FINAL
Hydraulics Report

Bunker Road and Mitchell Road
GOGA 104(1) & 105(2)
Contract No. DTFH68-10-D-00001
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I. INTRODUCTION

The scope of work is to perform environmental, engineering, hydraulic, geotechnical, right-of-way, surveying, mapping, and project management services towards delivery of a 95% plan set for the Federal Highway Administration (FHWA), Central Federal Lands Highway Division (CFLHD) for proposed improvements to Golden Gate National Recreation Area (GGNRA), Alexander Avenue, Mitchell Road, and Bunker Road.

The purpose of this project is to rehabilitate the roadways, construct minor roadway widening, improve drainage and safety, extend the left turn lane on Alexander Avenue at Danes Drive, and construct two new parking areas.

The purpose of this FINAL Hydraulics Report is to provide a summary of the final hydraulic recommendations for Bunker Road and Mitchell Road and Alexander Avenue to a 95% plan set. The preliminary hydrologic and hydraulic analysis performed under this task used recommendations from the CFLHD *Trip Report*, CFLHD CADD notes, a field review in November 2010 and April 2011, PBS&J's *Preliminary Hydraulics Recommendations Report*, PBS&J's *Rodeo Lagoon Preliminary Hydraulics Recommendations Report*, and Ayers's *Rodeo Lagoon Bridge Hydraulics and Scour Evaluation.*

II. PROJECT BACKGROUND AND DESCRIPTION

This project will be funded through the Federal Lands Highway Program. The National Park Service (NPS) completed an environmental impact statement for the Marin Headlands and Fort Baker areas. The Record of Decision (ROD) was signed on August 11, 2009.

Specific hydrologic and hydraulic components for this project will include developing the applicable criteria memorandum, identifying and evaluating the existing and proposed drainage facilities, supporting the design activities with water quality recommendations, developing a technical memorandum to document preliminary hydraulic recommendations, and preparing a draft and final hydraulics report for delivery of a 95% plan set. A scope of work to develop the remainder of the project to the 100% plan set level will be developed in the future.

HIGHWAY DESIGN IMPROVEMENTS

The general scope of roadway improvements is the rehabilitation of approximately 3.24 miles of roadway. Minor improvements will be made on Bunker Road "East." Guardrails, sign panels, and sign supports will also be upgraded to meet current standards.

Bunker Road consists of three segments:

- Segment 1: 0.20 miles on Old Bunker Road beginning at the intersection of Mitchell Road and Bunker Road "West" and continues northwest past the Marine Mammal Center.
- Segment 2: 2.53 miles on Bunker Road "West" beginning at the intersection of Mitchell Road and Old Bunker Road and proceeds east to the Baker-Barry Tunnel.
- Segment 3: 0.56 miles on Bunker Road "East" begins at Murray Circle and proceeds northwest to the Baker-Barry Tunnel. Only minor improvements to correct deficiencies (replace guardrail, restripe, and replace missing centerline raised reflectors) will be included in this project.

This project also includes 0.50 mile of work on Mitchell Road, which begins just west of Rodeo Beach and extends to the intersection of Bunker Road and Old Bunker Road. Work on Mitchell Road will be limited to approximately 2,700 feet of roadway from the intersection to the unpaved overflow parking area on Rodeo Beach.

A new parking lot will be constructed adjacent to Bunker Road "West" and Smith Road and a second parking lot is proposed along Old Bunker Road near the Marine Mammal Center. These parking lots will have a paved drive, accessible parking spaces, and gravel or permeable parking areas.

The left-turn lane on Alexander Avenue to Danes Drive will be extended to meet American Association of State Highway and Transportation Officials (AASHTO) design standards. This will require a rock cut on Alexander Avenue to widen the roadway and accommodate the extended turn lane. Danes Drive will be realigned at the intersection of Alexander Avenue to form a T-intersection.

GGNRA is the maintaining agency for this project, except on Alexander Avenue, which is maintained by Caltrans and the Golden Gate Bridge, Highway, and Transportation District (GGBHTD).

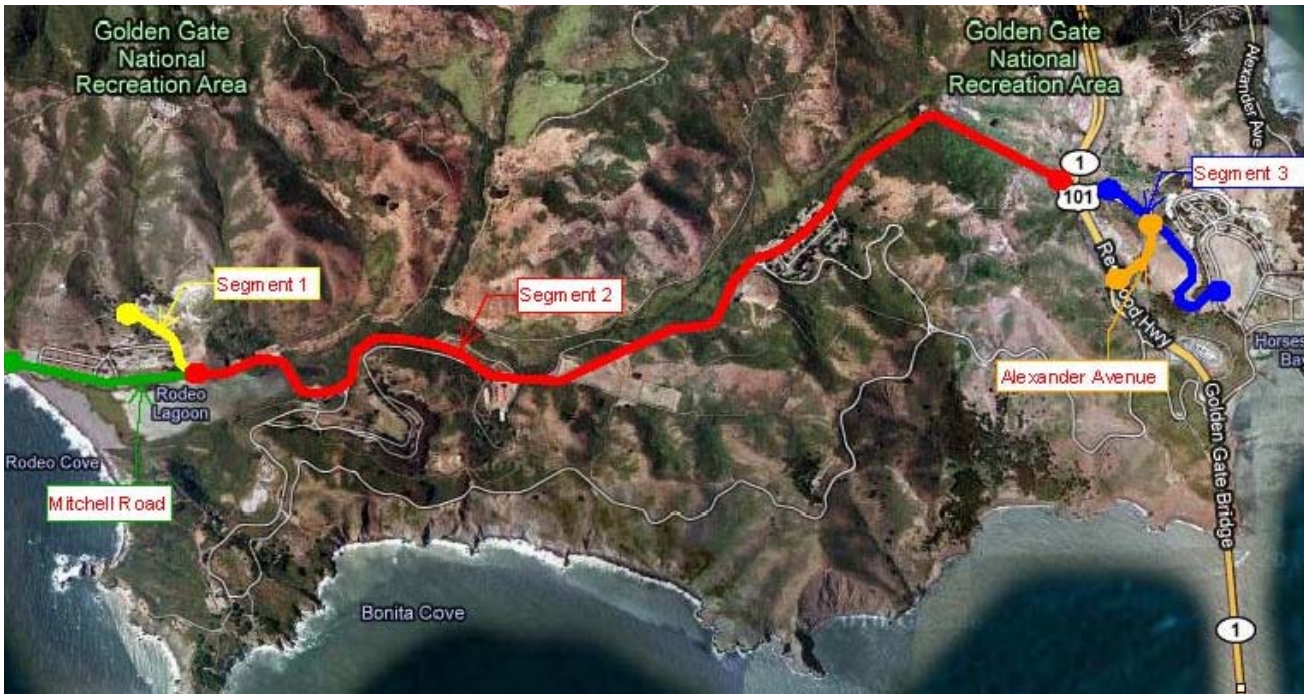
Table 1 includes a summary of the project segments and Figure 1 shows the project location.

Table 1
Project Segment Summary

Road	Functional Classification	Terrain	Type	Structures on Segment
Old Bunker Road: Segment 1	Class II: Connector Park Road	Rolling	4R	None
Bunker Road "West": Segment 2	Class I: Principal Park	Flat to Rolling	4R	Rodeo Lagoon Bridge
Bunker Road "East": Segment 3	Class I: Principal Park	Rolling	3R	None
Mitchell Road	Class II: Connector Park Road	Flat (until intersection with Bunker Road "West")	3R	None[1]
Alexander Avenue	Urban Arterial Streets	Flat to Rolling	4R	None

[1] *Two existing minor culverts, located along Mitchell Road, are immediately adjacent to proposed wetland restoration areas. Only the surfer parking lot restoration is included with this project.*

Figure 1
Project Segment Location



BRIDGE IMPROVEMENTS

The Rodeo Lagoon Bridge will receive rehabilitation work in the form of riprap repair of areas showing erosion and embankment replacement at the northwest wingwall.

HYDRAULIC IMPROVEMENTS

Within the roadway improvements, deteriorated culverts and drop inlets will be replaced and upsized as needed. All solid inlet covers will be replaced with slotted grate inlet covers for maintenance.

Although there is not an identified "drainage problem" in the area of the proposed parking lot at Bunker Road "West" and Smith Road, an attempt will be made to improve/restore the natural sheet flow draining northward from Bunker Road to Smith Road. The parking lot is will be designed to restore/maintain drainage into the riparian area.

WETLAND IMPROVEMENTS

The existing surfer parking lot off of Mitchell Road near Rodeo Beach will be graded to accommodate proposed wetland restoration. The existing culvert at the proposed wetland restoration does not provide adequate conveyance and the culvert and grate inlet will be replaced.

Preliminary designs for this project also investigated the replacement of an existing culvert crossing approximately 0.3 mile east of the surfer parking lot on Mitchell Road. The preliminary design included a four culvert system to accommodate future wetland restoration. However, due to funding and scheduling of the wetland restoration, accommodation of the future wetland restoration is not being incorporated with the Mitchell Road improvements associated with this project.

III. DRAINAGE CRITERIA

The drainage criteria memorandum, Hydrologic and Hydraulic Criteria and Computational Methods Technical Memorandum for Bunker Road and Mitchell Road FHWA Project: GOGA 104(1) & 105(2) was completed September 28, 2010, based on design standards outlined in Federal Lands Highway *Project Development and Design Manual* (PDDM) (2008) and Caltrans *Highway Design Manual* (2006). A copy of the criteria memorandum is included in Appendix A.

All segments of Mitchell Road and Bunker Road utilize CFLHD's criteria. To accommodate proposed wetland restoration projects adjacent to Mitchell Road, additional reference was provided by the following previous reports:

- *Wetland Processes and Opportunities for Restoration in the Rodeo Lagoon Watershed*, May 2006
- *Wetland Habitat Changes in the Rodeo Lagoon Watershed, Marin County, CA*, October 2004
- *Hydrologic Regime, Vegetation, Impact Analysis, and Restoration Concepts for the Rodeo Beach Wetland complex: Golden Gate National Recreational Area, California*, September 2008

IV. DATA COLLECTION AND SITE INVESTIGATION

A site inspection occurred in November 2010 and April 2011. These field reviews specifically addressed: verification of drainage patterns, determination if existing storm systems exist at the Marine Mammal Center and riding stables, the need to replace inlets at intersection of Old Bunker Road and Bunker Road "West," existing inlet clogging issues, whether the restored ditches should be paved or vegetated, outfalls that were not identified on the survey, and the need for additional inlets. Results of the November 2010 visit are documented in PBS&J's *Preliminary Hydraulics Recommendations Report.* Hydraulic results and discussions of the April 2011 visit are documented in this report.

V. HYDROLOGY

Hydrologic analysis for Bunker Road and Mitchell Road was determined using the Rational Method; the analysis for Rodeo Lagoon Bridge used StreamStat and regression equations because the bridge has a drainage area greater than 200 acres. The hydrologic analysis for Rodeo Lagoon Bridge does not include flow attenuation or detention effects of Rodeo Pond upstream of Rodeo Lagoon Bridge. Design rainfall used for this analysis is based on criteria obtained from the National Oceanic and Atmospheric Administration (NOAA) and rainfall depth-duration-frequency data obtained from California Department of Water Resources from the Marin City Station (station number E20 5342 35). Design Point Rainfall values for the site is shown in Table 2. These curves are used with the Rational Method for the hydrologic comparative analysis performed as part of the drainage calculations and are in Appendix B.

Table 2
Design Point Rainfall

Return Period	1-hour (inches)	6-hour (inches)	24-hour (inches)
2-year	0.64	1.26	1.92
5-year	0.91	1.77	2.69
10-year	1.08	2.11	3.22
50-year	1.46	2.86	4.34
100-year	1.62	3.16	4.81

Watershed basins were delineated using surveyed topography and U.S. Geological Survey (USGS) Quad maps where basins extended beyond the surveyed topography. Table 3 summarizes basins along the project. Basins shown in Table 3 and on the basin map focus on hydraulic recommendations presented in the *Preliminary Hydraulics Recommendations Report*. Areas not delineated typically drain to existing ditches, inlets or storm drains and are not expected to need improvements. A basin map is in Appendix B.

Table 3
Proposed Drainage Basins and Peak Discharges

Basin ID	Area (acres)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
A1	2.96	1.65	2.19	2.67	3.10
A2	0.55	0.40	0.54	0.66	0.76
A3	7.95	6.07	8.05	9.83	11.39
B1	1.17	0.75	1.00	1.22	1.42
C1	9.49	4.03	5.35	6.53	7.58
D1	69.94	23.06	30.61	37.31	43.23
D2	3.25	1.17	1.55	1.89	2.19
E1	4.32	1.65	2.19	2.67	3.10
F1	1.26	1.74	2.30	2.82	3.27
F2	0.53	0.68	0.90	1.10	1.28
F3	0.99	0.98	1.30	1.60	1.85
G1	21.99	7.03	9.33	11.37	13.17
H1	40.67	15.30	20.33	24.73	28.68
I1	1.61	2.49	3.30	3.69	4.11
H1 + J1	48.34	18.08	24.03	29.23	33.92
J1	7.67	2.74	3.64	4.43	5.14
K1	6.85	7.57	10.00	12.27	14.19
L1	1.00	1.62	2.14	2.62	3.03
M1	7.39	3.73	4.94	6.05	7.01
N1	4.83	2.87	3.79	4.66	5.40
EX1	169.08	45.84	60.70	74.36	85.95
EX2	98.50	36.87	48.92	59.71	69.14
EX3	2266	447	561	674	751

cfs = cubic feet per second

VI. FINAL HYDRAULIC ANALYSIS

The 95% design hydraulic analysis is based on the PBS&J *Preliminary Hydraulics Recommendations Report* and PBS&J *Rodeo Lagoon Preliminary Hydraulics Recommendations Report* and subsequent coordination with CFLHD. Approximately 70 hydraulic structures have been identified along the corridor. The scope of this project includes the evaluation of seven to eleven basins and the hydraulic structures included in each. In general, solid inlet covers will be replaced with slotted drop inlets, standard drop inlets will be added, culverts in poor condition or undersized will be replaced with appropriate sizes based on the criteria outlined for the project, and paved ditches will be re-established. Additional culverts on Mitchell Road are required to accommodate proposed wetland restoration. Bunker Road "West" follows design criteria for low standard roads.

Ditch and inlet improvements were evaluated using FHWA's Hydraulic Toolbox version 2.1. Ditch capacity was designed based on the 10-year design storm. Proposed ditch geometry consists of vegetated V-ditch with 1:4 (V:H) sideslopes and paved waterways with 1:6 (V:H) front slope and varied back slopes. Proposed drop inlet improvements to cross culverts were designed based on the 25-year design storm using FHWA's Hydraulic Toolbox.

Cross culverts were designed based on the 25-year design storm using FHWA's HY-8 version 7.2. Cross culverts to be replaced will use end treatments to increase efficiency, embankment stability, aesthetics and safety for vehicles.

CULVERTS

During the April 2011 field review, NPS requested that culverts discharging into the lagoon have a pipe culvert dissipator as the outlet end treatment. Cross culverts and driveway culverts along the project are summarized in Table 4. All proposed cross culverts are located on Bunker Road and will have culvert protection by means of a flared end sections with placed riprap at the culvert end section or a culvert dissipator.

Table 4
Final Culvert Analysis

Roadway Station	Basin ID	Diameter (inches)	Velocity (fps)	Design HW/D*	Comment
39+82	A1	24	5.53	0.35	Replace with HDPE, inlet, culvert dissipator
43+07	B1	24	2.98	0.23	Replace with HDPE, inlet, culvert dissipator
45+36	C1	24	4.93	0.58	Replace with HDPE, inlet, culvert dissipator
46+59	D1	36	7.83	0.91	Replace with HDPE, headwall, culvert dissipator
88+82	I1	24	3.90	0.38	Replace with HDPE and FES
92+27	H1	24	6.46	1.18	Driveway: Replace with HDPE and FES

HW/D= Headwater/Depth
Fps = feet per second
HDPE = high density polyethylene
FES = flared end sections
**Maximum HW/D = 1.5*

In several locations the CFLHD *Trip Report* has recommended adding concrete walls to existing culverts to convert to a standard drop inlet. Some locations have sealed inlet covers and need to be replaced with a grate inlet. The survey has identified most of the existing culverts as 16-inch reinforced concrete pipe (RCP). The minimum pipe size for cross culverts is 24 inches (or equivalent) and 18 inches (or equivalent) for driveway culverts. Because of the proposed roadway widening, some culverts will need to be replaced or extended; therefore, these culverts are recommended to be replaced in addition to adding grate inlets.

Existing culverts at approximate stations 39+82, 43+07, and 45+36 will need to be extended due to the proposed roadway widening; therefore it is recommended to replace with 24-inch high density polyethylene (HDPE) and add drop inlets. Pipe culvert dissipator with a rolled erosion control product will be placed at the culvert outlet.

It is recommended to replace the existing 36-inch RCP at approximate station 46+59 due to the proposed widening. It is recommended to replace with 36-inch HDPE and add a headwall to the entrance and pipe culvert dissipator with a rolled erosion control product at the exit.

The driveway culvert located at approximate station 88+82 and 92+27 will be replaced with a 24-inch HDPE, flared end sections, and placed riprap at the exit. This culvert carries offsite drainage to the roadway.

Based on the April 2011, the existing culverts at approximate station 119+78, 152+21, and 158+50 will not require replacement as previously recommended. At these locations, the culvert functions and will remain in place. There was no indication of scouring, culvert weathering, or high sedimentation.

Along the corridor a standard drop inlet will be added to cross culverts as discussed above and at some locations sealed inlet covers will be replaced with grate inlets. The analysis was based on the 25-year design storm and results are shown in Table 5. Caltrans Standard Detail D73, Type G1 for median inlets is recommended at these locations.

Table 5
Final Inlet Analysis

Location	Roadway Station	Basin ID	Depth at Inlet (feet)	Spread at Inlet (feet)	Comments
Old Bunker Road	310+25	A3	0.33	2.66	Remain as is
	310+70	A2	0.15	1.28	Restore
Bunker Road	39+82	A1	0.26	2.04	Remove & replace
	43+07	B1	0.28	2.12	Remove & replace
	45+36	C1	0.26	2.02	Remove & replace
	63+97	E1	0.60	3.61	Recondition
	70+13	F1	0.61	3.68	Recondition
	73+14	F2	0.48	2.36	Recondition
	75+13	F3	0.47	2.36	Recondition
	78+79	G1	0.75	3.77	Remain as is
	111+26	Not Analyzed			Recondition
	114+03	Not Analyzed			Recondition
	119+78	K1	0.95	4.76	Recondition
	123+29	Not Analyzed			Recondition
	126+92	L1	0.42	3.29	Add drop inlet
	136+54	Not Analyzed			Remove & replace
	137+24	Not Analyzed			Remove & replace
	152+21	M1	0.54	3.25	Recondition
	158+50	N1	0.49	2.95	Recondition
	161+62	Not Analyzed			Add drop inlet

On Old Bunker Road, at station 310+25 and 310+70, there are inlets that have been paved over. The inlet at station 310+25 discharges into a gathering area. To prevent flooding to this gathering area, the inlet has been paved over and is to remain as is. The inlet at station 310+70 is to be restored through reconditioning of the structure and adding a metal grate top.

Because of roadway widening and improvements, existing inlets and culverts will be removed and replaced at stations 39+82, 43+07, and 45+36.

Existing inlets at station 63+97, 70+13, 73+14, 75+13, 111+26, 114+03, 119+78, 123+29, 152+21, and 158+50 have sealed inlet covers that need to be removed and replaced with grates. In the plans, this is denoted with text that reads, “Recondition drainage structure, Install inlet, metal grate.” The existing size of the inlets has been provided in the construction plan set.

The drop inlet at station 78+79 will remain in place and as is.

A drop inlet will be added to the existing culvert at station 126+92 and 161+62.

Curb inlets at station 136+54 and 137+24 are to be replaced because of the widening and replacement of curb and gutter.

All grates will be bicycle safe grates.

PAVEMENT DRAINAGE

The plan set shows proposed curb and gutter along Old Bunker Road, but no additional drainage recommendations have been made for this segment.

DITCHES

The final ditch analysis recommends ditch reconditioning in vegetated areas and replacing paved ditches along Old Bunker Road as shown in Table 6. The proposed geometry consists of a vegetated V-ditch with 1:4 (V: H) side slopes with a minimum depth of 0.50 foot, a paved V-ditch with 1:6 (V: H) front and 1:3 (V: H) back slopes with a minimum depth of 0.50 foot, and a paved waterway with 1:10 (V: H) to the curb with a minimum depth of 0.30 foot.

Table 6
Final Ditch Analysis

Location	Roadway Station	Basin ID	Design Depth (feet)	Minimum Constructed Depth (feet)	Front & Back S:S (V:H)	Velocity (fps)	Lining
Old Bunker Road	304+52 to 310+25	A3	0.45	0.50	1:6 & 1:3	7.60	Paved
	310+25 to 310+70	A2	0.15	0.50	1:6 & 1:3	4.21	Paved
	310+70 to 313+95	A1	0.26	0.50	1:6 & 1:3	6.30	Paved
	313+95 to 39+81	A1	0.26	0.50	1:6 & 1:3	6.30	Paved
Bunker Road	39+84 to 43+05	B1	0.28	0.30	1:10 & 1:2	1.85	Paved waterway
	43+07 to 45+36	C1	0.60	0.50	1:4 & 1:4	2.76	Vegetated
	45+36 to 46+59	D1	0.37	0.50	1:4 & 1:4	2.03	Vegetated
	63+97 to 68+53	E1	0.60	0.75	1:4 & 1:2	1.51	Vegetated
	68+53 to 70+13	F1	0.50	0.65	1:4 & 1:2	1.51	Vegetated
	70+13 to 73+14						
	73+14 to 75+13	F2	0.43	0.80	1:4 & 1:2	1.21	Vegetated
	75+13 to 78+79	F3	0.47	0.80	1:4 & 1:2	1.77	Vegetated
	78+79 to 85+09	G1	0.76	0.66	1:4 & 1:2	5.34	Vegetated
	85+09 to 92+00	H1	Do not disturb existing bioswale				
	92+95 to 98+00	J1	0.49	0.77	1:4 & 1:4	3.78	Vegetated
	119+78 to 123+29	K1	0.95	1.00	1:4 & 1:4	3.39	Vegetated
	126+92 to 131+00	L1	0.41	0.75	1:4 & 1:4	2.39	Vegetated
	152+21 to 158+50	M1	0.54	0.75	1:4 & 1:4	4.23	Vegetated
	158+50 to 161+62	N1	0.49	0.50	1:4 & 1:4	3.96	Vegetated

Fps = feet per second

The existing paved ditch on Old Bunker Road from station 304+52 to 313+95 will be replaced by a paved V-ditch with 1:6 (V: H) side slopes with a minimum depth of 0.50 feet. Two inlets located within the proposed station range and will remain in place.

The ditch from Old Bunker Road station 304+52 to 313+95 will tie into the Bunker Road ditch at stations 39+81 to 46+59. There are three relief culverts within this station range.

At approximate station 44+75 the existing driveway culvert will be removed and replaced with the proposed ditch to extend to the proposed drop inlet at station 45+36.

Ditch reconditioning is recommended at station 63+97 to 85+09. There are five relief culverts within this range.

There is a bio-swale located between stations 85+09 to 92+00 that should not be disturbed.

Ditch reconditioning is recommended at stations 92+95 to 98+00, 119+78 to 123+29, 126+92 to 131+00, and 152+21 to 161+62.

SURFER PARKING CULVERT

The existing culvert located at Mitchell Road Station 12+05 consists of two 24-inch CMP. The existing upstream condition includes a grate inlet located north of Mitchell Road, between the surfer parking lot and Fort Cronkhite parking lot. The downstream condition includes the two 24-inch CMPs projecting from fill with a spill height of approximately 3 to 4 feet.

Wetland restoration of the existing surfer parking lot proposes to excavate the parking surface and establish wetland vegetation. NPS has expressed concerns that a concentrated culvert crossing may produce headcutting through the wetland.

Table 7 provides a summary of the hydraulic analysis for the existing and proposed culverts.

Table 7
Final Surfer Parking Culvert Analysis at Station 12+05

Diameter (inches)	Basin ID	Velocity (fps)	Design HW/D*	Comment
2-24” CMP	EX1	9.75	2.62	Existing, CMP
1-42” HDPE	EX1	12.18	1.18	Proposed HDPE, grate inlet upstream, pipe mitered to slope downstream

HW/D= Headwater/Depth
Fps = feet per second
HDPE = high density polyethylene
FES = flared end sections
**Maximum HW/D = 1.5*

The recommended culvert crossing includes one 42-inch HDPE with two, FHWA Catch Basin, Type 1 inlets at the upstream end. The grate inlet will help control potential head cutting within the wetland restoration area. The outlet of the culvert will be pipe mitered to slope with a rock riprap outlet pad and slope protection. The invert of the outlet will be above the lagoon high water elevation and above the estimated dune elevation to reduce the risk of future dune migration blocking the outlet of the culvert. The proposed rock rip rap at the outlet has been sized to protect the outfall area from the effects of the culvert discharge. The placement of the culvert outlet riprap has not designed for tidal protection of the roadway embankment. This location is on the lagoon side of Rodeo Beach and does not experience significant wave or tidal action. Rock has previously been placed at the culvert discharge and significant movement or disturbance has not been observed, even though the existing rock is somewhat rounded and smaller than the proposed Class 3 riprap.

Additional hydraulic structures could be added to enhance the wetland restoration. To provide a wider distribution of flow from the wetlands through Mitchell Road, a longer grate inlet complex would be constructed. The proposed two, FHWA Catch Basin, Type 1 inlets was designed to accommodate the Q25 peak discharge without overtopping the existing Mitchell Road. Another alternative to provide a wider distribution of flow would be construction of a porous rock road prism in Mitchell Road; however, rock road prism installation would require excavation and reconstruction of the existing roadway embankment. Sediment clogging of the rock road prism may also require significant maintenance for the porous rock road prism to function. The rock road prism would also require rock riprap along the entire length of the prism along the beachside roadway embankment. Due to the potential cost and maintenance concerns, a rock road prism is not recommended.

MITCHELL ROAD CULVERT AT STATION 30+16

The existing culvert located at Mitchell Road Station 30+16, formerly known as the "Wetland Delta Culvert" consists of a single 24-inch by 32-inch CMP. The existing upstream condition includes a concrete headwall structure. The downstream condition could not be observed due to existing lagoon vegetation but is assumed to be CMP projecting from fill.

The original intention for this culvert was to restore the wetlands by dispersing the flow distribution from the single existing culvert to four culverts separated by approximately 100 feet. To accommodate the lowered surface proposed by the wetland restoration, the proposed culverts would be below the high water elevation of Rodeo Lagoon and could be submerged during portions of the year. The lowered culverts would also require significant downstream excavation to provide positive drainage to Rodeo Lagoon. Input gathered during the site inspection (November, 2010) included recommendation to provide an open-bottom culvert.

Funds for the wetland restoration project would be secured through a different project. In the interim, the four culverts were considered as "place holders" for the anticipation of the wetland restoration project to minimize impacts to Mitchell Road. However, to do this would require major grading and utility relocation efforts. During the April 2011 field discussion occurred in regards to the construction scheduling. Based on available funds, it was determined that the wetland restoration cannot be accomplished with the reconstruction of Mitchell Road and that interim design considerations would not be developed. As a result, the culvert at this location will not function as a wetland restoration culvert, but as a stormwater conveyance culvert.

Table 8 provides a summary of the hydraulic analysis for the existing and proposed culverts.

Table 8
Mitchell Road Culvert at Station 30+16

Diameter (inches)	Basin ID	Velocity (fps)	Design HW/D*	Comment
32"x24" CMP	EX2	7.38	2.32	Existing, CMP
2-30" HDPE	EX2	7.18	1.07	Proposed HDPE, Safety End Sections upstream and downstream

HW/D= Headwater/Depth
Fps = feet per second
HDPE = high density polyethylene

FES = flared end sections
**Maximum HW/D = 1.5*

RODEO LAGOON BRIDGE

Hydraulic and scour analysis of the existing bridge has been conducted to size rock riprap rehabilitation. The existing Rodeo Lagoon Bridge is subject to contraction and abutment scour. The abutments are partially protected by the existing rock riprap; however, the coverage and extent of the riprap is not sufficient to comply with the recommendations of FHWA guidance document HEC-23, "Bridge Scour and Stream Instability Countermeasures." Additionally, the Bridge Inspection Report dated July 2006 recommends additional riprap on the downstream side of the bridge. Class 3 riprap is proposed to fill voids observed in the existing riprap. Additionally, Class 3 riprap and geotextile filter is proposed behind the existing sheet pile wall to provide additional scour and erosion protection.

Previous recommendations of placing additional riprap within the lagoon were deemed unnecessary by CFLHD staff. Other than minor voids observed in the existing riprap, no significant scouring of the bridge has been observed. The placement of riprap within the lagoon was also thought to be an unnecessary fill activity and unwanted impact to potential 404 permitting.

VII. SUMMARY

Table 9 summarizes final recommendations for this project to a 95% design. V-ditch geometry will be 1:4 (V:H) side slopes with a minimum depth of 0.75 feet. Grate inlets will use Caltrans Standard Detail D77A, Type 24-9 for median inlets. Proposed pipe material is HDPE. These final recommendations are consistent with the initial recommendations from the PBS&J *Preliminary Hydraulics Recommendations Report* , PBS&J *Rodeo Lagoon Preliminary Hydraulics Recommendations Report* and PBS&J *Bunker and Mitchell Roads Preliminary Hydraulics Report*.

Table 9
Summary of Recommended Design

Roadway Station	Location	Final Recommendations
15+00 to 18+00	Mitchell	Proposed pavement drains towards existing vegetated buffer
12+05	Mitchell	Replace existing culverts (2-30” HDPE) with 1-42” HDPE, grate inlet, riprap as agreed by wetland designers
30+16	Mitchell	Install culvert (2-30” HDPE), Safety End Sections, riprap
304+52 to 310+25	Old Bunker	Paved ditch
310+25 to 310+70	Old Bunker	Paved ditch
310+70	Old Bunker	Recondition existing inlet
310+70 to 313+95	Old Bunker	Paved ditch
313+95 to 39+81	Old Bunker to Bunker	Paved ditch
39+82	Bunker	Replace existing culvert (24” HDPE), grate inlet, pipe culvert dissipator
39+84 to 43+05	Bunker	Paved waterway
43+07	Bunker	Replace existing culvert (24” HDPE), grate inlet, pipe culvert dissipator
43+07 to 45+36	Bunker	Recondition ditch
44+75	Bunker	Remove 12” driveway culvert
45+36	Bunker	Replace existing culvert (24” HDPE), grate inlet, pipe culvert dissipator
45+36 to 46+59	Bunker	Recondition ditch
46+59	Bunker	Replace existing culvert (36” HDPE), headwall, pipe culvert dissipator
52+40	Rodeo Lagoon Bridge	Install additional riprap
63+97	Bunker	Recondition existing inlet, metal grate
63+97 to 70+13	Bunker	Recondition ditch
70+13	Bunker	Recondition existing inlet, metal grate
70+13 to 73+14	Bunker	Recondition ditch
73+14	Bunker	Recondition existing inlet, metal grate
73+14 to 75+13	Bunker	Recondition ditch
75+13	Bunker	Recondition existing inlet, metal grate
75+13 to 85+09	Bunker	Recondition ditch
83+00	Smith Parking Lot	Smith Parking drains to vegetated area between Smith Road and Bunker Road prior to discharging to Rodeo Pond
85+09 to 92+00	Bunker	Do not disturb existing bioswale
88+82	Bunker	**Replace existing culvert, FES, riprap
92+27	Bunker	Install 24” HDPE, FES, riprap

Table 9
Summary of Recommended Design

Roadway Station	Location	Final Recommendations
92+95	Bunker	Clean existing culvert
92+95 to 98+00	Bunker	Recondition ditch
102+95	Bunker	Do not disturb existing culvert
106+26, 108+18	Bunker	Clean existing culvert
111+26, 114+03	Bunker	Recondition existing inlet, metal grate
119+78	Bunker	**Recondition existing inlet, metal grate
119+78 to 123+29	Bunker	Recondition ditch
123+29	Bunker	Recondition existing inlet, metal grate, clean existing culvert
126+92	Bunker	**Recondition existing inlet, metal grate
126+92 to 131+00	Bunker	Recondition ditch
136+54, 137+24	Bunker	*Reset curb inlets due to curb and gutter modifications.
138+61, 138+78	Bunker	Do not disturb existing culverts
147+33	Bunker	Do not disturb existing culvert and headwall
152+21	Bunker	**Recondition existing inlet, metal grate
152+21 to 158+50	Bunker	Recondition ditch
158+50	Bunker	**Recondition existing inlet, metal grate
158+50 to 161+62	Bunker	Recondition ditch
161+62	Bunker	**Recondition existing inlet, metal grate

FES = flared end sections
**Differs from Preliminary Hydraulics Recommendations Report*
***Differs from Preliminary Hydraulics Report*

The analysis of the existing structures along Bunker Road "West," Segment 2 was evaluated based on the drainage criteria memorandum, Hydrologic and Hydraulic Criteria and Computational Methods Technical Memorandum for Bunker Road and Mitchell Road FHWA Project: GOGA 104(1) & 105(2), September 28, 2010. Recommendations for existing hydraulic structures were previously made for deficient structures identified in a CFLHD *Trip Report,* CFLHD CADD notes, field reviews in November 2010 and April 2011, PBS&J *Preliminary Hydraulics Recommendations Report,* and PBS&J *Rodeo Lagoon Preliminary Hydraulics Recommendations Report.*

The recommended culvert crossing to accommodate proposed wetland restoration at the Surfer Parking lot and wetland delta area have been provided to a 95% design level based on provided information.

VIII. DRAINAGE CRITERIA REFERENCES

California Department of Water Resources, *Rainfall Depth-Duration-Frequency Data for Marin City,* 2005.

Caltrans, *Highway Design Manual*, September 2006.

CA PRA GOGA 104(1) & 105(2) Rehab Bunker Road and Mitchell Road Scoping Field Review, May 7th, 2008.

Federal Lands Highway, *Project Development and Design Manual*, March 2008.

FHWA, *HY-8,* 2009.

FHWA, *Hydraulic Design Series No. 2,* October 2002.

FHWA, *HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels*, July 2006.

FHWA, *HEC No. 15, Design of Roadside Channels with Flexible Linings*, September 2005.

FHWA, *HDS No. 5, Hydraulic Design of Highway Culverts,* September 1985.

FHWA, *HEC No*. 23, *Bridge Scour and Stream Instability Countermeasures,* September *2009*

National Oceanic and Atmospheric Administration Atlas 2, Volume XI-California, Precipitation-Frequency Atlas of the Western United States, 1973.

NRCS Version 4, *Web Soil Survey, Marin County, California*, September 2010.

S. David Shaw, University of California, Berkeley, Center for Environmental Design Research, *Wetland Process and Opportunities for Restoration in the Rodeo Lagoon Watershed,* May 2006

Striplen, C., R. Grossinger, and J. Collins, *Wetland Habitat Changes in the Rodeo Lagoon Watershed, Marin County, CA.*, October 2004

FHWA, Bridge Inspection Report, *Rodeo Lagoon Bridge, Bunker Road Over Rodeo Lagoon, Golden Gate National Recreational Area,* July 2006

Cooper, Wolf, *Hydrologic regime, Vegetation Impact Analysis, and Restoration Concepts for the Rodeo Beach Wetland complex: Golden Gate National Recreation Area, California*, September 2008

TECHNICAL MEMORANDUM

TO: **Nate Allen, CFLHD Project Manager**
Matt Wessell, P.E., PBS&J Project Manager

FROM: **Josh Hollon, PBS&J Water Resources Engineer**
Tammy Kirkbride, PBS&J Water Resources Engineer

DATE: **September 28, 2010**

SUBJECT: **Hydrologic and Hydraulic Criteria and Computational Methods Technical Memorandum for Bunker and Mitchell Roads**
FHWA Project: GOGA 104(1) & 105(2)

1.0 INTRODUCTION

The Scope of Work is to perform environmental, engineering, hydraulic, geotechnical, right-of-way, surveying, mapping, and project management services towards delivery of a 70% plan set for the Federal Highway Administration, Central Federal Lands Highway Division (CFLHD) for proposed improvements to Gold Gate National Recreation Area (GGNRA), Alexander Avenue, Mitchell and Bunker Roads.

The purpose of this project is to rehabilitate the roadways, construct minor roadway widening, improve drainage and safety, extend the left turn lane on Alexander Avenue at Danes Drive, and construct a new parking area.

The purpose of this Hydrologic and Hydraulic Criteria and Computation Methods Technical Memorandum is to provide a brief summary of the applicable criteria that will be applied to the design activities for proposed improvements for Bunker and Mitchell Roads. An additional technical memorandum, Rodeo Lagoon Technical Memorandum will be provided for the Rodeo Lagoon Bridge and two Mitchell Road culverts that will service proposed wetland, environmental, and wetland restoration. The additional memo will provide any other specific design criteria developed through coordination with NPS and environmental personnel for those three drainage structures.

2.0 PROJECT BACKGROUND AND DESCRIPTION

This project will be funded through the Federal Lands Highway Program. The National Park Service (NPS) completed an Environmental Impact Statement for the Marin Headlands and Fort Baker areas. The Record of Decision (ROD) was signed on August 11, 2009.

Specific hydrologic and hydraulic components for this project will include developing the applicable criteria memorandum, identifying and evaluating the existing and proposed drainage facilities, supporting the design activities with water quality recommendations, developing a technical memorandum to document preliminary hydraulic recommendations, and preparing a draft and final hydraulics report for

delivery of a 70% plan set. A Scope of Work to develop the remainder of the project to the 100% plan set level will be developed in the future.

2.1 HIGHWAY DESIGN IMPROVEMENTS

The general scope of roadway improvements is rehabilitation of approximately 3.24 miles of roadway. Minor improvements will be made Bunker Road "East." Guardrails, sign panels, and sigh supports will also be upgraded to meet current standards.

Bunker Road consists of three segments.

- Segment 1: 0.20 miles on Old Bunker Road begins at the intersection of Mitchell Road and Bunker Road "west" and continues northwest past the Marine Mammal Center
- Segment 2: 2.53 miles on Bunker Road "West" begins at the intersection of Mitchell Road and Old Bunker Road and proceeds east to the Baker-Barry Tunnel.
- Segment 3: 0.56 miles on Bunker Road "East" begins at Murray Circle and proceeds northwest to the Fort Baker Tunnel. Only minor improvements to correct deficiencies (replace guardrail, restripe, and replace missing centerline raised reflectors will be included in this project.

This project also includes 0.50 miles of work on Mitchell Road, which begins just west of Rodeo Beach and extends to the intersection of Bunker Road and Old Bunker Road Work on Mitchell Road will be limited to approximately 2,700 ft of roadway from the intersection to the unpaved overflow parking area on Rodeo Beach.

A new parking lot will be constructed adjacent to Bunker Road "West" and Smith Road. This parking lot will have a paved drive, accessible parking spaces and gravel or permeable parking areas.

The left turn lane on Alexander Avenue to Danes Drive will be extended to meet AASHTO design standards. This will require a rock cut on Alexander Avenue to widened the roadway and accommodate the extended turn lane. Danes Drive will be realigned at the intersection Alexander Avenue to form a "T"-intersection.

GGNRA is the maintaining agency for this project, except on Alexander Avenue to which Caltrans and Golden Gate Bridge, Highway, and Transportation District (GGBHTD) are the maintaining agency.

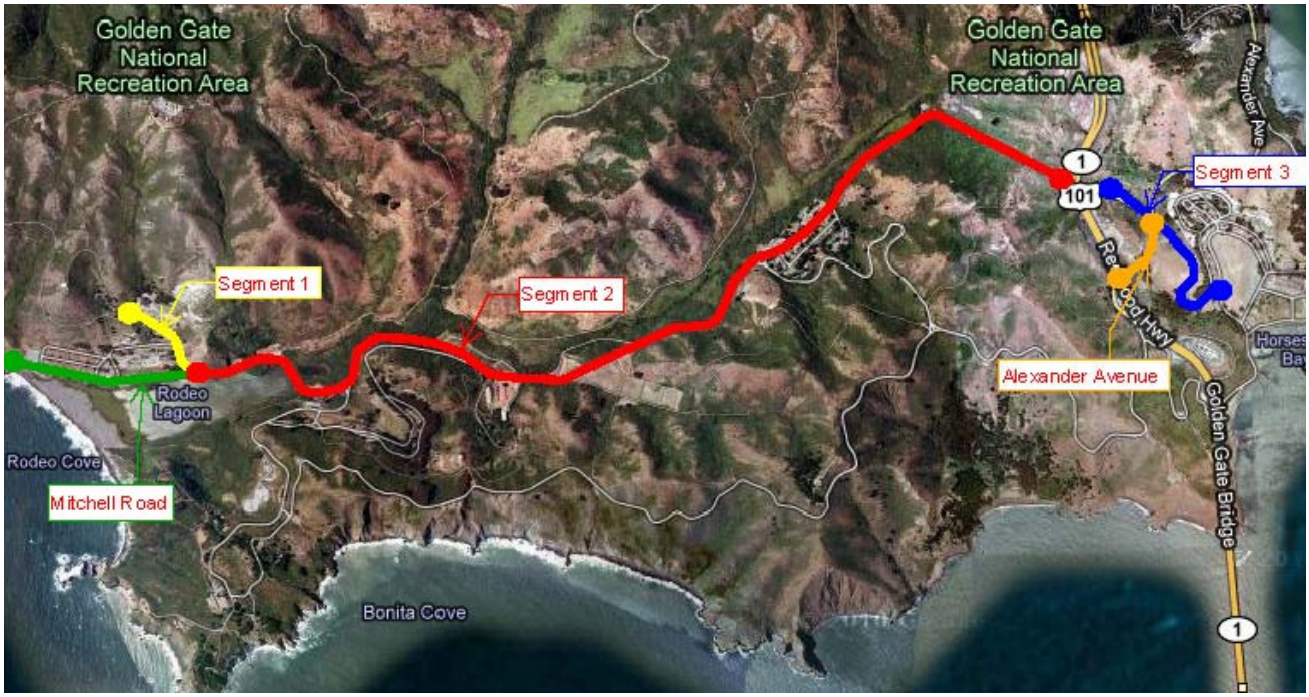
Table 1 shows the project location and Figure 1 includes a summary of the project segments.

Table 1
Project Segment Summary

Road	Functional Classification	Terrain	Type	Structures on Segment
Old Bunker Road: Segment 1	Class II: Connector Park Road	Rolling	3R+	None
Bunker Road "West": Segment 2	Class I: Principal Park	Flat to Rolling	3R+	Rodeo Lagoon Bridge
Bunker Road "East": Segment 3	Class I: Principal Park	Rolling	3R	None
Mitchell Road	Class II: Connector Park Road	Flat (until intersection with Bunker Road "West")	3R	None[1]
Alexander Avenue	Urban Arterial Streets	Flat to Rolling	3R+	None

[1] Two existing minor culverts located along Mitchell Road will be utilized for future wetland restoration and may be improved to structures based on coordination with NPS and environmental personnel

Figure 2
Project Segment Location



2.2 BRIDGE IMPROVEMENTS

The Rodeo Lagoon Bridge will receive rehabilitation work in the form of riprap repair of areas showing erosion and embankment replacement at the northwest wingwall.

2.3 HYDRUALIC IMPROVEMENTS

Within the roadway improvements, deteriorated culverts and drop inlets will be replaced and upsized as needed. All solid inlet covers will be replaced with slotted grate inlet covers for maintenance. Although there is not an identified "drainage problem" in the area of the proposed parking lot at Bunker Road "West" and Smith Road, an attempt will be made to improve/restore the natural sheet flow draining northward from Bunker Road to Smith Road. The parking lot will be shifted east if possible to restore/maintain drainage into the riparian area. Drainage will also be improved in the parking lot west of the stables.

In addition, restoration of channel flow at the overflow parking lot off of Mitchell Road near Rodeo Beach will be included in this project.

This project will also restore the hydraulic connection with proposed wetland restoration at Rodeo Lagoon approximately 0.3 miles east of the surfer parking lot on Mitchell Road.

3.0 DRAINAGE CRITERIA REFERENCES

Drainage analysis and design work associated with the proposed improvements will be in accordance with the methods, guidelines, and criteria set forth by NPS, CFLHD, American Association of State Highway and Transportation Officials (AASHTO), and Caltrans highway design standards. Of these agencies, Federal Lands Highway (CFLHD) and Caltrans have developed drainage criteria manuals establishing guidance or references to aid in the design process and or specific design standards:

- Federal Lands Highway *Project Development and Design Manual* (PDDM) (2008)
- Caltrans *Highway Design Manual* (2006)

A design matrix was developed with criteria from both agencies. All the segments of Bunker Road will utilize CFLHD's criteria. However, a portion of Alexander Avenue lies in Caltrans right-of-way. A decision will need to be made as to which criteria to use, Caltrans or CFLHD's criteria.

4.0 HYDROLOGY

Hydrologic analysis for the Bunker and Mitchell Roads will be determined using the Rational Method. Design rainfall used for this analysis is based on criteria obtained from the National Oceanic and Atmospheric Administration (NOAA) and rainfall depth-duration-frequency data obtained from California Department of Water Resources from the Marin City Station (station number E20 5342 35). Design Point Rainfall values for the site is shown in Table 3. These curves will be used with the Rational Method for the hydrologic comparative analysis performed as part of the drainage calculations.

Table 3
Design Point Rainfall

Return Period	1-hour (inches)	6-hour (inches)	24-hour (inches)
2-year	0.64	1.26	1.92
5-year	0.91	1.77	2.69
10-year	1.08	2.11	3.22
50-year	1.46	2.86	4.34
100-year	1.62	3.16	4.81

Watershed basin delineations will be prepared using available U.S. Geological Survey (USGS) Quad maps and surveyed topography.

Soil survey data and maps were obtained from the National Resources Conservation Service (NRCS). Based on the NRCS soil survey of the project area, the soils in the vicinity of Bunker Road are part of the Tamalpais-Barnabe Variant, Cronkhite-Barnabe Complex and Xerorthents-Urban Land Complex. All of the soils are classified as a Type "C" hydrologic soil group. These soils have a "slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission" (NRCS, 2010).

Additional soil types along Bunker Road include Humaquepts and Rodeo Clay Loam. These soils are classified as Type "D" hydrologic soil group. These soils have a "very slow infiltration rate when thoroughly wet. These consists chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and the soils that are shallow over nearly impervious material" (NRCS, 2010).

Near the vicinity of Mitchell Road and in some areas of Bunker Road, there were areas were NRCS did not identify soils. Instead a fill material, Xerorthents was delineated that does not have a NRCS soil rating.

The project limits does not lie within a Federal Emergency Management Agency (FEMA) mapped flood zone and can be found within Flood Insurance Rate Map Panel numbered 06041C0510D and 06041C0528D. The majority of the project lies within a National Recreation Area or Military Reservation and is unmapped by FEMA.

5.0 ROADWAY HYDRAULICS

The design of roadway hydraulic structures is based on CFLHD's roadway classification. There are two roadway classifications used in this project depending on the segment.

High Standard: if any of the following conditions apply to the section of the project:

- Design speed > 45 mph
- Design Average Daily Traffic (ADT) > 1500
- Designated as a critical access road

Low Standard: All other roads

Table 3 provides a summary of the roadway classification.

Table 3
FHWA Roadway Classification Summary

Road	Speed (mph)	ADT	Critical Access	Roadway Classification
Bunker Road: Segment 1	25-35	400	No	Low Standard
Bunker Road: Segment 2	25-35	1100	No	Low Standard
Bunker Road: Segment 3	25	4600	No	High Standard
Mitchell Road	25	1000	No	Low Standard
Alexander Avenue	40	7600	Yes	High Standard

5.1 CULVERTS

Existing culverts will be evaluated for the 10-, 25-, 50- and 100-year events for potential encroachments to determine water surface elevations and determine whether they meet current criteria. Culverts will be analyzed using HY8 Culvert Analysis software.

Caltrans preference for pipe material is reinforced concrete pipe, but alternative materials are also considered. CFLHD prefers to use corrugated metal pipe to maintain historic properties throughout the park. Based upon recent drainage improvements in the vicinity of this study which used RCP or plastic pipe these types will also serve as the primary material selection for this project. Existing culverts will be evaluated and if they do not meet current criteria, alternatives will be recommended. Existing hydraulic conditions will be evaluated and documented. For proposed conditions, culverts will be evaluated and designed based on the lowest headwater elevation based on the criteria shown in Table 4. It is recommended that culverts have end treatments to increase efficiency, embankment stability, aesthetics and safety for vehicles.

Table 4 summarizes the culvert requirements per Federal Lands Highway's PDDM unless otherwise noted.

Table 4
Culverts

Design Criteria	Standards
Storm Event:	100-year for proposed cross culverts (Caltrans) 50-year for proposed cross culverts (High Standard Road) 25-year for proposed cross culverts (Low Standard Road) 10-year for culverts conveying roadside ditches
Headwater Elevation (HW)	• Existing: HW shall not be greater than the shoulder hinge point at the local roadway low point and not allowed to spread onto roadway shoulder • New: HW shall not be greater than the bottom of the aggregate base layer for the roadway pavement structure at the local roadway low point
HW/D Ratio	1.5 for culverts less than or equal to 48 inches 1.2 for culverts greater than 48 inches
Minimum Pipe Size	Cross Culverts : 24 inches or equivalent Parallel Culverts in ditches : 18 inches or equivalent
Slope	Minimum: 0.5% All Materials Desirable: Greater than or equal to 2% Maximum: 25% Metal, 10% Concrete
Cover	Flexible Pavements: 2 feet (Caltrans) Rigid Pavements: 1.2 feet (Caltrans)
Anchors	Metal: Slopes 25% or greater
Materials	Reinforced Concrete Pipe (Caltrans) or plastic as alternative Corrugated Metal Pipe
Maximum Culvert Skew	45 degrees with roadway centerline
End Treatments	For new structures: • Pipe diameters less than or equal to 48 inches, use flared end sections • Pipe diameters greater than 48 inches or multiple pipes, use headwalls with beveled edges
Outlet Protection	• No scour potential or expected scour can be tolerated: no protection required • Standard outlet treatment: simple riprap outlet protection, Standard Detail CFL C255-50 • Minimal Outlet Protection: bedding, filter material, geotextile • Energy Dissipater for velocities greater than 18 feet per second (fps) (Caltrans)

5.2 STORM DRAINS

Roadway drainage criteria for storm drains is based on FHWA roadway classification, high standard and low standard roadway, and Caltrans roadway classification of a major urban arterial route with posted speeds 45 mph and under. Table 5 summarizes design criteria and standards for inlets, and Table 6 summarizes criteria for storm drain pipe design per Federal Lands Highway's PDDM unless otherwise noted.

Table 5
Inlets (Pavement Drainage)

Design Criteria	Standards
Storm Event	On-grade: 10-year Sumps: 50-year
Spread	• High Standard: Shall not exceed 3 feet of one travel lane • Low Standard: Shall not spread to half of one travel lane
Depth	• On-grade: Depth not to exceed the curb height or allowable spread • Sumps: Depth not to exceed 6 inches • Parking areas: Inlets adjacent to curbs, the flow depth shall not exceed the curb height; for sags the depth of flow at the gutter flowline shall not exceed 6 inches
Inlet Clogging Factor	On-grade: no clogging factor, unless it has previously been a problem, if clogging is considered minimum is 70% Sumps: • Grate Inlets: 50% • Curb Inlets: no clogging factor, unless it has previously been a problem • Rehabilitation Projects: no clogging factor, unless it has previously been a problem. If clogging is considered minimum is 50%
Inlet Types	• Curb Inlet Type OS or OL with Type A or B curbs (Caltrans) • Grate Inlet Type G1 or G2 (Caltrans)

Table 6
Storm Drains

Design Criteria	Standards
Storm Event Capacity Design	On-grade: 10-year Sumps: 50-year No pressure flow
Minimum size	• Trunk Line: 18 inches (Caltrans) • Trunk Laterals: 15 inches (18 inches if wholly or partly under the roadbed) (Caltrans) • Inlet Laterals: 15 inches (18 inches if wholly or partly under the roadbed) (Caltrans)
Minimum Slope	3 fps to insure self cleansing 0.5% as a minimum for constructability
Hydraulic Grade Line (HGL)	• Needs to be calculated over the full length of storm drains with four or more inlets connected in a series • If the design flood creates pressure flow, the HGL must remain below ground elevation • Energy gradient should not rise above the lip of the intake
Spacing between structures	15 to 24-inches: 300-feet 27 to 36-inches: 400-feet 42 to 54-inches: 600-feet 60-inches and up: 1000-feet If self cleansing velocity of 3 fps is unobtainable, spacing of 300-feet should be used
Overside Drains	• Location based on roadway drainage criteria • Sideslopes 4:1 or steeper • Minimum pipe diameter: 8-inches

5.3 DITCHES/OPEN CHANNELS

Roadside ditches will be analyzed using Bentley's FlowMaster. Table 7 summarizes the ditch requirements per Federal Lands Highway's PDDM unless otherwise noted.

Table 7
Ditches

Design Criteria	Standards
Storm Event	10-year design storm event
Depth	• Existing Ditches: no greater than the shoulder hinge point • New Ditches: no greater than the bottom of the aggregate sub-base layer of the roadway pavement
Slope	Desired Minimum: 1.0% Allowable Minimum: 0.5%
Cross Section Shape	Vee, trapezoidal
Stability	• 10-year design storm event • Permissible velocities are 3.5 fps for intermittent flow and 3.5 fps for sustained flows in vegetated ditches based on the project area soil type (Caltrans) • Temporary lining should be stable for the 2-year storm event
Erosion Protection	Lined with rock, stone, concrete

5.4 END TREATMENTS

Where possible, all proposed outlets will be designed to include some degree of scour protection. The proposed treatments include either flared end sections or headwalls for the entrances of culverts and pipe rundowns for the outlets. Table 4 includes criteria for end treatments and outlet protection. Typical outlet protection will use CFLHD Detail C-255-50. If additional protection is required the design methods in Hydraulic Engineering Circular (HEC) 11 and 14 will be applied.

Where practical, outlet protection is recommended for the existing culverts that are exhibiting erosion. Outlet protection will be provided when feasible for each new cross culvert and will be sized using the design storm event for the proposed culvert. Culvert outlet protection will consist of paved rundowns or placed riprap aprons per the FHWA standards.

5.5 BRIDGES

The Rodeo Lagoon Bridge will receive rehabilitation work in the form of riprap repair of areas showing erosion and embankment replacement at the northwest wingwall. HEC 11 and 23 will be used to size and place riprap at this location. Specific design criteria developed through coordination with NPS and environmental personnel during this project that impacts the Rodeo Lagoon Bridge will be documented in a separate Criteria Memo.

5.6 CONSTRUCTION SITE BEST MANAGEMENT PRACTICES

Erosion control measures will be used to protect the existing system and outfalls from sediment transport during construction. An erosion control plan should be prepared during project implementation phases based on FHWA Best Management Practices for Erosion and Sediment Control as well as Caltrans *Storm Water Quality Handbooks: Project Planning and Design Guide*. The following erosion control practices should be used, but not be limited to:

- Inlet protection
- Silt fence
- Erosion control logs
- Vehicle tracking control

Permanent (post-construction) erosion control measures will include revegetation, riprap aprons, and pipe rundowns.

6.0 ENVIRONMENTAL HYDRAULICS

6.1 STREAM RESTORATION AND REHABILITATION

The selected design will be reasonable in terms of satisfying social, environmental, and economic constraints. In the process of restoration and rehabilitation of streams, the goal is not a static, immovable channel. Rather, to restore the stream to reasonable stable, naturalistic system that exhibits a state of dynamic equilibrium.

An attempt will be made to replicate the historical plan form and channel geometries. Where historical geometries are unknown, the appropriate dominant discharge (2- to 10-year discharge) and regime theory to establish appropriate plan form and channel geometries will be used. Specific design criteria developed during this project that impacts the proposed Mitchell Road culverts or Rodeo Lagoon Bridge will be documented in a separate Criteria Memo.

6.2 WETLANDS

Wetland design and analysis is a highly interdisciplinary task requiring close coordination with CFHLD's Environmental Office, resource agencies, and the partner agencies. As detailed in Federal Lands Highway's PDDM, the primary role of the hydraulics engineer is for support and review of deliverables from specialty contractors, as requested. Specific design criteria developed during this project that impacts the proposed Mitchell Road culverts or Rodeo Lagoon Bridge will be documented in a separate Criteria Memo.

7.0 COASTAL HYDRAULICS

Although the roadway improvements ultimately discharge into coastal waters, the scope of work was based mostly on upland conditions. For the minor culverts and ditches that may be impacted by tidal elevations, review of the tidal elevations (provided by NPS) will be performed and appropriate backwater conditions established for hydraulic calculations.

8.0 SUMMARY

The information contained in this memorandum is only a summary of the applicable criteria. Criteria from both CFLHD and Caltrans have been outlined throughout this memorandum. All segments will use CFLHD's criteria, except along Alexander Ave. Further development of criteria along Alexander Avenue should include determination which criteria (CFLHD or Caltrans) will become the governing criteria for that segment of the project.

It is anticipated that an additional technical memorandum, Rodeo Lagoon Technical Memorandum will be provided for the Rodeo Lagoon Bridge and two Mitchell Road culverts that will service proposed wetland and environmental and wetland restoration. The additional memo will provide any other specific design criteria developed through coordination with NPS and environmental personnel for those three drainage structures.

During the design process all criteria will be adhered to by the project engineer. The review process will check adherence to this criteria during the quality assurance/quality control process. Any changes to the design criteria during the design process will be noted in future memorandums. Drainage analysis and design work associated with the proposed improvements will be in accordance with the methods, guidelines, and criteria set forth in the Federal Lands Highway PDDM, FHWA HEC and Hydraulic Design Series publications, and Caltrans *Highway Design Manual* (2006).

9.0 DRAINAGE CRITERIA REFERENCES

AASHTO, *Model Drainage Manual*, 2006.

California Department of Water Resources, *Rainfall Depth-Duration-Frequency Data for Marin City*, 2005.

Caltrans, *Storm Water Quality Handbooks*, March 2003.

Caltrans, *Highway Design Manual*, September 2006.

FEMA, *Flood Insurance Rate Map, Marin County, California*, May 4, 2009.

Federal Lands Highway, *Project Development and Design Manual*, March 2008.

NRCS Version 4, *Web Soil Survey, Marin County, California,* September 2010.

National Oceanic and Atmospheric Administration Atlas 2, Volume XI-California, Precipitation-Frequency Atlas of the Western United States, 1973.

FHWA, *HY-8*, 2009.

FHWA, *Hydraulic Design Series No. 2*, October 2002.

FHWA, *HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels*, July 2006.

FHWA, *HEC No. 15, Design of Roadside Channels with Flexible Linings*, April 1988.

FHWA, *HDS No. 5, Hydraulic Design of Highway Culverts*, September 1985.

LEGEND

B-1 (5.62 ac | 0.26 | 0.26)
- BASIN ID
- 10-YEAR RUNOFF COEFFICIENT
- 25-YEAR RUNOFF COEFFICIENT
- AREA (ACRES)

BASIN BOUNDARIES

PROPOSED DRAINAGE STRUCTURES

FLOW ARROWS

N

0 1,200' 2,400'

Scale in Feet

EX-1 169.1 ac | 0.25 | 0.28

EX-2 98.5 ac | 0.30 | 0.33

EX-3 2,265.6 ac

A-1 2.96 ac | 0.31 | 0.34

A-2 0.55 ac | 0.28 | 0.30

A-3 7.95 ac | 0.47 | 0.51

B-1 1.17 ac | 0.33 | 0.37

C-1 9.49 ac | 0.26 | 0.28

D-1 69.94 ac | 0.25 | 0.28

D-2 3.25 ac | 0.26 | 0.28

E-1 4.32 ac | 0.30 | 0.33

F-1 1.26 ac | 0.38 | 0.42

F-2 0.53 ac | 0.34 | 0.38

F-3 0.99 ac | 0.34 | 0.37

G-1 21.99 ac | 0.25 | 0.28

H-1 40.67 ac | 0.26 | 0.29

I-1 1.61 ac | 0.91 | 1.00

J-1 7.67 ac | 0.25 | 0.28

K-1 6.85 ac | 0.25 | 0.28

L-1 1.00 ac | 0.37 | 0.41

M-1 7.39 ac | 0.27 | 0.30

N-1 4.83 ac | 0.26 | 0.29

Golden Gate National Recreation Area

Surfer Parking Culvert

Wetland Delta Culverts

Rodeo Lagoon. Bridge

Mitchell Road

Old Bunker Road

Bunker Road "West"

Rodeo Lagoon

Rodeo Cove

Sausalito

Tennessee

Richardson East

Kirby

FORT BAKER MILITARY RESERVATION

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
CENTRAL FEDERAL LANDS HIGHWAY DIVISION

DRAINAGE BASIN MAP

Sheet 1 of 1

PRELIMINARY
NOT FOR CONSTRUCTION

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Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **A1**

Total Basin Area (A) = **2.96** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.26**	acres	8.78%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**2.70**	acres	91.22%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.311**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**220.00**	
$Elev_2$ =	**111.95**	
$Elev_1$-$Elev_2$ =	**108.05**	
Slope =	**36.02**	%
P =	**1.92**	
t_i =	**21.01**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**628.3**	ft
$Elev_1$ =	**111.95**	
$Elev_2$ =	**31.94**	
$Elev_1$-$Elev_2$ =	**80.01**	ft
Slope =	**12.73**	%
Velocity=	**7.25**	fps
Watercourse Type =	**Paved**	
t_t =	**1.45**	**min.**

t_i =	**21.01**	**min.**
t_t =	**1.45**	**min.**
$T_c = t_i + t_t$ =	**22.45**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**22.45**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.311	*0.311*		*0.311*
5-year	*1.000*	0.311	*0.311*		*0.311*
10-year	*1.000*	0.311	*0.311*		*0.311*
25-year	*1.100*	0.311	*0.343*		*0.343*
50-year	*1.200*	0.311	*0.374*		*0.374*
100-year	*1.250*	0.311	*0.389*		*0.389*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.06**
5-year	**1.50**
10-year	**1.79**
25-year	**2.16**
50-year	**2.42**
100-year	**2.69**

Calculated Flow

Peak Flow (cfs)
0.98 cfs
1.38 cfs
1.65 cfs
2.19 cfs
2.67 cfs
3.10 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **A2**

Total Basin Area (A) = **0.55** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.02**	acres	3.64%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**0.53**	acres	96.36%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.275**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**111.97**	ft
$Elev_1$ =	**202.23**	
$Elev_2$ =	**181.00**	
$Elev_1$-$Elev_2$ =	**21.23**	
Slope =	**18.96**	%
P =	**1.92**	
t_i =	**12.34**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**332.844**	ft
$Elev_1$ =	**181.00**	
$Elev_2$ =	**65.3545**	
$Elev_1$-$Elev_2$ =	**115.65**	ft
Slope =	**34.75**	%
Velocity=	**11.97**	fps
Watercourse Type =	**Paved**	
t_t =	**0.46**	**min.**

t_i =	**12.34**	**min.**
t_t =	**0.46**	**min.**
$T_c = t_i + t_t$ =	**12.81**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**12.81**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.275	*0.275*		*0.275*
5-year	*1.000*	0.275	*0.275*		*0.275*
10-year	*1.000*	0.275	*0.275*		*0.275*
25-year	*1.100*	0.275	*0.303*		*0.303*
50-year	*1.200*	0.275	*0.331*		*0.331*
100-year	*1.250*	0.275	*0.344*		*0.344*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.58**
5-year	**2.25**
10-year	**2.67**
25-year	**3.21**
50-year	**3.61**
100-year	**4.02**

Calculated Flow

Peak Flow (cfs)
0.24 cfs
0.34 cfs
0.40 cfs
0.54 cfs
0.66 cfs
0.76 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **A3**

Total Basin Area (A) = **7.95** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**2.45**	acres	30.82%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**5.50**	acres	69.18%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.466**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**237.23**	ft
$Elev_1$ =	**178.65**	
$Elev_2$ =	**141.00**	
$Elev_1$-$Elev_2$ =	**37.65**	
Slope =	**15.87**	%
P =	**1.92**	
t_i =	**24.16**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**628.7582**	ft
$Elev_1$ =	**141.00**	
$Elev_2$ =	**69**	
$Elev_1$-$Elev_2$ =	**72.00**	ft
Slope =	**11.45**	%
Velocity=	**6.87**	fps
Watercourse Type =	**Paved**	
t_t =	**1.53**	**min.**

t_i =	**24.16**	**min.**
t_t =	**1.53**	**min.**
$T_c = t_i + t_t$ =	**25.69**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**25.69**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.466	*0.466*		*0.466*
5-year	*1.000*	0.466	*0.466*		*0.466*
10-year	*1.000*	0.466	*0.466*		*0.466*
25-year	*1.100*	0.466	*0.512*		*0.512*
50-year	*1.200*	0.466	*0.559*		*0.559*
100-year	*1.250*	0.466	*0.582*		*0.582*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.98**
5-year	**1.37**
10-year	**1.64**
25-year	**1.98**
50-year	**2.21**
100-year	**2.46**

Calculated Flow

Peak Flow (cfs)
3.62 cfs
5.08 cfs
6.07 cfs
8.05 cfs
9.83 cfs
11.39 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **B1**

Total Basin Area (A) = **1.17** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.14**	acres	11.97%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**1.03**	acres	88.03%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.334**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**190.00**	
$Elev_2$ =	**35.14**	
$Elev_1$-$Elev_2$ =	**154.86**	
Slope =	**51.62**	%
P =	**1.92**	
t_i =	**18.19**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**311**	ft
$Elev_1$ =	**35.14**	
$Elev_2$ =	**25.93**	
$Elev_1$-$Elev_2$ =	**9.21**	ft
Slope =	**2.96**	%
Velocity=	**3.49**	fps
Watercourse Type =	**Paved**	
t_t =	**1.48**	**min.**

t_i =	**18.19**	**min.**
t_t =	**1.48**	**min.**
$T_c = t_i + t_t$ =	**19.67**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**19.67**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.334	*0.334*		*0.334*
5-year	*1.000*	0.334	*0.334*		*0.334*
10-year	*1.000*	0.334	*0.334*		*0.334*
25-year	*1.100*	0.334	*0.367*		*0.367*
50-year	*1.200*	0.334	*0.401*		*0.401*
100-year	*1.250*	0.334	*0.417*		*0.417*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.15**
5-year	**1.63**
10-year	**1.93**
25-year	**2.33**
50-year	**2.61**
100-year	**2.91**

Calculated Flow

Peak Flow (cfs)
0.45 cfs
0.64 cfs
0.75 cfs
1.00 cfs
1.22 cfs
1.42 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **C1**

Total Basin Area (A) = **9.49** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.08**	acres	0.84%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**9.41**	acres	99.16%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.256**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L= length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**450.00**	
$Elev_2$ =	**350.00**	
$Elev_1$-$Elev_2$ =	**100.00**	
Slope =	**33.33**	%
P =	**1.92**	
t_i =	**21.67**	**min.**

Shallow Concentrated/Channel

Section	1	2	3	4	
Length =	**466.879**	**314.679**	**991.4968**	**282.7501**	ft
$Elev_1$ =	**350.00**	**184**	**174**	**28.39**	
$Elev_2$ =	**184**	**174**	**28.39**	**19.5**	
$Elev_1$-$Elev_2$ =	**166.00**	**10.00**	**145.61**	**8.89**	ft
Slope =	**35.56**	**3.18**	**14.69**	**3.14**	%
Velocity=	**8.94**	12.1064	8.938032	12.10644	fps
Watercourse Type =	**GW**	**Paved**	**GW**	**Paved**	
t_t =	**0.87**	**0.43**	**1.85**	**0.39**	**min.**

t_i =	**21.67**	**min.**
t_t =	**3.54**	**min.**
$T_c = t_i + t_t$ =	**25.21**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**25.21**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.256	*0.256*		*0.256*
5-year	*1.000*	0.256	*0.256*		*0.256*
10-year	*1.000*	0.256	*0.256*		*0.256*
25-year	*1.100*	0.256	*0.281*		*0.281*
50-year	*1.200*	0.256	*0.307*		*0.307*
100-year	*1.250*	0.256	*0.320*		*0.320*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.99**
5-year	**1.39**
10-year	**1.66**
25-year	**2.00**
50-year	**2.24**
100-year	**2.50**

Calculated Flow

Peak Flow (cfs)
2.40 cfs
3.38 cfs
4.03 cfs
5.35 cfs
6.53 cfs
7.58 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **D1**

Total Basin Area (A) = **69.94** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.06**	acres	0.09%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**69.88**	acres	99.91%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.251**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**790.00**	
$Elev_2$ =	**750.00**	
$Elev_1$-$Elev_2$ =	**40.00**	
Slope =	**13.33**	%
P =	**1.92**	
t_i =	**31.26**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**3672**	ft
$Elev_1$ =	**750.00**	
$Elev_2$ =	**13.77**	
$Elev_1$-$Elev_2$ =	**736.23**	ft
Slope =	**20.05**	%
Velocity=	**6.71**	fps
Watercourse Type =	**GW**	
t_t =	**9.12**	**min.**

t_i =	**31.26**	**min.**
t_t =	**9.12**	**min.**
$T_c = t_i + t_t$ =	**40.38**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**40.38**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.251	*0.251*		*0.251*
5-year	*1.000*	0.251	*0.251*		*0.251*
10-year	*1.000*	0.251	*0.251*		*0.251*
25-year	*1.100*	0.251	*0.276*		*0.276*
50-year	*1.200*	0.251	*0.301*		*0.301*
100-year	*1.250*	0.251	*0.313*		*0.313*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.78**
5-year	**1.10**
10-year	**1.32**
25-year	**1.59**
50-year	**1.77**
100-year	**1.97**

Calculated Flow

Peak Flow (cfs)
13.74 cfs
19.27 cfs
23.06 cfs
30.61 cfs
37.31 cfs
43.23 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **D2**

Total Basin Area (A) = **3.25** acres (see basin map)

		% land use	C (HEC 22)
Area Paved =	**0.04** acres	1.23%	0.950
Area Unpaved (median) =	**0.00** acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00** acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00** acres	0.00%	0.150
Suburban =	**0.00**	0.00%	0.400
Parks =	**3.21** acres	98.77%	0.250
Other =	**0.00** acres	0.00%	0.900
Weighted C =			**0.259**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**228.68**	
$Elev_2$ =	**184.59**	
$Elev_1$-$Elev_2$ =	**44.09**	
Slope =	**14.70**	%
P =	**1.92**	
t_i =	**30.07**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**1320.3198**	ft
$Elev_1$ =	**184.59**	
$Elev_2$ =	**13.77**	
$Elev_1$-$Elev_2$ =	**170.82**	ft
Slope =	**12.94**	%
Velocity=	**5.39**	fps
Watercourse Type =	**GW**	
t_t =	**4.08**	**min.**

t_i =	**30.07**	**min.**
t_t =	**4.08**	**min.**
$T_c = t_i + t_t$ =	**34.15**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**34.15**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.259	*0.259*		*0.259*
5-year	*1.000*	0.259	*0.259*		*0.259*
10-year	*1.000*	0.259	*0.259*		*0.259*
25-year	*1.100*	0.259	*0.284*		*0.284*
50-year	*1.200*	0.259	*0.310*		*0.310*
100-year	*1.250*	0.259	*0.323*		*0.323*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.83**
5-year	**1.16**
10-year	**1.39**
25-year	**1.68**
50-year	**1.87**
100-year	**2.09**

Calculated Flow

Peak Flow (cfs)
0.70 cfs
0.97 cfs
1.17 cfs
1.55 cfs
1.89 cfs
2.19 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **E1**

Total Basin Area (A) = **4.32** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.28**	acres	6.48%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**4.04**	acres	93.52%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.295**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5} S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**294.67**	ft
$Elev_1$ =	**130.00**	
$Elev_2$ =	**111.30**	
$Elev_1$-$Elev_2$ =	**18.70**	
Slope =	**6.35**	%
P =	**1.92**	
t_i =	**41.47**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**323.7333**	ft
$Elev_1$ =	**111.30**	
$Elev_2$ =	**25.3476**	
$Elev_1$-$Elev_2$ =	**85.95**	ft
Slope =	**26.55**	%
Velocity=	**7.72**	fps
Watercourse Type =	**GW**	
t_t =	**0.70**	**min.**

t_i =	**41.47**	**min.**
t_t =	**0.70**	**min.**
$T_c = t_i + t_t$ =	**42.17**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**42.17**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.295	*0.295*		*0.295*
5-year	*1.000*	0.295	*0.295*		*0.295*
10-year	*1.000*	0.295	*0.295*		*0.295*
25-year	*1.100*	0.295	*0.325*		*0.325*
50-year	*1.200*	0.295	*0.354*		*0.354*
100-year	*1.250*	0.295	*0.369*		*0.369*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.77**
5-year	**1.08**
10-year	**1.29**
25-year	**1.56**
50-year	**1.75**
100-year	**1.94**

Calculated Flow

Peak Flow (cfs)
0.98 cfs
1.38 cfs
1.65 cfs
2.19 cfs
2.67 cfs
3.10 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **F1**

Total Basin Area (A) = **1.26** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.23**	acres	18.25%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**1.03**	acres	81.75%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.378**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**104.62**	ft
$Elev_1$ =	**112.73**	
$Elev_2$ =	**25.27**	
$Elev_1$-$Elev_2$ =	**87.46**	
Slope =	**83.60**	%
P =	**1.92**	
t_i =	**6.46**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**284**	ft
$Elev_1$ =	**25.27**	
$Elev_2$ =	**18.64**	
$Elev_1$-$Elev_2$ =	**6.63**	ft
Slope =	**2.33**	%
Velocity=	**3.10**	fps
Watercourse Type =	**Paved**	
t_t =	**1.53**	**min.**

t_i =	**6.46**	**min.**
t_t =	**1.53**	**min.**
$T_c = t_i + t_t$ =	**7.98**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**7.98**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.378	*0.378*		*0.378*
5-year	*1.000*	0.378	*0.378*		*0.378*
10-year	*1.000*	0.378	*0.378*		*0.378*
25-year	*1.100*	0.378	*0.416*		*0.416*
50-year	*1.200*	0.378	*0.453*		*0.453*
100-year	*1.250*	0.378	*0.472*		*0.472*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**2.18**
5-year	**3.07**
10-year	**3.66**
25-year	**4.40**
50-year	**4.94**
100-year	**5.49**

Calculated Flow

Peak Flow (cfs)
1.04 cfs
1.46 cfs
1.74 cfs
2.30 cfs
2.82 cfs
3.27 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **F2**

Total Basin Area (A) = **0.53** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.07**	acres	13.21%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**0.46**	acres	86.79%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.342**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**91.47**	ft
$Elev_1$ =	**80.52**	
$Elev_2$ =	**26.33**	
$Elev_1$-$Elev_2$ =	**54.19**	
Slope =	**59.24**	%
P =	**1.92**	
t_i =	**6.66**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**185.9397**	ft
$Elev_1$ =	**26.33**	
$Elev_2$ =	**21**	
$Elev_1$-$Elev_2$ =	**5.33**	ft
Slope =	**2.87**	%
Velocity=	**3.44**	fps
Watercourse Type =	**Paved**	
t_t =	**0.90**	**min.**

t_i =	**6.66**	**min.**
t_t =	**0.90**	**min.**
$T_c = t_i + t_t$ =	**7.56**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**7.56**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.342	*0.342*		*0.342*
5-year	*1.000*	0.342	*0.342*		*0.342*
10-year	*1.000*	0.342	*0.342*		*0.342*
25-year	*1.100*	0.342	*0.377*		*0.377*
50-year	*1.200*	0.342	*0.411*		*0.411*
100-year	*1.250*	0.342	*0.428*		*0.428*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**2.23**
5-year	**3.15**
10-year	**3.75**
25-year	**4.51**
50-year	**5.06**
100-year	**5.62**

Calculated Flow

Peak Flow (cfs)
0.41 cfs
0.57 cfs
0.68 cfs
0.90 cfs
1.10 cfs
1.28 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **F3**

Total Basin Area (A) = **0.99** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.12**	acres	12.12%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**0.87**	acres	87.88%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.335**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**109.12**	ft
$Elev_1$ =	**67.83**	
$Elev_2$ =	**35.69**	
$Elev_1$-$Elev_2$ =	**32.13**	
Slope =	**29.45**	%
P =	**1.92**	
t_i =	**10.14**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**309.1159**	ft
$Elev_1$ =	**35.69**	
$Elev_2$ =	**20.83**	
$Elev_1$-$Elev_2$ =	**14.86**	ft
Slope =	**4.81**	%
Velocity=	**4.45**	fps
Watercourse Type =	**Paved**	
t_t =	**1.16**	**min.**

t_i =	**10.14**	**min.**
t_t =	**1.16**	**min.**
$T_c = t_i + t_t$ =	**11.30**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**11.30**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.335	*0.335*		*0.335*
5-year	*1.000*	0.335	*0.335*		*0.335*
10-year	*1.000*	0.335	*0.335*		*0.335*
25-year	*1.100*	0.335	*0.368*		*0.368*
50-year	*1.200*	0.335	*0.402*		*0.402*
100-year	*1.250*	0.335	*0.419*		*0.419*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.76**
5-year	**2.48**
10-year	**2.97**
25-year	**3.57**
50-year	**4.01**
100-year	**4.46**

Calculated Flow

Peak Flow (cfs)
0.58 cfs
0.82 cfs
0.98 cfs
1.30 cfs
1.60 cfs
1.85 cfs

Comments

Project Name :	Bunker Road
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Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **G1**

Total Basin Area (A) = **21.99** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.02**	acres	0.09%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**21.97**	acres	99.91%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.251**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**230.00**	
$Elev_2$ =	**210.00**	
$Elev_1$-$Elev_2$ =	**20.00**	
Slope =	**6.67**	%
P =	**1.92**	
t_i =	**41.25**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**1177.5648**	ft
$Elev_1$ =	**210.00**	
$Elev_2$ =	**35.93**	
$Elev_1$-$Elev_2$ =	**174.07**	ft
Slope =	**14.78**	%
Velocity=	**7.81**	fps
Watercourse Type =	**Paved**	
t_t =	**2.51**	**min.**

t_i =	**41.25**	**min.**
t_t =	**2.51**	**min.**
$T_c = t_i + t_t$ =	**43.76**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**43.76**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.251	*0.251*		*0.251*
5-year	*1.000*	0.251	*0.251*		*0.251*
10-year	*1.000*	0.251	*0.251*		*0.251*
25-year	*1.100*	0.251	*0.276*		*0.276*
50-year	*1.200*	0.251	*0.301*		*0.301*
100-year	*1.250*	0.251	*0.313*		*0.313*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.76**
5-year	**1.07**
10-year	**1.27**
25-year	**1.54**
50-year	**1.72**
100-year	**1.91**

Calculated Flow

Peak Flow (cfs)
4.18 cfs
5.88 cfs
7.03 cfs
9.33 cfs
11.37 cfs
13.17 cfs

Comments

Project Name :	Bunker Road
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By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **I1**

Total Basin Area (A) = **1.61** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**1.52**	acres	94.41%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**0.09**	acres	5.59%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.911**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**394.00**	
$Elev_2$ =	**300.00**	
$Elev_1$-$Elev_2$ =	**94.00**	
Slope =	**31.33**	%
P =	**1.92**	
t_i =	**22.21**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**948**	**ft**
$Elev_1$ =	**300.00**	
$Elev_2$ =	**83.84**	
$Elev_1$-$Elev_2$ =	**216.16**	**ft**
Slope =	**22.80**	**%**
Velocity=	**7.16**	**fps**
Watercourse Type =	**GW**	
t_t =	**2.21**	**min.**

t_i =	**22.21**	**min.**
t_t =	**2.21**	**min.**
$T_c = t_i + t_t$ =	**24.42**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**24.42**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.911	*0.911*		*0.911*
5-year	*1.000*	0.911	*0.911*		*0.911*
10-year	*1.000*	0.911	*0.911*		*0.911*
25-year	*1.100*	0.911	*1.000*		*1.000*
50-year	*1.200*	0.911	*1.000*		*1.000*
100-year	*1.250*	0.911	*1.000*		*1.000*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.01**
5-year	**1.42**
10-year	**1.70**
25-year	**2.05**
50-year	**2.29**
100-year	**2.55**

Calculated Flow

Peak Flow (cfs)
1.48 cfs
2.09 cfs
2.49 cfs
3.30 cfs
3.69 cfs
4.11 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **H1**

Total Basin Area (A) = **40.67** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.09**	acres	0.22%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**4.48**	acres	11.02%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**36.10**	acres	88.76%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.263**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**340.00**	
$Elev_2$ =	**280.00**	
$Elev_1$-$Elev_2$ =	**60.00**	
Slope =	**20.00**	%
P =	**1.92**	
t_i =	**26.58**	**min.**

Shallow Concentrated/Channel

Section	**1**	**2**	
Length =	**1356.7479**	**88.949**	ft
$Elev_1$ =	**280.00**	**74.1572**	
$Elev_2$ =	**74.1572**	**73.26**	
$Elev_1$-$Elev_2$ =	**205.84**	**0.90**	ft
Slope =	**15.17**	**1.01**	%
Velocity=	**5.84**	**7.91**	fps
Watercourse Type =	**GW**	**Paved**	
t_t =	**3.87**	**0.19**	**min.**

t_i =	**26.58 min.**
t_t =	**4.06 min.**
$T_c = t_i + t_t$ =	**30.64 min.**
T_c (check) =	**N/A** min.
Tc (used for calculation) =	**30.64 min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.263	*0.263*		*0.263*
5-year	*1.000*	0.263	*0.263*		*0.263*
10-year	*1.000*	0.263	*0.263*		*0.263*
25-year	*1.100*	0.263	*0.289*		*0.289*
50-year	*1.200*	0.263	*0.315*		*0.315*
100-year	*1.250*	0.263	*0.328*		*0.328*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.86**
5-year	**1.19**
10-year	**1.43**
25-year	**1.73**
50-year	**1.93**
100-year	**2.15**

Calculated Flow

Peak Flow (cfs)
9.13 cfs
12.75 cfs
15.30 cfs
20.33 cfs
24.73 cfs
28.68 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **H1 + J1**

Total Basin Area (A) = **48.34** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.13**	acres	0.27%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**4.48**	acres	9.27%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**43.73**	acres	90.46%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.261**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**340.00**	
$Elev_2$ =	**280.00**	
$Elev_1$-$Elev_2$ =	**60.00**	
Slope =	**20.00**	%
P =	**1.92**	
t_i =	**26.58**	**min.**

Shallow Concentrated/Channel

Section	**1**	**2**	
Length =	**1356.7479**	**88.949**	ft
$Elev_1$ =	**280.00**	**74.1572**	
$Elev_2$ =	**74.1572**	**73.26**	
$Elev_1$-$Elev_2$ =	**205.84**	**0.90**	ft
Slope =	**15.17**	**1.01**	%
Velocity=	**5.84**	**7.91**	fps
Watercourse Type =	**GW**	**Paved**	
t_t =	**3.87**	**0.19**	**min.**

t_i =	**26.58 min.**
t_t =	**4.06 min.**
$T_c = t_i + t_t$ =	**30.64 min.**
T_c (check) =	**N/A** min.
Tc (used for calculation) =	**30.64 min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.261	*0.261*		*0.261*
5-year	*1.000*	0.261	*0.261*		*0.261*
10-year	*1.000*	0.261	*0.261*		*0.261*
25-year	*1.100*	0.261	*0.287*		*0.287*
50-year	*1.200*	0.261	*0.313*		*0.313*
100-year	*1.250*	0.261	*0.326*		*0.326*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.86**
5-year	**1.19**
10-year	**1.43**
25-year	**1.73**
50-year	**1.93**
100-year	**2.15**

Calculated Flow

Peak Flow (cfs)
10.80 cfs
15.07 cfs
18.08 cfs
24.03 cfs
29.23 cfs
33.90 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	06.13.11
By :	TYK
Checked By :	AJF

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **J1**

Total Basin Area (A) = **7.67** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.04**	acres	0.52%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**7.63**	acres	99.48%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.254**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**360.00**	
$Elev_2$ =	**320.00**	
$Elev_1$-$Elev_2$ =	**40.00**	
Slope =	**13.33**	%
P =	**1.92**	
t_i =	**31.26**	**min.**

Shallow Concentrated/Channel

Section	**1**	**2**	
Length =	**542.67**	**284.41**	ft
$Elev_1$ =	**320.00**	**87.79**	
$Elev_2$ =	**87.79**	**69.68**	
$Elev_1$-$Elev_2$ =	**232.21**	**18.11**	ft
Slope =	**42.79**	**6.37**	%
Velocity=	**9.81**	**13.28**	fps
Watercourse Type =	**GW**	**Paved**	
t_t =	**0.92**	**0.36**	**min.**

t_i =	**31.26 min.**
t_t =	**1.28 min.**
$T_c = t_i + t_t$ =	**32.54 min.**
T_c (check) =	**N/A** min.
Tc (used for calculation) =	**32.54 min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.254	*0.254*		*0.254*
5-year	*1.000*	0.254	*0.254*		*0.254*
10-year	*1.000*	0.254	*0.254*		*0.254*
25-year	*1.100*	0.254	*0.279*		*0.279*
50-year	*1.200*	0.254	*0.304*		*0.304*
100-year	*1.250*	0.254	*0.317*		*0.317*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.84**
5-year	**1.18**
10-year	**1.41**
25-year	**1.70**
50-year	**1.90**
100-year	**2.11**

Calculated Flow

Frequency	Peak Flow (cfs)
2-year	**1.64** cfs
5-year	**2.29** cfs
10-year	**2.74** cfs
25-year	**3.64** cfs
50-year	**4.43** cfs
100-year	**5.14** cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	09.22.10
By :	AJF
Checked By :	TYK

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **K1**

Total Basin Area (A) = **6.85** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.02**	acres	0.29%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**6.83**	acres	99.71%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.252**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.011**	paved
Length =	**300.00**	ft
$Elev_1$ =	**400.00**	
$Elev_2$ =	**240.00**	
$Elev_1$-$Elev_2$ =	**160.00**	
Slope =	**53.33**	%
P =	**1.92**	
t_i =	**1.01**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**664.6757**	ft
$Elev_1$ =	**240.00**	
$Elev_2$ =	**166.01**	
$Elev_1$-$Elev_2$ =	**73.99**	ft
Slope =	**11.13**	%
Velocity=	**6.77**	fps
Watercourse Type =	**Paved**	
t_t =	**1.64**	**min.**

t_i =	**1.01**	**min.**
t_t =	**1.64**	**min.**
$T_c = t_i + t_t$ =	**2.65**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**6.00**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.252	*0.252*		*0.252*
5-year	*1.000*	0.252	*0.252*		*0.252*
10-year	*1.000*	0.252	*0.252*		*0.252*
25-year	*1.100*	0.252	*0.277*		*0.277*
50-year	*1.200*	0.252	*0.302*		*0.302*
100-year	*1.250*	0.252	*0.315*		*0.315*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**2.62**
5-year	**3.71**
10-year	**4.38**
25-year	**5.26**
50-year	**5.92**
100-year	**6.58**

Calculated Flow

Peak Flow (cfs)
4.53 cfs
6.41 cfs
7.57 cfs
10.00 cfs
12.27 cfs
14.19 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	09.22.10
By :	AJF
Checked By :	TYK

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **L1**

Total Basin Area (A) = **1.00** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.17**	acres	17.00%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**0.83**	acres	83.00%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.369**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5} S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.011**	paved
Length =	**97.60**	ft
$Elev_1$ =	**184.71**	
$Elev_2$ =	**180.00**	
$Elev_1$-$Elev_2$ =	**4.71**	
Slope =	**4.83**	%
P =	**1.92**	
t_i =	**1.08**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**314.7**	ft
$Elev_1$ =	**180.00**	
$Elev_2$ =	**169.5**	
$Elev_1$-$Elev_2$ =	**10.50**	ft
Slope =	**3.34**	%
Velocity=	**3.71**	fps
Watercourse Type =	**Paved**	
t_t =	**1.41**	**min.**

t_i =	**1.08**	**min.**
t_t =	**1.41**	**min.**
$T_c = t_i + t_t$ =	**2.49**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**6.00**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.369	*0.369*		*0.369*
5-year	*1.000*	0.369	*0.369*		*0.369*
10-year	*1.000*	0.369	*0.369*		*0.369*
25-year	*1.100*	0.369	*0.406*		*0.406*
50-year	*1.200*	0.369	*0.443*		*0.443*
100-year	*1.250*	0.369	*0.461*		*0.461*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**2.62**
5-year	**3.71**
10-year	**4.38**
25-year	**5.26**
50-year	**5.92**
100-year	**6.58**

Calculated Flow

Peak Flow (cfs)
0.97 cfs
1.37 cfs
1.62 cfs
2.14 cfs
2.62 cfs
3.03 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	09.22.10
By :	AJF
Checked By :	TYK

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **M1**

Total Basin Area (A) = **7.39** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.24**	acres	3.25%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**7.15**	acres	96.75%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.273**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**700.00**	
$Elev_2$ =	**560.00**	
$Elev_1$-$Elev_2$ =	**140.00**	
Slope =	**46.67**	%
P =	**1.92**	
t_i =	**18.94**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**1042.7**	ft
$Elev_1$ =	**560.00**	
$Elev_2$ =	**256.07**	
$Elev_1$-$Elev_2$ =	**303.93**	ft
Slope =	**29.15**	%
Velocity=	**8.09**	fps
Watercourse Type =	**GW**	
t_t =	**2.15**	**min.**

t_i =	**18.94 min.**
t_t =	**2.15 min.**
$T_c = t_i + t_t$ =	**21.09 min.**
T_c (check) =	**N/A** min.
Tc (used for calculation) =	**21.09 min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.273	*0.273*		*0.273*
5-year	*1.000*	0.273	*0.273*		*0.273*
10-year	*1.000*	0.273	*0.273*		*0.273*
25-year	*1.100*	0.273	*0.300*		*0.300*
50-year	*1.200*	0.273	*0.327*		*0.327*
100-year	*1.250*	0.273	*0.341*		*0.341*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.10**
5-year	**1.56**
10-year	**1.85**
25-year	**2.23**
50-year	**2.50**
100-year	**2.78**

Calculated Flow

Peak Flow (cfs)
2.22 cfs
3.14 cfs
3.73 cfs
4.94 cfs
6.05 cfs
7.01 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	09.22.10
By :	AJF
Checked By :	TYK

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **N1**

Total Basin Area (A) = **4.83** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.06**	acres	1.24%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**4.77**	acres	98.76%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.259**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**300.00**	ft
$Elev_1$ =	**845.00**	
$Elev_2$ =	**560.00**	
$Elev_1$-$Elev_2$ =	**285.00**	
Slope =	**95.00**	%
P =	**1.92**	
t_i =	**14.25**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**782.8412**	ft
$Elev_1$ =	**560.00**	
$Elev_2$ =	**287.54**	
$Elev_1$-$Elev_2$ =	**272.46**	ft
Slope =	**34.80**	%
Velocity=	**8.84**	fps
Watercourse Type =	**GW**	
t_t =	**1.48**	**min.**

t_i =	**14.25**	**min.**
t_t =	**1.48**	**min.**
$T_c = t_i + t_t$ =	**15.73**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**15.73**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.259	*0.259*		*0.259*
5-year	*1.000*	0.259	*0.259*		*0.259*
10-year	*1.000*	0.259	*0.259*		*0.259*
25-year	*1.100*	0.259	*0.285*		*0.285*
50-year	*1.200*	0.259	*0.310*		*0.310*
100-year	*1.250*	0.259	*0.323*		*0.323*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**1.36**
5-year	**1.94**
10-year	**2.29**
25-year	**2.76**
50-year	**3.11**
100-year	**3.46**

Calculated Flow

Peak Flow (cfs)
1.70 cfs
2.43 cfs
2.87 cfs
3.79 cfs
4.66 cfs
5.40 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	09.13.10
By :	CD
Checked By :	JMH

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **EX1**

Total Basin Area (A) = **169.08** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**0.25**	acres	0.15%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**168.83**	acres	99.85%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.251**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5} S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**766.00**	ft
$Elev_1$ =	**740.00**	
$Elev_2$ =	**640.00**	
$Elev_1$-$Elev_2$ =	**100.00**	
Slope =	**13.05**	%
P =	**1.92**	
t_i =	**66.73**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**3467**	ft
$Elev_1$ =	**640.00**	
$Elev_2$ =	**23**	
$Elev_1$-$Elev_2$ =	**617.00**	ft
Slope =	**17.80**	%
Velocity=	**6.32**	fps
Watercourse Type =	**GW**	
t_t =	**9.14**	**min.**

t_i =	**66.73**	**min.**
t_t =	**9.14**	**min.**
$T_c = t_i + t_t$ =	**75.87**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**75.87**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.251	*0.251*		*0.251*
5-year	*1.000*	0.251	*0.251*		*0.251*
10-year	*1.000*	0.251	*0.251*		*0.251*
25-year	*1.100*	0.251	*0.276*		*0.276*
50-year	*1.200*	0.251	*0.301*		*0.301*
100-year	*1.250*	0.251	*0.314*		*0.314*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.64**
5-year	**0.91**
10-year	**1.08**
25-year	**1.30**
50-year	**1.46**
100-year	**1.62**

Calculated Flow

Peak Flow (cfs)
27.16 cfs
38.62 cfs
45.84 cfs
60.70 cfs
74.36 cfs
85.95 cfs

Comments

Project Name :	Bunker Road
Job No. :	100017371
Date	6/28/2011
By :	CD
Checked By :	JMH

ATKINS

Rational Method Calculations

Basin Charcteristics

Basin Description (ID) = **EX2**

Total Basin Area (A) = **98.50** acres (see basin map)

			% land use	C (HEC 22)
Area Paved =	**7.21**	acres	7.32%	0.950
Area Unpaved (median) =	**0.00**	acres	0.00%	0.020
Area Residential (> .5 < 2 acre lots) =	**0.00**	acres	0.00%	0.350
Area Residential (> 2 acre lots) =	**0.00**	acres	0.00%	0.150
Suburban =	**0.00**		0.00%	0.400
Parks =	**90.88**	acres	92.26%	0.250
Other =	**0.00**	acres	0.00%	0.900
Weighted C =				**0.300**

General Basin Description (undeveloped or urbanized) : **undeveloped**

Time of Concentration:

Time (initial) calculated using the following SCS TR-55 equation :

$$t_c = \frac{0.42\, n^{0.8} L^{0.8}}{P^{0.5}\, S^{0.4}}$$

where :

n = roughness coefficient:
L = length of overland flow in feet (500' maximum)
P = 2-year, 24-hour rainfall depth
S = average basin slope in percent

Shallow concentrated and channel travel time calculated using the following equation :

$$t_t = \frac{L}{60V}$$

where :

t_t = Travel Time (min)
L = flow length (ft)
V = velocity (fps)

Overland

n =	**0.4**	light underbrush
Length =	**588.00**	ft
$Elev_1$ =	**880.00**	
$Elev_2$ =	**680.00**	
$Elev_1$-$Elev_2$ =	**200.00**	
Slope =	**34.01**	%
P =	**1.92**	
t_i =	**36.82**	**min.**

Shallow Concentrated/Channel

Section	**1**	
Length =	**3578**	ft
$Elev_1$ =	**680.00**	
$Elev_2$ =	**20**	
$Elev_1$-$Elev_2$ =	**660.00**	ft
Slope =	**18.45**	%
Velocity=	**6.44**	fps
Watercourse Type =	**GW**	
t_t =	**9.26**	**min.**

t_i =	**36.82**	**min.**
t_t =	**9.26**	**min.**
$T_c = t_i + t_t$ =	**46.08**	**min.**
T_c (check) =	**N/A**	min.
Tc (used for calculation) =	**46.08**	**min.**

Runoff Coefficient (C):

c(f) from Caltrans Hydrology Design Criteria, 819.2 (1)
The product of C_f times C shall not exceed 1.0

	Runoff Coefficient				
Frequency	C_f	C	C_f*C	C_{other}	This Project (C)
2-year	*1.000*	0.300	*0.300*		*0.300*
5-year	*1.000*	0.300	*0.300*		*0.300*
10-year	*1.000*	0.300	*0.300*		*0.300*
25-year	*1.100*	0.300	*0.330*		*0.330*
50-year	*1.200*	0.300	*0.360*		*0.360*
100-year	*1.250*	0.300	*0.375*		*0.375*

Intensity (I):

Source :

Frequency	Intensity (inches/hour)
2-year	**0.74**
5-year	**1.04**
10-year	**1.25**
25-year	**1.50**
50-year	**1.68**
100-year	**1.87**

Calculated Flow

Peak Flow (cfs)
21.94 cfs
30.89 cfs
36.87 cfs
48.92 cfs
59.71 cfs
69.14 cfs

Comments

National Streamflow Statistics Program
Version 4.0
Based on Techniques and Methods Book 4-A6
Equations from database C:\Program Files\NSS\NSS_v4_2009-07-20.mdb
Updated by TKoenig 5/7/2009 at 2:02:34 PM Further clarify PROB_nDAY definitions.
Equations for California developed using English units

Site: Bunker Raod, California
User: 24335
Date: Tuesday, November 16, 2010 04:35 PM

Rural Estimate: Rural 1
  Basin Drainage Area: 3.54 square miles
  1 Region
  Region: North_Coast_Region
    Drainage_Area = 3.54 square miles
    Mean_Annual_Precipitation = 30 inches
    Altitude_Index = 1 thousand feet
  Crippen & Bue Region 17

Results for: Rural 1

Equations used:
PK2 = 3.52 (DRNAREA)^0.9 (PRECIP)^0.89 (ALTIND)^-0.47
PK5 = 5.04 (DRNAREA)^0.89 (PRECIP)^0.91 (ALTIND)^-0.35
PK10 = 6.21 (DRNAREA)^0.88 (PRECIP)^0.93 (ALTIND)^-0.27
PK25 = 7.64 (DRNAREA)^0.87 (PRECIP)^0.94 (ALTIND)^-0.17
PK50 = 8.57 (DRNAREA)^0.87 (PRECIP)^0.96 (ALTIND)^-0.08
PK100 = 9.23 (DRNAREA)^0.87 (PRECIP)^0.97
PK500 = <extrapolated>

Statistic	Value, cfs	Standard Error, %
PK2	227	66
PK5	343	60
PK10	447	60
PK25	561	60
PK50	674	63
PK100	751	66
PK500	1020*	

  *Extrapolated value
maximum: 17500 (for C&B region 17)

HY-8 Culvert Analysis Report

Bunker Road Culverts

Table 1 - Summary of Culvert Flows at Crossing: 39+82.28

Headwater Elevation (ft)	Total Discharge (cfs)	A1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
27.73	1.65	1.65	0.00	1
27.75	1.79	1.79	0.00	1
27.77	1.94	1.94	0.00	1
27.80	2.09	2.09	0.00	1
27.81	2.19	2.19	0.00	1
27.85	2.38	2.38	0.00	1
27.87	2.52	2.52	0.00	1
27.89	2.67	2.67	0.00	1
27.91	2.81	2.81	0.00	1
27.94	2.96	2.96	0.00	1
27.96	3.10	3.10	0.00	1
34.88	39.63	39.63	0.00	Overtopping

Rating Curve Plot for Crossing: 39+82.28

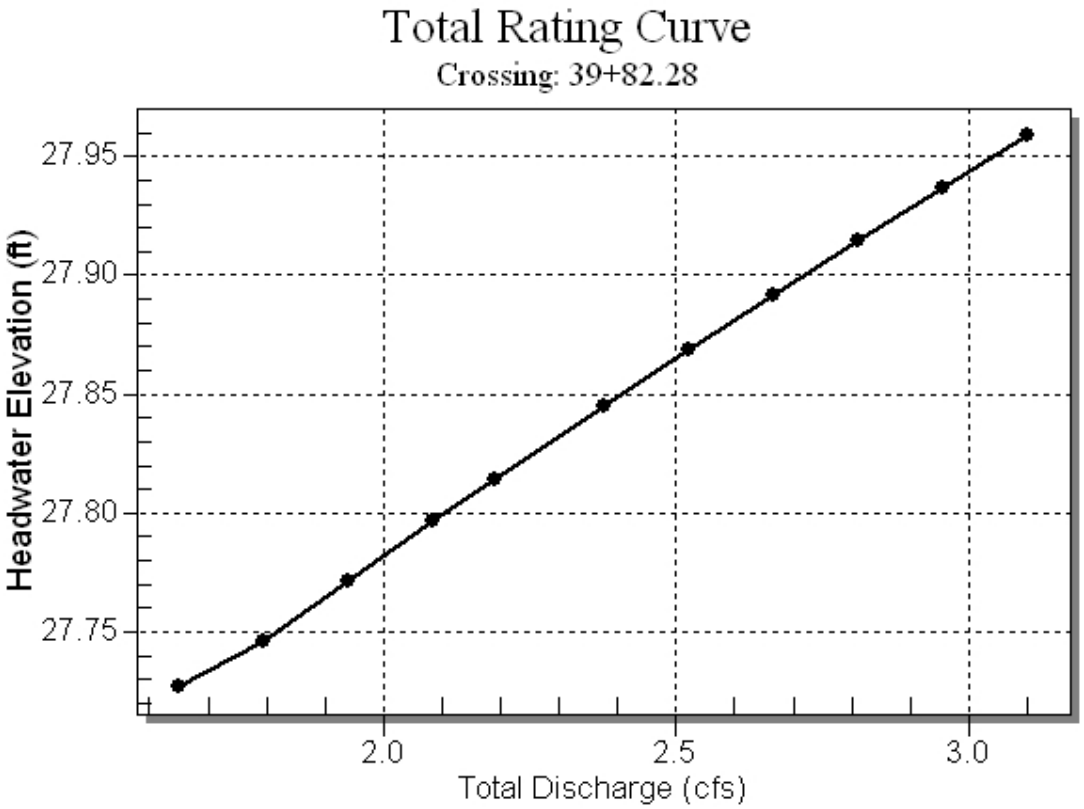


Table 2 - Culvert Summary Table: A1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
1.65	1.65	27.73	0.607	0.0*	1-S2n	0.304	0.438	0.328	0.000	4.778	0.000
1.79	1.79	27.75	0.626	0.0*	1-S2n	0.319	0.456	0.330	0.000	5.157	0.000
1.94	1.94	27.77	0.652	0.0*	1-S2n	0.334	0.474	0.334	0.000	5.485	0.000
2.09	2.09	27.80	0.677	0.0*	1-S2n	0.348	0.492	0.356	0.000	5.418	0.000
2.19	2.19	27.81	0.694	0.0*	1-S2n	0.359	0.505	0.364	0.000	5.528	0.000
2.38	2.38	27.85	0.725	0.0*	1-S2n	0.378	0.528	0.382	0.000	5.630	0.000
2.52	2.52	27.87	0.749	0.0*	1-S2n	0.392	0.546	0.395	0.000	5.728	0.000
2.67	2.67	27.89	0.772	0.0*	1-S2n	0.404	0.564	0.405	0.000	5.870	0.000
2.81	2.81	27.91	0.795	0.0*	1-S2n	0.413	0.582	0.421	0.000	5.895	0.000
2.96	2.96	27.94	0.817	0.0*	1-S2n	0.422	0.600	0.429	0.000	6.056	0.000
3.10	3.10	27.96	0.839	0.0*	1-S2n	0.431	0.613	0.433	0.000	6.275	0.000

* theoretical depth is impractical. Depth reported is corrected.

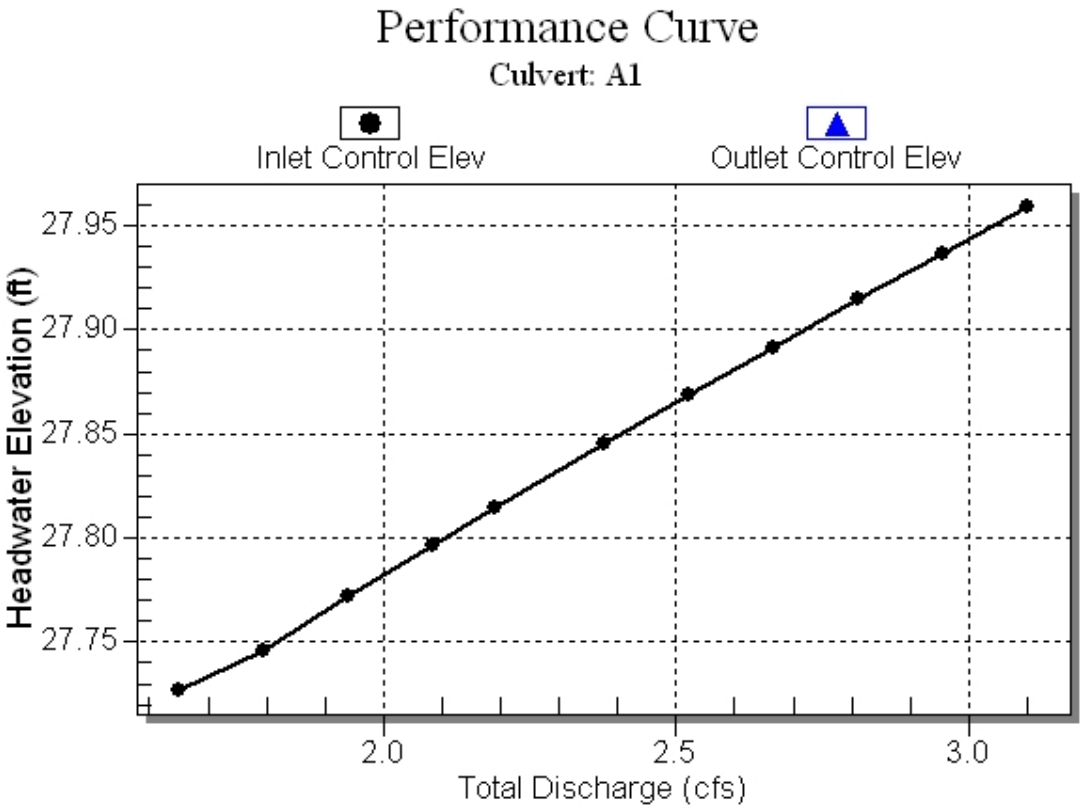
****

Inlet Elevation (invert): 27.12 ft, Outlet Elevation (invert): 26.42 ft

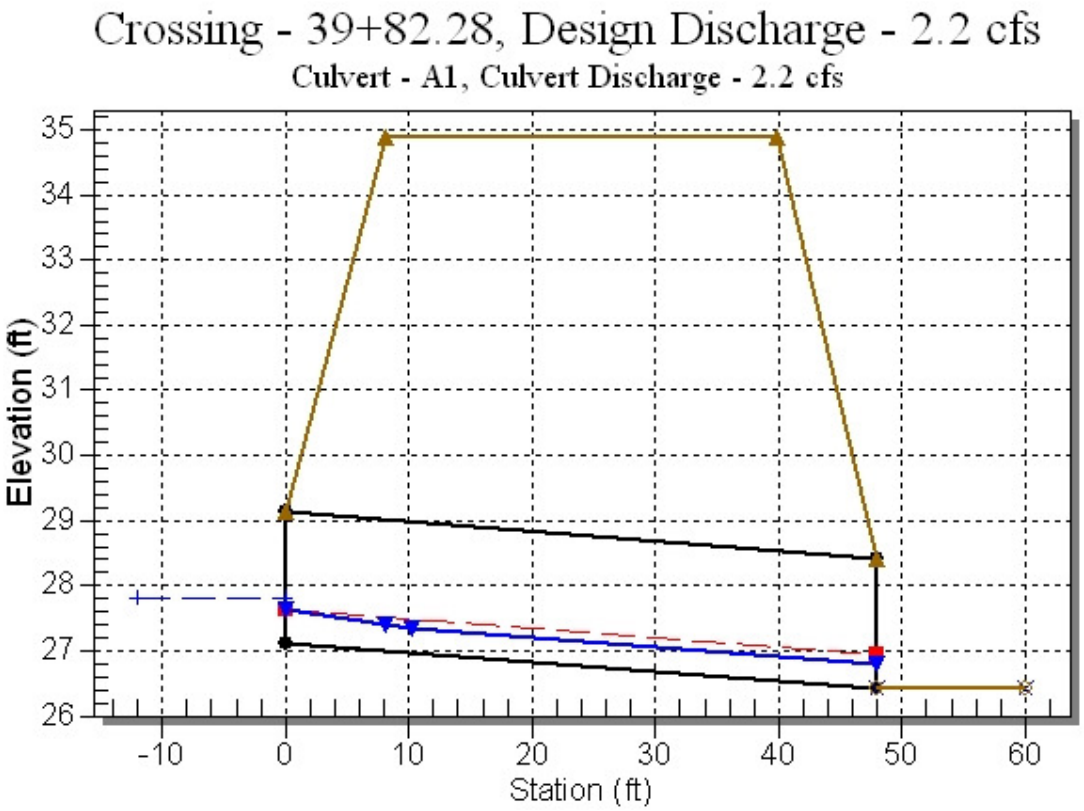
Culvert Length: 48.01 ft, Culvert Slope: 0.0146

****

Culvert Performance Curve Plot: A1



Water Surface Profile Plot for Culvert: A1



Site Data - A1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 27.12 ft

Outlet Station: 48.00 ft

Outlet Elevation: 26.42 ft

Number of Barrels: 1

Culvert Data Summary - A1

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 39+82.28)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
1.65	26.42	0.00
1.79	26.42	0.00
1.94	26.42	0.00
2.09	26.42	0.00
2.19	26.42	0.00
2.38	26.42	0.00
2.52	26.42	0.00
2.67	26.42	0.00
2.81	26.42	0.00
2.96	26.42	0.00
3.10	26.42	0.00

Tailwater Channel Data - 39+82.28

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 26.42 ft

Roadway Data for Crossing: 39+82.28

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 34.88 ft

Roadway Surface: Paved

Roadway Top Width: 31.60 ft

Table 4 - Summary of Culvert Flows at Crossing: 43+07.24

Headwater Elevation (ft)	Total Discharge (cfs)	B1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
17.52	0.75	0.75	0.00	1
17.54	0.82	0.82	0.00	1
17.55	0.88	0.88	0.00	1
17.57	0.95	0.95	0.00	1
17.58	1.00	1.00	0.00	1
17.60	1.09	1.09	0.00	1
17.62	1.15	1.15	0.00	1
17.64	1.22	1.22	0.00	1
17.65	1.29	1.29	0.00	1
17.67	1.35	1.35	0.00	1
17.68	1.42	1.42	0.00	1
26.90	45.11	45.11	0.00	Overtopping

Rating Curve Plot for Crossing: 43+07.24

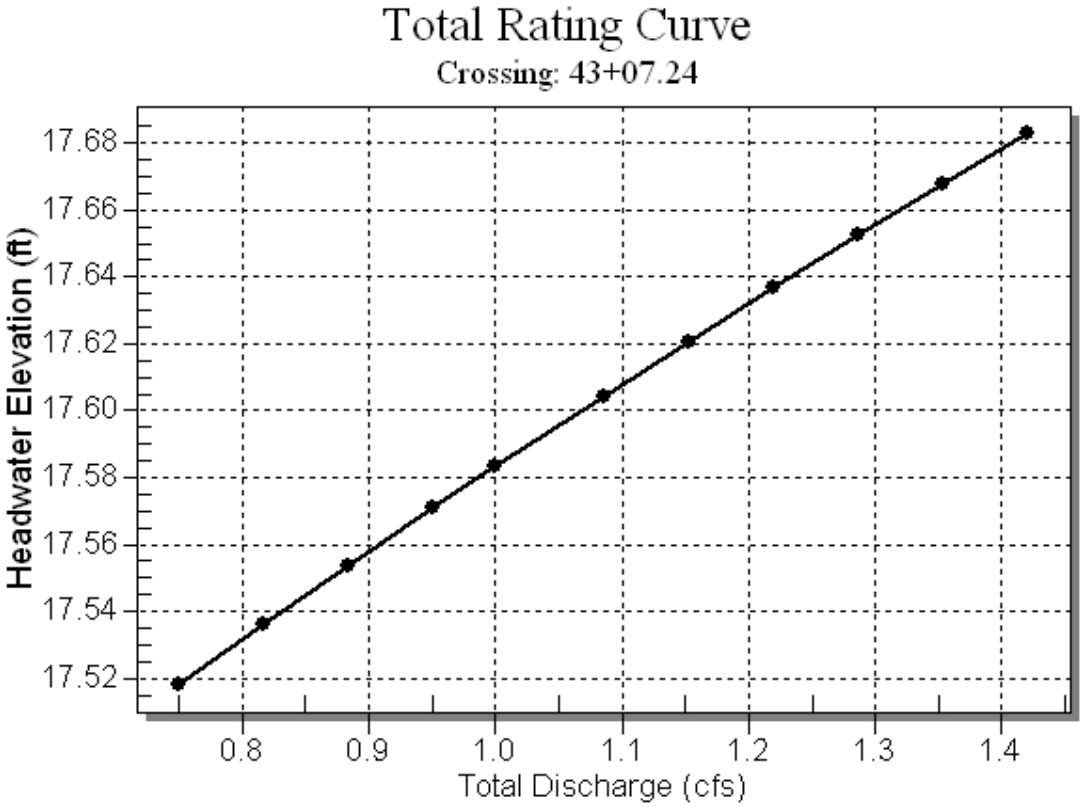


Table 5 - Culvert Summary Table: B1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.75	0.75	17.52	0.397	0.0*	1-S2n	0.266	0.282	0.272	0.000	2.830	0.000
0.82	0.82	17.54	0.416	0.0*	1-S2n	0.277	0.295	0.285	0.000	2.876	0.000
0.88	0.88	17.55	0.433	0.0*	1-S2n	0.289	0.308	0.298	0.000	2.917	0.000
0.95	0.95	17.57	0.450	0.0*	1-S2n	0.300	0.322	0.312	0.000	2.953	0.000
1.00	1.00	17.58	0.463	0.0*	1-S2n	0.308	0.332	0.322	0.000	2.976	0.000
1.09	1.09	17.60	0.484	0.0*	1-S2n	0.323	0.349	0.339	0.000	3.013	0.000
1.15	1.15	17.62	0.500	0.0*	1-S2n	0.334	0.362	0.352	0.000	3.038	0.000
1.22	1.22	17.64	0.516	0.0*	1-S2n	0.346	0.375	0.354	0.000	3.186	0.000
1.29	1.29	17.65	0.532	0.0*	1-S2n	0.357	0.389	0.359	0.000	3.307	0.000
1.35	1.35	17.67	0.547	0.0*	1-S2n	0.369	0.401	0.370	0.000	3.339	0.000
1.42	1.42	17.68	0.562	0.0*	1-S2n	0.380	0.410	0.384	0.000	3.348	0.000

* theoretical depth is impractical. Depth reported is corrected.

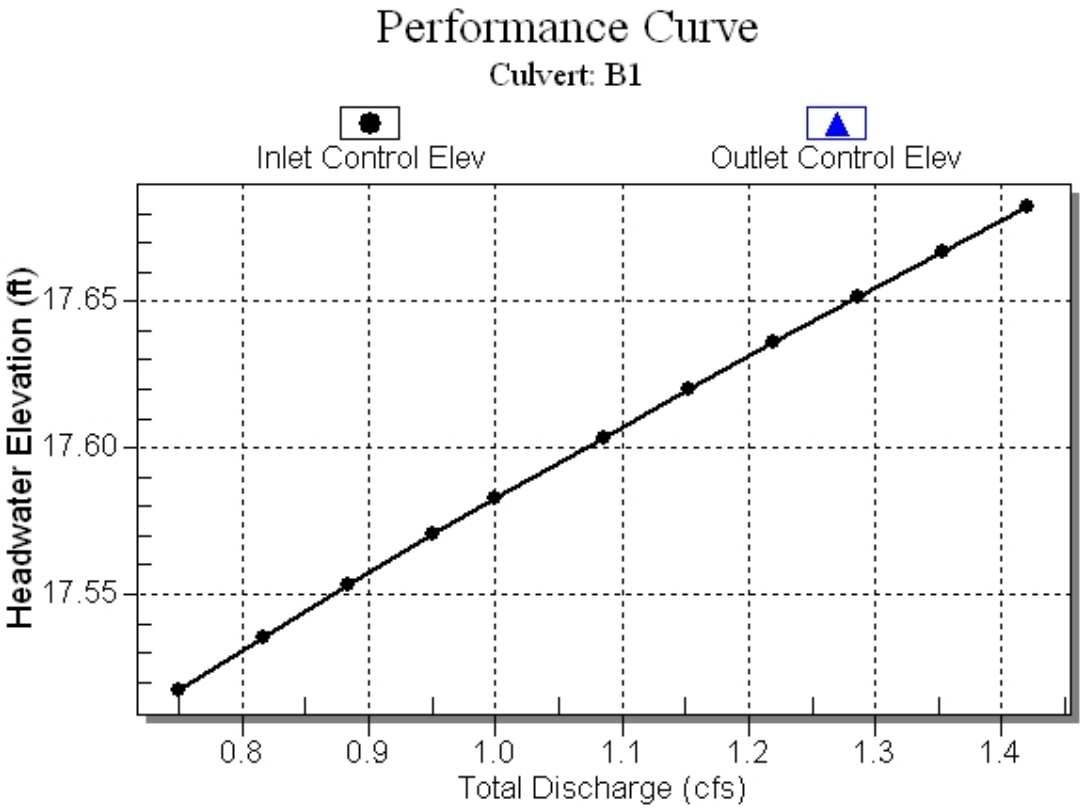
****

Inlet Elevation (invert): 17.12 ft, Outlet Elevation (invert): 16.86 ft

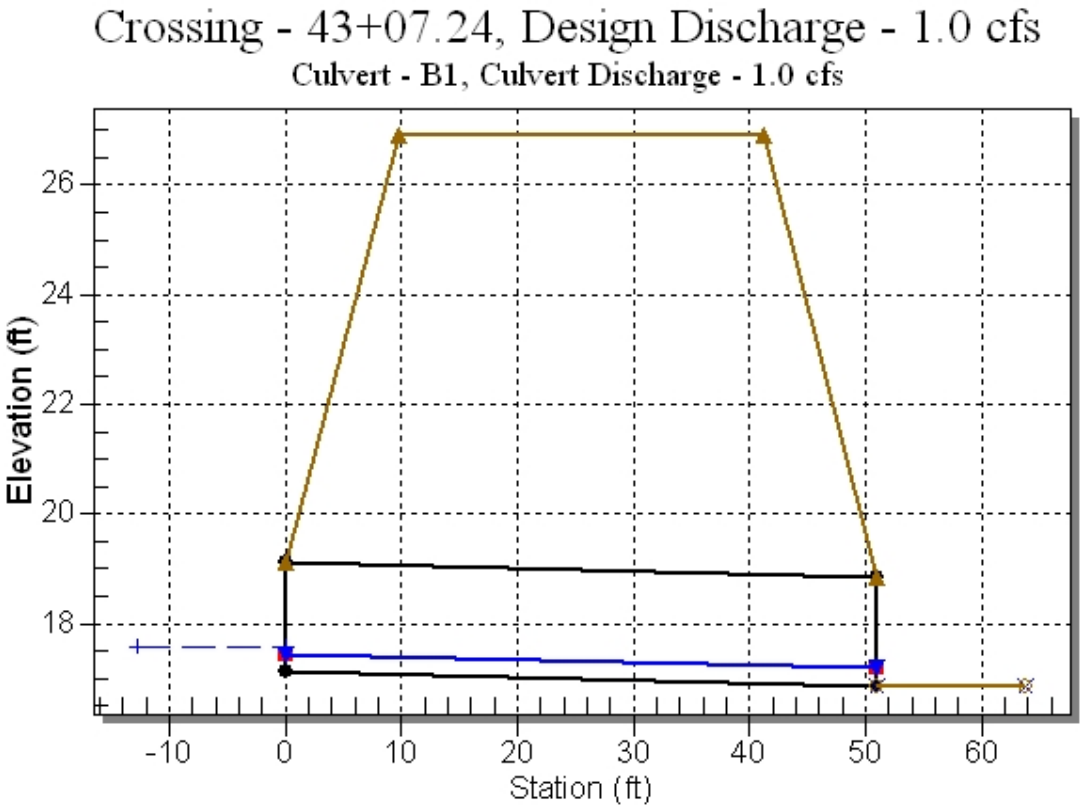
Culvert Length: 51.00 ft, Culvert Slope: 0.0051

****

Culvert Performance Curve Plot: B1



Water Surface Profile Plot for Culvert: B1



Site Data - B1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 17.12 ft

Outlet Station: 51.00 ft

Outlet Elevation: 16.86 ft

Number of Barrels: 1

Culvert Data Summary - B1

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 6 - Downstream Channel Rating Curve (Crossing: 43+07.24)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
0.75	16.86	0.00
0.82	16.86	0.00
0.88	16.86	0.00
0.95	16.86	0.00
1.00	16.86	0.00
1.09	16.86	0.00
1.15	16.86	0.00
1.22	16.86	0.00
1.29	16.86	0.00
1.35	16.86	0.00
1.42	16.86	0.00

Tailwater Channel Data - 43+07.24

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 16.86 ft

Roadway Data for Crossing: 43+07.24

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 26.90 ft

Roadway Surface: Paved

Roadway Top Width: 31.60 ft

Table 7 - Summary of Culvert Flows at Crossing: 45+35.94

Headwater Elevation (ft)	Total Discharge (cfs)	C1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
19.27	4.03	4.03	0.00	1
19.32	4.38	4.38	0.00	1
19.37	4.74	4.74	0.00	1
19.42	5.10	5.10	0.00	1
19.46	5.35	5.35	0.00	1
19.52	5.80	5.80	0.00	1
19.56	6.16	6.16	0.00	1
19.61	6.52	6.52	0.00	1
19.65	6.87	6.87	0.00	1
19.69	7.22	7.22	0.00	1
19.73	7.58	7.58	0.00	1
23.47	30.89	30.89	0.00	Overtopping

Rating Curve Plot for Crossing: 45+35.94

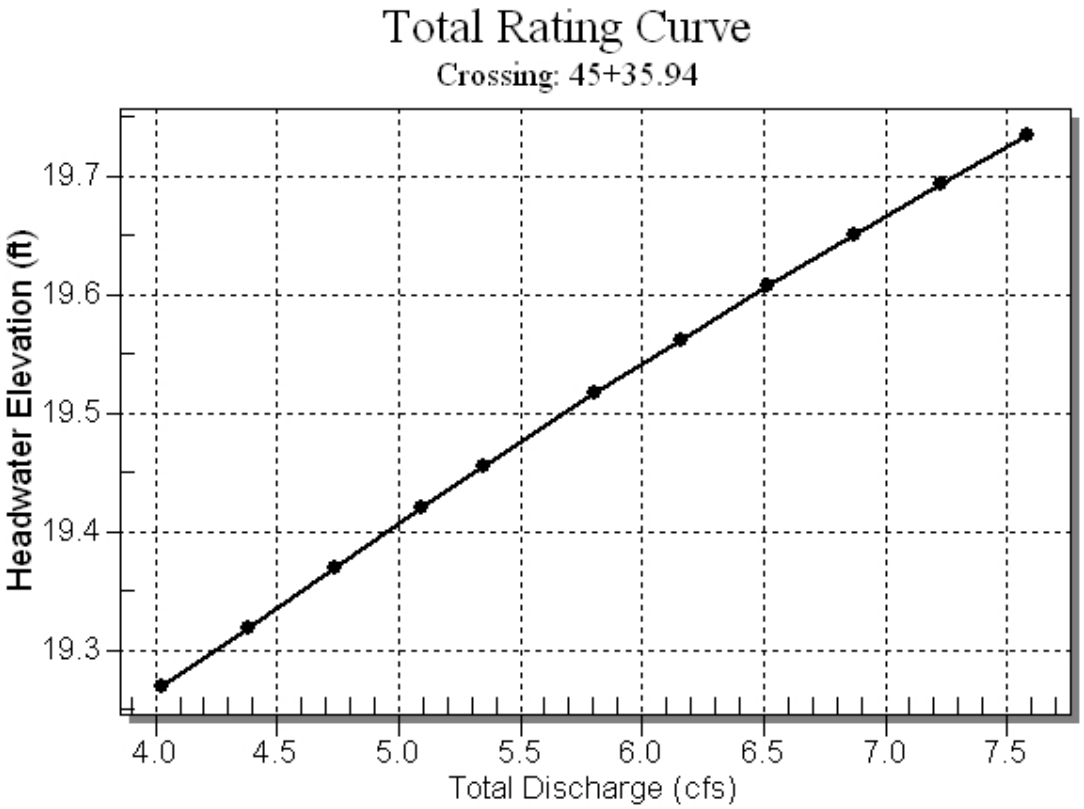


Table 8 - Culvert Summary Table: C1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
4.03	4.03	19.27	0.970	0.0*	1-S2n	0.646	0.698	0.650	0.000	4.588	0.000
4.38	4.38	19.32	1.018	0.0*	1-S2n	0.674	0.730	0.679	0.000	4.649	0.000
4.74	4.74	19.37	1.070	0.0*	1-S2n	0.703	0.762	0.711	0.000	4.718	0.000
5.10	5.10	19.42	1.121	0.0*	1-S2n	0.731	0.795	0.734	0.000	4.865	0.000
5.35	5.35	19.46	1.156	0.0*	1-S2n	0.752	0.814	0.753	0.000	4.932	0.000
5.80	5.80	19.52	1.217	0.0*	1-S2n	0.788	0.847	0.790	0.000	5.030	0.000
6.16	6.16	19.56	1.262	0.0*	1-S2n	0.814	0.873	0.815	0.000	5.122	0.000
6.52	6.52	19.61	1.307	0.0*	1-S2n	0.839	0.899	0.839	0.000	5.220	0.000
6.87	6.87	19.65	1.350	0.0*	1-S2n	0.864	0.925	0.864	0.000	5.282	0.000
7.22	7.22	19.69	1.393	0.0*	1-S2n	0.888	0.951	0.890	0.000	5.344	0.000
7.58	7.58	19.73	1.434	0.0*	1-S2n	0.913	0.977	0.916	0.000	5.401	0.000

* theoretical depth is impractical. Depth reported is corrected.

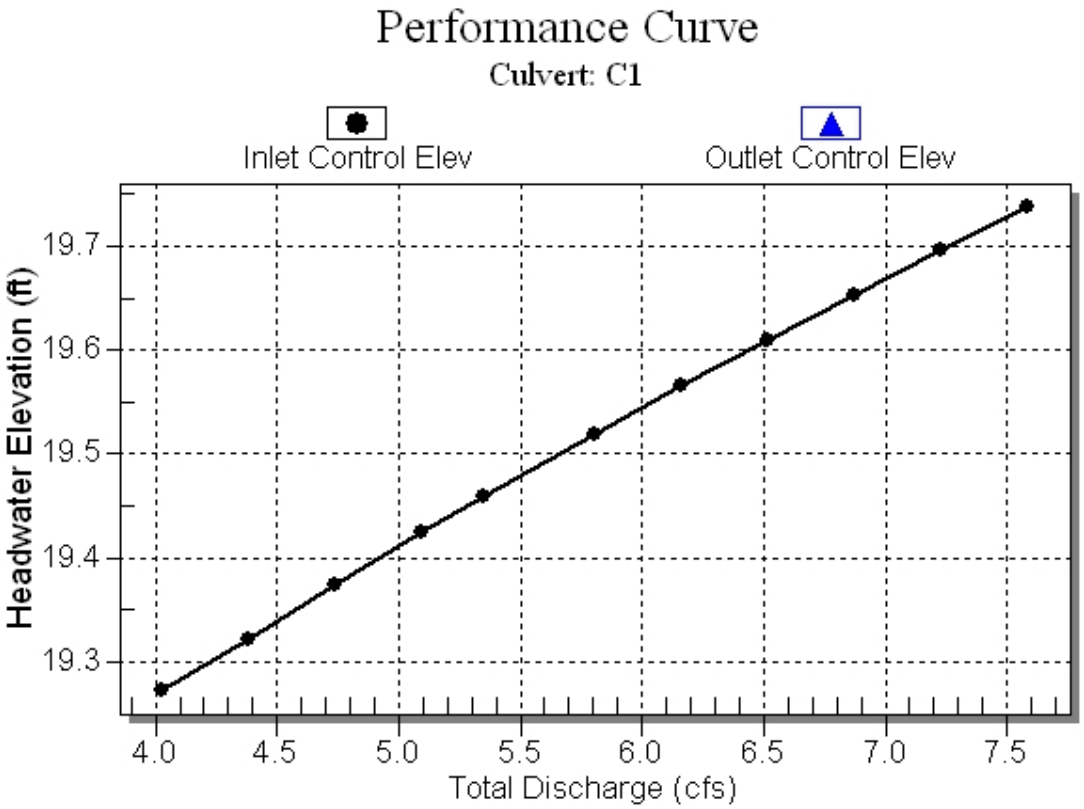
****

Inlet Elevation (invert): 18.30 ft, Outlet Elevation (invert): 18.00 ft

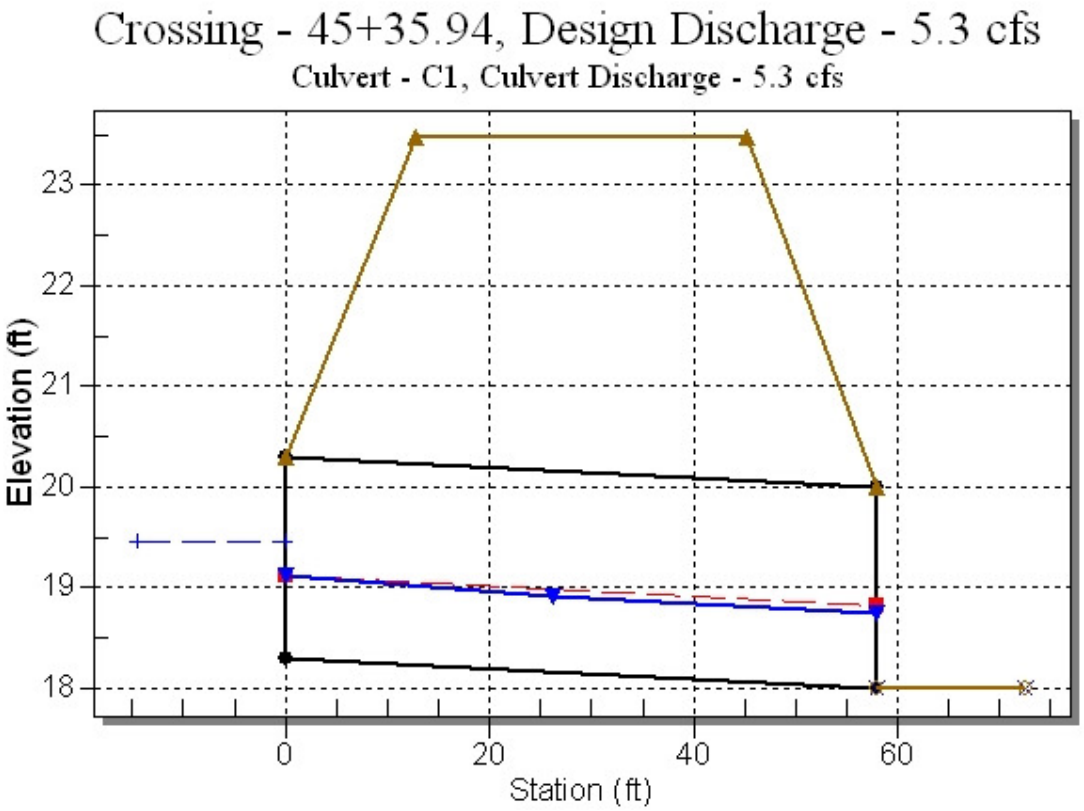
Culvert Length: 58.00 ft, Culvert Slope: 0.0052

****

Culvert Performance Curve Plot: C1



Water Surface Profile Plot for Culvert: C1



Site Data - C1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 18.30 ft

Outlet Station: 58.00 ft

Outlet Elevation: 18.00 ft

Number of Barrels: 1

Culvert Data Summary - C1

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 9 - Downstream Channel Rating Curve (Crossing: 45+35.94)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
4.03	18.00	0.00
4.38	18.00	0.00
4.74	18.00	0.00
5.10	18.00	0.00
5.35	18.00	0.00
5.80	18.00	0.00
6.16	18.00	0.00
6.52	18.00	0.00
6.87	18.00	0.00
7.22	18.00	0.00
7.58	18.00	0.00

Tailwater Channel Data - 45+35.94

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 18.00 ft

Roadway Data for Crossing: 45+35.94

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 23.47 ft

Roadway Surface: Paved

Roadway Top Width: 32.55 ft

Table 10 - Summary of Culvert Flows at Crossing: 46+59.22

Headwater Elevation (ft)	Total Discharge (cfs)	D1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
16.45	23.06	23.06	0.00	1
16.57	25.08	25.08	0.00	1
16.68	27.09	27.09	0.00	1
16.80	29.11	29.11	0.00	1
16.89	30.61	30.61	0.00	1
17.04	33.14	33.14	0.00	1
17.16	35.16	35.16	0.00	1
17.28	37.18	37.18	0.00	1
17.40	39.20	39.20	0.00	1
17.53	41.21	41.21	0.00	1
17.67	43.23	43.23	0.00	1
30.00	129.74	129.74	0.00	Overtopping

Rating Curve Plot for Crossing: 46+59.22

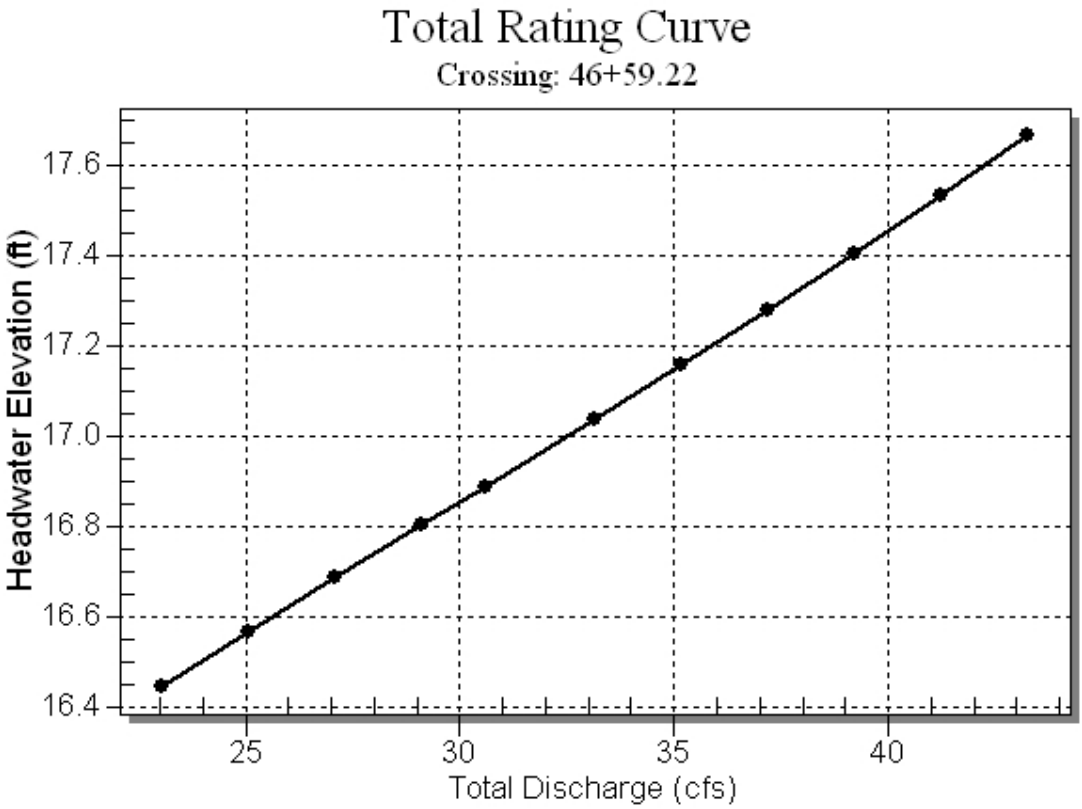


Table 11 - Culvert Summary Table: D1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
23.06	23.06	16.45	2.285	0.0*	1-S2n	1.367	1.543	1.375	0.000	7.295	0.000
25.08	25.08	16.57	2.406	0.0*	1-S2n	1.436	1.609	1.442	0.000	7.460	0.000
27.09	27.09	16.68	2.524	0.0*	1-S2n	1.505	1.676	1.508	0.000	7.617	0.000
29.11	29.11	16.80	2.641	0.0*	1-S2n	1.570	1.743	1.576	0.000	7.742	0.000
30.61	30.61	16.89	2.728	0.0*	1-S2n	1.619	1.792	1.625	0.000	7.834	0.000
33.14	33.14	17.04	2.876	0.0*	1-S2n	1.701	1.864	1.707	0.000	7.986	0.000
35.16	35.16	17.16	2.996	0.0*	1-S2n	1.766	1.921	1.770	0.000	8.106	0.000
37.18	37.18	17.28	3.118	0.0*	5-S2n	1.833	1.977	1.833	0.000	8.214	0.000
39.20	39.20	17.40	3.243	0.0*	5-S2n	1.901	2.033	1.902	0.000	8.303	0.000
41.21	41.21	17.53	3.372	0.0*	5-S2n	1.969	2.090	1.969	0.000	8.393	0.000
43.23	43.23	17.67	3.506	0.0*	5-S2n	2.037	2.138	2.037	0.000	8.469	0.000

* theoretical depth is impractical. Depth reported is corrected.

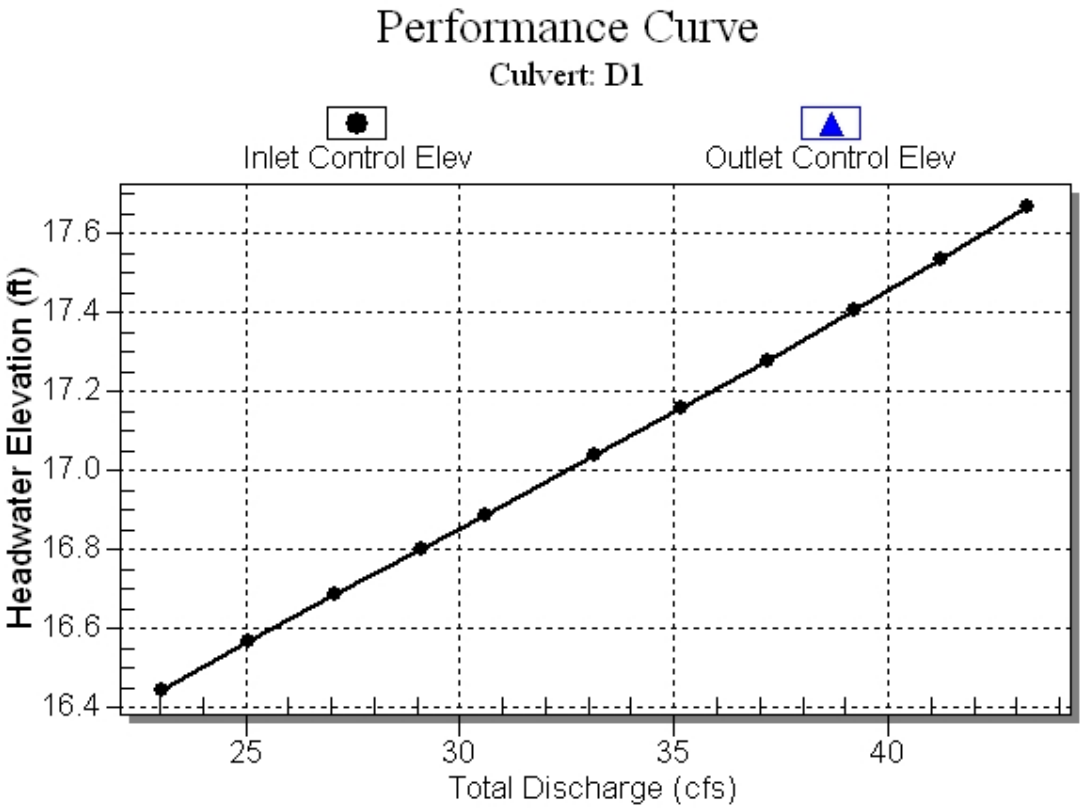
****

Inlet Elevation (invert): 14.16 ft, Outlet Elevation (invert): 13.80 ft

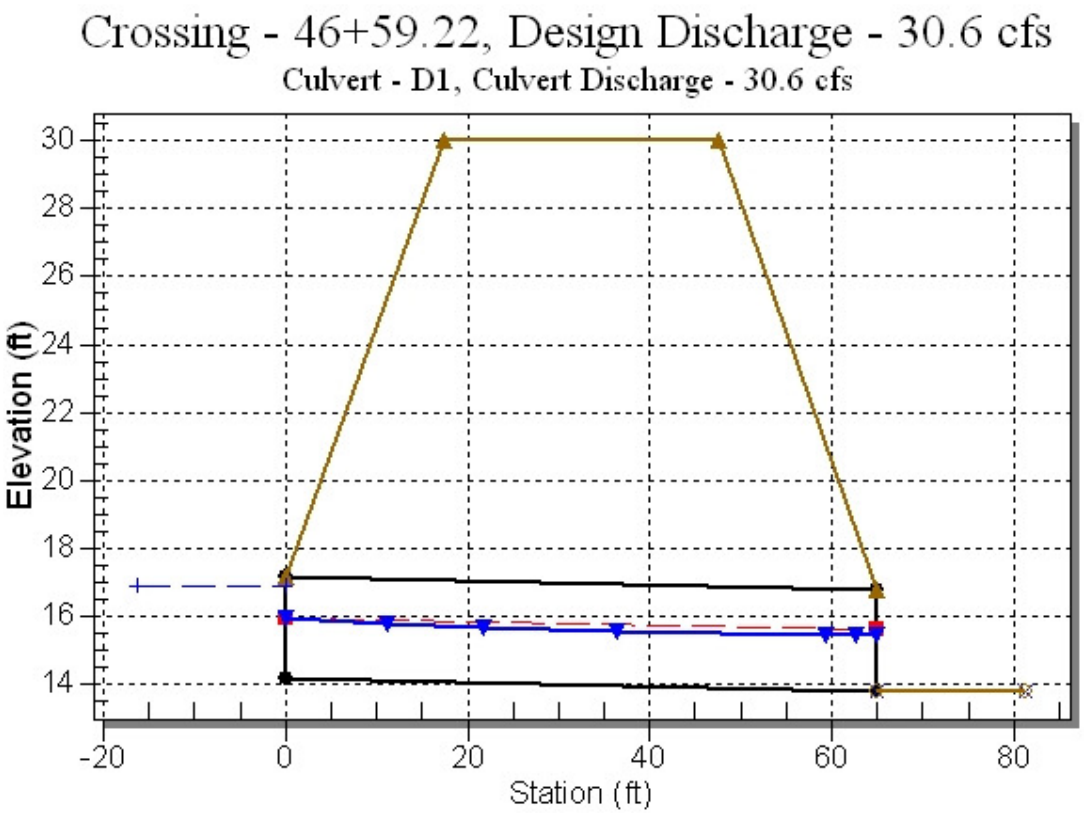
Culvert Length: 65.00 ft, Culvert Slope: 0.0055

****

Culvert Performance Curve Plot: D1



Water Surface Profile Plot for Culvert: D1



Site Data - D1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 14.16 ft

Outlet Station: 65.00 ft

Outlet Elevation: 13.80 ft

Number of Barrels: 1

Culvert Data Summary - D1

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 12 - Downstream Channel Rating Curve (Crossing: 46+59.22)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
23.06	13.80	0.00
25.08	13.80	0.00
27.09	13.80	0.00
29.11	13.80	0.00
30.61	13.80	0.00
33.14	13.80	0.00
35.16	13.80	0.00
37.18	13.80	0.00
39.20	13.80	0.00
41.21	13.80	0.00
43.23	13.80	0.00

Tailwater Channel Data - 46+59.22

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 13.80 ft

Roadway Data for Crossing: 46+59.22

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 30.00 ft

Roadway Surface: Paved

Roadway Top Width: 30.00 ft

Table 13 - Summary of Culvert Flows at Crossing: 88+81.91

Headwater Elevation (ft)	Total Discharge (cfs)	I1: Driveway Discharge (cfs)	Roadway Discharge (cfs)	Iterations
76.56	2.49	2.49	0.00	1
76.59	2.65	2.65	0.00	1
76.61	2.81	2.81	0.00	1
76.64	2.98	2.98	0.00	1
76.66	3.14	3.14	0.00	1
76.69	3.30	3.30	0.00	1
76.71	3.46	3.46	0.00	1
76.73	3.62	3.62	0.00	1
76.75	3.79	3.79	0.00	1
76.77	3.95	3.95	0.00	1
76.79	4.11	4.11	0.00	1
80.23	27.75	27.75	0.00	Overtopping

Rating Curve Plot for Crossing: 88+81.91

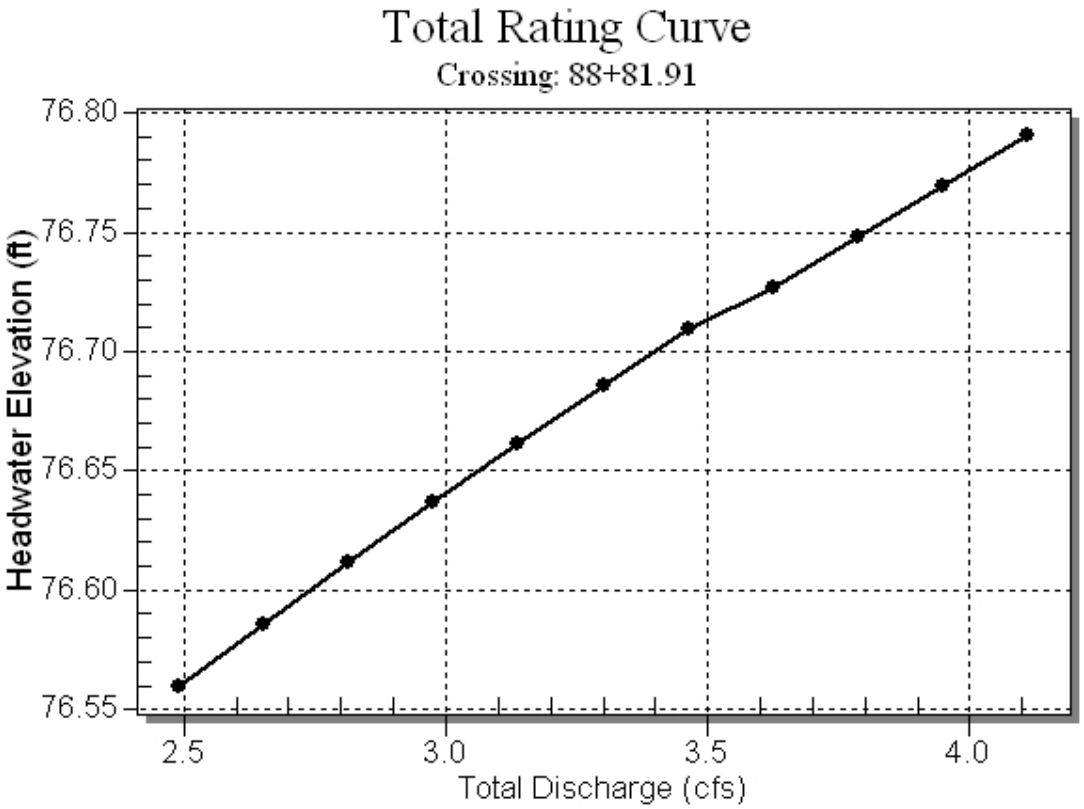


Table 14 - Culvert Summary Table: I1: Driveway

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.49	2.49	76.56	0.750	0.0*	1-S2n	0.503	0.542	0.511	0.264	3.896	1.876
2.65	2.65	76.59	0.776	0.0*	1-S2n	0.520	0.562	0.522	0.273	4.029	1.923
2.81	2.81	76.61	0.801	0.0*	1-S2n	0.538	0.582	0.541	0.284	4.072	1.958
2.98	2.98	76.64	0.827	0.0*	1-S2n	0.555	0.602	0.561	0.293	4.106	1.998
3.14	3.14	76.66	0.851	0.0*	1-S2n	0.572	0.616	0.575	0.302	4.183	2.036
3.30	3.30	76.69	0.875	0.001	1-S2n	0.589	0.631	0.590	0.311	4.254	2.070
3.46	3.46	76.71	0.899	0.009	1-S2n	0.605	0.646	0.606	0.319	4.313	2.110
3.62	3.62	76.73	0.917	0.019	1-S2n	0.618	0.661	0.620	0.329	4.384	2.139
3.79	3.79	76.75	0.938	0.027	1-S2n	0.631	0.675	0.634	0.337	4.443	2.174
3.95	3.95	76.77	0.959	0.036	1-S2n	0.645	0.690	0.649	0.346	4.498	2.199
4.11	4.11	76.79	0.980	0.044	1-S2n	0.658	0.705	0.664	0.354	4.494	2.230

* theoretical depth is impractical. Depth reported is corrected.

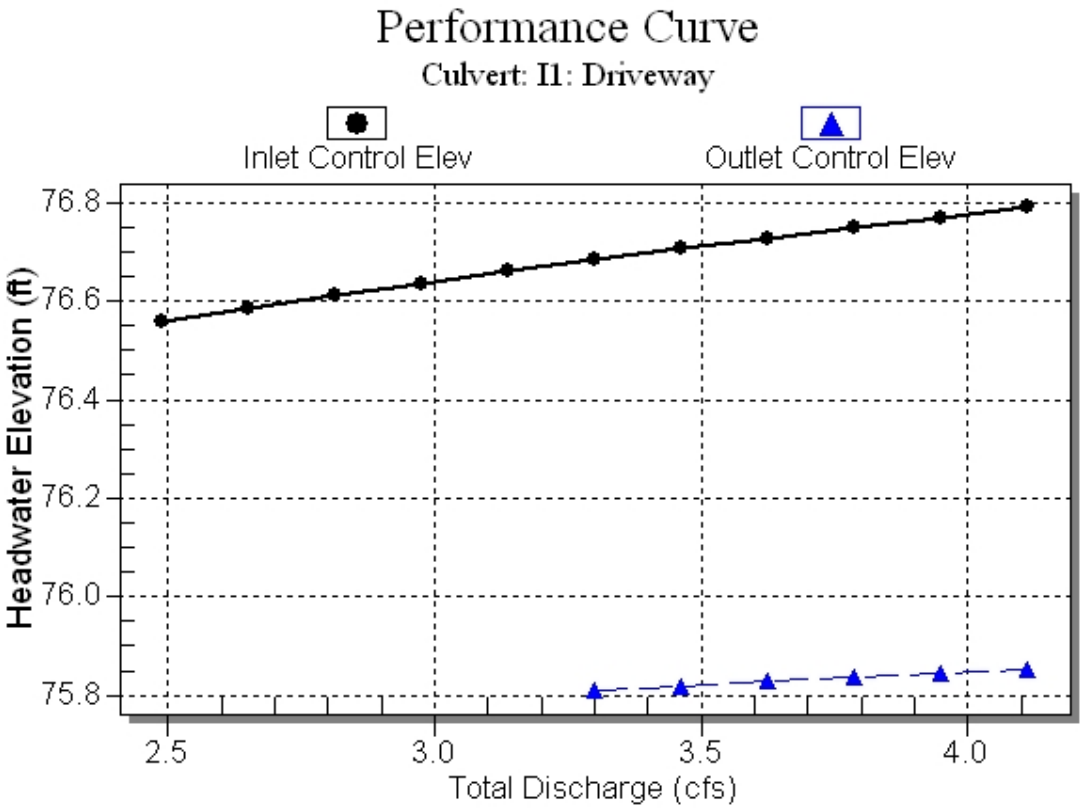
****

Inlet Elevation (invert): 75.81 ft, Outlet Elevation (invert): 75.50 ft

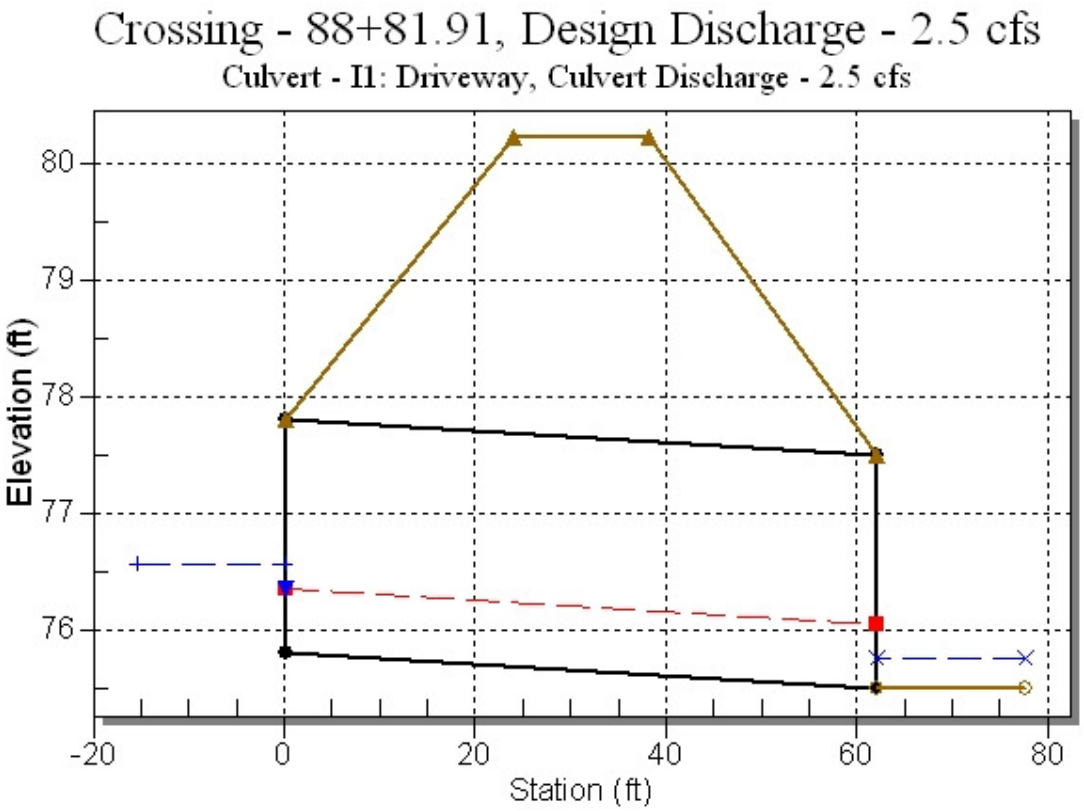
Culvert Length: 62.00 ft, Culvert Slope: 0.0050

****

Culvert Performance Curve Plot: I1: Driveway



Water Surface Profile Plot for Culvert: I1: Driveway



Site Data - I1: Driveway

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 75.81 ft

Outlet Station: 62.00 ft

Outlet Elevation: 75.50 ft

Number of Barrels: 1

Culvert Data Summary - I1: Driveway

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 15 - Downstream Channel Rating Curve (Crossing: 88+81.91)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
2.49	75.76	0.26	1.88	0.16	0.68
2.65	75.77	0.27	1.92	0.17	0.68
2.81	75.78	0.28	1.96	0.18	0.68
2.98	75.79	0.29	2.00	0.18	0.69
3.14	75.80	0.30	2.04	0.19	0.69
3.30	75.81	0.31	2.07	0.19	0.69
3.46	75.82	0.32	2.11	0.20	0.70
3.62	75.83	0.33	2.14	0.21	0.70
3.79	75.84	0.34	2.17	0.21	0.70
3.95	75.85	0.35	2.20	0.22	0.70
4.11	75.85	0.35	2.23	0.22	0.70

Tailwater Channel Data - 88+81.91

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.50 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0100

Channel Manning's n: 0.0300

Channel Invert Elevation: 75.50 ft

Roadway Data for Crossing: 88+81.91

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 80.23 ft

Roadway Surface: Paved

Roadway Top Width: 14.00 ft

Table 16 - Summary of Culvert Flows at Crossing: 92+24.47

Headwater Elevation (ft)	Total Discharge (cfs)	H1: Driveway Discharge (cfs)	Roadway Discharge (cfs)	Iterations
74.61	15.30	15.30	0.00	1
74.75	16.67	16.67	0.00	1
74.91	18.04	18.04	0.00	1
75.01	19.40	18.78	0.60	8
75.08	20.77	19.21	1.54	6
75.13	22.14	19.57	2.54	5
75.18	23.51	19.90	3.57	4
75.23	24.88	20.19	4.66	4
75.27	26.24	20.46	5.76	4
75.31	27.61	20.72	6.88	4
75.35	28.98	20.95	8.02	4
74.94	18.26	18.26	0.00	Overtopping

Rating Curve Plot for Crossing: 92+24.47

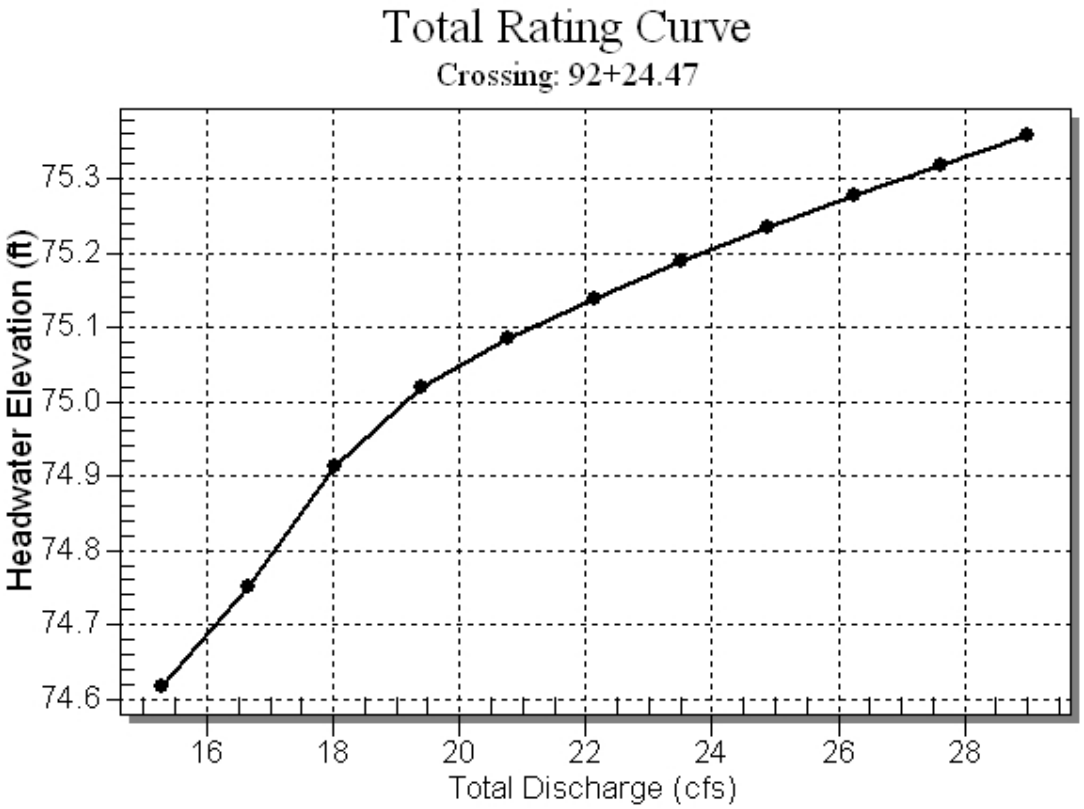


Table 17 - Culvert Summary Table: H1: Driveway

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
15.30	15.30	74.61	2.291	2.352	2-M2c	1.600	1.409	1.410	0.000	6.464	0.000
16.67	16.67	74.75	2.463	2.488	2-M2c	1.798	1.466	1.472	0.000	6.726	0.000
18.04	18.04	74.91	2.648	2.643	2-M2c	2.000	1.524	1.530	0.000	7.009	0.000
19.40	18.78	75.01	2.755	2.723	2-M2c	2.000	1.555	1.560	0.000	7.155	0.000
20.77	19.21	75.08	2.819	2.769	2-M2c	2.000	1.574	1.577	0.000	7.239	0.000
22.14	19.57	75.13	2.874	2.808	2-M2c	2.000	1.589	1.591	0.000	7.310	0.000
23.51	19.90	75.18	2.923	2.841	2-M2c	2.000	1.602	1.603	0.000	7.373	0.000
24.88	20.19	75.23	2.970	2.871	2-M2c	2.000	1.610	1.613	0.000	7.431	0.000
26.24	20.46	75.27	3.013	2.921	2-M2c	2.000	1.618	1.623	0.000	7.484	0.000
27.61	20.72	75.31	3.054	2.953	2-M2c	2.000	1.626	1.632	0.000	7.534	0.000
28.98	20.95	75.35	3.093	2.983	2-M2c	2.000	1.633	1.640	0.000	7.581	0.000

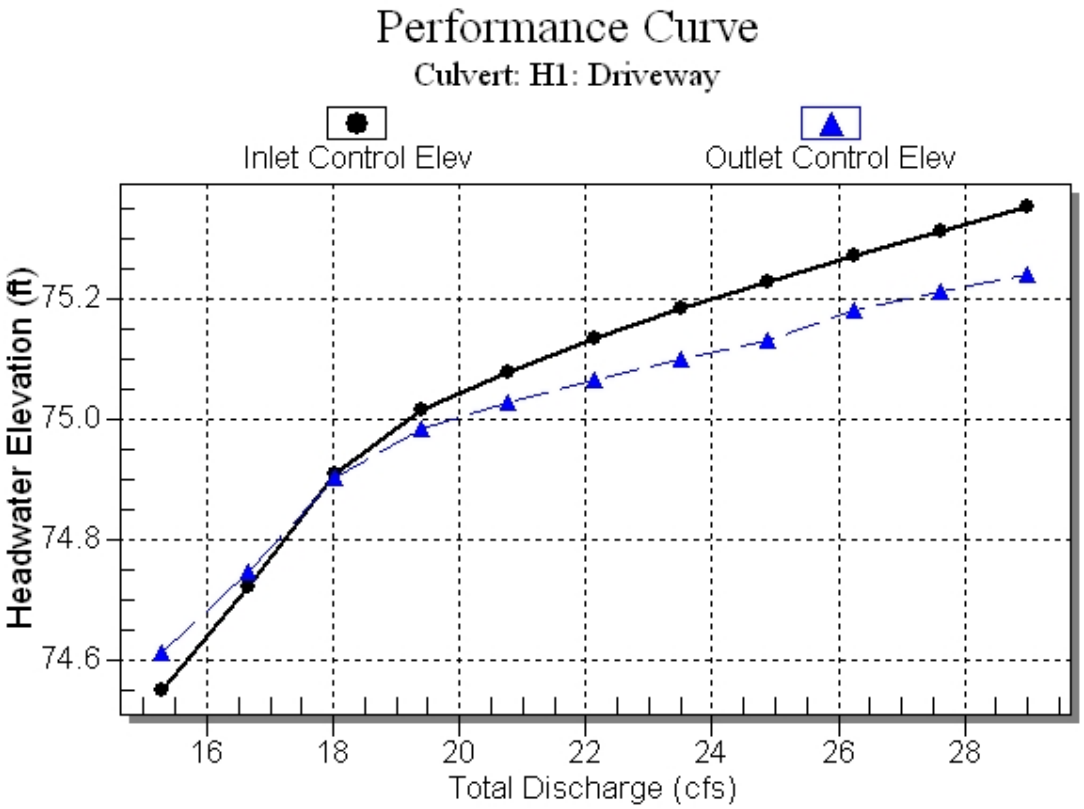
****

Inlet Elevation (invert): 72.26 ft, Outlet Elevation (invert): 72.13 ft

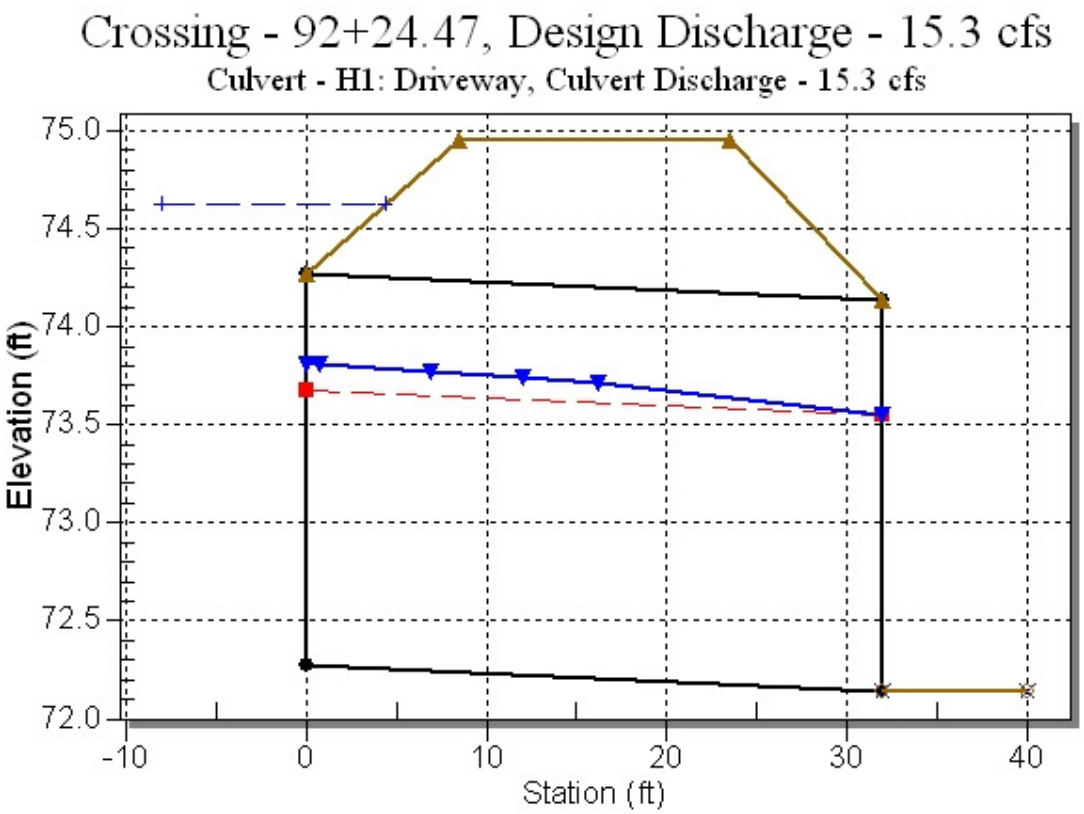
Culvert Length: 32.00 ft, Culvert Slope: 0.0041

****

Culvert Performance Curve Plot: H1: Driveway



Water Surface Profile Plot for Culvert: H1: Driveway



Site Data - H1: Driveway

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 72.26 ft

Outlet Station: 32.00 ft

Outlet Elevation: 72.13 ft

Number of Barrels: 1

Culvert Data Summary - H1: Driveway

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 18 - Downstream Channel Rating Curve (Crossing: 92+24.47)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
15.30	72.13	0.00
16.67	72.13	0.00
18.04	72.13	0.00
19.40	72.13	0.00
20.77	72.13	0.00
22.14	72.13	0.00
23.51	72.13	0.00
24.88	72.13	0.00
26.24	72.13	0.00
27.61	72.13	0.00
28.98	72.13	0.00

Tailwater Channel Data - 92+24.47

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 72.13 ft

Roadway Data for Crossing: 92+24.47

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 74.94 ft

Roadway Surface: Paved

Roadway Top Width: 15.00 ft

Hydraulic Analysis Report

Project Data

Project Title: 95% Bunker Road
Designer:
Project Date: Tuesday, February 15, 2011
Project Units: U.S. Customary Units
Notes:

Median/Ditch Drop-Inlet Analysis: A3: Ditch Inlet

Notes:
Using the following channel: A3: Historic Ditch

Channel Analysis: A3: Historic Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 6.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0520 (ft/ft)
Manning's n: 0.0160
Flow: 6.0700 (cfs)

Result Parameters

Depth: 0.4469 (ft)
Area of Flow: 0.7989 (ft^2)
Wetted Perimeter: 3.7177 (ft)
Hydraulic Radius: 0.2149 (ft)
Average Velocity: 7.5981 (ft/s)
Top Width: 3.5752 (ft)
Froude Number: 2.8326
Critical Depth: 0.3796 (ft)
Critical Velocity: 2.4721 (ft/s)
Critical Slope: 0.1242 (ft/ft)
Critical Top Width: 3.0366 (ft)
Calculated Max Shear Stress: 1.4501 (lb/ft^2)
Calculated Avg Shear Stress: 0.6973 (lb/ft^2)

Inlet Data:

Computing the required channel block (berm) height
Percent Clogging: 0.0000
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Perimeter: 10.5800 (ft)
Effective Perimeter: 10.5800 (ft)
Area: 2.2191 (ft^2)
Effective Area: 2.2191 (ft^2)
Depth at Center of Grate: 0.3319 (ft)
Computed Top Width at Center of Grate: 2.6555 (ft)
Flow Type: Weir Flow
Computed Velocity Head of Approach Flow: 0.8965 (ft/s)
Computed Depth at Block: 0.4185 (ft)
Computed Specific Energy: 1.3434 (ft)
Minimum Block Height: 1.3434 (ft)
Recommend 0.5 ft (0.15 m) Freeboard be added to Minimum Block Height
Efficiency: 1.0000

Channel Analysis: A3: Historic Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 6.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0520 (ft/ft)
Manning's n: 0.0160
Flow: 6.0700 (cfs)

Result Parameters

Depth: 0.4469 (ft)
Area of Flow: 0.7989 (ft^2)
Wetted Perimeter: 3.7177 (ft)
Hydraulic Radius: 0.2149 (ft)
Average Velocity: 7.5981 (ft/s)
Top Width: 3.5752 (ft)
Froude Number: 2.8326
Critical Depth: 0.3796 (ft)
Critical Velocity: 2.4721 (ft/s)
Critical Slope: 0.1242 (ft/ft)
Critical Top Width: 3.0366 (ft)
Calculated Max Shear Stress: 1.4501 (lb/ft^2)
Calculated Avg Shear Stress: 0.6973 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: A2: Ditch Inlet

Notes:

Using the following channel: A2: Historic Paved Ditch

Channel Analysis: A2: Historic Paved Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 6.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0660 (ft/ft)
Manning's n: 0.0160
Flow: 0.4000 (cfs)

Result Parameters

Depth: 0.1541 (ft)
Area of Flow: 0.0950 (ft^2)
Wetted Perimeter: 1.2821 (ft)
Hydraulic Radius: 0.0741 (ft)
Average Velocity: 4.2097 (ft/s)
Top Width: 1.2330 (ft)
Froude Number: 2.6724
Critical Depth: 0.0004 (ft)
Critical Velocity: 0.0825 (ft/s)
Critical Slope: 3022425548595.1646 (ft/ft)
Critical Top Width: 0.0034 (ft)
Calculated Max Shear Stress: 0.6347 (lb/ft^2)
Calculated Avg Shear Stress: 0.3052 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 0.4000 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.7278

Channel Analysis: A2: Historic Paved Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 6.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0660 (ft/ft)
Manning's n: 0.0160
Flow: 0.4000 (cfs)

Result Parameters

Depth: 0.1541 (ft)
Area of Flow: 0.0950 (ft^2)
Wetted Perimeter: 1.2821 (ft)
Hydraulic Radius: 0.0741 (ft)
Average Velocity: 4.2097 (ft/s)
Top Width: 1.2330 (ft)
Froude Number: 2.6724
Critical Depth: 0.0004 (ft)
Critical Velocity: 0.0825 (ft/s)
Critical Slope: 3022425548595.1646 (ft/ft)
Critical Top Width: 0.0034 (ft)
Calculated Max Shear Stress: 0.6347 (lb/ft^2)
Calculated Avg Shear Stress: 0.3052 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: A1: Ditch Inlet

Notes:

Using the following channel: A1: Historic Paved Ditch

Channel Analysis: A1: Historic Paved Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 6.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0660 (ft/ft)
Manning's n: 0.0150
Flow: 1.6500 (cfs)

Result Parameters

Depth: 0.2559 (ft)
Area of Flow: 0.2620 (ft^2)
Wetted Perimeter: 2.1292 (ft)
Hydraulic Radius: 0.1231 (ft)
Average Velocity: 6.2969 (ft/s)
Top Width: 2.0476 (ft)
Froude Number: 3.1020
Critical Depth: 0.0146 (ft)
Critical Velocity: 0.4852 (ft/s)
Critical Slope: 281509.7007 (ft/ft)
Critical Top Width: 0.1170 (ft)
Calculated Max Shear Stress: 1.0541 (lb/ft^2)
Calculated Avg Shear Stress: 0.5068 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 1.6500 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.4651

Channel Analysis: A1: Historic Paved Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 6.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0660 (ft/ft)
Manning's n: 0.0150
Flow: 1.6500 (cfs)

Result Parameters

Depth: 0.2559 (ft)
Area of Flow: 0.2620 (ft^2)
Wetted Perimeter: 2.1292 (ft)
Hydraulic Radius: 0.1231 (ft)
Average Velocity: 6.2969 (ft/s)
Top Width: 2.0476 (ft)
Froude Number: 3.1020
Critical Depth: 0.0146 (ft)
Critical Velocity: 0.4852 (ft/s)
Critical Slope: 281509.7007 (ft/ft)
Critical Top Width: 0.1170 (ft)
Calculated Max Shear Stress: 1.0541 (lb/ft^2)
Calculated Avg Shear Stress: 0.5068 (lb/ft^2)

Curb and Gutter Analysis: A1: Curbed Ditch

Notes:

Gutter Input Parameters

Longitudinal Slope of Road: 0.0660 (ft/ft)
Cross-Slope of Pavement: 0.0200 (ft/ft)
Depressed Gutter Geometry
Cross-Slope of Gutter: 0.1000 (ft/ft)
Manning's n: 0.0160
Gutter Width: 3.0000 (ft)
Width of Spread: 2.2329 (ft)

Gutter Result Parameters

Design Flow: 1.6500 (cfs)
Gutter Depression: 2.8800 (in)
Area of Flow: 0.4099 (ft^2)
Eo (Gutter Flow to Total Flow): 1.0000
Gutter Depth at Curb: 3.4159 (in)

Inlet Input Parameters

Inlet Location: Inlet on Grade
Inlet Type: Grate
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)
Local Depression: 0.0000 (in)

Inlet Result Parameters

Intercepted Flow: 1.1320 (cfs)
Bypass Flow: 0.5180 (cfs)
Approach Velocity: 4.0258 (ft/s)
Splash-over Velocity: 6.6245 (ft/s)
Efficiency: 0.6861

Curb and Gutter Analysis: B1: Curbed Ditch

Notes:

Gutter Input Parameters

Longitudinal Slope of Road: 0.0180 (ft/ft)
Cross-Slope of Pavement: 0.0200 (ft/ft)
Depressed Gutter Geometry
Cross-Slope of Gutter: 0.1000 (ft/ft)
Manning's n: 0.0160
Gutter Width: 3.0000 (ft)
Width of Spread: 2.1196 (ft)

Gutter Result Parameters

Design Flow: 0.7500 (cfs)
Gutter Depression: 2.8800 (in)
Area of Flow: 0.4049 (ft^2)
Eo (Gutter Flow to Total Flow): 1.0000
Gutter Depth at Curb: 3.3887 (in)

Inlet Input Parameters

Inlet Location: Inlet on Grade
Inlet Type: Grate
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)
Local Depression: 0.0000 (in)

Inlet Result Parameters

Intercepted Flow: 0.5832 (cfs)
Bypass Flow: 0.1668 (cfs)
Approach Velocity: 1.8522 (ft/s)
Splash-over Velocity: 6.6245 (ft/s)
Efficiency: 0.7775

Median/Ditch Drop-Inlet Analysis: C1: Ditch Inlet

Notes:
Using the following channel: C1: Vegetated Channel

Channel Analysis: C1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 4.0000 (ft/ft)
Longitudinal Slope: 0.0160 (ft/ft)
Manning's n: 0.0300
Flow: 4.0300 (cfs)

Result Parameters

Depth: 0.6038 (ft)
Area of Flow: 1.4584 (ft^2)
Wetted Perimeter: 4.9792 (ft)
Hydraulic Radius: 0.2929 (ft)
Average Velocity: 2.7633 (ft/s)
Top Width: 4.8305 (ft)
Froude Number: 0.8863
Critical Depth: 0.1363 (ft)
Critical Velocity: 1.4815 (ft/s)
Critical Slope: 44.7889 (ft/ft)
Critical Top Width: 1.0906 (ft)
Calculated Max Shear Stress: 0.6029 (lb/ft^2)
Calculated Avg Shear Stress: 0.2924 (lb/ft^2)

Inlet Data:

Computing the required channel block (berm) height
Percent Clogging: 0.0000
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Perimeter: 10.5800 (ft)
Effective Perimeter: 10.5800 (ft)
Area: 2.2191 (ft^2)
Effective Area: 2.2191 (ft^2)
Depth at Center of Grate: 0.2526 (ft)
Computed Top Width at Center of Grate: 2.0209 (ft)
Flow Type: Weir Flow
Computed Velocity Head of Approach Flow: 0.1186 (ft/s)
Computed Depth at Block: 0.2793 (ft)
Computed Specific Energy: 0.7224 (ft)
Minimum Block Height: 0.7224 (ft)
Recommend 0.5 ft (0.15 m) Freeboard be added to Minimum Block Height
Efficiency: 1.0000

Channel Analysis: C1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 4.0000 (ft/ft)
Longitudinal Slope: 0.0160 (ft/ft)
Manning's n: 0.0300
Flow: 4.0300 (cfs)

Result Parameters

Depth: 0.6038 (ft)
Area of Flow: 1.4584 (ft^2)
Wetted Perimeter: 4.9792 (ft)
Hydraulic Radius: 0.2929 (ft)
Average Velocity: 2.7633 (ft/s)
Top Width: 4.8305 (ft)
Froude Number: 0.8863
Critical Depth: 0.1363 (ft)
Critical Velocity: 1.4815 (ft/s)
Critical Slope: 44.7889 (ft/ft)
Critical Top Width: 1.0906 (ft)
Calculated Max Shear Stress: 0.6029 (lb/ft^2)
Calculated Avg Shear Stress: 0.2924 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: D2: Ditch Inlet

Notes:

Using the following channel: D2: Vegetated Ditch

Channel Analysis: D2: Vegetated Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 4.0000 (ft/ft)
Longitudinal Slope: 0.0160 (ft/ft)
Manning's n: 0.0300
Flow: 1.1700 (cfs)

Result Parameters

Depth: 0.3797 (ft)
Area of Flow: 0.5768 (ft^2)
Wetted Perimeter: 3.1314 (ft)
Hydraulic Radius: 0.1842 (ft)
Average Velocity: 2.0284 (ft/s)
Top Width: 3.0379 (ft)
Froude Number: 0.8203
Critical Depth: 0.0062 (ft)
Critical Velocity: 0.3157 (ft/s)
Critical Slope: 54767283.2861 (ft/ft)
Critical Top Width: 0.0495 (ft)
Calculated Max Shear Stress: 0.3791 (lb/ft^2)
Calculated Avg Shear Stress: 0.1839 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 1.1700 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0345

Channel Analysis: D2: Vegetated Ditch

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 4.0000 (ft/ft)
Longitudinal Slope: 0.0160 (ft/ft)
Manning's n: 0.0300
Flow: 1.1700 (cfs)

Result Parameters

Depth: 0.3797 (ft)
Area of Flow: 0.5768 (ft^2)
Wetted Perimeter: 3.1314 (ft)
Hydraulic Radius: 0.1842 (ft)
Average Velocity: 2.0284 (ft/s)
Top Width: 3.0379 (ft)
Froude Number: 0.8203
Critical Depth: 0.0062 (ft)
Critical Velocity: 0.3157 (ft/s)
Critical Slope: 54767283.2861 (ft/ft)
Critical Top Width: 0.0495 (ft)
Calculated Max Shear Stress: 0.3791 (lb/ft^2)
Calculated Avg Shear Stress: 0.1839 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: E1: Ditch Inlet

Notes:

Using the following channel: E1: Vegetated Channel

Channel Analysis: E1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0050 (ft/ft)
Manning's n: 0.0300
Flow: 1.6500 (cfs)

Result Parameters

Depth: 0.6026 (ft)
Area of Flow: 1.0895 (ft^2)
Wetted Perimeter: 3.8323 (ft)
Hydraulic Radius: 0.2843 (ft)
Average Velocity: 1.5144 (ft/s)
Top Width: 3.6159 (ft)
Froude Number: 0.4862
Critical Depth: 0.0300 (ft)
Critical Velocity: 0.6952 (ft/s)
Critical Slope: 44321.7804 (ft/ft)
Critical Top Width: 0.1801 (ft)
Calculated Max Shear Stress: 0.1880 (lb/ft^2)
Calculated Avg Shear Stress: 0.0887 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 1.6500 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0047

Channel Analysis: E1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0050 (ft/ft)
Manning's n: 0.0300
Flow: 1.6500 (cfs)

Result Parameters

Depth: 0.6026 (ft)
Area of Flow: 1.0895 (ft^2)
Wetted Perimeter: 3.8323 (ft)
Hydraulic Radius: 0.2843 (ft)
Average Velocity: 1.5144 (ft/s)
Top Width: 3.6159 (ft)
Froude Number: 0.4862
Critical Depth: 0.0300 (ft)
Critical Velocity: 0.6952 (ft/s)
Critical Slope: 44321.7804 (ft/ft)
Critical Top Width: 0.1801 (ft)
Calculated Max Shear Stress: 0.1880 (lb/ft^2)
Calculated Avg Shear Stress: 0.0887 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: F1: Ditch Inlet

Notes:

Using the following channel: F1: Vegetated Channel

Channel Analysis: F1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0050 (ft/ft)
Manning's n: 0.0300
Flow: 1.7400 (cfs)

Result Parameters

Depth: 0.6148 (ft)
Area of Flow: 1.1338 (ft^2)
Wetted Perimeter: 3.9094 (ft)
Hydraulic Radius: 0.2900 (ft)
Average Velocity: 1.5346 (ft/s)
Top Width: 3.6886 (ft)
Froude Number: 0.4878
Critical Depth: 0.0343 (ft)
Critical Velocity: 0.7429 (ft/s)
Critical Slope: 24277.8609 (ft/ft)
Critical Top Width: 0.2057 (ft)
Calculated Max Shear Stress: 0.1918 (lb/ft^2)
Calculated Avg Shear Stress: 0.0905 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 1.7400 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0036

Channel Analysis: F1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0050 (ft/ft)
Manning's n: 0.0300
Flow: 1.7400 (cfs)

Result Parameters

Depth: 0.6148 (ft)
Area of Flow: 1.1338 (ft^2)
Wetted Perimeter: 3.9094 (ft)
Hydraulic Radius: 0.2900 (ft)
Average Velocity: 1.5346 (ft/s)
Top Width: 3.6886 (ft)
Froude Number: 0.4878
Critical Depth: 0.0343 (ft)
Critical Velocity: 0.7429 (ft/s)
Critical Slope: 24277.8609 (ft/ft)
Critical Top Width: 0.2057 (ft)
Calculated Max Shear Stress: 0.1918 (lb/ft^2)
Calculated Avg Shear Stress: 0.0905 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: F2: Ditch Inlet

Notes:

Using the following channel: F2: Vegetated Channel

Channel Analysis: F2: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0050 (ft/ft)
Manning's n: 0.0300
Flow: 0.6800 (cfs)

Result Parameters

Depth: 0.4322 (ft)
Area of Flow: 0.5604 (ft^2)
Wetted Perimeter: 2.7485 (ft)
Hydraulic Radius: 0.2039 (ft)
Average Velocity: 1.2134 (ft/s)
Top Width: 2.5933 (ft)
Froude Number: 0.4600
Critical Depth: 0.0033 (ft)
Critical Velocity: 0.2296 (ft/s)
Critical Slope: 1022509977.8315 (ft/ft)
Critical Top Width: 0.0196 (ft)
Calculated Max Shear Stress: 0.1349 (lb/ft^2)
Calculated Avg Shear Stress: 0.0636 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 0.6800 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0197

Channel Analysis: F2: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0050 (ft/ft)
Manning's n: 0.0300
Flow: 0.6800 (cfs)

Result Parameters

Depth: 0.4322 (ft)
Area of Flow: 0.5604 (ft^2)
Wetted Perimeter: 2.7485 (ft)
Hydraulic Radius: 0.2039 (ft)
Average Velocity: 1.2134 (ft/s)
Top Width: 2.5933 (ft)
Froude Number: 0.4600
Critical Depth: 0.0033 (ft)
Critical Velocity: 0.2296 (ft/s)
Critical Slope: 1022509977.8315 (ft/ft)
Critical Top Width: 0.0196 (ft)
Calculated Max Shear Stress: 0.1349 (lb/ft^2)
Calculated Avg Shear Stress: 0.0636 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: F3: Ditch Inlet

Notes:

Using the following channel: F3: Vegetated Channel

Channel Analysis: F3: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 1.0000 (ft/ft)
Longitudinal Slope: 0.0100 (ft/ft)
Manning's n: 0.0300
Flow: 0.9800 (cfs)

Result Parameters

Depth: 0.4712 (ft)
Area of Flow: 0.5552 (ft^2)
Wetted Perimeter: 2.6094 (ft)
Hydraulic Radius: 0.2128 (ft)
Average Velocity: 1.7653 (ft/s)
Top Width: 2.3562 (ft)
Froude Number: 0.6409
Critical Depth: 0.0129 (ft)
Critical Velocity: 0.4553 (ft/s)
Critical Slope: 2182356.7677 (ft/ft)
Critical Top Width: 0.0644 (ft)
Calculated Max Shear Stress: 0.2940 (lb/ft^2)
Calculated Avg Shear Stress: 0.1328 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 0.9800 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0408

Channel Analysis: F3: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 1.0000 (ft/ft)
Longitudinal Slope: 0.0100 (ft/ft)
Manning's n: 0.0300
Flow: 0.9800 (cfs)

Result Parameters

Depth: 0.4712 (ft)
Area of Flow: 0.5552 (ft^2)
Wetted Perimeter: 2.6094 (ft)
Hydraulic Radius: 0.2128 (ft)
Average Velocity: 1.7653 (ft/s)
Top Width: 2.3562 (ft)
Froude Number: 0.6409
Critical Depth: 0.0129 (ft)
Critical Velocity: 0.4553 (ft/s)
Critical Slope: 2182356.7677 (ft/ft)
Critical Top Width: 0.0644 (ft)
Calculated Max Shear Stress: 0.2940 (lb/ft^2)
Calculated Avg Shear Stress: 0.1328 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: G1: Ditch Inlet

Notes:

Using the following channel: G1: Vegetated Channel

Channel Analysis: G1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 1.0000 (ft/ft)
Longitudinal Slope: 0.0420 (ft/ft)
Manning's n: 0.0300
Flow: 7.0300 (cfs)

Result Parameters

Depth: 0.7538 (ft)
Area of Flow: 1.4207 (ft^2)
Wetted Perimeter: 4.1742 (ft)
Hydraulic Radius: 0.3403 (ft)
Average Velocity: 4.9484 (ft/s)
Top Width: 3.7692 (ft)
Froude Number: 1.4204
Critical Depth: 1.7742 (ft)
Critical Velocity: 5.3446 (ft/s)
Critical Slope: 0.0004 (ft/ft)
Critical Top Width: 8.8712 (ft)
Calculated Max Shear Stress: 1.9756 (lb/ft^2)
Calculated Avg Shear Stress: 0.8920 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 7.0300 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0118

Channel Analysis: G1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 1.0000 (ft/ft)
Longitudinal Slope: 0.0420 (ft/ft)
Manning's n: 0.0300
Flow: 7.0300 (cfs)

Result Parameters

Depth: 0.7538 (ft)
Area of Flow: 1.4207 (ft^2)
Wetted Perimeter: 4.1742 (ft)
Hydraulic Radius: 0.3403 (ft)
Average Velocity: 4.9484 (ft/s)
Top Width: 3.7692 (ft)
Froude Number: 1.4204
Critical Depth: 1.7742 (ft)
Critical Velocity: 5.3446 (ft/s)
Critical Slope: 0.0004 (ft/ft)
Critical Top Width: 8.8712 (ft)
Calculated Max Shear Stress: 1.9756 (lb/ft^2)
Calculated Avg Shear Stress: 0.8920 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: H1: Ditch Inlet

Notes:

Using the following channel: H1: Vegetated Channel

Channel Analysis: H1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0160 (ft/ft)
Manning's n: 0.0300
Flow: 15.3000 (cfs)

Result Parameters

Depth: 1.1170 (ft)
Area of Flow: 3.7430 (ft^2)
Wetted Perimeter: 7.1031 (ft)
Hydraulic Radius: 0.5270 (ft)
Average Velocity: 4.0876 (ft/s)
Top Width: 6.7019 (ft)
Froude Number: 0.9639
Critical Depth: 7.8595 (ft)
Critical Velocity: 11.2489 (ft/s)
Critical Slope: 0.0000 (ft/ft)
Critical Top Width: 47.1573 (ft)
Calculated Max Shear Stress: 1.1152 (lb/ft^2)
Calculated Avg Shear Stress: 0.5261 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 13.6304 (cfs)
Bypass flow: 1.6696 (cfs)
Efficiency: 0.8909

Channel Analysis: H1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0160 (ft/ft)
Manning's n: 0.0300
Flow: 15.3000 (cfs)

Result Parameters

Depth: 1.1170 (ft)
Area of Flow: 3.7430 (ft^2)
Wetted Perimeter: 7.1031 (ft)
Hydraulic Radius: 0.5270 (ft)
Average Velocity: 4.0876 (ft/s)
Top Width: 6.7019 (ft)
Froude Number: 0.9639
Critical Depth: 7.8595 (ft)
Critical Velocity: 11.2489 (ft/s)
Critical Slope: 0.0000 (ft/ft)
Critical Top Width: 47.1573 (ft)
Calculated Max Shear Stress: 1.1152 (lb/ft^2)
Calculated Avg Shear Stress: 0.5261 (lb/ft^2)

Channel Analysis: J1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0410 (ft/ft)
Manning's n: 0.0300
Flow: 2.7400 (cfs)

Result Parameters

Depth: 0.4913 (ft)
Area of Flow: 0.7240 (ft^2)
Wetted Perimeter: 3.1241 (ft)
Hydraulic Radius: 0.2318 (ft)
Average Velocity: 3.7843 (ft/s)
Top Width: 2.9476 (ft)
Froude Number: 1.3456
Critical Depth: 0.1067 (ft)
Critical Velocity: 1.3105 (ft/s)
Critical Slope: 141.3391 (ft/ft)
Critical Top Width: 0.6400 (ft)
Calculated Max Shear Stress: 1.2569 (lb/ft^2)
Calculated Avg Shear Stress: 0.5929 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: K1: Ditch Inlet

Notes:

Using the following channel: K1: Vegetated Channel

Channel Analysis: K1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 1.0000 (ft/ft)
Longitudinal Slope: 0.0140 (ft/ft)
Manning's n: 0.0300
Flow: 7.5700 (cfs)

Result Parameters

Depth: 0.9523 (ft)
Area of Flow: 2.2673 (ft^2)
Wetted Perimeter: 5.2734 (ft)
Hydraulic Radius: 0.4300 (ft)
Average Velocity: 3.3387 (ft/s)
Top Width: 4.7617 (ft)
Froude Number: 0.8527
Critical Depth: 2.1348 (ft)
Critical Velocity: 5.8626 (ft/s)
Critical Slope: 0.0002 (ft/ft)
Critical Top Width: 10.6741 (ft)
Calculated Max Shear Stress: 0.8320 (lb/ft^2)
Calculated Avg Shear Stress: 0.3756 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 7.3410 (cfs)
Bypass flow: 0.2290 (cfs)
Efficiency: 0.9698

Channel Analysis: K1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 1.0000 (ft/ft)
Longitudinal Slope: 0.0140 (ft/ft)
Manning's n: 0.0300
Flow: 7.5700 (cfs)

Result Parameters

Depth: 0.9523 (ft)
Area of Flow: 2.2673 (ft^2)
Wetted Perimeter: 5.2734 (ft)
Hydraulic Radius: 0.4300 (ft)
Average Velocity: 3.3387 (ft/s)
Top Width: 4.7617 (ft)
Froude Number: 0.8527
Critical Depth: 2.1348 (ft)
Critical Velocity: 5.8626 (ft/s)
Critical Slope: 0.0002 (ft/ft)
Critical Top Width: 10.6741 (ft)
Calculated Max Shear Stress: 0.8320 (lb/ft^2)
Calculated Avg Shear Stress: 0.3756 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: L1: Ditch Inlet

Notes:

Using the following channel: L1: Vegetated Channel

Channel Analysis: L1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 4.0000 (ft/ft)
Longitudinal Slope: 0.0200 (ft/ft)
Manning's n: 0.0300
Flow: 1.6200 (cfs)

Result Parameters

Depth: 0.4114 (ft)
Area of Flow: 0.6772 (ft^2)
Wetted Perimeter: 3.3929 (ft)
Hydraulic Radius: 0.1996 (ft)
Average Velocity: 2.3924 (ft/s)
Top Width: 3.2916 (ft)
Froude Number: 0.9295
Critical Depth: 0.0140 (ft)
Critical Velocity: 0.4742 (ft/s)
Critical Slope: 1370221.5705 (ft/ft)
Critical Top Width: 0.1117 (ft)
Calculated Max Shear Stress: 0.5135 (lb/ft^2)
Calculated Avg Shear Stress: 0.2491 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 1.6200 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0293

Channel Analysis: L1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 4.0000 (ft/ft)
Longitudinal Slope: 0.0200 (ft/ft)
Manning's n: 0.0300
Flow: 1.6200 (cfs)

Result Parameters

Depth: 0.4114 (ft)
Area of Flow: 0.6772 (ft^2)
Wetted Perimeter: 3.3929 (ft)
Hydraulic Radius: 0.1996 (ft)
Average Velocity: 2.3924 (ft/s)
Top Width: 3.2916 (ft)
Froude Number: 0.9295
Critical Depth: 0.0140 (ft)
Critical Velocity: 0.4742 (ft/s)
Critical Slope: 1370221.5705 (ft/ft)
Critical Top Width: 0.1117 (ft)
Calculated Max Shear Stress: 0.5135 (lb/ft^2)
Calculated Avg Shear Stress: 0.2491 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: M1: Ditch Inlet

Notes:

Using the following channel: M1: Vegetated Channel

Channel Analysis: M1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0450 (ft/ft)
Manning's n: 0.0300
Flow: 3.7300 (cfs)

Result Parameters

Depth: 0.5420 (ft)
Area of Flow: 0.8812 (ft^2)
Wetted Perimeter: 3.4465 (ft)
Hydraulic Radius: 0.2557 (ft)
Average Velocity: 4.2329 (ft/s)
Top Width: 3.2518 (ft)
Froude Number: 1.4330
Critical Depth: 0.2306 (ft)
Critical Velocity: 1.9270 (ft/s)
Critical Slope: 4.2862 (ft/ft)
Critical Top Width: 1.3839 (ft)
Calculated Max Shear Stress: 1.5219 (lb/ft^2)
Calculated Avg Shear Stress: 0.7179 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 3.7300 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0566

Channel Analysis: M1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0450 (ft/ft)
Manning's n: 0.0300
Flow: 3.7300 (cfs)

Result Parameters

Depth: 0.5420 (ft)
Area of Flow: 0.8812 (ft^2)
Wetted Perimeter: 3.4465 (ft)
Hydraulic Radius: 0.2557 (ft)
Average Velocity: 4.2329 (ft/s)
Top Width: 3.2518 (ft)
Froude Number: 1.4330
Critical Depth: 0.2306 (ft)
Critical Velocity: 1.9270 (ft/s)
Critical Slope: 4.2862 (ft/ft)
Critical Top Width: 1.3839 (ft)
Calculated Max Shear Stress: 1.5219 (lb/ft^2)
Calculated Avg Shear Stress: 0.7179 (lb/ft^2)

Median/Ditch Drop-Inlet Analysis: N1: Ditch Inlet

Notes:

Using the following channel: N1: Vegetated Channel

Channel Analysis: N1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0450 (ft/ft)
Manning's n: 0.0300
Flow: 2.8700 (cfs)

Result Parameters

Depth: 0.4912 (ft)
Area of Flow: 0.7239 (ft^2)
Wetted Perimeter: 3.1239 (ft)
Hydraulic Radius: 0.2317 (ft)
Average Velocity: 3.9644 (ft/s)
Top Width: 2.9474 (ft)
Froude Number: 1.4097
Critical Depth: 0.1198 (ft)
Critical Velocity: 1.3887 (ft/s)
Critical Slope: 83.5809 (ft/ft)
Critical Top Width: 0.7187 (ft)
Calculated Max Shear Stress: 1.3794 (lb/ft^2)
Calculated Avg Shear Stress: 0.6507 (lb/ft^2)

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet on grade
Grate Type: 30 degree tilt-bar
Grate Width: 1.9600 (ft)
Grate Length: 3.3300 (ft)

Computed Data:

Intercepted flow: 2.8700 (cfs)
Bypass flow: 0.0000 (cfs)
Efficiency: 1.0833

Channel Analysis: N1: Vegetated Channel

Notes:

Input Parameters

Channel Type: Triangular
Side Slope 1 (Z1): 4.0000 (ft/ft)
Side Slope 2 (Z2): 2.0000 (ft/ft)
Longitudinal Slope: 0.0450 (ft/ft)
Manning's n: 0.0300
Flow: 2.8700 (cfs)

Result Parameters

Depth: 0.4912 (ft)
Area of Flow: 0.7239 (ft^2)
Wetted Perimeter: 3.1239 (ft)
Hydraulic Radius: 0.2317 (ft)
Average Velocity: 3.9644 (ft/s)
Top Width: 2.9474 (ft)
Froude Number: 1.4097
Critical Depth: 0.1198 (ft)
Critical Velocity: 1.3887 (ft/s)
Critical Slope: 83.5809 (ft/ft)
Critical Top Width: 0.7187 (ft)
Calculated Max Shear Stress: 1.3794 (lb/ft^2)
Calculated Avg Shear Stress: 0.6507 (lb/ft^2)

HY-8 Culvert Analysis Report

Surfer Parking Lot Culvert

Table 1 - Summary of Culvert Flows at Crossing: Work: P 2-24" 19,17

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
24.00	60.70	60.70	0.00	1
25.00	68.30	68.30	0.00	Overtopping

Rating Curve Plot for Crossing: Work: P 2-24" 19,17

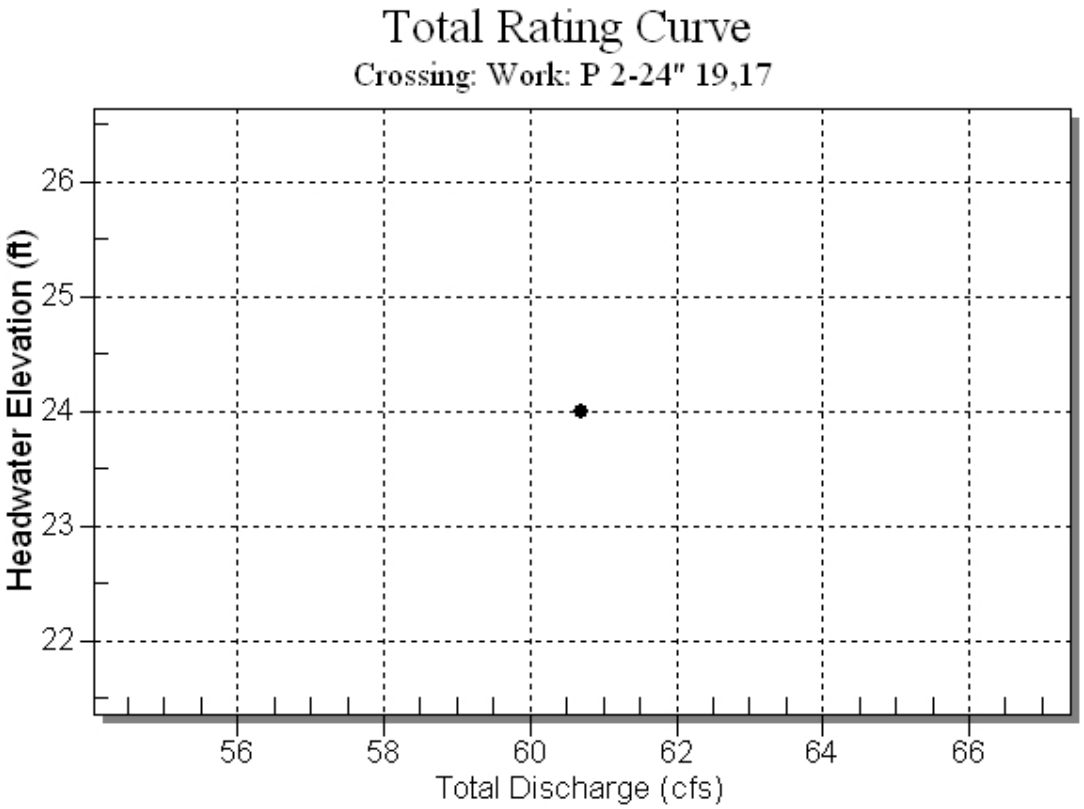


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000
60.70	60.70	24.00	5.004	0.0*	5-S2n	1.172	1.910	1.320	0.000	13.818	0.000

* theoretical depth is impractical. Depth reported is corrected.

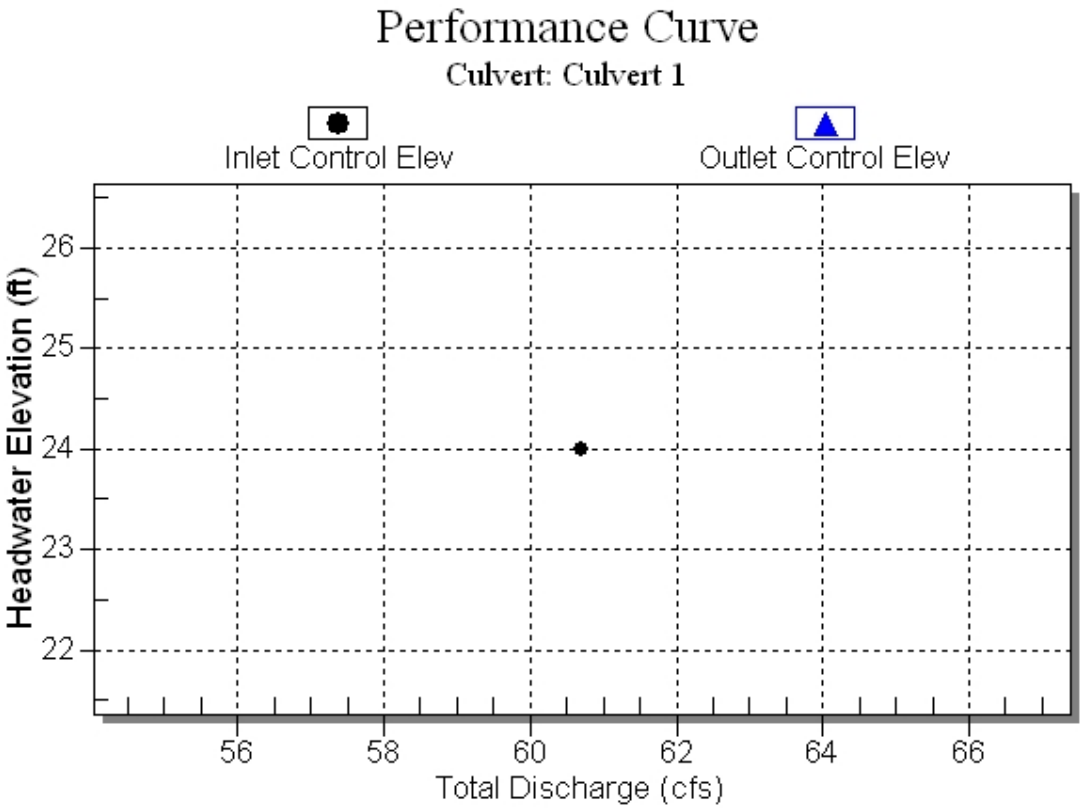
****

Inlet Elevation (invert): 19.00 ft, Outlet Elevation (invert): 17.00 ft

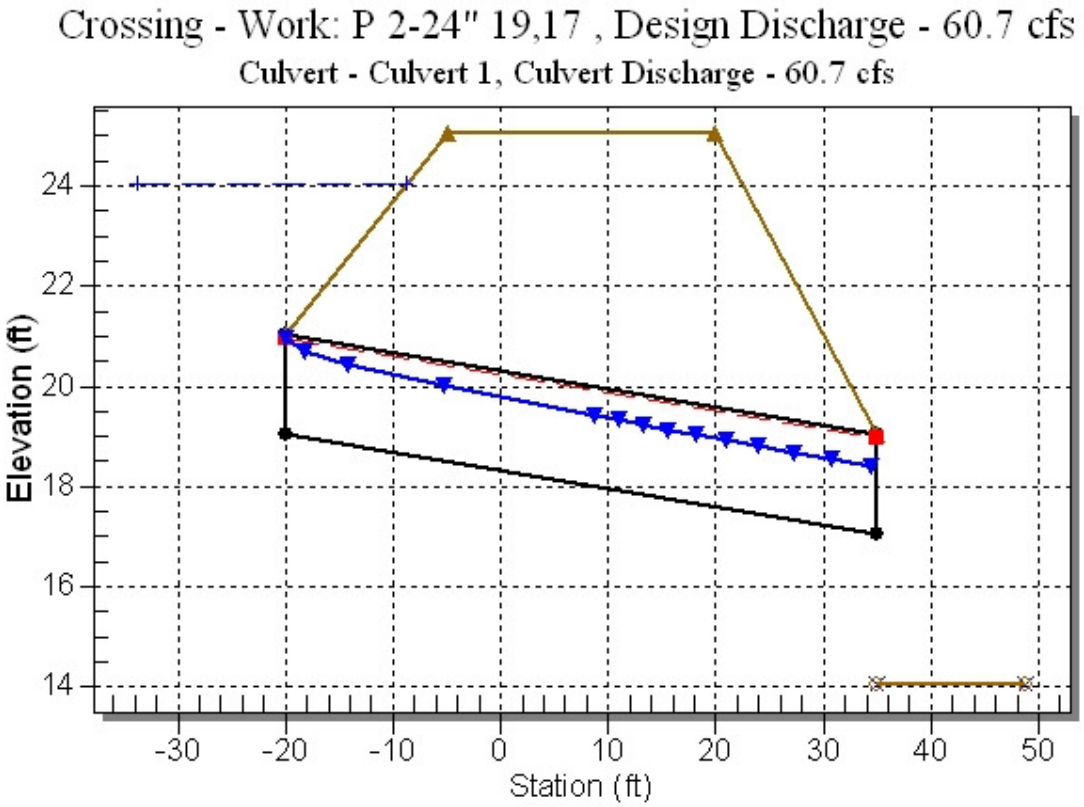
Culvert Length: 55.04 ft, Culvert Slope: 0.0364

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: -20.00 ft

Inlet Elevation: 19.00 ft

Outlet Station: 35.00 ft

Outlet Elevation: 17.00 ft

Number of Barrels: 2

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Work: P 2-24" 19,17)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00
60.70	14.00	0.00

Tailwater Channel Data - Work: P 2-24" 19,17

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.00 ft

Roadway Data for Crossing: Work: P 2-24" 19,17

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 25.00 ft

Roadway Surface: Paved

Roadway Top Width: 25.00 ft

Table 4 - Summary of Culvert Flows at Crossing: P 42" 18,17

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
22.13	60.70	60.70	0.00	1
25.00	94.23	94.23	0.00	Overtopping

Rating Curve Plot for Crossing: P 42" 18,17

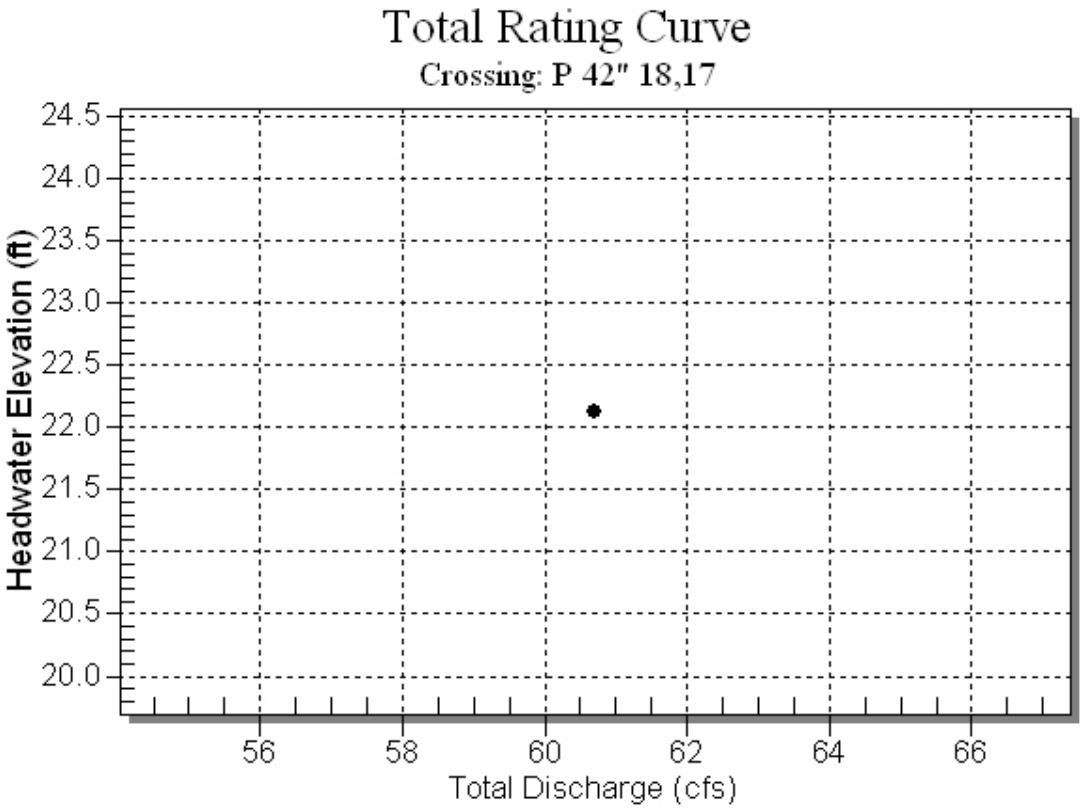


Table 5 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000
60.70	60.70	22.13	4.132	0.0*	5-S2n	1.533	2.441	1.800	0.000	12.182	0.000

* theoretical depth is impractical. Depth reported is corrected.

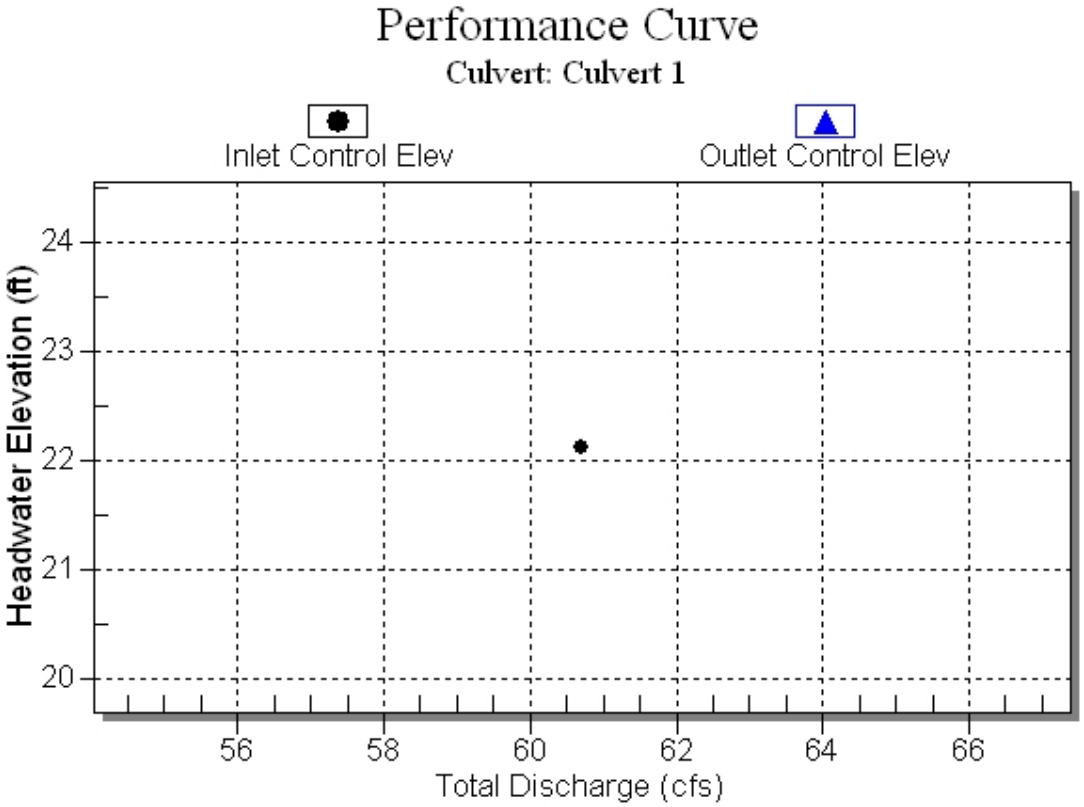
****

Inlet Elevation (invert): 18.00 ft, Outlet Elevation (invert): 17.00 ft

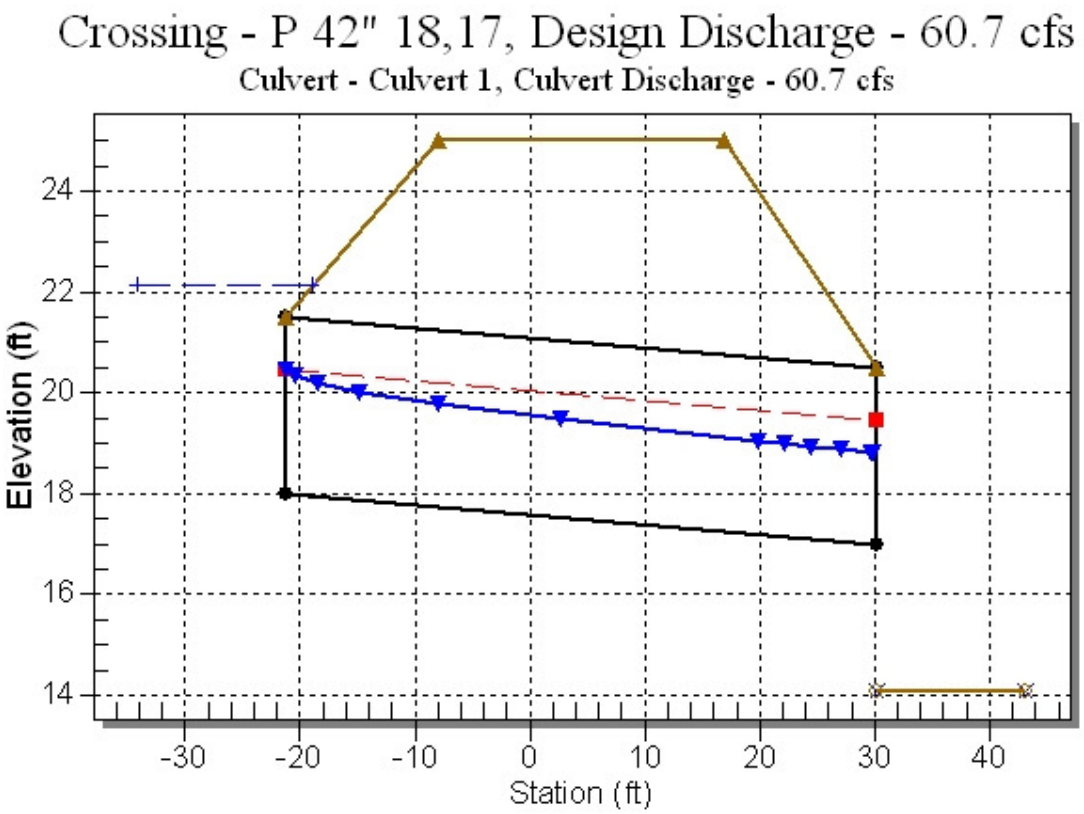
Culvert Length: 51.51 ft, Culvert Slope: 0.0194

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: -21.50 ft

Inlet Elevation: 18.00 ft

Outlet Station: 30.00 ft

Outlet Elevation: 17.00 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 3.50 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Mitered to Conform to Slope

Inlet Depression: None

Table 6 - Downstream Channel Rating Curve (Crossing: P 42" 18,17)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00
60.70	14.08	0.00

Tailwater Channel Data - P 42" 18,17

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.08 ft

Roadway Data for Crossing: P 42" 18,17

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 25.00 ft

Roadway Surface: Paved

Roadway Top Width: 25.00 ft

Hydraulic Analysis Report: Surfer Parking Lot

Project Data

Project Title: Project - Surfer Parking Culvert

Designer:

Project Date: Tuesday, February 22, 2011

Project Units: U.S. Customary Units

Notes:

Median/Ditch Drop-Inlet Analysis: Median/Ditch Drop-Inlet Analysis

Notes:

Using Local Channel

Channel Analysis: Channel Analysis

Notes:

Input Parameters

Channel Type: Trapezoidal

Side Slope 1 (Z1): 10.0000 (ft/ft)

Side Slope 2 (Z2): 10.0000 (ft/ft)

Channel Width: 20.0000 (ft)

Longitudinal Slope: 0.0050 (ft/ft)

Manning's n: 0.2867

Lining Type: Vegetative - Class A

Permissible Shear Stress: 3.7000 (lb/ft^2)

Flow: 60.7000 (cfs)

Result Parameters

Depth: 2.5875 (ft)
Area of Flow: 118.7005 (ft^2)
Wetted Perimeter: 72.0078 (ft)
Hydraulic Radius: 1.6484 (ft)
Average Velocity: 0.5114 (ft/s)
Top Width: 71.7497 (ft)
Froude Number: 0.0701
Critical Depth: 0.5936 (ft)
Critical Velocity: 3.9429 (ft/s)
Critical Slope: 1.5304 (ft/ft)
Critical Top Width: 31.8715 (ft)
Calculated Max Shear Stress: 0.8073 (lb/ft^2)
Calculated Avg Shear Stress: 0.5143 (lb/ft^2)
Stability Factor: 4.5832

Inlet Data:

Not computing the channel block (berm) height
Inlet Location: Inlet in sag
Percent Clogging: 50.0000
Grate Type: P - 1-7/8 - 4
Grate Width: 8.0000 (ft)
Grate Length: 3.0000 (ft)

Computed Data:

Perimeter: 22.0000 (ft)
Effective Perimeter: 11.0000 (ft)
Area: 19.2000 (ft^2)
Effective Area: 9.6000 (ft^2)
Depth at Center of Grate: 1.5012 (ft)
Computed Top Width at Sag: 50.0248 (ft)
Flow Type: Weir Flow
Efficiency: 1.0000

HY-8 Culvert Analysis Report

Mitchell Road Culvert at Station 30+16

Table 1 - Summary of Culvert Flows at Crossing: 30+16.22

Headwater Elevation (ft)	Total Discharge (cfs)	EX2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
16.75	36.87	36.87	0.00	1
16.87	40.10	40.10	0.00	1
17.00	43.32	43.32	0.00	1
17.13	46.55	46.55	0.00	1
17.22	48.92	48.92	0.00	1
17.39	53.00	53.00	0.00	1
17.63	56.23	56.23	0.00	1
17.73	59.46	59.46	0.00	1
17.84	62.69	62.69	0.00	1
18.01	65.91	65.91	0.00	1
18.18	69.14	69.14	0.00	1
19.00	82.46	82.46	0.00	Overtopping

Rating Curve Plot for Crossing: 30+16.22

Table 2 - Culvert Summary Table: EX2

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
36.87	36.87	16.75	2.200	0.0*	1-S2n	1.360	1.451	1.365	0.000	6.730	0.000
40.10	40.10	16.87	2.323	0.0*	1-S2n	1.433	1.518	1.437	0.000	6.868	0.000
43.32	43.32	17.00	2.448	0.0*	1-S2n	1.506	1.577	1.506	0.000	7.007	0.000
46.55	46.55	17.13	2.575	0.0*	5-S2n	1.583	1.637	1.586	0.000	7.098	0.000
48.92	48.92	17.22	2.671	0.0*	5-S2n	1.638	1.680	1.639	0.000	7.180	0.000
53.00	53.00	17.39	2.843	0.0*	5-S2n	1.735	1.754	1.736	0.000	7.286	0.000
56.23	56.23	17.63	2.985	3.079	2-M2c	1.822	1.803	1.808	0.000	7.397	0.000
59.46	59.46	17.73	3.135	3.185	2-M2c	1.912	1.852	1.859	0.000	7.596	0.000
62.69	62.69	17.84	3.292	3.290	2-M2c	2.002	1.900	1.907	0.000	7.816	0.000
65.91	65.91	18.01	3.458	3.416	2-M2c	2.145	1.949	1.954	0.000	8.018	0.000
69.14	69.14	18.18	3.632	3.537	2-M2c	2.500	1.997	1.998	0.000	8.219	0.000

* theoretical depth is impractical. Depth reported is corrected.

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Inlet Elevation (invert): 14.55 ft, Outlet Elevation (invert): 14.26 ft

Culvert Length: 56.00 ft, Culvert Slope: 0.0052

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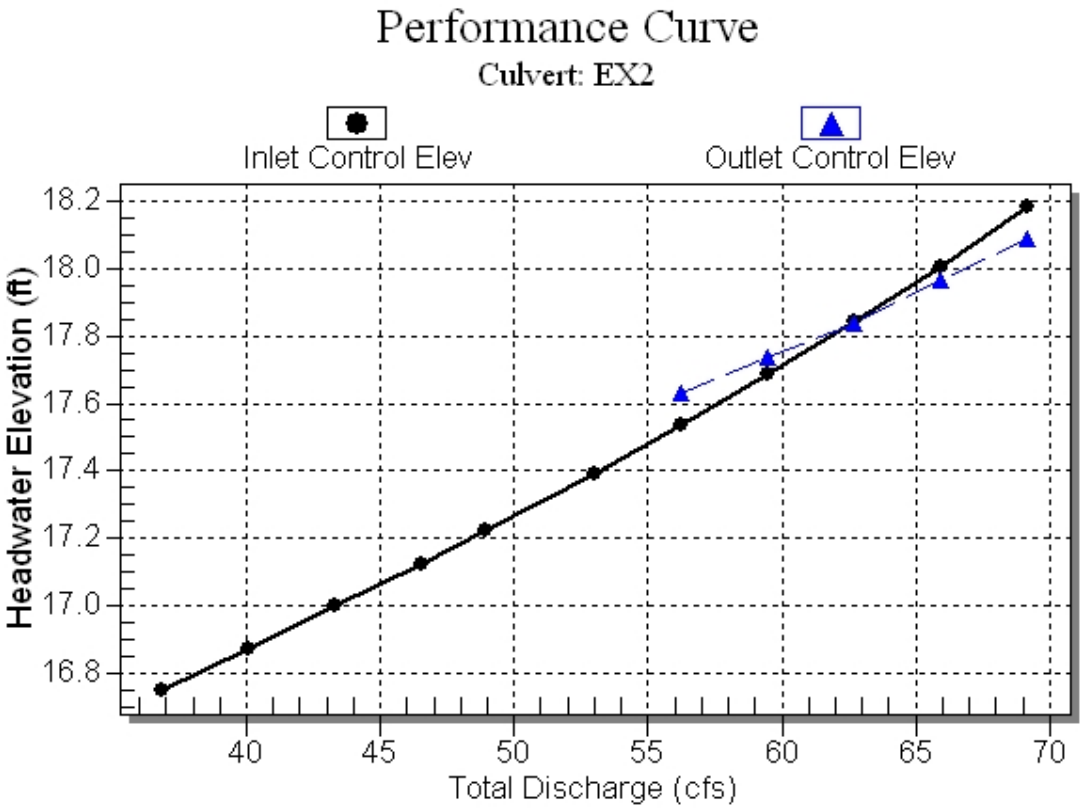
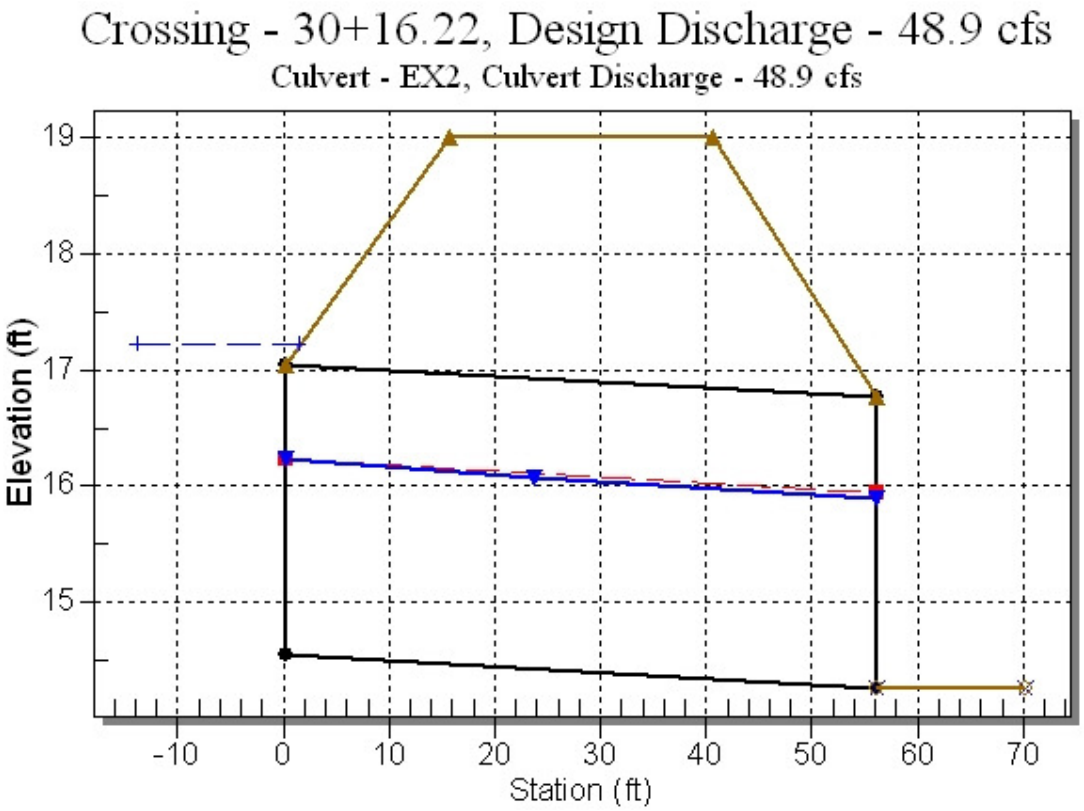
Culvert Performance Curve Plot: EX2



Water Surface Profile Plot for Culvert: EX2



Site Data - EX2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 14.55 ft

Outlet Station: 56.00 ft

Outlet Elevation: 14.26 ft

Number of Barrels: 2

Culvert Data Summary - EX2

Barrel Shape: Circular

Barrel Diameter: 2.50 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 30+16.22)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
36.87	14.26	0.00
40.10	14.26	0.00
43.32	14.26	0.00
46.55	14.26	0.00
48.92	14.26	0.00
53.00	14.26	0.00
56.23	14.26	0.00
59.46	14.26	0.00
62.69	14.26	0.00
65.91	14.26	0.00
69.14	14.26	0.00

Tailwater Channel Data - 30+16.22

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.26 ft

Roadway Data for Crossing: 30+16.22

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 19.00 ft

Roadway Surface: Paved

Roadway Top Width: 25.00 ft