Hydrological Study & Flood Protection Report
Electrical Express Train-Blue Line
Sector 'C' Part (1)
From St. (336+100) to St. (431+800)

إيكون للاستشارات ش.ذ.م.م
AIECon Consultants L.L.C

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Table of content

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List of tables

List of figures

Abbreviations

Sector 'C' Part (1)	The Sector of Electrical Express Train from Station 336+100 to station 431+800

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1 Introduction

A successful development in the transportation sector in Egypt is noticed in the recent years. In this context, a new huge national project “Electrical Express Train” is started with an estimated design speed of about 250 km/h for the train, that means that the distance from 6th of October City, Luxor, Aswan and Abu Simbel near the Sudan border can be traveled in about 5.5-hrs. The project aims to construct a new train with new luxury touristic stations with total length 2000km.

The network of The Electrical Express Train is planned to connect Upper Egypt with lower Egypt. Also, the project will participate in the development of Upper Egypt.

The National Authority for Tunnels and the General Authority for Embankments and Bridges have commissioned the floods protection consultant to perform the hydrologic study for the (EET) route. In accordance with this, this report presents the results of the conducted study, specifically for Part (1) of Sector ‘C’ that extends from station (336+100) to the station (431+800) (Manflout - Gerga).

1.1 Report Structure

The document is divided into six chapters as follows:

Chapter One: Introduction

This section will briefly describe the project location. In addition, the scope of study within the project will be presented, the international standards & codes applied and utilized in the hydrologic study of the project area.

Chapter Two: Meteorological Analysis

This section will briefly describe the outcomes of the frequency analysis carried out for the collected rainfall data and the IDF curves developed for these data.

Chapter Three: Morphological Analysis

This part will present the delineation of the external watersheds affecting the embankment in addition, estimation of the Morphological parameters for these watersheds, which are presented in some important characteristics such as area, length, and average slope.

Chapter Four: Hydrological Analysis

This part shows the study of hydrological parameters and theories which have been used in the calculations for this study and how to apply it according to the inputs and the type of the studied place. The outcome of this study is to determine the peak design flows from each watershed and its corresponding runoff hydrograph.

Chapter Five: Hydraulic Design Criteria

This part shows the Hydraulic Basis which will be taken into consideration while designing the proposed structures, Also the Specifications & Details of the proposed structures.

Chapter Six: Protection Works and Recommendations

This chapter illustrates the adopted design standards, the proposed flood protection systems, and recommendations from the flood consultative that must be followed to ensure the efficiency of the proposed protection works.

1.2 Study Area

The EET path (Sector 'C') extends from Manflout northward to Gerga southward, Scope of this report is Part (1) of the Sector 'C' which extends from station 336+100 to station 431+800 with an approximate length of 96 km, the Sector 'C' area is located between Latitude 26°00', 27°30' and Longitude 30°50', 31°55' as shown in figure 1.

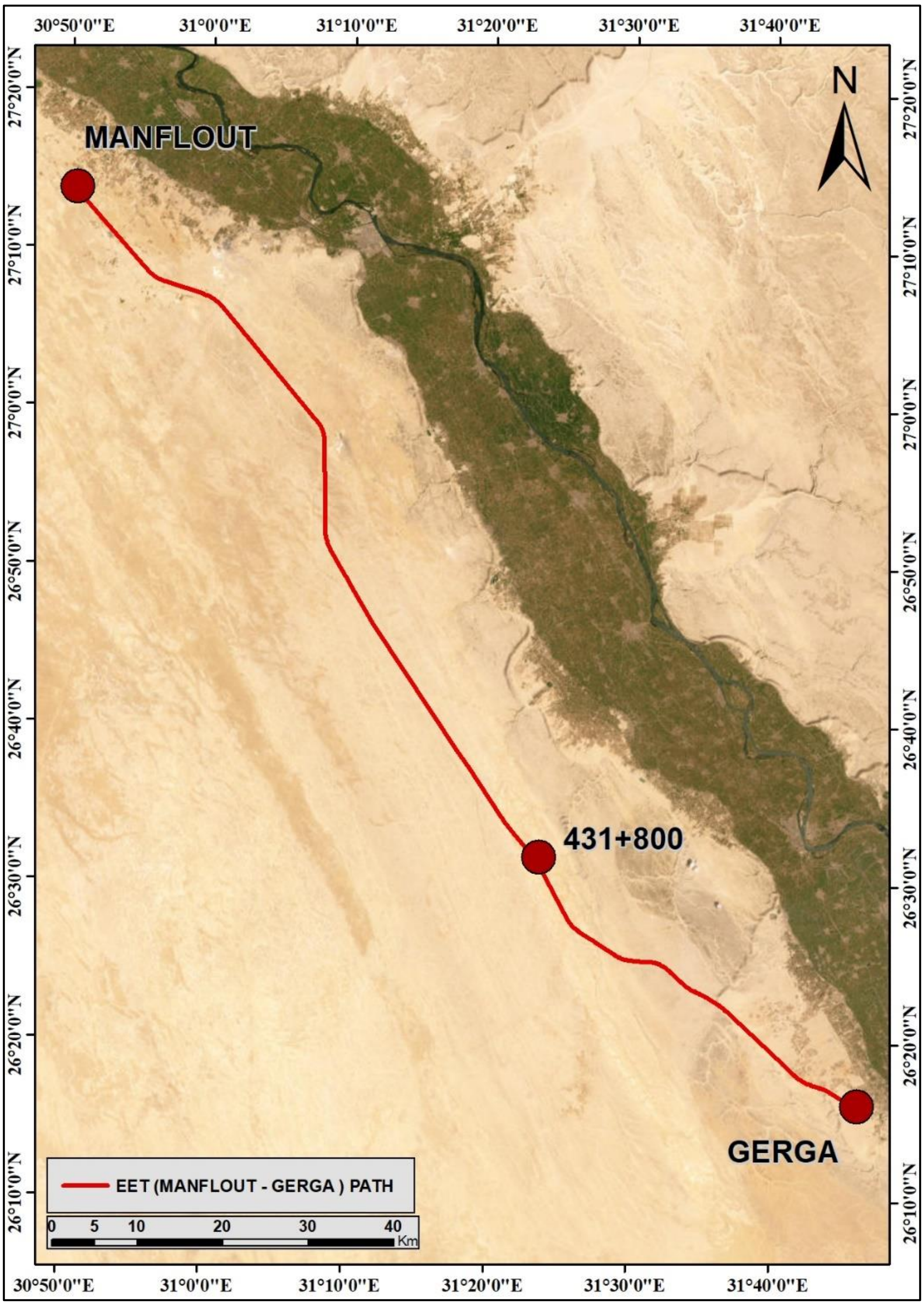

Figure 1 General Location of the Study Area

1.3 Study Objectives & Scope of Work

The hydrological Study aims to define the hydrological conditions in the study area, thereafter, comes setting design strategies and different solutions then choosing the most adequate, and finally reach the optimal proposed design and carry out detailed design for its elements:

The study will be carried out through the following tasks:

- Collecting Data.
- Design Criteria and Standards.
- Designed Return Period.
- Rainfall Analysis.
- Calculate Peak design flows and estimate flood hydrographs.
- Providing solutions and recommendations.
- Detailed Design of Flood protection works.

1.4 Standard Codes & Software Packages

The hydrological studies and hydraulic design/analysis in this study follows:

- `Chapter 7 (Protection of Embankment from Rainfall, Floods and Quicksand). (2008). In HBRC, The Egyptian Code for Urban Embankment Works. HBRC.
- Subramanya, K. (2015). FLOW IN OPEN CHANNELS (Fourth ed.). McGraw Hill Education (India) Private Limited

Also, the following Programs and software packages are used in the design and analysis of the study:

- AutoCAD Civil 3D
- ArcGIS + Arc Hydro tools
- HEC-HMS
- Global Mapper
- SAS Planet
- HYFRAN+
- Bentley FlowMaster
- Bentley CulvertMaster

2 Meteorological Analysis

2.1 General

The statistical analysis of rainfall data is one of the most important analytical studies to be carried out in any flood protection and storm drainage project, where rainfall is the main element causing the flow in streams , and this is why this study was given maximum priority from the compilation of data, study and detailed analysis, conducting a series of statistical tests on them using the best means to deduce the design storms, and developing the IDF curves, for which design flows will be calculated., Figure 2 shows the distribution of avg. annual daily rainfall depth in Egypt from 1990 to 2020, Also shows that the avg. annual rainfall depths varies from 0 to 68.64 mm at the most regions.

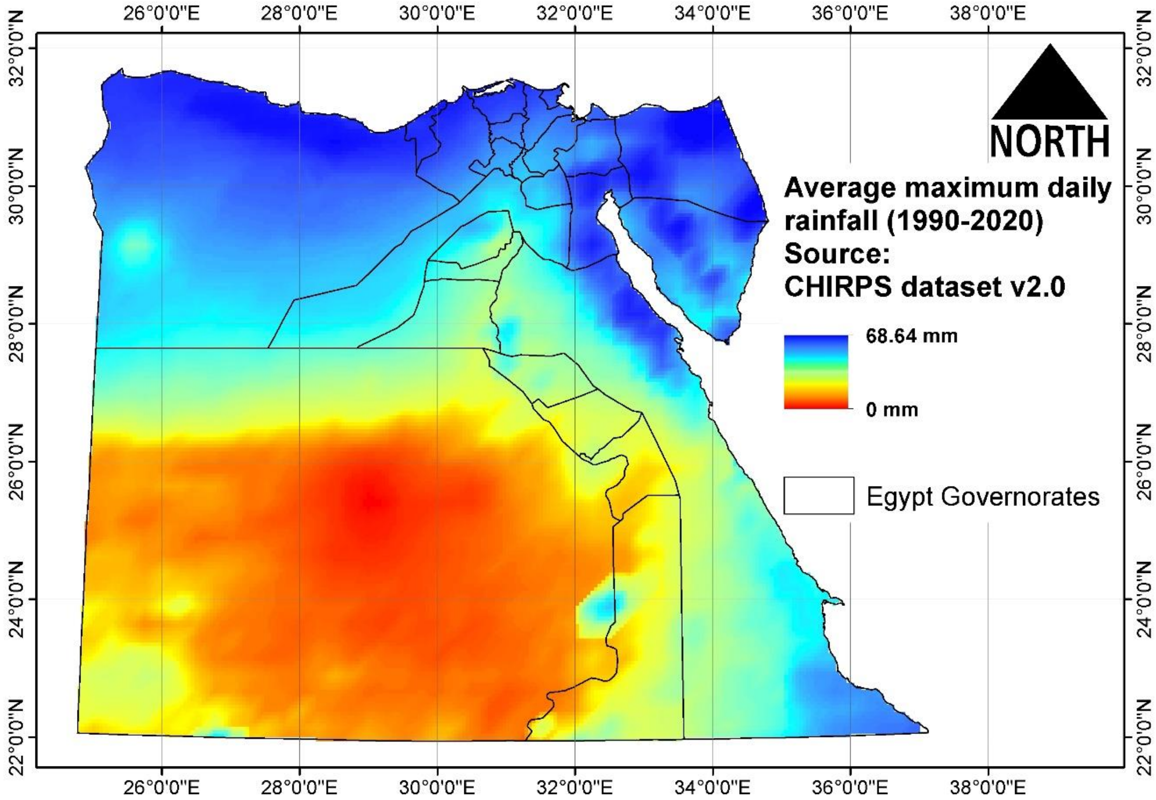

Figure 2 Distribution of Avg. Maximum Daily Rainfall Depth in Egypt (1990 – 2020)

2.2 Rainfall Data Collection

Figure 3 shows the location of Assiut Airport Rainfall Station, which is spatially near to the project location. Thus, its data have been collected in order to perform the meteorological and hydrological study.

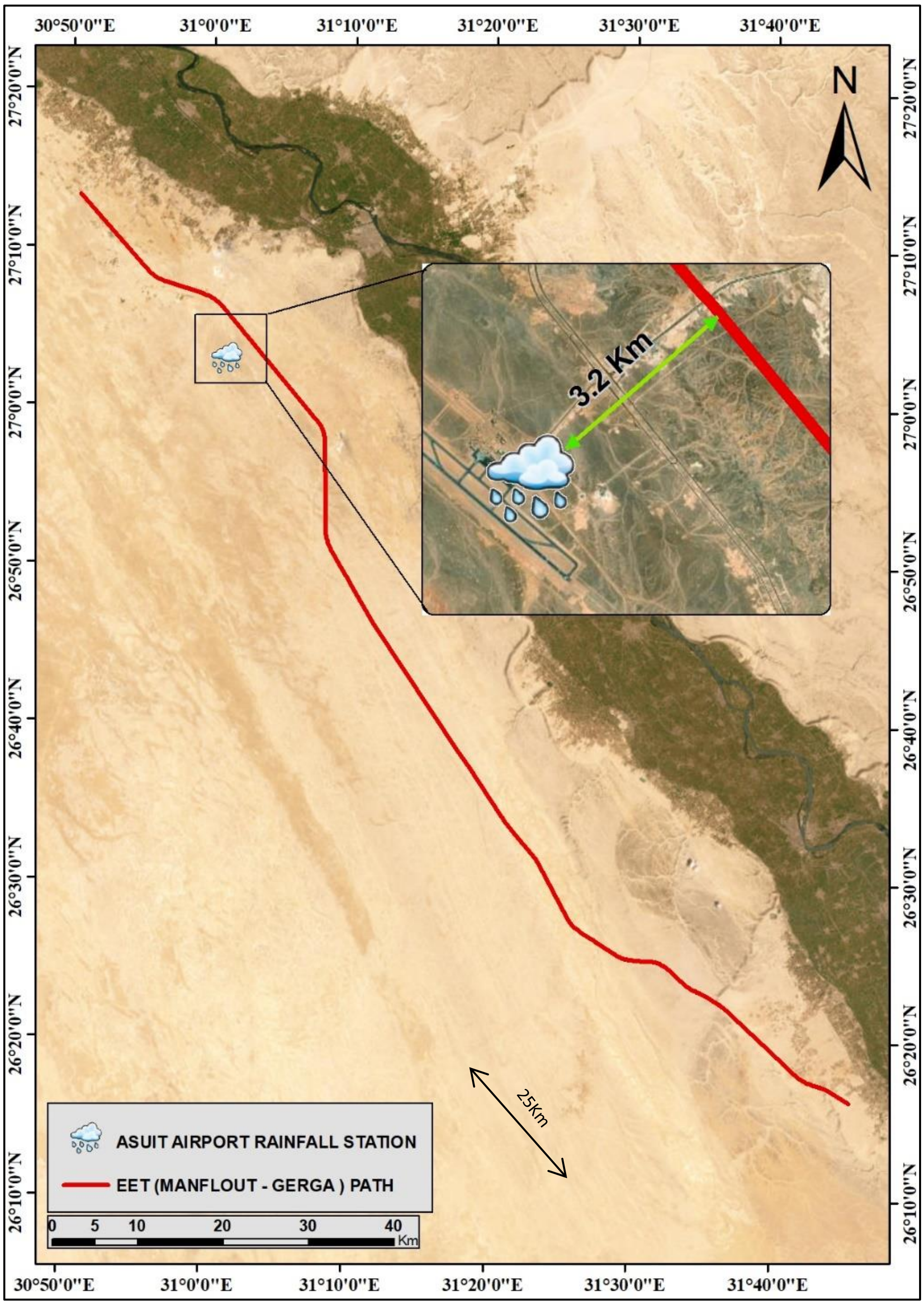

Figure 3 Location of Assiut Airport Rainfall Station relative to the project location

Max Daily Rainfall Depths were collected for Assiut Airport Rainfall Station from 1961 to 2018, the max daily rainfall depth is **24** mm in 1994, Figure 4 shows the max daily rainfall depths records for Assiut Airport Rainfall Station from 1961 to 2018.

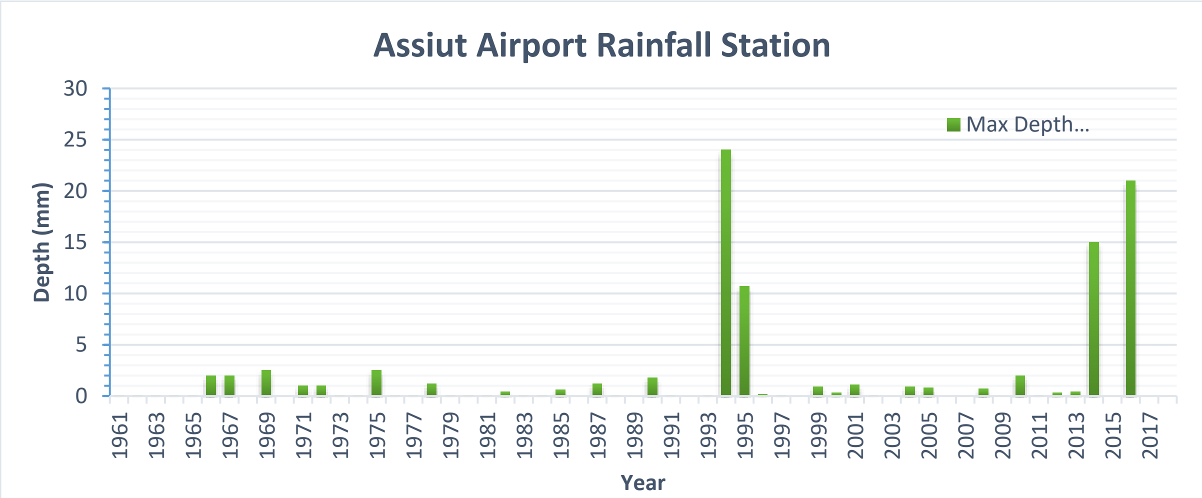

Figure 4 Max Daily Rainfall Depth for Assiut Airport Rainfall Station from (1976-2020)

2.3 Statistical Analysis for Assiut Airport Rainfall Station Data

Statistical analysis of rainfall data was carried out in several ways using HYFRAN+ program and it was found that (Weibull) was the best distribution that matches the statistical characteristics of Assiut Airport Rainfall Station data, then deduce the maximum daily rain depth of the return period 2, 5, 10, 25, 50 and 100 years as there as there are no rainfall data for short duration periods less than daily period.

Table 1 shows Max Daily Rainfall Depth for Assiut Airport Rainfall Station for Different Returned Periods.

Table 1 Max Daily Rainfall Depth for Assiut Airport Rainfall Station for Different Returned Periods.

Name	Distribution	P 100y (mm)	P 50y (mm)	P 25y (mm)	P 10y (mm)	P 5y (mm)
Assiut Airport Rainfall Station	Weibull	36.14	27.59	19.95	11.51	6.36

Note: A storm with a depth of **60 mm** has been recorded and reported by the National Water Resources Center (NWRC) at Assiut airport rainfall station. Hence, this value cannot be ignored and will be used a rainfall depth equal to **60 mm** (maximum 24 hrs. rainfall depth) has been used as a design value for the protection works.

For obtaining the intensity-duration-frequency (IDF) curves, the results of previous statistical analysis and Bell Ratios (as shown below) have been used, Figure 5 shows the developed IDF curve for Assiut Airport Rainfall Station for the different returned periods.

$$\text{Bell's Ratio} = (0.54 * \mathrm{D}^{0.25}) - 0.5$$

D = Duration of rainfall (min)

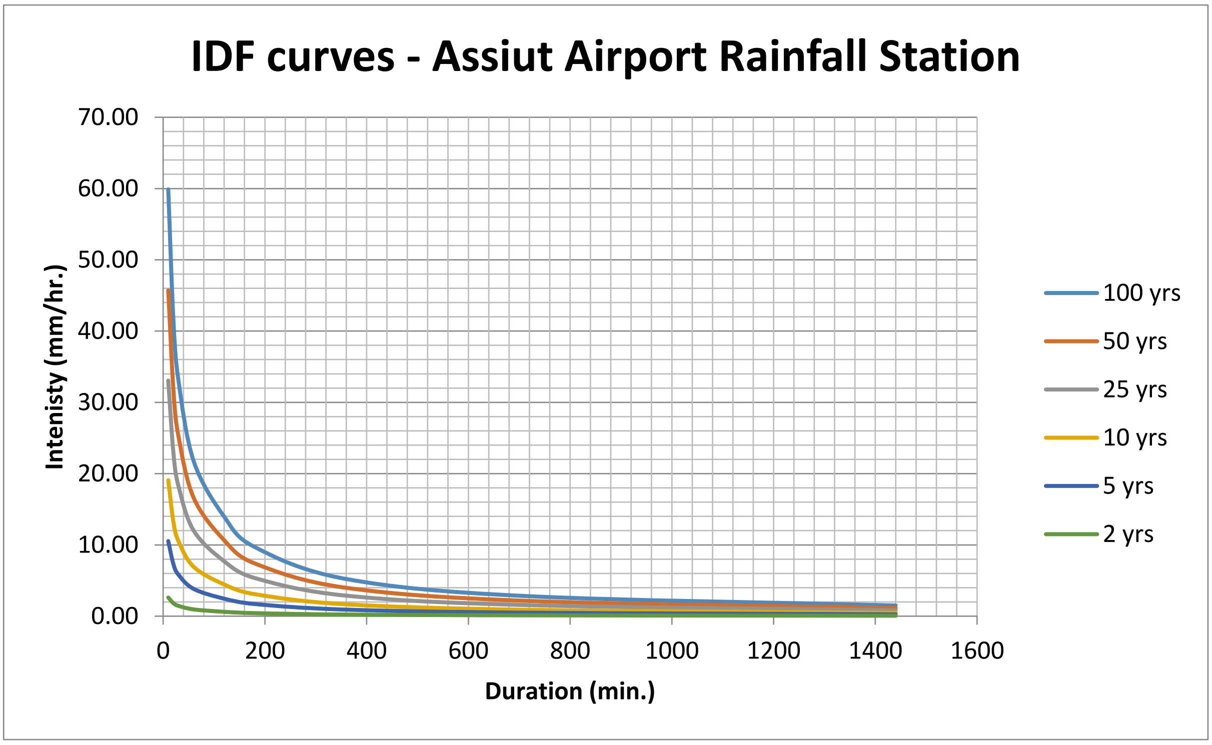

Figure 5 IDF curve for Assiut Airport Rainfall Station

3 Morphological Analysis

3.1 General

Morphological analysis is the stage of determination the main external streams affecting the study area, determining their relevant watersheds and their morphological parameters (i.e. area, time of concentration, slope, curve number …etc.), then by using these parameters and rainfall data we carry out the Hydrological analysis to determine the peak discharges, runoff hydrographs and the water volume to design the flood protection structures, Topographic maps & DEM (Digital Elevation Model) were used to carry out a complete morphological analysis for the study area to identify the major watersheds affecting it, as well as the different morphological parameters such as:

1. Watershed Extent
2. Longest Flow Path
3. Watershed Area
4. Watershed Slope
5. Watershed Shape
6. Time of concentration

The morphological parameters calculated as follows:

1. Wadi Slope

$$S = H / L_B$$

Where:

S: Wadi Slope

H: Elevation difference in meters

L_B: Wadi length in meters

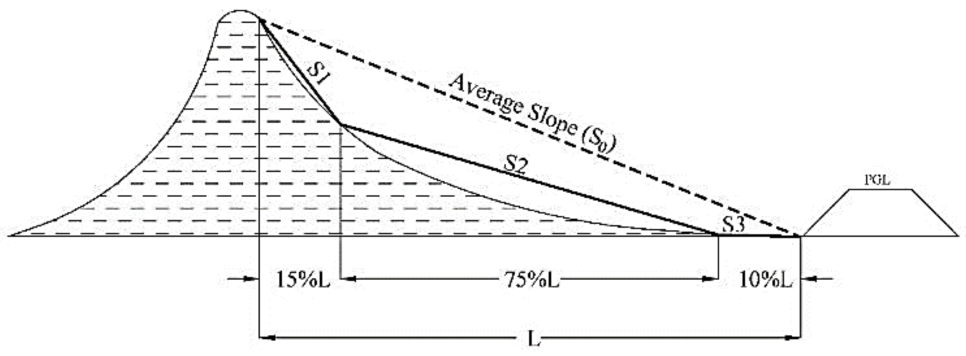

Figure 6 Slope Calculations

2. Time of Concentration

It's the time needed for the full contribution of the watershed to form the peak flood discharge and it's the same travel time that runoff needs from the most distant point in the watershed till the outlet, and there are few equations to calculate the time of concentration and the most commonly used and most recommended in this study is Kirpich equation:

$$T_C \text{ (min.)} = 0.01944 \, (LB)^{0.77} / (S)^{0.385}$$

Where:

LB: The length of the stream in meters

S: The slope of the stream as a m/m

3. Lag Time

The standard lag time is defined as the time between the center of mass for the excess rainfall and the peak flow of the resulting hydrograph.

$$T_L \text{ (min.)} = 0.6 * T_C$$

Where:

T_L: lag time (minutes)

T_C: time of concentration (minutes)

3.2 Morphological Study Results

Using the Arc GIS software and by simulating the natural terrain under study, the main streams affecting the embankment and their watersheds are identified and their morphological parameters are determined.

The DEM (Digital Elevation Model) of the study area & surrounding areas were used to determine the streams affecting the railway embankment. Arc Hydro Tools, one of the applications used within the ArcGIS program, was used to determine the watersheds affecting the study area. Figure 7 shows the watersheds resulting from the GIS program.

The recent satellite images and topo maps have been used to verify the output delineation results of the ArcGIS. After the completion of the simulation and the verifications required to determine the streams affecting the embankment under study, Figures 8 & 9 show the watersheds that are affecting the project, while Table 2 shows the morphological parameters of the watersheds that affect the study area.

Table 2 Morphological parameters of watersheds that affect the study area

No.	WS Name	Area (km^2)	LFP (m)	ElevUP	Elev85	Elev10	ElevDS	S over 85	S 85 10	S less 10	T_c (min)	T_{Lag} (min)
1	W-01	15.59	12161	239	219	168	165	1.10%	0.56%	0.25%	243	146
2	W-02	0.79	1109	196	195	183	180	0.60%	1.44%	2.71%	28	17
3	W-03	8.16	7955	239	233	186	183	0.50%	0.79%	0.38%	165	99
4	W-04	5.93	5873	247	235	193	191	1.36%	0.95%	0.34%	117	70
5	W-05	0.82	2625	242	225	203	202	4.32%	1.12%	0.38%	56	34
6	W-06	0.15	869	212	209	206	205	2.30%	0.46%	1.15%	30	18
7	W-07	0.71	2138	258	226	207	206	9.98%	1.18%	0.47%	45	27
8	W-08	0.49	1755	264	254	220	219	3.80%	2.58%	0.57%	33	20
9	W-09	0.36	630	237	233	225	224	4.23%	1.69%	1.59%	15	9
10	W-10	0.05	4415	246	245	236	235	0.15%	0.27%	0.23%	154	93
11	W-11	4.55	3677	289	251	218	217	6.89%	1.20%	0.27%	73	44
12	W-12	1.89	1893	236	233	218	217	1.06%	1.06%	0.53%	47	28
13	W-13	80.07	22016	286	263	216	215	0.70%	0.28%	0.05%	537	322
14	W-14	0.67	1034	215	214	213	211	0.64%	0.13%	1.93%	52	31
15	W-15	4.28	2788	230	219	206	203	2.63%	0.62%	1.08%	66	40
16	W-16	1.26	1685	228	222	208	207	2.37%	1.11%	0.59%	40	24

No.	WS Name	Area (km^2)	LFP (m)	ElevUP	Elev85	Elev10	ElevDS	S over 85	S 85 10	S less 10	T_c (min)	T_{Lag} (min)
17	W-17	0.71	1294	231	226	216	215	2.58%	1.03%	0.77%	33	20
18	W-18	1.97	2098	235	228	215	214	2.22%	0.83%	0.48%	52	31
19	W-19	0.46	1251	251	239	223	218	6.39%	1.71%	4.00%	24	14
20	W-20	1.68	1760	247	234	219	216	4.92%	1.14%	1.70%	37	22
21	W-21	32.06	13370	290	267	223	218	1.15%	0.44%	0.37%	270	162
22	W-22	0.43	1337	263	248	232	231	7.48%	1.60%	0.75%	28	17
23	W-23	0.15	457	285	284	268	266	1.46%	4.66%	4.37%	9	6
24	W-24	0.04	363	281	279	270	269	3.67%	3.30%	2.75%	8	5
25	W-25	0.16	361	274	273	263	262	1.85%	3.69%	2.77%	8	5
26	W-26	0.80	1114	273	269	257	254	2.39%	1.44%	2.69%	25	15
27	W-27	0.27	683	282	278	258	256	3.91%	3.91%	2.93%	13	8
28	W-28	0.11	395	270	269	255	254	1.69%	4.72%	2.53%	9	5
29	W-29	0.16	640	278	274	257	256	4.17%	3.54%	1.56%	13	8
30	W-30	0.41	648	270	264	255	254	6.18%	1.85%	1.54%	15	9
31	W-31	0.50	1739	266	261	259	255	1.92%	0.15%	2.30%	70	42
32	W-32	12.61	5452	271	265	253	251	0.73%	0.29%	0.37%	155	93
33	W-33	10.18	7392	299	285	260	256	1.26%	0.45%	0.54%	165	99
34	W-34	3.33	3506	284	273	254	252	2.09%	0.72%	0.57%	79	48
35	W-35	1.86	2045	262	260	251	249	0.65%	0.59%	0.98%	58	35
36	W-36	0.31	1314	269	265	257	254	2.03%	0.81%	2.28%	34	20
37	W-37	44.53	10779	275	270	251	249	0.31%	0.24%	0.19%	305	183
38	W-38	0.28	773	282	278	261	260	3.45%	2.93%	1.29%	16	10
39	W-39	0.69	709	267	264	261	259	2.82%	0.56%	2.82%	23	14
40	W-40	0.07	346	276	275	263	262	1.93%	4.63%	2.89%	8	5
41	W-41	10.27	6908	304	291	264	263	1.25%	0.52%	0.14%	166	99
42	W-42	0.06	433	278	277	270	267	1.54%	2.16%	6.93%	11	6
43	W-43	0.24	433	309	306	296	295	4.62%	3.08%	2.31%	9	6
44	W-44	2.08	2335	302	301	297	296	0.29%	0.23%	0.43%	91	55
45	W-45	4.08	2196	299	298	297	296	0.30%	0.06%	0.46%	127	76
46	W-46	1.21	2866	313	311	297	293	0.47%	0.65%	1.40%	74	44
47	W-47	5.77	5115	330	314	296	295	2.09%	0.47%	0.20%	129	77
48	W-48	0.03	301	300	298	295	293	4.44%	1.33%	6.66%	9	5
49	W-49	0.47	1049	308	306	296	295	1.27%	1.27%	0.95%	27	16
50	W-50	0.46	1086	296	294	289	288	1.23%	0.61%	0.92%	34	20

No.	WS Name	Area (km^2)	LFP (m)	ElevUP	Elev85	Elev10	ElevDS	S over 85	S 85 10	S less 10	T_c (min)	T_{Lag} (min)
51	W-51	18.19	8130	319	315	293	286	0.33%	0.36%	0.86%	202	121
52	W-52	0.51	1194	297	296	288	287	0.56%	0.89%	0.84%	35	21
53	W-53	1.38	1926	312	302	290	289	3.46%	0.83%	0.52%	47	28
54	W-54	24.27	8547	316	303	287	284	1.01%	0.25%	0.35%	226	136
55	W-55	7.87	5684	334	314	291	284	2.35%	0.54%	1.23%	119	72
56	W-56	0.74	1277	291	290	288	287	0.52%	0.21%	0.78%	55	33
57	W-57	1.95	2502	330	321	290	288	2.40%	1.65%	0.80%	48	29
58	W-58	0.22	614	303	295	291	289	8.68%	0.87%	3.26%	17	10
59	W-59	163.25	30338	385	372	305	290	0.29%	0.29%	0.49%	609	365
60	W-60	13.81	7532	350	341	306	300	0.80%	0.62%	0.80%	155	93
61	W-61	0.25	952	340	336	311	307	2.80%	3.50%	4.20%	17	10
62	W-62	9.36	5845	350	345	316	310	0.57%	0.66%	1.03%	127	76
63	W-63	3.71	3079	373	357	348	341	3.46%	0.39%	2.27%	79	47
64	W-64	2.53	3069	405	401	349	347	0.87%	2.26%	0.65%	57	34
65	W-65	0.94	1471	415	407	396	390	3.62%	1.00%	4.08%	33	20
66	W-66	1.58	1644	412	405	388	387	2.84%	1.38%	0.61%	37	22
67	W-67	0.37	1077	416	413	392	391	1.86%	2.60%	0.93%	23	14
68	W-68	0.31	977	400	394	390	389	4.09%	0.55%	1.02%	30	18
69	W-01S	0.18	540	175	171	164	163	4.94%	1.73%	1.85%	13	8
70	W-02S	0.14	575	222	216	202	201	6.96%	3.25%	1.74%	12	7
71	W-03S	0.94	1600	248	236	219	217	5.00%	1.42%	1.25%	33	20
72	W-04S	0.47	1813	236	231	220	219	1.84%	0.81%	0.55%	47	28
73	W-05S	5.30	4246	284	271	257	255	2.04%	0.44%	0.47%	107	64
74	W-06S	0.38	1340	267	261	253	251	2.98%	0.80%	1.49%	34	21
75	W-07S	3.19	2269	250	249	248	247	0.29%	0.06%	0.44%	131	79
76	W-08S	1.92	3134	277	266	250	249	2.34%	0.68%	0.32%	77	46
77	W-09S	0.32	1112	282	276	261	260	3.60%	1.80%	0.90%	24	15
78	W-10S	4.78	5081	304	294	271	268	1.31%	0.60%	0.59%	114	68
79	W-11S	0.33	1371	300	298	295	293	0.97%	0.29%	1.46%	50	30
80	W-12S	0.75	2070	315	304	298	289	3.54%	0.39%	4.35%	57	34
81	W-13S	0.48	769	336	333	312	309	2.60%	3.64%	3.90%	14	9

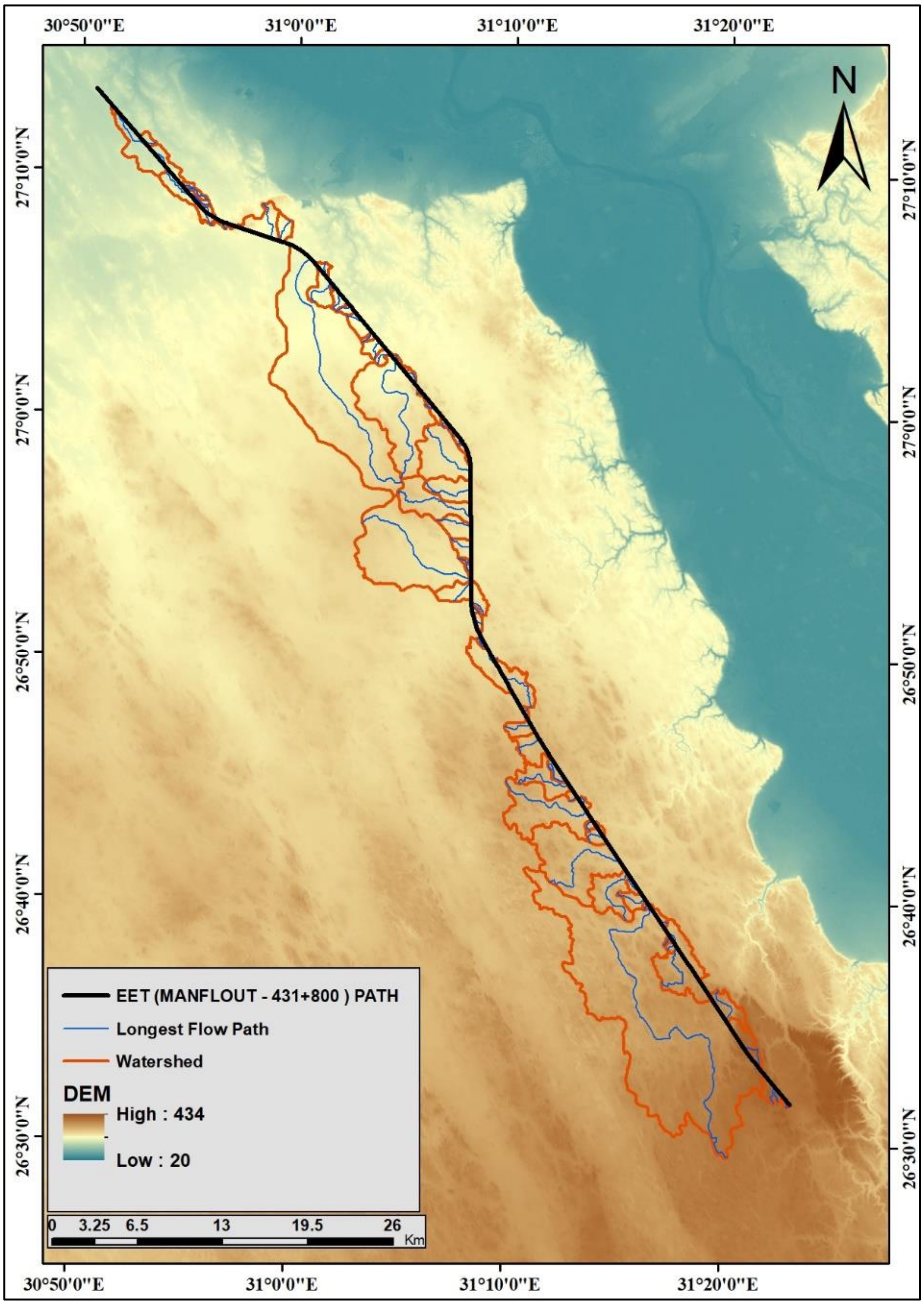

Figure 7 Watersheds generated from GIS program

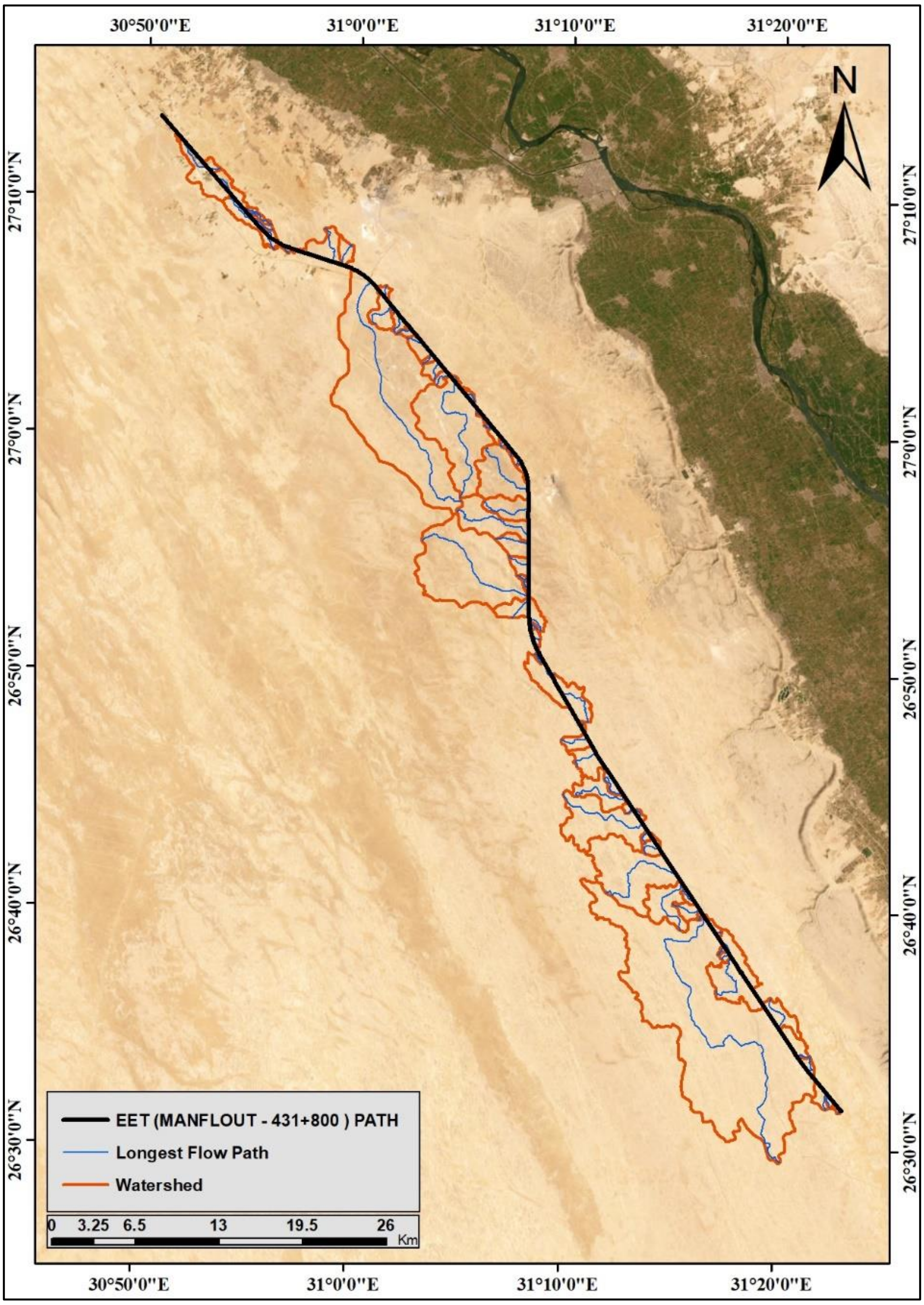

Figure 8 Watersheds affecting the study area on Satellite image

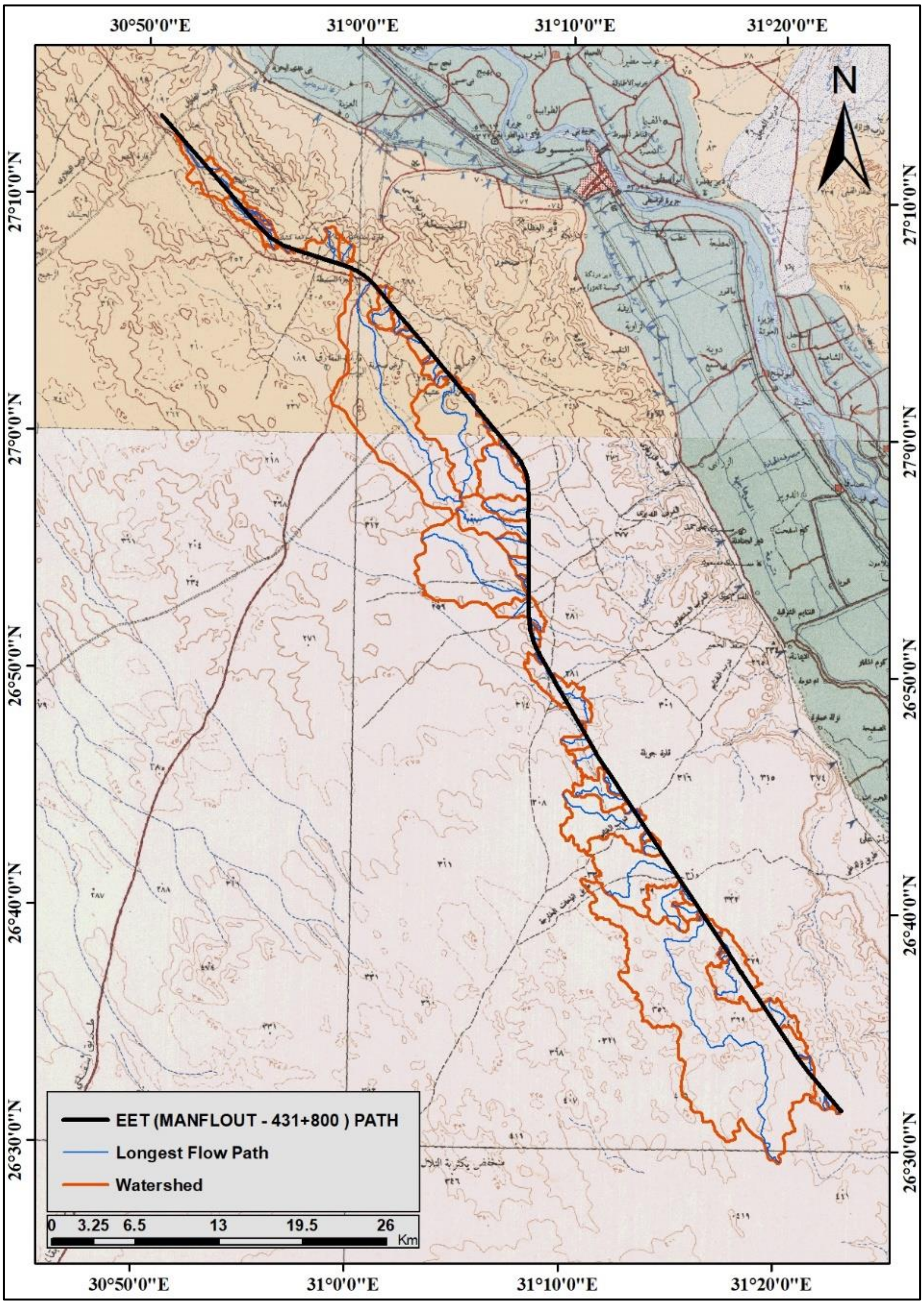

Figure 9 Watersheds affecting the study area on Topographic Map

4 Hydrological Analysis

The hydrological study aims to determine the peak values of surface runoff and flowing water volumes depending on the morphological and meteorological study taking into account the design storms and their distribution and the areas affected by these storms, and Surface runoff is the rate of movement or discharge of water (volume / time) in natural watercourses.

Factors affecting runoff can be divided into rainfall-related factors such as rainfall intensity, duration of rainfall, return period of rainfall, distribution of rainfall over watershed, and other factors associated with the watershed such as the area, the length of the main stream, the slope of the main stream and the shape of the watershed, as well as soil-related factors such as infiltration and land cover/use types, the following are the mathematical methods that can be used to estimate the maximum runoff from the contributing watersheds to the embankment under study according to the data available and the most relevant to the case being studied.

4.1 Design Storm Distribution

The SCS Type II design storm distribution is the most commonly used rainfall distribution in the arid and semi-arid regions as it provides logical and safe values, due to its dependence on the concentration of the bulk of rainfall in a short time. Figure 10 shows a sample of the SCS type II storm distribution for 24 hours.

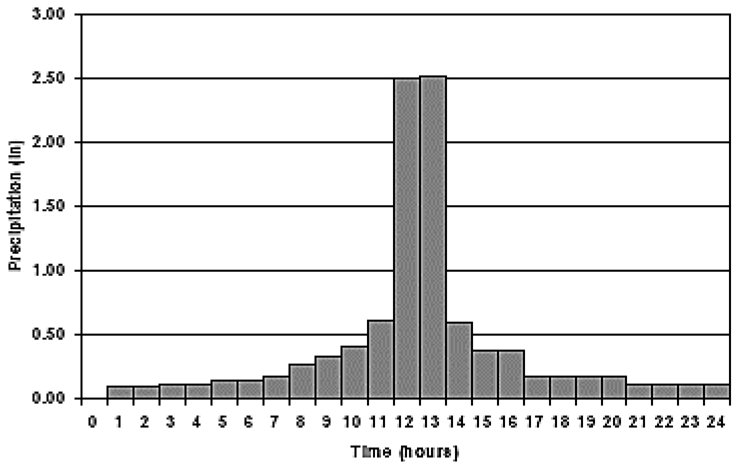

Figure 10 Distribution of SCS type II storm for 24 hours

In order to calculate the peak flood discharge, the Rational equation is applied to watersheds with areas less than 1 km^2, for watersheds with areas greater than 1 km^2, SCS Unit Hydrograph method is used to avoid high illogic runoff values resulting from the use of the "Rational method" for large watersheds so as not to result in unnecessary large mitigation structures.

4.2 Rational Method

Rational method is the most commonly used method in urban areas & relatively small watersheds in rural areas for calculating the max discharge at the outlet of the watersheds.

These terms should be taken into consideration when using this method:

- Area of watershed less than 100 hectares.
- Time of concentration less than 2 hours.
- The watershed has no bonds.
- The connectivity of the surfaces that has low permeability like (asphalt-concrete - Rocky surface).

Rational Method Formula:

$$Q_p = 0.278\ CIA$$

Whereas:

Qp: The peak discharge (m^3/s)

C: Runoff Coefficient

I: Precipitation Intensity (mm/hr)

A: Watershed area (km^2)

4.2.1 Runoff Coefficient (C)

Runoff Coefficient: is the ratio of rainfall flowing from drainage basins. This coefficient is affected by the nature of the drainage basin, It is value varies between (0-1), the more the value were near to zero the higher the permeability of the soil & the soil keeps most of the rainfall, The more the value were near to one the lower the permeability of the soil & most of the rainfall would runoff on the soil surface, Table 3 shows the runoff coefficient values for different kinds of surfaces & Land uses.

Table 3 Runoff Coefficient values for Rational Method

Watershed characteristic	Extreme	High	Normal	Low
Relief - C_r	0.28-0.35 Steep, rugged terrain with average slopes above 30%	0.20-0.28 Hilly, with average slopes of 10-30%	0.14-0.20 Rolling, with average slopes of 5-10%	0.08-0.14 Relatively flat land, with average slopes of 0-5%
Soil infiltration - C_i	0.12-0.16 No effective soil cover; either rock or thin soil mantle of negligible infiltration capacity	0.08-0.12 Slow to take up water, clay or shallow loam soils of low infiltration capacity or poorly drained	0.06-0.08 Normal; well drained light or medium textured soils, sandy loams	0.04-0.06 Deep sand or other soil that takes up water readily; very light, well-drained soils
Vegetal cover - C_v	0.12-0.16 No effective plant cover, bare or very sparse cover	0.08-0.12 Poor to fair; clean cultivation, crops or poor natural cover, less than 20% of drainage area has good cover	0.06-0.08 Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in cultivated crops	0.04-0.06 Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover
Surface Storage - C_s	0.10-0.12 Negligible; surface depressions few and shallow, drainageways steep and small, no marshes	0.08-0.10 Well-defined system of small drainageways, no ponds or marshes	0.06-0.08 Normal; considerable surface depression, e.g., storage lakes and ponds and marshes	0.04-0.06 Much surface storage, drainage system not sharply defined; large floodplain storage, large number of ponds or marshes
Note: The total runoff coefficient based on the 4 runoff components is $C = C_r + C_i + C_v + C_s$				

When the land use varies through the study area then we use a weighted runoff coefficient as follow:

$$C\ (\text{Weighted}) = \frac{c_1 \text{Area}_1 + c_2 \text{Area}_2}{\text{Area}_1 + \text{Area}_2}$$

4.3 SCS Curve Number Method

The SCS (CN/Unit Hydrograph) method is applied to watersheds with areas greater than 1 km^2, where part of the rainfall infiltrates when it falls into the ground. Surface soil type, slope and geometric dimensions of the stream reaches control the increase or decrease of losses.

In order to calculate the excess rainfall values, which causes the surface runoff affecting the embankment under study after taking into consideration the different losses, mathematical equations to determine these losses and connect between rainfall land resultant runoff values are required.

Accordingly, the Soil Conservation Service (SCS) - Curve Number (CN) method, which is one of the most widely used practical methods for determining losses, is based on Soil Type and Land Use. The following equations are applied to calculate the runoff value:

$$P_e = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where:

Pe: Excess rainfall, is the value of rain that contributes to runoff (mm)

Ia: Initial abstraction, is the value of the initial interception, which includes interstitial losses, leaching and surface storage, all of which occur before the start of surface runoff (mm).

$$I_a = 0.2 \times S$$

S is the soil retention which depends on the type of soil and the surface cover of the drainage basins which is dependent on the curve number value ranging between 1 and 100, the following equation shows the relationship between them:

$$S = \frac{25400}{CN} - 254$$

According to the geological classification of surface soil, surface cover and land use, the value of the curve number and therefore the amount of water lost by infiltration can be estimated using the above equations as well as the amount of excess rainfall that causes the runoff, and the hydrological model has been fed with all these data for use in calculating the hydrograph.

Figure 11 shows the values of Curve Number (CN) for the different regions in Egypt.

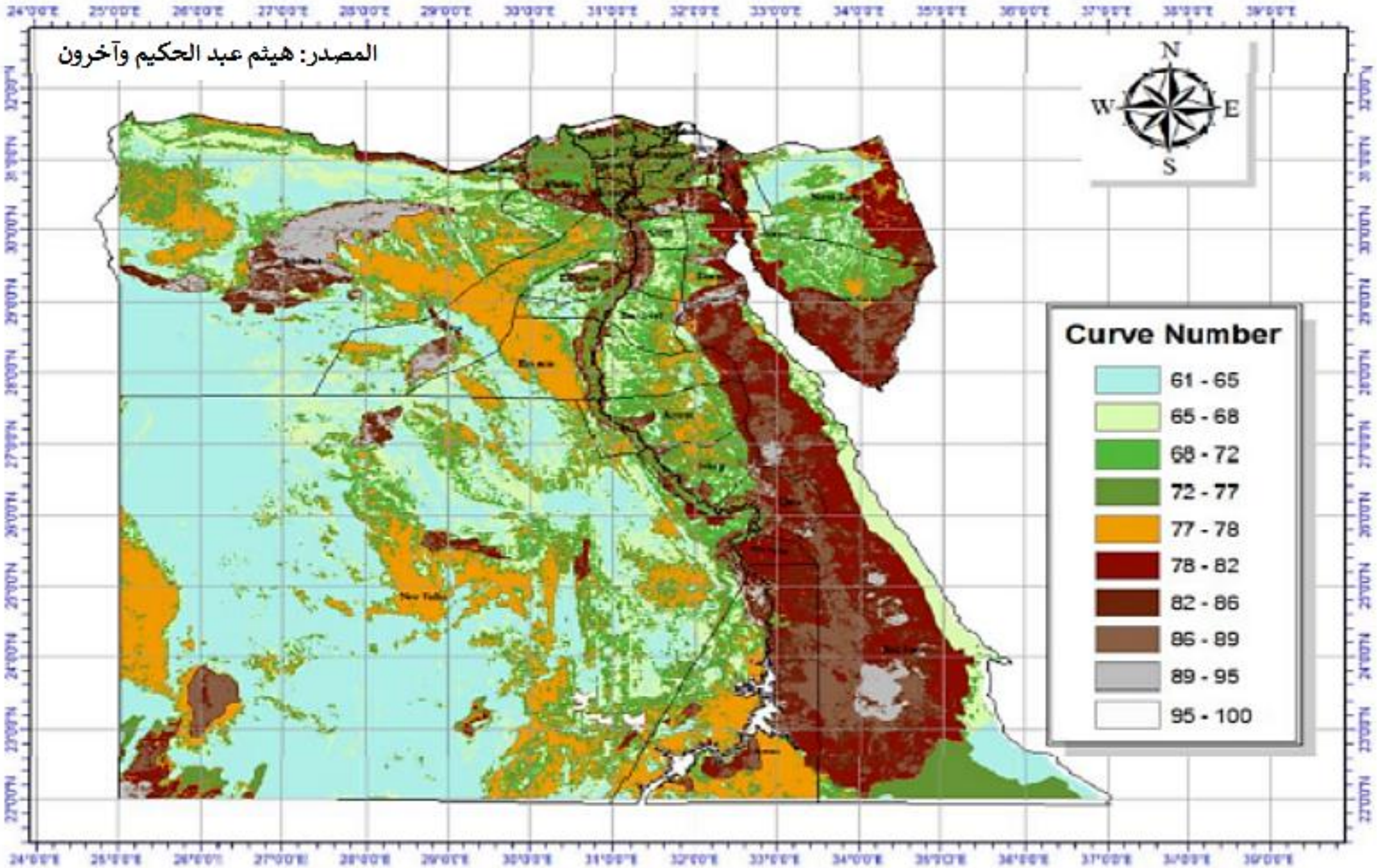

Figure 11 Curve Number (CN) map for Egypt, (https://www.tandfonline.com/doi/full/10.1080/02626667.2015.1027709)

Table 4 shows the values of Curve Number (CN) depending on soil type & land use.

Table 4 Curve Number (CN) values for arid & semi-arid areas

Cover description		Curve Numbers for hydrologic soil group			
Cover Type	Hydrologic condition	A	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosote bush, black brush, bursage, Paloverde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

Poor: <30% ground cover (litter, grass, and brush).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.

4.4 Hydrological Study Methodology

Based on the above, the methodology of the hydrological study that is used when dealing with the problem of flood risk mitigation can be summarized in the following steps:

1. The morphological & Hydrological different parameters would be determined according to the basis at chapter 3 &4.
2. Using the morphological parameters of the watersheds, the hydrological model of each watershed is determined.
3. The runoff coefficient and the curve number values are determined based on the land use/land cover types and using the above-mentioned coefficients and reference tables.
4. The longest flow path for the mainstream within each watershed is determined and the slope of this path and the time of concentration is calculated.
5. The design rainfall depth of each watershed is obtained according to its condition and the above mentioned, the returned period that taken in design of flood protection works is 100 years.
6. The different mentioned formulas would be applied (Rational Method – SCS-Curve Number) to calculate the discharges & volumes which we will use to take the right decision.
7. Any existing structure that is likely to affect the hydrograph at the watershed outlet, such as dams, artificial lakes and marshes have been taken into consideration.

4.5 Hydrological Study Results

Table 5 shows the results of the hydrological study by using the above-mentioned methods.

Table 5 Hydrological Study Results

No.	Watershed Name	Area (km2)	CN	C	Calc. Method	T_C (min)	Q (m^3/s)
1	W-01	15.59	76	--	SCS	243	11.60
2	W-02	0.79	--	0.4	Rational	28	5.04
3	W-03	8.16	76	--	SCS	165	8.10
4	W-04	5.93	76	--	SCS	117	7.60
5	W-05	0.82	--	0.4	Rational	56	3.42
6	W-06	0.15	--	0.4	Rational	30	0.92
7	W-07	0.71	--	0.4	Rational	45	3.39
8	W-08	0.49	--	0.4	Rational	33	2.85
9	W-09	0.36	--	0.4	Rational	15	3.22
10	W-10	0.05	--	0.4	Rational	154	0.10
11	W-11	4.55	76	--	SCS	73	8.30
12	W-12	1.89	83	--	SCS	47	8.30
13	W-13	80.07	83	--	SCS	537	54.80
14	W-14	0.67	--	0.4	Rational	52	2.92
15	W-15	4.28	83	--	SCS	66	14.60
16	W-16	1.26	83	--	SCS	40	6.20
17	W-17	0.71	--	0.4	Rational	33	4.15
18	W-18	1.97	83	--	SCS	52	8.10
19	W-19	0.46	--	0.4	Rational	24	3.17
20	W-20	1.68	83	--	SCS	37	8.80
21	W-21	32.06	83	--	SCS	270	37.50
22	W-22	0.43	--	0.4	Rational	28	2.70
23	W-23	0.15	--	0.4	Rational	9	1.22
24	W-24	0.04	--	0.4	Rational	8	0.34
25	W-25	0.16	--	0.4	Rational	8	1.25
26	W-26	0.80	--	0.4	Rational	25	5.42
27	W-27	0.27	--	0.4	Rational	13	2.65
28	W-28	0.11	--	0.4	Rational	9	0.88
29	W-29	0.16	--	0.4	Rational	13	1.54
30	W-30	0.41	--	0.4	Rational	15	3.74
31	W-31	0.50	--	0.4	Rational	70	1.83
32	W-32	12.61	83	--	SCS	155	22.70
33	W-33	10.18	83	--	SCS	165	17.50
34	W-34	3.33	83	--	SCS	79	9.90
35	W-35	1.86	83	--	SCS	58	7.00
36	W-36	0.31	--	0.4	Rational	34	1.75

No.	Watershed Name	Area (km2)	CN	C	Calc. Method	T_C (min)	Q (m^3/s)
37	W-37	44.53	83	--	SCS	305	47.40
38	W-38	0.28	--	0.4	Rational	16	2.44
39	W-39	0.69	--	0.4	Rational	23	4.94
40	W-40	0.07	--	0.4	Rational	8	0.53
41	W-41	10.27	79	--	SCS	166	13.10
42	W-42	0.06	--	0.4	Rational	11	0.67
43	W-43	0.24	--	0.4	Rational	9	1.90
44	W-44	2.08	79	--	SCS	91	4.10
45	W-45	4.08	79	--	SCS	127	6.40
46	W-46	1.21	79	--	SCS	74	2.90
47	W-47	5.77	79	--	SCS	129	8.90
48	W-48	0.03	--	0.4	Rational	9	0.27
49	W-49	0.47	--	0.4	Rational	27	3.06
50	W-50	0.46	--	0.4	Rational	34	2.63
51	W-51	18.19	79	--	SCS	202	19.90
52	W-52	0.51	--	0.4	Rational	35	2.84
53	W-53	1.38	79	--	SCS	47	4.50
54	W-54	24.27	79	--	SCS	226	24.30
55	W-55	7.87	79	--	SCS	119	12.80
56	W-56	0.74	--	0.4	Rational	55	3.14
57	W-57	1.95	79	--	SCS	48	6.20
58	W-58	0.22	--	0.4	Rational	17	1.85
59	W-59	163.25	79	--	SCS	609	77.40
60	W-60	13.81	79	--	SCS	155	18.50
61	W-61	0.25	--	0.4	Rational	17	2.10
62	W-62	9.36	79	--	SCS	127	14.60
63	W-63	3.71	79	--	SCS	79	8.30
64	W-64	2.53	79	--	SCS	57	7.20
65	W-65	0.94	--	0.4	Rational	33	5.45
66	W-66	1.58	79	--	SCS	37	6.10
67	W-67	0.37	--	0.4	Rational	23	2.63
68	W-68	0.31	--	0.4	Rational	30	1.87
69	W-01S	0.18	--	0.4	Rational	13	1.74
70	W-02S	0.14	--	0.4	Rational	12	1.47
71	W-03S	0.94	--	0.4	Rational	33	5.46
72	W-04S	0.47	--	0.4	Rational	47	2.19
73	W-05S	5.30	83	--	SCS	107	12.70
74	W-06S	0.38	--	0.4	Rational	34	2.16
75	W-07S	3.19	79	--	SCS	131	19.00
76	W-08S	1.92	79	--	SCS	77	4.40
77	W-09S	0.32	--	0.4	Rational	24	2.22
78	W-10S	4.78	79	--	SCS	114	8.10

No.	Watershed Name	Area (km2)	CN	C	Calc. Method	T_C (min)	Q (m^3/s)
79	W-11S	0.33	--	0.4	Rational	50	1.48
80	W-12S	0.75	--	0.4	Rational	57	3.11
81	W-13S	0.48	--	0.4	Rational	14	4.45

5 Hydraulic Design Criteria

5.1 General

The hydraulic design is a fundamental factor in the design of projects exposed to the danger of floods, whether as protection against the danger of flash floods or storm water drainage. Whenever water attacks the area under development, the flows must be estimated accurately as possible and transported safely, so the design aims to provide drainage facilities that are capable of accommodation of the largest flood discharges with the least maintenance over its lifetime.

The hydraulic design process consists of setting standards, developing, and evaluating alternatives, and selecting the alternative that meets the design standards.

5.2 Returned Period

It is the frequency of storms within a specified period of time. The extent of the storm frequency reflects the severity of the floods. The choice of the design period depends on the importance and location of the proposed protection work. Table 6 shows the proposed protection works & their returned periods.

Table 6 Returned periods for the protection works

Protection work	Returned period for the design storm
Dams	100-200 years
Bridge	100 years
Culvert	100 years
Slope protection	100 years
Chute	100 years
Diversion Channel	100 years
Side Ditch	100 years
Dike	100 years

5.3 Design Standards

- Water drained as much as possible into the natural wadi path instead of diverting it or allowing water to be stored and stagnant.
- Minimize the protection works as possible.
- All protection works for this project are designed/assessed against return period of 100 years' storm event.
- Taking into consideration the economic aspects by decreasing the cost of required protection system as much as possible by achieving safe and optimum design.
- Water velocity should be kept within the allowable range to avoid the risks of scouring in the downstream of the flood mitigation structures.

5.4 Hydraulic design basis

5.4.1 Culvert

The following considerations are taken in designing and evaluating culverts:

- The minimum size of the circular culvert is Two openings with diameter (1 meter).
- The minimum size of the Box culvert is Two opening with Width=2m and Height =1.5m
- The maximum water level in the upstream of the flow before entering the culvert should not exceed 1.2 x (culvert height).
- Grading should be provided when needed at the entrance and exit of the culvert as the natural condition of some areas includes scattered small hills specially in the downstream area of the culvert that may cause obstruction of flow.
- Protection work should be provided at the entrance and exit of the culvert for protection against scouring. It is recommended to use loose riprap protection when the flow velocity is less than 6.5 m/s and if the velocity exceeds 6.5 m/s, an energy dissipater system should be used.

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Website: www.aiecons.com

Generally, flow in culverts occurs under one of this two situations: inlet control culvert or outlet control culvert. For culverts designed according to the condition of inlet control, the characteristics of the culvert entrance will be such that losses occurred at entrance section are the dominant element in determining the height of the water level of the culvert.

It is customary for the culvert to be designed under conditions of flows that are not fully submerged, meaning that the entrance surface of the culvert is above the water level flowing through it wherever possible. Note that the maximum water level in the upstream of the culvert before entering the drain facilities should not exceed 1.2 x (height of the culvert).

The general equations used while the design phase of culverts are as follows:

For box culverts:

$$Q = n * 1.5 * W * H^{1.5}$$

For pipe culverts:

$$Q = n * 1.232 * D^{2.5}$$

Whereas:

n: No. of Culvert openings.

W: Box Culvert Width (m).

H: Box Culvert Height (m).

D: Pipe Culvert Diameter (m).

(CulvertMaster) program will be used to determine the sizes of the proposed culverts, as well as to determine the level of water level at the entrance of the culvert and the exit velocity of water from it.

Box Culverts are designed of reinforced concrete in streams and wadis where the concrete allows the passage of maximum discharges while using an economical concrete section. The multi-openings culverts are used in watersheds and waterways when needed instead of bridges, in the case of watersheds that are characterized by long, mild & very wide longitudinal slopes, and the cross-section of the wadi is not well defined. The multi-openings culverts are designed to accommodate the maximum flows that are likely to pass through.

Entrance and exit structures are connected to the culvert in order to reduce the erosion of the embankment or the rail and slopes in the downstream, to prevent seepage, protection of embankments and structural fixation of the ends to improve the hydraulic properties of the culvert.

5.4.1.1 • Types of Culverts Control.

A general description of the characteristics of inlet and outlet control flow is given below. A culvert flowing in inlet control has shallow, high velocity flow categorized as "supercritical." For supercritical flow, the control section is at the upstream end of the barrel (the inlet). Conversely, a culvert flowing in outlet control will have relatively deep, lower velocity flow termed "subcritical" flow. For subcritical flow the control is at the downstream end of the culvert (the outlet). The tail water depth is either critical depth at the culvert outlet or the downstream channel depth, whichever is higher.

a. Inlet Control

Figure 12 depicts several different examples of inlet control flow. The type of flow depends on the submergence of the inlet and outlet ends of the culvert. In all of these examples, the control section is at the inlet end of the culvert. Depending on the tailwater, a hydraulic jump may occur downstream of the inlet.

Figure 12-A depicts a condition where neither the inlet nor the outlet end of the culvert are submerged. The flow passes through critical depth just downstream of the culvert entrance and the flow in the barrel is supercritical. The barrel flows partly full over its length, and the flow approaches normal depth at the outlet end.

Figure 12-B shows that submergence of the outlet end of the culvert does not assure outlet control. In this case, the flow just downstream of the inlet is supercritical and a hydraulic jump forms in the culvert barrel.

Figure 12-C is a more typical design situation. The inlet end is submerged, and the outlet end flows freely. Again, the flow is supercritical and the barrel flows partly full over its length. Critical depth is located just downstream of the culvert entrance, and the flow is approaching normal depth at the downstream end of the culvert.

Figure 12-D is an unusual condition illustrating the fact that even submergence of both the inlet and the outlet ends of the culvert does not assure full flow. In this case, a hydraulic jump will form in the barrel. The median inlet provides ventilation of the culvert barrel. If the barrel were not ventilated, sub-atmospheric pressures could develop which might create an unstable condition during which the barrel would alternate between full flow and partly full flow.

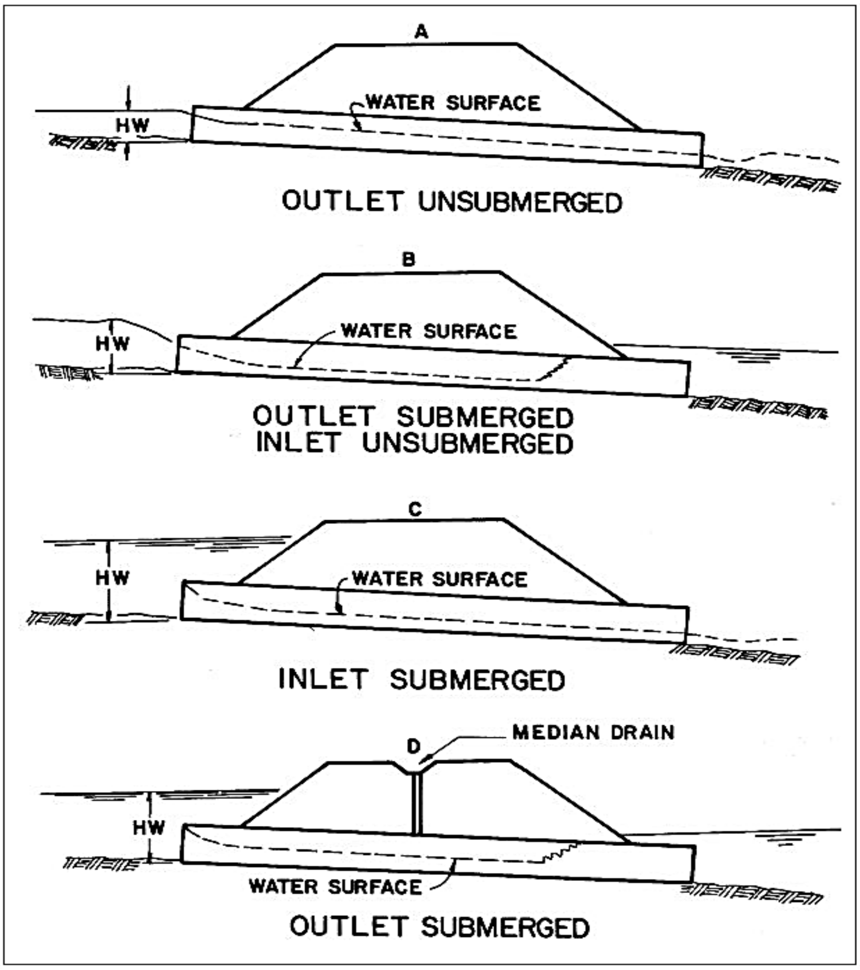


Figure 12 Types of inlet control

• Factors Influencing Inlet Control

Since the control is at the upstream end in inlet control, only the headwater and the inlet configuration affect the culvert performance. The Head water depth is measured from the invert of the inlet control section to the surface of the upstream pool. The inlet area is the cross-sectional area of the face of the culvert. Generally, the inlet face area is the same as the barrel area, but for tapered inlets the face area is enlarged, and the control section is at the throat. The inlet edge configuration describes the entrance type. Some typical inlet edge configurations are thin edge projecting, mitered, square edges in a headwall, and beveled edge. The inlet shapes usually the same as the shape of the culvert barrel; however, it may be enlarged as in the case of a tapered inlet. Typical shapes are rectangular, circular, and elliptical. Whenever the inlet face is a different size or shape than the culvert barrel, the possibility of an additional control section within the barrel exists.

An additional factor which influences inlet control performance is the barrel slope. The effect is small, however, and it can be ignored, or a small slope correction factor can be inserted in the inlet control equations.

The inlet edge configuration is a major factor in inlet control performance, and it can be modified to improve performance.

• Inlet Control Calculations

The inlet control calculations determine the headwater elevation required to pass the design flow through the selected culvert configuration in inlet control. The approach velocity head may be included as part of the headwater, if desired.

The inlet control nomographs are used in the design process. For the following discussion, refer to the schematic inlet control nomograph shown in Figure 13.

a. Locate the selected culvert size (point 1) and flow rate (point 2) on the appropriate scales of the inlet control nomograph. (Note that for box culverts, the flow rate per foot of barrel width is used.)

b. Using a straightedge, carefully extend a straight line from the culvert size (point 1) through the flow rate (point 2) and mark a point on the first headwater/culvert height (HW/D) scale (point 3). The first HW/D scale is also a turning line.

c. If another HW/D scale is required, extend a horizontal line from the first HW/D scale (the turning line) to the desired scale and read the result.

d. Multiply HW/D by the culvert height, D, to obtain the required headwater (HW) from the invert of the control section to the energy grade line. If the approach velocity is neglected, HW equals the required headwater depth (HWi). If the approach velocity is included in the calculations, deduct the approach velocity head from HW to determine HWi.

e. Calculate the required depression (FALL) of the inlet control section below the stream bed as follows:

Possible results and consequences of this calculation are:

(1) If the FALL is negative or zero, set FALL equal to zero and proceed to step f.

(2) If the FALL is positive, the inlet control section invert must be depressed below the streambed at the face by that amount. If the FALL is acceptable, proceed to step f.

(3) If the FALL is positive and greater than is judged to be acceptable, select another culvert configuration and begin again at step a.

f. Calculate the inlet control section invert elevation as follows:

Eli = ELsf - Fall

where Eli is the invert elevation at the face of a culvert (ELf) or at the throat of a culvert with a tapered inlet (ELt).

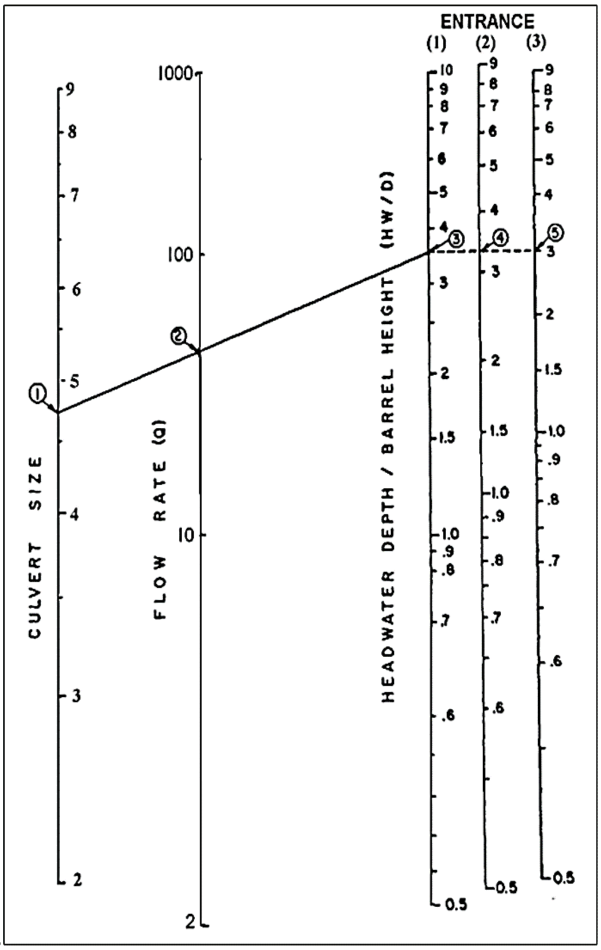


Figure 13 Inlet Control Nomograph (schematic)

b. Outlet Control

Figure 14 illustrates various outlet control flow conditions. In all cases, the control section is at the outlet end of the culvert or further downstream.

Condition 14-A represents the classic full flow condition, with both inlet and outlet submerged.

The barrel is in pressure flow throughout its length. This condition is often assumed in calculations, but seldom actually exists.

Condition 14-B depicts the outlet submerged with the inlet unsubmerged. For this case, the headwater is shallow so that the inlet crown is exposed as the flow contracts into the culvert.

Condition 14-C shows the entrance submerged to such a degree that the culvert flows full throughout its entire length while the exit is unsubmerged. This is a rare condition. It requires an extremely high headwater to maintain full barrel flow with no tailwater. The outlet velocities are usually high under this condition.

Condition 14-D is more typical. The culvert entrance is submerged by the headwater and the outlet end flows freely with a low tailwater. For this condition, the barrel flows partly full over at least part of its length (subcritical flow) and the flow passes through critical depth just upstream of the outlet.

Condition 14-E is also typical, with neither the inlet nor the outlet ends of the culvert submerged.

The barrel flows partly full over its entire length, and the flow profile is subcritical.

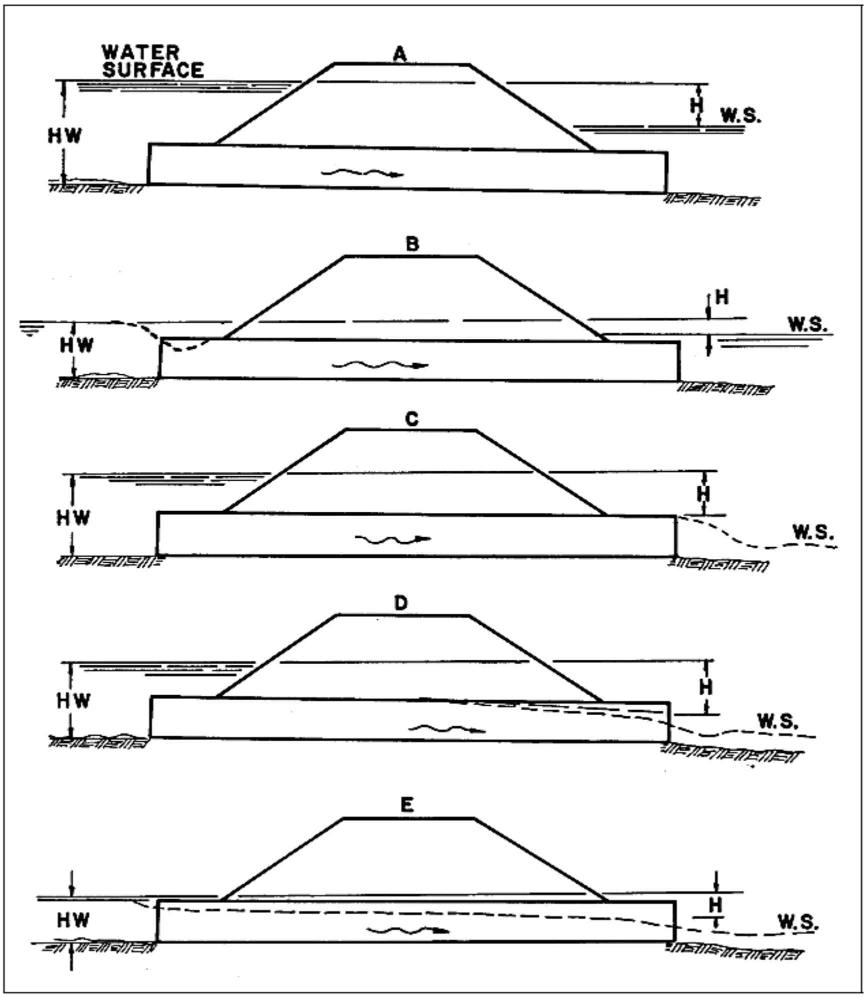


Figure 14 Types of Outlet Control

• Factors Influencing Outlet Control.

All the factors influencing the performance of a culvert in inlet control also influence culverts in outlet control. In addition, the barrel characteristics (roughness, area, shape, length, and slope) and the tailwater elevation affect culvert performance in outlet control.

The barrel roughness is a function of the material used to fabricate the barrel. Typical materials include concrete and corrugated metal. The roughness is represented by a hydraulic resistance coefficient such as the Manning's n value.

The barrel area and barrel shape are self-explanatory.

The barrel length is the total culvert length from the entrance to the exit of the culvert. Because the design height of the barrel and the slope influence the actual length, an approximation of barrel length is usually necessary to begin the design process.

The barrel slope is the actual slope of the culvert barrel. The barrel slope is often the same as the natural stream slope. However, when the culvert inlet is raised or lowered, the barrel slope is different from the stream slope.

The tailwater elevation is based on the downstream water surface elevation. Backwater calculations from a downstream control, a normal depth approximation, or field observations are used to define the tailwater elevation.

• Outlet Control Calculations

The outlet control calculations result in the headwater elevation required to convey the design discharge through the selected culvert in outlet control. The approach and downstream velocities may be included in the design process, if desired. The critical depth charts and outlet control nomographs of Appendix D are used in the design process. For illustration, refer to the schematic critical depth chart and outlet control nomograph shown in Figures 15 and 16, respectively.

a. Determine the tailwater depth above the outlet invert (TW) at the design flow rate. This is obtained from backwater or normal depth calculations, or from field observations.

(1) If the Manning's n value given in the outlet control nomograph is different than the Manning's n for the culvert, adjust the culvert length using the formula:

$$L_1 = L\left(\frac{n_1}{n}\right)^2 \tag{9}$$

L_1 is the adjusted culvert length, m (ft)
L is the actual culvert length, m (ft)
n_1 is the desired Manning's n value
n is the Manning's n value from the outlet control chart

Then, use L1rather than the actual culvert length when using the outlet control nomograph.

(2) Using a straightedge, connect the culvert size (point 1) with the culvert length on the appropriate scale (point 2). This defines a point on the turning line (point 3).

(3) Again, using the straightedge, extend a line from the discharge (point 4) through the point on

the turning line (point 3) to the Head Loss (H) scale. Read H. H is the energy loss through the culvert, including entrance, friction, and outlet losses.

Note: Careful alignment of the straightedge in necessary to obtain good results from the outlet control nomograph.

g. Calculate the required outlet control headwater elevation.

$$EL_{ho} = EL_o + H + h_o \tag{10}$$

where Elo is the invert elevation at the outlet. (If it is desired to include the approach and downstream velocities in the calculations, add the downstream velocity head and subtract the approach velocity head from the right side of Equation (10).

h. If the outlet control headwater elevation exceeds the design headwater elevation, a new culvert configuration must be selected, and the process repeated. Generally, an enlarged barrel will be necessary since inlet improvements are of limited benefit in outlet control.

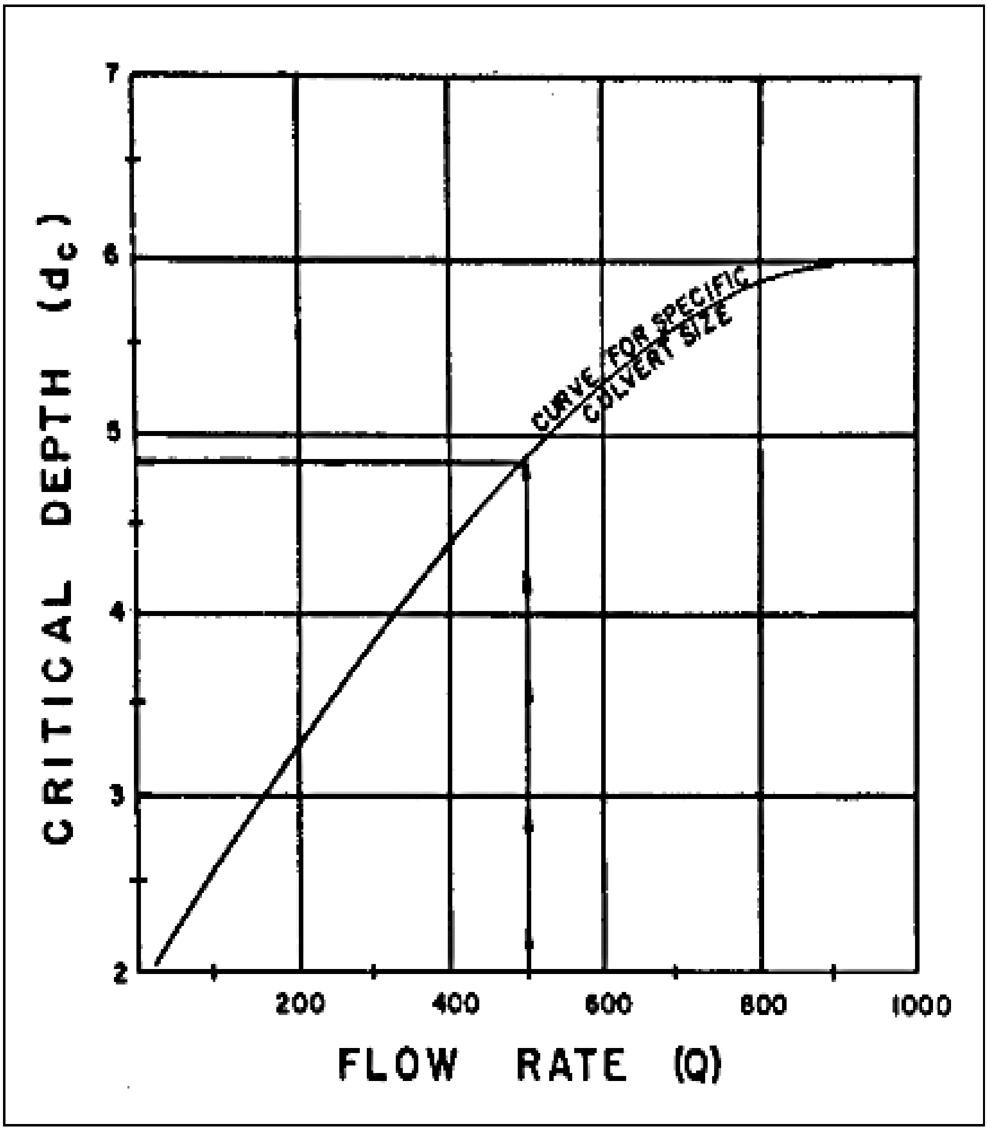


Figure 15 Critical Depth Chart

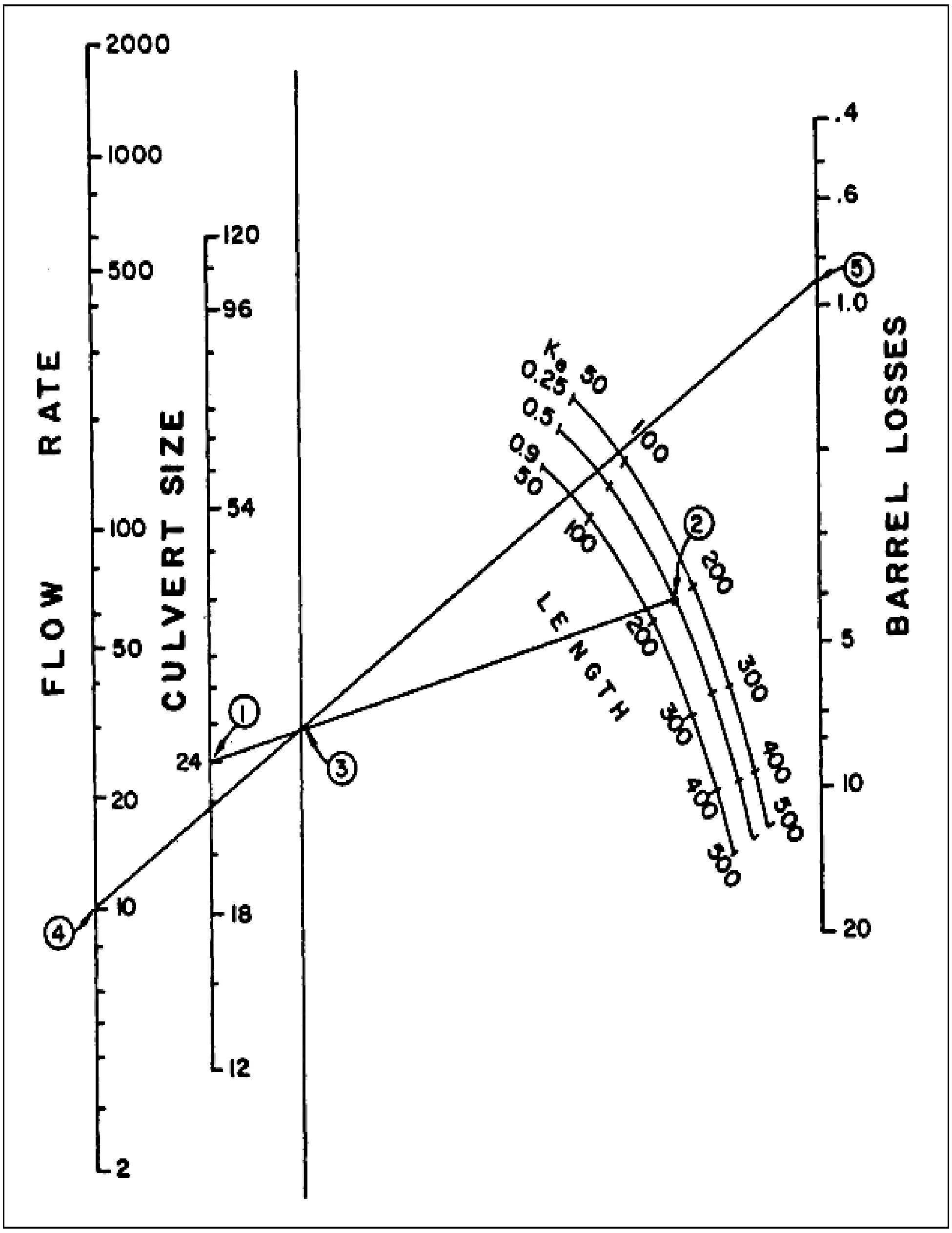


Figure 16 Outlet Control Nomograph

5.4.2 Protection works from erosion

Erosion and abrasion are familiar conditions that occurs in wadis, at drainage structures such as culvert exits and at drainage points, as the velocity of water at the exit in the culverts is greater than the velocity in the natural channels.

As mentioned previously, the velocity at the culvert exit varies between 3 and 6 m/s and may exceed this value for culverts on steep slopes. Under these conditions a minimum level of protection against erosion and abrasion should be provided. The objective of providing the required protection and its quality is to resist the velocity of water, with taking into consideration the natural conditions of the site. The proposed protection structures can withstand the design storm, (design flows and resulting velocities).

Generally, appropriate protection works will be provided in the entrance & exit of the structures: Loose riprap will be used in the entrance & exit of each culvert.

The dimensions of the stones used in protection depends on the velocities at the entrance & exit of the culvert, Isbach equation will be used to calculate D50 for the stones as follow:

$$D_{50} = \frac{1}{\varphi^2} \times \left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right) \times \frac{V^2}{2g}$$

Whereas:

D50: Avg. Diameter of stones (m).

Φ: Empirical factor (1.2).

γw: Specific weight of water (1 t/m^3).

γs: Specific weight of stones (2.65 t/m^3).

g: gravitational acceleration (9.81 m/s^2).

v: water velocity (m/s).

The thickness of the protective layer is twice the average diameter of the stones (2xD_{50}), and the length of the protective layer can be twice the height of the culvert.

5.4.3 Open channel

Manning's equation is commonly used to determine the velocity in open channels/ gravitational storm drainage pipes under uniform flow conditions. The equation is expressed as follows:

$$V = \frac{1}{n} R^{2/3} S^{0.5}$$

Where:

V, is the mean velocity of flow, in m/s.

n, is the Manning's roughness coefficient for open channel flow, n should be taken from appropriate tables, depending on channel types and materials, etc.

R, is the hydraulic radius in m.

S, is the slope of energy grade line, or channel bed slope, in m/m.

Acceptable free board:

The minimum permissible vertical distance from the maximum water surface inside the channel to the upper level of the channel (min. Free board) is 25 cm, the behavior of higher frequency discharges and the extent of their influence on both sides of the channel, as well as the effect of horizontal curves in the channel's path on the depth of water would be studied.

Design speed for open channels:

The design velocities for the flow should be non-settling and non-scouring. Minimum velocities should be self-cleaning and prevent solids sedimentation in the drainage, the maximum velocity shall be determined to reduce the negative effects of channel erosion.

- Min velocity in open channels is 0.75 m/s (self-cleaning velocity).
- Max Velocity in the lined channels of the entire cross section is 4.5 m/s for Grouted riprap & 6 m/s for lined concrete.

5.4.3.1 Side Ditch

The water is drained at cut sections by side ditches that convey the water drained from the embankment and cut slopes. After the runoff water is drained & collected to side ditch, it will be transported to fill sections then drained to natural ground level, Figure 17 shows the proposed typical side ditch at cut section along the EET in the natural condition and in agricultural/high water level areas (as some excavation works observed it).

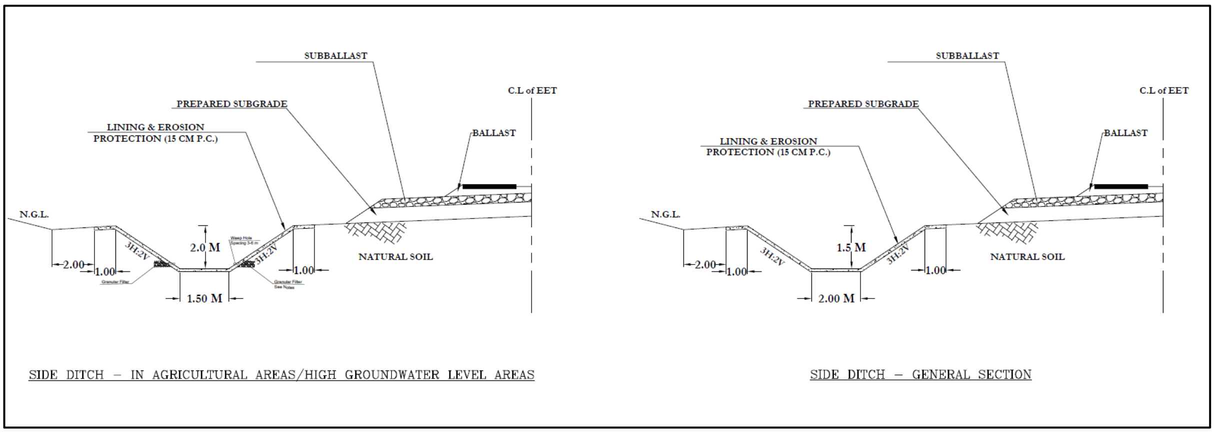


Figure 17 Proposed Typical Details for Cut Ditches at EET

5.4.3.2 Diversion Channel

The water is diverted from wadis (sloping towards the EET) by using diversion channels to be drained to the nearest culvert or diverted to the nearest wadi which would divert the water away from the project area, Figure 18 shows the typical detail of the diversion channels for the different cases along the EET.

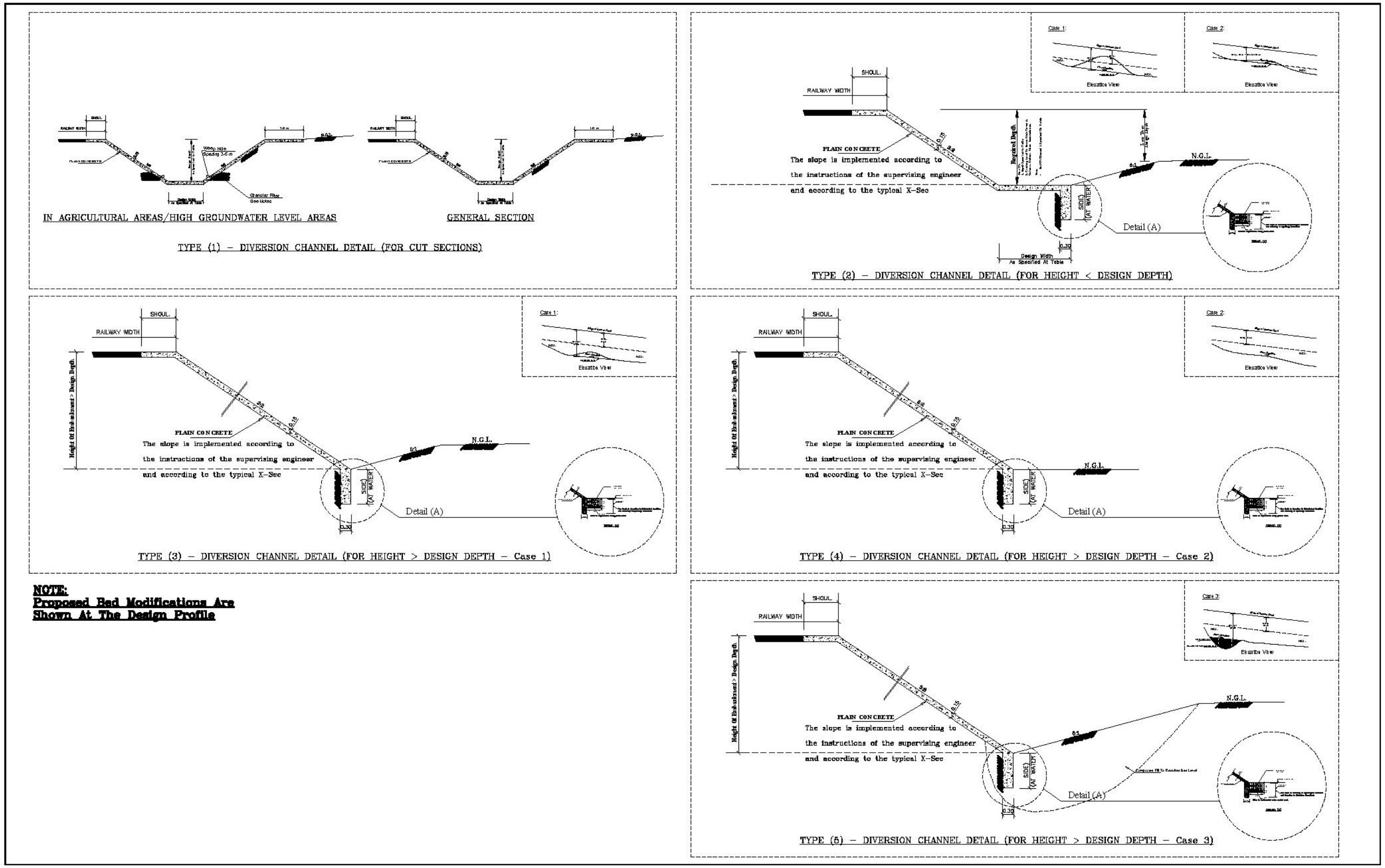


Figure 18 Typical Details for Proposed Diversion Channels at EET

5.4.4 Dike

The dike is used adjacent to some culverts in order to divert the flooding water to the culverts. The height of the dike is proposed to be higher than the water depth upstream the culvert. Figure 19 shows the typical detail of the dike along the EET.

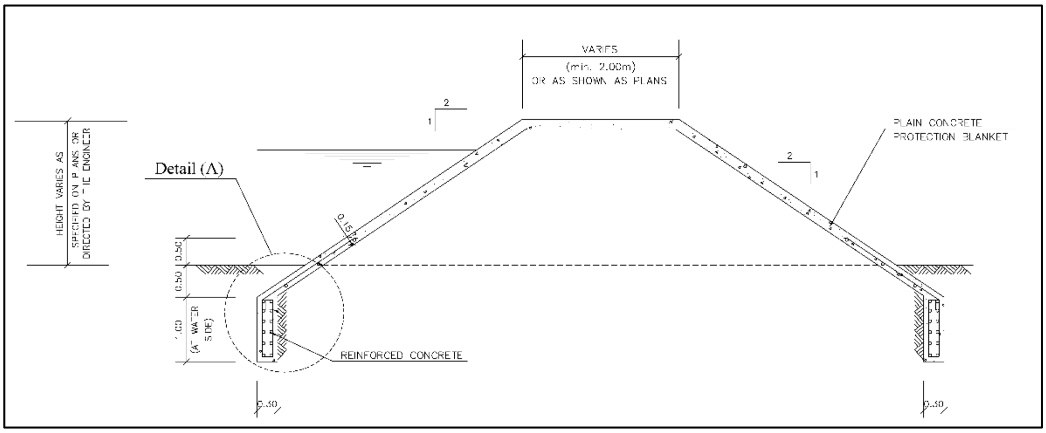


Figure 19 Typical Details for Proposed dike at EET

6 Protection works and recommendations

6.1 Proposed Works

Based on the hydrological study, the morphological & meteorological analysis, the following works were proposed to protect the area with all its components from the dangers of floods:

6.1.1 Proposed Culverts

Water is drained in the fill sections of the EET at the directions of natural wadis which is among the design criteria so that the water is not allowed to be stored or stagnant, Table 7 shows the data of the proposed culvert at the project.

Table 7 Proposed Culverts Data at EET Sector ''C'' Part (1)

No.	Station	Effective Watershed	No. of Vents	Size (mm)	Skew angle (°)	USIL (m)	DSIL (m)	Length (m)	Slope
1	336+595	W-01	8	Ø 1000	88°	161.09	160.53	60	0.93%
2	339+600	W-02	4	Ø 1000	57°	178.26	177.17	57	1.91%
3	340+285	W-03	7	Ø 1000	39°	179.88	179.79	49	0.18%
4	342+395	W-04	6	Ø 1000	72°	189.52	189.51	32	0.03%
5	344+040	W-05	3	Ø 1000	84°	201.87	199.57	44	5.23%
6	344+340	W-06	2	Ø 1000	57°	202.00	201.25	53	1.42%
7	344+740	W-07	3	Ø 1000	38°	205.13	204.77	55	0.65%
8	346+060	W-08	3	Ø 1000	35°	217.45	216.69	65	1.17%
9	348+410	W-09	3	Ø 1000	76°	222.90	219.07	103	3.72%
10	349+035	W-10	2	Ø 1000	75°	236.24	235.08	43	2.70%
11	352+770	W-11	7	Ø 1000	45°	215.14	214.25	70	1.27%
12	352+930	W-12	7	Ø 1000	89°	215.49	215.01	45	1.07%
13	355+810	W-13	9	2000*1500	66°	211.65	211.34	37	0.84%
14	357+355	W-14	3	Ø 1000	18°	209.61	208.04	106	1.48%
15	358+250	W-15	3	2000*1500	57°	199.35	198.96	76	0.51%
16	359+040	W-16	5	Ø 1000	35°	203.20	201.12	138	1.51%
17	360+400	W-17	4	Ø 1000	41°	211.86	211.70	85	0.35%
18	362+645	W-18	7	Ø 1000	75°	212.61	212.37	38	0.63%
19	363+100	W-19	3	Ø 1000	58°	216.49	216.13	36	1.00%
20	363+960	W-20	7	Ø 1000	75°	214.55	214.32	38	0.61%
21	365+045	W-21	5	2000*2000	49°	216.76	216.67	45	0.20%
22	366+915	W-22	2	Ø 1000	47°	229.65	228.63	88	1.16%
23	369+000	W-23	2	Ø 1000	73°	263.47	261.98	34	4.38%
24	369+225	W-24	2	Ø 1000	74°	265.36	263.31	37	5.54%
25	369+830	W-25	2	Ø 1000	71°	259.61	258.66	59	1.61%

No.	Station	Effective Watershed	No. of Vents	Size (mm)	Skew angle (°)	USIL (m)	DSIL (m)	Length (m)	Slope
26	370+810	W-26	4	Ø 1000	42°	253.80	253.29	76	0.67%
27	371+915	W-27	2	Ø 1000	78°	255.02	253.34	42	4.00%
28	372+255	W-28	2	Ø 1000	79°	252.77	251.02	52	3.37%
29	372+585	W-29	2	Ø 1000	53°	255.70	254.80	50	1.80%
30	373+625	W-30	3	Ø 1000	66°	254.12	253.40	53	1.36%
31	375+700	W-31	2	Ø 1000	79°	253.36	253.11	56	0.45%
32	376+315	W-32	4	2000*1500	73°	248.97	248.85	76	0.16%
33	379+925	W-33	3	2000*1500	42°	253.59	253.49	53	0.19%
34	381+215	W-34	8	Ø 1000	49°	251.02	250.89	46	0.28%
35	382+200	W-35	6	Ø 1000	90°	247.54	247.46	43	0.19%
36	383+360	W-36	2	Ø 1000	42°	252.00	251.40	54	1.11%
37	384+440	W-37	6	2000*2000	90°	247.38	247.26	33	0.36%
38	386+685	W-38	2	Ø 1000	50°	259.54	259.22	49	0.65%
39	387+615	W-39	4	Ø 1000	55°	258.69	258.23	42	1.10%
40	388+360	W-40	2	Ø 1000	36°	262.00	258.73	72	4.54%
41	389+695	W-41	3	2000*1500	67°	260.02	259.87	50	0.30%
42	391+195	W-42	2	Ø 1000	34°	266.50	266.15	86	0.41%
43	395+740	W-43	2	Ø 1000	55°	294.63	293.67	63	1.52%
44	396+665	W-44	4	Ø 1000	58°	296.88	296.63	38	0.66%
45	397+885	W-45	5	Ø 1000	46°	299.78	299.71	51	0.14%
46	401+820	W-46	3	Ø 1000	41°	290.20	290.10	53	0.19%
47	402+050	W-47	7	Ø 1000	57°	291.53	291.47	37	0.16%
48	402+415	W-48	2	Ø 1000	60°	291.55	290.77	38	2.05%
49	402+715	W-49	3	Ø 1000	82°	291.01	290.95	33	0.18%
50	404+355	W-50	2	Ø 1000	82°	283.58	283.52	33	0.18%
51	404+860	W-51	4	2000*1500	54°	281.94	281.41	38	1.39%
52	405+190	W-52	3	Ø 1000	56°	281.51	281.45	41	0.15%
53	406+980	W-53	4	Ø 1000	53°	286.48	285.72	59	1.29%
54	409+125	W-54	5	2000*1500	73°	280.76	280.61	35	0.43%
55	409+895	W-55	3	2000*1500	46°	280.70	280.50	78	0.26%
56	411+830	W-56	3	Ø 1000	50°	285.33	283.57	44	4.00%
57	412+585	W-57	5	Ø 1000	61°	285.85	285.16	40	1.72%
58	412+950	W-58	2	Ø 1000	48°	286.02	285.11	53	1.72%
59	413+215	W-59	5	2500*2500	33°	285.90	285.69	70	0.30%
60	415+125	W-60	4	2000*1500	55°	296.68	296.58	53	0.19%
61	416+315	W-61	2	Ø 1000	55°	304.53	303.64	50	1.78%
62	416+850	W-62	3	2000*1500	30°	307.02	306.90	90	0.13%
63	423+580	W-63	6	Ø 1000	63°	340.49	340.27	71	0.31%
64	424+210	W-64	6	Ø 1000	79°	340.25	340.05	94	0.21%
65	427+545	W-65	4	Ø 1000	34°	381.79	380.33	136	1.07%
66	429+820	W-66	5	Ø 1000	36°	383.24	382.03	63	1.92%
67	430+355	W-67	2	Ø 1000	75°	384.54	384.28	39	0.67%
68	430+955	W-68	2	Ø 1000	36°	383.18	383.10	46	0.17%

6.1.2 Proposed Diversion Channels

Diversion Channels were used to collect the water from the streams and transport it to the nearest culvert, Table 8 shows the data of the proposed diversion channels, the attached drawings show the location and direction of the proposed channels on the plan and the profile, while the attached typical details show the X-Sec of the EET at channels location.

Table 8 Proposed Diversion Channels data at EET Sector "C" Part (1)

No.	Station		Effective Watershed	Location to EET Center line	Length (m)	Bottom Width (m)	Depth (m)	Side Slope (H:V)
	From	To						
1	336+310	336+595	W-01S	Right	285	2	1	3:2
2	339+030	336+595	W-01	Right	2435	2	1.5	3:2
3	339+405	339+600	W-02	Left	195	2	1	3:2
4	340+205	339+600	W-02	Left	605	2	1	3:2
5	340+485	340+285	W-03	Left	200	2	1.5	3:2
6	344+030	342+390	W-03	Left	1640	2	1	3:2
7	344+260	344+040	W-05	Left	220	2	1.5	3:2
8	344+730	344+340	W-06	Left	400	2	1	3:2
9	345+950	344+740	W-07	Left	1210	2	1	3:2
10	345+950	346+060	W-08	Left	110	2	1	3:2
11	346+060	344+740	W-04	Right	1320	2	1	3:2
12	346+475	346+060	W-08	Left	415	2	1	3:2
13	347+185	346+060	W-04	Right	1125	2	1	3:2
14	348+065	348+410	W-09	Right	345	2	1	3:2
15	348+930	348+410	W-09	Right	520	2	1	3:2
16	349+140	349+030	W-10	Right	105	2	1	3:2
17	350+150	352+770	W-11	Left	2620	2	1	3:2
18	352+880	352+770	W-11	Left	110	2	1	3:2
19	353+005	352+930	W-12	Left	75	2	1.5	3:2
20	357+170	357+355	W-14	Left	185	2	1	3:2
21	357+565	357+355	W-14	Left	210	2	1	3:2
22	358+090	358+250	W-15	Right	160	2	1.5	3:2
23	358+380	358+250	W-02S	Right	130	2	1	3:2
24	358+840	359+040	W-16	Right	200	2	1	3:2
25	359+300	359+040	W-16	Right	260	2	1	3:2
26	362+105	362+645	W-18	Right	540	2	1.5	3:2
27	362+930	362+645	W-18	Right	285	2	1	3:2
28	363+305	363+100	W-19	Right	205	2	1	3:2
29	363+735	363+960	W-20	Right	225	2	1	3:2
30	364+175	363+960	W-20	Right	215	2	1	3:2
31	364+875	365+045	W-03S	Right	170	2	1	3:2
32	365+880	365+045	W-21	Right	835	3	2	3:2

No.	Station		Effective Watershed	Location to EET Center line	Length (m)	Bottom Width (m)	Depth (m)	Side Slope (H:V)
	From	To						
33	366+755	365+045	W-04S	Left	1710	2	1	3:2
34	367+495	366+915	W-22	Left	580	2	1	3:2
35	369+105	369+225	W-24	Right	120	2	1	3:2
36	369+380	369+225	W-24	Right	155	2	1	3:2
37	370+705	370+810	W-26	Right	105	2	1	3:2
38	370+915	370+810	W-26	Right	105	2	1	3:2
39	371+615	371+915	W-27	Right	300	2	1	3:2
40	374+320	375+700	W-31	Right	1380	2	1	3:2
41	377+115	377+725	W-05S	Right	610	2	1.5	3:2
42	378+050	377+770	W-05S	Right	280	2	1	3:2
43	380+455	381+215	W-34	Right	760	2	1.75	3:2
44	381+600	382+200	W-35	Right	600	2	1	3:2
45	382+605	382+200	W-35	Right	405	2	1	3:2
46	383+210	383+360	W-36	Right	150	2	1	3:2
47	383+835	384+440	W-06S	Right	605	2	1	3:2
48	384+805	384+440	W-08S	Left	605	2	1	3:2
49	384+805	384+440	W-07S	Right	365	2	1.5	3:2
50	388+100	387+615	W-39	Left	485	2	1	3:2
51	388+265	388+360	W-40	Left	95	2	1	3:2
52	389+465	389+695	W-09S	Right	230	2	1	3:2
53	390+685	389+695	W-41	Right	990	2	1.5	3:2
54	391+000	391+195	W-42	Left	195	2	1	3:2
55	391+325	391+195	W-42	Left	130	2	1	3:2
56	391+810	391+385	W-10S	Left	425	2	1	3:2
57	397+770	397+885	W-45	Right	115	2	1	3:2
58	402+260	402+415	W-48	Right	155	2	1	3:2
59	403+015	402+715	W-49	Right	300	2	1	3:2
60	403+560	404+355	W-50	Left	795	2	1	3:2
61	404+745	404+860	W-51	Right	115	2	1.5	3:2
62	405+095	404+860	W-51	Right	235	2	1.5	3:2
63	406+220	406+980	W-11S	Left	760	2	1	3:2
64	408+685	409+125	W-54	Right	440	2	1.5	3:2
65	409+685	409+125	W-54	Right	560	2	1.75	3:2
66	410+755	411+830	W-56	Right	1075	2	1	3:2
67	412+090	411+830	W-56	Right	260	2	1	3:2
68	412+670	412+950	W-58	Right	280	2	1	3:2
69	415+125	413+215	W-12S	Left	1910	2	1	3:2
70	415+790	415+125	W-60	Left	665	2	1.5	3:2
71	416+525	416+850	W-13S	Right	325	2	1.5	3:2
72	422+175	423+580	W-63	Left	1405	2	1.5	3:2

No.	Station		Effective Watershed	Location to EET Center line	Length (m)	Bottom Width (m)	Depth (m)	Side Slope (H:V)
	From	To						
73	424+545	424+210	W-64	Left	335	2	1	3:2
74	427+740	427+545	W-65	Left	195	2	1	3:2

6.1.3 Proposed Dikes

The dike is used adjacent to some culverts in order to divert the flooding water to the culverts. Table 9 shows the data of the proposed dikes, the attached drawings show the location and direction of the proposed dike on the plan and the profile, while the attached typical details show the X-Sec of the Dike.

Table 9 Proposed Dike data at EET Sector "C" Part (1)

No.	Station	Location To EET Center line	Length (m)	Top width (m)	Side Slope (Hz:Vl)	Min. Height (m)
1	344+035	Left	200	2	2:1	2
2	344+295	Left	345			
3	344+730	Left	520			
4	349+030	Right	75			
5	352+920	Left	210			
6	415+100	Left	200			

6.1.4 Proposed Slope protections

Slope protections were used in all the fill sections to protect the side slopes from erosion, the attached typical details show the typical detail of the proposed slope protections.

6.1.5 Proposed Side Ditches

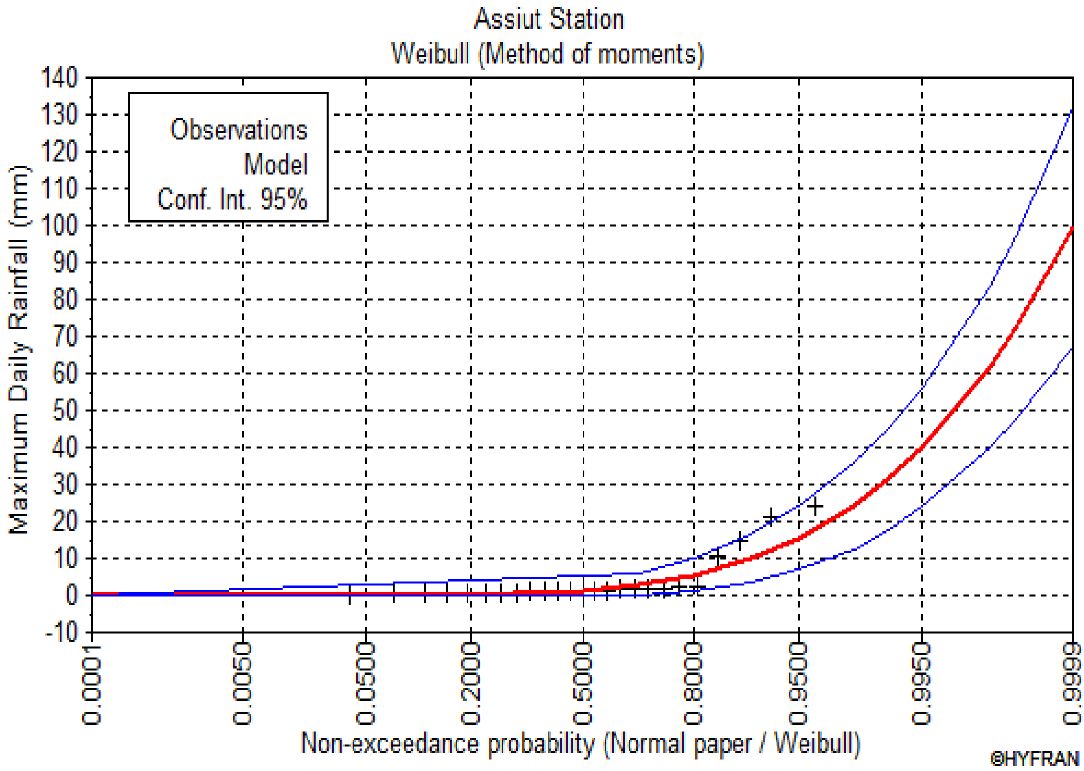
Side Ditches are relied on in all the cut sections of the project to collect water and transport it to the fill sections where the water is drained, the attached typical details show the details of the side ditch. Also, following dimensions are the standard dimensions of all Side Ditches at cut sections:

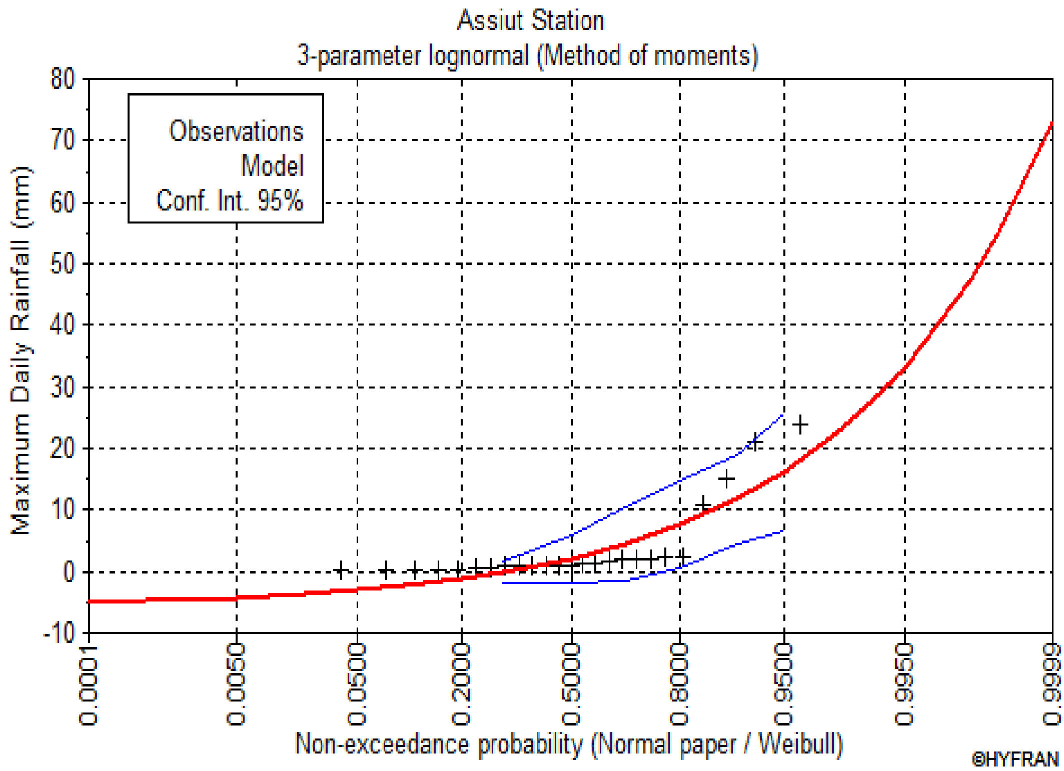
- General Case:
  - Bed Width = 2.00 m
  - Design Depth = 1.50 m
  - Side Slope (H:V) = 3:2

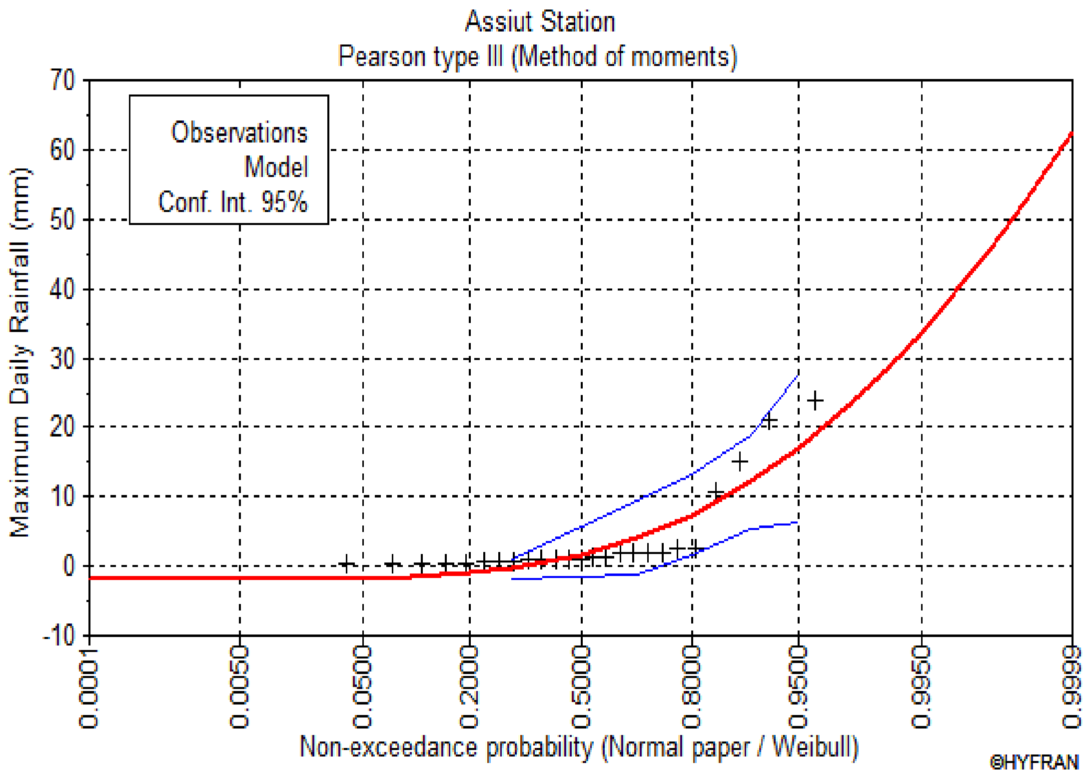
- Agricultural/high water level areas:
  - Bed Width = 1.00 m
  - Design Depth = 2.00 m
  - Side Slope (H:V) = 3:2

7 Annex 1

7.1 Annex 1: Some of the different studied probability distributions for Assiut Airport Rainfall Station by HyFrAn+




Assiut Station
3-parameter lognormal (Method of moments)
Observations
Model
Conf. Int. 95%
Maximum Daily Rainfall (mm)
80
70
60
50
40
30
20
10
0
-10
0.0001
0.0050
0.0500
0.2000
0.5000
0.8000
0.9500
0.9950
0.9999
Non-exceedance probability (Normal paper / Weibull)
©HYFRAN


Assiut Station
Pearson type III (Method of moments)
Observations
Model
Conf. Int. 95%
Maximum Daily Rainfall (mm)
70
60
50
40
30
20
10
0
-10
0.0001
0.0050
0.0500
0.2000
0.5000
0.8000
0.9500
0.9950
0.9999
Non-exceedance probability (Normal paper / Weibull)
©HYFRAN

7.2 Annex 2: Bentley CulvertMaster reports for proposed culverts

Culvert Calculator Report
336+595

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	0.00	m	Headwater Depth/Height	1.17	
Computed Headwater Elevation	162.26	m	Discharge	11.6000	m³/s
Inlet Control HW Elev.	162.21	m	Tailwater Elevation	0.00	m
Outlet Control HW Elev.	162.26	m	Control Type	Entrance Control	

Grades					
Upstream Invert	161.09	m	Downstream Invert	160.53	m
Length	60.00	m	Constructed Slope	0.009333	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.57	m
Slope Type	Steep		Normal Depth	0.57	m
Flow Regime	Supercritical		Critical Depth	0.69	m
Velocity Downstream	3.11	m/s	Critical Slope	0.005323	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.00	m
Section Size	1000 mm		Rise	1.00	m
Number Sections	8				

Outlet Control Properties					
Outlet Control HW Elev.	162.26	m	Upstream Velocity Head	0.32	m
Ke	0.50		Entrance Loss	0.16	m

Inlet Control Properties					
Inlet Control HW Elev.	162.21	m	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	6.3	m²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
339+600

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.07
Computed Headwater Elevation	179.33 m	Discharge	5.0400 m³/s
Inlet Control HW Elev.	179.26 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	179.33 m	Control Type	Entrance Control

Grades

Upstream Invert	178.26 m	Downstream Invert	177.17 m
Length	57.00 m	Constructed Slope	0.019123 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.43 m
Slope Type	Steep	Normal Depth	0.43 m
Flow Regime	Supercritical	Critical Depth	0.65 m
Velocity Downstream	3.89 m/s	Critical Slope	0.004905 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	179.33 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	179.26 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
340+285

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.02
Computed Headwater Elevation	180.90 m	Discharge	8.1000 m³/s
Inlet Control HW Elev.	180.83 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	180.90 m	Control Type	Outlet Control

Grades

Upstream Invert	179.88 m	Downstream Invert	179.79 m
Length	53.00 m	Constructed Slope	0.001698 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.62 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.62 m
Velocity Downstream	2.27 m/s	Critical Slope	0.004709 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	7		

Outlet Control Properties

Outlet Control HW Elev.	180.90 m	Upstream Velocity Head	0.15 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	180.83 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	5.5 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
342+395

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.10
Computed Headwater Elevation	190.62 m	Discharge	7.6000 m³/s
Inlet Control HW Elev.	190.53 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	190.62 m	Control Type	Outlet Control

Grades

Upstream Invert	189.52 m	Downstream Invert	189.51 m
Length	32.00 m	Constructed Slope	0.000313 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.65 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.65 m
Velocity Downstream	2.35 m/s	Critical Slope	0.004919 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	6		

Outlet Control Properties

Outlet Control HW Elev.	190.62 m	Upstream Velocity Head	0.16 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	190.53 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	4.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
344+040

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.00
Computed Headwater Elevation	202.87 m	Discharge	3.4200 m³/s
Inlet Control HW Elev.	202.78 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	202.87 m	Control Type	Entrance Control

Grades

Upstream Invert	201.87 m	Downstream Invert	199.57 m
Length	44.00 m	Constructed Slope	0.052273 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.32 m
Slope Type	Steep	Normal Depth	0.31 m
Flow Regime	Supercritical	Critical Depth	0.61 m
Velocity Downstream	5.36 m/s	Critical Slope	0.004679 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	202.87 m	Upstream Velocity Head	0.26 m
Ke	0.50	Entrance Loss	0.13 m

Inlet Control Properties

Inlet Control HW Elev.	202.78 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
344+340

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	0.00	m	Headwater Depth/Height	0.59	
Computed Headwater Elevation	202.59	m	Discharge	0.9200	m³/s
Inlet Control HW Elev.	202.53	m	Tailwater Elevation	0.00	m
Outlet Control HW Elev.	202.59	m	Control Type	Entrance Control	

Grades					
Upstream Invert	202.00	m	Downstream Invert	201.25	m
Length	55.00	m	Constructed Slope	0.013636	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.27	m
Slope Type	Steep		Normal Depth	0.27	m
Flow Regime	Supercritical		Critical Depth	0.38	m
Velocity Downstream	2.63	m/s	Critical Slope	0.003841	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.00	m
Section Size	1000 mm		Rise	1.00	m
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	202.59	m	Upstream Velocity Head	0.14	m
Ke	0.50		Entrance Loss	0.07	m

Inlet Control Properties					
Inlet Control HW Elev.	202.53	m	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	1.6	m²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
344+740

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.00
Computed Headwater Elevation	206.13 m	Discharge	3.3900 m^3/s
Inlet Control HW Elev.	206.06 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	206.13 m	Control Type	Entrance Control

Grades			
Upstream Invert	205.13 m	Downstream Invert	204.77 m
Length	55.00 m	Constructed Slope	0.006545 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.55 m
Slope Type	Steep	Normal Depth	0.55 m
Flow Regime	Supercritical	Critical Depth	0.61 m
Velocity Downstream	2.56 m/s	Critical Slope	0.004661 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties			
Outlet Control HW Elev.	206.13 m	Upstream Velocity Head	0.26 m
Ke	0.50	Entrance Loss	0.13 m

Inlet Control Properties			
Inlet Control HW Elev.	206.06 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.4 m^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
346+060

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.90
Computed Headwater Elevation	218.35 m	Discharge	2.8500 m³/s
Inlet Control HW Elev.	218.28 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	218.35 m	Control Type	Entrance Control

Grades			
Upstream Invert	217.45 m	Downstream Invert	216.69 m
Length	64.00 m	Constructed Slope	0.011875 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.42 m
Slope Type	Steep	Normal Depth	0.42 m
Flow Regime	Supercritical	Critical Depth	0.56 m
Velocity Downstream	3.06 m/s	Critical Slope	0.004371 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties			
Outlet Control HW Elev.	218.35 m	Upstream Velocity Head	0.23 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	218.28 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
348+410

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.97
Computed Headwater Elevation	223.87 m	Discharge	3.2200 m³/s
Inlet Control HW Elev.	223.78 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	223.87 m	Control Type	Entrance Control

Grades

Upstream Invert	222.90 m	Downstream Invert	219.07 m
Length	103.00 m	Constructed Slope	0.037184 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.33 m
Slope Type	Steep	Normal Depth	0.33 m
Flow Regime	Supercritical	Critical Depth	0.59 m
Velocity Downstream	4.79 m/s	Critical Slope	0.004564 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	223.87 m	Upstream Velocity Head	0.25 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	223.78 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
349+035

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.19
Computed Headwater Elevation	236.43 m	Discharge	0.1000 m³/s
Inlet Control HW Elev.	236.39 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	236.43 m	Control Type	Entrance Control

Grades

Upstream Invert	236.24 m	Downstream Invert	235.08 m
Length	43.00 m	Constructed Slope	0.026977 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.08 m
Slope Type	Steep	Normal Depth	0.08 m
Flow Regime	Supercritical	Critical Depth	0.12 m
Velocity Downstream	1.73 m/s	Critical Slope	0.004249 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	236.43 m	Upstream Velocity Head	0.04 m
Ke	0.50	Entrance Loss	0.02 m

Inlet Control Properties

Inlet Control HW Elev.	236.39 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
352+770

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.03
Computed Headwater Elevation	216.17 m	Discharge	8.3000 m³/s
Inlet Control HW Elev.	216.10 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	216.17 m	Control Type	Entrance Control

Grades

Upstream Invert	215.14 m	Downstream Invert	214.25 m
Length	70.00 m	Constructed Slope	0.012714 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.46 m
Slope Type	Steep	Normal Depth	0.46 m
Flow Regime	Supercritical	Critical Depth	0.63 m
Velocity Downstream	3.33 m/s	Critical Slope	0.004761 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	7		

Outlet Control Properties

Outlet Control HW Elev.	216.17 m	Upstream Velocity Head	0.27 m
Ke	0.50	Entrance Loss	0.13 m

Inlet Control Properties

Inlet Control HW Elev.	216.10 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	5.5 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
352+930

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.03
Computed Headwater Elevation	216.52 m	Discharge	8.3000 m³/s
Inlet Control HW Elev.	216.45 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	216.52 m	Control Type	Entrance Control

Grades

Upstream Invert	215.49 m	Downstream Invert	215.01 m
Length	45.00 m	Constructed Slope	0.010667 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.49 m
Slope Type	Steep	Normal Depth	0.49 m
Flow Regime	Supercritical	Critical Depth	0.63 m
Velocity Downstream	3.08 m/s	Critical Slope	0.004761 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	7		

Outlet Control Properties

Outlet Control HW Elev.	216.52 m	Upstream Velocity Head	0.27 m
Ke	0.50	Entrance Loss	0.13 m

Inlet Control Properties

Inlet Control HW Elev.	216.45 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	5.5 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
355+810

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.14
Computed Headwater Elevation	213.37 m	Discharge	54.8000 m³/s
Inlet Control HW Elev.	213.20 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	213.37 m	Control Type	Entrance Control

Grades

Upstream Invert	211.65 m	Downstream Invert	211.34 m
Length	38.00 m	Constructed Slope	0.008158 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.80 m
Slope Type	Steep	Normal Depth	0.77 m
Flow Regime	Supercritical	Critical Depth	0.98 m
Velocity Downstream	3.82 m/s	Critical Slope	0.004150 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	9		

Outlet Control Properties

Outlet Control HW Elev.	213.37 m	Upstream Velocity Head	0.49 m
Ke	0.50	Entrance Loss	0.25 m

Inlet Control Properties

Inlet Control HW Elev.	213.20 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	27.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
357+355

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.91
Computed Headwater Elevation	210.52 m	Discharge	2.9200 m³/s
Inlet Control HW Elev.	210.45 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	210.52 m	Control Type	Entrance Control

Grades

Upstream Invert	209.61 m	Downstream Invert	208.04 m
Length	106.00 m	Constructed Slope	0.014811 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.40 m
Slope Type	Steep	Normal Depth	0.40 m
Flow Regime	Supercritical	Critical Depth	0.57 m
Velocity Downstream	3.34 m/s	Critical Slope	0.004405 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	210.52 m	Upstream Velocity Head	0.23 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	210.45 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
358+250

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.99
Computed Headwater Elevation	200.83 m	Discharge	14.6000 m³/s
Inlet Control HW Elev.	200.69 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	200.83 m	Control Type	Entrance Control

Grades			
Upstream Invert	199.35 m	Downstream Invert	198.96 m
Length	77.00 m	Constructed Slope	0.005065 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.77 m
Slope Type	Steep	Normal Depth	0.77 m
Flow Regime	Supercritical	Critical Depth	0.85 m
Velocity Downstream	3.15 m/s	Critical Slope	0.003967 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	3		

Outlet Control Properties			
Outlet Control HW Elev.	200.83 m	Upstream Velocity Head	0.42 m
Ke	0.50	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	200.69 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	9.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
359+040

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.06
Computed Headwater Elevation	204.26 m	Discharge	6.2000 m³/s
Inlet Control HW Elev.	204.19 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	204.26 m	Control Type	Entrance Control

Grades

Upstream Invert	203.20 m	Downstream Invert	201.12 m
Length	140.00 m	Constructed Slope	0.014857 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.45 m
Slope Type	Steep	Normal Depth	0.45 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.57 m/s	Critical Slope	0.004867 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	204.26 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	204.19 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	3.9 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
360+400

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.96
Computed Headwater Elevation	212.82 m	Discharge	4.1500 m³/s
Inlet Control HW Elev.	212.74 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	212.82 m	Control Type	Outlet Control

Grades

Upstream Invert	211.86 m	Downstream Invert	211.70 m
Length	85.00 m	Constructed Slope	0.001882 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.58 m
Slope Type	Mild	Normal Depth	0.82 m
Flow Regime	Subcritical	Critical Depth	0.58 m
Velocity Downstream	2.18 m/s	Critical Slope	0.004505 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	212.82 m	Upstream Velocity Head	0.14 m
Ke	0.50	Entrance Loss	0.07 m

Inlet Control Properties

Inlet Control HW Elev.	212.74 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
362+645

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.01
Computed Headwater Elevation	213.62 m	Discharge	8.1000 m³/s
Inlet Control HW Elev.	213.56 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	213.62 m	Control Type	Entrance Control

Grades

Upstream Invert	212.61 m	Downstream Invert	212.37 m
Length	39.00 m	Constructed Slope	0.006154 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.57 m
Slope Type	Steep	Normal Depth	0.57 m
Flow Regime	Supercritical	Critical Depth	0.62 m
Velocity Downstream	2.52 m/s	Critical Slope	0.004709 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	7		

Outlet Control Properties

Outlet Control HW Elev.	213.62 m	Upstream Velocity Head	0.26 m
Ke	0.50	Entrance Loss	0.13 m

Inlet Control Properties

Inlet Control HW Elev.	213.56 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	5.5 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
363+100

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.96
Computed Headwater Elevation	217.45 m	Discharge	3.1700 m³/s
Inlet Control HW Elev.	217.38 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	217.45 m	Control Type	Entrance Control

Grades

Upstream Invert	216.49 m	Downstream Invert	216.13 m
Length	39.00 m	Constructed Slope	0.009231 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.48 m
Slope Type	Steep	Normal Depth	0.48 m
Flow Regime	Supercritical	Critical Depth	0.59 m
Velocity Downstream	2.84 m/s	Critical Slope	0.004536 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	217.45 m	Upstream Velocity Head	0.25 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	217.38 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
363+960

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.07
Computed Headwater Elevation	215.62 m	Discharge	8.8000 m³/s
Inlet Control HW Elev.	215.56 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	215.62 m	Control Type	Entrance Control

Grades

Upstream Invert	214.55 m	Downstream Invert	214.32 m
Length	43.00 m	Constructed Slope	0.005349 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.63 m
Slope Type	Steep	Normal Depth	0.63 m
Flow Regime	Supercritical	Critical Depth	0.65 m
Velocity Downstream	2.43 m/s	Critical Slope	0.004900 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	7		

Outlet Control Properties

Outlet Control HW Elev.	215.62 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	215.56 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	5.5 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
365+045

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.97
Computed Headwater Elevation	218.70 m	Discharge	37.5000 m³/s
Inlet Control HW Elev.	218.54 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	218.70 m	Control Type	Outlet Control

Grades

Upstream Invert	216.76 m	Downstream Invert	216.67 m
Length	46.00 m	Constructed Slope	0.001957 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	1.13 m
Slope Type	Mild	Normal Depth	1.54 m
Flow Regime	Subcritical	Critical Depth	1.13 m
Velocity Downstream	3.33 m/s	Critical Slope	0.004357 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 2000mm	Rise	2.00 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	218.70 m	Upstream Velocity Head	0.39 m
Ke	0.50	Entrance Loss	0.20 m

Inlet Control Properties

Inlet Control HW Elev.	218.54 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	20.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
366+915

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.12
Computed Headwater Elevation	230.77 m	Discharge	2.7000 m³/s
Inlet Control HW Elev.	230.71 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	230.77 m	Control Type	Entrance Control

Grades

Upstream Invert	229.65 m	Downstream Invert	228.63 m
Length	90.00 m	Constructed Slope	0.011333 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.52 m
Slope Type	Steep	Normal Depth	0.52 m
Flow Regime	Supercritical	Critical Depth	0.67 m
Velocity Downstream	3.30 m/s	Critical Slope	0.005092 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	230.77 m	Upstream Velocity Head	0.30 m
Ke	0.50	Entrance Loss	0.15 m

Inlet Control Properties

Inlet Control HW Elev.	230.71 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
369+000

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.70
Computed Headwater Elevation	264.17 m	Discharge	1.2200 m³/s
Inlet Control HW Elev.	264.08 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	264.17 m	Control Type	Entrance Control

Grades

Upstream Invert	263.47 m	Downstream Invert	261.98 m
Length	36.00 m	Constructed Slope	0.041389 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.24 m
Slope Type	Steep	Normal Depth	0.24 m
Flow Regime	Supercritical	Critical Depth	0.44 m
Velocity Downstream	4.19 m/s	Critical Slope	0.003962 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	264.17 m	Upstream Velocity Head	0.17 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	264.08 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
369+225

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.35
Computed Headwater Elevation	265.71 m	Discharge	0.3400 m^3/s
Inlet Control HW Elev.	265.64 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	265.71 m	Control Type	Entrance Control

Grades

Upstream Invert	265.36 m	Downstream Invert	263.31 m
Length	39.00 m	Constructed Slope	0.052564 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.12 m
Slope Type	Steep	Normal Depth	0.12 m
Flow Regime	Supercritical	Critical Depth	0.23 m
Velocity Downstream	3.16 m/s	Critical Slope	0.003827 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	265.71 m	Upstream Velocity Head	0.08 m
Ke	0.50	Entrance Loss	0.04 m

Inlet Control Properties

Inlet Control HW Elev.	265.64 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
369+830

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.71
Computed Headwater Elevation	260.32 m	Discharge	1.2500 m³/s
Inlet Control HW Elev.	260.24 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	260.32 m	Control Type	Entrance Control

Grades

Upstream Invert	259.61 m	Downstream Invert	258.66 m
Length	59.00 m	Constructed Slope	0.016102 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.31 m
Slope Type	Steep	Normal Depth	0.31 m
Flow Regime	Supercritical	Critical Depth	0.45 m
Velocity Downstream	3.05 m/s	Critical Slope	0.003976 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	260.32 m	Upstream Velocity Head	0.17 m
Ke	0.50	Entrance Loss	0.09 m

Inlet Control Properties

Inlet Control HW Elev.	260.24 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
370+810

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.12
Computed Headwater Elevation	254.92 m	Discharge	5.4200 m³/s
Inlet Control HW Elev.	254.86 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	254.92 m	Control Type	Entrance Control

Grades

Upstream Invert	253.80 m	Downstream Invert	253.29 m
Length	76.00 m	Constructed Slope	0.006711 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.61 m
Slope Type	Steep	Normal Depth	0.61 m
Flow Regime	Supercritical	Critical Depth	0.67 m
Velocity Downstream	2.70 m/s	Critical Slope	0.005106 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	254.92 m	Upstream Velocity Head	0.30 m
Ke	0.50	Entrance Loss	0.15 m

Inlet Control Properties

Inlet Control HW Elev.	254.86 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
371+915

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.10
Computed Headwater Elevation	256.12 m	Discharge	2.6500 m³/s
Inlet Control HW Elev.	256.05 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	256.12 m	Control Type	Entrance Control

Grades

Upstream Invert	255.02 m	Downstream Invert	253.34 m
Length	43.00 m	Constructed Slope	0.039070 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.37 m
Slope Type	Steep	Normal Depth	0.36 m
Flow Regime	Supercritical	Critical Depth	0.66 m
Velocity Downstream	4.95 m/s	Critical Slope	0.005039 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	256.12 m	Upstream Velocity Head	0.29 m
Ke	0.50	Entrance Loss	0.15 m

Inlet Control Properties

Inlet Control HW Elev.	256.05 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
372+255

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.58
Computed Headwater Elevation	253.35 m	Discharge	0.8800 m³/s
Inlet Control HW Elev.	253.27 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	253.35 m	Control Type	Entrance Control

Grades			
Upstream Invert	252.77 m	Downstream Invert	251.02 m
Length	52.00 m	Constructed Slope	0.033654 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.21 m
Slope Type	Steep	Normal Depth	0.21 m
Flow Regime	Supercritical	Critical Depth	0.37 m
Velocity Downstream	3.58 m/s	Critical Slope	0.003829 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	253.35 m	Upstream Velocity Head	0.14 m
Ke	0.50	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	253.27 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
372+585

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.79
Computed Headwater Elevation	256.49 m	Discharge	1.5400 m³/s
Inlet Control HW Elev.	256.42 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	256.49 m	Control Type	Entrance Control

Grades

Upstream Invert	255.70 m	Downstream Invert	254.80 m
Length	50.00 m	Constructed Slope	0.018000 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.33 m
Slope Type	Steep	Normal Depth	0.33 m
Flow Regime	Supercritical	Critical Depth	0.50 m
Velocity Downstream	3.36 m/s	Critical Slope	0.004132 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	256.49 m	Upstream Velocity Head	0.20 m
Ke	0.50	Entrance Loss	0.10 m

Inlet Control Properties

Inlet Control HW Elev.	256.42 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
373+625

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.06
Computed Headwater Elevation	255.18 m	Discharge	3.7400 m³/s
Inlet Control HW Elev.	255.12 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	255.18 m	Control Type	Entrance Control

Grades

Upstream Invert	254.12 m	Downstream Invert	253.40 m
Length	54.00 m	Constructed Slope	0.013333 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.47 m
Slope Type	Steep	Normal Depth	0.47 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.40 m/s	Critical Slope	0.004879 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	255.18 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	255.12 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
375+700

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.88
Computed Headwater Elevation	254.24 m	Discharge	1.8300 m³/s
Inlet Control HW Elev.	254.17 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	254.24 m	Control Type	Entrance Control

Grades

Upstream Invert	253.36 m	Downstream Invert	253.11 m
Length	56.00 m	Constructed Slope	0.004464 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.54 m
Flow Regime	Supercritical	Critical Depth	0.55 m
Velocity Downstream	2.11 m/s	Critical Slope	0.004320 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	254.24 m	Upstream Velocity Head	0.22 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties

Inlet Control HW Elev.	254.17 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
376+315

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.08
Computed Headwater Elevation	250.60 m	Discharge	22.7000 m³/s
Inlet Control HW Elev.	250.45 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	250.60 m	Control Type	Outlet Control

Grades

Upstream Invert	248.97 m	Downstream Invert	248.85 m
Length	75.00 m	Constructed Slope	0.001600 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.94 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.94 m
Velocity Downstream	3.03 m/s	Critical Slope	0.004089 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	250.60 m	Upstream Velocity Head	0.29 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	250.45 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	12.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
379+925

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.10
Computed Headwater Elevation	255.23 m	Discharge	17.5000 m³/s
Inlet Control HW Elev.	255.10 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	255.23 m	Control Type	Outlet Control

Grades

Upstream Invert	253.59 m	Downstream Invert	253.49 m
Length	53.00 m	Constructed Slope	0.001887 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.95 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.95 m
Velocity Downstream	3.06 m/s	Critical Slope	0.004112 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	255.23 m	Upstream Velocity Head	0.32 m
Ke	0.50	Entrance Loss	0.16 m

Inlet Control Properties

Inlet Control HW Elev.	255.10 m	Flow Control	N/A
Inlet Type	45° wingwall flares - offset	Area Full	9.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
381+215

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.04
Computed Headwater Elevation	252.06 m	Discharge	9.9000 m³/s
Inlet Control HW Elev.	252.02 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	252.06 m	Control Type	Outlet Control

Grades			
Upstream Invert	251.02 m	Downstream Invert	250.89 m
Length	46.00 m	Constructed Slope	0.002826 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.64 m
Slope Type	Mild	Normal Depth	0.79 m
Flow Regime	Subcritical	Critical Depth	0.64 m
Velocity Downstream	2.33 m/s	Critical Slope	0.004861 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	8		

Outlet Control Properties			
Outlet Control HW Elev.	252.06 m	Upstream Velocity Head	0.19 m
Ke	0.50	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	252.02 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	6.3 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
382+200

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.02
Computed Headwater Elevation	248.56 m	Discharge	7.0000 m³/s
Inlet Control HW Elev.	248.50 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	248.56 m	Control Type	Outlet Control

Grades

Upstream Invert	247.54 m	Downstream Invert	247.46 m
Length	43.00 m	Constructed Slope	0.001860 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.62 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.62 m
Velocity Downstream	2.28 m/s	Critical Slope	0.004728 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	6		

Outlet Control Properties

Outlet Control HW Elev.	248.56 m	Upstream Velocity Head	0.16 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	248.50 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	4.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
383+360

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.86
Computed Headwater Elevation	252.86 m	Discharge	1.7500 m³/s
Inlet Control HW Elev.	252.78 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	252.86 m	Control Type	Entrance Control

Grades

Upstream Invert	252.00 m	Downstream Invert	251.40 m
Length	55.00 m	Constructed Slope	0.010909 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.41 m
Slope Type	Steep	Normal Depth	0.41 m
Flow Regime	Supercritical	Critical Depth	0.53 m
Velocity Downstream	2.90 m/s	Critical Slope	0.004265 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	252.86 m	Upstream Velocity Head	0.21 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties

Inlet Control HW Elev.	252.78 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
384+440

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.00
Computed Headwater Elevation	249.39 m	Discharge	47.4000 m³/s
Inlet Control HW Elev.	249.23 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	249.39 m	Control Type	Outlet Control

Grades

Upstream Invert	247.38 m	Downstream Invert	247.26 m
Length	37.00 m	Constructed Slope	0.003243 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	1.17 m
Slope Type	Mild	Normal Depth	1.31 m
Flow Regime	Subcritical	Critical Depth	1.17 m
Velocity Downstream	3.38 m/s	Critical Slope	0.004415 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 2000mm	Rise	2.00 m
Number Sections	6		

Outlet Control Properties

Outlet Control HW Elev.	249.39 m	Upstream Velocity Head	0.48 m
Ke	0.50	Entrance Loss	0.24 m

Inlet Control Properties

Inlet Control HW Elev.	249.23 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	24.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
386+685

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.05
Computed Headwater Elevation	260.59 m	Discharge	2.4400 m³/s
Inlet Control HW Elev.	260.52 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	260.59 m	Control Type	Entrance Control

Grades

Upstream Invert	259.54 m	Downstream Invert	259.22 m
Length	37.00 m	Constructed Slope	0.008649 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.53 m
Slope Type	Steep	Normal Depth	0.53 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	2.87 m/s	Critical Slope	0.004827 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	260.59 m	Upstream Velocity Head	0.27 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	260.52 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
387+615

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.05
Computed Headwater Elevation	259.74 m	Discharge	4.9400 m³/s
Inlet Control HW Elev.	259.68 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	259.74 m	Control Type	Entrance Control

Grades

Upstream Invert	258.69 m	Downstream Invert	258.23 m
Length	42.00 m	Constructed Slope	0.010952 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.50 m
Slope Type	Steep	Normal Depth	0.50 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.13 m/s	Critical Slope	0.004856 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	259.74 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	259.68 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
388+360

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.44
Computed Headwater Elevation	262.44 m	Discharge	0.5300 m³/s
Inlet Control HW Elev.	262.37 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	262.44 m	Control Type	Entrance Control

Grades

Upstream Invert	262.00 m	Downstream Invert	258.73 m
Length	72.00 m	Constructed Slope	0.045417 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.15 m
Slope Type	Steep	Normal Depth	0.15 m
Flow Regime	Supercritical	Critical Depth	0.29 m
Velocity Downstream	3.43 m/s	Critical Slope	0.003778 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	262.44 m	Upstream Velocity Head	0.10 m
Ke	0.50	Entrance Loss	0.05 m

Inlet Control Properties

Inlet Control HW Elev.	262.37 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
389+695

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.90
Computed Headwater Elevation	261.37 m	Discharge	13.1000 m³/s
Inlet Control HW Elev.	261.26 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	261.37 m	Control Type	Outlet Control

Grades

Upstream Invert	260.02 m	Downstream Invert	259.87 m
Length	50.00 m	Constructed Slope	0.003000 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.79 m
Slope Type	Mild	Normal Depth	0.86 m
Flow Regime	Subcritical	Critical Depth	0.79 m
Velocity Downstream	2.78 m/s	Critical Slope	0.003892 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	261.37 m	Upstream Velocity Head	0.33 m
Ke	0.50	Entrance Loss	0.16 m

Inlet Control Properties

Inlet Control HW Elev.	261.26 m	Flow Control	N/A
Inlet Type	45° wingwall flares - offset	Area Full	9.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
391+195

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.50
Computed Headwater Elevation	267.00 m	Discharge	0.6700 m³/s
Inlet Control HW Elev.	266.95 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	267.00 m	Control Type	Entrance Control

Grades

Upstream Invert	266.50 m	Downstream Invert	266.15 m
Length	86.00 m	Constructed Slope	0.004070 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.32 m
Slope Type	Steep	Normal Depth	0.32 m
Flow Regime	Supercritical	Critical Depth	0.32 m
Velocity Downstream	1.56 m/s	Critical Slope	0.003783 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	267.00 m	Upstream Velocity Head	0.12 m
Ke	0.50	Entrance Loss	0.06 m

Inlet Control Properties

Inlet Control HW Elev.	266.95 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
395+740

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.90
Computed Headwater Elevation	295.53 m	Discharge	1.9000 m^3/s
Inlet Control HW Elev.	295.45 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	295.53 m	Control Type	Entrance Control

Grades			
Upstream Invert	294.63 m	Downstream Invert	293.67 m
Length	41.00 m	Constructed Slope	0.023415 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.35 m
Slope Type	Steep	Normal Depth	0.35 m
Flow Regime	Supercritical	Critical Depth	0.56 m
Velocity Downstream	3.81 m/s	Critical Slope	0.004371 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	295.53 m	Upstream Velocity Head	0.23 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	295.45 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
396+665

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.94
Computed Headwater Elevation	297.82 m	Discharge	4.1000 m³/s
Inlet Control HW Elev.	297.75 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	297.82 m	Control Type	Entrance Control

Grades

Upstream Invert	296.88 m	Downstream Invert	296.63 m
Length	37.00 m	Constructed Slope	0.006757 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.51 m
Slope Type	Steep	Normal Depth	0.51 m
Flow Regime	Supercritical	Critical Depth	0.58 m
Velocity Downstream	2.53 m/s	Critical Slope	0.004486 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	297.82 m	Upstream Velocity Head	0.24 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	297.75 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
397+885

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.11
Computed Headwater Elevation	300.89 m	Discharge	6.4000 m³/s
Inlet Control HW Elev.	300.80 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	300.89 m	Control Type	Outlet Control

Grades

Upstream Invert	299.78 m	Downstream Invert	299.71 m
Length	52.00 m	Constructed Slope	0.001346 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.65 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.65 m
Velocity Downstream	2.36 m/s	Critical Slope	0.004946 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	300.89 m	Upstream Velocity Head	0.16 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	300.80 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	3.9 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
401+820

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.91
Computed Headwater Elevation	291.11 m	Discharge	2.9000 m³/s
Inlet Control HW Elev.	291.04 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	291.11 m	Control Type	Outlet Control

Grades

Upstream Invert	290.20 m	Downstream Invert	290.10 m
Length	57.00 m	Constructed Slope	0.001754 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.56 m
Slope Type	Mild	Normal Depth	0.79 m
Flow Regime	Subcritical	Critical Depth	0.56 m
Velocity Downstream	2.12 m/s	Critical Slope	0.004396 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	291.11 m	Upstream Velocity Head	0.13 m
Ke	0.50	Entrance Loss	0.07 m

Inlet Control Properties

Inlet Control HW Elev.	291.04 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
402+050

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.09
Computed Headwater Elevation	292.62 m	Discharge	8.9000 m³/s
Inlet Control HW Elev.	292.55 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	292.62 m	Control Type	Outlet Control

Grades

Upstream Invert	291.53 m	Downstream Invert	291.47 m
Length	43.00 m	Constructed Slope	0.001395 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.65 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.65 m
Velocity Downstream	2.36 m/s	Critical Slope	0.004928 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	7		

Outlet Control Properties

Outlet Control HW Elev.	292.62 m	Upstream Velocity Head	0.16 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	292.55 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	5.5 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
402+415

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.31
Computed Headwater Elevation	291.86 m	Discharge	0.2700 m³/s
Inlet Control HW Elev.	291.82 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	291.86 m	Control Type	Entrance Control

Grades

Upstream Invert	291.55 m	Downstream Invert	290.77 m
Length	50.00 m	Constructed Slope	0.015600 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.14 m
Slope Type	Steep	Normal Depth	0.14 m
Flow Regime	Supercritical	Critical Depth	0.20 m
Velocity Downstream	1.93 m/s	Critical Slope	0.003886 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	291.86 m	Upstream Velocity Head	0.07 m
Ke	0.50	Entrance Loss	0.04 m

Inlet Control Properties

Inlet Control HW Elev.	291.82 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
402+715

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.95
Computed Headwater Elevation	291.96 m	Discharge	3.0600 m³/s
Inlet Control HW Elev.	291.88 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	291.96 m	Control Type	Outlet Control

Grades

Upstream Invert	291.01 m	Downstream Invert	290.95 m
Length	48.00 m	Constructed Slope	0.001250 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.58 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.58 m
Velocity Downstream	2.16 m/s	Critical Slope	0.004476 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	291.96 m	Upstream Velocity Head	0.13 m
Ke	0.50	Entrance Loss	0.07 m

Inlet Control Properties

Inlet Control HW Elev.	291.88 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
404+355

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.10
Computed Headwater Elevation	284.68 m	Discharge	2.6300 m³/s
Inlet Control HW Elev.	284.62 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	284.68 m	Control Type	Outlet Control

Grades

Upstream Invert	283.58 m	Downstream Invert	283.52 m
Length	36.00 m	Constructed Slope	0.001667 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.66 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.66 m
Velocity Downstream	2.39 m/s	Critical Slope	0.005018 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	284.68 m	Upstream Velocity Head	0.18 m
Ke	0.50	Entrance Loss	0.09 m

Inlet Control Properties

Inlet Control HW Elev.	284.62 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
404+860

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.00
Computed Headwater Elevation	283.44 m	Discharge	19.9000 m³/s
Inlet Control HW Elev.	283.30 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	283.44 m	Control Type	Entrance Control

Grades

Upstream Invert	281.94 m	Downstream Invert	281.41 m
Length	42.00 m	Constructed Slope	0.012619 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.61 m
Slope Type	Steep	Normal Depth	0.57 m
Flow Regime	Supercritical	Critical Depth	0.86 m
Velocity Downstream	4.11 m/s	Critical Slope	0.003983 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	283.44 m	Upstream Velocity Head	0.43 m
Ke	0.50	Entrance Loss	0.21 m

Inlet Control Properties

Inlet Control HW Elev.	283.30 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	12.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
405+190

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.91
Computed Headwater Elevation	282.42 m	Discharge	2.8400 m³/s
Inlet Control HW Elev.	282.34 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	282.42 m	Control Type	Outlet Control

Grades

Upstream Invert	281.51 m	Downstream Invert	281.45 m
Length	47.00 m	Constructed Slope	0.001277 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.56 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.56 m
Velocity Downstream	2.11 m/s	Critical Slope	0.004367 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	282.42 m	Upstream Velocity Head	0.12 m
Ke	0.50	Entrance Loss	0.06 m

Inlet Control Properties

Inlet Control HW Elev.	282.34 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
406+980

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.99
Computed Headwater Elevation	287.47 m	Discharge	4.5000 m³/s
Inlet Control HW Elev.	287.41 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	287.47 m	Control Type	Entrance Control

Grades

Upstream Invert	286.48 m	Downstream Invert	285.72 m
Length	59.00 m	Constructed Slope	0.012881 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.45 m
Slope Type	Steep	Normal Depth	0.45 m
Flow Regime	Supercritical	Critical Depth	0.61 m
Velocity Downstream	3.30 m/s	Critical Slope	0.004652 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	287.47 m	Upstream Velocity Head	0.26 m
Ke	0.50	Entrance Loss	0.13 m

Inlet Control Properties

Inlet Control HW Elev.	287.41 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
409+125

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.99
Computed Headwater Elevation	282.24 m	Discharge	24.3000 m³/s
Inlet Control HW Elev.	282.20 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	282.24 m	Control Type	Entrance Control

Grades

Upstream Invert	280.76 m	Downstream Invert	280.61 m
Length	35.00 m	Constructed Slope	0.004286 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.82 m
Slope Type	Steep	Normal Depth	0.82 m
Flow Regime	Supercritical	Critical Depth	0.84 m
Velocity Downstream	2.96 m/s	Critical Slope	0.003966 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	282.24 m	Upstream Velocity Head	0.42 m
Ke	0.50	Entrance Loss	0.21 m

Inlet Control Properties

Inlet Control HW Elev.	282.20 m	Flow Control	N/A
Inlet Type	90 and 15° wingwall flares	Area Full	15.0 m²
K	0.06100	HDS 5 Chart	8
M	0.75000	HDS 5 Scale	2
C	0.04000	Equation Form	1
Y	0.80000		

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Culvert Calculator Report
409+895

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.89
Computed Headwater Elevation	282.03 m	Discharge	12.8400 m³/s
Inlet Control HW Elev.	281.93 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	282.03 m	Control Type	Outlet Control

Grades

Upstream Invert	280.70 m	Downstream Invert	280.50 m
Length	70.00 m	Constructed Slope	0.002857 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.78 m
Slope Type	Mild	Normal Depth	0.87 m
Flow Regime	Subcritical	Critical Depth	0.78 m
Velocity Downstream	2.76 m/s	Critical Slope	0.003879 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	282.03 m	Upstream Velocity Head	0.31 m
Ke	0.50	Entrance Loss	0.16 m

Inlet Control Properties

Inlet Control HW Elev.	281.93 m	Flow Control	Unsubmerged
Inlet Type	45° wingwall flares - offset	Area Full	9.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

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Culvert Calculator Report
411+830

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.95
Computed Headwater Elevation	286.28 m	Discharge	3.1400 m³/s
Inlet Control HW Elev.	286.20 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	286.28 m	Control Type	Entrance Control

Grades

Upstream Invert	285.33 m	Downstream Invert	283.57 m
Length	44.00 m	Constructed Slope	0.040000 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.32 m
Slope Type	Steep	Normal Depth	0.32 m
Flow Regime	Supercritical	Critical Depth	0.59 m
Velocity Downstream	4.76 m/s	Critical Slope	0.004520 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	286.28 m	Upstream Velocity Head	0.24 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	286.20 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.4 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
412+585

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.06
Computed Headwater Elevation	286.91 m	Discharge	6.2000 m³/s
Inlet Control HW Elev.	286.84 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	286.91 m	Control Type	Entrance Control

Grades

Upstream Invert	285.85 m	Downstream Invert	285.16 m
Length	40.00 m	Constructed Slope	0.017250 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.45 m
Slope Type	Steep	Normal Depth	0.44 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.63 m/s	Critical Slope	0.004867 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	286.91 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	286.84 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.9 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
412+950

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.88
Computed Headwater Elevation	286.90 m	Discharge	1.8500 m³/s
Inlet Control HW Elev.	286.83 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	286.90 m	Control Type	Entrance Control

Grades

Upstream Invert	286.02 m	Downstream Invert	285.11 m
Length	55.00 m	Constructed Slope	0.016545 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.38 m
Slope Type	Steep	Normal Depth	0.38 m
Flow Regime	Supercritical	Critical Depth	0.55 m
Velocity Downstream	3.43 m/s	Critical Slope	0.004335 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	286.90 m	Upstream Velocity Head	0.22 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties

Inlet Control HW Elev.	286.83 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
413+215

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.08
Computed Headwater Elevation	288.61 m	Discharge	77.4000 m³/s
Inlet Control HW Elev.	288.39 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	288.61 m	Control Type	Outlet Control

Grades

Upstream Invert	285.90 m	Downstream Invert	285.69 m
Length	70.00 m	Constructed Slope	0.003000 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	1.58 m
Slope Type	Mild	Normal Depth	1.80 m
Flow Regime	Subcritical	Critical Depth	1.58 m
Velocity Downstream	3.93 m/s	Critical Slope	0.004225 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.50 m
Section Size	2500 x 2500 mm	Rise	2.50 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	288.61 m	Upstream Velocity Head	0.63 m
Ke	0.50	Entrance Loss	0.31 m

Inlet Control Properties

Inlet Control HW Elev.	288.39 m	Flow Control	N/A
Inlet Type	45° wingwall flares - offset	Area Full	31.3 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
415+125

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.94
Computed Headwater Elevation	298.09 m	Discharge	18.5000 m³/s
Inlet Control HW Elev.	297.97 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	298.09 m	Control Type	Outlet Control

Grades

Upstream Invert	296.68 m	Downstream Invert	296.58 m
Length	53.00 m	Constructed Slope	0.001887 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.82 m
Slope Type	Mild	Normal Depth	1.07 m
Flow Regime	Subcritical	Critical Depth	0.82 m
Velocity Downstream	2.83 m/s	Critical Slope	0.003931 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	298.09 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	297.97 m	Flow Control	N/A
Inlet Type	45° wingwall flares - offset	Area Full	12.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
416+315

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.95
Computed Headwater Elevation	305.48 m	Discharge	2.1000 m³/s
Inlet Control HW Elev.	305.41 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	305.48 m	Control Type	Entrance Control

Grades

Upstream Invert	304.53 m	Downstream Invert	303.64 m
Length	50.00 m	Constructed Slope	0.017800 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.40 m
Slope Type	Steep	Normal Depth	0.39 m
Flow Regime	Supercritical	Critical Depth	0.59 m
Velocity Downstream	3.60 m/s	Critical Slope	0.004525 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	305.48 m	Upstream Velocity Head	0.24 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	305.41 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
416+850

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.99
Computed Headwater Elevation	308.50 m	Discharge	14.6000 m³/s
Inlet Control HW Elev.	308.36 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	308.50 m	Control Type	Outlet Control

Grades

Upstream Invert	307.02 m	Downstream Invert	306.90 m
Length	90.00 m	Constructed Slope	0.001333 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.85 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.85 m
Velocity Downstream	2.88 m/s	Critical Slope	0.003967 m/m

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 m
Section Size	2000 x 1500 mm	Rise	1.50 m
Number Sections	3		

Outlet Control Properties

Outlet Control HW Elev.	308.50 m	Upstream Velocity Head	0.24 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties

Inlet Control HW Elev.	308.36 m	Flow Control	N/A
Inlet Type	45° wingwall flares - offset	Area Full	9.0 m²
K	0.49700	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	1
C	0.03020	Equation Form	2
Y	0.83500		

Culvert Calculator Report
423+580

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.13
Computed Headwater Elevation	341.62 m	Discharge	8.3000 m³/s
Inlet Control HW Elev.	341.57 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	341.62 m	Control Type	Outlet Control

Grades

Upstream Invert	340.49 m	Downstream Invert	340.27 m
Length	72.00 m	Constructed Slope	0.003056 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.68 m
Slope Type	Mild	Normal Depth	0.87 m
Flow Regime	Subcritical	Critical Depth	0.68 m
Velocity Downstream	2.44 m/s	Critical Slope	0.005168 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	6		

Outlet Control Properties

Outlet Control HW Elev.	341.62 m	Upstream Velocity Head	0.20 m
Ke	0.50	Entrance Loss	0.10 m

Inlet Control Properties

Inlet Control HW Elev.	341.57 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	4.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
424+210

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.05
Computed Headwater Elevation	341.30 m	Discharge	7.2000 m^3/s
Inlet Control HW Elev.	341.22 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	341.30 m	Control Type	Outlet Control

Grades

Upstream Invert	340.25 m	Downstream Invert	340.05 m
Length	94.00 m	Constructed Slope	0.002128 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.63 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.63 m
Velocity Downstream	2.30 m/s	Critical Slope	0.004789 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	6		

Outlet Control Properties

Outlet Control HW Elev.	341.30 m	Upstream Velocity Head	0.15 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties

Inlet Control HW Elev.	341.22 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	4.7 m^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
427+545

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.12
Computed Headwater Elevation	382.91 m	Discharge	5.4500 m³/s
Inlet Control HW Elev.	382.85 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	382.91 m	Control Type	Entrance Control

Grades

Upstream Invert	381.79 m	Downstream Invert	380.33 m
Length	136.00 m	Constructed Slope	0.010735 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.53 m
Slope Type	Steep	Normal Depth	0.53 m
Flow Regime	Supercritical	Critical Depth	0.67 m
Velocity Downstream	3.24 m/s	Critical Slope	0.005122 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	382.91 m	Upstream Velocity Head	0.30 m
Ke	0.50	Entrance Loss	0.15 m

Inlet Control Properties

Inlet Control HW Elev.	382.85 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	3.1 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
429+820

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.05
Computed Headwater Elevation	384.29 m	Discharge	6.1000 m³/s
Inlet Control HW Elev.	384.22 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	384.29 m	Control Type	Entrance Control

Grades

Upstream Invert	383.24 m	Downstream Invert	382.03 m
Length	72.00 m	Constructed Slope	0.016806 m/m

Hydraulic Profile

Profile	S2	Depth, Downstream	0.44 m
Slope Type	Steep	Normal Depth	0.44 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.72 m/s	Critical Slope	0.004825 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	5		

Outlet Control Properties

Outlet Control HW Elev.	384.29 m	Upstream Velocity Head	0.27 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties

Inlet Control HW Elev.	384.22 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	3.9 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
430+355

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	0.00 m	Headwater Depth/Height	1.10
Computed Headwater Elevation	385.64 m	Discharge	2.6300 m^3/s
Inlet Control HW Elev.	385.58 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	385.64 m	Control Type	Entrance Control

Grades			
Upstream Invert	384.54 m	Downstream Invert	384.28 m
Length	31.00 m	Constructed Slope	0.008387 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.56 m
Slope Type	Steep	Normal Depth	0.56 m
Flow Regime	Supercritical	Critical Depth	0.66 m
Velocity Downstream	2.88 m/s	Critical Slope	0.005018 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	385.64 m	Upstream Velocity Head	0.29 m
Ke	0.50	Entrance Loss	0.15 m

Inlet Control Properties			
Inlet Control HW Elev.	385.58 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
430+955

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	0.00 m	Headwater Depth/Height	0.90
Computed Headwater Elevation	384.08 m	Discharge	1.8700 m³/s
Inlet Control HW Elev.	384.00 m	Tailwater Elevation	0.00 m
Outlet Control HW Elev.	384.08 m	Control Type	Outlet Control

Grades

Upstream Invert	383.18 m	Downstream Invert	383.10 m
Length	57.00 m	Constructed Slope	0.001404 m/m

Hydraulic Profile

Profile	M2	Depth, Downstream	0.55 m
Slope Type	Mild	Normal Depth	0.86 m
Flow Regime	Subcritical	Critical Depth	0.55 m
Velocity Downstream	2.10 m/s	Critical Slope	0.004349 m/m

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.00 m
Section Size	1000 mm	Rise	1.00 m
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	384.08 m	Upstream Velocity Head	0.12 m
Ke	0.50	Entrance Loss	0.06 m

Inlet Control Properties

Inlet Control HW Elev.	384.00 m	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	1.6 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Annex 3: Bentley FlowMaster reports for proposed diversion channels

Worksheet for From St. 336+310 to St. 336+595

Project Description

Friction Method	Manning Formula	
Solve For	Normal Depth	

Input Data

Roughness Coefficient	0.015	
Channel Slope	3.07000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	1.70	m³/s

Results

Normal Depth	0.20	m
Flow Area	0.47	m²
Wetted Perimeter	2.74	m
Hydraulic Radius	0.17	m
Top Width	2.61	m
Critical Depth	0.38	m
Critical Slope	0.00358	m/m
Velocity	3.61	m/s
Velocity Head	0.67	m
Specific Energy	0.87	m
Froude Number	2.72	
Flow Type	Supercritical	

Worksheet for From St. 339+030 to St. 336+595

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.66000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	11.60	m^3/s

Results

Normal Depth	0.91	m
Flow Area	3.08	m^2
Wetted Perimeter	5.29	m
Hydraulic Radius	0.58	m
Top Width	4.74	m
Critical Depth	1.13	m
Critical Slope	0.00281	m/m
Velocity	3.77	m/s
Velocity Head	0.73	m
Specific Energy	1.64	m
Froude Number	1.50	
Flow Type	Supercritical	

Worksheet for From St. 339+405 to St. 339+600

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.48000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	5.10	m^3/s

Results

Normal Depth	0.64	m
Flow Area	1.90	m^2
Wetted Perimeter	4.32	m
Hydraulic Radius	0.44	m
Top Width	3.93	m
Critical Depth	0.72	m
Critical Slope	0.00311	m/m
Velocity	2.68	m/s
Velocity Head	0.37	m
Specific Energy	1.01	m
Froude Number	1.23	
Flow Type	Supercritical	

Worksheet for From St. 340+205 to St. 339+600

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.32000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	5.10	m³/s

Results

Normal Depth	0.72	m
Flow Area	2.20	m²
Wetted Perimeter	4.58	m
Hydraulic Radius	0.48	m
Top Width	4.15	m
Critical Depth	0.72	m
Critical Slope	0.00311	m/m
Velocity	2.31	m/s
Velocity Head	0.27	m
Specific Energy	0.99	m
Froude Number	1.01	
Flow Type	Supercritical	

Worksheet for From St. 340+485 to St. 340+285

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.16000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.10	m^3/s

Results

Normal Depth	1.09	m
Flow Area	3.97	m^2
Wetted Perimeter	5.94	m
Hydraulic Radius	0.67	m
Top Width	5.28	m
Critical Depth	0.93	m
Critical Slope	0.00294	m/m
Velocity	2.04	m/s
Velocity Head	0.21	m
Specific Energy	1.30	m
Froude Number	0.75	
Flow Type	Subcritical	

Worksheet for From St. 344+030 to St. 342+390

Project Description

Friction Method	Manning Formula	
Solve For	Normal Depth	

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.64000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.10	m^3/s

Results

Normal Depth	0.76	m
Flow Area	2.40	m^2
Wetted Perimeter	4.75	m
Hydraulic Radius	0.50	m
Top Width	4.29	m
Critical Depth	0.93	m
Critical Slope	0.00294	m/m
Velocity	3.38	m/s
Velocity Head	0.58	m
Specific Energy	1.34	m
Froude Number	1.44	
Flow Type	Supercritical	

Worksheet for From St. 344+260 to St. 334+040

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.02000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.40	m³/s

Results

Normal Depth	1.19	m
Flow Area	4.51	m²
Wetted Perimeter	6.29	m
Hydraulic Radius	0.72	m
Top Width	5.57	m
Critical Depth	0.57	m
Critical Slope	0.00327	m/m
Velocity	0.75	m/s
Velocity Head	0.03	m
Specific Energy	1.22	m
Froude Number	0.27	
Flow Type	Subcritical	

Worksheet for From St. 344+730 to St. 344+340

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.81000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.92	m³/s

Results

Normal Depth	0.21	m
Flow Area	0.49	m²
Wetted Perimeter	2.76	m
Hydraulic Radius	0.18	m
Top Width	2.63	m
Critical Depth	0.26	m
Critical Slope	0.00391	m/m
Velocity	1.89	m/s
Velocity Head	0.18	m
Specific Energy	0.39	m
Froude Number	1.40	
Flow Type	Supercritical	

Worksheet for From St. 345+950 to St. 344+740

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.14000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.40	m³/s

Results

Normal Depth	0.40	m
Flow Area	1.05	m²
Wetted Perimeter	3.46	m
Hydraulic Radius	0.30	m
Top Width	3.21	m
Critical Depth	0.57	m
Critical Slope	0.00327	m/m
Velocity	3.22	m/s
Velocity Head	0.53	m
Specific Energy	0.93	m
Froude Number	1.80	
Flow Type	Supercritical	

Worksheet for From St. 345+950 to St. 346+060

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.40000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.80	m³/s

Results

Normal Depth	0.34	m
Flow Area	0.86	m²
Wetted Perimeter	3.23	m
Hydraulic Radius	0.27	m
Top Width	3.03	m
Critical Depth	0.51	m
Critical Slope	0.00335	m/m
Velocity	3.26	m/s
Velocity Head	0.54	m
Specific Energy	0.88	m
Froude Number	1.95	
Flow Type	Supercritical	

Worksheet for From St. 346+060 to St. 344+740

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.93000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	7.60	m^3/s

Results

Normal Depth	0.67	m
Flow Area	2.00	m^2
Wetted Perimeter	4.40	m
Hydraulic Radius	0.45	m
Top Width	4.00	m
Critical Depth	0.90	m
Critical Slope	0.00296	m/m
Velocity	3.80	m/s
Velocity Head	0.74	m
Specific Energy	1.40	m
Froude Number	1.72	
Flow Type	Supercritical	

Worksheet for From St. 346+475 to St. 346+060

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.64000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.80	m^3/s

Results

Normal Depth	0.33	m
Flow Area	0.81	m^2
Wetted Perimeter	3.18	m
Hydraulic Radius	0.26	m
Top Width	2.98	m
Critical Depth	0.51	m
Critical Slope	0.00335	m/m
Velocity	3.44	m/s
Velocity Head	0.60	m
Specific Energy	0.93	m
Froude Number	2.10	
Flow Type	Supercritical	

Worksheet for From St. 347+185 to St. 346+060

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.55000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	7.60	m³/s

Results

Normal Depth	0.58	m
Flow Area	1.67	m²
Wetted Perimeter	4.09	m
Hydraulic Radius	0.41	m
Top Width	3.74	m
Critical Depth	0.90	m
Critical Slope	0.00296	m/m
Velocity	4.56	m/s
Velocity Head	1.06	m
Specific Energy	1.64	m
Froude Number	2.18	
Flow Type	Supercritical	

Worksheet for From St. 348+065 to St. 348+410

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	2.65000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.20	m^3/s

Results

Normal Depth	0.31	m
Flow Area	0.76	m^2
Wetted Perimeter	3.11	m
Hydraulic Radius	0.24	m
Top Width	2.92	m
Critical Depth	0.55	m
Critical Slope	0.00329	m/m
Velocity	4.23	m/s
Velocity Head	0.91	m
Specific Energy	1.22	m
Froude Number	2.66	
Flow Type	Supercritical	

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Worksheet for From St. 348+930 to St. 348+410

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	2.25000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.20	m^3/s

Results

Normal Depth	0.32	m
Flow Area	0.80	m^2
Wetted Perimeter	3.16	m
Hydraulic Radius	0.25	m
Top Width	2.97	m
Critical Depth	0.55	m
Critical Slope	0.00329	m/m
Velocity	4.00	m/s
Velocity Head	0.82	m
Specific Energy	1.14	m
Froude Number	2.46	
Flow Type	Supercritical	

Worksheet for From St. 349+140 to St. 349+030

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.23000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.10	m³/s

Results

Normal Depth	0.08	m
Flow Area	0.17	m²
Wetted Perimeter	2.30	m
Hydraulic Radius	0.08	m
Top Width	2.25	m
Critical Depth	0.06	m
Critical Slope	0.00577	m/m
Velocity	0.57	m/s
Velocity Head	0.02	m
Specific Energy	0.10	m
Froude Number	0.66	
Flow Type	Subcritical	

Worksheet for From St. 350+150 to St. 352+770

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.88000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.30	m^3/s

Results

Normal Depth	0.71	m
Flow Area	2.17	m^2
Wetted Perimeter	4.56	m
Hydraulic Radius	0.48	m
Top Width	4.13	m
Critical Depth	0.95	m
Critical Slope	0.00293	m/m
Velocity	3.82	m/s
Velocity Head	0.74	m
Specific Energy	1.45	m
Froude Number	1.68	
Flow Type	Supercritical	

Worksheet for From St. 352+880 to St. 352+770

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.25000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.30	m³/s

Results

Normal Depth	0.65	m
Flow Area	1.92	m²
Wetted Perimeter	4.33	m
Hydraulic Radius	0.44	m
Top Width	3.94	m
Critical Depth	0.95	m
Critical Slope	0.00293	m/m
Velocity	4.33	m/s
Velocity Head	0.96	m
Specific Energy	1.60	m
Froude Number	1.98	
Flow Type	Supercritical	

Worksheet for From St. 353+005 to St. 352+930

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.41000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.30	m^3/s

Results

Normal Depth	0.87	m
Flow Area	2.87	m^2
Wetted Perimeter	5.13	m
Hydraulic Radius	0.56	m
Top Width	4.60	m
Critical Depth	0.95	m
Critical Slope	0.00293	m/m
Velocity	2.90	m/s
Velocity Head	0.43	m
Specific Energy	1.30	m
Froude Number	1.17	
Flow Type	Supercritical	

Worksheet for From St. 357+170 to St. 357+355

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.55000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.90	m³/s

Results

Normal Depth	0.34	m
Flow Area	0.85	m²
Wetted Perimeter	3.22	m
Hydraulic Radius	0.26	m
Top Width	3.02	m
Critical Depth	0.52	m
Critical Slope	0.00333	m/m
Velocity	3.41	m/s
Velocity Head	0.59	m
Specific Energy	0.93	m
Froude Number	2.05	
Flow Type	Supercritical	

Worksheet for From St. 357+565 to St. 357+355

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.17000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.90	m³/s

Results

Normal Depth	0.63	m
Flow Area	1.84	m²
Wetted Perimeter	4.26	m
Hydraulic Radius	0.43	m
Top Width	3.88	m
Critical Depth	0.52	m
Critical Slope	0.00333	m/m
Velocity	1.57	m/s
Velocity Head	0.13	m
Specific Energy	0.75	m
Froude Number	0.73	
Flow Type	Subcritical	

Worksheet for From St. 358+090 to St. 358+250

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.21000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	14.60	m³/s

Results

Normal Depth	0.88	m
Flow Area	2.92	m²
Wetted Perimeter	5.17	m
Hydraulic Radius	0.56	m
Top Width	4.64	m
Critical Depth	1.28	m
Critical Slope	0.00274	m/m
Velocity	5.01	m/s
Velocity Head	1.28	m
Specific Energy	2.16	m
Froude Number	2.02	
Flow Type	Supercritical	

Worksheet for From St. 358+380 to St. 358+250

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	2.06000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	1.50	m³/s

Results

Normal Depth	0.21	m
Flow Area	0.49	m²
Wetted Perimeter	2.77	m
Hydraulic Radius	0.18	m
Top Width	2.64	m
Critical Depth	0.35	m
Critical Slope	0.00364	m/m
Velocity	3.03	m/s
Velocity Head	0.47	m
Specific Energy	0.68	m
Froude Number	2.24	
Flow Type	Supercritical	

Worksheet for From St. 358+840 to St. 359+040

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.64000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	6.20	m^3/s

Results

Normal Depth	0.51	m
Flow Area	1.41	m^2
Wetted Perimeter	3.84	m
Hydraulic Radius	0.37	m
Top Width	3.53	m
Critical Depth	0.81	m
Critical Slope	0.00303	m/m
Velocity	4.38	m/s
Velocity Head	0.98	m
Specific Energy	1.49	m
Froude Number	2.21	
Flow Type	Supercritical	

Worksheet for From St. 358+840 to St. 359+040

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.64000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	6.20	m^3/s

Results

Normal Depth	0.51	m
Flow Area	1.41	m^2
Wetted Perimeter	3.84	m
Hydraulic Radius	0.37	m
Top Width	3.53	m
Critical Depth	0.81	m
Critical Slope	0.00303	m/m
Velocity	4.38	m/s
Velocity Head	0.98	m
Specific Energy	1.49	m
Froude Number	2.21	
Flow Type	Supercritical	

Worksheet for From St. 362+105 to St. 362+645

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.46000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.10	m^3/s

Results

Normal Depth	0.83	m
Flow Area	2.70	m^2
Wetted Perimeter	5.00	m
Hydraulic Radius	0.54	m
Top Width	4.49	m
Critical Depth	0.93	m
Critical Slope	0.00294	m/m
Velocity	3.00	m/s
Velocity Head	0.46	m
Specific Energy	1.29	m
Froude Number	1.24	
Flow Type	Supercritical	

Worksheet for From St. 362+930 to St. 362+645

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.71000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.10	m³/s

Results

Normal Depth	0.74	m
Flow Area	2.31	m²
Wetted Perimeter	4.67	m
Hydraulic Radius	0.49	m
Top Width	4.22	m
Critical Depth	0.93	m
Critical Slope	0.00294	m/m
Velocity	3.51	m/s
Velocity Head	0.63	m
Specific Energy	1.37	m
Froude Number	1.52	
Flow Type	Supercritical	

Worksheet for From St. 362+930 to St. 362+645

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.71000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.10	m^3/s

Results

Normal Depth	0.74	m
Flow Area	2.31	m^2
Wetted Perimeter	4.67	m
Hydraulic Radius	0.49	m
Top Width	4.22	m
Critical Depth	0.93	m
Critical Slope	0.00294	m/m
Velocity	3.51	m/s
Velocity Head	0.63	m
Specific Energy	1.37	m
Froude Number	1.52	
Flow Type	Supercritical	

Worksheet for From St. 363+735 to St. 363+960

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.89000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.80	m³/s

Results

Normal Depth	0.73	m
Flow Area	2.26	m²
Wetted Perimeter	4.63	m
Hydraulic Radius	0.49	m
Top Width	4.19	m
Critical Depth	0.98	m
Critical Slope	0.00291	m/m
Velocity	3.90	m/s
Velocity Head	0.77	m
Specific Energy	1.50	m
Froude Number	1.69	
Flow Type	Supercritical	

Worksheet for From St. 364+175 to St. 363+960

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.00000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.80	m³/s

Results

Normal Depth	0.71	m
Flow Area	2.17	m²
Wetted Perimeter	4.55	m
Hydraulic Radius	0.48	m
Top Width	4.12	m
Critical Depth	0.98	m
Critical Slope	0.00291	m/m
Velocity	4.06	m/s
Velocity Head	0.84	m
Specific Energy	1.55	m
Froude Number	1.79	
Flow Type	Supercritical	

Worksheet for From St. 364+875 to St. 365+045

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.53000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	5.46	m^3/s

Results

Normal Depth	0.65	m
Flow Area	1.93	m^2
Wetted Perimeter	4.34	m
Hydraulic Radius	0.44	m
Top Width	3.95	m
Critical Depth	0.75	m
Critical Slope	0.00308	m/m
Velocity	2.83	m/s
Velocity Head	0.41	m
Specific Energy	1.06	m
Froude Number	1.29	
Flow Type	Supercritical	

Worksheet for From St. 365+880 to St. 365+045

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.39000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	3.00	m
Discharge	37.50	m³/s

Results

Normal Depth	1.64	m
Flow Area	8.97	m²
Wetted Perimeter	8.92	m
Hydraulic Radius	1.01	m
Top Width	7.93	m
Critical Depth	1.85	m
Critical Slope	0.00241	m/m
Velocity	4.18	m/s
Velocity Head	0.89	m
Specific Energy	2.53	m
Froude Number	1.25	
Flow Type	Supercritical	

Worksheet for From St. 366+755 to St. 365+045

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.74000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.20	m^3/s

Results

Normal Depth	0.36	m
Flow Area	0.91	m^2
Wetted Perimeter	3.29	m
Hydraulic Radius	0.28	m
Top Width	3.07	m
Critical Depth	0.44	m
Critical Slope	0.00346	m/m
Velocity	2.43	m/s
Velocity Head	0.30	m
Specific Energy	0.66	m
Froude Number	1.43	
Flow Type	Supercritical	

Worksheet for From St. 367+495 to St. 366+915

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.74000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.70	m^3/s

Results

Normal Depth	0.31	m
Flow Area	0.78	m^2
Wetted Perimeter	3.13	m
Hydraulic Radius	0.25	m
Top Width	2.94	m
Critical Depth	0.50	m
Critical Slope	0.00336	m/m
Velocity	3.47	m/s
Velocity Head	0.61	m
Specific Energy	0.93	m
Froude Number	2.16	
Flow Type	Supercritical	

Worksheet for From St. 369+105 to St. 369+225

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.24000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.30	m³/s

Results

Normal Depth	0.10	m
Flow Area	0.21	m²
Wetted Perimeter	2.34	m
Hydraulic Radius	0.09	m
Top Width	2.29	m
Critical Depth	0.13	m
Critical Slope	0.00470	m/m
Velocity	1.46	m/s
Velocity Head	0.11	m
Specific Energy	0.20	m
Froude Number	1.56	
Flow Type	Supercritical	

Worksheet for From St. 369+380 to St. 369+225

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.92000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.30	m^3/s

Results

Normal Depth	0.10	m
Flow Area	0.23	m^2
Wetted Perimeter	2.38	m
Hydraulic Radius	0.09	m
Top Width	2.31	m
Critical Depth	0.13	m
Critical Slope	0.00470	m/m
Velocity	1.33	m/s
Velocity Head	0.09	m
Specific Energy	0.19	m
Froude Number	1.36	
Flow Type	Supercritical	

Worksheet for From St. 370+705 to St. 370+810

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.67000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	5.40	m³/s

Results

Normal Depth	0.47	m
Flow Area	1.28	m²
Wetted Perimeter	3.70	m
Hydraulic Radius	0.34	m
Top Width	3.41	m
Critical Depth	0.75	m
Critical Slope	0.00308	m/m
Velocity	4.23	m/s
Velocity Head	0.91	m
Specific Energy	1.39	m
Froude Number	2.21	
Flow Type	Supercritical	

Worksheet for From St. 370+915 to St. 370+810

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	2.21000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	5.40	m³/s

Results

Normal Depth	0.44	m
Flow Area	1.16	m²
Wetted Perimeter	3.57	m
Hydraulic Radius	0.32	m
Top Width	3.31	m
Critical Depth	0.75	m
Critical Slope	0.00308	m/m
Velocity	4.67	m/s
Velocity Head	1.11	m
Specific Energy	1.55	m
Froude Number	2.52	
Flow Type	Supercritical	

Worksheet for From St. 371+615 to St. 371+915

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.52000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.70	m^3/s

Results

Normal Depth	0.44	m
Flow Area	1.18	m^2
Wetted Perimeter	3.60	m
Hydraulic Radius	0.33	m
Top Width	3.33	m
Critical Depth	0.50	m
Critical Slope	0.00336	m/m
Velocity	2.29	m/s
Velocity Head	0.27	m
Specific Energy	0.71	m
Froude Number	1.23	
Flow Type	Supercritical	

Worksheet for From St. 374+320 to St. 375+700

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.22000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	1.80	m³/s

Results

Normal Depth	0.45	m
Flow Area	1.20	m²
Wetted Perimeter	3.62	m
Hydraulic Radius	0.33	m
Top Width	3.35	m
Critical Depth	0.39	m
Critical Slope	0.00355	m/m
Velocity	1.50	m/s
Velocity Head	0.11	m
Specific Energy	0.56	m
Froude Number	0.80	
Flow Type	Subcritical	

Worksheet for From St. 377+115 to St. 377+725

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.45000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	12.70	m^3/s

Results

Normal Depth	1.06	m
Flow Area	3.78	m^2
Wetted Perimeter	5.80	m
Hydraulic Radius	0.65	m
Top Width	5.17	m
Critical Depth	1.19	m
Critical Slope	0.00279	m/m
Velocity	3.36	m/s
Velocity Head	0.58	m
Specific Energy	1.63	m
Froude Number	1.25	
Flow Type	Supercritical	

Worksheet for From St. 378+050 to St. 377+770

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.49000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	12.70	m^3/s

Results

Normal Depth	0.77	m
Flow Area	2.44	m^2
Wetted Perimeter	4.79	m
Hydraulic Radius	0.51	m
Top Width	4.32	m
Critical Depth	1.19	m
Critical Slope	0.00279	m/m
Velocity	5.20	m/s
Velocity Head	1.38	m
Specific Energy	2.15	m
Froude Number	2.21	
Flow Type	Supercritical	

Worksheet for From St. 380+455 to St. 381+215

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.13000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	9.90	m^3/s

Results

Normal Depth	1.27	m
Flow Area	4.97	m^2
Wetted Perimeter	6.59	m
Hydraulic Radius	0.75	m
Top Width	5.82	m
Critical Depth	1.04	m
Critical Slope	0.00287	m/m
Velocity	1.99	m/s
Velocity Head	0.20	m
Specific Energy	1.47	m
Froude Number	0.69	
Flow Type	Subcritical	

Worksheet for From St. 381+600 to St. 382+200

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.54000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	7.00	m³/s

Results

Normal Depth	0.74	m
Flow Area	2.29	m²
Wetted Perimeter	4.66	m
Hydraulic Radius	0.49	m
Top Width	4.21	m
Critical Depth	0.86	m
Critical Slope	0.00299	m/m
Velocity	3.05	m/s
Velocity Head	0.48	m
Specific Energy	1.21	m
Froude Number	1.32	
Flow Type	Supercritical	

Worksheet for From St. 382+605 to St. 382+200

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.63000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	7.00	m^3/s

Results

Normal Depth	0.71	m
Flow Area	2.17	m^2
Wetted Perimeter	4.55	m
Hydraulic Radius	0.48	m
Top Width	4.12	m
Critical Depth	0.86	m
Critical Slope	0.00299	m/m
Velocity	3.23	m/s
Velocity Head	0.53	m
Specific Energy	1.24	m
Froude Number	1.42	
Flow Type	Supercritical	

Worksheet for From St. 383+210 to St. 383+360

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.05000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	1.70	m^3/s

Results

Normal Depth	0.65	m
Flow Area	1.95	m^2
Wetted Perimeter	4.36	m
Hydraulic Radius	0.45	m
Top Width	3.96	m
Critical Depth	0.38	m
Critical Slope	0.00358	m/m
Velocity	0.87	m/s
Velocity Head	0.04	m
Specific Energy	0.69	m
Froude Number	0.40	
Flow Type	Subcritical	

Worksheet for From St. 383+835 to St. 384+440

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.52000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.20	m^3/s

Results

Normal Depth	0.39	m
Flow Area	1.02	m^2
Wetted Perimeter	3.42	m
Hydraulic Radius	0.30	m
Top Width	3.18	m
Critical Depth	0.44	m
Critical Slope	0.00346	m/m
Velocity	2.15	m/s
Velocity Head	0.24	m
Specific Energy	0.63	m
Froude Number	1.21	
Flow Type	Supercritical	

Worksheet for From St. 384+805 to St. 384+440

Project Description

Friction Method	Manning Formula	
Solve For	Normal Depth	

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.45000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	19.00	m³/s

Results

Normal Depth	1.29	m
Flow Area	5.08	m²
Wetted Perimeter	6.66	m
Hydraulic Radius	0.76	m
Top Width	5.87	m
Critical Depth	1.47	m
Critical Slope	0.00266	m/m
Velocity	3.74	m/s
Velocity Head	0.71	m
Specific Energy	2.00	m
Froude Number	1.28	
Flow Type	Supercritical	

Worksheet for From St. 384+805 to St. 384+440

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.52000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	4.40	m^3/s

Results

Normal Depth	0.58	m
Flow Area	1.67	m^2
Wetted Perimeter	4.09	m
Hydraulic Radius	0.41	m
Top Width	3.74	m
Critical Depth	0.66	m
Critical Slope	0.00316	m/m
Velocity	2.64	m/s
Velocity Head	0.36	m
Specific Energy	0.94	m
Froude Number	1.26	
Flow Type	Supercritical	

Worksheet for From St. 388+100 to St. 387+615

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.51000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	4.90	m^3/s

Results

Normal Depth	0.62	m
Flow Area	1.81	m^2
Wetted Perimeter	4.23	m
Hydraulic Radius	0.43	m
Top Width	3.86	m
Critical Depth	0.71	m
Critical Slope	0.00312	m/m
Velocity	2.71	m/s
Velocity Head	0.37	m
Specific Energy	0.99	m
Froude Number	1.26	
Flow Type	Supercritical	

Worksheet for From St. 388+265 to St. 388+360

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	3.51000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.50	m³/s

Results

Normal Depth	0.10	m
Flow Area	0.20	m²
Wetted Perimeter	2.34	m
Hydraulic Radius	0.09	m
Top Width	2.29	m
Critical Depth	0.18	m
Critical Slope	0.00431	m/m
Velocity	2.45	m/s
Velocity Head	0.31	m
Specific Energy	0.40	m
Froude Number	2.62	
Flow Type	Supercritical	

Worksheet for From St. 389+465 to St. 389+695

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.94000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.22	m³/s

Results

Normal Depth	0.27	m
Flow Area	0.66	m²
Wetted Perimeter	2.98	m
Hydraulic Radius	0.22	m
Top Width	2.82	m
Critical Depth	0.45	m
Critical Slope	0.00345	m/m
Velocity	3.38	m/s
Velocity Head	0.58	m
Specific Energy	0.86	m
Froude Number	2.24	
Flow Type	Supercritical	

Worksheet for From St. 390+685 to St. 389+695

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.71000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	13.10	m³/s

Results

Normal Depth	0.95	m
Flow Area	3.27	m²
Wetted Perimeter	5.44	m
Hydraulic Radius	0.60	m
Top Width	4.86	m
Critical Depth	1.21	m
Critical Slope	0.00277	m/m
Velocity	4.00	m/s
Velocity Head	0.82	m
Specific Energy	1.77	m
Froude Number	1.56	
Flow Type	Supercritical	

Worksheet for From St. 391+000 to St. 391+195

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.02000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.70	m³/s

Results

Normal Depth	0.17	m
Flow Area	0.38	m²
Wetted Perimeter	2.60	m
Hydraulic Radius	0.14	m
Top Width	2.50	m
Critical Depth	0.22	m
Critical Slope	0.00408	m/m
Velocity	1.86	m/s
Velocity Head	0.18	m
Specific Energy	0.34	m
Froude Number	1.53	
Flow Type	Supercritical	

Worksheet for From St. 391+325 to St. 391+195

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.27000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	0.70	m³/s

Results

Normal Depth	0.25	m
Flow Area	0.59	m²
Wetted Perimeter	2.89	m
Hydraulic Radius	0.20	m
Top Width	2.74	m
Critical Depth	0.22	m
Critical Slope	0.00408	m/m
Velocity	1.20	m/s
Velocity Head	0.07	m
Specific Energy	0.32	m
Froude Number	0.83	
Flow Type	Subcritical	

Worksheet for From St. 391+810 to St. 391+385

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.67000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.10	m^3/s

Results

Normal Depth	0.75	m
Flow Area	2.36	m^2
Wetted Perimeter	4.72	m
Hydraulic Radius	0.50	m
Top Width	4.26	m
Critical Depth	0.93	m
Critical Slope	0.00294	m/m
Velocity	3.44	m/s
Velocity Head	0.60	m
Specific Energy	1.36	m
Froude Number	1.48	
Flow Type	Supercritical	

Worksheet for From St. 397+770 to St. 397+885

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.29000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	4.20	m^3/s

Results

Normal Depth	0.44	m
Flow Area	1.17	m^2
Wetted Perimeter	3.59	m
Hydraulic Radius	0.33	m
Top Width	3.32	m
Critical Depth	0.65	m
Critical Slope	0.00318	m/m
Velocity	3.59	m/s
Velocity Head	0.66	m
Specific Energy	1.10	m
Froude Number	1.93	
Flow Type	Supercritical	

Worksheet for From St. 402+260 to St. 402+415

Project Description

Friction Method	Manning Formula		
Solve For	Normal Depth		

Input Data

Roughness Coefficient		0.015	
Channel Slope		1.21000	%
Left Side Slope		1.50	m/m (H:V)
Right Side Slope		1.50	m/m (H:V)
Bottom Width		2.00	m
Discharge		0.30	m³/s

Results

Normal Depth		0.10	m
Flow Area		0.21	m²
Wetted Perimeter		2.35	m
Hydraulic Radius		0.09	m
Top Width		2.29	m
Critical Depth		0.13	m
Critical Slope		0.00470	m/m
Velocity		1.45	m/s
Velocity Head		0.11	m
Specific Energy		0.20	m
Froude Number		1.54	
Flow Type	Supercritical		

Worksheet for From St. 403+015 to St. 402+715

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.13000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.06	m³/s

Results

Normal Depth	0.38	m
Flow Area	0.98	m²
Wetted Perimeter	3.38	m
Hydraulic Radius	0.29	m
Top Width	3.15	m
Critical Depth	0.54	m
Critical Slope	0.00331	m/m
Velocity	3.11	m/s
Velocity Head	0.49	m
Specific Energy	0.88	m
Froude Number	1.78	
Flow Type	Supercritical	

Worksheet for From St. 403+560 to St. 404+355

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.55000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	2.60	m^3/s

Results

Normal Depth	0.43	m
Flow Area	1.13	m^2
Wetted Perimeter	3.54	m
Hydraulic Radius	0.32	m
Top Width	3.28	m
Critical Depth	0.49	m
Critical Slope	0.00338	m/m
Velocity	2.31	m/s
Velocity Head	0.27	m
Specific Energy	0.70	m
Froude Number	1.26	
Flow Type	Supercritical	

Worksheet for From St. 404+745 to St. 404+860

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.90000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	19.90	m³/s

Results

Normal Depth	1.11	m
Flow Area	4.07	m²
Wetted Perimeter	6.01	m
Hydraulic Radius	0.68	m
Top Width	5.33	m
Critical Depth	1.51	m
Critical Slope	0.00264	m/m
Velocity	4.88	m/s
Velocity Head	1.22	m
Specific Energy	2.33	m
Froude Number	1.78	
Flow Type	Supercritical	

Worksheet for From St. 405+095 to St. 404+860

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.51000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	19.90	m^3/s

Results

Normal Depth	1.28	m
Flow Area	5.02	m^2
Wetted Perimeter	6.62	m
Hydraulic Radius	0.76	m
Top Width	5.84	m
Critical Depth	1.51	m
Critical Slope	0.00264	m/m
Velocity	3.96	m/s
Velocity Head	0.80	m
Specific Energy	2.08	m
Froude Number	1.36	
Flow Type	Supercritical	

Worksheet for From St. 406+220 to St. 406+980

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.46000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	1.50	m³/s

Results

Normal Depth	0.33	m
Flow Area	0.82	m²
Wetted Perimeter	3.19	m
Hydraulic Radius	0.26	m
Top Width	2.99	m
Critical Depth	0.35	m
Critical Slope	0.00364	m/m
Velocity	1.83	m/s
Velocity Head	0.17	m
Specific Energy	0.50	m
Froude Number	1.12	
Flow Type	Supercritical	

Worksheet for From St. 408+685 to St. 409+125

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.25000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	24.30	m^3/s

Results

Normal Depth	1.13	m
Flow Area	4.18	m^2
Wetted Perimeter	6.08	m
Hydraulic Radius	0.69	m
Top Width	5.39	m
Critical Depth	1.67	m
Critical Slope	0.00258	m/m
Velocity	5.81	m/s
Velocity Head	1.72	m
Specific Energy	2.85	m
Froude Number	2.11	
Flow Type	Supercritical	

Worksheet for From St. 409+685 to St. 409+125

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.55000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	24.30	m³/s

Results

Normal Depth	1.39	m
Flow Area	5.66	m²
Wetted Perimeter	7.00	m
Hydraulic Radius	0.81	m
Top Width	6.16	m
Critical Depth	1.67	m
Critical Slope	0.00258	m/m
Velocity	4.29	m/s
Velocity Head	0.94	m
Specific Energy	2.33	m
Froude Number	1.43	
Flow Type	Supercritical	

Worksheet for From St. 410+755 to St. 411+830

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.17000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.10	m^3/s

Results

Normal Depth	0.65	m
Flow Area	1.93	m^2
Wetted Perimeter	4.34	m
Hydraulic Radius	0.45	m
Top Width	3.95	m
Critical Depth	0.54	m
Critical Slope	0.00331	m/m
Velocity	1.60	m/s
Velocity Head	0.13	m
Specific Energy	0.78	m
Froude Number	0.73	
Flow Type	Subcritical	

Worksheet for From St. 412+090 to St. 411+830

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.75000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.10	m³/s

Results

Normal Depth	0.43	m
Flow Area	1.14	m²
Wetted Perimeter	3.56	m
Hydraulic Radius	0.32	m
Top Width	3.30	m
Critical Depth	0.54	m
Critical Slope	0.00331	m/m
Velocity	2.71	m/s
Velocity Head	0.37	m
Specific Energy	0.81	m
Froude Number	1.47	
Flow Type	Supercritical	

Worksheet for From St. 412+670 to St. 412+950

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.19000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	1.90	m^3/s

Results

Normal Depth	0.48	m
Flow Area	1.31	m^2
Wetted Perimeter	3.74	m
Hydraulic Radius	0.35	m
Top Width	3.45	m
Critical Depth	0.41	m
Critical Slope	0.00353	m/m
Velocity	1.45	m/s
Velocity Head	0.11	m
Specific Energy	0.59	m
Froude Number	0.75	
Flow Type	Subcritical	

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Worksheet for From St. 415+125 to St. 413+215

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.59000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	3.10	m³/s

Results

Normal Depth	0.46	m
Flow Area	1.24	m²
Wetted Perimeter	3.67	m
Hydraulic Radius	0.34	m
Top Width	3.39	m
Critical Depth	0.54	m
Critical Slope	0.00331	m/m
Velocity	2.49	m/s
Velocity Head	0.32	m
Specific Energy	0.78	m
Froude Number	1.31	
Flow Type	Supercritical	

Worksheet for From St. 415+790 to St. 415+125

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.16000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	18.50	m³/s

Results

Normal Depth	1.00	m
Flow Area	3.52	m²
Wetted Perimeter	5.62	m
Hydraulic Radius	0.63	m
Top Width	5.01	m
Critical Depth	1.45	m
Critical Slope	0.00266	m/m
Velocity	5.26	m/s
Velocity Head	1.41	m
Specific Energy	2.41	m
Froude Number	2.00	
Flow Type	Supercritical	

Worksheet for From St. 416+525 to St. 416+850

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.04000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	4.50	m³/s

Results

Normal Depth	1.15	m
Flow Area	4.29	m²
Wetted Perimeter	6.15	m
Hydraulic Radius	0.70	m
Top Width	5.45	m
Critical Depth	0.67	m
Critical Slope	0.00315	m/m
Velocity	1.05	m/s
Velocity Head	0.06	m
Specific Energy	1.21	m
Froude Number	0.38	
Flow Type	Subcritical	

Worksheet for From St. 422+175 to St. 423+580

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	0.48000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	8.30	m³/s

Results

Normal Depth	0.83	m
Flow Area	2.71	m²
Wetted Perimeter	5.00	m
Hydraulic Radius	0.54	m
Top Width	4.50	m
Critical Depth	0.95	m
Critical Slope	0.00293	m/m
Velocity	3.07	m/s
Velocity Head	0.48	m
Specific Energy	1.31	m
Froude Number	1.26	
Flow Type	Supercritical	

Worksheet for From St. 424+545 to St. 424+210

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	2.32000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	9.80	m^3/s

Results

Normal Depth	0.60	m
Flow Area	1.73	m^2
Wetted Perimeter	4.15	m
Hydraulic Radius	0.42	m
Top Width	3.79	m
Critical Depth	1.04	m
Critical Slope	0.00287	m/m
Velocity	5.66	m/s
Velocity Head	1.64	m
Specific Energy	2.23	m
Froude Number	2.68	
Flow Type	Supercritical	

Worksheet for From St. 427+740 to St. 427+545

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.015	
Channel Slope	1.49000	%
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	1.50	m/m (H:V)
Bottom Width	2.00	m
Discharge	5.50	m³/s

Results

Normal Depth	0.49	m
Flow Area	1.34	m²
Wetted Perimeter	3.77	m
Hydraulic Radius	0.36	m
Top Width	3.47	m
Critical Depth	0.75	m
Critical Slope	0.00308	m/m
Velocity	4.09	m/s
Velocity Head	0.85	m
Specific Energy	1.34	m
Froude Number	2.10	
Flow Type	Supercritical	