ENERCON	CALCULATION COVER SHEET	CALC. NO. TXUT-001-FSAR 2.4.2-CALC-020
		REV. 3
		PAGE NO. 1 of 36

Title:	Analysis of the Effects of Local Intense Precipitation at the Comanche Peak Nuclear Power Plant Units 3 and 4.	Client: Luminant Project: MITS116 - Luminant COLA

Item	Cover Sheet Items	Yes	No
1	Does this calculation contain any open assumptions that require confirmation? (If **YES**, identify the assumptions)__________		X
2	Does this calculation serve as an "Alternate Calculation"? (If **YES**, identify the design verified calculation.) **Design Verified Calculation No.**__________		X
3	Does this calculation supersede an existing calculation? (If **YES**, identify the superseded calculation.) **Superseded Calculation No.**__________		X

Scope of Revision: Enercon calculation TXUT-001-FSAR 2.4.3-CALC-012, Rev. 2, provides the peak water surface elevation of 793.66 ft (NAVD 88) for the SCR. The effects of local intense precipitation analysis were revised to utilize the peak water surface elevation of 793.66 ft (NAVD 88) as the tailwater elevation for the weirs. The discharge coefficient value (C_d) was also revised to 2.5, the lower C_d value represents a conservative approach which results in a higher headwater depth. Revision 3 also contains formatting and editorial revisions of a non technical nature.

Revision Impact on Results: The resulting maximum water surface elevation due to a local intense precipitation increased by 0.07 ft. to 820.90 ft (NAVD88).

Study Calculation ☐ **Final Calculation** ☒

Safety-Related ☒ **Non-safety-Related** ☐

(Print Name and Sign)

Originator: Suraj Balan	**Date: 06/10/2010**
Design Verifier: Bryan Cline Bryan A. Cline	**Date: 06/10/2010**
Approver: Joseph Mancinelli JPMancinelli	**Date:** 6/24/10

ENERCON	CALCULATION REVISION STATUS SHEET	CALC. NO. TXUT-001-FSAR 2.4.2-CALC-020 REV. 3 PAGE NO. 2 of 36

CALCULATION REVISION STATUS

REVISION	DATE	DESCRIPTION
0	August 22, 2008	Original Calculation
1	April, 9, 2009	Revision 1
2	August 14, 2009	Revision 2
3		Revised peak water surface elevation of SCR to 793.66 ft. and revised discharge coefficient to 2.5.

PAGE REVISION STATUS

PAGE NO.	REVISION	PAGE NO.	REVISION
All	3		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
None	N/A	N/A			

Calculation Design Verification Plan:

Apply CSP Number 3.01, Revision 6, Section 4.5.a, Design Review Method and to include at a minimum:

1. Review the changes due to the initial review and determine if the calculation provides a reasonable estimate of the site's effects and the maximum water surface elevation due to a local intense precipitation at the Comanche Peak Nuclear Power Plant Units 3 and 4.
2. Review the design methodology and determine if it is appropriate and correctly applied and is accurate.

(Print Name and Sign for Approval – mark "N/A" if not required)

Approver: **Joseph Mancinelli**	**Date:** 6/24/10

I have reviewed the Analysis of the Effects of Local Intense Precipitation at the Comanche Peak Nuclear Power Plant Units 3 and 4 calculation and have made the following conclusions:

1. The guidelines for the site effects of local intense precipitation and stormwater run-off analysis calculation are appropriate and applicable.
2. The calculation for the site effects of local intense precipitation and stormwater run-off analysis report follows the correct procedures.
3. The site effects of local intense precipitation and stormwater run-off analysis summary and calculations have been independently verified.
4. The Originator has addressed the recommendations given during the review process.

(Print Name and Sign)

Design Verifier: Bryan Cline Bryan A. Cline	**Date:** **06/10/2010**
Others:	**Date:**

Item	Cover Sheet Items	Yes	No	N/A
1	**Design Inputs** - Were the design inputs correctly selected, referenced (latest revision), consistent with the design basis and incorporated in the calculation?	X		
2	**Assumptions** – Were the assumptions reasonable and adequately described, justified and/or verified, and documented?	X		
3	**Quality Assurance** – Were the appropriate QA classification and requirements assigned to the calculation?	X		
4	**Codes, Standard and Regulatory Requirements** – Were the applicable codes, standards and regulatory requirements, including issue and addenda, properly identified and their requirements satisfied?	X		
5	**Construction and Operating Experience** – Have applicable construction and operating experience been considered?			X
6	**Interfaces** – Have the design interface requirements been satisfied, including interactions with other calculations?	X		
7	**Methods** – Was the calculation methodology appropriate and properly applied to satisfy the calculation objective?	X		
8	**Design Outputs** – Was the conclusion of the calculation clearly stated, did it correspond directly with the objectives and are the results reasonable compared to the inputs?	X		
9	**Radiation Exposure** – Has the calculation properly considered radiation exposure to the public and plant personnel?			X
10	**Acceptance Criteria** – Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?	X		
11	**Computer Software** – Is a computer program or software used, and if so, are the requirements of CSP 3.02 met?	X		

COMMENTS:

(Print Name and Sign)

Design Verifier: Bryan Cline Bryan A. Cline	**Date:** **06/10/2010**
Others:	**Date:**

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1.0 Purpose And Scope

Determine the effects of the local intense precipitation at the Comanche Peak Nuclear Power Plant (CPNPP) Units 3 and 4.

2.0 Summary Of Results And Conclusions

Site drainage area details are tabulated in Table 2-1. The resulting probable maximum precipitation (PMP) water surface elevations at the points of discharge from an intense local precipitation are shown in Table 2-2. The local intense precipitation results in water surface elevations below the plant grade elevation of 822 feet (NAVD 88) for safety-related structures.

Table 2-1, Site Drainage Areas and Peak Runoff Summary

Drainage Sub Basin	Area A (ac)	Total T_c (min)	PMP Intensity I (inch/hr)	Runoff Coefficient (C)	Peak Runoff Q (cfs)
1	9.22	15.9	38.0	1.00	350.36
2	8.53	11.0	47.0	1.00	400.91
3	5.97	5.0	74.4	1.00	444.17
4	8.83	15.9	38.0	1.00	335.54
5	9.66	15.6	38.2	1.00	369.01
6	6.22	5.1	74.3	1.00	462.15
7	24.68	5.2	74.2	1.00	1831.26
8	20.49	34.6	27.0	1.00	553.23
9	31.32	16.6	37.5	1.00	1174.50
10	13.49	10.6	47.5	1.00	640.78
11	56.40	13.5	41.0	1.00	2312.40

Table 2-2, Resulting PMP Water Surface Elevation at Points of Discharge Summary

Points Of Discharge	Drainage Sub Basins	Peak Runoff at Point of Discharge (cfs)	Crest Length L (ft)	Tailwater Elevation (ft) (NAVD 88)	Discharge Coefficient	Weir Elevation (ft) (NAVD 88)	Over Topping Depth Hw (ft)	Resulting Water Surface Elevation (ft) (NAVD 88)
W1	1+2+3	1195.44	560	793.66	2.50	820	0.90	820.90
W2	4+5+6	1166.70	365	793.66	2.50	815	1.18	816.18
W3	7+8	2384.49	490	793.66	2.50	810	1.56	811.56
W4	9+10+11	4127.68	315	793.66	2.50	814	3.02	817.02

3.0 References

1. American Nuclear Society, "American National Standard for Determining Design Basis Flooding at Power Reactor Sites," ANSI/ANS-2.8-1992, July 28, 1992.

2. Autodesk, AutoCAD Civil 3D 2009 software.

3. Luminant / Comanche Units 3 & 4 MNES US APWR, Post Development Drainage Area Map Drawing Number CVL-12-11-101-001 Rev. G, by Washington Group of URS, February 9, 2010.

4. Luminant/Comanche Peak Units 3 & 4 MNES US APWR, Site Plan, Drawing - GAS-05-11-100-002 Rev. D, by Washington Group International, July 10, 2008.

5. Enercon Calculation TXUT-001-FSAR 2.4.2-CALC-019, Rev. 1 - MITS004 - Determination of the Local Intense Precipitation at the Comanche Peak Nuclear Power Plant Units 3 and 4. (HMR 51 & HMR 52).

6. Enercon Calculation TXUT-001-FSAR 2.4.3-CALC-012, Rev. 2, MITS004 – Probable Maximum Flood Calculation for Comanche Peak Nuclear Power Plant Units 3 and 4 (HEC-HMS & HEC-RAS).

7. Natural Resources Conservation Service, "Technical Release 55: Urban Hydrology for Small Watersheds," United States Department of Agriculture, June 1986.

8. Federal Highway Administration, Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5, September 2001, Revised May 2005.

9. Chow V.T., Maidment D.R., Mays L.W., "Applied Hydrology," McGraw Hill, NewYork, 1988.

10. Schreiner, L.C., and J.T., Riedel, "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Hydrometeorological Report No. 51, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Washington, D.C., June 1978.

11. Hansen, E.M., L.C. Schreiner, and J.F. Miller, "Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian," Hydrometeorological Report No. 52, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Washington, D.C., August 1982.

12. Technical Paper No. 40, Rainfall Frequency Atlas of the United States, for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years. Prepared by Co-operative Studies Section, Hydrologic Services Division for Engineering Division, Soil Conservation Service, U.S. Department of Agriculture, May 1961.

13. U.S. Nuclear Regulatory Commission, "Standard Review Plan," NUREG-0800, March 2007.

14. U.S. Nuclear Regulatory Commission, "Design Basis Floods for Nuclear Power Plants, Alternative Methods of Estimating Probable Maximum Floods," Regulatory Guide 1.59, August 1977.

15. U.S. Nuclear Regulatory Commission, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Regulatory Guide 1.70, November 1978.

16. U.S. Nuclear Regulatory Commission, "Flood Protection for Nuclear Power Plants," Regulatory Guide 1.102, September 1976.

17. U.S. Nuclear Regulatory Commission, "Combined License Applications for Nuclear Power Plants (LWR Edition)," Regulatory Guide 1.206, June 2007.

18. U.S. Nuclear Regulatory Commission, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," 10 CFR Part 52, August 2007.

19. U.S. Nuclear Regulatory Commission, "Industry Guidelines for Combined License Applicants under 10 CFR Part 52," NEI 04-05, October 2005.

20. United States Advanced Pressurized Water Reactor (USAPWR) Design Control Document Rev. 1B.

4.0 Assumptions

Any site drainage facilities (e.g. inlets, culverts, etc.) are assumed to be non-functional resulting in only surface water drainage.

Tailwater conditions for site runoff to the Squaw Creek Reservoir (SCR) are assumed as the probable maximum flood (PMF) peak water surface elevation determined by separate calculations identified in Section 5.0 as design inputs. This assumption maximizes the tailwater conditions and the potential for those water bodies to create backwater effects on the site drainage. The areas adjoining the power block on the north and east side are open to the downward slopes leading into the SCR. This feature does not provide a barrier and allows drainage to pass freely across the site to the SCR. Runoff flowing to the CPNPP Units 3 and 4 is accounted for in this analysis.

In order to derive a conservative outcome, runoff losses were not assumed. Also, it was assumed that peak flows from each sub basin reach the outlet without any attenuation due to routing. The runoff coefficient was assumed to be equal to one. This assumption is conservative in considering that there will be some loss in runoff at the site. All rainfall is assumed to be converted to runoff. The rational method runoff coefficient is assumed, C = 1. This assumption is conservative by not accounting for any runoff losses to occur, thus maximizing runoff.

The results from any intermediate calculations are rounded for subsequent computations.

5.0 Design Inputs

Site Topography

Luminant / Comanche Units 3 & 4 MNES US APWR, Post Development Drainage Area Map Drawing Number CVL-12-11-101-001 Rev. G, by Washington Group of URS, February 9, 2010. (Reference 3) was used for contour elevations, and distances. Safety-related facilities have a plant grade elevation of 822 ft (NAVD 88) (Reference 4).

Rainfall

The Enercon calculation TXUT-001-FSAR 2.4.2-CALC-019 (Reference 5) provides the derivation of the local intense PMP estimates. Figure 5-1 and Table 5-1 identifies the depth-duration relationship determined as part of the referenced calculation.

2 year 24-hour (hr) rainfall event depth of 3.75 inches for the sheet flow Time of Concentration (T_c) calculation was selected from Technical Paper No. 40, Rainfall Frequency Atlas of the United States (Reference 12).

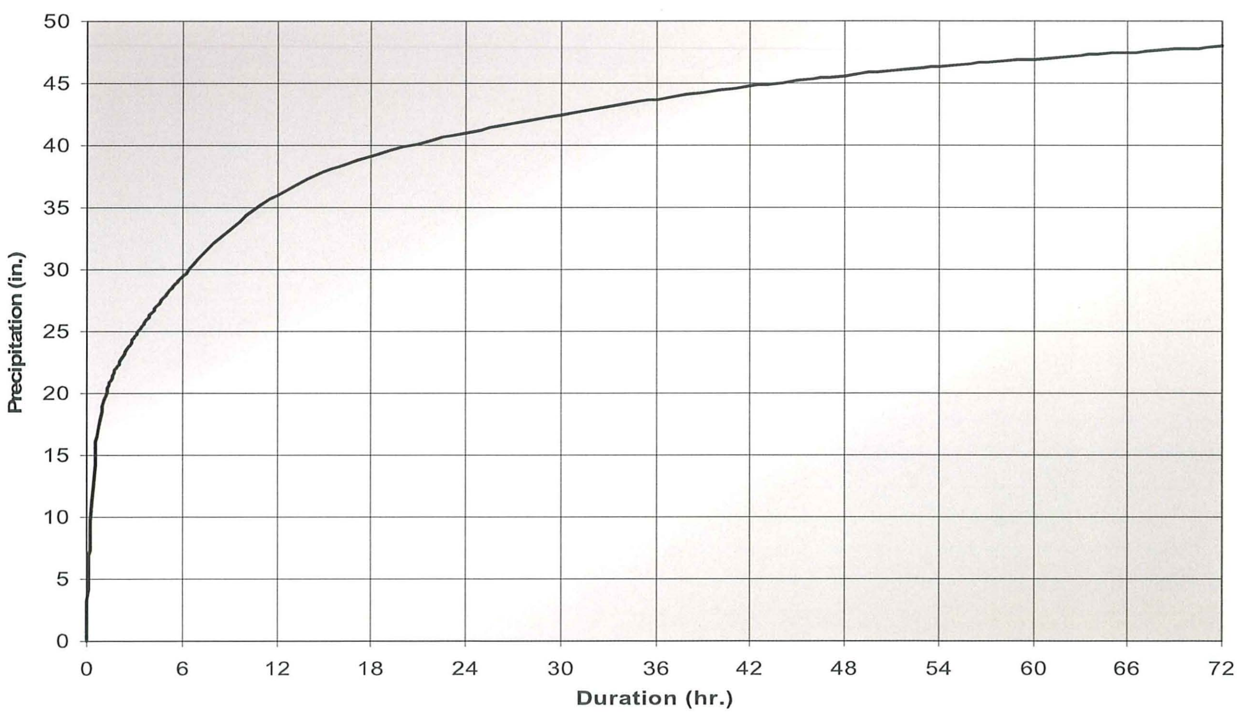

Figure 5-1, PMP Depth Duration Curve.

Table 5-1, 6-Hour Rainfall Depth-Duration Cumulative PMP Loading

Minutes	Cumulative PMP(in.)	Incremental PMP (in.)	Minutes	Cumulative PMP(in.)	Incremental PMP (in.)
5	6.20	6.20	185	24.78	0.16
10	8.12	1.92	190	24.94	0.16
15	9.70	1.58	195	25.10	0.16
20	11.23	1.53	200	25.25	0.16
25	12.73	1.50	205	25.41	0.15
30	14.20	1.47	210	25.56	0.15
35	15.55	1.35	215	25.71	0.15
40	16.59	1.04	220	25.86	0.15
45	17.38	0.79	225	26.01	0.15
50	18.02	0.63	230	26.15	0.15
55	18.55	0.53	235	26.29	0.14
60	19.00	0.45	240	26.44	0.14
65	19.40	0.40	245	26.58	0.14
70	19.76	0.36	250	26.72	0.14
75	20.09	0.33	255	26.85	0.14
80	20.40	0.31	260	26.99	0.14
85	20.69	0.29	265	27.12	0.13
90	20.96	0.27	270	27.26	0.13
95	21.23	0.26	275	27.39	0.13
100	21.48	0.25	280	27.52	0.13
105	21.72	0.24	285	27.65	0.13
110	21.95	0.23	290	27.78	0.13
115	22.17	0.22	295	27.91	0.13
120	22.39	0.22	300	28.04	0.13
125	22.60	0.21	305	28.16	0.13
130	22.80	0.20	310	28.29	0.13
135	23.00	0.20	315	28.41	0.12
140	23.20	0.19	320	28.54	0.12
145	23.39	0.19	325	28.66	0.12
150	23.57	0.19	330	28.78	0.12
155	23.75	0.18	335	28.90	0.12
160	23.93	0.18	340	29.02	0.12
165	24.11	0.18	345	29.14	0.12
170	24.28	0.17	350	29.26	0.12
175	24.45	0.17	355	29.38	0.12
180	24.61	0.17	360	29.50	0.12

Downstream Boundary Conditions

Enercon calculation Enercon Calculation TXUT-001-FSAR 2.4.3-CALC-012, Rev. 2, (Reference 6) provides the peak water surface elevation for the SCR, 793.66 ft (NAVD 88). As the weirs W1, W2, W3 and W4 discharge to the SCR, the tailwater elevation for all the weirs will be 793.66 ft (NAVD 88). Please refer to Figure 7-1 for weir locations.

6.0 Methodology

Reference to and compliance with the following listed design guides was considered in analyzing the effects of local intense precipitation at the CPNPP Units 3 and 4 site. All other procedures, instructions and design guides listed in section 5.4 of Project Planning Document (PPD No. TXUT-001, Rev. 3) was not specifically applicable in analyzing the effects of local intense precipitation at the CPNPP Units 3 and 4 site.

- U.S. Nuclear Regulatory Commission, "Standard Review Plan," NUREG-0800, March 2007, (Reference 13).
- U.S. Nuclear Regulatory Commission, "Design Basis Floods for Nuclear Power Plants, Alternative Methods of Estimating Probable Maximum Floods," Regulatory Guide 1.59, August 1977, (Reference 14).
- American Nuclear Society, "Determining Design Basis Flooding at Power Reactor Sites," ANSI/ANS-2.8-1992, July 28, 1992, (Reference 1).
- U.S. Nuclear Regulatory Commission, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Regulatory Guide 1.70, November 1978, (Reference 15).
- U.S. Nuclear Regulatory Commission, "Flood Protection for Nuclear Power Plants," Regulatory Guide 1.102, September 1976, (Reference 16).
- U.S. Nuclear Regulatory Commission, "Combined License Applications for Nuclear Power Plants (LWR Edition)," Regulatory Guide 1.206, June 2007, (Reference 17).
- U.S. Nuclear Regulatory Commission, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants," 10 CFR Part 52, August 2007, (Reference 18).
- U.S. Nuclear Regulatory Commission, "Industry Guidelines for Combined License Applicants under 10 CFR Part 52," NEI 04-05, October 2005, (Reference 19).

The CPNPP Units 3 and 4 site grading and drainage were evaluated for the PMP. The site is graded such that overall runoff will drain away from safety-related structures directly to the SCR. The PMP flood analysis assumes that storm drainage structures within the local area are non-functioning. The site grading and drainage plan is shown in Figure 7-1.

The local intense PMP is defined by Hydrometeorological Report (HMR) Nos. 51 and 52. PMP values for durations from 6-hr. to 72-hr. are determined using the procedures as described in HMR No. 51 for areas of 10 square mile (sq. mi). (Reference 10). Using the CPNPP location, the rainfall depth is read from the HMR No. 51 PMP chart for the time durations. The 1-sq. mi. PMP values for durations of 1-hour and less are determined using the procedures as described in HMR No. 52 (Reference 11). Using the CPNPP location, the rainfall depth for each duration is read from the HMR No. 52 1-sq. mi. PMP chart. A smooth curve was fitted to the data points. The derived PMP curve is detailed in Table 5-1. The corresponding PMP depth duration curve is shown in Figure 5-1.

HMR 52 guidance indicates that PMP rates for 10-sq. mi. areas are the same as point rainfall. Also indicated in HMR 52, the 1-sq. mi. PMP rates may also be considered the point rainfall for areas less than 1-sq. mi. Therefore, intensities for any drainage areas with durations longer than 1-hr. are derived from the PMP rates for 10-sq. mi. areas. Intensities for drainage areas with durations equal to or less than 1-hr. are derived from the PMP rates for 1-sq. mi. areas. The United States Advanced Pressurized Water Reactor (USAPWR) by Mitsubishi Heavy Industries Limited plant design is based on a maximum rainfall rate of 19.4 in/hr and maximum short term rainfall rate of 6.3 in/5 min (Reference 20). The derived local intense PMP was 19.0 in/hr and the derived maximum short term rainfall rate was 6.2 in/5 min for the CPNPP site. The derived local intense PMP curve is detailed in Table 7-1. The corresponding local intense PMP Intensity duration curve is shown in Figure 7-2 and 7-3. The CPNPP Units 3 and 4 site is within the plant design limits of a maximum rainfall rate of 19.4 in/hr and maximum short term rainfall rate of 6.3 in/5 min.

CPNPP Units 3 and 4 site was divided into 11 sub basins for analyzing the effects of local intense precipitation as shown in Figure 7-1. The peak runoff flows due to the PMP are based on the time of concentration. The time of concentration is calculated using the NRCS segmental approach as described in Technical Release (TR)-55 (Reference 7). The time of concentration (T_c) is the sum of the time for the runoff to flow from the upper part of the sub basin to the point of concentration. A combination of sheet flow, shallow flow and channel flow conditions for the sub basins was considered in determining the total $T_{c.}$. A trapezoidal cross section was considered in determining the channel flow conditions.

AutoCAD Civil 3D 2009 software (Reference 2) was used to determine spatial distances and areas using the list function.

T_c = Sheet flow T_t + Shallow concentrated flow T_t + Channel flow T_t

T_t is calculated using the following equation for Sheet Flow:

Sheet flow $T_t = \dfrac{0.007 \cdot (n \cdot L)^{0.8}}{P_2^{0.5} \cdot S^{0.4}}$ (Reference 7)

Where:

T_t= Sheet flow travel time (hr)

n = Manning's Friction Factor

L = Flow Length of the Runoff, which is not greater than 300 (ft)

P_2 = Rainfall Depth of the 2 year 24 hour rainfall event (in)
(3.75 Inches for CPNPP Units 3 and 4 site, Reference 12)

S = Slope of the Runoff Travel Path (ft/ft)

T_t is calculated using the following equation for Shallow Concentrated Flow:

$T_t = \dfrac{L}{3600V}$ (Reference 7)

Where:

T_t = Shallow concentrated flow travel time (hr)
L = Flow Length (ft)
V= Velocity of flow (fps)

$V = 20.3282 \cdot S^{0.5}$ (Paved) (Reference 7)

S = Slope of the Runoff Travel Path (ft/ft)

T_t is calculated using the following equation for Channel Flow:

$$T_t = \frac{L}{3600V}$$ (Reference 7)

Where:

T_t = Channel flow travel time (hr)

L = Flow Length (ft)

V= Velocity of flow (fps)

$$V = \frac{1.49}{n} \cdot r^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$ (Manning's Equation) (Reference 7)

Where:
V = average velocity (ft/s), and

r = hydraulic radius (ft) and is equal to A/P_w

S = channel slope, (ft/ft)

n = Manning roughness coefficient (Reference 9)

$r = A/ P_w$

A = cross sectional flow area (ft^2)

$A = (h*((W_b+W_t)/2))$

Where:

h= Channel Depth (ft)

W_b= Channel Bottom Width (ft)

W_t= Channel Top Width (ft)

P_w = Wetted perimeter (ft)

$P_w = W_b + 2 *((((W_t - W_b)/2)^2 + h^2)^{0.5})$

The rational method was used to determine peak runoff rates for the drainage sub basins. The rational method is given by the equation:

$Q = C \cdot i \cdot A$ (Reference 9)

Where:

Q = Runoff (cfs)

C = Unitless runoff coefficient

i = Intensity (in/hr)

A = Drainage area (ac.)

Runoff losses were not assumed. Therefore, the runoff coefficient was assumed to be equal to one. This assumption is conservative in considering that all precipitation will turn into runoff. The weir equation is used to determine the PMF elevation for the peak runoff rate from the sub basins with a tail water elevation at 793.66 ft (NAVD 88) from a PMF at the SCR.

The equation for a weir is given by the equation:

$Q = C_d \cdot L \cdot HW_r^{1.5}$ (Reference 8)

Where:

Q = Runoff (cfs)

C_d= Overtopping discharge coefficient (Reference 8)

L = Crest length of overflow section (ft)

HW_r= Head water elevation for the weir (ft)

AutoCAD Civil 3D 2009 and Microsoft Excel software has been verified and validated in accordance with CSP 3.02, Revision 5. The verification and validation documents are maintained by Enercon as part of the Quality Assurance program.

7.0 Calculations

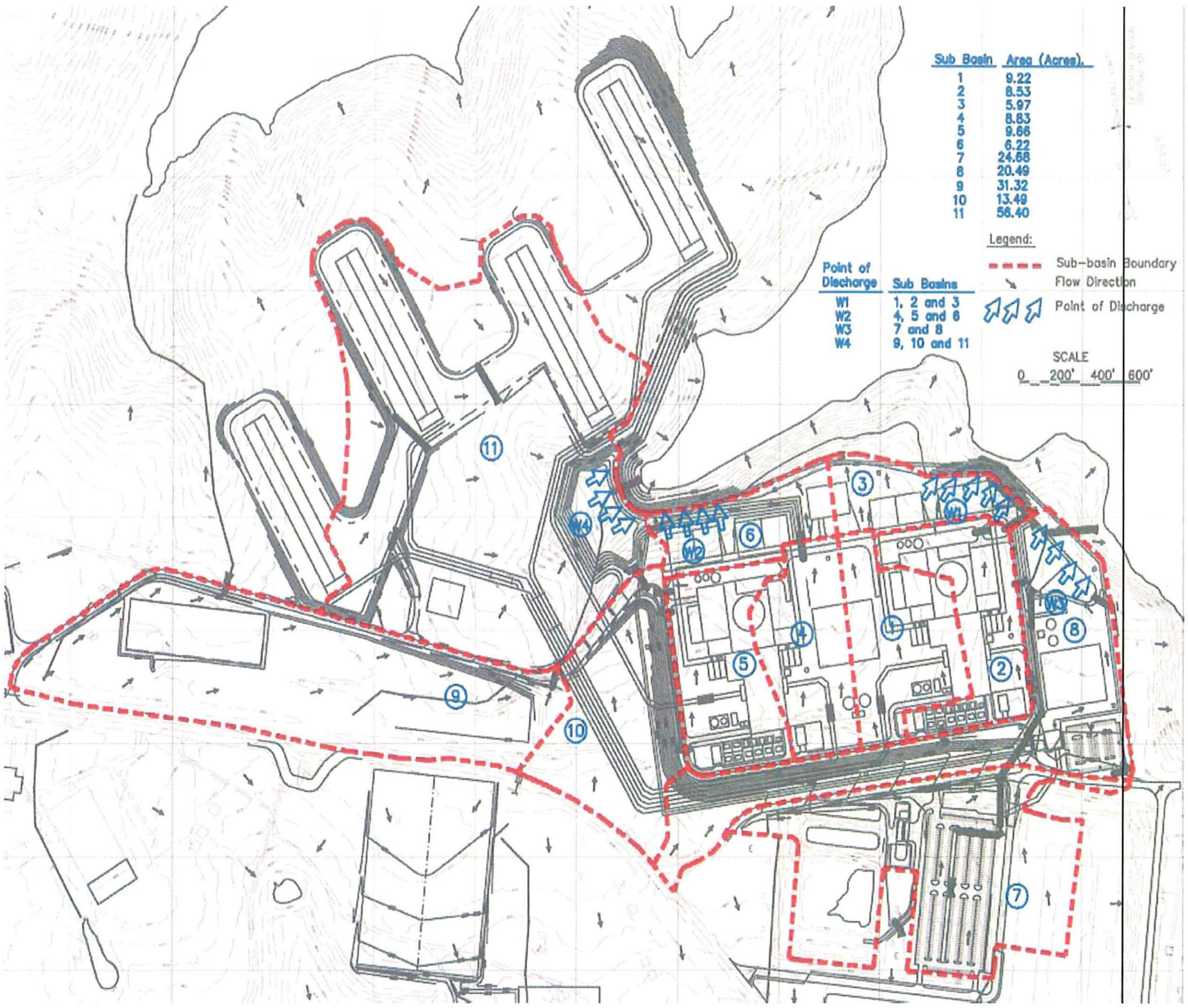

Figure 7-1, Site Drainage Concept Plan

<u>Site Drainage Concept Plan</u>

The CPNPP Units 3 and 4 site has been graded to drain runoff from the nuclear islands in all directions. Luminant / Comanche Units 3 & 4 MNES US APWR, Post Development Drainage Area Map Drawing Number CVL-12-11-101-001 Rev. G, by Washington Group of URS, February 9, 2010. (Reference 3) was used for contour elevations, and distances. Safety-related facilities have a plant grade elevation of 822 ft (NAVD 88) (Reference 4). The concept drainage plan is shown in Figure 7-1. The areas adjoining the CPNPP Units 3 and 4 on the north and east side are open to the downward slopes leading into the SCR. The downward slopes leading to the SCR do not provide a barrier and allow runoff to drain to the SCR during local intense precipitation.

All subsurface drainage features are assumed to be non-functional during a PMP event based on ANSI/ANS-2.8-1992 (Reference 1) guidance.

Runoff Coefficient (C)

As a conservative approach and in order to account for any antecedent soil conditions, the coefficient of runoff is assumed, C = 1.

Intensity (i)

The design input PMP depth duration values from Table 5-1 were converted to PMP intensities per hour for the durations. The following equation was used to develop the intensities reported in Table 7-1.

$$\text{Intensity} = \frac{\text{Depth (in.)}}{\text{Duration (min.)}} \bullet \frac{60\text{ min.}}{1\text{hr.}}$$

Table 7-1, PMP Depths Converted to Intensities

Minutes	PMP Depth (in.)	PMP Intensity (in/hr)	Minutes	PMP Depth (in.)	PMP Intensity (in/hr)
5	6.20	74.4	185	24.78	8.0
10	8.12	48.7	190	24.94	7.9
15	9.70	38.8	195	25.10	7.7
20	11.23	33.7	200	25.25	7.6
25	12.73	30.6	205	25.41	7.4
30	14.20	28.4	210	25.56	7.3
35	15.55	26.7	215	25.71	7.2
40	16.59	24.9	220	25.86	7.1
45	17.38	23.2	225	26.01	6.9
50	18.02	21.6	230	26.15	6.8
55	18.55	20.2	235	26.29	6.7
60	19.00	19.0	240	26.44	6.6
65	19.40	17.9	245	26.58	6.5
70	19.76	16.9	250	26.72	6.4
75	20.09	16.1	255	26.85	6.3
80	20.40	15.3	260	26.99	6.2
85	20.69	14.6	265	27.12	6.1
90	20.96	14.0	270	27.26	6.1
95	21.23	13.4	275	27.39	6.0
100	21.48	12.9	280	27.52	5.9
105	21.72	12.4	285	27.65	5.8
110	21.95	12.0	290	27.78	5.7
115	22.17	11.6	295	27.91	5.7
120	22.39	11.2	300	28.04	5.6
125	22.60	10.8	305	28.16	5.5
130	22.80	10.5	310	28.29	5.5
135	23.00	10.2	315	28.41	5.4
140	23.20	9.9	320	28.54	5.4
145	23.39	9.7	325	28.66	5.3
150	23.57	9.4	330	28.78	5.2
155	23.75	9.2	335	28.90	5.2
160	23.93	9.0	340	29.02	5.1
165	24.11	8.8	345	29.14	5.1
170	24.28	8.6	350	29.26	5.0
175	24.45	8.4	355	29.38	5.0
180	24.61	8.2	360	29.50	4.9

The PMP intensities for a 6-hour duration are plotted as shown in Figure 7-2. The PMP intensities for up to 40 minutes are plotted as shown in Figure 7-3. Intensity Duration Curve for durations up to 40 minutes was used as the intensity input for the rational method approach in the following calculations.

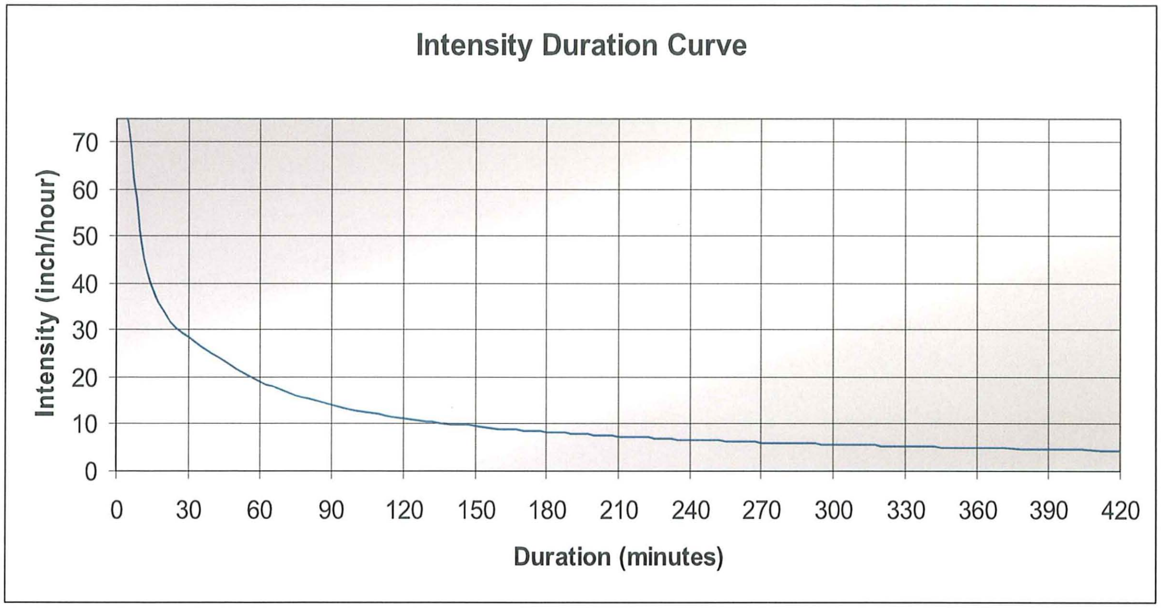

Figure 7-2, Intensity Duration Curve for Durations up to 6 Hours

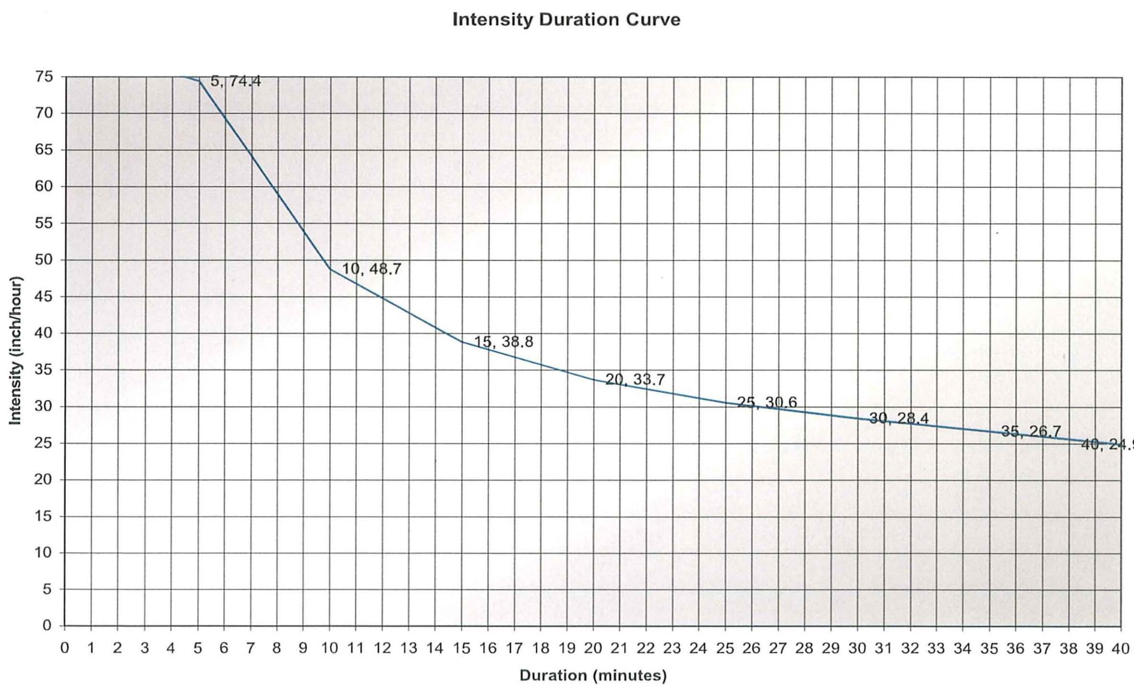

Figure 7-3 Intensity Duration Curve for Durations up to 40 minutes

Site Drainage Area Details

Drainage areas for the sub basins were determined using the Luminant / Comanche Units 3 & 4 MNES US APWR, Grading and Drainage Plan, Drawing Number CVL-12-11-101-001- Rev. G, by Washington Group of URS, February 9, 2010 (Reference 3) in AutoCAD format. Drainage areas for sub basins, distances and elevations were identified from the AutoCAD drawing. The areas adjoining the power block on the north and east side are open to the downward slopes leading into the SCR. This area is assumed to flow unimpeded to the SCR. Channel flow conditions T_t were calculated for the sub basins with a depth of channel equal to the over topping depth at the point of the discharge. Selecting the over topping depth at the point of the discharge as the depth of channel flow results in higher peak runoff. The channel lengths and slopes were identified from the AutoCAD Drawing.

Manning's roughness coefficients were based on post development cover types. The areas around the power block are primarily paved or gravel, while all other areas are estimated to have maintained grass cover. The most downstream cross section is below the site and estimated to have a higher roughness coefficient based on areas below the site being largely undeveloped and subject to coincident flooding on the SCR.

The slope is based on Conceptual Grading and Drainage Plan (Reference 3). The Enercon calculation TXUT-001-FSAR-2.4.3-CALC-012, Rev. 1, (Reference 6) was used to determine the downstream water surface elevation of 793.66 ft (NAVD 88) resulting from a PMF at the SCR.

Point of Discharge W1
Runoff from drainage sub basins 1, 2 and 3 discharges to point W1 as indicated on Figure 7-1. The sub basin characteristics and sheet flow T_t calculations for sub basin 1, 2 and 3 are shown in Table 7-2. The shallow concentrated flow T_t calculations for the sub basins are shown in Table 7-3. The channel flow T_t calculations for the sub basins are shown in Table 7-4.

Table 7-2, Sub Basin Characteristics and Sheet Flow T_t Calculations for Sub Basins 1, 2 & 3

Sub Basin	**1**	**2**	**3**
Area (ac)	9.22	8.53	5.97
TR-55	T_t = 0.007* (n*L)^0.8 / (P2^0.5 S^0.4) (Sheet Flow)		
SHEET FLOW			
Manning's (n)	0.011	0.011	0.011
length, ft (L)	300	300	300
2 Yr-24 Hr Rainfall, inch (P2) (Reference 12)	3.75	3.75	3.75
slope, ft/ft (S)	0.0019	0.002	0.019
T_t (hrs)	0.1152	0.1128	0.0459
T_t (min)	6.9110	6.7707	2.7513

Table 7-3, Shallow Concentrated Flow T_t Calculations for Sub Basins 1, 2 & 3

SHALLOW CONCENTRATED FLOW			
T_t =L/3600V, V=20.3282*S^1/2 (Paved)			
Sub Basin	**1**	**2**	**3**
area (ac)	9.22	8.53	5.97
length, ft (L)	432	144	100
slope, ft/ft	0.0019	0.002	0.019
paved V, fps	0.8861	0.9091	2.8020
T_t (hrs)	0.1354	0.0440	0.0099
T_t (min)	8.1256	2.6400	0.5948

Table 7-4, Channel Flow T_t for Sub Basins 1, 2 & 3

CHANNEL FLOW			
T_t =L/3600V			
V = 1.49 * r^2/3 * S^1/2 / n and r=A/P			
Sub Basin	**1**	**2**	**3**
area (ac)	9.22	8.53	5.97
length, ft (L)	301	486	119
Manning's (n)	0.03	0.03	0.03
slope, ft/ft	0.0019	0.002	0.019
bottom width, ft (W_b)	125	125	125
top width, ft (W_t)	125	125	125
depth, ft (h)	0.82	0.82	0.82
area channel, ft^2 (A) $A=(h*((W_b + W_t)/2))$	102.5	102.5	102.5
wetted perimeter, ft (P) $P=W_b + 2*((((W_t - W_b)/2)^2 + h^2)^{0.5})$	126.64	126.64	126.64
Velocity, fps (V)	1.8752	1.9239	5.9298
T_t (hrs)	0.0446	0.0702	0.0056
T_t (min)	2.6753	4.2102	0.3345

The total T_c is the sum of the sheet flow, shallow concentrated flow and channel flow T_t. The total T_c and the PMP intensity from the intensity duration curve are shown in Table 7-5.

Table 7-5, Total T_c and PMP Intensity from Intensity Duration Curve for Sub Basins 1, 2 & 3

Total T_c (min)	17.7120	13.6209	3.6806
Use T_c (min)	**17.7**	**13.6**	**5.0**
PMP Intensity from IDF Curve (Figure 7-3) (in/hr)	**36.0**	**43.0**	**74.4**

Point of Discharge W2

Runoff from drainage sub basins 4, 5 and 6 discharges to point W2 as indicated on Figure 7-1. The sub basin characteristics and sheet flow T_t calculations for sub basin 4, 5 and 6 are shown in Table 7-6. The shallow concentrated flow T_t calculations for the sub basins are shown in Table 7-7. The channel flow T_t calculations for the sub basins are shown in Table 7-8.

Table 7-6, Sub Basin Characteristics and Sheet Flow T_t for Sub Basins 4, 5 & 6

Sub Basin	**4**	**5**	**6**
area (ac)	8.83	9.66	6.22
TR-55 **SHEET FLOW**	T_t = 0.007* (n*L)^0.8 / (P2^0.5 S^0.4) (Sheet Flow)		
Manning's (n)	0.011	0.011	0.011
length, ft (L)	300	300	300
2 Yr 24- Hr Rainfall, inch (P2) (Reference 12)	3.75	3.75	3.75
slope, ft/ft (S)	0.002	0.002	0.012
T_t (hrs)	0.1128	0.1128	0.0551
T_t (min)	6.7707	6.7707	3.3065

Table 7-7, Shallow Concentrated Flow T_t for Sub Basins 4, 5 & 6

SHALLOW CONCENTRATED FLOW			
T_t =L/3600V, V=20.3282*S^1/2 (Paved)			
Sub Basin	**4**	**5**	**6**
area (ac)	8.83	9.66	6.22
length, ft (L)	419	452	200
slope, ft/ft	0.0019	0.002	0.012
paved V, fps	0.8861	0.9091	2.2268
T_t (hrs)	0.1314	0.1381	0.0249
T_t (min)	7.8811	8.2865	1.4969

Table 7-8, Channel Flow T_t for Sub Basins 4, 5 & 6

CHANNEL FLOW			
T_t =L/3600V			
V = 1.49 * r^2/3 * S^1/2 / n and r=A/P			
Sub Basin	**4**	**5**	**6**
area (ac)	8.83	9.66	6.22
length, ft (L)	466	290	356
Manning's (n)	0.03	0.03	0.03
slope, ft/ft	0.0019	0.002	0.012
bottom width, ft (Wb)	100	100	125
top width, ft (Wt)	100	100	125
depth, ft (h)	1.05	1.05	1.05
area channel, ft^2 (A) $A=(h*((W_b + W_t)/2))$	105	105	131.25
wetted perimeter, ft (P) $P=W_b + 2*((((W_t - W_b)/2)^2 + h^2)^{0.5})$	102.1	102.1	127.1
Velocity, fps (V)	2.1998	2.2569	5.5436
T_t (hrs)	0.0588	0.0357	0.0178
T_t (min)	3.5306	2.1415	1.0703

The total T_c is the sum of the sheet flow, shallow concentrated flow and channel flow T_t. The total T_c and the PMP intensity from the intensity duration curve are shown in Table 7-9.

Table 7-9, Total T_c and PMP Intensity from Intensity Duration Curve for Sub Basins 4, 5 & 6

Sub Basin	4	5	6
Total T_c (min)	18.1824	17.1988	5.8737
Use T_c (min)	**18.2**	**17.2**	**5.9**
PMP Intensity from IDF Curve (Figure 7-3) (in/hr)	**35.5**	**36.5**	**70.0**

Point of Discharge W3

Runoff from drainage sub basins 7 and 8 discharges to point W3 as indicated on Figure 7-1. The sub basin characteristics and sheet flow T_t calculations for sub basin 7 and 8 are shown in Table 7-10. The shallow concentrated flow T_t calculations for the sub basins are shown in Table 7-11. The channel flow T_t calculations for the sub basins are shown in Table 7-12.

Table 7-10, Sub Basin Characteristics and Sheet Flow T_t for Sub Basins 7 & 8

Sub Basin	**7**	**8**
area (ac)	24.68	20.49
TR-55 **SHEET FLOW**	T_t = 0.007* (n*L)^0.8 / (P2^0.5 S^0.4) for Sheet Flow	
Manning's (n)	0.011	0.011
length, ft (L)	300	300
2 Yr-24 Hr Rainfall, Inch (P2)	3.75	3.75
slope, ft/ft (S)	0.023	0.0035
T_t (hrs)	0.0425	0.0902
T_t (min)	2.5489	5.4127

Table 7-11, Shallow Concentrated Flow T_t for Sub Basins 7 & 8

SHALLOW CONCENTRATED FLOW		
T_t =L/3600V, V=20.3282*S^1/2 (Paved)		
Sub Basin	**7**	**8**
area (ac)	24.68	20.49
length, ft (L)	300	2043
slope, ft/ft	0.023	0.0035
paved V, fps	3.0829	1.2026
T_t (hrs)	0.0270	0.4719
T_t (min)	1.6218	28.3129

Table 7-12, Channel Flow T_t for Sub Basins 7 & 8

CHANNEL FLOW		
T_t =L/3600V		
V = 1.49 * r^2/3 * S^1/2 / n and r=A/P		
Sub Basin	**7**	**8**
area (ac)	24.68	20.49
length, ft (L)	1339	549
Manning's (n)	0.03	0.03
slope, ft/ft	0.023	0.0035
bottom width, ft (Wb)	100	80
top width, ft (Wt)	100	80
depth, ft (h)	1.33	1.33
area channel, ft^2 (A) $A=(h*((W_b + W_t)/2))$	133	106.4
wetted perimeter, ft (P) $P=W_b + 2*((((W_t - W_b)/2)^2 + h^2)^{0.5})$	102.66	82.66
Velocity, fps (V)	8.9275	3.4676
T_t (hrs)	0.0417	0.0440
T_t (min)	2.4998	2.6387

The total T_c is the sum of the sheet flow, shallow concentrated flow and channel flow T_t. The total T_c and the PMP intensity from the derived intensity duration curve are shown in Table 7-13.

Table 7-13, Total T_c and PMP Intensity from Intensity Duration Curve for Sub Basins 7 & 8

Sub Basin	**7**	**8**
Total T_c (min)	6.6705	36.3643
Use T_c (min)	**6.7**	**36.4**
PMP Intensity from IDF Curve (Figure 7-3) (in/hr)	**65.0**	**25.2**

Point of Discharge W4

Runoff from drainage sub basins 9, 10 and 11 discharges to point W4 as indicated on Figure 7-1. The sub basin characteristics and sheet flow T_t calculations for sub basin 9, 10 and 11 are shown in Table 7-14. The shallow concentrated flow T_t calculations for the sub basins are shown in Table 7-15. The channel flow T_t calculations for the sub basins are shown in Table 7-16.

Table 7-14, Sub Basin Characteristics and Sheet Flow T_t for Sub Basins 9, 10 & 11

Sub Basin	**9**	**10**	**11**
area (ac)	31.32	13.49	56.4
TR-55	T_t = 0.007* (n*L)^0.8 / (P2^0.5 S^0.4) for Sheet Flow		
SHEET FLOW			
Manning's (n)	0.15	0.15	0.15
length, ft (L)	300	300	300
2 Yr 24-Hr Rainfall, Inch (P2)	3.75	3.75	3.75
slope, ft/ft (S)	0.023	0.047	0.037
T_t (hrs)	0.3435	0.2581	0.2840
T_t (min)	20.6116	15.4869	17.0421

Table 7-15, Shallow Concentrated Flow T_t for Sub Basins 9, 10 & 11

SHALLOW CONCENTRATED FLOW			
T_t =L/3600V			
Sub Basin	**9**	**10**	**11**
area (ac)	31.32	13.49	56.4
length, ft (L)	620	417	788
slope, ft/ft	0.023	0.047	0.037
paved V, fps	3.0829	4.4070	3.9102
T_t (hrs)	0.0559	0.0263	0.0560
T_t (min)	3.3518	1.5770	3.3587

Table 7-16, Channel Flow T_t for Sub Basins 9, 10 & 11

CHANNEL FLOW			
T_t =L/3600V			
V = 1.49 * r^2/3 * S^1/2 / n and r=A/P			
Sub Basin	**9**	**10**	**11**
area (ac)	31.32	13.49	56.4
length, ft (L)	2008	330	703
Manning's (n)	0.03	0.03	0.03
slope, ft/ft	0.023	0.047	0.037
bottom width ft (wb)	210	125	400
top width, ft (wt)	400	125	400
depth, ft (h)	2.3	2.3	2.3
area channel, ft^2 (A) $A=(h*((W_b + W_t)/2))$	701.5	287.5	920
wetted perimeter, ft (P) $P=W_b + 2*((((W_t - W_b)/2)^2 + h^2)^{0.5})$	400.0557	129.6	404.6
velocity (V)	10.9236	18.2656	16.4755
T_t (hrs)	0.0511	0.0050	0.0119
T_t (min)	3.0637	0.3011	0.7112

The total T_c is the sum of the sheet flow, shallow concentrated flow and channel flow T_t. The total T_c and the PMP intensity from the intensity duration curve are shown in Table 7-17.

Table 7-17, Total T_c and PMP Intensity from Intensity Duration Curve for Sub Basins 9, 10 & 11

Sub Basin	**9**	**10**	**11**
Total T_c (min)	27.0271	17.3650	21.1120
Use T_c (min)	**27.0**	**17.4**	**21.1**
PMP Intensity from IDF Curve (Figure 7-3) (in/hr)	**30.0**	**36.0**	**33.0**

The rational method was used to determine peak runoff rates for the drainage sub basins. The rational method is given by the equation:

Q = C * i * A (Reference 9)

Where:

Q = Runoff (cfs)
C = Unitless coefficient of runoff
i = Intensity (in/hr)
A = Drainage area (ac.)

The runoff coefficient of one is used, as discussed earlier in Section 6.0.

Table 7-18, Site Drainage Area Details

Drainage Sub Basin	Area A (ac)	Total T_c (min)	PMP Intensity I (inch/hr)	Runoff Coefficient (C)	Peak Runoff using Rational Method Q (cfs)
1	9.22	17.7	36.0	1.00	331.92
2	8.53	13.6	43.0	1.00	366.79
3	5.97	5.0	74.4	1.00	444.17
4	8.83	18.2	35.5	1.00	313.47
5	9.66	17.2	36.5	1.00	352.59
6	6.22	5.9	70.0	1.00	435.40
7	24.68	6.7	65.0	1.00	1604.20
8	20.49	36.4	25.2	1.00	516.35
9	31.32	27.0	30.0	1.00	939.60
10	13.49	17.4	36.0	1.00	485.64
11	56.40	21.1	33.0	1.00	1861.20

The equation for a weir is given by the equation:

$Q = C_d * L * HW_r^{1.5}$ (Reference 8)

Where:

Q = runoff (cfs)
C_d= Overtopping discharge coefficient (Reference 8)
L = Crest length of overflow section (ft)
HW_r= Head water depth for the weir (ft)

Site drainage area details are tabulated in Table 7-18.

A discharge coefficient (C_d) value of 2.5 was selected for this application based on the information presented in the Federal Highway Administration, Hydraulic Design on Highway Culverts, Hydraulic Design Series No. 5 (FHA HDS5), (Reference 8). The FHA HDS5 graph for discharge coefficient is shown in Figure 7-4 (Reference 8). A lower C_d value will result in a higher headwater depth (HW_r). Hence, to represent a conservative approach HW_r was computed using the lowest C_d value of 2.5. The weirs at the points of discharge were considered as suppressed weirs with no submergence since the weirs do not have any constrictions and the down stream area is a steep downhill with tail water elevation of 793.66 ft (NAVD 88) due to a PMF on SCR. The resulting HW_r at the points of discharge are presented in Table 7-19. The resulting PMP water surface elevations from intense local precipitation at the points of discharge are shown in Table 7-19. The effects of a local intense precipitation will result in water surface elevations below the plant grade elevation for safety-related structures of 822 ft (NAVD 88).

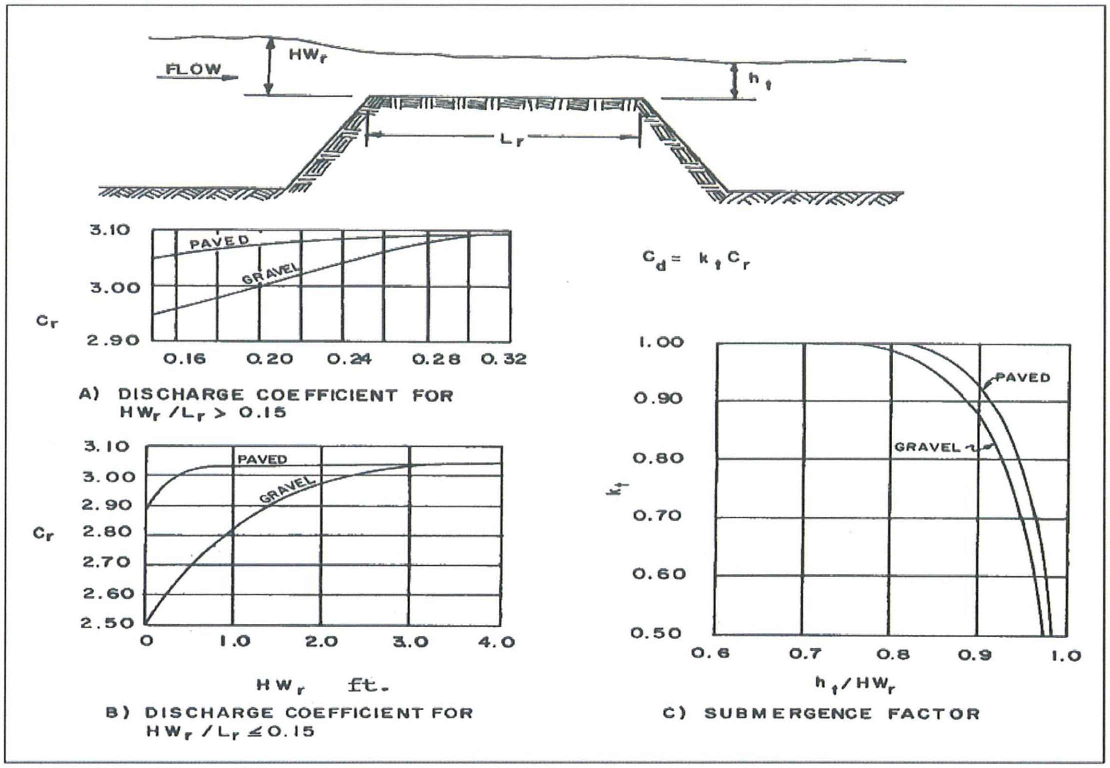

Figure 7-4, Discharge Coefficient

Table 7-19, Resulting PMP Water Surface Elevation at Points of Discharge

Point Of Discharge	Drainage Sub Basins	Peak Runoff at Point of Discharge (cfs)	Crest Length L (ft)	Tailwater Elevation (ft) (NAVD 88)	Discharge Coefficient	Weir Elevation (ft) (NAVD 88)	Over Topping Depth Hw_r (ft)	Resulting Water Surface Elevation (ft) (NAVD 88)
W1	1+2+3	1142.88	560	793.66	2.5	820	0.87	820.87
W2	4+5+6	1101.46	365	793.66	2.5	815	1.13	816.13
W3	7+8	2120.55	490	793.66	2.5	810	1.44	811.44
W4	9+10+11	3286.44	315	793.66	2.5	814	2.59	816.59

Manning's Roughness Coefficient Sensitivity Analysis

Due to the variability of the nature for ground cover, the analysis was evaluated using adjusted Manning's roughness coefficients. Manning's roughness coefficients were adjusted by a 50 percent decrease and 50 percent decrease. References 7, 22 and 23 do not report a sheet flow Manning's roughness coefficient value lower than 0.01 for any range normally found in practice. Sheet flow roughness coefficient for Basins 1 through 8 was set to a value of 0.01 for the 50 percent decreased Manning's roughness coefficient sensitivity analysis. The new time of concentration and flows were used to calculate the resulting water surface elevation at the points of discharge.

A summary of the results for the time of concentration for each drainage sub basin for a 50 percent decrease in Manning's roughness coefficient is provided in Table 7-20. A summary of the results for the time of concentration for each drainage sub basin for a 50 percent increase in Manning's roughness coefficient is provided in 7-21. A summary of the results for the resulting peak runoff volume for each drainage sub basin for a 50 percent decrease in Manning's roughness coefficient is provided in Table 7-22. A summary of the results for the resulting peak runoff volume for each drainage sub basin for a 50 percent increase in Manning's roughness coefficient is provided in 7-23. The headwater depth $HW_{r,}$ was calculated using a discharge coefficient C_d value of 2.5 and the weir equation (Reference 8) as described above to determine the resultant water surface elevation due to 50 percent change.

The resulting water surface elevation at the points of discharge for a 50 percent decrease in Manning's roughness coefficient for the sensitivity analysis is shown in Table 7-24. The resultant water surface elevation at the points of discharge for a 50 percent increase in Manning's roughness coefficient for the sensitivity analysis is shown in Table 7-25. The 50 percent increased Manning's roughness coefficient sensitivity analysis results in a lower water surface elevation. The resulting water surface elevation from the 50 percent decreased Manning's roughness coefficient sensitivity analysis is relatively insensitive to roughness coefficient changes. The sensitivity analysis resulted in all water surface elevations below the plant grade elevation of 822 ft (NAVD 88) for safety-related facilities.

Table 7-20, Manning's Roughness Coefficient (n) Decreased by 50 Percent - T_c Calculation Summary

Sub Basin	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
area (ac)	9.22	8.53	5.97	8.83	9.66	6.22	24.68	20.49	31.32	13.49	56.40
Sheet Flow	T_t = 0.007* (n*L)^0.8 / (P_2^0.5 S^0.4) for Sheet Flow										
Manning's friction factor,Paved (n)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.075	0.075	0.075
length, ft (L)	300	300	300	300	300	300	300	300	300	300	300
2 Yr 24-Hr Rainfall, Inch (P2)	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
slope, ft/ft (S)	0.0019	0.002	0.019	0.002	0.002	0.012	0.023	0.0035	0.023	0.047	0.037
T_t (hrs)	0.1067	0.1046	0.0425	0.1046	0.1046	0.0511	0.0394	0.0836	0.1973	0.1482	0.1631
T_t (min)	6.4037	6.2736	2.5493	6.2736	6.2736	3.0638	2.3618	5.0154	11.8383	8.8949	9.7881
SHALLOW CONCENTRATED FLOW	Tt =L/3600V for Shallow Concentrated Flow, V=20.3282*S^1/2 (Paved)										
length, ft (L)	432	144	100	419	452	200	300	2043	620	417	788
slope, ft/ft	0.0019	0.002	0.019	0.0019	0.002	0.012	0.023	0.0035	0.023	0.047	0.037
paved V, fps	0.8861	0.9091	2.8020	0.8861	0.9091	2.2268	3.0829	1.2026	3.0829	4.4070	3.9102
T_t (hrs)	0.1354	0.0440	0.0099	0.1314	0.1381	0.0249	0.0270	0.4719	0.0559	0.0263	0.0560
T_t (min)	8.1256	2.6400	0.5948	7.8811	8.2865	1.4969	1.6218	28.3129	3.3518	1.5770	3.3587
CHANNEL FLOW	Tt =L/3600V for Shallow Concentrated Flow					V = 1.49 * r^2/3 * S^1/2 / n				r=A/P	
length, ft (L)	301	486	119	466	290	356	1339	549	2008	330	703
Manning's (n)	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
slope, ft/ft	0.0019	0.002	0.019	0.0019	0.002	0.012	0.023	0.0035	0.023	0.047	0.037
bottom width, ft (wb)	125	125	125	100	100	125	100	80	210	125	400
top width, ft (wt)	125	125	125	100	100	125	100	80	400	125	400
depth, ft (h)	0.83	0.83	0.83	1.09	1.09	1.09	1.44	1.44	2.67	2.67	2.67
area channel, ft^2 (A)	103.75	103.75	103.75	109	109	136.25	144	115.2	814.35	333.75	1068
wetted perimeter, ft (P)	126.66	126.66	126.66	102.18	102.18	127.18	102.88	82.88	400.075	130.34	405.34
Velocity, fps (V)	3.7804	3.8786	11.9546	4.5083	4.6254	11.3622	18.7995	7.2996	24.1308	40.1981	36.3521
T_t (hrs)	0.0221	0.0348	0.0028	0.0287	0.0174	0.0087	0.0198	0.0209	0.0231	0.0023	0.0054
T_t (min)	1.3270	2.0884	0.1659	1.7228	1.0450	0.5222	1.1871	1.2535	1.3869	0.1368	0.3223

Table 7-20, Manning's Roughness Coefficient (n) Decreased by 50 Percent - T_c Calculation Summary (Continued)

Sub Basin	1	2	3	4	5	6	7	8	9	10	11
Total T_c (min)	15.8563	11.0020	3.3101	15.8775	15.6051	5.0829	5.1707	34.5818	16.5770	10.6087	13.4692
Use T_c (min)	**15.9**	**11.0**	**5.0**	**15.9**	**15.6**	**5.1**	**5.2**	**34.6**	**16.6**	**10.6**	**13.5**
PMP Intensity from IDF Curve (Figure 7-3) (in/hr)	**38.0**	**47.0**	**74.4**	**38.0**	**38.2**	**74.3**	**74.2**	**27.0**	**37.5**	**47.5**	**41.0**

Table 7-21, Manning's Roughness Coefficient (n) Increased by 50 Percent - T_c Calculation Summary

Sub Basin	1	2	3	4	5	6	7	8	9	10	11
area (ac)	9.22	8.53	5.97	8.83	9.66	6.22	24.68	20.49	31.32	13.49	56.40
Sheet Flow	$T_t = 0.007^*(n^*L)^{\wedge 0.8} / (P_2{}^{\wedge 0.5}\ S^{\wedge 0.4})$ for Sheet Flow										
Manning's friction factor,Paved (n)	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.225	0.225	0.225
length, ft (L)	300	300	300	300	300	300	300	300	300	300	300
2 Yr 24-Hr Rainfall, Inch (P2)	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
slope, ft/ft (S)	0.0019	0.002	0.019	0.002	0.002	0.012	0.023	0.0035	0.023	0.047	0.037
T_t (hrs)	0.1593	0.1561	0.0634	0.1561	0.1561	0.0762	0.0588	0.1248	0.4752	0.3570	0.3929
T_t (min)	9.5591	9.3650	3.8055	9.3650	9.3650	4.5735	3.5255	7.4867	28.5092	21.4209	23.5720
SHALLOW CONCENTRATED FLOW	Tt =L/3600V for Shallow Concentrated Flow, V=20.3282*S^1/2 (Paved)										
length, ft (L)	432	144	100	419	452	200	300	2043	620	417	788
slope, ft/ft	0.0019	0.002	0.019	0.0019	0.002	0.012	0.023	0.0035	0.023	0.047	0.037
paved V, fps	0.8861	0.9091	2.8020	0.8861	0.9091	2.2268	3.0829	1.2026	3.0829	4.4070	3.9102
T_t (hrs)	0.1354	0.0440	0.0099	0.1314	0.1381	0.0249	0.0270	0.4719	0.0559	0.0263	0.0560
T_t (min)	8.1256	2.6400	0.5948	7.8811	8.2865	1.4969	1.6218	28.3129	3.3518	1.5770	3.3587
CHANNEL FLOW	Tt =L/3600V for Shallow Concentrated Flow V = 1.49 * r^2/3 * S^1/2 / n r=A/P										
length, ft (L)	301	486	119	466	290	356	1339	549	2008	330	703
Manning's (n)	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
slope, ft/ft	0.0019	0.002	0.019	0.0019	0.002	0.012	0.023	0.0035	0.023	0.047	0.037
bottom width, ft (wb)	125	125	125	100	100	125	100	80	210	125	400
top width, ft (wt)	125	125	125	100	100	125	100	80	400	125	400
depth, ft (h)	0.77	0.77	0.77	0.98	0.98	0.98	1.24	1.24	2.39	2.39	2.39
area channel, ft^2 (A)	96.25	96.25	96.25	98	98	122.5	124	99.2	728.95	298.75	956
wetted perimeter, ft (P)	126.54	126.54	126.54	101.96	101.96	126.96	102.48	82.48	400.0601	129.78	404.78
Velocity, fps (V)	1.1994	1.2306	3.7928	1.4019	1.4383	3.5322	5.6867	2.2094	7.4711	12.4812	11.2650
T_t (hrs)	0.0697	0.1097	0.0087	0.0923	0.0560	0.0280	0.0654	0.0690	0.0747	0.0073	0.0173
T_t (min)	4.1826	6.5824	0.5229	5.5401	3.3604	1.6798	3.9244	4.1413	4.4795	0.4407	1.0401

Table 7-21, Manning's Roughness Coefficient (n) Increased by 50 Percent - T_c Calculation Summary (Continued)

Sub Basin	1	2	3	4	5	6	7	8	9	10	11
Total T_c (min)	21.8673	18.5873	4.9233	22.7862	21.0119	7.7501	9.0718	39.9409	36.3405	23.4386	27.9708
Use T_c (min)	**21.9**	**18.6**	**5.0**	**22.8**	**21.0**	**7.8**	**9.1**	**39.9**	**36.3**	**23.4**	**28.0**
PMP Intensity from IDF Curve (Figure 7-3) (in/hr)	**32.8**	**36.0**	**74.4**	**32.5**	**33.5**	**62.0**	**57.0**	**24.8**	**26.5**	**32.5**	**29.5**

Table 7-22, Manning's Roughness Coefficient (n) Decreased by 50 Percent - Resulting Peak Runoff Volume

Drainage Sub Basin	Area A (ac)	Total T_c (min)	PMP Intensity I (inch/hr)	Runoff Coefficient (C)	Peak Runoff Q (cfs)
1	9.22	15.9	38.0	1.00	350.36
2	8.53	11.0	47.0	1.00	400.91
3	5.97	5.0	74.4	1.00	444.17
4	8.83	15.9	38.0	1.00	335.54
5	9.66	15.6	38.2	1.00	369.01
6	6.22	5.1	74.3	1.00	462.15
7	24.68	5.2	74.2	1.00	1831.26
8	20.49	34.6	27.0	1.00	553.23
9	31.32	16.6	37.5	1.00	1174.50
10	13.49	10.6	47.5	1.00	640.78
11	56.40	13.5	41.0	1.00	2312.40

Table 7-23, Manning's Roughness Coefficient (n) Increased by 50 Percent - Resulting Peak Runoff Volume

Drainage Sub Basin	Area A (ac)	Total T_c (min)	PMP Intensity I (inch/hr)	Runoff Coefficient (C)	Peak Runoff Q (cfs)
1	9.22	21.9	32.8	1.00	302.42
2	8.53	18.6	36.0	1.00	307.08
3	5.97	5.0	74.4	1.00	444.17
4	8.83	22.8	32.5	1.00	286.98
5	9.66	21.0	33.5	1.00	323.61
6	6.22	7.8	62.0	1.00	385.64
7	24.68	9.1	57.0	1.00	1406.76
8	20.49	39.9	24.8	1.00	508.15
9	31.32	36.3	26.5	1.00	829.98
10	13.49	23.4	32.5	1.00	438.43
11	56.40	28.0	29.5	1.00	1663.80

Table 7-24, Manning's Roughness Coefficient (n) Decreased by 50 Percent - Resulting Water Surface Elevation at Points of Discharge

Point Of Discharge	Drainage Sub Basins	Peak Runoff at Point of Discharge (cfs)	Crest Length L (ft)	Tailwater Elevation (ft) (NAVD 88)	Discharge Coefficient	Weir Elevation (ft) (NAVD 88)	Over Topping Depth Hw_r (ft)	Resulting Water Surface Elevation (ft) (NAVD 88)
W1	**1+2+3**	1195.44	560	793.66	2.5	820	0.90	820.90
W2	**4+5+6**	1166.70	365	793.66	2.5	815	1.18	816.18
W3	**7+8**	2384.49	490	793.66	2.5	810	1.56	811.56
W4	**9+10+11**	4127.68	315	793.66	2.5	814	3.02	817.02

Table 7-25, Manning's Roughness Coefficient (n) Increased by 50 Percent - Resulting Water Surface Elevation at Points of Discharge

Point Of Discharge	Drainage Sub Basins	Peak Runoff at Point of Discharge (cfs)	Crest Length L (ft)	Tailwater Elevation (ft) (NAVD 88)	Discharge Coefficient	Weir Elevation (ft) (NAVD 88)	Over Topping Depth Hw_r (ft)	Resulting Water Surface Elevation (ft) (NAVD 88)
W1	**1+2+3**	1053.66	560	793.66	2.5	820	0.83	820.83
W2	**4+5+6**	996.23	365	793.66	2.5	815	1.06	816.06
W3	**7+8**	1914.91	490	793.66	2.5	810	1.35	811.35
W4	**9+10+11**	2932.21	315	793.66	2.5	814	2.40	816.40

8.0 Appendices

None