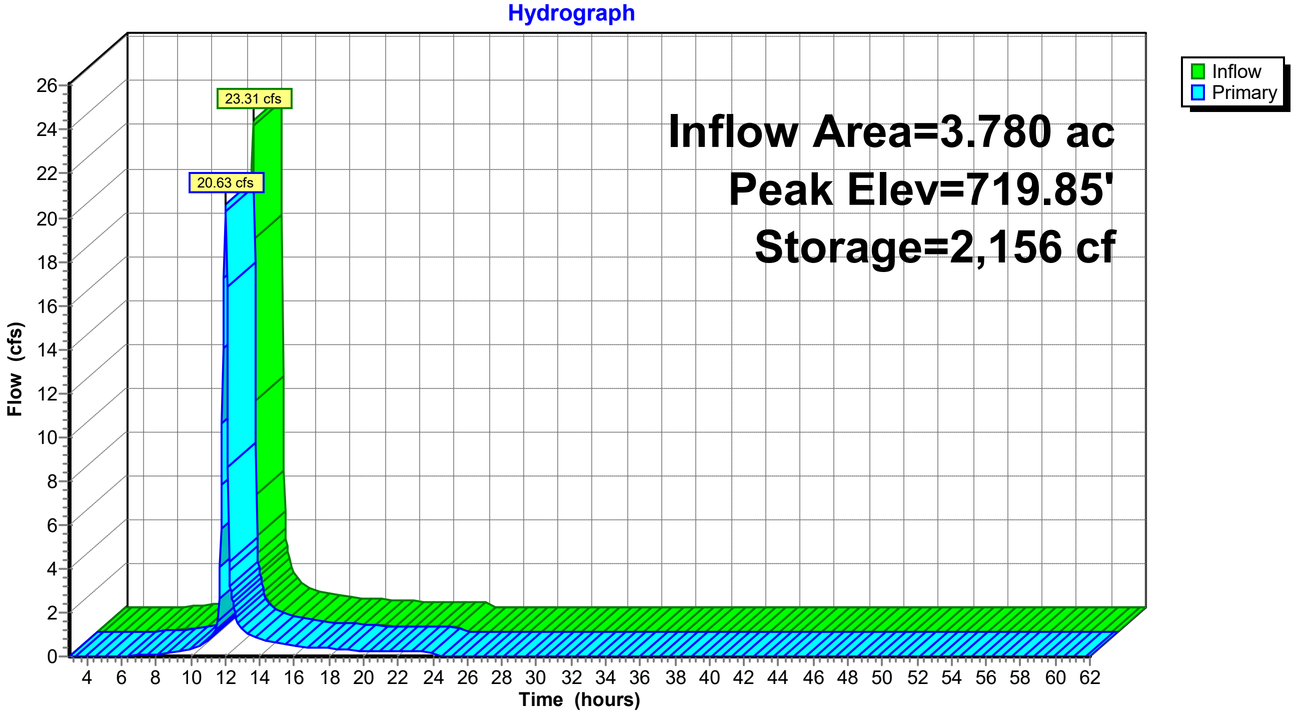
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
718.00	805	0	0
720.00	1,580	2,385	2,385
722.00	3,330	4,910	7,295

Device	Routing	Invert	Outlet Devices
#1	Primary	718.00'	**24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=20.17 cfs @ 12.03 hrs HW=719.78' (Free Discharge)
└─**1=Orifice/Grate** (Orifice Controls 20.17 cfs @ 6.42 fps)

Pond 7P: Pond1

PONDING AT 24" LETDOWN STRUCTURE LD-1



Summary for Pond 8P: Pond2

PONDING AT 24" LETDOWN STRUCTURE LD-2

Inflow Area = 3.390 ac, 0.00% Impervious, Inflow Depth = 3.85" for 25Yr event
Inflow = 20.65 cfs @ 11.99 hrs, Volume= 1.088 af
Outflow = 18.92 cfs @ 12.03 hrs, Volume= 1.088 af, Atten= 8%, Lag= 2.1 min
Primary = 18.92 cfs @ 12.03 hrs, Volume= 1.088 af

Routing by Dyn-Stor-Ind method, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Peak Elev= 743.56' @ 12.03 hrs Surf.Area= 1,270 sf Storage= 1,358 cf

Plug-Flow detention time= 1.1 min calculated for 1.087 af (100% of inflow)
Center-of-Mass det. time= 1.2 min (805.9 - 804.8)

Volume	Invert	Avail.Storage	Storage Description
#1	742.00'	7,638 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

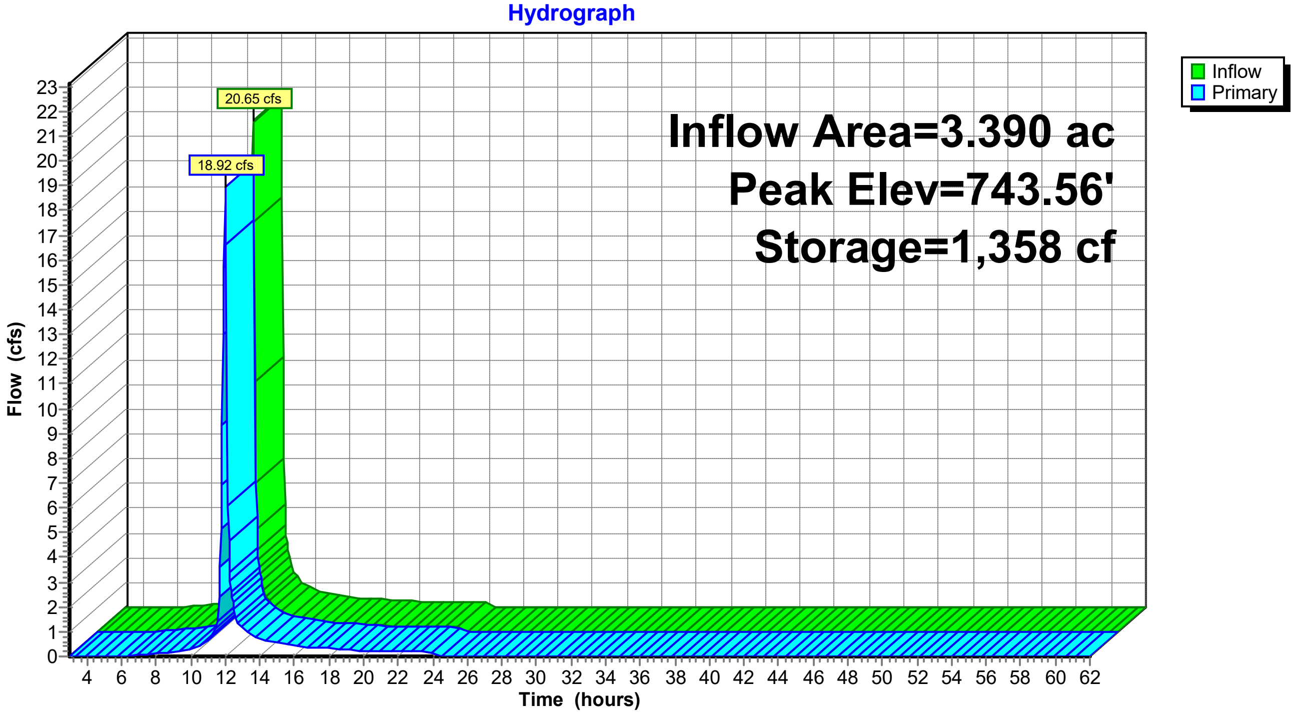
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
742.00	475	0	0
744.00	1,496	1,971	1,971
746.00	4,171	5,667	7,638

Device	Routing	Invert	Outlet Devices
#1	Primary	742.00'	**24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=18.45 cfs @ 12.03 hrs HW=743.49' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 18.45 cfs @ 5.87 fps)

Pond 8P: Pond2

PONDING AT 24" LETDOWN STRUCTURE LD-2



Summary for Pond 18P: Pond3.2

PONDING AT 24" LETDOWN STRUCTURE LD-3

Inflow Area = 5.960 ac, 0.00% Impervious, Inflow Depth = 3.85" for 25Yr event
Inflow = 27.91 cfs @ 12.09 hrs, Volume= 1.913 af
Outflow = 23.05 cfs @ 12.17 hrs, Volume= 1.913 af, Atten= 17%, Lag= 4.9 min
Primary = 23.05 cfs @ 12.17 hrs, Volume= 1.913 af

Routing by Dyn-Stor-Ind method, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Peak Elev= 730.32' @ 12.17 hrs Surf.Area= 3,897 sf Storage= 4,883 cf

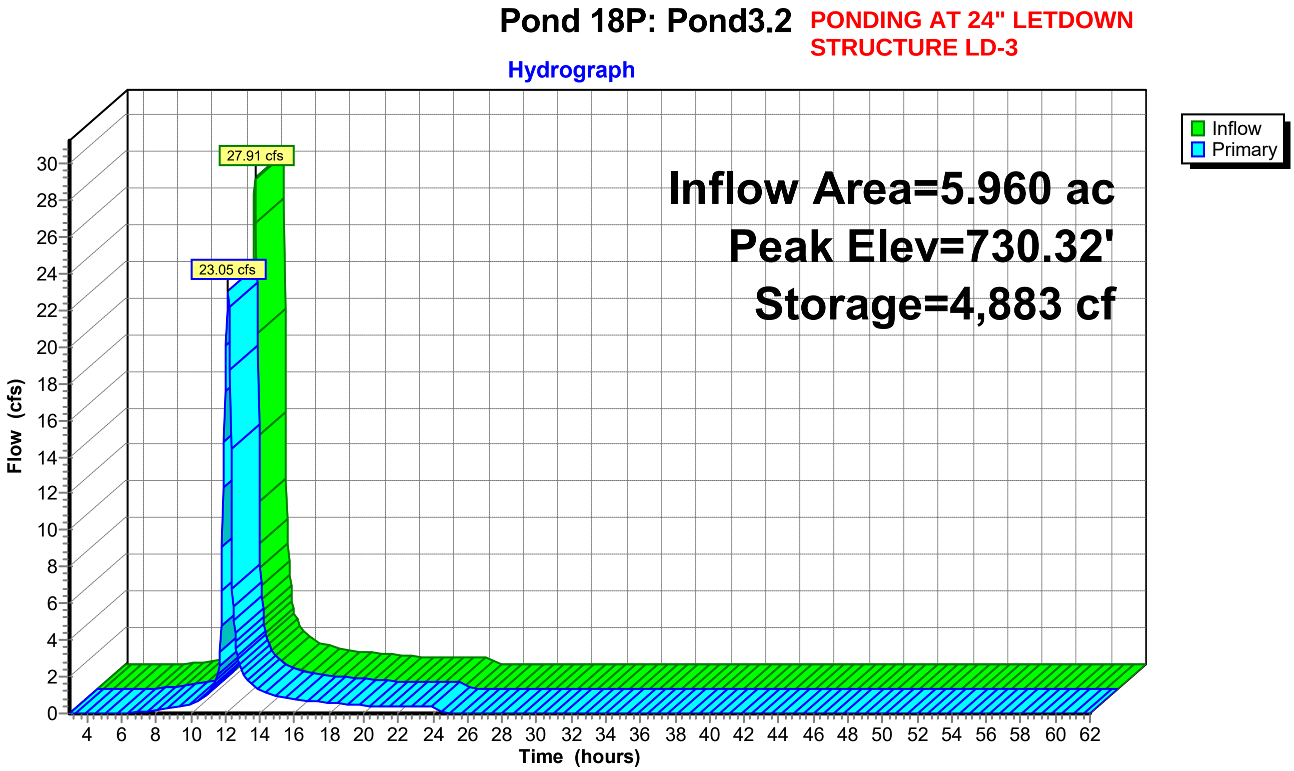
Plug-Flow detention time= 1.5 min calculated for 1.911 af (100% of inflow)
Center-of-Mass det. time= 1.5 min (813.6 - 812.2)

Volume	Invert	Avail.Storage	Storage Description
#1	728.00'	13,416 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
728.00	261	0	0
730.00	3,441	3,702	3,702
732.00	6,273	9,714	13,416

Device	Routing	Invert	Outlet Devices
#1	Primary	728.00'	**24.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=22.92 cfs @ 12.17 hrs HW=730.30' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 22.92 cfs @ 7.29 fps)


Pond 18P: Pond3.2
PONDING AT 24" LETDOWN STRUCTURE LD-3
Hydrograph
Inflow
Primary
27.91 cfs
23.05 cfs
Inflow Area=5.960 ac
Peak Elev=730.32'
Storage=4,883 cf
Flow (cfs)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Time (hours)
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62

Summary for Pond 19P: Pond3.1

DITCH PONDING UPSTREAM OF 30" CULVERT

Inflow Area =	4.750 ac,	0.00% Impervious, Inflow Depth = 3.85"	for 25Yr event	
Inflow =	25.11 cfs @	12.04 hrs, Volume=	1.525 af	
Outflow =	23.00 cfs @	12.08 hrs, Volume=	1.525 af,	Atten= 8%, Lag= 2.5 min
Primary =	23.00 cfs @	12.08 hrs, Volume=	1.525 af	

Routing by Dyn-Stor-Ind method, Time Span= 3.00-62.00 hrs, dt= 0.05 hrs
Peak Elev= 736.45' @ 12.08 hrs Surf.Area= 2,647 sf Storage= 3,092 cf

Plug-Flow detention time= 2.4 min calculated for 1.523 af (100% of inflow)
Center-of-Mass det. time= 2.5 min (811.2 - 808.7)

Volume	Invert	Avail.Storage	Storage Description
#1	734.00'	9,280 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

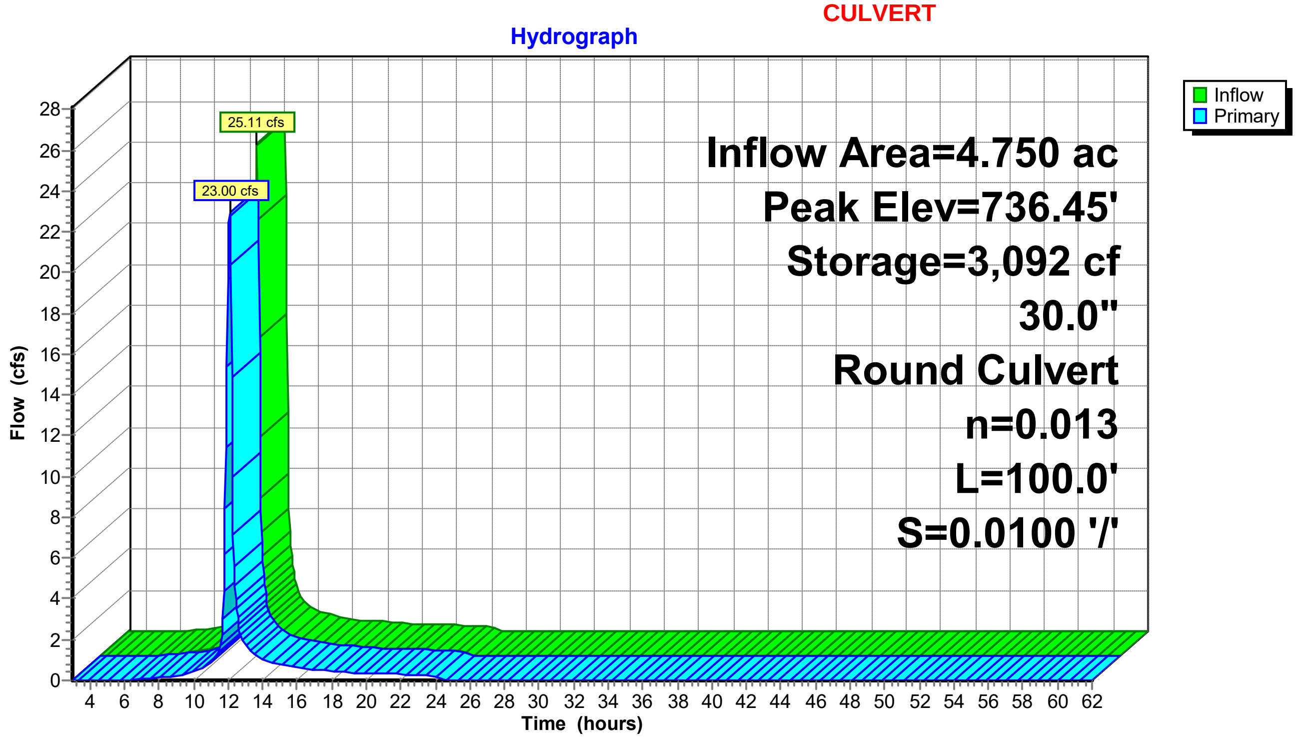
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
734.00	204	0	0
736.00	1,876	2,080	2,080
738.00	5,324	7,200	9,280

Device	Routing	Invert	Outlet Devices
#1	Primary	734.00'	**30.0" Round Culvert** L= 100.0' CMP, mitered to conform to fill, Ke= 0.700 Inlet / Outlet Invert= 734.00' / 733.00' S= 0.0100 '/' Cc= 0.900 n= 0.013 Corrugated PE, smooth interior, Flow Area= 4.91 sf

Primary OutFlow Max=22.68 cfs @ 12.08 hrs HW=736.42' TW=729.98' (Dynamic Tailwater)
↑—**1=Culvert** (Inlet Controls 22.68 cfs @ 4.67 fps)

Pond 19P: Pond3.1

DITCH PONDING UPSTREAM OF 30" CULVERT



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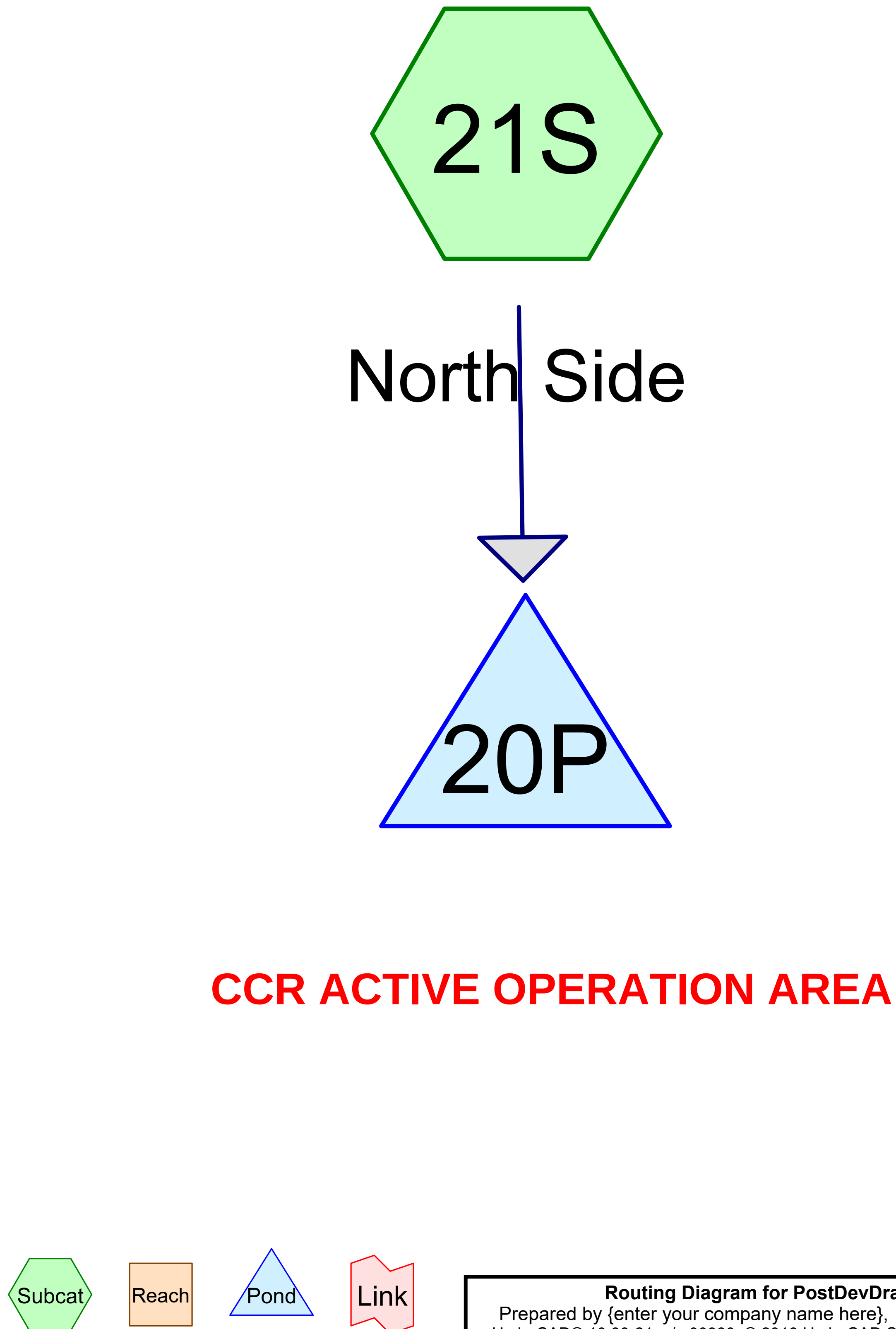
APPENDIX C

ACTIVE OPERATIONS AREA - CURRENT CONDITIONS HYDROCAD ANALYSIS



Routing Diagram for PostDevDrainage
Prepared by {enter your company name here}, Printed 2/18/2019

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
4.860	98	(21S)
4.860	**98**	**TOTAL AREA**

Time span=3.00-100.00 hrs, dt=0.05 hrs, 1941 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment21S: **CCR ACTIVE OPERATION AREA** Area=4.860 ac 100.00% Impervious Runoff Depth>5.34"
Tc=12.7 min CN=98 Runoff=31.31 cfs 2.161 af

Pond 20P: **CCR ACTIVE OPERATION AREA** Peak Elev=730.88' Storage=1.533 af Inflow=31.31 cfs 2.161 af
Outflow=0.96 cfs 2.095 af

Total Runoff Area = 4.860 ac Runoff Volume = 2.161 af Average Runoff Depth = 5.34"
0.00% Pervious = 0.000 ac 100.00% Impervious = 4.860 ac

Summary for Subcatchment 21S: CCR ACTIVE OPERATION AREA

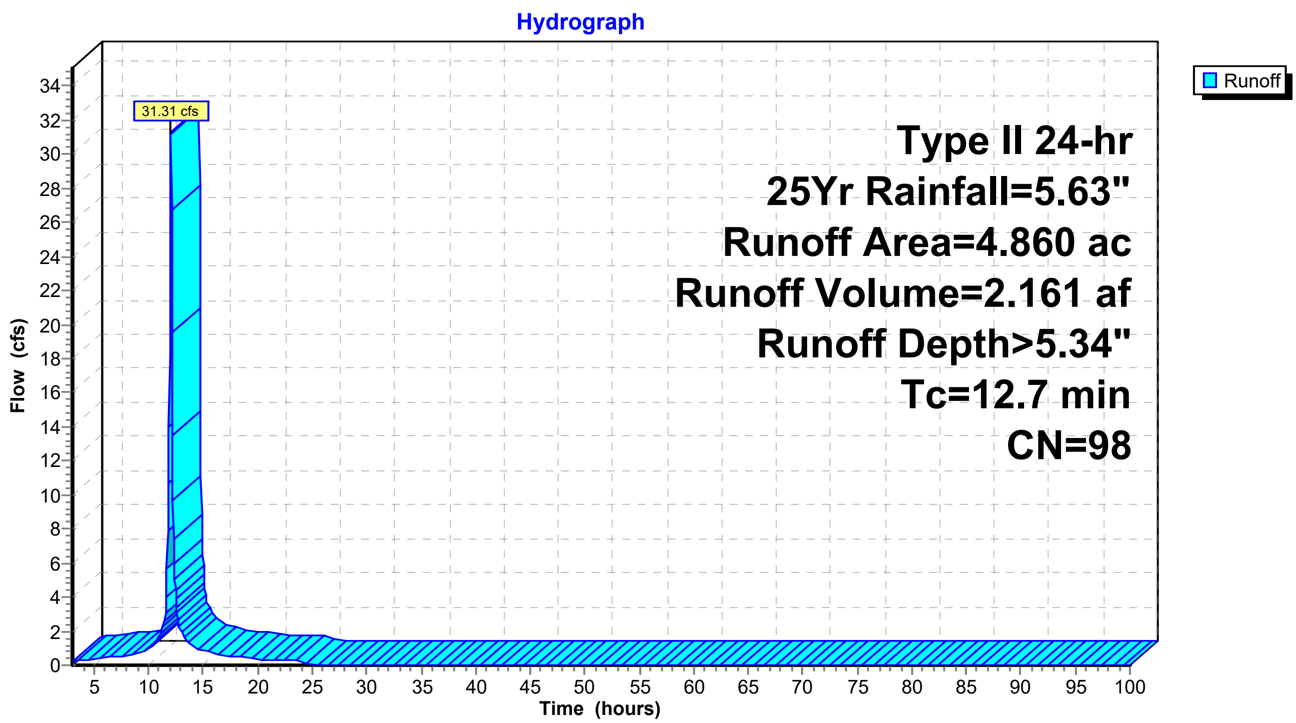
Runoff = 31.31 cfs @ 12.04 hrs, Volume= 2.161 af, Depth> 5.34"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 3.00-100.00 hrs, dt= 0.05 hrs
Type II 24-hr 25Yr Rainfall=5.63"

	Area (ac)	CN	Description
*	4.860	98	
	4.860		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.7					**Direct Entry,**

Subcatchment 21S: CCR ACTIVE OPERATION AREA



Summary for Pond 20P: CCR ACTIVE OPERATION AREA

[82] Warning: Early inflow requires earlier time span

Inflow Area = 4.860 ac,100.00% Impervious, Inflow Depth > 5.34" for 25Yr event
Inflow = 31.31 cfs @ 12.04 hrs, Volume= 2.161 af
Outflow = 0.96 cfs @ 14.51 hrs, Volume= 2.095 af, Atten= 97%, Lag= 148.3 min
Primary = 0.96 cfs @ 14.51 hrs, Volume= 2.095 af

Routing by Dyn-Stor-Ind method, Time Span= 3.00-100.00 hrs, dt= 0.05 hrs
Peak Elev= 730.88' @ 14.51 hrs Surf.Area= 1.514 ac Storage= 1.533 af

Plug-Flow detention time= 1,173.7 min calculated for 2.094 af (97% of inflow)
Center-of-Mass det. time= 1,153.5 min (1,908.0 - 754.6)

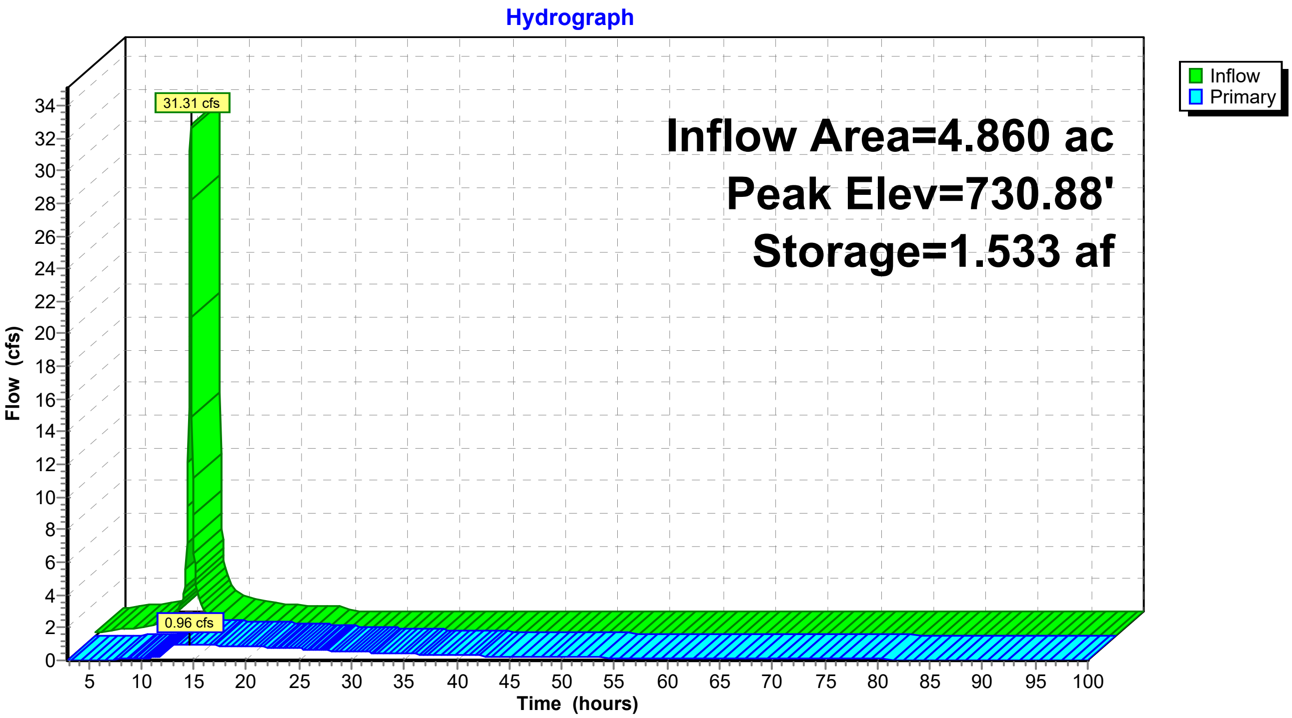
Volume	Invert	Avail.Storage	Storage Description
#1	729.00'	8.075 af	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
729.00	0.210	0.000	0.000
730.00	0.810	0.510	0.510
731.00	1.610	1.210	1.720
732.00	2.100	1.855	3.575
734.00	2.400	4.500	8.075

Device	Routing	Invert	Outlet Devices
#1	Primary	729.00'	**0.4" Vert. Orifice/Grate X 10.00 columns** X 30 rows with 2.0" cc spacing C= 0.600
#2	Primary	729.50'	**0.4" Vert. Orifice/Grate X 10.00 columns** X 30 rows with 2.0" cc spacing C= 0.600
#3	Primary	730.00'	**0.4" Vert. Orifice/Grate X 10.00 columns** X 30 rows with 2.0" cc spacing C= 0.600
#4	Primary	730.50'	**0.4" Vert. Orifice/Grate X 10.00 columns** X 30 rows with 2.0" cc spacing C= 0.600

Primary OutFlow Max=0.96 cfs @ 14.51 hrs HW=730.88' (Free Discharge)
- **1=Orifice/Grate** (Orifice Controls 0.46 cfs @ 4.37 fps)
- **2=Orifice/Grate** (Orifice Controls 0.29 cfs @ 3.74 fps)
- **3=Orifice/Grate** (Orifice Controls 0.16 cfs @ 2.98 fps)
- **4=Orifice/Grate** (Orifice Controls 0.05 cfs @ 1.96 fps)

Pond 20P: CCR ACTIVE OPERATION AREA



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APPENDIX D

LANDFILL SURFACE DRAINAGE CALCULATIONS – 1991

These calculations are taken from the following document:
Green Environmental Services, Inc., Supporting Documentation for Muscatine Power and Water Coal Combustion Residue Landfill, 1991.

APPENDIX B

SURFACE DRAINAGE CALCULATIONS

North Slope Drainage Analysis

Area 1:

Time of concentration from furthest tributary point:

A. Overland flow

Slope length: 150 ft
Slope: 13 / 150 = 8.67%
From Seelye Design nomograph for poor grass:

tc = 8.65 min.

B. Channelized flow — From: Marion - Storm Water Management Design Manual 1985

Slope: 1.15%
channel length: 521 ft — V = 1.6 fps

$$t_c = \frac{521}{1.6 \times 60} = 5.43$$

C. Let Down Structure flow

Slope length: 420 ft
Slope: 84 / 420 = 20.0%
From Seelye Design nomograph for poor grass:

tc = 7.80 min.

tc_{total} = 8.65 + 5.43 + 7.80 = 21.88 min.

Intensity:

i = 5.0 in/hr (100 year storm, Des Moines)

2.6 in/hr 25 year storm

Area 1 calculations:
A_1 = 0.5*157*(347+180)+0.5*285*100+0.5*162*372 = 71,620 ft^2
= 1.64 acres

Runoff coefficient:
c = 0.80 (steep grassed area)

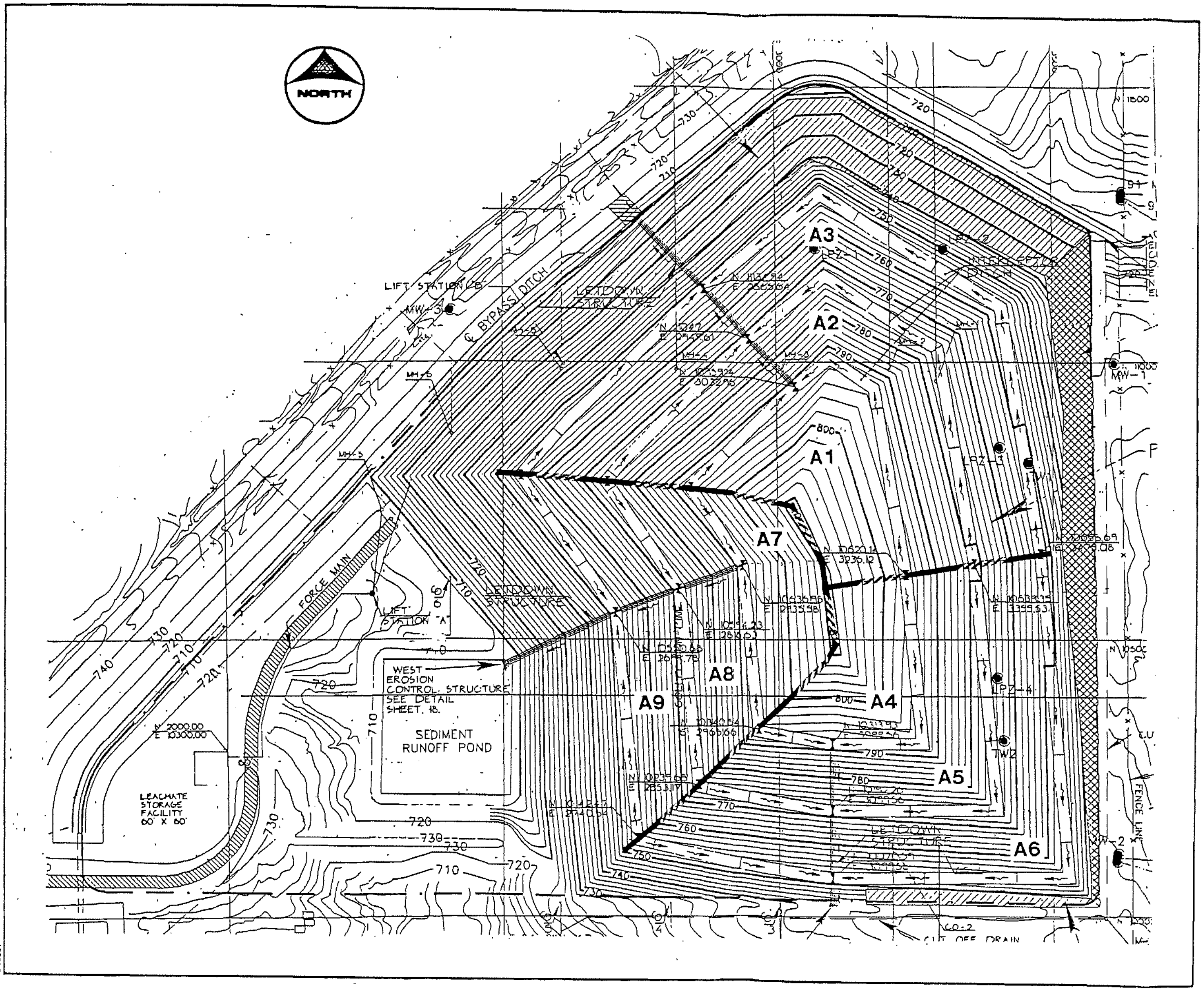

FIGURE B - 1

DRAINAGE AREAS

MUSCATINE
POWER AND WATER
CCR LANDFILL

MUSCATINE, IOWA

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Green
Environmental
Services, Inc.

545857

Peak flow:

$Q_1 = ciA_1$
$= 0.80 \times 5.0 \times 1.64 = \underline{6.56 \text{ cfs}}$

Channel Design Check

$$A=\frac{7}{2}\times d^2$$

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

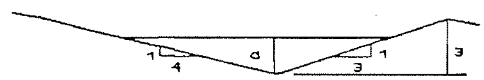
$$WP=\sqrt{d^2+9d^2}+\sqrt{d^2+16d^2}$$

$$=d(\sqrt{10}+\sqrt{17})$$

$$R=\frac{A}{WP}$$

Assume
$d = 1$ ft
$S_o = 1\%$

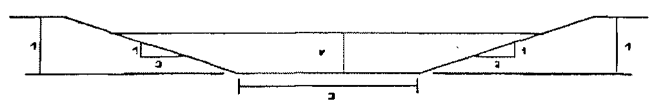
$A = 3.50 \text{ ft}^2$
$WP = 7.29$ ft
$R = 0.48$ ft



$Q = 10.66 \text{ cfs} > 6.56 \text{ cfs}$ Design OK

Let Down Structure Design

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



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

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: $n = 0.03$ $b = 3$ ft
$S_o = 20\%$ $Q = 6.56$ cfs

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.016$$

From design nomograph for open channel hydraulics:

$y/b = 0.08$ <u>y = 0.24 ft</u>

$A = (3 + 3(0.24))*0.24$
$= 0.89\ ft^2$

$$V=\frac{Q}{A}=\frac{6.56}{0.89}=7.35fps$$

Therefore use: <u>3 ft x 3 ft x 3 ft</u> let down structure

<u>Area 2:</u>

Time of concentration from furthest tributary point:

A. Overland flow

Slope length: 112 ft
Slope: 18 / 112 = 16%
From Seelye Design nomograph for poor grass:

tc = 6.9 min.

B. Channel flow — From: Marion - Storm Water Management Design Manual 1985

Slope: 1.17%
channel length: 815 ft — V = 1.65 fps

$$t_c=\frac{815}{1.65\times60}=8.23\text{min.}$$

C. Let Down Structure flow

Slope length: 300 ft
Slope: 60 / 300 = 20%
From Seelye Design nomograph for poor grass:

tc = 6.80 min.

$tc_{total} = 6.90 + 8.23 + 6.80 =$ <u>21.93 min.</u>

Intensity:

i = 5.0 in/hr (100 year storm, Des Moines)

Area 2 calculations:

$A_2 = 0.5*121*750+0.5*121*363+0.5*121*278+0.5*121*660 =$ <u>124,085 ft²</u>
$=$ <u>2.85 acres</u>

Runoff coefficient:

$c = 0.80$ (steep grassed area)

Peak flow:

$Q_2 = ciA_2$

$= 0.5 \times 5.0 \times 2.85 = \underline{11.40 \text{ cfs}}$

Channel Design Check

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

Assume

$d = 1.5$ ft $\quad S_o = 1\%$

$A = 7.88 \text{ ft}^2$

$WP = 10.93$ ft

$R = 0.72$ ft

$Q = 31.46$ cfs > 11.40 cfs $\quad$ Design OK

Let Down Structure Design

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: $n = 0.03$ $\quad b = 3$ ft

$S_o = 20\%$

Total flow: $Q_{1,2} = Q_1 + Q_2 = 6.56 + 11.40 = \underline{17.96 \text{ cfs}}$

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.043$$

From design nomograph for open channel hydraulics:

$y/b = 0.15$ $\quad \underline{y = 0.45 \text{ ft}}$

$A = (3 + 3(0.45))*0.45$

$= 1.96 \text{ ft}^2$

$$V=\frac{Q}{A}=\frac{17.96}{1.96}=9.17\,fps$$

Therefore use: 3 ft x 3 ft x 3 ft let down structure

Area 3:

Time of concentration from furthest tributary point:

A. Overland flow

Slope length: 112 ft
Slope: 17 / 112 = 15.18%
From Seelye Design nomograph for poor grass:

tc = 6.95 min.

B. Channel flow — From: Marion - Storm Water Management Design Manual 1985

Slope: 1.08%
channel length: 1110 ft — V = 1.5 fps

$$t_c = \frac{1110}{1.5 \times 60} = 12.33 \text{min.}$$

C. Let Down Structure flow

Slope length: 180 ft
Slope: 36 / 180 = 20.00%
From Seelye Design nomograph for poor grass:

tc = 5.00 min.

tc_{total} = 6.95 + 12.33 + 5.00 = 24.28 min.

Intensity:

i = 5.0 in/hr (100 year storm, Des Moines)

Area 3 calculations:

A_3 = 121*1225+0.5*182*84+0.5*155*146+0.5*135*102 = 174,472 ft^2
= 4.01 acres

Runoff coefficient:
c = 0.80 (steep grassed area)

Peak flow:

$Q_3 = ciA_3$
$= 0.80 \times 5.0 \times 4.01 = \underline{16.04\ cfs}$

Channel Design Check

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

Assume

d = 1.5 ft $\quad S_o = 1\%$

A = 7.88 ft²
WP = 10.93 ft
R = 0.72 ft

Q = 31.46 cfs > 16.04 cfs $\quad$ Design OK

Let Down Structure Design

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: n = 0.03 $\quad$ b = 3 ft
$S_o = 20\%$

Total flow: $Q = Q_{1,2} + Q_3 = 17.96 + 16.04 = \underline{34.0\ cfs}$

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.082$$

From design nomograph for open channel hydraulics:

y/b = 0.20 $\quad$ <u>y = 0.60 ft</u>

A = (3 + 3(0.60))*0.60
= 2.88 ft²

$$V=\frac{Q}{A}=\frac{34.0}{2.88}=11.81 fps$$

Therefore use: <u>3 ft x 3 ft x 3 ft</u> let down structure

South Slope Drainage Analysis

Area 4:

Time of concentration from furthest tributary point:

A. Overland flow

Slope length: 150 ft
Slope: 13 / 150 = 8.67%
From Seelye Design nomograph for poor grass:

tc = 8.65 min.

B. Channel flow — From: Marion - Storm Water Management Design Manual 1985

Slope: 1.26%
channel length: 478 ft — V = 1.7 fps

$$t_c = \frac{478}{1.7 \times 60} = 4.69 \text{min.}$$

C. Let Down Structure flow

Slope length: 280 ft
Slope: 56 / 280 = 20.00%
From Seelye Design nomograph for poor grass:

tc = 6.60 min.

tc_{total} = 8.65 + 4.69 + 6.60 = 19.94 min.

Intensity:

i = 5.55 in/hr (100 year storm, Des Moines)

Area 4 calculations:

A_4 = 0.5*321*160+0.5*152*(320+143)+0.5*321*14 = 63,115 ft^2
= 1.45 acres

Runoff coefficient:
c = 0.80 (steep grassed area)

Peak flow:

Q_4 = ciA
= 0.80 x 5.55 x 1.45 = <u>6.44 cfs</u>

Channel Design Check

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

Assume
d = 1 ft S_o = 1%

A = 3.50 ft^2
WP = 7.29 ft
R = 0.48 ft

Q = 10.66 cfs > 6.44 cfs   Design OK

Let Down Structure Design

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: n = 0.03   b = 3 ft
S_o = 20% Q_4 = 6.44 cfs

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.015$$

From design nomograph for open channel hydraulics:

y/b = 0.08   y = 0.24 ft

A = (3 + 3(0.24))*0.24
= 0.89 ft^2

$$V=\frac{Q}{A}=\frac{6.44}{0.89}=7.24fps$$

Therefore use: 3 ft x 3 ft x 3 ft let down structure

Area 5:

Time of concentration from furthest tributary point:

A. Overland flow

Slope length: 112 ft
Slope: 18 / 112 = 16.07%
From Seelye Design nomograph for poor grass:

tc = 6.90 min.

B. Channel flow — From: Marion - Storm Water Management Design Manual 1985

Slope: 1.27%
channel length: 750 ft — V = 1.7 fps

$$t_c=\frac{750}{1.7\times60}=7.35\text{min.}$$

C. Let Down Structure flow

Slope length: 160 ft
Slope: 32 / 160 = 20.00%
From Seelye Design nomograph for poor grass:

tc = 4.00 min.

tc_{total} = 6.90 + 7.35 + 4.00 = 18.25 min.

Intensity:

i = 5.55 in/hr (100 year storm, Des Moines)

Area 5 calculations:

A_5 = 0.5*121*(310+175)+60.5*(263+150)+60.5*(461+320) = 101,580 ft^2
= 2.33 acres

Runoff coefficient:

c = 0.80 (steep grassed area)

Peak flow:

$Q_5 = ciA_5$
= 0.80 x 5.55 x 2.33 = 10.35 cfs

Channel Design Check

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

Assume
d = 1 ft S_o = 1%

$A = 3.50\ ft^2$
$WP = 7.29\ ft$
$R = 0.48\ ft$

$Q = 10.66\ cfs > 10.35\ cfs$ Design OK

Let Down Structure Design

$$\frac{A \times R^{2/3}}{b^{8/3}} = \frac{Q \times n}{1.49 \times S_o^{1/2} \times b^{8/3}}$$

Assumptions: $n = 0.03$ $b = 3\ ft$
$S_o = 20\%$

Total flow: $Q_{4,5} = Q_4 + Q_5 = 6.44 + 10.35 = \underline{16.79\ cfs}$

$$\frac{A \times R^{2/3}}{b^{8/3}} = 0.040$$

From design nomograph for open channel hydraulics:

$y/b = 0.13$ $\underline{y = 0.39\ ft}$

$A = (3 + 3(0.39))*0.39$
$= 1.63\ ft^2$

$$V = \frac{Q}{A} = \frac{16.79}{1.63} = 10.32 fps$$

Therefore use: 3 ft x 3 ft x 3 ft let down structure

Area 6:

Time of concentration from furthest tributary point:

A. Overland flow
Slope length: 112 ft
Slope: 17 / 112 = 15.18%
From Seelye Design nomograph for poor grass:

tc = 6.95 min.

B. Channel flow From: Marion - Storm Water Management Design Manual 1985
Slope: 1.18%
channel length: 1021 ft V = 1.65 fps

$$t_c=\frac{1021}{1.65\times60}=10.31\text{min.}$$

C. Let Down Structure flow

Slope length: 40 ft
Slope: 8 / 40 = 20.00%
From Seelye Design nomograph for poor grass:

tc = 2.00 min.

tc_{total} = 6.95 + 10.31 + 2.00 = 19.26 min.

Intensity:

i = 5.55 in/hr (100 year storm, Des Moines)

Area 6 calculations:

A_6 = 0.5*121*(380+263)+60.5*(440+310)+60.5*(600+460) = 148,400 ft^2
= 3.41 acres

Runoff coefficient:

c = 0.80 (steep grassed area)

Peak flow:

Q_6 = ciA_6
= 0.80 x 5.55 x 3.41 = 15.14 cfs

Channel Design Check

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

Assume
d = 1.5 ft S_o = 1%

A = 7.88 ft^2
WP = 10.93 ft
R = 0.72 ft

Q = 31.46 cfs > 15.14 cfs Design OK

Let Down Structure Design

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: $n = 0.03$ $b = 3$ ft

$S_o = 20\%$

Total flow: $Q = Q_{4,5} + Q_6 = 16.79 + 15.14 =$ 31.93 cfs

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.077$$

From design nomograph for open channel hydraulics:

$y/b = 0.20$ $y = 0.60$ ft

$A = (3 + 3(0.60))*0.60$
$= 2.88\ ft^2$

$$V=\frac{Q}{A}=\frac{31.93}{2.88}=11.09\,fps$$

Therefore use: 3 ft x 3 ft x 3 ft let down structure

West Slope Drainage Analysis

Area 7:

Time of concentration from furthest tributary point:

A. Overland flow
   - Slope length: 200 ft
   - Slope: 17 / 200 = 8.50%
   - From Seelye Design nomograph for poor grass:

     $t_c = 9.70$ min.

B. Channel flow — From: Marion - Storm Water Management Design Manual 1985
   - Slope: 1.30%
   - channel length: 300 ft — $V = 1.71$ fps

$$t_c=\frac{300}{1.71\times 60}=2.92\text{min.}$$

C. Let Down Structure flow

Slope length: 460 ft
Slope: 92 / 460 = 20.00%
From Seelye Design nomograph for poor grass:

$tc = 8.06$ min.

$tc_{total} = 9.70 + 2.92 + 8.06 =$ <u>20.68 min.</u>

Intensity:

$i = 5.54$ in/hr (100 year storm, Des Moines)

Area 7 calculations:

$A_7 = 0.5*161*(172+306)+0.5*120*144+0.5*144*168 =$ <u>59,215 ft²</u>
$= $ <u>1.36 acres</u>

Runoff coefficient:

$c = 0.80$ (steep grassed area)

Peak flow:

$Q_7 = ciA_7$
$= 0.80 \times 5.55 \times 1.36 =$ <u>5.93 cfs</u>

<u>Channel Design Check</u>

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

<u>Assume</u>
d = 1 ft $S_o = 1\%$

A = 3.50 ft²
WP = 7.29 ft
R = 0.48 ft

Q = 10.66 cfs > 5.93 cfs Design OK

<u>Let Down Structure Design</u>

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: n = 0.03 b = 3 ft

$S_o = 20\%$ $Q_7 = 5.93$ cfs

$$\frac{A \times R^{2/3}}{b^{8/3}} = 0.040$$

From design nomograph for open channel hydraulics:

y/b = 0.13   <u>y = 0.39 ft</u>

A = (3 + 3(0.39))*0.39
= 1.63 ft^2

$$V = \frac{Q}{A} = \frac{5.93}{1.63} = 3.65 fps$$

Therefore use: <u>3 ft x 3 ft x 3 ft</u> let down structure

<u>Area 8:</u>

Time of concentration from furthest tributary point:

A. Overland flow

Slope length: 140 ft
Slope: 18 / 140 = 12.86%
From Seelye Design nomograph for poor grass:

tc = 7.85 min.

B. Channel flow   From: Marion - Storm Water Management Design Manual 1985

Slope: 1.18%
channel length: 355 ft   V = 1.65 fps

$$t_c = \frac{355}{1.65 \times 60} = 3.60 min.$$

C. Let Down Structure flow

Slope length: 335 ft
Slope: 67 / 335 = 20.00%
From Seelye Design nomograph for poor grass:

tc = 7.10 min.

tc_{total} = 7.85 + 3.60 + 7.10 = <u>18.55 min.</u>

Intensity:

i = 5.45 in/hr   (100 year storm, Des Moines)

Area 8 calculations:

A_8 = 0.5*121*(367+280)+60.5*(292+144)+0.5*126*62 = <u>69,430 ft²</u>

= <u>1.59 acres</u>

Runoff coefficient:

c = 0.80 (steep grassed area)

Peak flow:

$Q_8 = ciA_8$

= 0.80 x 5.45 x 1.59 = <u>6.93 cfs</u>

<u>Channel Design Check</u>

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

<u>Assume</u>

d = 1 ft S_o = 1%

A = 3.50 ft²
WP = 7.29 ft
R = 0.48 ft

Q = 10.66 cfs > 6.93 cfs Design OK

<u>Let Down Structure Design</u>

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: n = 0.03 b = 3 ft

S_o = 20%

Total flow: $Q_{7,8} = Q_7 + Q_8$ = 5.93 + 6.93 = <u>12.86 cfs</u>

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.031$$

From design nomograph for open channel hydraulics:

y/b = 0.12 <u>y = 0.36 ft</u>

A = (3 + 3(0.36))*0.36

$= 1.47\ ft^2$

$$V=\frac{Q}{A}=\frac{12.86}{1.47}=8.76\,fps$$

Therefore use: 3 ft x 3 ft x 3 ft let down structure

Area 9:

Time of concentration from furthest tributary point:

A. Overland flow
Slope length: 140 ft
Slope: 22.25 / 140 = 15.90%
From Seelye Design nomograph for poor grass:

tc = 7.40 min.

B. Channel flow — From: Marion - Storm Water Management Design Manual 1985

Slope: 1.06%
channel length: 415 ft — V = 1.5 fps

$$t_c=\frac{415}{1.5\times60}=4.61\text{min.}$$

C. Let Down Structure flow

Slope length: 210 ft
Slope: 42 / 210 = 20.00%
From Seelye Design nomograph for poor grass:

tc = 5.90 min.

tc_{total} = 7.40 + 4.61 + 5.90 = 17.91 min.

Intensity:

i = 5.45 in/hr (100 year storm, Des Moines)

Area 9 calculations:
A_9 = 0.5*121*(420+330)+60.5*(306+213)+125*30 = $80,525\ ft^2$
= 1.85 acres

Runoff coefficient:
c = 0.80 (steep grassed area)

Peak flow:

$Q_9 = ciA_9$
$= 0.80 \times 5.45 \times 1.85 = \underline{8.07\ cfs}$

Channel Design Check

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

Assume
d = 1 ft S_o = 1%

A = 3.50 ft^2
WP = 7.29 ft
R = 0.48 ft

Q = 10.66 cfs > 8.07 cfs   Design OK

Let Down Structure Design

$$\frac{A\times R^{2/3}}{b^{8/3}}=\frac{Q\times n}{1.49\times S_o^{1/2}\times b^{8/3}}$$

Assumptions: n = 0.03   b = 3 ft
S_o = 20%

Total flow: $Q = Q_{7,8} + Q_9 = 12.86 + 8.07 = \underline{20.93\ cfs}$

$$\frac{A\times R^{2/3}}{b^{8/3}}=0.050$$

From design nomograph for open channel hydraulics:

y/b = 0.15   ∴ y = 0.45 ft

A = (3 + 3(0.45))*0.45
= 1.96 ft^2

$$V=\frac{Q}{A}=\frac{20.93}{1.96}=10.69\,fps$$

Therefore use: 3 ft x 3 ft x 3 ft let down structure