DRAFT
DRAINAGE REPORT
FOR
SUNSET ROAD,
SILVERBELL ROAD TO INTERSTATE 10

SUBMITTED TO:

PIMA COUNTY
TRANSPORTATION

PIMA COUNTY DEPARTMENT OF TRANSPORTATION
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OCTOBER 2014

DRAFT

DRAINAGE REPORT

FOR

SUNSET ROAD,

SILVERBELL ROAD TO INTERSTATE 10

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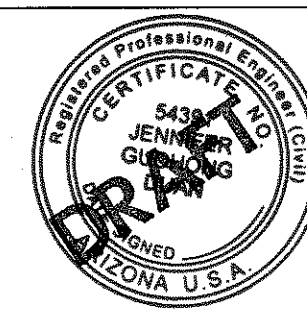

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1.0 Introduction

1.1 Project Description

The Sunset Road project is located in west Tucson, Arizona. More specifically the project is located within Sections 8, 17 and 18 of Township 13 South, Range 13 East of the Gila and Salt River Meridian. Figure 1 provides a schematic overview of the project location.

This project includes preparing conceptual and final drainage design as part of the Sunset Road, Silverbell Road to I-10 roadway project. Major components of this project include a new signalized Tee intersection at Silverbell Road, a new bridge over the Santa Cruz River and tying into the existing traffic interchange at Interstate 10. The alignment was identified as part of the Silverbell Road Corridor Design Concept Report prepared for the City of Tucson Department of Transportation, Reference 1. The new Sunset Road alignment begins approximately 1000-feet south of the current Sunset Road Alignment on Silverbell Road. The Sunset Road alignment traverses east across the Santa Cruz River and an active sand and gravel mining pit to I-10 where it connects to the existing west leg of the traffic interchange. Figure 2, provides a closer representation of the project work limits and river crossing.

The Santa Cruz River crossing will include a new 6-span bridge with piers oriented to span the existing effluent flow contained within the low flow channel and the Army Corps of Engineers (ACOE) jurisdictional areas within the main channel and overbanks of the river.

1.2 Key Points of Interest

This specific project is separated into three distinct areas of interest; onsite drainage, offsite drainage and the Santa Cruz River.

Onsite Drainage

The proposed roadway is uncurbed with the exception of the bridge itself which has a combination of curb and barrier. From Silverbell Road to just east of the Santa Cruz River the roadway is elevated above the adjacent grade and will drain storm water runoff directly onto the roadway embankment and onto the existing ground adjacent to the road. The region east of the river is slightly depressed below the adjacent grade and will require roadside ditches to collect storm water runoff from the pavement. The ditches will direct runoff to area inlets and storm drain systems. A road side channel along the south side of Sunset Road will collect runoff from both onsite and offsite sources. Section 2 of this report discusses the hydrologic and hydraulic analyses associated with the onsite drainage analysis.

Offsite Drainage

The offsite drainage impacting the project limits includes the area west of Silverbell Road, the Santa Cruz River and the area between the river and Interstate 10. The drainage report for the Silverbell Road DCR, Reference 2, was reviewed for the offsite drainage analysis within the project limits. Channels and scour countermeasures are proposed to protect the at-grade crossings for Silverbell Road. East of the Santa Cruz River a roadside collector channel culvert will collect runoff reaching the proposed depressed roadway and direct the flow to a proposed

culvert to convey the flow under the roadway to the logical outlet location. Section 3 of this report discusses the hydrologic and hydraulic analyses associated with the offsite drainage for this project.

The Santa Cruz River analysis and bridge hydraulic design is covered in a Section 4 of this report. The Santa Cruz River bisects the proposed Sunset Road between Silverbell Road to the west and I-10 to the east. The proposed improvement for this segment of the project includes a 6-span bridge that will be founded on drilled shafts to mitigate potential scour resulting from flood events. Grading and a sloping abutment is proposed to mitigate an increase in water surface elevation resulting from the floodplain encroachment on the left overbank. Section 4 of this report discusses the hydraulic modeling associated with the proposed bridge over the Santa Cruz River.

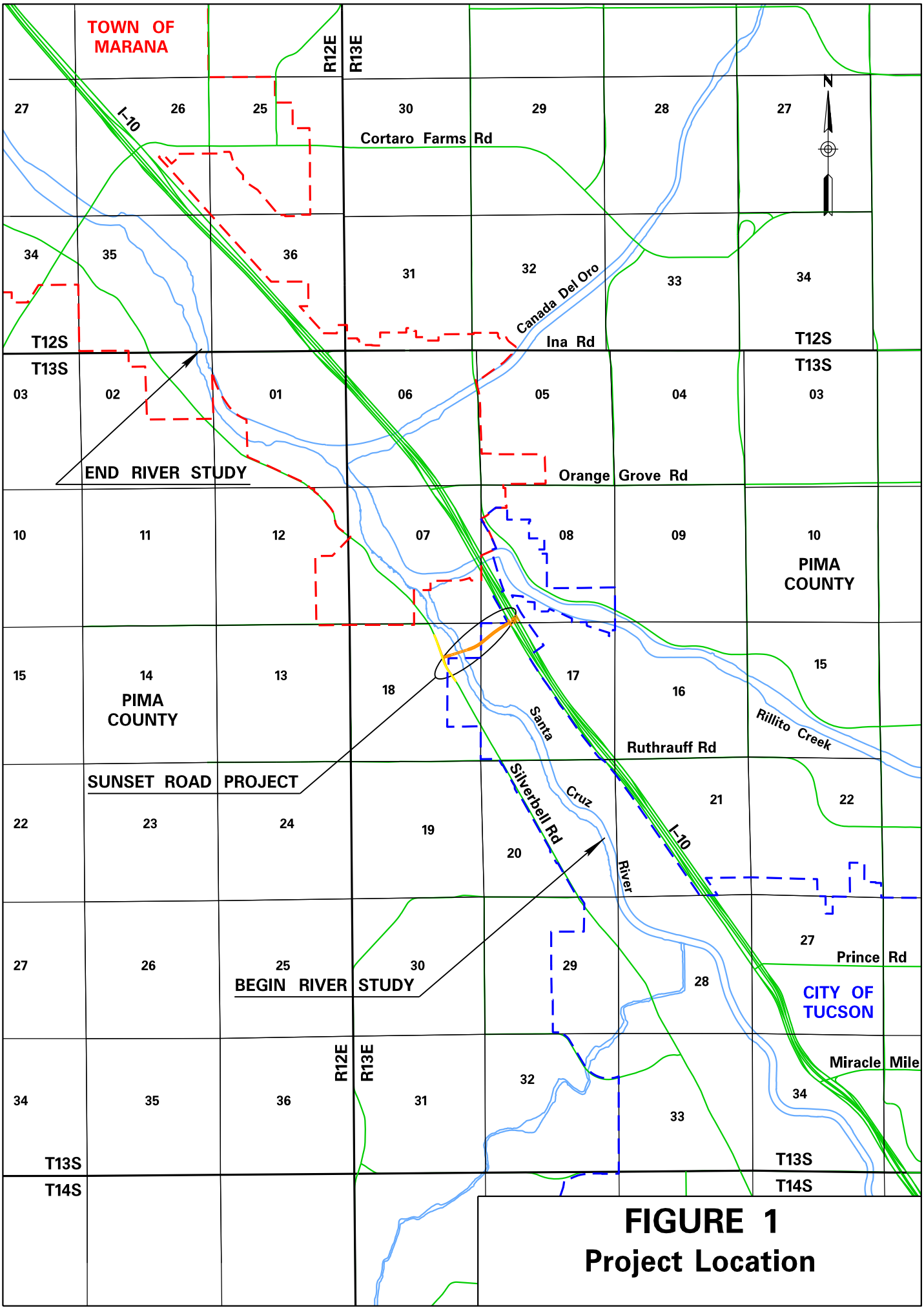

FIGURE 1
Project Location

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FIGURE 2
PROJECT LIMITS

SUNSET ROAD, SILVERBELL ROAD TO I-10

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1.3 Scope of Work

The purpose of this report is to document the analyses and design for drainage considerations and calculations made in conjunction with the engineering design of this roadway improvement project. The drainage design proposes to accommodate onsite, offsite and riverine runoff, and is described in qualitative terms within the body of this report and quantitative terms included in the appendices. The onsite (Pavement) drainage design was performed by AECOM and is specifically addressed in Section 2 of this report. Offsite drainage and riverine analyses and design elements are addressed in Sections 3 and 4 of this report.

The following provides the scope of work for the drainage portion of the project:

A. To determine the quantity of runoff affecting this project using the Pima County hydrology program (PC-Hydro).
B. To design the conveyance structures for the offsite contributing areas include collector/roadside channels, conveyance channels and pipe culverts.
C. To design new storm drain facilities to capture and convey roadway runoff to logical outfalls.
D. To design scour mitigation measures as needed to protect against erosion.
E. To appropriately size and provide design scour mitigation measures for the proposed bridge crossing the Santa Cruz River.

1.4 Basis of Survey Control

Project Topographic Mapping & Survey

The survey control for this project consists of two separate data sets. The first was established by EEC who has provided the following Horizontal and Vertical Control as well as the Basis of Bearing for the roadway portion of the project.

Basis of Bearing:

"The Basis of Bearing for this project is a grid bearing of N55^{0}56'26.29"E between Pima County DOT/City of Tucson DOT Geodetic, control point AL03 and Pima County DOT/City of Tucson DOT Geodetic, control point AG09, as established from the Arizona Coordinate System 1983 (Harn 92), Central Zone 0202."

Vertical Control:

"Vertical control for this project is based on Pima County benchmark designation Q291 aka NGS Q291 CZ0554. Elevation based on NAVD 88 Datum having an elevation of 2232.24 feet. Benchmark is located N88^{0}19'E 1,024 feet from the ¼ corner of Section 8, Township 123 South, Range 13 East, Gila and Salt River Meridian, Pima County, Arizona."

A copy of the Survey Control provided by EEC is included in Appendix A.

Santa Cruz River Study Reach Mapping

Mapping used for the Santa Cruz Hydraulic Analysis consists of LIDAR data provided by the Pima County Regional Flood Control District (District). The majority of the project study reach is encompassed by the 2011 LIDAR data;

however, there were portions of the reach that required supplemental mapping. The 2008 LIDAR data set was used to augment the 2011 data set. Survey Control documentation for the 2008 and 2011 LIDAR data sets are included in Appendix A.

1.5 Design Criteria

The design criteria for the Sunset Road project is in accordance with Pima County's Roadway Design Manual, Revised 2013; Reference 3 and the District's Policies. The three categories of drainage design and analysis are; Onsite Drainage, Offsite Drainage and River Hydraulics. The specific criteria for each are provided in the tables below.

Table 1 Onsite Drainage Design Criteria

Design Element	Criteria
Design storm	10-yr (for both roadside ditch and storm drain system)
Spread criteria	n/a
Minimum T_c	5-minute
Min storm drain size	18-inch for laterals, 24-inch for trunk lines
Pipe material	All Storm drain pipes shall be Reinforce Concrete Pipe (RCP)
Design velocity	Minimum 3 fps at full flow
Pressure flow design	HGL 1' min below inlet
Catch basin capture ratios	Per Table 2-9 in Roadway Design Manual

T_c = time of concentration

Table 2 Offsite Drainage Design Criteria

Design Element	Criteria
Design Storm	100-yr (for roadside channels and culverts) Under Roadway Preferred
Minimum T_c	5-minute
Minimum Culvert Size	24-inch Diameter for Pipe Culverts & 6'x5' (Span x Height) Box Culvert
Culvert Material	Reinforced Concrete
Design Velocity	Meet or Exceed Existing Condition Upstream Sediment Transport Capacity

T_c = time of concentration

Table 3 Santa Cruz River Design Criteria

Design Element	Criteria
Design storm	100-Yr. Design Flow Rate – PCRFCD Provided
Minimum Freeboard	100-Yr. 3-feet, 500-Yr. 1-foot
Scour Analysis	100-Yr. Design Storm with Debris Loading
Debris Loading	2 X Pier Diameter to a Maximum of 4-foot Additional Width for Debris

2.0 Onsite Drainage

2.1 General

The roadway typical section is crowned and uncurbed, with roadside ditches located 30 feet from the edge of travelled way. In general, these ditches will be used to collect and convey flow to area inlets located within the ditch. However, between Sunset Road Station 84+57 and the eastbound frontage road, pavement drainage will be collected by the roadside channel constructed on the south side of the roadway for offsite drainage.

The roadside ditches constructed as part of the roadway typical section will be located outside the clear zone, and will be 2 feet deep with 4:1 side slopes. The roadside ditch on the north side of Sunset Road will be drained via two small storm drain systems that outfall into the proposed 2 -36"x440' Pipe Culvert near Station 83+20. The storm drain systems and area inlets are being used to keep pavement drainage from flowing into the pit on either side of the new road. One system will connect directly to one of the cross drainage pipes, and the other will outfall through a wing-wall at the cross drainage outfall. The roadside ditch on the south will drain directly into the inlet of the cross drainage facility.

Bridge scuppers will be used to drain pavement drainage on the bridge over the Santa Cruz River. The scuppers will be located at quarter points of each girder. A total of 18 bridge scuppers on each side of the bridge will be used.

2.2 Hydrology

The Pima County hydrology program (PC-Hydro) was used to determine the peak flow reaching each area inlet. The analyses were done for the interim condition and the ultimate condition where Sunset Road rises to match the eastbound frontage roads. It is assumed that the drainage improvements for the future traffic interchange at Sunset Road will separate from the Sunset Road drainage system. Therefore, only the area west of the eastbound frontage road is being accounted for in this design. The pavement drainage watersheds are shown in Figure 3.

Hydrology for the bridge scuppers is not included at this time. The analyses will be completed after the bridge and pier configuration have been finalized.

2.3 Hydraulics

The preliminary design of the storm drain was performed using the Manning's formula for open channel, non-pressure flow. The storm drain pipes were considered to be trunk lines using the minimum 24-inch diameter pipe.

Area inlet design and scupper design has not been performed for this preliminary report. The design will be documented in subsequent versions of this report. In addition, the hydraulics for the bridge scuppers is not included at this time. The scupper analyses will be completed after the bridge and pier configuration have been finalized.

2.4 Results

The results of the hydrologic and hydraulic analyses are shown in Table 4 and Table 5. Note that the peak flow for ultimate conditions is less than that for the interim conditions. Therefore the current design will accommodate the anticipated future flows. All calculations associated with the Onsite Drainage analysis are included in Appendix B.

Table 4 Onsite Drainage Hydrologic Results

Watershed/Inlet ID	Location	Area (ac)	Q_{10} (ft^3/sec)
1	Sta 81+31 Rt	0.48	1.7
2	Sta 81+56 Lt	0.46	1.6
3	Sta 83+87 Lt	0.55	1.9
4	Sta 85+50 Lt	0.49	1.7
5	Sta 88+29 Lt	1.56	5.2
5 (Ultimate Conditions)	Sta 88+29 Lt	1.31	4.9

Table 5 Onsite Drainage Hydraulic Results

Watershed/Inlet ID	Design Flow (ft^3/sec)	Pipe Size (in)	Normal Depth (ft)	Velocity (ft/sec)
1	3.3	24	0.33	5.04
2	1.6	24	0.44	6.23
3	8.8	24	1.18	4.56
4	6.9	24	1.02	4.30
5	5.2	24	0.75	4.82

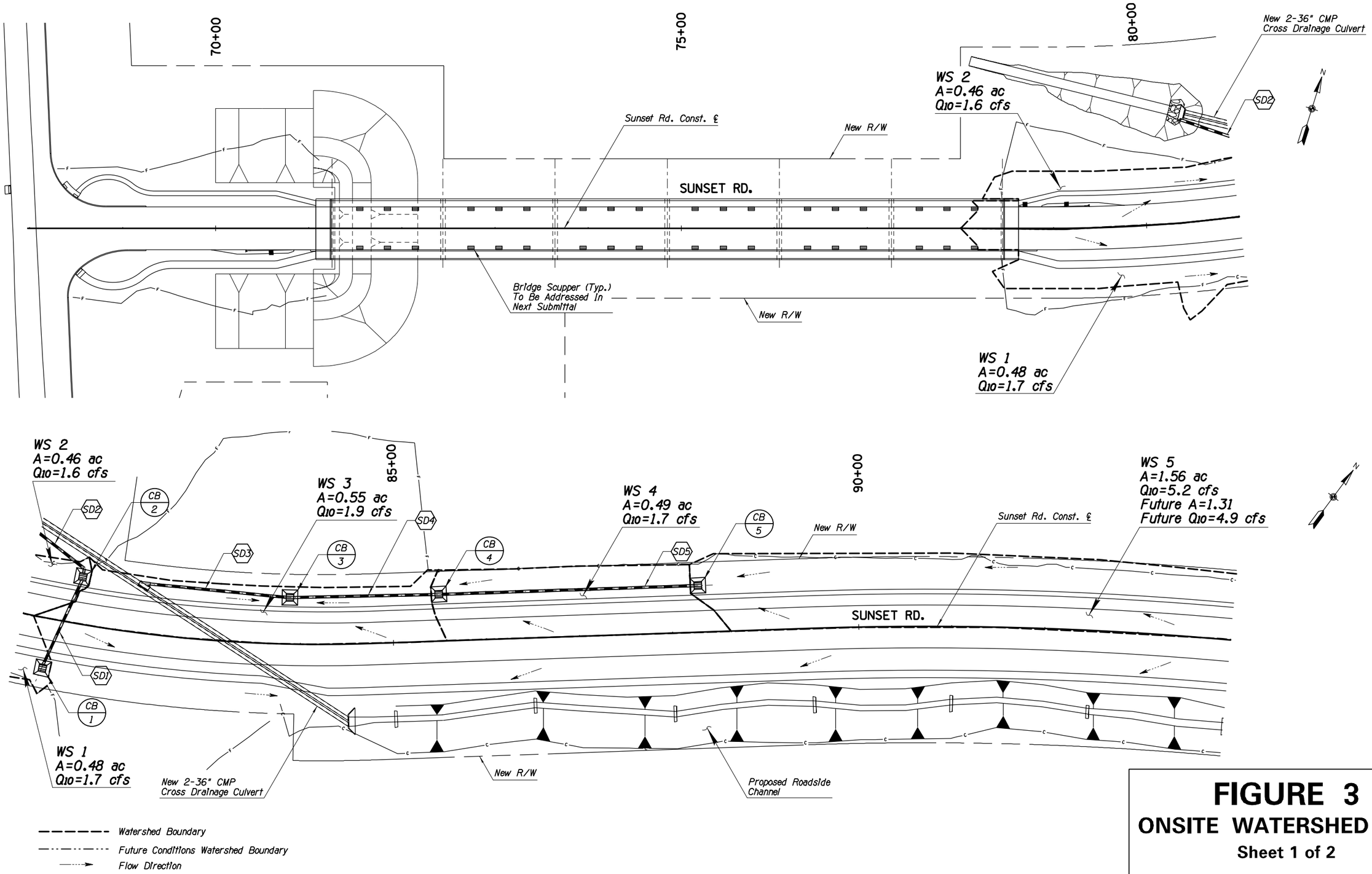

FIGURE 3
ONSITE WATERSHED MAP
Sheet 1 of 2

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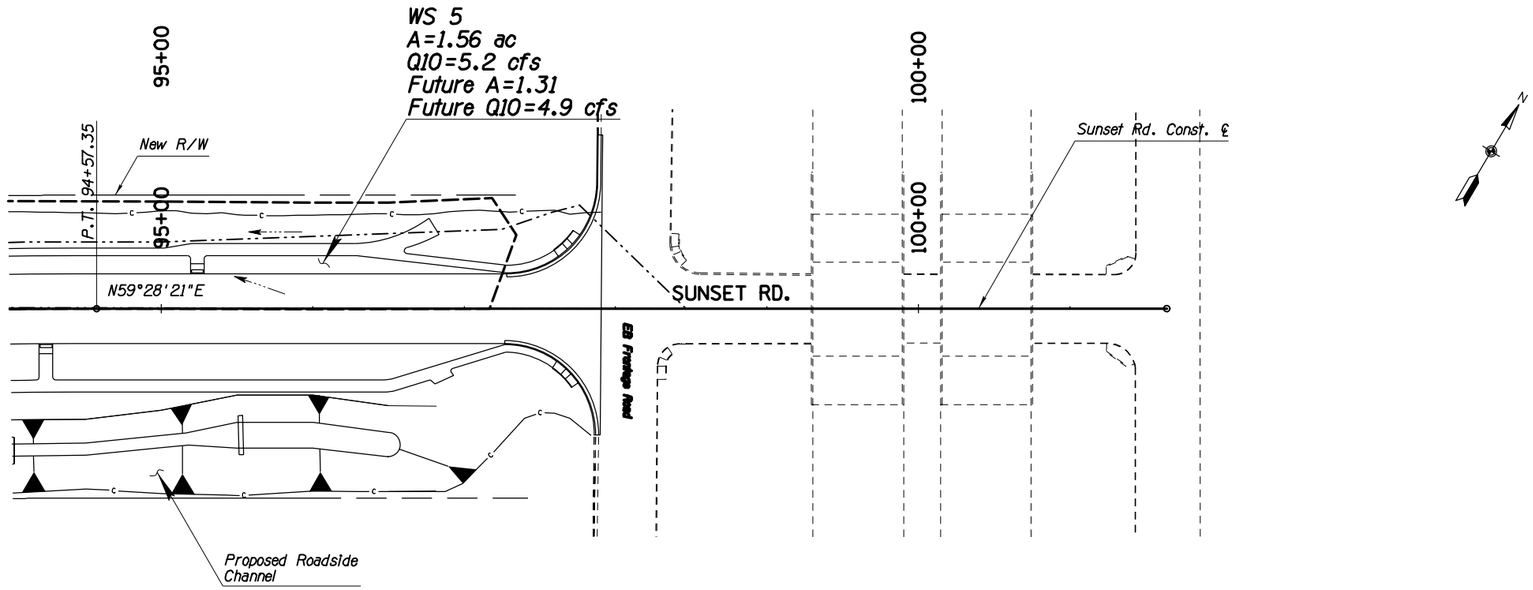

Watershed Boundary

Future Conditions Watershed Boundary

Flow Direction

FIGURE 3

ONSITE WATERSHED MAP

Sheet 2 of 2

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3.0 Offsite Drainage

3.1 General

The proposed Sunset Road alignment affects relatively large watershed areas. There are four offsite watershed areas in the vicinity of the proposed roadway improvements; one large watershed drains the area between I-10 and an active mining pit east of the Santa Cruz River and three (2-large and 1-small) are located west of Silverbell Road and the Santa Cruz River. This section of the report will document the hydrologic and hydraulic analyses associated with the offsite drainage and present recommended mitigation measures for the impacts caused by the proposed roadway. Figure 4 provides an overview of the offsite drainage configuration as well as existing and proposed watershed delineations.

3.2 Hydrology

East Roadside Channel:

Between I-10 and the Santa Cruz River, storm water runoff will travel as sheet flow from the south adjacent to the I-10 eastbound frontage road north – northwest to the northeastern edge of an active mining pit, Point of Concentration (POC) E1 (Denoted in Figure 4 as E1). The Pima County hydrology program (PC-Hydro) was used to compute the discharge reaching this point of concentration. The runoff coefficient of this watershed is based on the USDA Natural Resources Conservation Service Soil Survey which can be found in Appendix C. The total runoff reaching POC E1 is 77-ft^3/sec.

The proposed Sunset Road alignment crosses the existing watershed diagonally. The area was delineated to include the contributing pavement area for the proposed roadway and ditches adjacent to the road. This proposed watershed (POC P1) is identified as P1 on Figure 4. The area that now drains to the roadside channel contains 60 acres which is a reduction from the 66 acres under existing. The peak discharge reaching the roadside channel (POC P1) is increased to 97-ft^3/sec. The peak discharge increase is a result of a significantly reduced flow path which reduces Time of Concentration and increases precipitation intensity. Proposed condition runoff will continue to the new point of concentration as sheet flow, similar to the existing condition.

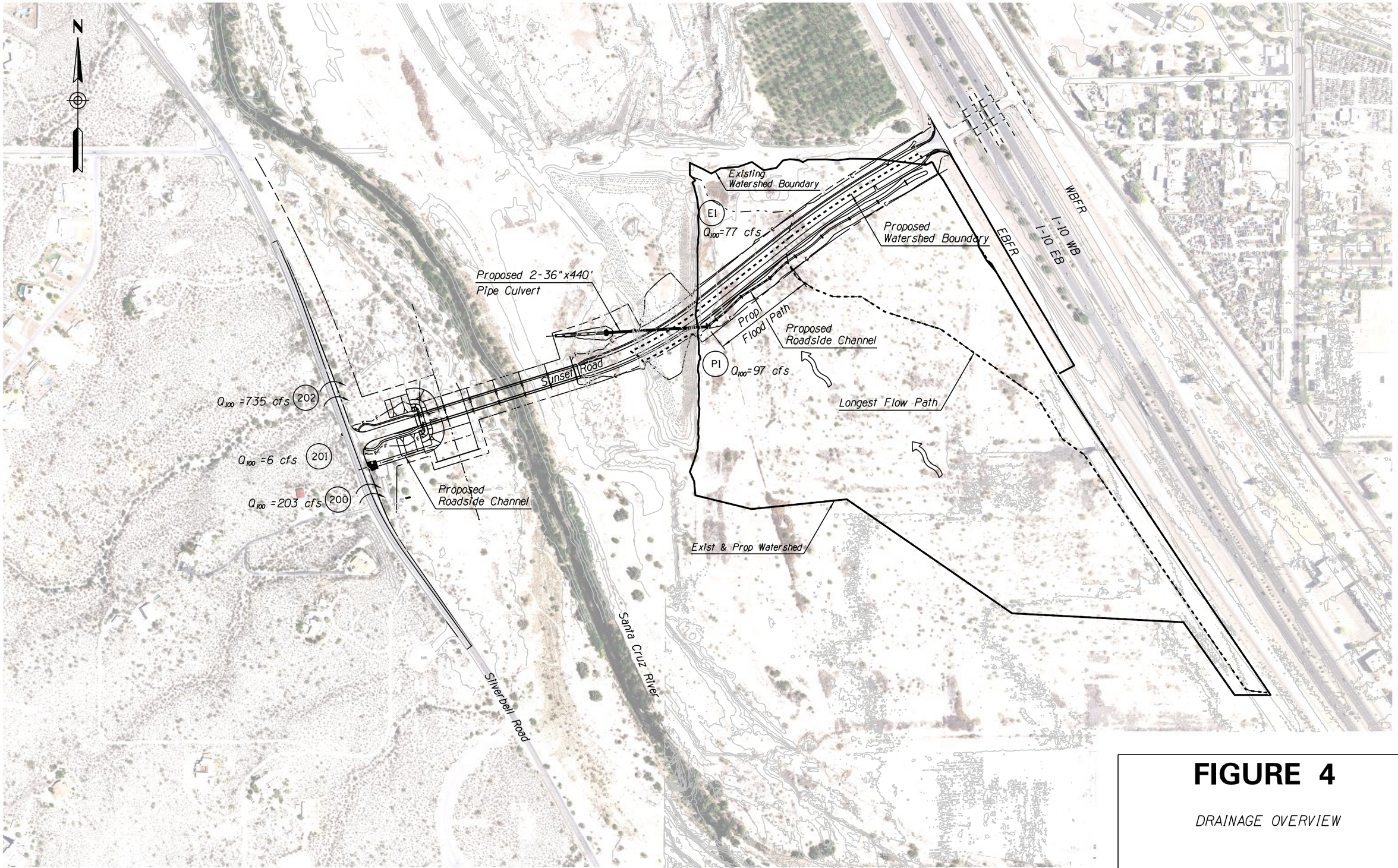

FIGURE 4

DRAINAGE OVERVIEW

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West of Santa Cruz River:

The offsite hydrologic analysis, in this region, was previously evaluated for the Silverbell Road DCR, Reference 1. The concentration point labels that were used in the Preliminary Drainage Report are being used for this analysis for ease of translation. The key concentration points that are within the project limits include: POC 200, 201 and 202. All of these areas contribute runoff from the west with Silverbell Road at their point(s) of concentration. No additional hydrologic analysis was conducted for these areas. Discharges from the DCR drainage report are provided in Table 6 of the Results Section, Section 3.4. Areas east of Silverbell Road, including the left overbank of the Santa Cruz River, will continue to sheet flow towards the river and are not impacted by the proposed roadway. POC 201 only has a 100-Yr discharge of 6-ft^3/sec and is considered nuisance flow; no further analysis will be considered for this POC. Runoff from POC 200 and POC 202, after crossing Silverbell Road, will continue as sheet flow to the Santa Cruz River.

There are other areas not encapsulated by the watershed boundaries described above; however, these areas are typically located on the overbanks of the Santa Cruz River and all drain towards the river without impact by the proposed roadway. No additional hydrologic analyses are provided for these overbank areas.

3.3 Hydraulics

Hydraulic modeling for the existing and proposed condition analysis uses HEC-RAS and Culvert Master. The geometry is based on cross sections along the path of the runoff. These sections were imported from MicroStation by the use of the INROADS application, within MicroStation. The INROADS software package is able to obtain the elevations from a digital terrain model (DTM) if the cross section alignment is given. To establish existing conditions, elevations were obtained from an existing ground DTM and directly imported into HEC-RAS. For the proposed analysis, the proposed road embankment and proposed grading, such as roadside channels, were merged with the existing surface to obtain proposed cross sections for each point of concentration.

East Roadside Channel:

The east roadside channel will intercept the sheet flow from the adjacent contributing drainage area, POC P1, and direct it to a proposed pipe culvert that conveys the runoff to the north side of Sunset Road and into the Santa Cruz River. Culver Master was used to size the culvert and establish the resulting headwater elevation. HEC-RAS used to compute the backwater within the roadside channel. A series of check dams spaced every 150-feet are proposed within the channel to aid in water harvesting and promote vegetation growth. Wheat Design Group (Landscape Architects) assisted in laying out the initial configuration of the channel which is the basis for this design. The check dams are modeled as in-line weirs within HEC-RAS.

To increase the stability of the check dams, Gabions or wire tired riprap baskets are being proposed as the check dams rather than dumped riprap. The outlet conditions for the culvert warrant a scour countermeasure; a riprap apron design in accordance with HEC-14, Reference 4, will mitigate the culvert outlet scour. Calculations are included in Appendix C.

It should be noted that under Existing Condition analysis no hydraulic analysis was conducted due to the “sheet-flow” nature of the watershed. The proposed roadside channel will intercept the sheet flow and direct it to the proposed culvert. Figure 5 provides the overview of the proposed hydraulic results.

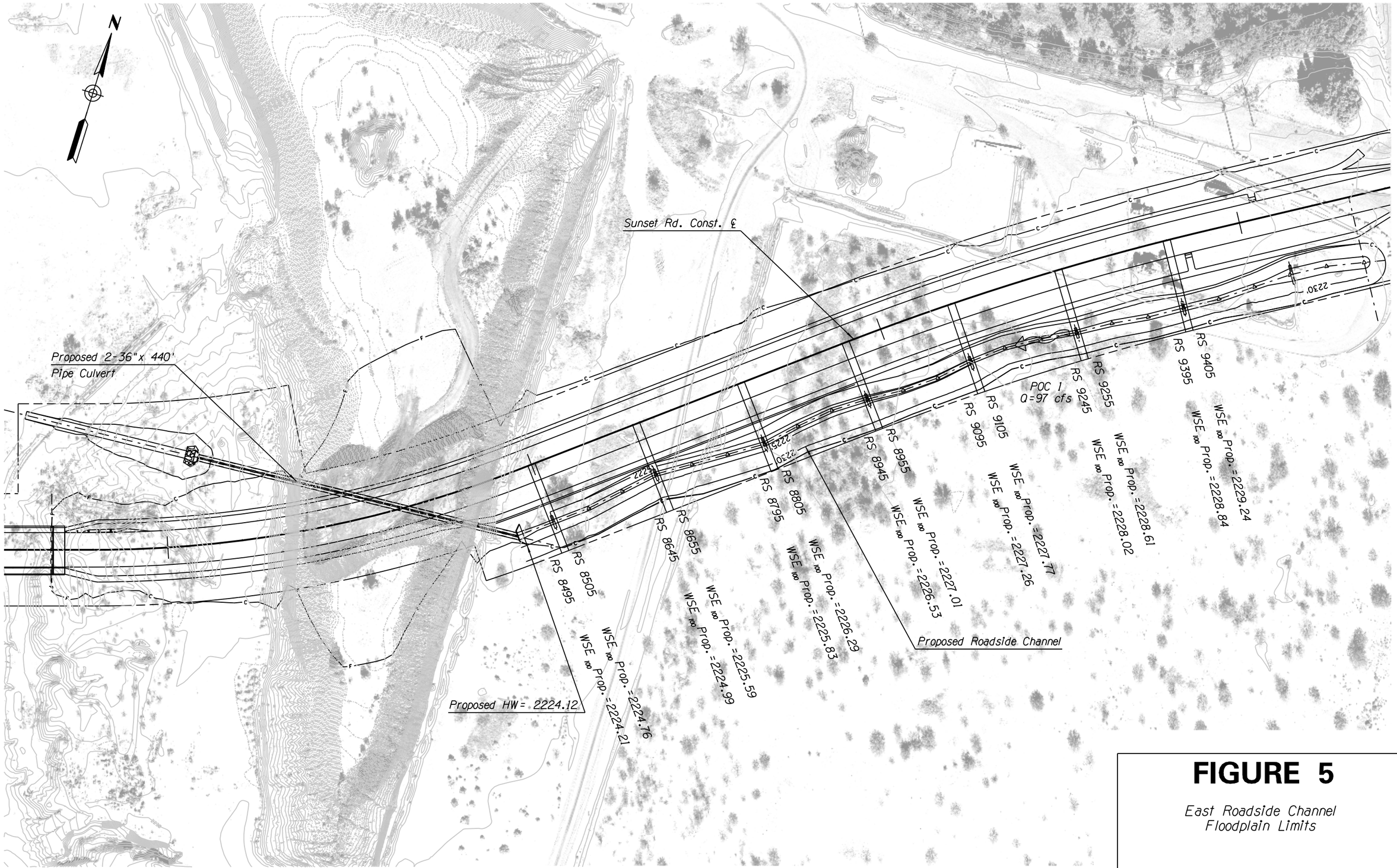

FIGURE 5

East Roadside Channel
Floodplain Limits

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West of Santa Cruz River:

There are two key locations west of the river that warrant evaluation. The first location is POC 200 and the second is POC 202. As previously stated, POC 201 is considered nuisance flow so no further evaluation was conducted for this project. POC 200 is located 130-feet south of the proposed intersection of Sunset Road and Silverbell Road; whereas, POC 202 is located 150-feet north of the proposed intersection of Silverbell Road and Sunset Road. Each location is within the improvement limits for Silverbell Road; however, Silverbell Road will be widened at the current grade with minimal impact to the at-grade crossings. HECRAS was used to establish the existing and proposed condition for both points of concentration.

POC 200 is just south of the proposed Sunset Road alignment. The water surface elevations and floodplain limits were calculated under the existing conditions. As runoff crosses Silverbell Road, it will turn to a northeastern direction towards the Santa Cruz River. The proposed Sunset Road alignment will impede the existing flow path east of Silverbell Road; as a result a new 20-foot bottom trapezoidal roadside channel is being proposed to restore conveyance lost due to the roadway embankment. After examining the proposed model, it was identified that in most sections the water surface was lowered, and therefore not worsening the extent of the 100-Yr floodplain resulting from runoff from POC200. The 100-Year floodplain from the Santa Cruz River is at higher elevations than the floodplain from PC200 east of Silverbell Road. Figure 6 presents the existing floodplain and Figure 7 presents the proposed roadside channel. Results show that this proposed configure collects and conveys the runoff from POC 200.

POC 202 is located north of the proposed Sunset Road alignment and is not directly impacted by its design. HECRAS models were created for the existing and proposed condition to show that there is no adverse impact as a result of this project. Figure 8 shows the results for both existing and proposed hydraulic models and that there is no impact from Sunset Road.

Runoff crossing Silverbell Road does not create a scour condition. General scour computations show that there is no lowering of the thalweg due to runoff crossing Silverbell Road for POC 200 and POC 202. Scour computations are included in Appendix C and are in accordance with the City of Tucson's drainage manual and HEC-15, Reference 5 and Reference 6. A 2-foot Ford Wall is proposed along the eastern edge of Silverbell Road to mitigate potential scour from the Santa Cruz River during the 100-Year event.

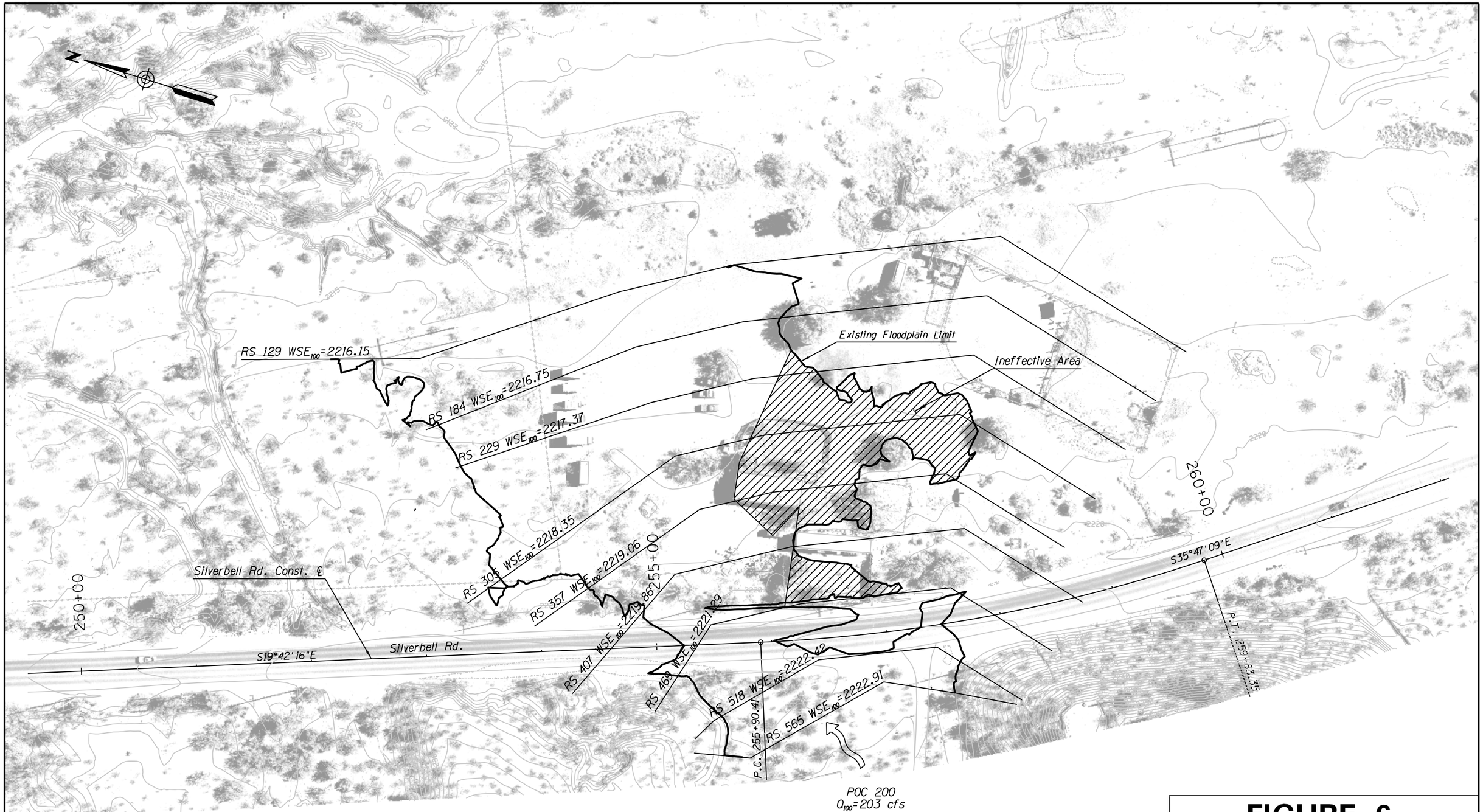

FIGURE 6

Existing POC 200
Floodplain Limits

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FIGURE 7

Proposed POC 200
Floodplain Limits

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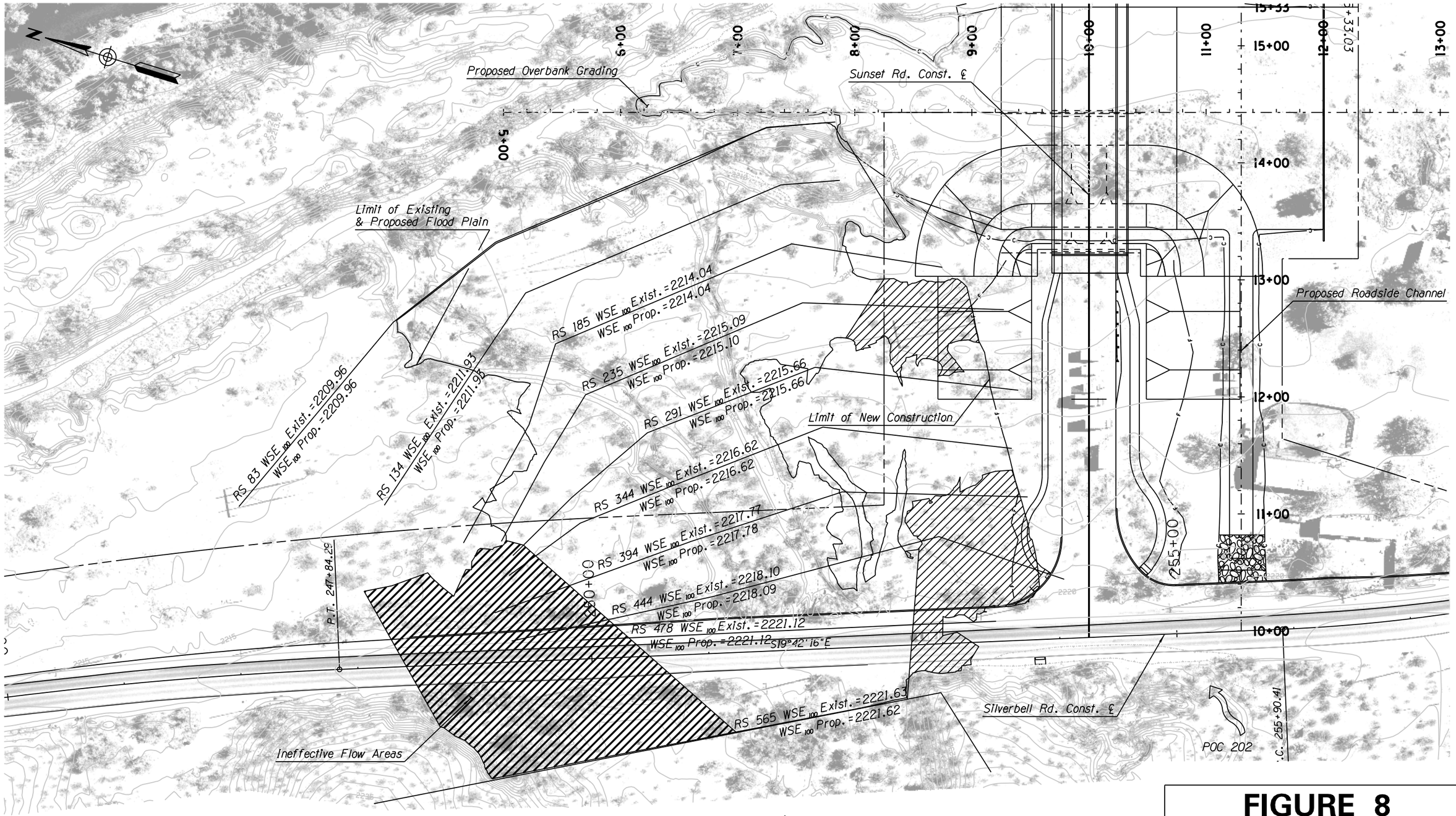

FIGURE 8

Existing and Proposed POC 202
Floodplain Limits

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3.4 Results

Results from the hydrologic analysis are included in Table 6. These discharge rates were used in the hydraulic analyses.

Table 6 Offsite Drainage Hydrologic Summary

Point of Concentration (POC) (ft^3/sec)	Existing condition (ft^3/sec)	Proposed Condition (ft^3/sec)	Δ Discharge (ft^3/sec)
200	203	203	-
201	6	6	-
202	735	735	-
1	77	97	+20

The offsite hydraulic analyses resulted in a design that adequately captures and conveys the runoff to the logical outfalls. The east channel and culvert results are included in Table 7.

Table 7 POC 1 Hydraulic Results

River Station	100-Year Discharge (ft^3/sec)	Proposed WSE (ft)	Channel Velocity (ft)
9555	97.00	2229.43	1.43
9545	97.00	2229.42	1.49
9405	97.00	2229.24	2.17
9400	Check Dam as Inline Structure		
9395	97.00	2228.84	2.25
9255	97.00	2228.61	2.37
9250	Check Dam as Inline Structure		
9245	97.00	2228.02	3.01
9105	97.00	2227.77	2.20
9100	Check Dam as Inline Structure		
9095	97.00	2227.26	2.57
8955	97.00	2227.01	2.27
8950	Check Dam as Inline Structure		
8945	97.00	2226.53	2.45
8805	97.00	2226.29	2.27
8800	Check Dam as Inline Structure		
8795	97.00	2225.83	2.49
8655	97.00	2225.59	2.28
8650	Check Dam as Inline Structure		
8645	97.00	2224.99	2.76
8505	97.00	2224.76	2.19
8500	Check Dam as Inline Structure		
8495	97.00	2224.21	2.45
8450	97.00	2224.12	2.43

Table 8 below shows the results of the hydraulic analysis of POC 200.

Table 8 Hydraulic Results POC 200

River Station	100-Year Discharge (ft^3/sec)	Existing WSE (ft)	Proposed WSE (ft)	Δ WSE (ft)
563	203.00	2222.91	2222.91	0
518	203.00	2222.42	2222.44	0.02
469	203.00	2221.29	2221.24	-0.05
407	203.00	2219.86	2217.65	-2.21
357	203.00	2219.06	2217.43	-1.63
305	203.00	2218.35	2217.22	-1.13
229	203.00	2217.37	2216.79	-0.58
184	203.00	2216.75	2216.59	-0.16
129	203.00	2216.15	2216.31	0.16

Table 9 shows the results of the hydraulic analysis of POC 202. Even with no impact from the proposed roadway embankment, there seems to be some changes in water surface elevations. This is most likely due to tolerances within the HECRAS settings.

Table 9 Hydraulic Results POC 202

River Station	100-Year Discharge (ft^3/sec)	Existing WSE (ft)	Proposed WSE (ft)	Δ WSE (ft)
565	735.00	2222.63	2222.63	0
444	735.00	2219.00	2219.01	0.01
394	735.00	2218.07	2218.11	0.04
344	735.00	2217.05	2217.05	0
295	735.00	2216.37	2216.37	0
235	735.00	2215.69	2215.69	0
194	735.00	2214.71	2214.71	0
144	735.00	2212.14	2212.14	0
83	735.00	2210.40	2210.40	0

Results from the hydraulic analysis for POC 200 and POC 202 show that there are no significant impacts as a result of the proposed roadway. It should be noted that during a 100-Year event on the Santa Cruz River, the resulting water surface elevations are significantly higher than those for these local watersheds. Section 4 of this report discusses the hydraulic analyses and results for the Santa Cruz River.

4.0 Santa Cruz River

4.1 General

The Sunset Road alignment crosses the Santa Cruz River with the use of a 6-span bridge. The Santa Cruz River is a FEMA regulated watercourse; however, this project began with the intent to evaluate and mitigate the impact from placement of the bridge without interaction with FEMA. Early in the design development, Pima County Regional Flood Control District staff requested that the floodplain be remapped for this reach to include the proposed bridge.

The study reach of the Santa Cruz River is bounded by two fairly recent Letters of Map Revision (LOMRs). The downstream LOMR was prepared by Tetra-Tech for the District and has an Effective Date of September 03, 2010; Case No. 09-09-0233P, Reference 7. The upstream LOMR was prepared by JE Fuller for the District and has an Effective Date of November 28, 2011; Case No. 10-099-2016P, Reference 8. These two LOMR models were obtained through the District for evaluation and inclusion into this study. In both cases, this study reach was overlain with cross sections from the two LOMRs and the hydraulic models were incorporated into this hydraulic model in order to identify the tie-in point for both floodplain and floodway limits. Problems were found with the two LOMR HEC-RAS models. The downstream model piers for both bridges were not correctly represented in the HEC-RAS coding, piers did not extend into the channel, and the upstream model did not include the El Camino Del Cerro Bridge, which could result in artificially lower water surface elevations. Both issues were corrected with this project's HEC-RAS model. The original LOMR model results are included in Appendix D and the HEC-RAS models are included on the accompanying disc.

It should be noted that there will be a separate FEMA submittal and development of a Technical Data Notebook (TDN) for a Conditional Letter of Map Revision (CLOMR) for this study reach of the Santa Cruz River. Once construction is complete, a LOMR package will be submitted to FEMA to remap the floodplain and floodway.

Two proposed condition evaluations are included with this hydraulic evaluation, an interim condition and an ultimate condition. The interim condition represents the proposed condition that will be constructed as a result of this project; whereas, the ultimate condition attempts to account for the Silverbell Road future project. The interim scenario represents a typical perched bridge scenario with the potential for weir flow over Sunset Road. Once Silverbell Road is constructed to its final configuration the floodplain should be contained east of Silverbell Road. The plan is for Silverbell Road to be raised to 1-foot above the Regulatory flood elevation. A simplified method of using ineffective and blocked flow was used to approximate the ultimate condition. The ultimate analyses are only used for design purposes and will not be included in the FEMA submittals.

A separate sediment transport and bridge scour analysis is being conducted by the University of Arizona Civil Engineering Department; a summary is provided in Section 4.4.

4.2 Hydrology

No hydrologic analyses were conducted for the Santa Cruz River. Since this is a FEMA regulatory watercourse, the FEMA regulatory flow rates were used for the floodplain mapping and the District provided the 100-Year design flow

rate. Table 10, below, provides a summary of the flow rates used for the hydraulic study. The FEMA regulatory flow rates were obtained from the current Flood Insurance Study (FIS), Reference 9.

Table 10 Regulatory & Design Discharges, Santa Cruz River

Location	Drainage Area	Peak Discharges, (ft^3/sec)	Peak Discharges, (ft^3/sec)	Peak Discharges, (ft^3/sec)	Peak Discharges, (ft^3/sec)	Design Discharges, (ft^3/sec)
	(sq. mile)	10-% (10-Yr)	2-% (50-Yr)	1-% (100-Yr)	0.2-% (500-Yr)	1-% (100-Yr)
Upstream of Canada Del Oro Wash	3,232	21,800	48,000	70,000	107,400	80,000
Upstream of Rillito Creek	2,282	16,800	41,000	60,000	93,000	70,000
At Congress Street	2,222	16,800	41,000	60,000	93,000	70,000

4.3 Hydraulic Analysis & Bridge Design

The Santa Cruz River hydraulic analysis is divided into two separate analyses; Design and FEMA Floodplain. The design hydraulic modeling uses discharge rates that are larger than the FEMA regulatory discharge rates for freeboard and scour/bridge design. The FEMA hydraulic modeling is specifically for remapping of the current regulatory floodplain; preparation of a CLOMR and ultimately a LOMR to update the regulatory floodplain/floodway. The current regulatory floodplain/floodway was completed in the late 1980's. Topography has changed significantly since the current regulatory mapping effort was conducted which results in preparation of an existing condition model in lieu of a corrected effective model which is in accordance with District recommendations. The hydraulic modeling for both the design and FEMA efforts require updated topography and hydraulic parameters to establish the model. The model is then used in the initial and final design of the bridge and scour mitigation measures.

4.3.1 Mapping & Survey

As discussed in Section 1 of this report, the mapping used in conjunction with the floodplain mapping effort incorporates LIDAR data. The District provided the necessary LIDAR data sets for this study. Specifically, 2011 supplemented by 2008 LIDAR data was used to develop HECRAS cross section data for this study. The mapping control is included in Appendix A.

To develop the geometric data for use in HECRAS, the LIDAR data was evaluated using GIS. From the GIS platform, 3-D contours were created and exported in to MicroStation (CADD) platform. Once in the CADD platform, the 3-D contours were used to create surfaces (DTMs) from which the HECRAS cross sectional data was extracted and imported in to HECRAS for use in the hydraulic modeling.

The density of the 2011 LIDAR data set caused numerous problems with the GIS data translation. As a result prior to geometric extraction, it was necessary to thin the data. The GIS technician performed a dissemination exercise on all data, 2008 and 2011 to the same level of thinning which results in data suitable for 2-foot interval cross sections. For an in depth discussion to the process used, please refer to the ARCGIS documentation, Reference 10.

4.3.2 Hydraulic Model Parameters

Key parameters are necessary to in order to develop the hydraulic model for the Santa Cruz River study reach. These parameters include geometric data (cross section and bank stations) discharge rates and Manning's Roughness coefficients.

Geometric Data

The LIDAR data was used to develop the geometric data for the hydraulic models. Once the study reach was identified, an alignment and cross section locations were established based on a previous hydraulic model that was provided by the District. Digital Terrain Models (DTMs) were created within INROADS and MICROSTATION in order to extract cross section data that is spatially correct. The INROADS software package has built in capability to export geometric data from DTMs in GIS format that HECRAS can import directly into a geometry file. The District provided HECRAS models for the LOMRs upstream and downstream of this project's study reach. These spatially correct models were imported to the HECRAS model to extend the model into the LOMR reaches to simplify the tie-in locations. Bridge data for the reach were obtained through the use of As-Built Plans, field survey or a combination of both. Bridges were coded into the HEC-RAS model through the Bridge/Culvert editor.

Geometry from the upstream and downstream LOMRs were imported into this model from the "official" FEMA HEC-RAS models provided by the District. Before importing, it was determined that both models were spatially correct and on the same coordinate system as this project's model. Both LOMR models were coded using the NAVD88 datum so no additional adjustment was needed to translate to this project's datum. As mentioned in the introduction of this section, the downstream LOMR that was prepared by Tetra-Tech for the District with an effective Date of September 03, 2010; Case No. 09-09-0233P did not have the piers for the Cortaro Road Bridge and Ina Road Bridge coded properly. The bridge piers for the Cortaro Road Bridge were added based on the As-Built plans and the piers for the Ina Road Bridge were added based on the survey and As-Built plans. The cross sections for the bridges were not adjusted; only the pier data was revised for this project's hydraulic model.

Manning's Roughness Estimation

Roughness coefficients were evaluated in accordance with the District's Technical Policy 019, which incorporates the approach for developing Manning's Roughness Coefficients based on Reference 11. The following steps were taken to evaluate the Manning's Roughness Coefficient with the inclusion of vegetation:

1. 2011 Aerial Maps were analyzed for vegetation densities by PB's Sub-Consultant, University of Arizona Civil Engineering Department. The 2011 aerial photos were loaded into GIS platform and densities evaluated. This information was provided to PB for use in the roughness estimation and are included in Appendix D.
2. The 2011 aerial maps were referenced into CADD and delineated based on the vegetation density analysis and location of vegetation; i.e. overbank or main channel, etc…
3. A field visit was conducted to examine type of vegetation, height of vegetation, confirm density, and also identify obstructions. Photographs and notes were taken at various locations throughout the reach.
4. A photo-log was created documenting the findings from the field visit.

5. Notes and photographs were then translated into the numerical factors to develop a roughness coefficient according to the document "Selection of Manning's Roughness Coefficient for Natural and Constructed Vegetated and Non-Vegetated Channels, and Vegetation Maintenance Plan Guidelines for Vegetated Channels in Central Arizona," Phillips and Tadayon, Reference 12.
6. Roughness coefficients were computed for the different regions.
7. HECRAS Model cross sections were overlain onto the aerial photos and each associated roughness logged for use in the hydraulic model.

Computations, Photo-log and Exhibits showing the roughness coefficients for similar vegetative areas are included in Appendix D.

Table 11 Santa Cruz River Historic Peak Discharges (USGS Website)

DATE	Cortoro, Az DISCHARGE	Tucson, Az DISCHARGE
(--)	(ft^3/sec)	(ft^3/sec)
October 02, 1983	65,000	52,700
January 19, 1993	N/A	37,400
July 31, 2006	40,900	7,200
July 31, 2007	11,400	13,200
January 28, 2008	4,270	N/A
July 20, 2008	N/A	4,500
July 04, 2009	2,130	4,470
July 20, 2009	N/A	4,500
July 31, 2010	16,800	11,400
September 10, 2011	12,000	N/A
September 15, 2011	N/A	9,880
July 15, 2012	8,230	1,620
July 20, 2013	1,160	1,240

Revised Roughness Coefficients

Recent evaluation of historic photos (1992-2011) initiated the need to review the procedure for estimating Manning's Roughness Coefficients for the Santa Cruz River from Sweetwater Road to Ina Road. On July 29, 2014 a meeting was held at the Pima County Regional Flood Control District (District) to discuss the estimation of roughness coefficients used for the Santa Cruz River CLOMR being prepared in association with the Sunset Road project, meeting minutes are included in Appendix D. Upon review of a number of historic photos, the consensus was that the majority of the vegetation within the main channel is scoured out during high flow events.

Further investigation of flow rates on the Santa Cruz River in comparison to the historic aerial photos was conducted in order to evaluate realistic Manning's coefficients. Peak stream flow data was obtained for specific dates through the USGS website; (http://nwis.waterdata.usgs.gov/az/nwis/peak), for two locations on the Santa Cruz River@ Cortaro, Arizona and @ Tucson, Arizona. PDFs are included in Appendix D and Table 11 contains peak flow rates for key flow events and those from 2006 to 2013. The dates of photos showing minor amount of vegetation were compared to the historic peak flow dates.

The FEMA regulatory flow rates are provided in Table 10. A comparison of the regulatory flow rates with the 1983 flow event, results in the October 1983 flood event falling between a 50-Yr and 100-Yr return period. Review of the post flood aerial photo shows that the majority of vegetation within the main channel was removed.

Photo 1, Aerial Photo after 1983 Flood Event (http://www.geo.arizona.edu/Tucson/image_archive/flood83/flood83.html,

Subject: Santa Cruz
Date: December 2, 1984
Copyright Information: 1984 - Peter Kresan
Description: Santa Cruz River at Ina Road. Aerial view south.

Two key photos used for the comparison of post flood events are included for reference in determining the large event Manning's Roughness Coefficients. Photo 1 shows the resulting vegetation loss after the 1983 flood. This photo was obtained through the University of Arizona website and shows that the Santa Cruz River main channel lost most of the vegetation. Photo 2 also shows a similar result at the Ina Road bridge location after the 2006 flood event. In both cases the vegetation within the main channel was stripped of the majority of vegetation after the flood events.

There has not been a significant flood event on the Santa Cruz River since 2006. As a result, the vegetation has had time to re-establish within the main channel, see the Santa Cruz River Photo Log in Appendix D.

As a result the vegetative roughness coefficients are no longer valid. Photographs for the key events, October 1983 and July 2006, correlate to regulatory flow rates less than the 100-Year regulatory discharge. Since these events significantly scoured the vegetation from the main channel, a realistic roughness coefficient falls within the FIS range of 0.025 to 0.035. Main channel roughness coefficients are in accordance with Table 12, based on the segments of the reach. It should be noted that the main difference between the sub reaches, identified in Table 12, is that the middle reach is not bank protected; it is a natural meandering alignment. Therefore, the higher end of the range was selected for this area. The upper and lower segments contain 100-Year event within the banks resulting in higher velocities and a greater affinity to scour the vegetation.

The Manning's Roughness Coefficient estimation (Tech Policy 019, Reference 11) previously discussed results in much higher roughness coefficients resulting in a higher water surface elevation. After a review of the results and the historic photos with District staff it was determined that the higher values are more in-line with the more frequent events like the 10-Year event. To take the evaluation one step further, the Manning's roughness coefficients were reviewed for

Photo 2, Aerial Photo after 2006 Flow Event (Google Earth Historic Photos) – Majority of Vegetation Scoured from main channel.

the LOMR upstream and downstream of this study reach. The FEMA models used the same main channel roughness for the 10-Year profile as in the 100-Year profile. To follow this approach, the main channel roughness was not revised for the 10-Year event. The main channel roughness coefficients estimated using the photos were used for all profiles. Table 12 provides the ranges of roughness coefficients used for this analysis. These values fall within the range reported in the Flood Insurance Study.

Table 12 Santa Cruz River Roughness Coefficients

Sub-Reach	N
Upstream of El Camino Del Cerro Bridge (Begin Project)	0.025
El Camino Del Cerro Bridge to Ina Road Bridge	0.030-0.035
Downstream of Ina Road Bridge (End Project)	0.025

4.3.3 Bridge Sizing & Design

The design effort consists of evaluating multiple bridge configurations and constant coordination with the design team. Ultimately, the final bridge configuration is a 6-Span, 720-foot Bridge with cylindrical columns and drilled shafts for a foundation. Two types of abutment configurations were considered; vertical and sloping. A sloping abutment was chosen due to a significant reduction in scour when compared to the resulting scour depths with a vertical abutment configuration. A key component to bridge configuration, pier spacing, is the ability to span the ACOE jurisdictional and wetland delineations within the vicinity of the proposed bridge. The bridge sizing procedure began with spanning the approximated floodway and checking the increase in water surface elevation upstream of the bridge.

During the initial bridge sizing exercise a 960-foot bridge was sized to accommodate the allowable 0.1-foot increase in water surface elevation at the floodway fringe upstream of the proposed bridge site. This bridge configuration was eliminated early in the design development due to the proximity of the western abutment to Silverbell Road. This configuration would require the ultimate build-out for Silverbell Road and was cost prohibitive for this project. Discussions with the District resulted in allowing more of an increase of water surface elevation upstream of the bridge. A maximum increase of 1-foot was established in order to size the bridge. The 720-foot 6-span bridge meets the revised allowable water surface increase; however, after reviewing the impact to private properties west of Silverbell Road south of the project site, it was determined that an alternative was necessary to mitigate this increase in water surface elevation. Two alternatives were investigated to mitigate the increase in water surface elevation; use of grading under the bridge to increase conveyance and the potential use of a culvert(s) behind the abutment that could be used as an equipment and/or pedestrian underpass. Preliminary conveyance calculations showed that grading produced significantly more conveyance than culverts would, at a fraction of the cost, and it generated a source of fill dirt that would be needed for the roadway embankment and the bridge approach. The team agreed to eliminate the culvert option and proceed with the grading option. As a result, grading in the left overbank was modeled and provides the necessary increase in conveyance to minimize the back water increases resulting from the proposed bridge.

The freeboard requirements for the proposed bridge are based on Pima County's policy for establishing scour and freeboard, Reference 13. The allowable freeboard is 1-foot for the 500-Year design flow and 3-feet for the 100-Year design flow. Since the bridge is set on a crest vertical curve the freeboard varies along the length of the bridge. Actual freeboard results are provided in the following section of this report.

4.4 Hydraulic Model Results

The Santa Cruz River hydraulic results are provided for both the Design and FEMA modeling conditions. Each analysis is discussed in separate sections of this report, below. Detailed results are provided for specific models are also included. Additional results and the HEC-RAS models for all hydraulic analyses with various alternatives are included in Appendix D.

4.4.1 Design Hydraulic Results

The purpose of the design model is to size the bridge and establish the freeboard and scour for foundation design. Figure 9, provides an overview of the design hydraulic results for both the 100-Year and 500-Year events and includes the ultimate condition for a Silverbell Road future condition. For the interim configuration, the freeboard ranges from 1.3-feet to 7.3-feet for the 100-Year design discharge and -0.7-feet to 5.2-feet for the 500-Year design discharge with the worse case occurring on the west abutment. The 500-Year design discharge actually results in a water surface elevation higher than the west low chord. The cause is attributed to the debris loading and the bridge length just spanning the proposed floodway. Since the Freeboard requirements are not met at the west abutment, a design exception may be needed. Floodplain results are not presented in this section only the hydraulic results for bridge design are provided. The interim design condition does allow approximately 1850-ft^3/sec to cross over Sunset Road at the intersection with Silverbell Road for the 100-Year design discharge and 4750-ft^3/sec in for the 500-Year design discharge. Scour analysis shows that there will not be any scour as a result of over topping discharge; however, Ford walls will be placed upstream and downstream of Sunset Road as a precautionary measure to mitigate the potential effects of scour.

4.4.2 FEMA Hydraulic Results

The FEMA model is intended to remap the current regulatory floodplain and floodway. A separate TDN will be prepared and submitted to FEMA to remap this project revising the current floodplain and floodway to incorporate the proposed Sunset Road Bridge. The existing condition model was created in order to establish a base condition to compare the changes in water surface elevation from the proposed improvements. The first step is to identify the tie-in locations to the current regulatory water surface elevations. Table 13 provides the results of the existing condition 100-Year model and the tie-in locations for the upstream and downstream LOMR water surface elevations. In accordance with FEMA requirements the tie-in location water surface elevation must be within 6-inches of the current regulatory water surface elevation. These locations are identified by the highlighted rows on the table.

The proposed condition model incorporates the proposed bridge configuration. Results are compared against the existing condition model to determine if additional mitigation measures are necessary. Table 14 provides the results from the 100-Year proposed condition analysis and compares them against the existing condition analysis results to show the potential change in water surface elevation. Figure 10 provides the hydraulic results with FEMA discharge rates for the proposed bridge. There is a significant decrease in water surface elevation when compared to the design analysis; the freeboard with the FEMA flow rate ranges from 2.4-feet to 8.3-feet for the 100-Year FEMA discharge and 0.2-feet to 5.4-feet for the 500-Year FEMA discharge with the worse condition located at the west abutment. Calculations are included in Appendix D along with the Work Maps that will be submitted to FEMA with the TDN.

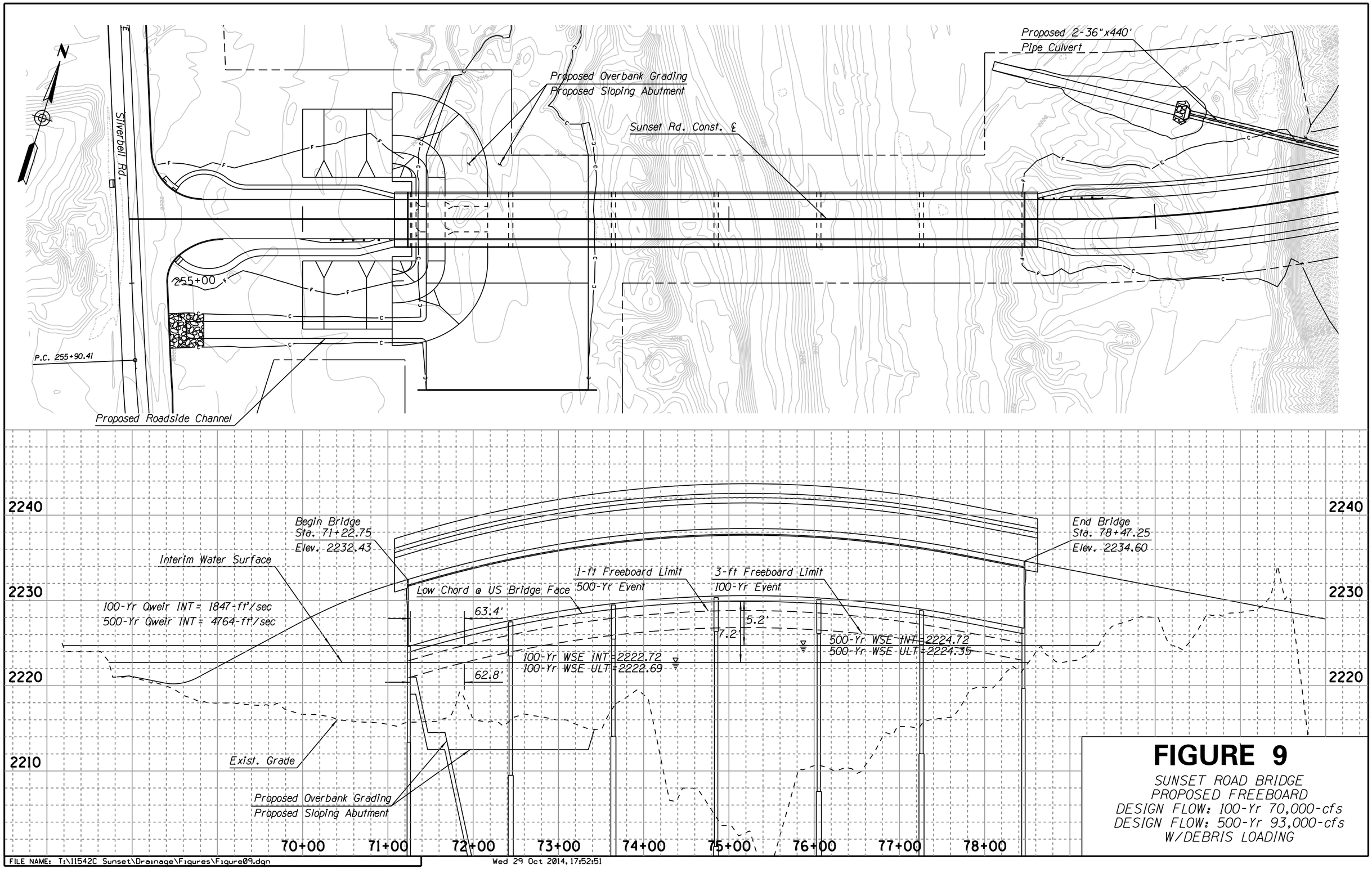

FIGURE 9

SUNSET ROAD BRIDGE
PROPOSED FREEBOARD
DESIGN FLOW: 100-Yr 70,000-cfs
DESIGN FLOW: 500-Yr 93,000-cfs
W/DEBRIS LOADING

FILE NAME: T:\11542C Sunset\Drainage\Figures\Figure09.dgn

Wed 29 Oct 2014, 17:52:51

TABLE 13 LOMR TIE-IN AND EXISTING CONDITION RESULTS
4RTSUN Sunset Road, Silverbell Road to I-10
Santa Cruz River Hydraulic Model Comparison

JE Fuller 100-Yr Run (Case No. 10-09-2016P)								Sunset 100-Yr Existing Cond							Comparison		
Reach	River Sta	Equiv STA	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Δ Froude	Δ Min Ch	Δ WSE
	(miles)	(ft)		(cfs)	(ft)	(ft)					(cfs)	(ft)	(ft)			(ft)	(ft)
1	26.372	59588	Regulatory	60000	2226.99	2249.78	0.54	Sunset	59588	100-Yr	60000	2226.99	2249.78	0.54	0	0	0
1	26.278	59088	Regulatory	60000	2226.21	2248.48	0.61	Sunset	59088	100-Yr	60000	2226.21	2248.49	0.61	0	0	0.01
1	26.172	58533	Regulatory	60000	2224.44	2244.94	0.85	Sunset	58533	100-Yr	60000	2224.44	2245.07	0.84	-0.01	0	0.13
1	26.068	57982	Regulatory	60000	2224.2	2242.74	0.87	Sunset	57982	100-Yr	60000	2224.2	2244.28	0.67	-0.2	0	1.54
1	25.988	57561	Regulatory	60000	2222.54	2241.28	0.78	Sunset	57561	100-Yr	60000	2222.54	2243.29	0.62	-0.16	0	2.01
1	25.913	57165	Regulatory	60000	2221.13	2240.97	0.69	Sunset	57165	100-Yr	60000	2221.13	2243.42	0.5	-0.19	0	2.45
1	25.851	56836	Regulatory	60000	2220.88	2240.67	0.59	Sunset	56836	100-Yr	60000	2221	2242.61	0.52	-0.07	0.12	1.94
								Sunset	56608	100-Yr	60000	2221	2243.02	0.36			
								Sunset	56526 El	0	Bridge	0	0	0			
								Sunset	56440	100-Yr	60000	2220.5	2239.09	0.57			
								Sunset	55999	100-Yr	60000	2217	2235.68	0.83			
								Sunset	55499	100-Yr	60000	2216	2234.18	0.74			
								Sunset	54999	100-Yr	60000	2214	2233.15	0.66			
								Sunset	54499	100-Yr	60000	2213	2230	0.84			
								Sunset	53999	100-Yr	60000	2211	2228.98	0.67			
								Sunset	53499	100-Yr	60000	2207	2228.06	0.66			
								Sunset	52999	100-Yr	60000	2205	2227.48	0.56			
								Sunset	52499	100-Yr	60000	2204	2224.81	0.83			
								Sunset	51999	100-Yr	60000	2203	2223.82	0.56			
								Sunset	51499	100-Yr	60000	2201	2223.27	0.44			
								Sunset	51057	100-Yr	60000	2199	2221.35	0.67			
								Sunset	50945	100-Yr	60000	2199	2219.81	0.81			
								Sunset	50500	100-Yr	60000	2198	2219.26	0.71			
								Sunset	49996	100-Yr	60000	2197	2218.07	0.57			
								Sunset	49501	100-Yr	60000	2197	2215.42	0.83			
								Sunset	48999	100-Yr	60000	2196	2214.62	0.54			
								Sunset	48499	100-Yr	60000	2195	2211.39	0.94			
								Sunset	47499	100-Yr	70000	2193.11	2209.95	0.39			
								Sunset	46999	100-Yr	70000	2191	2206.38	0.76			
								Sunset	46499	100-Yr	70000	2189	2203.07	1			
								Sunset	45999	100-Yr	70000	2189	2200.41	0.97			
								Sunset	45499	100-Yr	70000	2187	2199.25	0.71			
								Sunset	44999	100-Yr	70000	2186	2197.6	0.71			
								Sunset	44499	100-Yr	70000	2184	2195.94	0.69			
								Sunset	43999	100-Yr	70000	2183	2194.97	0.56			
								Sunset	43499	100-Yr	70000	2181	2193.58	0.62			
								Sunset	42999	100-Yr	70000	2180	2190.49	0.91			
								Sunset	42499	100-Yr	70000	2175	2190.18	0.48			
								Sunset	41999	100-Yr	70000	2176	2190.18	0.3			
								Sunset	41499	100-Yr	70000	2175	2189.35	0.45			
								Sunset	40999	100-Yr	70000	2174	2188.59	0.45			

								Sunset	40499	100-Yr	70000	2172	2185.33	0.97			
								Sunset	39999	100-Yr	70000	2171	2184.07	0.63			
Tetra Tech 100-Yr Run (Case No. 09-09-0233P)								Sunset 100-Yr Existing Cond							Comparison		
Reach	River Sta	Equiv STA	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Δ Froude	Δ Min Ch	Δ WSE
		(ft)		(cfs)	(ft)	(ft)					(cfs)	(ft)	(ft)			(ft)	(ft)
Reach #1	22.5	39399	PF 1	70000	2168	2182.81	0.51	Sunset	39399	100-Yr	70000	2168	2182.81	0.51	0	0	0
Reach #1	22.4	38909	PF 1	70000	2168	2182.21	0.42	Sunset	38909	100-Yr	70000	2168	2182.21	0.42	0	0	0
Reach #1	22.31	38409	PF 1	70000	2168	2181.47	0.41	Sunset	38409	100-Yr	70000	2168	2181.47	0.41	0	0	0
Reach #1	22.21	37929	PF 1	70000	2166	2180.6	0.43	Sunset	37929	100-Yr	70000	2166	2180.6	0.43	0	0	0
Reach #1	22.12	37509	PF 1	70000	2166	2179.93	0.45	Sunset	37509	100-Yr	70000	2166	2179.93	0.45	0	0	0
Reach #1	22.02	36859	PF 1	70000	2164	2178.57	0.5	Sunset	36859	100-Yr	70000	2164	2178.57	0.5	0	0	0
Reach #1	21.93	36439	PF 1	70000	2162	2177.15	0.58	Sunset	36439	100-Yr	70000	2162	2177.15	0.58	0	0	0

TABLE 14 EXISTING AND PROPOSED CONDITION COMPARISON
4RTSUN Sunset Road, Silverbell Road to I-10
Santa Cruz River Hydraulic Model Comparison

Sunset 100-Yr Existing Cond							Sunset 100-Yr Proposed Interim Alt-2							Comparison		
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Δ Froude	Δ Min Ch	Δ WSE
			(cfs)	(ft)	(ft)					(cfs)	(ft)	(ft)			(ft)	(ft)
Sunset	59588	100-Yr	60000	2226.99	2249.78	0.54	Sunset	59588	100-Yr	60000	2226.99	2249.78	0.54	0	0	0
Sunset	59088	100-Yr	60000	2226.21	2248.49	0.61	Sunset	59088	100-Yr	60000	2226.21	2248.49	0.61	0	0	0
Sunset	58533	100-Yr	60000	2224.44	2245.07	0.84	Sunset	58533	100-Yr	60000	2224.44	2245.07	0.84	0	0	0
Sunset	57982	100-Yr	60000	2224.2	2244.28	0.67	Sunset	57982	100-Yr	60000	2224.2	2244.28	0.67	0	0	0
Sunset	57561	100-Yr	60000	2222.54	2243.29	0.62	Sunset	57561	100-Yr	60000	2222.54	2243.29	0.62	0	0	0
Sunset	57165	100-Yr	60000	2221.13	2243.42	0.5	Sunset	57165	100-Yr	60000	2221.13	2243.42	0.5	0	0	0
Sunset	56836	100-Yr	60000	2221	2242.61	0.52	Sunset	56836	100-Yr	60000	2221	2242.61	0.52	0	0	0
Sunset	56608	100-Yr	60000	2221	2243.02	0.36	Sunset	56608	100-Yr	60000	2221	2243.02	0.36	0	0	0
Sunset	56526 El C	0	Bridge	0	0	0	Sunset	56526 El C	0	Bridge	0	0		0	0	0
Sunset	56440	100-Yr	60000	2220.5	2239.09	0.57	Sunset	56440	100-Yr	60000	2220.5	2239.09	0.57	0	0	0
Sunset	55999	100-Yr	60000	2217	2235.68	0.83	Sunset	55999	100-Yr	60000	2217	2235.68	0.83	0	0	0
Sunset	55499	100-Yr	60000	2216	2234.18	0.74	Sunset	55499	100-Yr	60000	2216	2234.18	0.74	0	0	0
Sunset	54999	100-Yr	60000	2214	2233.15	0.66	Sunset	54999	100-Yr	60000	2214	2233.15	0.66	0	0	0
Sunset	54499	100-Yr	60000	2213	2230	0.84	Sunset	54499	100-Yr	60000	2213	2230	0.84	0	0	0
Sunset	53999	100-Yr	60000	2211	2228.98	0.67	Sunset	53999	100-Yr	60000	2211	2228.99	0.67	0	0	0.01
Sunset	53499	100-Yr	60000	2207	2228.06	0.66	Sunset	53499	100-Yr	60000	2207	2228.07	0.66	0	0	0.01
Sunset	52999	100-Yr	60000	2205	2227.48	0.56	Sunset	52999	100-Yr	60000	2205	2227.49	0.55	-0.01	0	0.01
Sunset	52499	100-Yr	60000	2204	2224.81	0.83	Sunset	52499	100-Yr	60000	2204	2224.56	0.88	0.05	0	-0.25
Sunset	51999	100-Yr	60000	2203	2223.82	0.56	Sunset	51999	100-Yr	60000	2203	2223.28	0.61	0.05	0	-0.54
Sunset	51499	100-Yr	60000	2201	2223.27	0.44	Sunset	51499	100-Yr	60000	2201	2222.49	0.5	0.06	0	-0.78
Sunset	51057	100-Yr	60000	2199	2221.35	0.67	Sunset	51057	100-Yr	60000	2199	2221.61	0.54	-0.13	0	0.26
							Sunset	51000 Pro	0	Bridge	0	0		0	0	0
Sunset	50945	100-Yr	60000	2199	2219.81	0.81	Sunset	50945	100-Yr	60000	2199	2220.53	0.59	-0.22	0	0.72
Sunset	50500	100-Yr	60000	2198	2219.26	0.71	Sunset	50500	100-Yr	60000	2198	2219.29	0.73	0.02	0	0.03
Sunset	49996	100-Yr	60000	2197	2218.07	0.57	Sunset	49996	100-Yr	60000	2197	2218.07	0.57	0	0	0
Sunset	49501	100-Yr	60000	2197	2215.42	0.83	Sunset	49501	100-Yr	60000	2197	2215.42	0.83	0	0	0
Sunset	48999	100-Yr	60000	2196	2214.62	0.54	Sunset	48999	100-Yr	60000	2196	2214.62	0.54	0	0	0
Sunset	48499	100-Yr	60000	2195	2211.39	0.94	Sunset	48499	100-Yr	60000	2195	2211.39	0.94	0	0	0
Sunset	47499	100-Yr	70000	2193.11	2209.95	0.39	Sunset	47499	100-Yr	70000	2193.11	2209.95	0.39	0	0	0
Sunset	46999	100-Yr	70000	2191	2206.38	0.76	Sunset	46999	100-Yr	70000	2191	2206.38	0.76	0	0	0
Sunset	46499	100-Yr	70000	2189	2203.07	1	Sunset	46499	100-Yr	70000	2189	2203.07	1	0	0	0
Sunset	45999	100-Yr	70000	2189	2200.41	0.97	Sunset	45999	100-Yr	70000	2189	2200.41	0.97	0	0	0
Sunset	45499	100-Yr	70000	2187	2199.25	0.71	Sunset	45499	100-Yr	70000	2187	2199.25	0.71	0	0	0
Sunset	44999	100-Yr	70000	2186	2197.6	0.71	Sunset	44999	100-Yr	70000	2186	2197.6	0.71	0	0	0
Sunset	44499	100-Yr	70000	2184	2195.94	0.69	Sunset	44499	100-Yr	70000	2184	2195.94	0.69	0	0	0
Sunset	43999	100-Yr	70000	2183	2194.97	0.56	Sunset	43999	100-Yr	70000	2183	2194.97	0.56	0	0	0
Sunset	43499	100-Yr	70000	2181	2193.58	0.62	Sunset	43499	100-Yr	70000	2181	2193.58	0.62	0	0	0
Sunset	42999	100-Yr	70000	2180	2190.49	0.91	Sunset	42999	100-Yr	70000	2180	2190.49	0.91	0	0	0
Sunset	42499	100-Yr	70000	2175	2190.18	0.48	Sunset	42499	100-Yr	70000	2175	2190.18	0.48	0	0	0
Sunset	41999	100-Yr	70000	2176	2190.18	0.3	Sunset	41999	100-Yr	70000	2176	2190.18	0.3	0	0	0
Sunset	41499	100-Yr	70000	2175	2189.35	0.45	Sunset	41499	100-Yr	70000	2175	2189.35	0.45	0	0	0
Sunset	40999	100-Yr	70000	2174	2188.59	0.45	Sunset	40999	100-Yr	70000	2174	2188.59	0.45	0	0	0
Sunset	40499	100-Yr	70000	2172	2185.33	0.97	Sunset	40499	100-Yr	70000	2172	2185.33	0.97	0	0	0
Sunset	39999	100-Yr	70000	2171	2184.07	0.63	Sunset	39999	100-Yr	70000	2171	2184.07	0.63	0	0	0
Sunset	39399	100-Yr	70000	2168	2182.81	0.51	Sunset	39399	100-Yr	70000	2168	2182.81	0.51	0	0	0

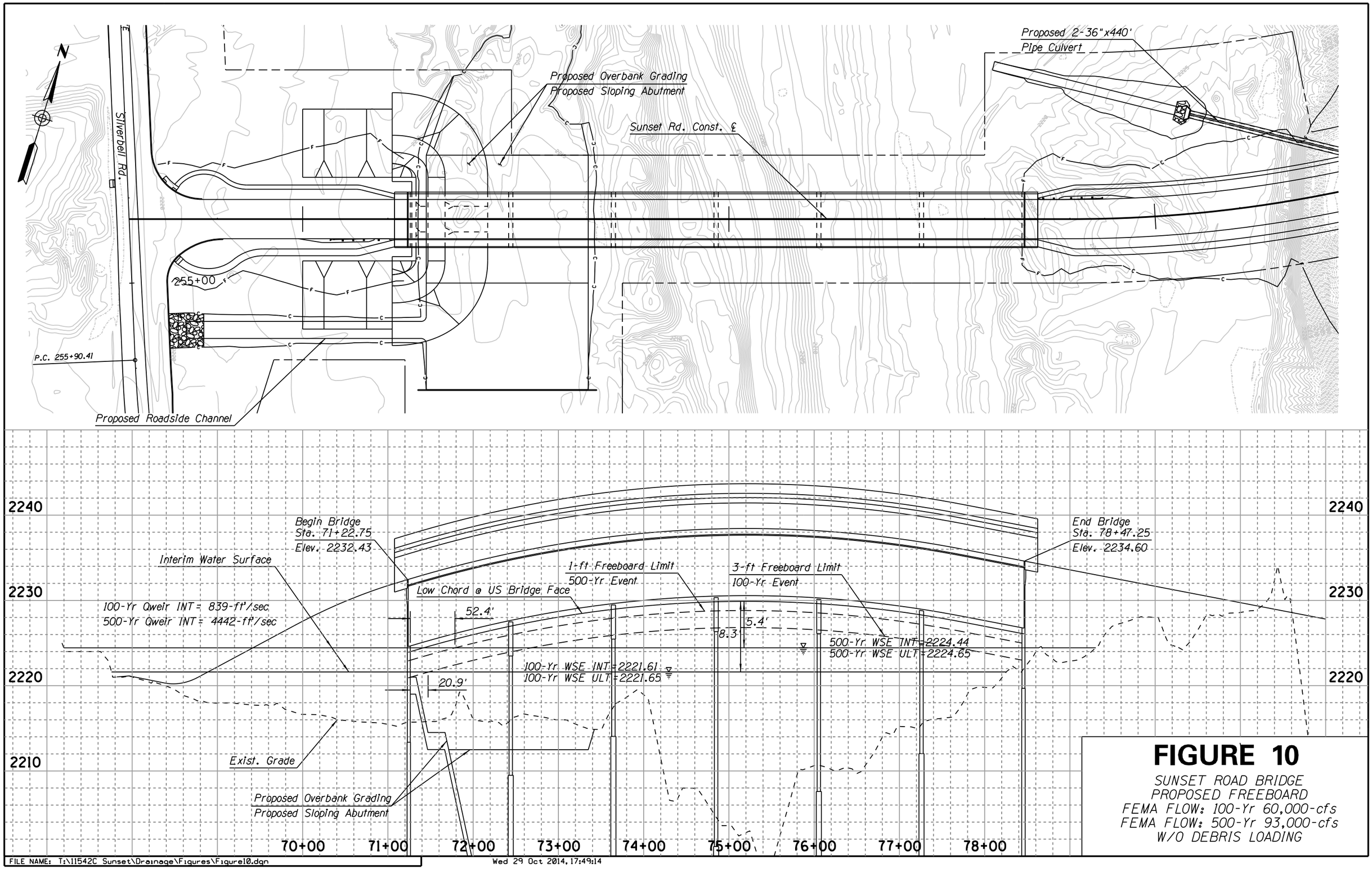

FIGURE 10

SUNSET ROAD BRIDGE
PROPOSED FREEBOARD
FEMA FLOW: 100-Yr 60,000-cfs
FEMA FLOW: 500-Yr 93,000-cfs
W/O DEBRIS LOADING

FILE NAME: T:\11542C Sunset\Drainage\Figures\Figure10.dgn

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4.5 Sediment Transport & Scour Evaluation

Dr Jennifer Duan with the University of Arizona has provided the following summary regarding the scour and sediment transport analysis for this project. A separate scour analysis report is provided in Appendix D.

Summary of Bridge Scour Study

Jennifer G. Duan, PhD, P.E.

The bridge scour study at the proposed Sunset Bridge site has three components: preliminary assessment; total scour calculation; and HEC-RAS sediment transport model. The following is a summary of the key assumptions, methods, and results from these three parts. Detailed explanations of results can be found in the report entitled "Bridge Scour Report for the Proposed Sunset Bridge" submitted to Pima County Department of Transportation (PCDOT).

Preliminary Study

In the preliminary assessment, we analyzed vegetation coverage, collected sediment samples for gradation analysis, quantified meandering migration distance in 10 and 75 years, and analyzed flow skewness angles at the bridge site using SRH2D model. The averaged vegetation coverage for HEC-RAS model covered area is 42.19% using 2011 aerial photos. Bed surface materials are coarse sand and gravels. The median sediment sizes range from 0.55 to 8.10 mm. The base flow channel at the bridge location tends to migrate to the West toward the Silverbell Road. The migration distance of channel curvature center in 75 years is approximately 2319 ft. The current bridge alignment is nearly perpendicular to flow velocity in 100-year design flow. The maximum skewness angle is 21°.

Total Scour Depth

From data obtained in preliminary study, we calculated the total scour depth at the piers and both abutments using 100-year and 500-year flood flows. The toe of the East Abutment is above water surface for both 100-year and 500-year flows, so no scour will occur there. The local scour depth at the piers and the West Abutment were calculated as the summation of contraction scour (also called general scour), local scour, long-term bed degradation, and bend scour, as outlined in "Guidelines for Establishing Scour and Freeboard for Bridges in Pima County, August 2012".

The long-term bed degradation is calculated based on the Federal Highway Administration's "Stream Stability at Highway Structures Manual" (HEC 20) recommended by HEC-18 (Evaluating Scour at Bridges, 5th edition, Hydraulic Engineering Circular No. 18, 2012). Those results are compared with the results using the method in the City of Tucson (COT) Drainage Manual. The base elevation control is chosen as the top of soil cement at the Ina Road Bridge. The South end of soil cement cap is approximately at the toe elevation of as-built bridge pier, 2158.0 ft (NAVD88). This elevation is shown in HEC-RAS model, and also verified by the recent survey at the soil cement section. Therefore, 2158.0 ft is used as the control elevation.

In HEC 20 Manual, two scenarios were considered to calculate the long-term bed degradation depth: one is clear water; the other is to assume a reduction in sediment supply that will cause channel incision. 10-year flow is recommended for the long-term degradation analysis. Clear water scenario assumes sediment concentration is nearly zero, so channel bed is incised to achieve an equilibrium slope. The equilibrium slope can be calculated by two approaches: the Shields parameter approach (Equation 6.17 in HEC 20), and Meyer-Peter Muller equation approach (Equation 6.18 in HEC 20). The scenario of sediment reduction assumes a fractional reduction of sediment load that will result in a reduction of channel slope through degradation. The new equilibrium slope will produce hydraulic conditions where the channel sediment transport capacity matches the upstream sediment supply. Two equations in

HEC 20 can be used to calculate the equilibrium slope due to sediment reduction: Equation 6.23 and Equation 6.24. Eq. 6.23 needs the calculation of sediment transport capacity. According HEC-20, the sediment capacity equation (Eq. 6.19 - 6.22 in HEC-20) is developed for channel slope less than 0.002. Its applicability to this reach, which has an averaged channel slope of 0.0025, has not been verified. Therefore, the results by using Eq. 6.23 in HEC-20 are for reference only. This study assumes sediment supply will reduce by 10% and 30% in the future.

In the City of Tucson Drainage Manual, two scenarios are recommended to calculate the long-term bed degradation depth: one is clear water scour using Equation 6.25 (Page 6.32) to calculate the equilibrium channel slope; the other is to assume an urban growth scenario that will cause channel incision and storm flow increase. 10-year flow is recommended for the long-term degradation analysis. An aggressive urban growth scenario is assumed, in which channel thalweg will be incised 20 ft, and 10-year flow will increase by 5000 cfs.

Results showed if assuming clear water scour, the maximum long-term degradation ranges from 25.96 ft calculated from COT Drainage Manual to 39.99 ft from Eq. 6.18 in HEC-20. Since it's unlikely clear water scour situation will occur in this reach of Santa Cruz River, the sediment load reduction assumption is more realistic. Therefore, Eq.6.23 and 6.24 in HEC-20 are the choices for the long-term degradation estimation. Results from Eq.6.23 showed aggradation at the bridge site. Since the validity of Eq.6.23 to this reach is not verified, results from Eq.6.23 were neglected. The long term degradation depth at the bridge site calculated from Eq. 6.24 in HEC-20 is 2.6 ft for 10% sediment reduction and 8.16 ft for 30% sediment reduction. The urban growth scenario using COT Manual also showed 6.25 ft of degradation at the bridge site. This study assumes a minor sediment load reduction in the bridge reach, the long-term degradation rate from Eq.6.24 in HEC-20 is 2.6 ft. ***This estimation is optimistic because there is no grade control structure in this 17,000 ft river reach from the bridge site to the Ina Road Bridge. If sediment supply will significantly reduce in the future, a system wide incision will occur in this reach, which may result in a considerable incision at the bridge site. Therefore, periodic monitoring of bed elevation changes near the bridge site should be carried on to ensure stable bed elevation. In case of incision, a grade control structure should be built at the bridge site or within 2000 ft downstream from the bridge site.***

The bend scour is calculated by using the method in the COT Drainage Manual. The bend scour depth relates to channel curvature, flow depth, and velocity. 10-year flow is used for the calculation. The calculated bend scour depth is 2.21 ft for both interim and ultimate geometry.

The contraction and local scour depth are calculated based on HEC-18 recommended CSU equation (Eq.7.1 in HEC-18). The calculation used the preliminary design, which has five pier groups and each group has two circular pier aligned perpendicular to the bridge centerline spacing at 20 ft. Three pier diameters, 4 ft, 6 ft, and 8 ft, are considered. Both 100-year and 500-year flows are used. The alignment of the bridge is assumed to be $\pm 15^{o}$ to the flow direction. Two sets of geometric data, interim and ultimate, are used. The maximum scour depths from these two geometrical data are chosen for calculating the total scour depth.

The debris width is assumed to be 4 ft. The debris can be of triangular and rectangular shapes as suggested in HEC-18. The triangular shaped debris is more realistic in our region based on observation. The debris is assumed to extend up to the local flow depth. The equivalent diameter with the consideration of 4 ft wide debris throughout the flow depth is calculated using the method in HEC-18.

The bed material size distributions are provided by NCS Consultants, LLC at seven boring holes at the bridge site. The data are separated into two groups: the top layer (0.0 ft – 20.0 ft), and the bottom layer (40.0 ft). If soil data at 40 ft is not available, we used the data closest to the 40 ft, for example at 35-36 ft. There are three bore holes on the left floodplain, three in the channel, and one on the right floodplain. Sediment samples on the left floodplain were mixed to obtain the average sediment size distribution, and sediment samples in the channel were also mixed to obtain the average. To obtain the averaged grain size distribution, we first interpolate grain size distributions to standard gradations for Sieve Number #200 – 3". Then, we average the percentages of each size fraction. At last, the D_{50} was obtained from the grain size distribution curve of the mixture.

The contraction scour is the scour caused by the contraction of cross section at the bridge section. Two flow conditions are commonly assumed: one is clear water, and the other is live bed. Both methods were used for calculating contraction scour at the bridge site. The method using clear water assumption always predicts larger contraction scour depth than the method using the live bed method. At the bridge site, suspended sediment concentration is very high during flood events, and significant sediment transport were also observed in this reach during flood events. Therefore, live-bed scour assumption is most suitable for predicting contraction scour in this reach. Besides, HEC-18 also recommends the adaption of smaller contraction scour depths from both methods. Therefore, the contraction scour depth is the results using the Live-Bed scour relation in HEC-18.

The pier scour depth was calculated using the maximum velocity and flow depth at the bridge section. The debris was assumed to be triangular or rectangular shaped. Additionally, we also calculated the maximum scour depth if adding the full width of debris to the pier diameter. If adding the full width of debris to the pier diameter, the calculated total scour depth is summarized in Table 3.5.1. The maximum total scour depth for 4 ft pier is 42.12 ft for ultimate channel geometry. If assuming triangular shaped debris, the total scour depth for two circular piers at different flow and geometric conditions are summarized in Table 3.5.2. The total scour depth for 4 ft piers is 28.46 ft for the ultimate geometry design.

The calculations of abutment scour depth used both the Froehlich's equation and the HIRE equation in HEC-18. Two skewness angles, +15° and -15°, are considered in the calculations. The maximum abutment scour depths from these two methods were selected as the abutment scour depth, which are also shown in Table 15 and 16. The abutment scour depth ranges from 39 to 42 ft depending on pier diameter and channel geometry.

Table 15 Total Scour Depth Using 0-20-feet Soil Data (Maximum Possible Scour)

Flow and Geometry Condition		100-year design flow Q=70,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	44.14	52.68	60.99	45.53	54.52	63.34
	channel	41.07	49.44	57.78	42.12	50.94	59.79
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	39.03	39.53	39.94	40.24	40.64	40.95
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	40.19	40.70	41.11	41.43	41.84	42.15
	east	no flow					
Flow and Geometry Condition		500-year design flow Q=93,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	45.94	54.83	63.46	48.91	58.88	67.69
	channel	43.01	51.70	60.35	45.89	56.12	64.41
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	45.32	45.92	46.38	47.01	48.21	48.16
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	46.72	47.32	46.80	48.43	49.65	49.61
	east	no flow					

Table 16 Total Scour Depth Using 0-20-feet Soil Data (Triangular Debris)

Flow and Geometry Condition		100-year design flow Q=70,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	30.87	39.47	47.86	31.87	40.87	49.71
	channel	27.79	36.24	44.65	28.46	37.29	46.15
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	39.03	39.53	39.94	40.24	40.64	40.95
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	40.19	40.70	41.11	41.43	41.84	42.15
	east	no flow					
Flow and Geometry Condition		500-year design flow Q=93,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	32.18	41.14	49.85	34.38	44.41	53.27
	channel	29.25	38.01	46.74	31.36	41.66	49.98
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	45.32	45.92	46.38	47.01	48.21	48.16
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	46.72	47.32	46.80	48.43	49.65	49.61
	east	no flow					

To ensure the bridge safety, this study assumes that the channel thalweg may migrate across the bridge section. Therefore, channel bed elevation after a scour event is calculated using the thalweg elevation. The thalweg elevation is 2197.5 ft. The lowest scoured bed elevation is obtained by subtracting the total scour depth from the thalweg elevation. **The total scour depth is 28.46 ft in the channel. The channel elevation after scour is 2169.04 ft. However, none of the pier is located at the thalweg, so the realistic bed elevation after scour is the elevation after subtracting the total scour depth from the toe elevation of the lowest pier at 2211 ft. The channel elevation after scour is at 2182.54 ft.** The base of West Abutment is at 2212.49 ft. The scoured abutment elevation needs to subtract the abutment scour depth from the current base elevation. Table 17 (using 0-20 ft soil) is the scoured bed elevations for two 4-ft piers for 100-year and 500-year flows assuming triangular debris.

Table 17 Thalweg and Abutment Elevation Using 0-20-feet Soil Sample (Triangular Debris)

Flow Condition	100-year design flow Q=70,000 cfs					
	Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)	4.00	6.00	8.00	4.00	6.00	8.00
Thalweg Elevation (ft)	2197.50					
channel scour depth (ft)	27.79	36.24	44.65	28.46	37.29	46.15
Thalweg elevation after scour (ft)	2169.71	2161.26	2152.85	2169.04	2160.21	2151.35
Lowest Pier Bottom Elevation (ft)	2211.00					
channel scour depth (ft)	27.79	36.24	44.65	28.46	37.29	46.15
Thalweg elevation after scour (ft)	**2183.21**	**2174.76**	**2166.35**	**2182.54**	**2173.71**	**2164.85**
West Abutment Elevation (ft)	2212.49					
Abutment Scour Depth (ft)	40.19	40.70	41.11	41.43	41.84	42.15
Abutment Scoured Elevation (ft)	2172.30	2171.79	2171.38	2171.06	2170.65	2170.34
Flow Condition	500-year design flow Q=93,000 cfs					
	Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)	4.00	6.00	8.00	4.00	6.00	8.00
Thalweg Elevation (ft)	2197.50					
Channel scour depth (ft)	29.25	38.01	46.74	31.36	41.66	49.98
Thalweg Elevation After Scour (ft)	2168.25	2159.49	2150.76	2166.14	2155.84	2147.52
West Abutment Elevation (ft)	2212.49					
Abutment Scour Depth (ft)	46.72	47.32	46.80	48.43	49.65	49.61
West Abutment Scoured Elevation (ft)	2165.77	2165.17	2165.69	2164.06	2162.84	2162.88

HEC-RAS Sediment Model

The HEC-RAS quasi-unsteady flow model simulates sediment transport and bed changes using quasi-unsteady flow hydrograph. The study reach was divided into 105 sub-reaches. The distance between two cross sections is about 200-600 ft, and each cross section has about 150 to 300 stations. The geometric data including current, interim, and ultimate were provided by PB World, Inc. The hydrographs for 100-year and 500-year events were used as the upstream boundary conditions. The downstream boundary condition is "normal depth", which indicates that Manning's equation is valid at the downstream boundary. The corresponding friction slope was chosen as 0.003, the same as the bed slope. Water temperate is chosen as 68°F. Manning's n values range from 0.025 to 0.04 in the main channel, and from 0.022 to 0.06 on the floodplain. The simulation time step is 4.8 minutes (0.08 hour).

Table 18 is the summary of the bed elevation change at the thalweg at each cross section near the Sunset Bridge for two design flows and two geometries using the Laursen's equation. 100-year flood will cause 5.98 ft and 6.14 ft

erosion, immediately downstream from the bridge for intermediate and ultimate geometry condition respectively. The maximum scour depth is about 17.12 feet, and will occur at about 1000 ft from the bridge for the intermediate geometry. However, 500-year event will scour about 15.3 ft and 11 ft for the interim and ultimate design geometry immediately downstream from the bridge. The maximum scour depth 22.39 ft will occur at 1000 ft from the bridge. Those scour depth indicated moderate risk of downstream scour from the bridge site.

Table 18 Invert Change of Cross Sections near the Proposed Sunset Bridge (Laursen's Equation)

Sediment Equation		Laursen-sediment equation			
Flow Condition		100 Year Flow		500 Year Flow	
Bridge Condition		Intermediate Design	Ultimate Design	Intermediate Design	Ultimate Design
Scenario Number		1	2	3	4
HEC-RAS RS Number	Distance to Sunset Bridge	Invent Change (ft)			
52999	1999	2.49	1.51	-0.40	1.44
52499	1499	0.28	0.43	1.26	3.35
51999	999	1.84	0.22	0.65	1.47
51499	499	5.14	4.57	1.88	5.44
51057	57	2.56	2.36	2.79	2.51
51000	Bridge Location				
50945	-55	-5.98	-6.14	-15.22	-10.71
50500	-500	-5.13	-4.16	1.16	-5.49
49996	-1004	-17.21	-16.89	-22.39	-22.30
49501	-1499	0.13	0.09	-1.64	-2.00
48999	-2001	-16.03	-15.89	-15.52	-19.93
48499	-2501	-3.16	-0.69	-3.52	-5.16

The results by using the Yang's sediment equation are shown in Table 19. 500-year event will cause minor erosion for the ultimate geometry. For other cases, deposition will occur at the downstream from the bridge. Therefore, there is nearly no erosion that will occur downstream from the bridge.

Table 19 Invert Change of Cross Sections near the Proposed Sunset Bridge (Yang's Equation)

Sediment Equation		Yang-sediment equation			
Flow Condition		100 Year Flow		500 Year Flow	
Bridge Condition		Intermediate Design	Ultimate Design	Intermediate Design	Ultimate Design
Scenario Number		5	6	7	8
HEC-RAS RS Number	Distance to Sunset Bridge	Invent Change (ft)			
52999	1999	1.40	1.14	2.43	1.41
52499	1499	0.92	1.02	3.22	2.05
51999	999	0.82	0.71	2.24	1.00
51499	499	0.22	0.30	2.73	1.50
51057	57	0.11	0.07	1.99	0.23
51000	Bridge Location				
50945	-55	0.44	0.87	-0.25	1.98
50500	-500	0.01	-0.10	-0.44	0.29
49996	-1004	-0.25	0.73	-4.07	1.54
49501	-1499	-0.04	-0.40	0.24	-0.03
48999	-2001	-1.18	-0.02	-0.83	0.55
48499	-2501	1.05	0.42	0.17	0.73

The results from Yang's equation showed no erosion downstream from the bridge, while those using Larsen's equation showed maximum scour depth of 22.39 ft occurred at 1000 ft downstream from the bridge. Those indicated that a large scour hole downstream from the bridge is not likely. Therefore, a grade control structure at the immediate downstream may not be necessary at this stage.

Recommended Counter-Scour Measurements

Pier scour depth was estimated by using the CSU equation in HEC-18. The scoured bed elevation is determined by subtracting the total scour depth from the thalweg or the toe elevation of the lowest pier. The bridge structural design will base on the scoured bed elevation that assumes bed surface will be lowered the total scour depth. Therefore, no pier protection is needed.

After the bridge is constructed, the maximum scour depth (about 22 ft) in 100-year event will occur approximately 1000 ft downstream from the bridge if using Laursen's sediment transport equation. Yang's equation predicted deposition immediately downstream from the bridge for 100-year flow, and minor erosion for 500-year event. Although Laursen's sediment transport equation predicted moderate erosion immediately downstream from the bridge, this is unlikely occur if considering the prediction from using the Yang's equation. Therefore, sediment modeling results indicate that the proposed bridge will not result in a significant scour downstream from the bridge. Therefore, grade control structure is not immediately necessary for the proposed bridge. However, other factors, such as headcut from the gravel pits, the storm drainage immediately at the neighborhood of the bridge may cause

excessive scour in the vicinity of the bridge. In particular, the lack of a grade control structure from the Sunset to the Ina Road may expose this reach to long-term degradation if there will be a considerable reduction in sediment supply. Those scour together with local scour may threaten the safety of bridge. A grade control structure will be necessary if either local scour, channel incision, or head cut start to occur in the neighborhood of bridge.

5.0 Summary & Conclusions

The planned drainage improvements for this project will accommodate the required design storms meeting the current Pima County DOT and District requirements. Table 15 provides an overview summary of the planned improvements for this project. All Calculations are included in the appropriate Appendices. The onsite drainage improvements will collect and convey runoff from the proposed roadway keeping the roadway free of ponding or flowing water within the travel lanes. Offsite improvements collect and convey the runoff entering the project limits and include appurtenances for water harvesting and scour countermeasures. Finally, the proposed river improvements will allow for the bridge to be constructed and serve its design life without significant upstream impacts. The preliminary plans (equivalent 15%-30% level) are provided in Appendix E.

Table 20 Proposed Drainage Improvements

Onsite Drainage Improvements	Offsite Drainage Improvements	River Improvements
Bridge Deck Scuppers	Roadside Channel w/ Gabion Mattress Scour Countermeasure	6-Span Bridge w/4' Dia Piers
Roadside Ditches	Roadside Channel w/ Gabion Check Dams for Water Harvesting	West Sloping Abutment & Soil Cement Bank Roadway Approach
Type 4 Area Inlets (Off-Roadway) w/ Storm Drain System	2-36" RCP Culvert w/ Headwalls & Dumped Riprap Apron	Left Overbank Grading for Increased Conveyance w/ Concrete Ford Wall to mitigate head-cutting
	Ford Walls Along Silverbell Road to Mitigate Scour	Ford Walls @ Upstream & Downstream Edge of Sunset Road to Mitigate Scour from Overtopping

6.0 References

1. HDR, *Silverbell Road, Grant Road to Ina Road Design Concept Report, Hydrologic and Hydraulic Analysis for Existing Conditions*, July 2010.
2. HDR, *Silverbell Road, Grant Road to Ina Road Design Concept Report, Hydrologic and Hydraulic Analysis for Proposed Cross Drainage*, May 2011.
3. *Pima County Roadway Design Manual, Fourth Edition*, Pima County Department of Transportation, 2013
4. Hydraulic Engineering Circular No 14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*, *Publication No. FHWA-NHI-06-086,* July 2006
5. *Standards Manual For Drainage Design And Floodplain Management in Tucson, Arizona*, Simons, Li & Associates, December 1989, updated July 29, 1998.
6. Hydraulic Engineering Circular No. 15*, Design of Roadside Channels with Flexible Linings, Publication No. FHWA-IP-87-7,* U.S. Department of Transportation Federal Highway Administration, April 1988.
7. LOMR 1 Tetra-Tech for the District and has an Effective Date of September 03, 2010; Case No. 09-09-0233P
8. LOMR 2 JE Fuller for the District and has an Effective Date of November 28, 2011; Case No. 10-099-2016P
9. *Flood Insurance Study. Pima County Arizona And Unincorporated Areas, Volumes 1,2 & 5 of 5*, Federal Emergency Management Agency, September 28, 2012.
10. *Esri, ArcGIS Help Documentation Ver. 10.1.*
11. Standards for Floodplain Hydraulic Modeling, Technical Policy, TECH-019, Pima County Regional Flood Control District, November 19, 2012
12. Selection of Manning's Roughness Coefficient for Natural and Constructed Vegetated and Non-Vegetated Channels, and Vegetation Maintenance Plan Guidelines for Vegetated Channels in Central Arizona, Phillips and Tadayon, 2007
13. Guidelines For Establishing Scour and Freeboard for Bridges in Pima County, Pima County Regional Flood Control District & Pima County Department of Transportation, August 2012.

APPENDECIES

APPENDIX A	PROJECT MAPPING AND SURVEY CONTROL
APPENDIX B	ONSITE DRAINAGE
APPENDIX C	OFFSITE DRAINAGE
APPENDIX D	SANTA CRUZ HYDRAULICS
APPENDIX E	DCR LEVEL CONSTRUCTION PLANS

APPENDECIES

APPENDIX A ***PROJECT MAPPING AND SURVEY CONTROL***

APPENDIX B ONSITE DRAINAGE

APPENDIX C OFFSITE DRAINAGE

APPENDIX D SANTA CRUZ HYDRAULICS

APPENDIX E DCR LEVEL CONSTRUCTION PLANS

PROJECT SURVEY

Engineering and Environmental Consultants, Inc.

4625 East Fort Lowell Road | Tucson, Arizona 85712 | Tel 520.321.4625 | Fax 520.321.0333

Revised December 10, 2013
November 27, 2013
EEC No. 13039

SURVEY CONTROL

SUNSET ROAD
SILVERBELL ROAD TO RIVER ROAD

HORIZONTAL CONTROL

The horizontal control for this project is based on existing survey control points as provided by Pima County – City of Tucson geodetic control points.

The Published Combined Factor for "AJ05" = 0.9998762050 was used to convert grid coordinates to surface.

Surface Northing coordinates are derived by dividing the grid coordinates by 0.9998762050 and then subtracting 400,000.

Surface Easting coordinates are derived by dividing the grid coordinate by 0.9998762050 and then subtracting 900,000.

VERTICAL CONTROL

Vertical control for this project is based on Pima County benchmark designation Q291 aka NGS Q291 CZ0554.

Based on NAVD 88 DATUM having an elevation of 2,232.24 feet.

Station Mark is a Benchmark Disk set in concrete standard Q291 1951.
Stamped Q291 1951

Benchmark is located N 88°19' E 1,024 feet from the South ¼ corner of Section 8, Township 13 South, Range 13 East, Gila and Salt River Meridian, Pima County, Arizona.

BASIS OF BEARING

The **BASIS OF BEARINGS** for this project is a grid bearing of N 55°56'26.29" E between Pima County DOT/City of Tucson DOT Geodetic, control point AL03 and Pima County DOT/City of

Tucson DOT Geodetic, control point AG09, as established from the Arizona Coordinate System, 1983 (Harn 92), Central Zone 0202:

Prepared by:

ENGINEERING AND ENVIRONMENTAL CONSULTANTS, INC.

James L. Dean, RLS

REGISTERED LAND SURVEYOR
CERTIFICATE NO.
14145
JAMES L.
DEAN
Date Signed 12-10-13
ARIZONA, U.S.A.
Expires 9/30/14

JLD:\bh

O:\13039 Sunset Rd\Survey Control.docx

SANTA CRUZ RIVER LIDAR DATA

2008

Appendix C: Survey Field Notes

Pima County Regional
FLOOD CONTROL
DISTRICT

PIMA COUNTY
REGIONAL FLOOD CONTROL DISTRICT
97 EAST CONGRESS STREET, THIRD FLOOR
TUCSON, ARIZONA 85701-1797

SUZANNE SHIELDS, P.E.
DIRECTOR

(520) 243-1800
FAX (520) 243-1821

January 2, 2009

Craig S. Kennedy, CFM, Program Specialist
Engineering Management Branch
Mitigation Directorate
FEMA
500C Street SW
Washington, DC 20472

Re: Re: Acceptability of LiDAR

Dear Mr. Kennedy:

The Pima Association of Governments (PAG) has contracted with Sanborn to generate ortho rectified aerial photography and LiDAR. Figure 1 shows the extent of the LiDAR coverage for Pima County and the FIRM Special Flood Hazard Areas. The next version of Flood Insurance Rate Maps for Pima County will be converted to the North American Vertical Datum of 1988 (NAVD88). Attached to this letter you will find a draft letter from Sanborn indicating the vertical accuracy of the LiDAR meets FEMA's Map Modernization requirements.

The Pima County Regional Flood Control District (District) requests that the documentation in the draft letter be examined by FEMA to verify the LiDAR and topography created from this data would meet FEMA's vertical requirements for mapping to the NAVD88 Datum. If acceptable, the District will request PAG to have Sanborn seal the documentation so that it may be used in FEMA re-mapping processes. The District understands the digital maps generated from the LiDAR would need to be re-projected to FEMA's UTM coordinate system for LOMR applications.

Please call me at 520-243-1800, should you have any questions with this request.

Sincerely,

R. "Terry" Hendricks, CFM, Chief Hydrologist
Planning and Development Division

RTH/cd

Cc: Steve Whitney, GIS Manager, Pima County Department of Transportation
Kenneth Maits, Senior GIS Analyst, PC Regional Flood Control District
Manny M. Rosas, GIS Administrator, Pima Association of Governments.

Enclosures

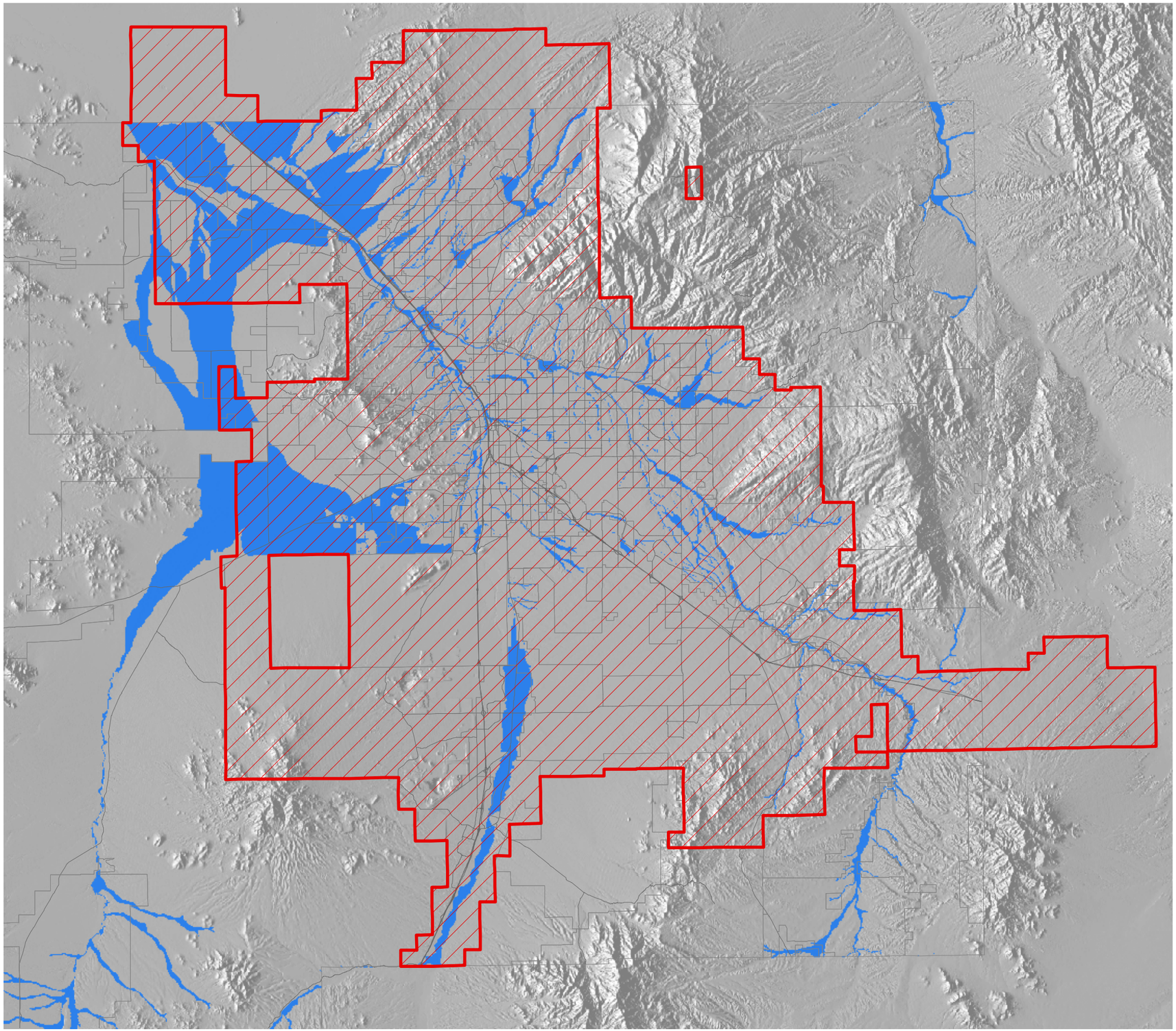


Exhibit 1: 2008 LiDAR Coverage and FEMA Special Flood Hazard Areas

2008 LiDAR Coverage

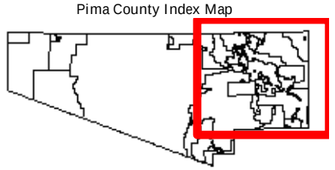
FEMA Floodplains

Major Streets

Jurisdiction Lines

Not Shown: Western Pima County, including Ajo and LiDAR coverage on Tohono O'dham Nation.

Pima County Index Map



Index Map Scale 1:5,250,000

The information depicted on this display is the result of digital analyses performed on a variety of databases provided and maintained by several governmental agencies. The accuracy of the information presented is limited to the collective accuracy of these databases on the date of the analysis. The Pima County Regional Flood Control Department makes no claims regarding the accuracy of the information depicted herein.

This product is subject to the Department of Transportation Technical Services Division's Use Restriction Agreement.

Pima County Regional Flood Control District

Scale 1:415,000

\\gislib\rfcd\projects\imd\ken\lidar08\fema_08cov.mxd km

Corporate Headquarters: Colorado Springs Colorado

Ann Arbor Michigan

Charlotte North Carolina

Ft. Collins Colorado

Pelham New York

Portland Oregon

Sacramento California

St. Louis Missouri

Sanborn Middle East

Mumbai India

30 December 2008

Manny Rosas, GIS Administrator
Pima Association of Governments
177 N. Church Ave.
Suite 405
Tucson, AZ 85701

Re: FEMA Results for the PAG 2008 Ortho Project (Contract – 08-5951-01)

Dear Mr. Rosas,

Attached you will find the results of the FEMA checkpoints for PAG 2008 LiDAR data. Sanborn's contracted Arizona State Registered Land-Surveyor, Greg Thompson, performed a review of the report and is in agreement with the results.

Background

To ensure the accuracy of the PAG 2008 LiDAR data, Sanborn was contracted to implement a project plan that included the integration of FEMA checkpoints as part of the QA/QC process. To support this initiative, Sanborn collected 69 checkpoints as part of the control survey effort. This meets the minimum standards for vertical accuracy testing and reporting as defined in FEMA's map modernization requirements. FEMA recommends 20 checkpoints in each of the major land cover categories representative of floodplains being mapped; this normally requires a minimum of 60 checkpoints for at least three land cover categories. The three categories surveyed were:

1. Bare Earth and Low Grass
2. High Grass, Weeds, and Crops
3. Brush lands/low trees

Field data was acquired using GPS equipment and static surveying methods. Sanborn team surveyed all checkpoint following the procedures in NOAA Technical Memorandum NOS NGS-58, "Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm)" and use NGS' latest Geoid Model to compute NAVD88 orthometric heights accurate to 5-cm at the 95% confidence level. (The x and y coordinates of checkpoints will be accurate to 2-cm at the 95% confidence level.)

Final adjusted results were adjusted to Arizona State Plane Coordinates, Central Zone NAD83-92 (HARN), NAVD88, in units of International Foot.

Testing Methodology

As stated in the Guidelines and Specifications for Flood Hazard Mapping Partners (April 2003), Section A.87.6.1, "The Root Mean Square Error (RMSE) is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points…TINs (and DEMs derived therefrom) should normally have a maximum RMSE of 18.5 centimeters, equivalent to

2-foot contours, in flat terrain. The following are the results from the PAG 2008 Ortho Program.

Bare Earth:

Number	Easting	Northing	Known Z	Laser Z	Dz ----------
1	1001837.162	410093.611	2587.031	2587.530	+0.499
7	999345.782	449442.944	2441.401	2441.640	+0.239
20	933721.166	412981.849	2439.091	2439.310	+0.219
17	933650.558	412993.658	2438.451	2438.660	+0.209
15	897369.501	552863.803	1937.257	1937.430	+0.173
3	1159921.689	349431.234	4294.062	4294.210	+0.148
8	1005806.086	434836.185	2509.196	2509.340	+0.144
9	1000927.946	448200.185	2446.309	2446.400	+0.091
13	994444.372	503631.914	2655.984	2656.070	+0.086
11	994513.846	503595.055	2658.012	2658.090	+0.078
18	955798.751	425094.504	2540.814	2540.880	+0.066
2	906521.919	540616.247	1946.585	1946.640	+0.055
12	987338.200	503575.338	2542.972	2542.930	-0.042
14	965580.705	519074.819	2667.182	2667.120	-0.062
21	955893.647	425085.496	2541.302	2541.240	-0.062
5	1021871.892	457772.536	2472.149	2472.080	-0.069
6	1033139.499	445741.877	2610.656	2610.580	-0.076
16	939704.593	416728.203	2432.726	2432.640	-0.086
10	985754.835	454784.703	2313.130	2312.980	-0.150
19	939508.793	416651.451	2432.802	2432.630	-0.172
22	1027485.930	416573.872	2740.833	2740.650	-0.183
4	1156429.917	365109.827	4055.003	outside	*

Average dz	+0.053
Minimum dz	-0.183
Maximum dz	+0.499
Average magnitude	0.139
Root mean square	**0.171 (foot)**
Std deviation	0.166

Medium Vegetation:

Number	Easting	Northing	Known Z	Laser Z	Dz ----------
1	1187028.525	351518.925	4080.561	4080.540	-0.021
2	1117108.620	363592.785	3587.077	3586.940	-0.137
3	1073972.909	383419.761	3240.515	3240.590	+0.075
4	1010832.502	410849.441	2643.786	2643.990	+0.204
5	1005445.314	419156.617	2579.495	2579.880	+0.385
6	1045092.088	435136.157	2724.009	2724.050	+0.041

7	1069748.640	446273.392	2760.125	2760.050	-0.075
8	1033371.126	464364.855	2518.606	2518.310	-0.296
9	1054207.161	418935.174	2886.854	2886.950	+0.096
10	955203.805	487660.945	2178.734	2179.130	+0.396
11	997532.713	434803.804	2460.164	2460.250	+0.086
12	979509.921	492673.940	2417.792	2418.190	+0.398
13	995655.491	465569.990	2344.777	2344.690	-0.087
14	997550.935	482620.376	2598.648	2598.550	-0.098
15	1001334.429	474026.061	2493.153	2493.240	+0.087
16	990196.690	487542.780	2546.083	outside	*
17	990519.334	490352.801	2559.039	2559.110	+0.071
18	998219.739	493708.248	2936.804	2937.080	+0.276
19	996795.607	504234.682	2727.497	2727.370	-0.127
20	988245.902	501104.027	2560.988	2560.870	-0.118
21	985960.009	501595.086	2553.169	2553.130	-0.039
22	997446.853	506178.000	2694.613	2695.140	+0.527
23	987398.768	503506.302	2546.335	2546.410	+0.075
24	985971.797	501493.493	2552.516	2552.570	+0.054
25	997540.656	506124.929	2707.864	2708.230	+0.366
26	991206.370	506306.455	2518.406	2518.250	-0.156
27	978945.698	519233.465	2782.405	2782.330	-0.075
28	978935.642	519272.398	2784.006	2784.080	+0.074
29	965555.375	519044.382	2666.260	2666.260	+0.000
30	897298.425	552978.606	1937.352	1937.730	+0.378
31	910066.011	514280.384	2003.658	2003.840	+0.182

Average dz	+0.085
Minimum dz	-0.296
Maximum dz	+0.527
Average magnitude	0.167
Root mean square	**0.217 (foot)**
Std deviation	0.203

High Vegetation:

Number	Easting	Northing	Known Z	Laser Z	Dz
1	1041505.790	408998.331	2868.881	2869.410	+0.529
4	1007421.616	441240.211	2501.880	2502.270	+0.390
9	988302.547	500937.045	2557.959	2558.170	+0.211
10	993323.041	504876.742	2616.818	2616.900	+0.082
3	944799.536	483176.205	2406.404	2406.480	+0.076
6	993338.640	505132.410	2616.096	2616.130	+0.034
13	995168.385	519848.931	2773.051	2773.040	-0.011
8	996811.199	504124.980	2733.504	2733.470	-0.034
14	995094.857	519807.072	2771.624	2771.590	-0.034
5	995053.089	492295.493	2741.552	2741.500	-0.052
7	986911.443	504348.439	2463.848	2463.780	-0.068

11	986965.447	504425.310	2458.159	2458.090	-0.069
12	993296.411	506167.522	2598.730	2598.640	-0.090
16	919968.908	521623.590	2003.520	2003.130	-0.390
15	909979.986	514314.158	2004.186	2003.740	-0.446
2	988498.629	488163.006	2506.243	outside	*

Average dz	+0.009
Minimum dz	-0.446
Maximum dz	+0.529
Average magnitude	0.168
Root mean square	**0.240 (foot)**
Std deviation	0.248

Sanborn concludes that the overall RMSE of the LiDAR data is within PAG 2008 Ortho project requirements, as it meets the +/- 15.0 cm (0.492 foot) RMSE at 95% confidence for all three categories. RMSE is an indicator of overall accuracy of the product and is not used for individual point accuracy.

Please contact me at (719) 593-0093 extension 5645 or Jamie Young (General Manager – ext. 5602) if you have any question regarding the report.

Sincerely,

Andrew Lucero
Sanborn
Senior Project Manager

Evan Canfield

From: Kenneth Maits
Sent: Monday, May 03, 2010 12:20 PM
To: Evan Canfield
Subject: FW: PAG 2008 Orthos/Lidar

From: Curtis, Edward [mailto:Edward.Curtis@dhs.gov]
Sent: Tuesday, November 10, 2009 2:44 PM
To: Manny M. Rosas
Cc: Terry Hendricks; Lucero, Andrew; Caldwell, Jason; Akl, Pascal
Subject: RE: PAG 2008 Orthos/Lidar

Mr. Rosas –

I apologize for the delay in responding to you regarding the Sanborn LiDAR report. Pascal Akl of Michael Baker, Jr. reviewed the updated July 2009 report on behalf of FEMA and advised me that all of the concerns raised in his May 18, 2009 memorandum titled "Pima County, CA [sic] Sanborn LiDAR Report Items" were addressed in the updated report except the comment that the original report lacked a sufficient number of checkpoints in urban areas and dense vegetation areas. No additional checkpoints were surveyed in such arease to permit analysis of data accuracy in these land cover categories. However, in the data voids analysis section of the updated report (p. 16), Sanborn states the following: "*Specific areas, dense vegetation or undergrowth near small streams, for example, prevents the LiDAR pulses to fully penetrate to the true ground surface. Thus, for mapping products such as floodplain or contour mapping, LiDAR data must often be manually supplemented with breaklines and mass-points to accurately model the terrain surface.*" As long as the data is used with caution and supplemented with additional ground survey data where necessary in accordance with this statement, I am satisfied that the terrain data meets FEMA standards for use in detailed flood studies.

Please contact me if you have any questions regarding our review and comments.

Ed Curtis, P.E., CFM
Risk Analysis Branch
FEMA Region IX
(510) 627-7207 - office
(510) 295-5249 - mobile

From: Manny M. Rosas [mailto:MRosas@pagnet.org]
Sent: Tuesday, November 10, 2009 7:29 AM
To: 'Lucero, Andrew'; 'Caldwell, Jason'
Cc: 'Terry Hendricks'; Curtis, Edward
Subject: PAG 2008 Orthos/Lidar

Hi Andy,
I resent Sanborn's Version 3 document produced in July 2009 and yet to receive any comments from FEMA, Pima County and Michael Baker Inc. therefore
please proceed with direct communications with Michael Baker Inc (Pascal Akl) to resolve all issues regarding the FEMA guidelines

Thank You
Manny

Manny M. Rosas Jr.
GIS Administrator

Pima Association of Governments

177 N Church Ave. Suite 405
Tucson, Arizona 85701

520-792-1093 (tel)
520-620-6981 (fax)

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INDEX PAGE

JOB NO.	PROJECT	PAGE NUMBER
112279	SILVERBELL RD, GRANT RD TO INA RD. (C.O.T.) (REF. JOB NO. 15794 IN HDR F.B. 201)	ALL
	COT FB # 2255	
	I HEREBY CERTIFY THAT THE SURVEY	
CONTAINED	HEREIN WAS CONDUCTED UNDER MY	
DIRECT	SUPERVISION BETWEEN MAY, 2009 AND	
MAY, 2010. I	FURTHER CERTIFY	
THAT THIS	SURVEY WAS	
CONDUCTED	AS A CONTROL	
AND DESIGN	SURVEY FOR	
SILVERBELL RD.	FROM GRANT RD.	
TO INA RD.	THE INFORMATION	
CONTAINED HEREIN	IS TRUE, ACCURATE	
AND SUFFICIENT	TO RETRACE THIS SURVEY.	
THIS SURVEY	MEETS OR EXCEEDS THE	
MINIMUM	STANDARDS FOR SURVEYS IN	
ARIZONA.		

REGISTERED LAND SURVEYOR CERTIFICATE NO. 18211 FRANK D. ABELL Date Signed 5-6-10 ARIZONA, U.S.A.

TETRA TECH, INC.

The accuracy of the lidar data was verified using the methods described in sections A.3, A.4 and A.8 of the *FEMA Guidelines and Specifications for Flood Hazard Mapping Partners* (April, 2003). Ground cover categories (1) bare-earth and low grass and (5) urban area, roadways were evaluated. A total of 493 points were compared. The difference was determined to be 0.2 feet (median value).

A total of 506 points were collected throughout the area defined by the 100yr flood limit (TetraTech Job 0939-FVW-LOMR) plus an additional 300 feet, from Stone Loop northeasterly to North 1st Avenue, all within Section 13, T13S, R13E and Section 18, T13S, R14E. The survey utilized a GPS/RTK base and receiver, localized on survey monuments with Arizona State Plane, Central Zone NAD83 coordinates (horizontal) and orthometric heights relative to NAVD88, published by the Pima Association of Governments (PAG). The field survey was conducted in October and November of 2007. A total of 13 points were discarded due to man-made changes in the ground surface or insufficient satellite reception.

The surface used for this survey was provided by Pima County Flood Control as lidar point file (13S13E13) using LAS format and a XYZ point cloud covering the approximate same area. A TIN was created using ArcGIS 9.2 3D Analyst and elevations extracted at locations as determined per the field survey and differences between the two were calculated.

It was found that accuracy of the lidar surface was within the two-foot equivalent contour interval ($accuracy_z$ = 1.2 foot at the 95-percent confidence level) criteria specified by FEMA. The actual ground elevation was higher then the lidar surface by an average of 0.2 feet, with a min/max range of 1.1 feet. The verification demonstrates that the lidar surface meets the criteria for lidar compliance specified in sections A.3, A.4 and A.8 of FEMA Guidelines and Specifications for Flood Hazard Mapping Partners.

15667
JOHN B.
LYNCH
11/30/07
ARIZONA U.S.A.

Tetra Tech Job Number: 0939 Friendly Village Wash LOMR

SANTA CRUZ RIVER LIDAR DATA

2011

Pima Association of Governments (PAG)

LiDAR Campaign (Pima County, AZ) Report of Survey

August, 2011

EXECUTIVE SUMMARY

The Pima Association of Governments (PAG) contracted with Sanborn to provide LiDAR mapping services for the Tucson area. Utilizing multi-return systems, Light Detection and Ranging (LiDAR) data in the form of 3-dimensional positions of a dense set of mass points was collected for approximately 600 square miles between April 10, 2011 and April 25, 2011. All systems consist of geodetic GPS positioning, orientation derived from high-end inertial sensors and high-accurate lasers. The sensor is attached to the aircraft's underside and emits rapid pulses of light that are used to determine distances between the plane and terrain below.

Specifically, the Leica ALS-50 system was used to collect data for the survey campaign. The LiDAR system is calibrated by conducting flight passes over a known ground surface before and after each LiDAR mission. During final data processing, the calibration parameters are inserted into post-processing software.

Four airborne GPS (Global Positioning System) base stations were used in the Pima County Project. A new point, point 501, was created at Tucson International Airport. The other three base stations were set up at National Geodetic Survey (NGS) markers. NGS points with PID's CZ2519, AC6836, and DK4138 were used in the Pima County project. These four base stations were tied to the other point to create a GPS survey network. The coordinates of these stations were checked against each other with the three dimensional GPS baseline created at the airborne support set up and determined to be within project specifications.

The acquired LiDAR data was processed to obtain first and last return point data. The last return data was further filtered to yield a LiDAR surface representing the bare earth.

The contents of this report summarize the methods used to establish the base station coordinate check, perform the LiDAR data collection and post-processing as well as the results of these methods.

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1.0 INTRODUCTION

This document contains the technical write-up of the LiDAR campaign, including system calibration techniques, the establishment and processing of base stations, and the collection and post-processing of the LiDAR data.

1.1 Contact Information

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1.2 Purpose of the LiDAR Acquisition

As stated in the Statement of Work for Acquisition and Production of High Resolution Elevation data for Pima County, this LiDAR operation was designed to create high resolution data sets that will establish an authoritative source for elevation information for the state of Arizona.

1.3 Project Location

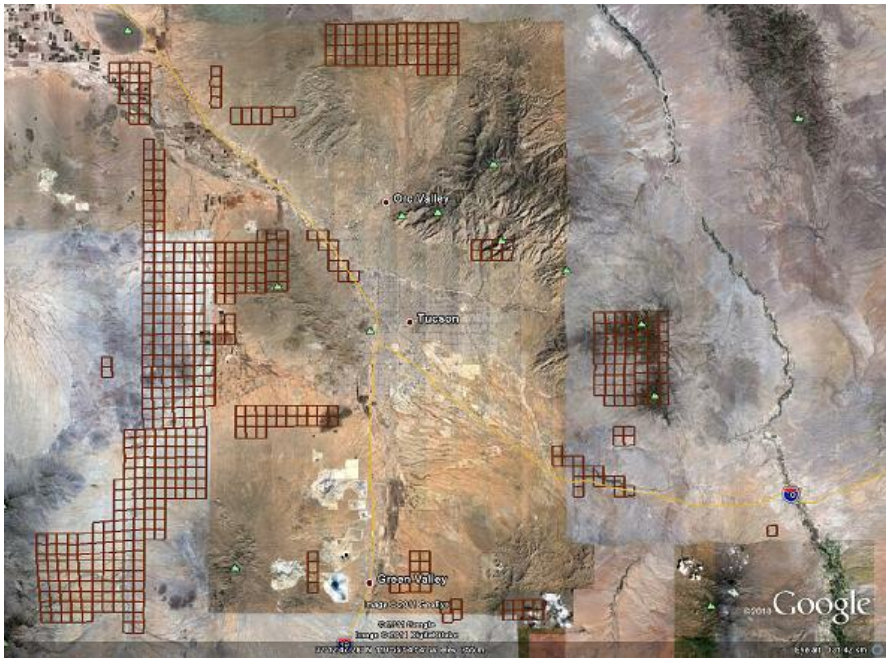

Figure 1: Area of Collection

1.4 Standard Specifications for LiDAR

Data Acquisition		
Requirement	Description	
Returns per pulse	LiDAR sensor shall be capable of recording up to 3 (or more) returns per pulse, including 1st and last returns	
Scan angle	≤ ±20 degrees	*
Swath overlap	Nominal sidelap on adjoining swaths, i.e., survey shall be designed for 100% double coverage at planned aircraft height above ground	30%
Design pulse density (nominal)	Pulses/m2 (includes swath overlap; e.g., with 30% sidelap, ≥ 3 pulses/m2 in each swath)	≥1
GPS procedures	At least 2 GPS reference stations in operation during all missions, sampling positions at 1 Hz or higher frequently. Differential GPS baseline lengths shall not exceed 30 km. Differential GPS unit in aircraft shall sample position at 2 Hz or higher. LiDAR data shall only be acquired when GPS PDOP is ≤ 3.5 and at least 6 satellites are in view.	*
Data Collection Season	Target window for collection of LiDAR data ends in April, 2011. This may be extended with approval by State program managers	*
Survey conditions	Leaf-off and no significant snow cover, as observed by state contract representatives.	*
Geographic Coverage and Continuity		
Coverage	No voids between swaths. No voids because of cloud cover or instrument failure.	
Swath overlap	30% no-overlap area per project.	

2.0 LIDAR CALIBRATION

2.1 Introduction

LiDAR calibrations are performed to determine and therefore eliminate systematic biases that occur within the hardware of the Leica ALS-50 system. Once the biases are determined they can be modeled out. The systematic biases are corrected for include scale, roll, heading, and pitch.

The following procedures are intended to prevent operational errors in the field and office work, and are designed to detect inconsistencies. The emphasis is not only on the quality control (QC) aspects, but also on the documentation, i.e., on the quality assurance (QA).

2.2 Calibration Procedures

Sanborn performs two types of calibrations on its LiDAR system. The first is a building calibration, and it is done any time the LiDAR system has been moved from one plane to another. New calibration parameters are computed and compared with previous calibration runs. If there is any change, the new values are updated internally or during the LiDAR post-processing. These values are applied to all data collected with the plane and the ALS-50 system configurations.

Once final processing calibration parameters are established from the building data, a precisely-surveyed surface is observed with the LiDAR system to check for stability in the system. This is done several times during each mission. An average of the systematic biases are applied on a per mission basis.

2.3 Building Calibration

Whenever the ALS-50 system is moved to a new aircraft, a building calibration is performed. The rooftop of a large, flat, rectangular building is surveyed on the ground using conventional survey methods, and used as the LiDAR calibration target. The aircraft flies several specified passes over the building with the ALS-50 system set first in scan mode, then in profile mode, and finally in both scan and profile modes with the scan angle set to zero degrees.

Figure 2 shows a pass over the center of the building. The purpose of this pass is to identify a systematic bias in the scale of the system.

Figure 3 demonstrates a pass along a distinct edge of the building to verify the roll compensation performed by the Inertial Navigation System, INS.

Additionally, a pass is made in profile mode across the middle of the building to compensate for any bias in pitch.

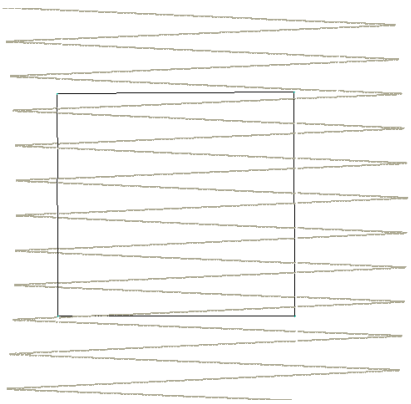

Figure 2: Calibration Pass 1

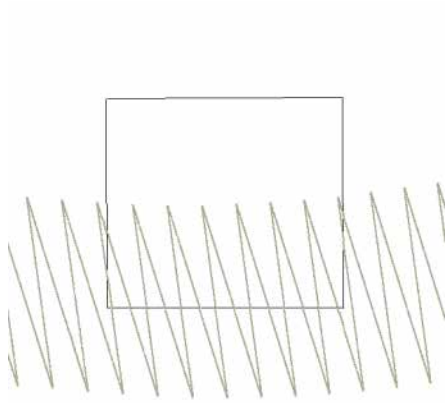

Figure 3: Calibration Pass 2

2.4 Runway Calibration, System Performance Validation

An active asphalt runway was precisely-surveyed at the Tucson International Airport for Pima using kinematic GPS survey techniques (accuracy: ±3cm at 1σ, along each coordinate axis) to establish an accurate digital terrain model of the runway surface. The LiDAR system is flown at right angles over the runway several times and residuals are generated from the processed data. Figure 4 shows a typical pass over the runway surface.

Approximately 30,000 LiDAR points are observed with each pass. A Triangulated Irregular Network (TIN) surface is created from these passes. The ground control x,y,z points are then compared with the z of the LiDAR surface to compute vertical residuals of the LiDAR data. After careful analysis of noise associated with non-runway returns, any system bias is documented and removed from the process.

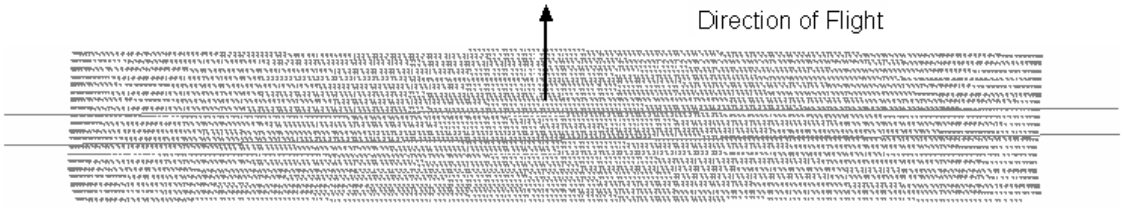

Figure 4: Runway Calibration

3.0 RUNWAY CALIBRATION AND SYSTEM PERFORMANCE VALIDATION

3.1 Calibration Results

The LiDAR data captured over the building is used to determine whether there have been any changes to the alignment of the Inertial Measurement Unit, IMU, with respect to the laser system. The parameters are designed to eliminate systematic biases within certain system parameters.

The runway over-flights are intended to be a quality check on the calibration and to identify any system irregularities and the overall noise. IMU misalignments and internal system calibration parameters are verified by comparing the collected LiDAR points with the runway surface.

Figure 5 shows the typical results of a runway over-flight analysis. The X-axis represents the position along the runway. The overall statistics from this analysis provides evidence of the overall random noise in the data (typically, 7 cm standard deviation – an unbiased estimator, and 8 cm RMS which includes any biases) and indicates that the system is performing within specifications. As described in later sections of this report, this analysis will identify any peculiarities within the data along with mirror-angle scale errors (identified as a "smile" or "frown" in the data band) or roll biases.

The calibration is done based on a kinematic survey on the runway. Given that the Kinematic survey RMSE is no better than 4 centimeters as a result of the exact height of the antenna and weight of the aircraft. Sanborn was required to do additional check points in the project area to meet the 15 centimeter vertical accuracy requirement knowing that the calibration site is only good to 8 centimeters RMSE. A z bump adjustment was made to the entire data set based on the survey points in the project area and the relative accuracy of the data to itself and in all areas.

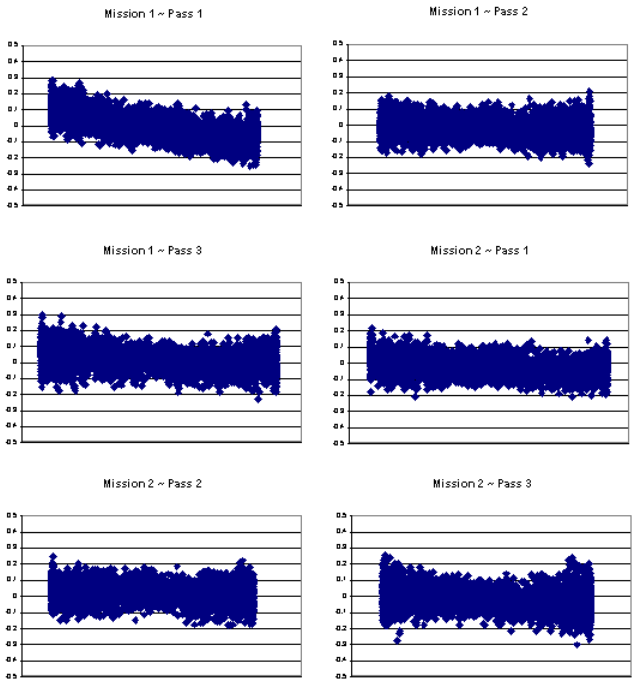

Figure 5: Runway Calibration Results

4.0 LIDAR FLIGHT AND SYSTEM REPORT

4.1 Introduction

This section addresses LiDAR system, flight reporting and data acquisition methodology used during the collection of the Pima County campaign. Although Sanborn conducts all LiDAR with the same rigorous and strict procedures and processes, all LiDAR collections are unique.

4.2 Field Work Procedures

Pre-flight checks such as cleaning the sensor head glass are performed. A four minute INS initialization is conducted on the ground, with the engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by flying within ten kilometers of the base stations.

The flight missions were typically four or five hours in duration including runway calibration flights flown at the beginning and the end of each mission. During the data collection, the operator recorded information on log sheets which includes weather conditions, LiDAR operation parameters, and flight line statistics. Near the end of the mission GPS ambiguities are again resolved by flying within ten kilometers of the base stations, to aid in post-processing.

Table 1 shows the planned LiDAR acquisition parameters with a flying height of 900 to 8, 000 meters above ground level (AGL) for the Leica ALS-50 on a mission to mission basis.

Table 1: LiDAR Leica Acquisition Parameters

Average Altitude	900-8000 Meters AGL
Airspeed	~120 Knots
Scan Frequency	30-44 Hertz
Scan Width Half Angle	11-20 Degrees
Pulse Rate	48,000-104,200 Hertz

Preliminary data processing was performed in the field immediately following the missions for quality control of GPS data and to ensure sufficient overlap between flight lines. Any problematic data could then be re-flown immediately as required. Final data processing was completed in the Colorado Springs office.

Table 2: Collection Dates, Times, Average Per Flight Collection Parameters and PDOP

Mission	Date	Sensor SN (1 or 2)	Start Time	End Time	Altitude (m)	Airspeed (Knots)	Scan Angle	Scan Rate	Pulse Rate	PDOP
100a	Apr 10	Leica-1	05:08	07:46	1300	120	22˚	44	83300	1.2
100b	Apr 10	Leica-1	21:48	01:19	5000	120	28˚	44	74400	1.2
101a	Apr 11	Leica-1	07:25	12:07	900	120	40˚	36	104200	1.1
101b	Apr 11	Leica-1	01:11	05:43	2600	120	22˚	30	48000	1.3
101c	Apr 11	Leica-1	21:20	04:45	5000	120	28˚	44	74400	1.2
102a	Apr 12	Leica-1	07:39	12:08	900	120	40˚	36	104200	1.2
102b	Apr 12	Leica-1	21:20	03:19	5000	120	28˚	44	74400	1.2
103a	Apr 13	Leica-1	08:11	14:15	1500	120	28˚	44	74400	1.4
103b	Apr 13	Leica-1	20:04	22:53	5000	120	28˚	44	76000	1.2
104a	Apr 14	Leica-1	10:46	14:13	5000	120	28˚	44	74400	1.2
105a	Apr 15	Leica-1	09:52	15:25	8000	120	22˚	30	48000	1.3
105b	Apr 15	Leica-1	03:13	08:23	1500	120	28˚	44	74400	1.3
106a	Apr 16	Leica-1	08:53	14:15	5000	120	28˚	44	74400	1.3
110a	Apr 20	Leica-2	17:18	20:33	4800	120	28˚	44	74400	1.7
110b	Apr 20	Leica-2	22:42	06:14	4800	120	28˚	44	74400	1.1
111a	Apr 21	Leica-1	13:29	17:20	7500	120	22˚	30	48000	1.3
111b	Apr 21	Leica-1	19:03	01:15	4800	120	28˚	44	74400	1.2
111a	Apr 21	Leica-2	15:46	19:22	4800	120	28˚	44	74400	1.5
112a	Apr 22	Leica-1	08:52	14:13	8000	120	22˚	30	48000	1.3
112b	Apr 22	Leica-1	22:34	01:37	2600	120	22˚	30	48000	1.1
112a	Apr 22	Leica-2	14:20	18:19	4800	120	28˚	44	74400	1.4
113a	Apr 23	Leica-1	22:28	05:13	1500	120	28˚	44	74400	1.1
113b	Apr 23	Leica-1	02:55	07:45	1500	120	28˚	44	74400	1.3
114a	Apr 24	Leica-1	09:37	12:52	8000	120	22˚	30	48000	1.2
115a	Apr 25	Leica-1	17:38	21:25	4800	120	22˚	30	48000	1.2

4.3 Final LiDAR Processing

Final post-processing of LiDAR data involves several steps. The airborne GPS data was post-processed using Waypoint's GravNAV™ software (version 7.5). A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. The data was processed for both base stations and combined. In the event that the solution worsened as a result of the combination of both solutions the best of both solutions was used to yield more accurate data. LiDAR acquisition was limited to periods when the PDOP was less than 3.

The GPS trajectory was combined with the raw IMU data and post-processed using Applanix Inc.'s POSPROC (version 4.4) Kalman Filtering software. This results in a two-fold improvement in the attitude accuracies over the real-time INS data. The best estimated trajectory (BET) and refined attitude data are then re-introduced into the LEICA ALS post processor for the Leica system to compute the laser point-positions. The trajectory is then combined with the attitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points.

All return values are produced within ALS Post processing software for the Leica system. The multi-return information is processed to obtain the "Bare Earth Dataset" as a deliverable. All LiDAR data is processed using the binary LAS format 1.2 file format.

LiDAR filtering was accomplished using TerraSolid, TerraScan LiDAR processing and modeling software. The filtering process reclassifies all the data into classes with in the LAS formatted file based scheme set using the LAS format 1.2 specifications or by the client. Once the data is classified, the entire data set is reviewed and manually edited for anomalies that are outside the required guidelines of the product specification or contract guidelines, whichever apply.

The coordinate and datum transformations are then applied to the data set to reflect the required deliverable projection, coordinate and datum systems as provided in the contract.

The client required deliverables are then generated. At this time, a final QC process is undertaken to validate all deliverables for the project. Prior to release of data for delivery, Sanborn's Quality control/ quality assurance department reviews the data and then releases it for delivery.

Table 3: Processing Accuracies and Requirements

Accuracy of LiDAR Data (H)	1.64ft RMSE
Accuracy of LiDAR data in bare areas	0.49ft RMSE

5.0 ACCURACY ASSESSMENT

5.1 Final LiDAR Verification

The LiDAR data was evaluated using a collection of 17 GPS surveyed checkpoints in which Sanborn acquired, and 109 checkpoints were collected from a subcontractor. These two sets of checkpoints were evaluated against the LiDAR resulting in a lower RMSE and standard deviation than the project required. Table 9 and 10 shows the results for Pima County and each point including the overall results as it compares to the LiDAR data set.

Table 4: LiDAR Accuracy Assessment based on the Checkpoint Report (Sanborn, Feet)

Name	Vegetation Class	Easting	Northing	Known Z	Laser Z	Dz
17	Bare Earth	1024733.311	293793.960	3689.029	3689.810	+0.781
23	Bare Earth	900201.474	433915.051	2311.280	2311.940	+0.660
8	Bare Earth	901816.338	380958.082	2829.550	2830.050	+0.500
19	Bare Earth	864544.979	386856.858	2644.035	2644.350	+0.315
10	Bare Earth	874366.355	368701.925	2742.760	2743.060	+0.300
18	Bare Earth	912872.663	470575.885	2262.299	2262.560	+0.261
11	Bare Earth	869956.830	338484.073	2987.611	2987.800	+0.189
5	Bare Earth	869956.850	338484.087	2987.622	2987.800	+0.178
25	Bare Earth	1117464.586	361379.398	3593.018	3593.180	+0.162
24	Bare Earth	915897.099	447499.675	2287.622	2287.750	+0.128
12	Bare Earth	957538.022	315475.622	3538.412	3538.510	+0.098
7	Bare Earth	897963.405	397351.263	2526.548	2526.620	+0.072
20	Bare Earth	863325.291	331234.301	2878.193	2878.160	-0.033
21	Bare Earth	857454.543	304371.690	3005.676	3005.620	-0.056
9	Bare Earth	889744.582	365014.266	3114.748	3114.620	-0.128
4	Bare Earth	1093310.004	371250.627	3427.550	3427.420	-0.130
22	Bare Earth	847155.327	295954.592	3158.344	3157.810	-0.534

Average dz	+0.163
Minimum dz	-0.534
Maximum dz	+0.781
Average Magnitude	0.266
Root Mean Square	**0.343**
Std deviation	0.311

Table 5: LiDAR Accuracy Assessment based on the Checkpoint Report (Subcontracted, Feet)

Name	Vegetation Class	Easting	Northing	Known Z	Laser Z	Dz
128	Bare Earth	953890.831	491135.317	2152.898	2153.500	+0.602
100	Bare Earth	870591.740	371204.421	2653.120	2653.570	+0.450
114	Bare Earth	931192.612	387026.280	2898.319	2898.710	+0.391
55	Bare Earth	849398.070	578068.280	1762.938	1763.310	+0.372
104	Bare Earth	885330.812	386968.655	2598.638	2598.970	+0.332
127	Bare Earth	956414.611	488690.682	2160.996	2161.320	+0.324
26	Bare Earth	1106911.841	416025.240	3236.953	3237.270	+0.317
116	Bare Earth	960003.026	393554.825	2734.385	2734.700	+0.315
39	Bare Earth	1014442.908	328558.891	2958.946	2959.260	+0.314
126	Bare Earth	960055.969	483474.756	2193.795	2194.080	+0.285
125	Bare Earth	966504.081	477720.407	2215.176	2215.460	+0.284
75	Bare Earth	861310.180	310085.873	3003.438	3003.710	+0.272
119	Bare Earth	972239.419	468391.934	2255.120	2255.390	+0.270
118	Bare Earth	941115.054	401198.069	2606.602	2606.870	+0.268
124	Bare Earth	965776.813	473268.131	2328.212	2328.480	+0.268
103	Bare Earth	882261.176	382473.954	2638.616	2638.880	+0.264
40	Bare Earth	997185.073	307499.086	2994.736	2994.990	+0.254
54	Bare Earth	865317.116	568858.057	1817.190	1817.430	+0.240
102	Bare Earth	879136.352	376941.656	2686.940	2687.180	+0.240
34	Bare Earth	959300.979	317683.745	3552.552	3552.790	+0.238
80	Bare Earth	859643.591	385100.848	2657.568	2657.800	+0.232
101	Bare Earth	880693.861	369402.707	2835.225	2835.450	+0.225
112	Bare Earth	948387.396	393806.941	2755.294	2755.500	+0.206
113	Bare Earth	941783.332	393318.920	2754.188	2754.390	+0.202
79	Bare Earth	869151.695	388109.136	2593.527	2593.710	+0.183
37	Bare Earth	1017800.357	310293.430	3299.850	3300.030	+0.180
33	Bare Earth	959725.740	327840.203	3600.832	3601.010	+0.178
82	Bare Earth	915711.767	449497.303	2294.095	2294.270	+0.175
38	Bare Earth	1016558.422	320042.667	3110.841	3111.010	+0.169
115	Bare Earth	935778.320	393114.752	2742.087	2742.220	+0.133
85	Bare Earth	869353.683	486602.461	2074.240	2074.370	+0.130
70	Bare Earth	1082919.927	382433.266	3358.477	3358.580	+0.103
117	Bare Earth	948472.147	401126.700	2623.560	2623.660	+0.100
77	Bare Earth	863088.148	338083.259	2859.866	2859.960	+0.094
48	Bare Earth	1109091.107	413126.606	3278.250	3278.340	+0.090
105	Bare Earth	887002.260	392042.582	2545.776	2545.850	+0.074
56	Bare Earth	902233.257	555887.955	2003.904	2003.970	+0.066
61	Bare Earth	1049602.818	478078.820	2946.506	2946.570	+0.064
111	Bare Earth	956349.742	398355.370	2668.513	2668.570	+0.057
76	Bare Earth	862306.473	323420.736	2921.773	2921.830	+0.057
121	Bare Earth	971009.469	471387.566	2242.579	2242.630	+0.051
45	Bare Earth	1106265.387	418832.671	3380.671	3380.720	+0.049
72	Bare Earth	825474.586	300369.045	3523.035	3523.080	+0.045
129	Bare Earth	960697.992	487608.122	2187.126	2187.160	+0.034
41	Bare Earth	1027671.887	301175.504	3702.717	3702.750	+0.033
135	Bare Earth	960541.766	490059.532	2183.954	2183.970	+0.016
110	Bare Earth	901887.171	370217.742	3164.685	3164.690	+0.005
120	Bare Earth	973959.401	467714.662	2251.247	2251.250	+0.003

63	Bare Earth	1115005.965	384040.508	3743.350	3743.340	-0.010
74	Bare Earth	848198.511	298925.734	3129.152	3129.140	-0.012
86	Bare Earth	875196.052	520443.973	1960.874	1960.860	-0.014
35	Bare Earth	1024813.032	294065.174	3692.601	3692.580	-0.021
83	Bare Earth	897233.192	454603.087	2216.701	2216.680	-0.021
60	Bare Earth	1037971.613	480182.555	2783.236	2783.210	-0.026
78	Bare Earth	867397.123	356300.908	2783.026	2783.000	-0.026
95	Bare Earth	905265.535	470519.626	2157.938	2157.910	-0.028
108	Bare Earth	901669.537	380617.335	2839.378	2839.350	-0.028
91	Bare Earth	935009.018	479483.118	2567.374	2567.340	-0.034
58	Bare Earth	918035.664	547038.766	2140.880	2140.840	-0.040
57	Bare Earth	902132.309	563976.857	2032.376	2032.330	-0.046
16	Bare Earth	881580.521	486145.911	2068.747	2068.680	-0.067
46	Bare Earth	1108450.693	417880.725	3284.825	3284.750	-0.075
134	Bare Earth	967800.011	486375.784	2234.611	2234.530	-0.081
96	Bare Earth	915712.252	470518.994	2341.958	2341.870	-0.088
132	Bare Earth	970045.662	477153.315	2231.684	2231.590	-0.094
106	Bare Earth	893874.547	395442.047	2537.297	2537.200	-0.097
47	Bare Earth	1110668.549	418363.878	3408.007	3407.910	-0.097
84	Bare Earth	875917.639	470339.190	2120.759	2120.660	-0.099
97	Bare Earth	870914.632	354301.174	2878.257	2878.150	-0.107
30	Bare Earth	832864.224	297946.689	3377.079	3376.970	-0.109
123	Bare Earth	978033.363	469377.521	2262.980	2262.870	-0.110
88	Bare Earth	915878.102	483358.082	2211.766	2211.650	-0.116
130	Bare Earth	963798.782	485833.813	2206.009	2205.890	-0.119
107	Bare Earth	901556.740	399117.929	2512.173	2512.050	-0.123
94	Bare Earth	915865.932	464332.016	2350.726	2350.590	-0.136
64	Bare Earth	1121882.368	384218.723	3815.707	3815.570	-0.137
122	Bare Earth	973697.453	471751.357	2247.520	2247.380	-0.140
90	Bare Earth	926451.064	486447.137	2308.370	2308.190	-0.180
62	Bare Earth	1112046.873	384278.770	3651.415	3651.220	-0.195
131	Bare Earth	967517.859	481479.023	2213.151	2212.950	-0.201
59	Bare Earth	931285.838	555802.778	2422.305	2422.080	-0.225
73	Bare Earth	823823.542	306330.311	3466.907	3466.680	-0.227
109	Bare Earth	901916.693	360496.834	3442.918	3442.690	-0.228
93	Bare Earth	925386.175	468453.409	2735.614	2735.380	-0.234
136	Bare Earth	963599.343	492824.350	2257.484	2257.250	-0.234
98	Bare Earth	875999.832	364794.806	2829.856	2829.620	-0.236
69	Bare Earth	1080366.482	372985.080	3372.178	3371.940	-0.238
81	Bare Earth	915831.464	433940.135	2291.433	2291.180	-0.253
71	Bare Earth	1085585.045	380935.955	3439.728	3439.450	-0.278
92	Bare Earth	933053.950	469776.361	2946.699	2946.420	-0.279
133	Bare Earth	974262.720	474871.368	2249.825	2249.540	-0.285
42	Bare Earth	1060705.649	295793.921	5305.642	5305.350	-0.292
89	Bare Earth	926284.898	481927.078	2369.620	2369.320	-0.300
99	Bare Earth	883579.670	359409.186	3080.986	3080.660	-0.326
87	Bare Earth	915887.050	483484.019	2210.508	2210.170	-0.338
23	Bare Earth	870528.080	361866.030	2770.265	2769.870	-0.395
52	Bare Earth	1008699.353	580965.168	3521.203	3520.790	-0.413
44	Bare Earth	1093367.811	371120.142	3429.724	3429.310	-0.414
66	Bare Earth	1117210.247	363557.226	3589.764	3589.350	-0.414
51	Bare Earth	1028775.389	581272.978	3876.890	3876.450	-0.440
50	Bare Earth	1023433.058	590954.325	3801.579	3801.130	-0.449

65	Bare Earth	1112394.285	367885.994	3555.063	3554.610	-0.453
68	Bare Earth	1091796.641	356999.203	3654.984	3654.500	-0.484
53	Bare Earth	988397.820	583832.022	3633.498	3633.010	-0.488
67	Bare Earth	1121221.730	360885.075	3646.423	3645.920	-0.503
29	Bare Earth	1020517.594	598414.328	3741.028	3740.490	-0.538
28	Bare Earth	971350.530	599113.328	3222.538	3221.970	-0.568
49	Bare Earth	1021712.411	584247.451	3772.381	3771.790	-0.591
20	Bare Earth	1028686.995	575246.335	3867.421	3866.600	-0.821

Average dz	-0.040
Minimum dz	-0.821
Maximum dz	+0.602
Average Magnitude	0.210
Root Mean Square	**0.264**
Std deviation	0.262

6.0 COORDINATES AND DATUM

6.1 Introduction

The final adjustment was constrained to the published NAD83 geodetic coordinates (ϕ, λ) and NAVD88 elevations. The adjustment was cross-referenced to the GEOID09 model to enable the estimation of orthometric heights.

6.2 Horizontal Datum

The final horizontal coordinates are provided in State Plane HARN on the North American Datum of 1983 (NAD83 adjustment of 1992) in the Central Zone with units of international feet.

6.3 Vertical Datum

The final orthometric elevations were determined for all points in the network using Geoid09 model and are provided on the North American Vertical Datum of 1988 in units of international feet.

LiDAR VERTICAL ACCURACY REPORT

PROJECT TITLE:	Pima Association of Governments
Contract Number:	1130001900
CONSULTANT NAME:	Wilson & Company, Inc., Engineers & Architects
PROJECT MANAGER:	Greg Thompson

Services Provided By: Wilson & Company
9401 Reeds Road
Overland Park, KS 66207
1/26/2012

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DATA ANALYSIS

This report documents the vertical accuracy of the LIDAR data as compared to the surveyed ground truth data for PAG 2011. The Fundamental Vertical Accuracy, the Overall Vertical Accuracy and the Supplemental Vertical Accuracies have been calculated based on the appropriate land cover classes, and are shown in the following sections.

Data analysis was accomplished by comparing ground truth checkpoints with LIDAR points from the edited data set, which were based on the LiDAR triangulated surface where the slope angle and Z tolerance were controlled. Note that the edited LIDAR points are simply a subset of the raw LIDAR points. The points that fell above the ground surface on vegetation canopies, buildings, or other obstructions were removed from the data set.

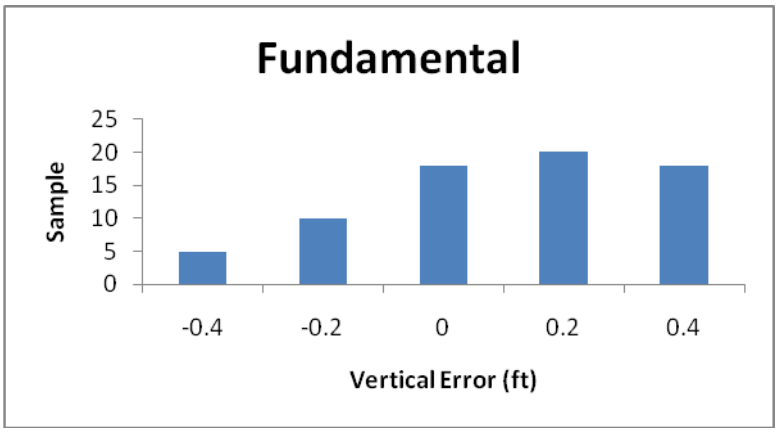
Ground truth data was collected for each of the following land cover categories:

1. Bare Earth
2. Urban Area
3. Vegetation

FUNDAMENTAL VERTICAL ACCURACY

The Fundamental Vertical Accuracy is calculated using the bare earth and urban land classes. A comparison of these values indicated a Vertical Root Mean Square Error (RMSEz) of 0.218 feet, which equates to a Vertical Accuracy of 0.427 feet at the 95% confidence level. Descriptive statistics and a histogram of the vertical error distribution are shown below.

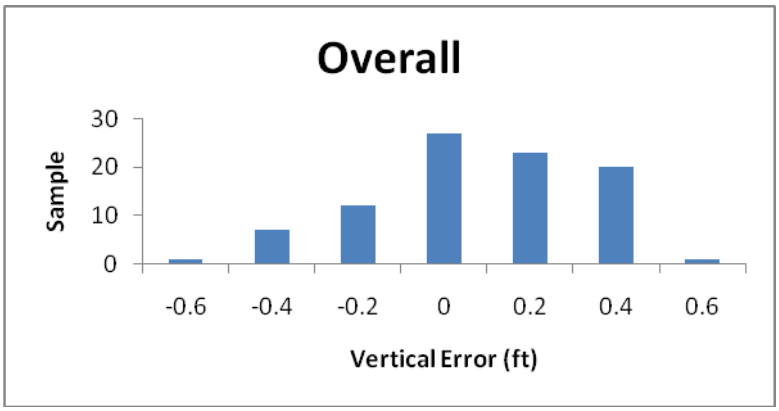
Fundamental (ft)	
RMSEz	0.218
Mean	0.003957746
Standard Error	0.026069381
Median	0.016
Mode	-0.097
Standard Deviation	0.219664513
Sample Variance	0.048252498
Kurtosis	-0.632397166
Skewness	-0.431148314
Range	0.86
Minimum	-0.488
Maximum	0.372
Count	71



OVERALL VERTICAL ACCURACY

The Overall Vertical Accuracy is calculated using all of the land classes collected. A comparison of these values indicated a Vertical Root Mean Square Error (RMSEz) of 0.225 feet, which equates to a Vertical Accuracy of 0.441 feet at the 95% confidence level. Descriptive statistics and a histogram of the vertical error distribution are shown below.

Overall (ft)	
RMSEz	0.225
Mean	-0.0133077
Standard Error	0.0239394
Median	-0.012
Mode	-0.414
Standard Deviation	0.22836733
Sample Variance	0.05215164
Kurtosis	-0.4725855
Skewness	-0.3357542
Range	1.041
Minimum	-0.591
Maximum	0.45
Count	91



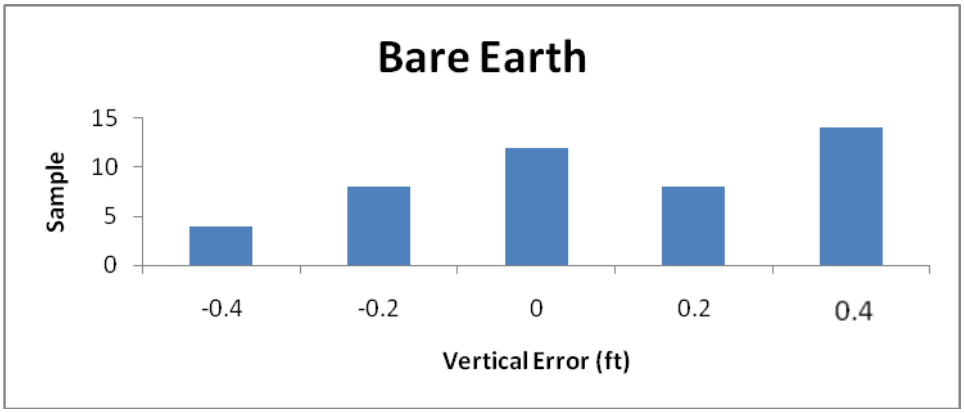
SUPPLEMENTAL VERTICAL ACCURACIES

The Supplemental Vertical Accuracies are calculated using each of the individual land cover classes. The land cover classes include bare earth, urban areas and vegetation. The RMSEz values and Vertical Accuracies are shown with each respective land class, along with histograms of vertical error distribution.

Bare Earth

This set includes only those points that were collected in areas of open ground. The resulting RMSEz is 0.240 feet, which equates to a Vertical Accuracy of 0.470 feet at the 95% confidence level.

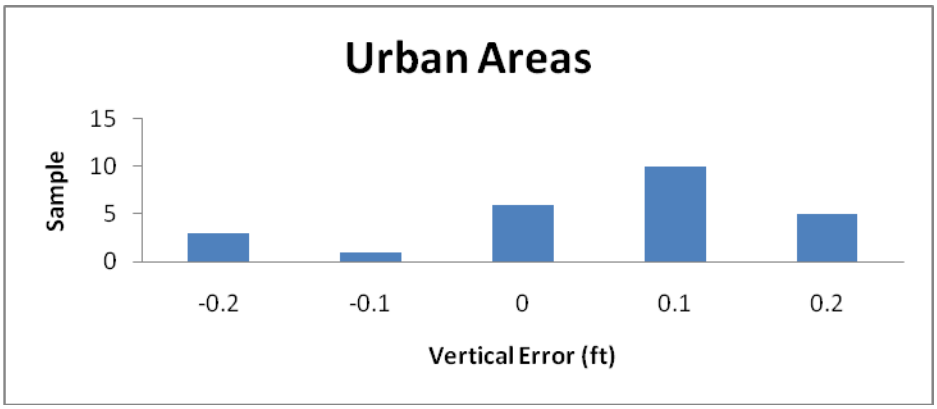
Bare Earth (ft)	
RMSEz	0.24
Mean	-0.0071087
Standard Error	0.03579266
Median	-0.013
Mode	-0.021
Standard Deviation	0.2427576
Sample Variance	0.05893125
Kurtosis	-1.0449697
Skewness	-0.2817876
Range	0.86
Minimum	-0.488
Maximum	0.372
Count	46



Urban Areas

This set includes only those points that were collected in areas with man-made features, such as roads and parking lots. The resulting RMSEz is 0.196, which equates to a Vertical Accuracy of 0.384 feet at the 95% confidence level.

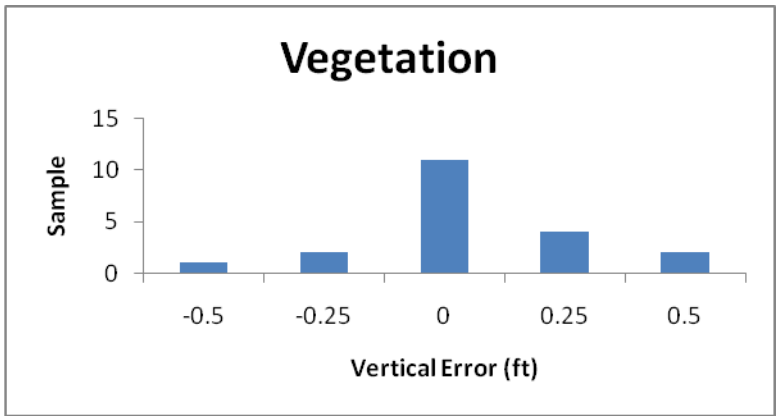
Urban Areas (ft)	
RMSEz	0.17
Mean	0.02432
Standard Error	0.034394027
Median	0.049
Mode	-0.097
Standard Deviation	0.171970133
Sample Variance	0.029573727
Kurtosis	1.114169833
Skewness	-0.826641136
Range	0.71
Minimum	-0.44
Maximum	0.27
Count	25



Vegetation

This data set includes only those points that were collected in areas of grass, shrubs and cacti. The resulting RMSEz is 0.255 feet, which equates to a vertical accuracy of 0.500 feet at the 95% confidence level.

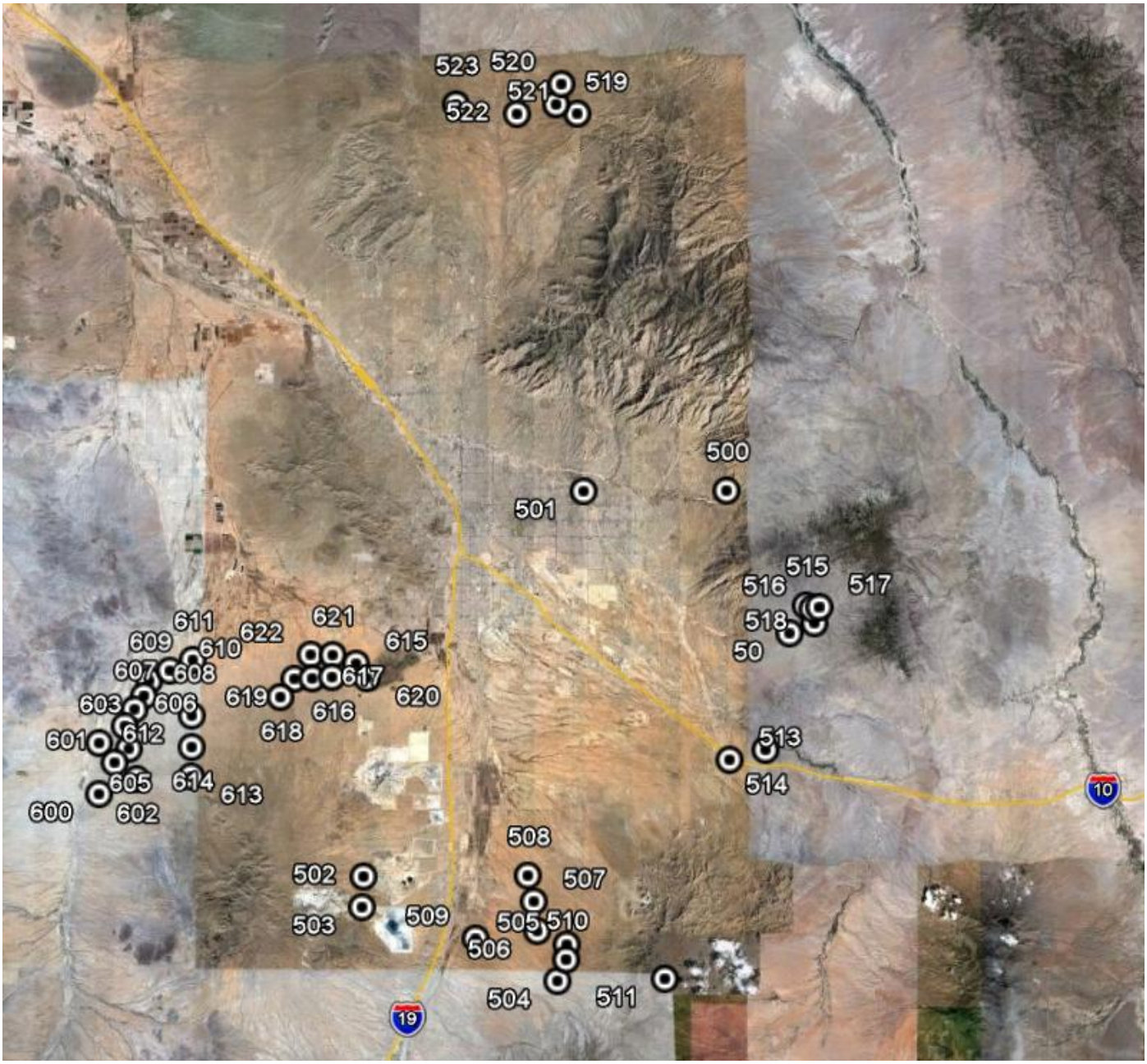
Vegetation (ft)	
RMSEz	0.258
Mean	-0.0746
Standard Error	0.056653908
Median	-0.0605
Mode	#N/A
Standard Deviation	0.253363978
Sample Variance	0.064193305
Kurtosis	0.298302838
Skewness	0.044811486
Range	1.041
Minimum	-0.591
Maximum	0.45
Count	20



PAG 2011

Ground Truth Survey Locations

March 2011



Legend:

Survey Point

0 5.0 10.0 miles

N W E S

Ground Truth Analysis

Comparison of LiDAR Points to Ground Survey Points

Horizontal Units = US State Plane Arizona Central Zone, NAD83, International Feet

Vertical Units = NAVD88 Geoid 09 International Feet

Number	Easting	Northing	Survey Z	LiDAR Z	DZ	Description
600	870914.6	354301.2	2878.257	2878.15	-0.107	Bare Earth
601	875999.8	364794.8	2829.856	2829.62	-0.236	Bare Earth
602	883579.7	359409.2	3080.986	3080.66	-0.326	Bare Earth
605	880693.9	369402.7	2835.225	2835.45	0.225	Bare Earth
612	901669.5	380617.3	2839.378	2839.35	-0.028	Bare Earth
613	901916.7	360496.8	3442.918	3442.69	-0.228	Bare Earth
615	956349.7	398355.4	2668.513	2668.57	0.057	Bare Earth
617	941783.3	393318.9	2754.188	2754.39	0.202	Bare Earth
618	931192.6	387026.3	2898.319	2898.59	0.271	Bare Earth
619	935778.3	393114.8	2742.087	2742.22	0.133	Bare Earth
620	960003	393554.8	2734.385	2734.7	0.315	Bare Earth
621	948472.1	401126.7	2623.56	2623.66	0.1	Bare Earth
622	941115.1	401198.1	2606.602	2606.87	0.268	Bare Earth
624	973959.4	467714.7	2251.247	2251.25	0.003	Bare Earth
626	973697.5	471751.4	2247.52	2247.38	-0.14	Bare Earth
628	965776.8	473268.1	2328.212	2328.48	0.268	Bare Earth
629	966504.1	477720.4	2215.176	2215.46	0.284	Bare Earth
630	960056	483474.8	2193.795	2194.08	0.285	Bare Earth
631	956414.6	488690.7	2160.996	2161.32	0.324	Bare Earth
634	963798.8	485833.8	2206.009	2205.89	-0.119	Bare Earth
638	967800	486375.8	2234.611	2234.53	-0.081	Bare Earth
503	959301	317683.7	3552.552	3552.79	0.238	Bare Earth
504	1024813	294065.2	3692.601	3692.58	-0.021	Bare Earth
505	1027787	306074.6	3597.7	No Data	*	Bare Earth
501	1031959	456204.5	2536.412	No Data	*	Bare Earth
508	1014443	328558.9	2958.946	No Data	*	Bare Earth
511	1060706	295793.9	5305.642	5305.35	-0.292	Bare Earth
518	1109091	413126.6	3278.25	3278.34	0.09	Bare Earth

Number	Easting	Northing	Survey Z	LiDAR Z	DZ	Description
522	1008699	580965.2	3521.203	3520.79	-0.413	Bare Earth
523	988397.8	583832	3633.498	3633.01	-0.488	Bare Earth
524	865317.1	568858.1	1817.19	1817.43	0.24	Bare Earth
525	849398.1	578068.3	1762.938	1763.31	0.372	Bare Earth
529	931285.8	555802.8	2422.305	No Data	*	Bare Earth
535	1112394	367886	3555.063	3554.61	-0.453	Bare Earth
536	1117210	363557.2	3589.764	3589.35	-0.414	Bare Earth
538	1091797	356999.2	3654.984	No Data	*	Bare Earth
539	1080366	372985.1	3372.178	No Data	*	Bare Earth
541	1085585	380936	3439.728	3439.45	-0.278	Bare Earth
542	825474.6	300369	3523.035	3523.08	0.045	Bare Earth
544	848198.5	298925.7	3129.152	3129.14	-0.012	Bare Earth
545	861310.2	310085.9	3003.438	3003.71	0.272	Bare Earth
549	869151.7	388109.1	2593.527	2593.71	0.183	Bare Earth
550	859643.6	385100.8	2657.568	2657.8	0.232	Bare Earth
551	915831.5	433940.1	2291.433	2291.18	-0.253	Bare Earth
553	897233.2	454603.1	2216.701	2216.68	-0.021	Bare Earth
554	875917.6	470339.2	2120.759	2120.66	-0.099	Bare Earth
555	869353.7	486602.5	2074.24	2074.37	0.13	Bare Earth
556	875196.1	520444	1960.874	1960.86	-0.014	Bare Earth
557	915887.1	483484	2210.508	2210.17	-0.338	Bare Earth
564	915865.9	464332	2350.726	2350.59	-0.136	Bare Earth
566	915712.3	470519	2341.958	2341.87	-0.088	Bare Earth
562	933054	469776.4	2946.699	2946.42	-0.279	Bare Earth
517	1110669	418363.9	3408.007	3407.91	-0.097	Urban Area
531	1049603	478078.8	2946.506	2946.57	0.064	Urban Area
540	1082920	382433.3	3358.477	3358.58	0.103	Urban Area
546	862306.5	323420.7	2921.773	2921.83	0.057	Urban Area
547	863088.1	338083.3	2859.866	2859.96	0.094	Urban Area
548	867397.1	356300.9	2783.026	2783	-0.026	Urban Area
552	915711.8	449497.3	2294.095	No Data	*	Urban Area
506	1017800	310293.4	3299.85	3300.03	0.18	Urban Area
515	1106265	418832.7	3380.671	3380.72	0.049	Urban Area
502	959725.7	327840.2	3600.832	3601.01	0.178	Urban Area
509	997185.1	307499.1	2994.736	2994.99	0.254	Urban Area
513	1081444	367669.1	3446.131	No Data	*	Urban Area
521	1028775	581273	3876.89	3876.45	-0.44	Urban Area

Number	Easting	Northing	Survey Z	LiDAR Z	DZ	Description
530	1037972	480182.6	2783.236	2783.21	-0.026	Urban Area
559	926284.9	481927.1	2369.62	2369.32	-0.3	Urban Area
565	905265.5	470519.6	2157.938	2157.91	-0.028	Urban Area
623	972239.4	468391.9	2255.12	2255.39	0.27	Urban Area
625	971009.5	471387.6	2242.579	2242.63	0.051	Urban Area
633	960698	487608.1	2187.126	2187.16	0.034	Urban Area
636	970045.7	477153.3	2231.684	No Data	*	Urban Area
639	960541.8	490059.5	2183.954	2183.97	0.016	Urban Area
640	963599.3	492824.4	2257.484	No Data	*	Urban Area
614	901887.2	370217.7	3164.685	3164.69	0.005	Urban Area
606	879136.4	376941.7	2686.94	2687.18	0.24	Urban Area
607	882261.2	382474	2638.616	2638.88	0.264	Urban Area
609	887002.3	392042.6	2545.776	2545.85	0.074	Urban Area
627	978033.4	469377.5	2262.98	2262.87	-0.11	Urban Area
635	967517.9	481479	2213.151	2212.95	-0.201	Urban Area
637	974262.7	474871.4	2249.825	No Data	*	Urban Area
500	1079679	456436.2	2757.224	No Data	*	Urban Area
610	893874.5	395442	2537.297	2537.2	-0.097	Urban Area
611	901556.7	399117.9	2512.173	No Data	*	Urban Area
516	1108451	417880.7	3284.825	3284.75	-0.075	Vegetation
533	1115006	384040.5	3743.35	3743.34	-0.01	Vegetation
534	1121882	384218.7	3815.707	3815.57	-0.137	Vegetation
510	1027672	301175.5	3702.717	3702.75	0.033	Vegetation
526	902233.3	555888	2003.904	2003.97	0.066	Vegetation
527	902132.3	563976.9	2032.376	2032.33	-0.046	Vegetation
528	918035.7	547038.8	2140.88	2140.84	-0.04	Vegetation
543	823823.5	306330.3	3466.907	3466.68	-0.227	Vegetation
558	915878.1	483358.1	2211.766	2211.65	-0.116	Vegetation
560	926451.1	486447.1	2308.37	2308.19	-0.18	Vegetation
561	935009	479483.1	2567.374	2567.34	-0.034	Vegetation
519	1021712	584247.5	3772.381	3771.79	-0.591	Vegetation
520	1023433	590954.3	3801.579	3801.13	-0.449	Vegetation
603	870591.7	371204.4	2653.12	2653.57	0.45	Vegetation
608	885330.8	386968.7	2598.638	2598.97	0.332	Vegetation
616	948387.4	393806.9	2755.294	2755.5	0.206	Vegetation
632	953890.8	491135.3	2152.898	Removed	*	Vegetation
514	1093368	371120.1	3429.724	3429.31	-0.414	Vegetation

Number	Easting	Northing	Survey Z	LiDAR Z	DZ	Description
532	1112047	384278.8	3651.415	3651.22	-0.195	Vegetation
563	925386.2	468453.4	2735.614	2735.38	-0.234	Vegetation
507	1016558	320042.7	3110.841	3111.01	0.169	Vegetation

APPENDECIES

APPENDIX A PROJECT MAPPING AND SURVEY CONTROL

APPENDIX B ONSITE DRAINAGE

APPENDIX C OFFSITE DRAINAGE

APPENDIX D SANTA CRUZ HYDRAULICS

APPENDIX E DCR LEVEL CONSTRUCTION PLANS

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: PCDOT | Prepared by: EGM

Project Name: Sunset Rd Silverbell to River | Date: 9/17/2014

Concentration Point: WS 1 (Sta 81+31 Rt) | Job #: 4RTSUN

Watershed Area: 0.5 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	9.8	348	0.0282	.030

Length of Watercourse (Lc): 348 feet | Mean Slope: 0.0282

Length to Cen. of Gravity (Lca): 170 feet | Weighted Basin Fac.: 0.030

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 5 %

RETURN PERIOD: 100-years

Rainfall Depths: Manual Input of Rainfal Depths by User

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97
Areal Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	84.	86.89	0.499
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	65	99.	99.	0.950

Weighted Runoff Coef. (Cw): 0.792

Time of Concentration: 5.0 min

Rainfall Intensity (i) @ Tc: 8.88 in/hr

Runoff Supply Rate (q) @ Tc: 7.03 in/hr

PEAK DISCHARGE: 3.4 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.25	0.9
5-year	0.35	1.2
10-year	0.50	1.7
25-year	0.70	2.4
50-year	0.90	3.1

PC-Hydro, Ver 5.4.3

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: PCDOT | Prepared by: EGM

Project Name: Sunset Rd Silverbell to River | Date: 9/17/2014

Concentration Point: WS 2 (Sta 81+56 Lt) | Job #: 4RTSUN

Watershed Area: 0.5 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	10.2	364	0.0280	.030

Length of Watercourse (Lc): 364 feet | Mean Slope: 0.0280

Length to Cen. of Gravity (Lca): 180 feet | Weighted Basin Fac.: 0.030

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 5 %

RETURN PERIOD: 100-years

Rainfall Depths: Manual Input of Rainfal Depths by User

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97
Areal Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	84.	86.89	0.499
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	65	99.	99.	0.950

Weighted Runoff Coef. (Cw): 0.792

Time of Concentration: 5.0 min

Rainfall Intensity (i) @ Tc: 8.88 in/hr

Runoff Supply Rate (q) @ Tc: 7.03 in/hr

PEAK DISCHARGE: 3.3 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.25	0.8
5-year	0.35	1.1
10-year	0.50	1.6
25-year	0.70	2.3
50-year	0.90	2.9

PC-Hydro, Ver 5.4.3

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: PCDOT | Prepared by: EGM

Project Name: Sunset Rd Silverbell to River | Date: 9/17/2014

Concentration Point: WS 3 (Sta 83+87 Lt) | Job #: 4RTSUN

Watershed Area: 0.6 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	5.9	272	0.0217	.030

Length of Watercourse (Lc): 272 feet | Mean Slope: 0.0217

Length to Cen. of Gravity (Lca): 130 feet | Weighted Basin Fac.: 0.030

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 5 %

RETURN PERIOD: 100-years

Rainfall Depths: Manual Input of Rainfal Depths by User

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97
Areal Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	84.	86.89	0.499
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	65	99.	99.	0.950

Weighted Runoff Coef. (Cw): 0.792

Time of Concentration: 5.0 min

Rainfall Intensity (i) @ Tc: 8.88 in/hr

Runoff Supply Rate (q) @ Tc: 7.03 in/hr

PEAK DISCHARGE: 3.9 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.25	1.0
5-year	0.35	1.4
10-year	0.50	1.9
25-year	0.70	2.7
50-year	0.90	3.5

PC-Hydro, Ver 5.4.3

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: PCDOT | Prepared by: EGM

Project Name: Sunset Rd Silverbell to River | Date: 9/17/2014

Concentration Point: WS 4 (Sta 85+50 Lt) | Job #: 4RTSUN

Watershed Area: 0.5 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	5.0	310	0.0161	.030

Length of Watercourse (Lc): 310 feet | Mean Slope: 0.0161

Length to Cen. of Gravity (Lca): 155 feet | Weighted Basin Fac.: 0.030

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 5 %

RETURN PERIOD: 100-years

Rainfall Depths: Manual Input of Rainfal Depths by User

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97
Areal Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	84.	86.89	0.499
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	65	99.	99.	0.950

Weighted Runoff Coef. (Cw): 0.792

Time of Concentration: 5.0 min

Rainfall Intensity (i) @ Tc: 8.88 in/hr

Runoff Supply Rate (q) @ Tc: 7.03 in/hr

PEAK DISCHARGE: 3.5 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.25	0.9
5-year	0.35	1.2
10-year	0.50	1.7
25-year	0.70	2.4
50-year	0.90	3.1

PC-Hydro, Ver 5.4.3

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: PCDOT | Prepared by: EGM

Project Name: Sunset Rd Silverbell to River | Date: 9/17/2014

Concentration Point: WS 5 (Sta 88+29 Lt) | Job #: 4RTSUN

Watershed Area: 1.6 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	7.2	922	0.0078	.030

Length of Watercourse (Lc): 922 feet | Mean Slope: 0.0078

Length to Cen. of Gravity (Lca): 450 feet | Weighted Basin Fac.: 0.030

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 5 %

RETURN PERIOD: 100-years

Rainfall Depths: Manual Input of Rainfal Depths by User

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97
Areal Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	84.	86.89	0.499
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	65	99.	99.	0.950

Weighted Runoff Coef. (Cw): 0.792

Time of Concentration: 5.7 min

Rainfall Intensity (i) @ Tc: 8.35 in/hr

Runoff Supply Rate (q) @ Tc: 6.62 in/hr

PEAK DISCHARGE: 10 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.25	2.6
5-year	0.35	3.6
10-year	0.50	5.2
25-year	0.70	7.3
50-year	0.90	9.4

PC-Hydro, Ver 5.4.3

Verify Ultimate Conditions Flow is less than Interim Conditions Flow

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: PCDOT | Prepared by: EGM

Project Name: Sunset Rd Silverbell to River | Date: 9/18/2014

Concentration Point: Ult Conditions (Sta 88+29 Lt) | Job #: 4RTSUN

Watershed Area: 1.3 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	27.0	1,030	0.0262	.016

Length of Watercourse (Lc): 1,030 feet | Mean Slope: 0.0262

Length to Cen. of Gravity (Lca): 515 feet | Weighted Basin Fac.: 0.016

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 5 %

RETURN PERIOD: 100-years

Rainfall Depths: Manual Input of Rainfal Depths by User

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97
Areal Values (in)	0.74	1.13	1.40	1.88	2.33	2.61	2.73	2.97	3.21	3.97

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	84.	86.89	0.499
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	75	99.	99.	0.950

Weighted Runoff Coef. (Cw): 0.837

Time of Concentration: 5.0 min

Rainfall Intensity (i) @ Tc: 8.88 in/hr

Runoff Supply Rate (q) @ Tc: 7.43 in/hr

PEAK DISCHARGE: 9.8 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.25	2.5
5-year	0.35	3.4
10-year	0.50	4.9
25-year	0.70	6.9
50-year	0.90	8.8

PC-Hydro, Ver 5.4.3

Worksheet for Pipe SD1

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.01400	ft/ft
Diameter	2.00	ft
Discharge	1.70	ft^3/s

Results

Normal Depth	0.33	ft
Flow Area	0.34	ft^2
Wetted Perimeter	1.67	ft
Hydraulic Radius	0.20	ft
Top Width	1.48	ft
Critical Depth	0.45	ft
Percent Full	16.4	%
Critical Slope	0.00385	ft/ft
Velocity	5.04	ft/s
Velocity Head	0.40	ft
Specific Energy	0.72	ft
Froude Number	1.86	
Maximum Discharge	31.19	ft^3/s
Discharge Full	29.00	ft^3/s
Slope Full	0.00005	ft/ft
Flow Type	SuperCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	16.43	%
Downstream Velocity	Infinity	ft/s

Worksheet for Pipe SD1

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	0.33	ft
Critical Depth	0.45	ft
Channel Slope	0.01400	ft/ft
Critical Slope	0.00385	ft/ft

Worksheet for Pipe SD2

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.01500	ft/ft
Diameter	2.00	ft
Discharge	3.20	ft^3/s

Results

Normal Depth	0.44	ft
Flow Area	0.51	ft^2
Wetted Perimeter	1.96	ft
Hydraulic Radius	0.26	ft
Top Width	1.66	ft
Critical Depth	0.62	ft
Percent Full	22.0	%
Critical Slope	0.00380	ft/ft
Velocity	6.23	ft/s
Velocity Head	0.60	ft
Specific Energy	1.04	ft
Froude Number	1.97	
Maximum Discharge	32.29	ft^3/s
Discharge Full	30.01	ft^3/s
Slope Full	0.00017	ft/ft
Flow Type	SuperCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	22.05	%
Downstream Velocity	Infinity	ft/s

Worksheet for Pipe SD2

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	0.44	ft
Critical Depth	0.62	ft
Channel Slope	0.01500	ft/ft
Critical Slope	0.00380	ft/ft

Worksheet for Pipe SD3

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.00300	ft/ft
Diameter	2.00	ft
Discharge	8.80	ft^3/s

Results

Normal Depth	1.18	ft
Flow Area	1.93	ft^2
Wetted Perimeter	3.51	ft
Hydraulic Radius	0.55	ft
Top Width	1.97	ft
Critical Depth	1.06	ft
Percent Full	59.1	%
Critical Slope	0.00427	ft/ft
Velocity	4.56	ft/s
Velocity Head	0.32	ft
Specific Energy	1.50	ft
Froude Number	0.81	
Maximum Discharge	14.44	ft^3/s
Discharge Full	13.42	ft^3/s
Slope Full	0.00129	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	59.06	%
Downstream Velocity	Infinity	ft/s

Worksheet for Pipe SD3

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	1.18	ft
Critical Depth	1.06	ft
Channel Slope	0.00300	ft/ft
Critical Slope	0.00427	ft/ft

Worksheet for Pipe SD4

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.00300	ft/ft
Diameter	2.00	ft
Discharge	6.90	ft^3/s

Results

Normal Depth	1.02	ft
Flow Area	1.60	ft^2
Wetted Perimeter	3.17	ft
Hydraulic Radius	0.51	ft
Top Width	2.00	ft
Critical Depth	0.93	ft
Percent Full	50.8	%
Critical Slope	0.00404	ft/ft
Velocity	4.30	ft/s
Velocity Head	0.29	ft
Specific Energy	1.30	ft
Froude Number	0.85	
Maximum Discharge	14.44	ft^3/s
Discharge Full	13.42	ft^3/s
Slope Full	0.00079	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	50.82	%
Downstream Velocity	Infinity	ft/s

Worksheet for Pipe SD4

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	1.02	ft
Critical Depth	0.93	ft
Channel Slope	0.00300	ft/ft
Critical Slope	0.00404	ft/ft

Worksheet for Pipe SD5

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.012	
Channel Slope	0.00500	ft/ft
Diameter	2.00	ft
Discharge	5.20	ft^3/s

Results

Normal Depth	0.75	ft
Flow Area	1.08	ft^2
Wetted Perimeter	2.64	ft
Hydraulic Radius	0.41	ft
Top Width	1.94	ft
Critical Depth	0.80	ft
Percent Full	37.6	%
Critical Slope	0.00389	ft/ft
Velocity	4.82	ft/s
Velocity Head	0.36	ft
Specific Energy	1.11	ft
Froude Number	1.14	
Maximum Discharge	18.64	ft^3/s
Discharge Full	17.33	ft^3/s
Slope Full	0.00045	ft/ft
Flow Type	SuperCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%
Normal Depth Over Rise	37.56	%
Downstream Velocity	Infinity	ft/s

Worksheet for Pipe SD5

GVF Output Data

Upstream Velocity	Infinity	ft/s
Normal Depth	0.75	ft
Critical Depth	0.80	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00389	ft/ft

APPENDECIES

APPENDIX A PROJECT MAPPING AND SURVEY CONTROL

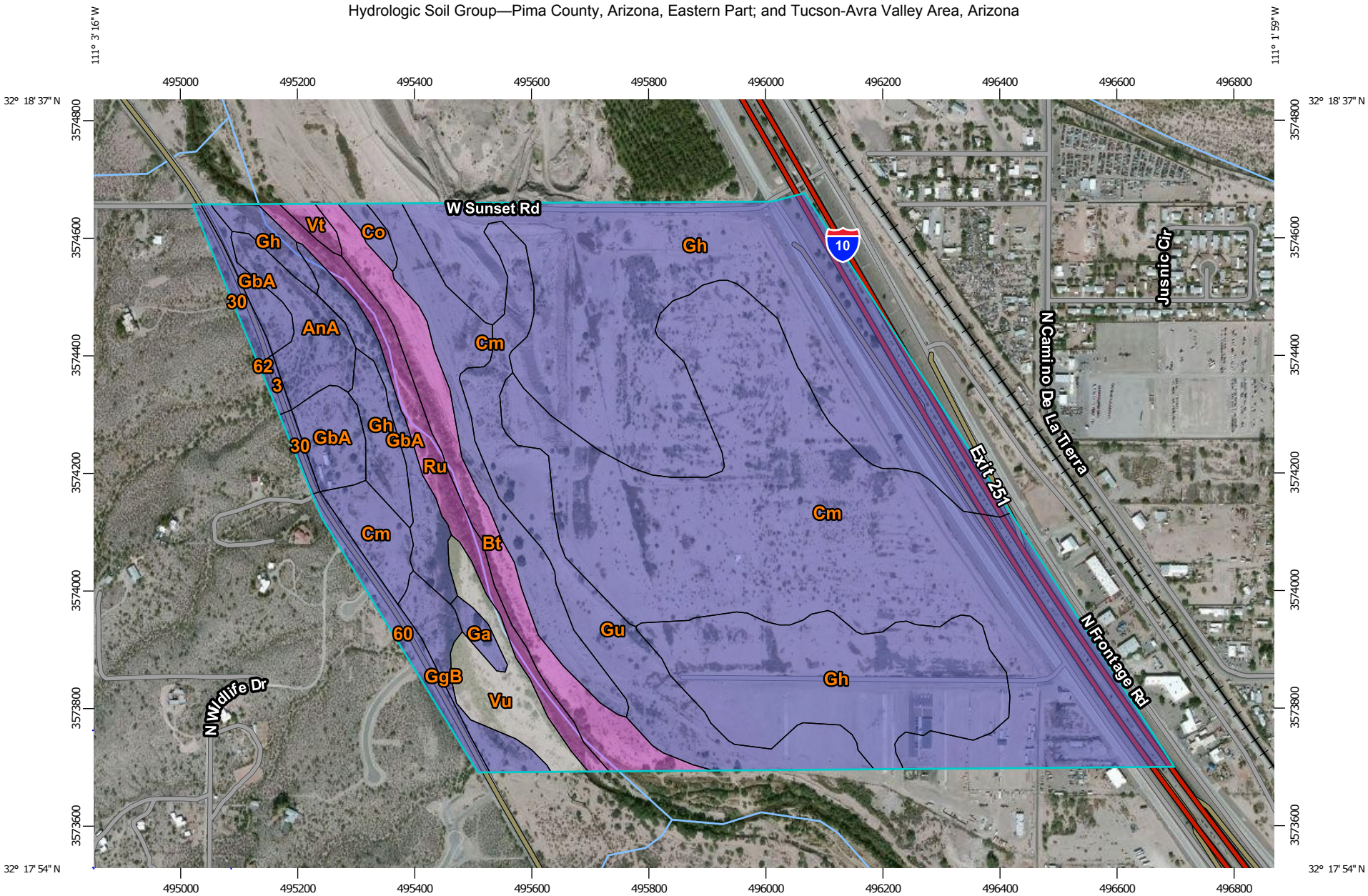
APPENDIX B ONSITE DRAINAGE

APPENDIX C OFFSITE DRAINAGE

APPENDIX D SANTA CRUZ HYDRAULICS

APPENDIX E DCR LEVEL CONSTRUCTION PLANS

POC 1 (EAST OFFSITE DRAINAGE)



Map Scale: 1:9,230 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 100 200 400 600

Feet: 0 400 800 1600 2400

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:20,000 to 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Pima County, Arizona, Eastern Part
Survey Area Data: Version 9, Dec 15, 2013

Soil Survey Area: Tucson-Avra Valley Area, Arizona
Survey Area Data: Version 7, Dec 15, 2013

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 20, 2010—Nov 27, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Pima County, Arizona, Eastern Part (AZ669)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
3	Anthony fine sandy loam, 0 to 3 percent slopes	B	0.6	0.2%
30	Glendale silt loam, 0 to 3 percent slopes	B	2.4	0.9%
60	Pinaleno-Stagecoach complex, 5 to 16 percent slopes	B	3.8	1.4%
62	Pinaleno very cobbly sandy loam, 1 to 8 percent slopes	B	0.0	0.0%
Subtotals for Soil Survey Area			**6.8**	**2.5%**
Totals for Area of Interest			**275.3**	**100.0%**

Hydrologic Soil Group— Summary by Map Unit — Tucson-Avra Valley Area, Arizona (AZ668)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
AnA	Anthony gravelly sandy loam, 0 to 1 percent slopes	B	6.1	2.2%
Bt	Brazito sandy loam	A	13.3	4.8%
Cm	Comoro sandy loam	B	98.8	35.9%
Co	Comoro loam	B	1.1	0.4%
Ga	Gila sandy loam	B	1.1	0.4%
GbA	Gila loam, 0 to 1 percent slopes	B	11.5	4.2%
GgB	Grabe gravelly sandy loam, 1 to 3 percent slopes	B	4.3	1.5%
Gh	Grabe loam	B	95.0	34.5%
Gu	Gullied land	B	20.9	7.6%
Ru	Riverwash	A	8.3	3.0%
Vt	Vinton sandy loam	A	0.9	0.3%
Vu	Vinton-anthony sandy loams		7.2	2.6%
Subtotals for Soil Survey Area			**268.5**	**97.5%**
Totals for Area of Interest			**275.3**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having 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.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist 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 soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: Pima County DOT | Prepared by: GB

Project Name: Sunset Road (SEG 1) | Date: 5/8/2014

Concentration Point: DAE1 | Job #: 4RTSUN

Watershed Area: 66.0 ac | Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	0.2	267	0.0007	.030
2	0.4	4	0.1000	.030
3	0.4	65	0.0062	.030
4	1.3	27	0.0481	.030
5	0.4	72	0.0056	.030
6	0.2	1,233	0.0002	.040
7	0.1	117	0.0009	.030
8	0.4	545	0.0007	.030
9	1.0	530	0.0019	.030
10	2.0	310	0.0065	.030
11	1.0	355	0.0028	.030
12	1.0	130	0.0077	.030

Length of Watercourse (Lc): 3,655 feet | Mean Slope: 0.0005

Length to Cen. of Gravity (Lca): 1,505 feet | Weighted Basin Fac.: 0.036

Veg. Cover Type(s): Desert Brush | Veg. Cover Density: 10 %

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.3067 Longitude: 111.0440

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.84	1.28	1.59	2.14	2.65	2.95	3.09	3.35	3.59	4.43
Areal Values (in)	0.84	1.28	1.59	2.14	2.65	2.95	3.09	3.35	3.59	4.43

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	85.	88.52	0.585
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	5	99.	99.	0.956

Weighted Runoff Coef. (Cw): 0.603

Time of Concentration: 1.5 hrs

Rainfall Intensity (i) @ Tc: 1.92 in/hr

Runoff Supply Rate (q) @ Tc: 1.16 in/hr

PEAK DISCHARGE: 77 cfs

PC-Hydro, Ver 5.3.1

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.10	7.7
5-year	0.23	18
10-year	0.35	27
25-year	0.55	42
50-year	0.75	58

HYDROLOGIC DATA SHEET FOR PIMA COUNTY FLOOD PEAK PROCEDURE

Pima County Regional Flood Control District

Client: Pima County DOT | Prepared by: GB
Project Name: Sunset Road (SEG 1) | Date: 09/2014
Concentration Point: DAE1-Prop | Job #: 4RTSUN

Watershed Area: 60.0 ac Watershed Type: Undeveloped-Valley

Watercourse Data By Reach

Reach No.	Height (Hi)	Length (Li)	Slope (Si)	Basin Factor (Nb)
1	1.0	453	0.0022	.030
2	0.1	870	0.0002	.040
3	0.1	117	0.0009	.030
4	0.4	545	0.0007	.030
5	1.0	530	0.0019	.030
6	2.0	310	0.0065	.030
7	1.0	355	0.0028	.030
8	1.0	130	0.0077	.030

Length of Watercourse (Lc): 3,310 feet Mean Slope: 0.0007
Length to Cen. of Gravity (Lca): 1,412 feet Weighted Basin Fac.: 0.033
Veg. Cover Type(s): Desert Brush Veg. Cover Density: 10 %

RETURN PERIOD: 100-years

Rainfall Depths: NOAA Atlas 14 (90% UCL) @ Latitude: 32.3067 Longitude: 111.0440

Duration:	5-min	10-min	15-min	30-min	60-min	2-hr	3-hr	6-hr	12-hr	24-hr
Point Values (in)	0.84	1.28	1.59	2.14	2.65	2.95	3.09	3.35	3.59	4.43
Areal Values (in)	0.84	1.28	1.59	2.14	2.65	2.95	3.09	3.35	3.59	4.43

Soils Data

Soil Type	Percent	Curve # (CN)	Adj. Curve # (CN*)	Runoff Coef. (C)
B	100	85.	88.52	0.585
C	0	.	.	0.000
D	0	.	.	0.000
Imp.	5	99.	99.	0.956

Weighted Runoff Coef. (Cw): 0.603
Time of Concentration: 60.0 min
Rainfall Intensity (i) @ Tc: 2.65 in/hr
Runoff Supply Rate (q) @ Tc: 1.60 in/hr

PEAK DISCHARGE: 97 cfs

Lesser Return Periods

Return Period	Ratio	Qpeak
2-year	0.10	9.7
5-year	0.23	22
10-year	0.35	34
25-year	0.55	53
50-year	0.75	73

PC-Hydro, Ver 5.4.3

Culvert Designer/Analyzer Report
DAE1-Prop

Analysis Component			
Storm Event	Design	Discharge	97.00 cfs

Peak Discharge Method: User-Specified			
Design Discharge	97.00 cfs	Check Discharge	100.00 cfs

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	97.00 cfs	Bottom Elevation	2,217.25 ft
Depth	2.31 ft	Velocity	2.48 ft/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	2-36 inch Circular	97.00 cfs	2,224.94 ft	8.56 ft/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Designer/Analyzer Report
DAE1-Prop

Component:Culvert-1

Culvert Summary					
Computed Headwater Eleva	2,224.94	ft	Discharge	97.00	cfs
Inlet Control HW Elev.	2,224.88	ft	Tailwater Elevation	2,219.56	ft
Outlet Control HW Elev.	2,224.94	ft	Control Type	Entrance Control	
Headwater Depth/Height	1.31				

Grades					
Upstream Invert	2,221.00	ft	Downstream Invert	2,218.18	ft
Length	440.00	ft	Constructed Slope	0.006409	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	2.24	ft
Slope Type	Steep		Normal Depth	2.24	ft
Flow Regime	Supercritical		Critical Depth	2.27	ft
Velocity Downstream	8.56	ft/s	Critical Slope	0.006245	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	2				

Outlet Control Properties					
Outlet Control HW Elev.	2,224.94	ft	Upstream Velocity Head	1.11	ft
Ke	0.50		Entrance Loss	0.56	ft

Inlet Control Properties					
Inlet Control HW Elev.	2,224.88	ft	Flow Control	Transition	
Inlet Type	Square edge w/headwall		Area Full	14.1	ft^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Project:	4RTSUN Sunset Road, Silverbell to I-10	Calc'd By:	Bambauer	Date:	9/19/2014
Culvert ID:	CPE1-Prop	Chk'd By:		Date:	
Station:	83+19				

CULVERT RIPRAP APRON DESIGN

Riprap Apron Design (HEC-14, FHWA, Chapter 10)

Enter Data in: Field

Discharge/Cell	Q	49	(ft^3/sec)
Height	D	36	(inch)
Tailwater Depth	TW	2.31	(ft)

Step 1. Tailwater Test

TW/D = 0.77

If TW/D < 0.4D Use 0.4D as TW

TW= 1.2 (ft)

Step 2. Compute D_{50}

D_{50} = 8.1 (inch)

Step 3. Determine Riprap Class From Table, Below

RIPRAP CLASS & APRON DIMENSIONS

Class	D50	Apron Length	Apron Depth
1	5	4D	$3.5D_{50}$
2	6	4D	$3.3D_{50}$
3	10	5D	$2.4D_{50}$
4	14	6D	$2.2D_{50}$
5	20	7D	$2.0D_{50}$
6	22	8D	$2.0D_{50}$

Use Riprap Class: 3

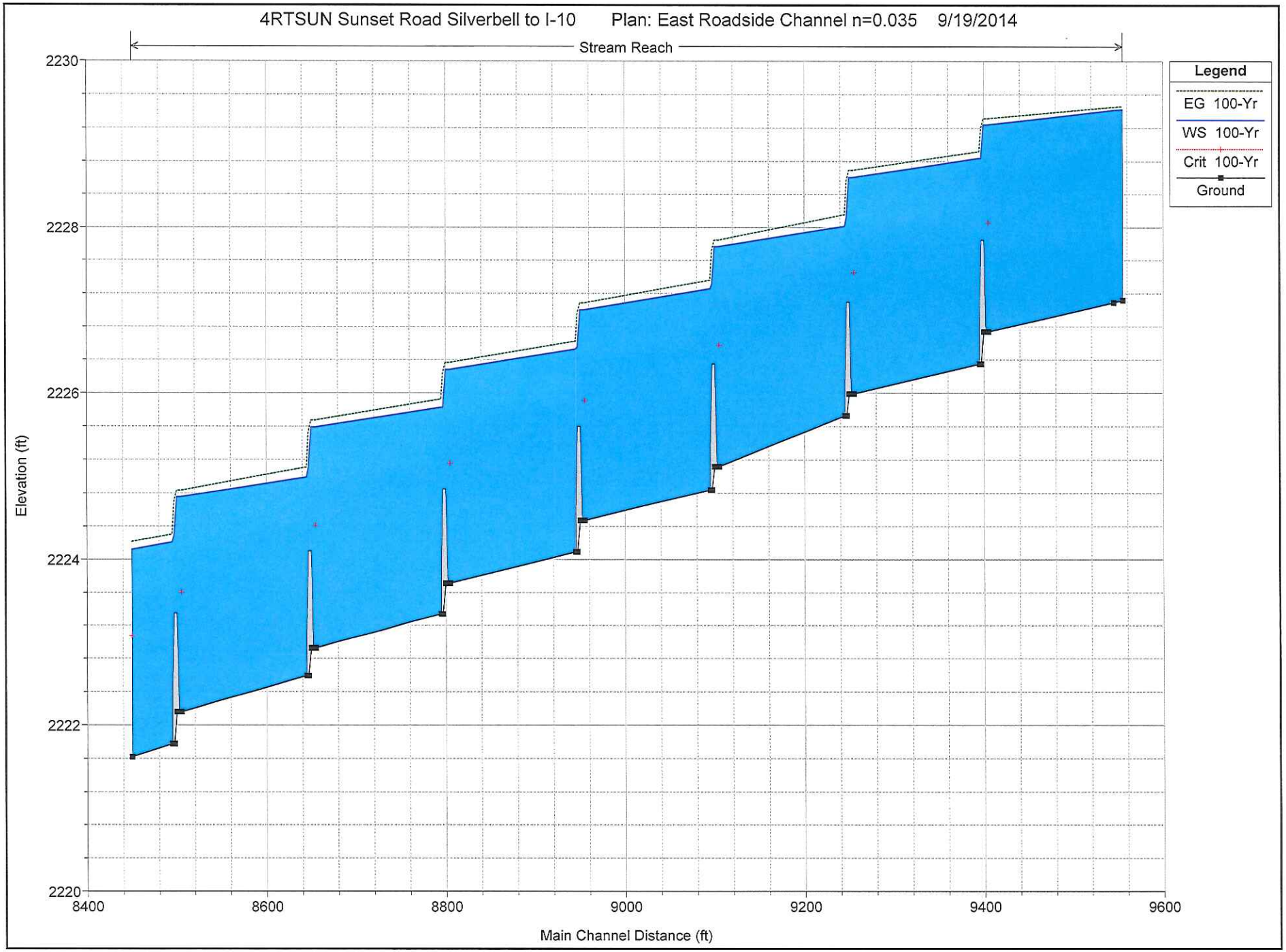
D_{50} = 10.0 (inch)

Step 4. Estimate Apron Dimensions

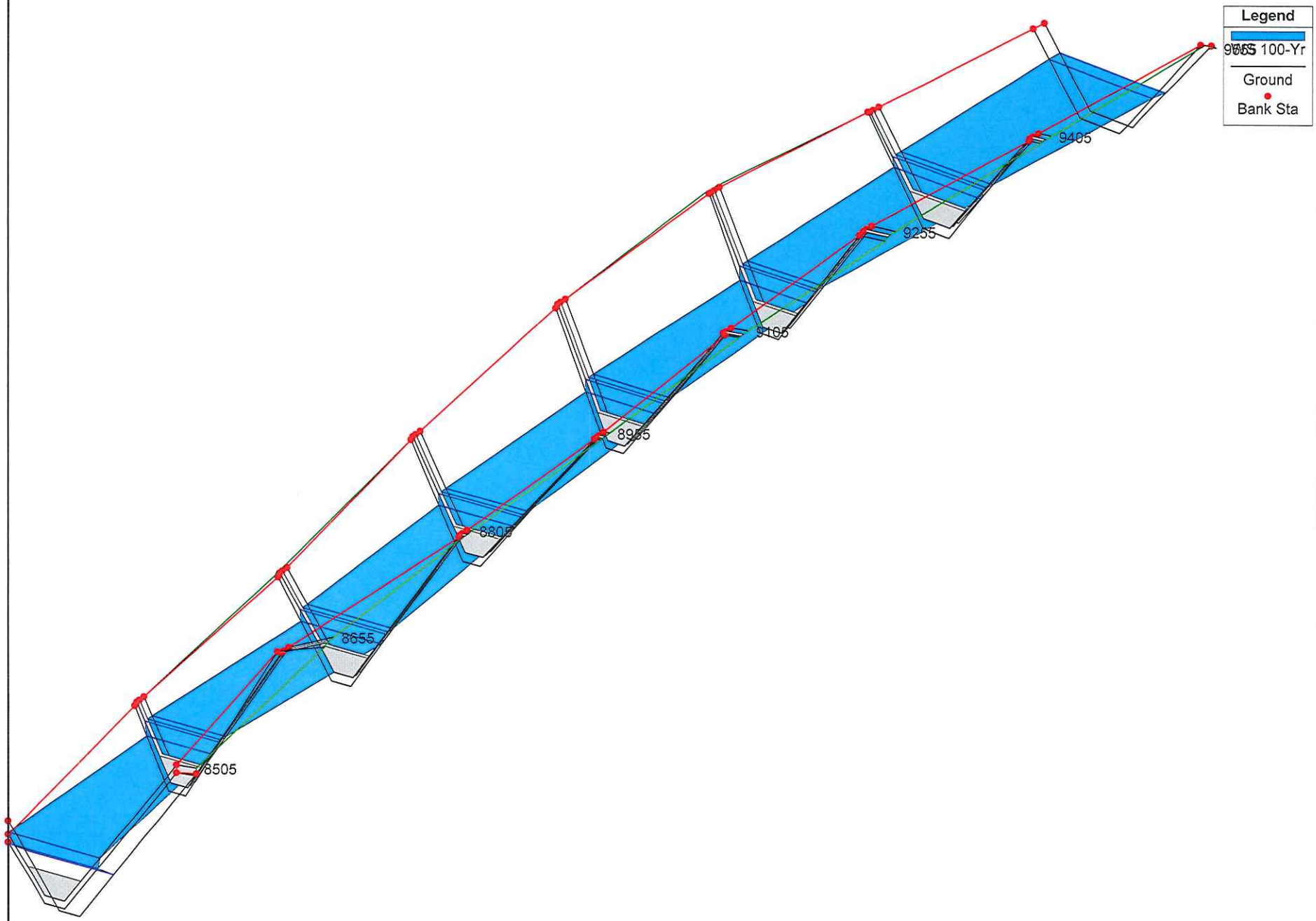
Length:	5D	15	(ft)	Length From End of Apron
Depth:	2.4D50	24	(inches)	Thickness
Width:	(Adj'd for 3:1 Expansion)	10	(feet)	Add to Apron Width

HEC-RAS Plan: ECHNL-0.035 River: Stream Reach: Reach Profile: 100-Yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	9555	100-Yr	97.00	2227.12	2229.43		2229.46	0.000613	1.43	67.62	41.97	0.20
Reach	9545	100-Yr	97.00	2227.09	2229.42		2229.45	0.000656	1.49	65.22	40.32	0.21
Reach	9405	100-Yr	97.00	2226.74	2229.24	2228.06	2229.32	0.001426	2.17	44.66	27.69	0.30
Reach	9400		Inl Struct									
Reach	9395	100-Yr	97.00	2226.35	2228.84		2228.92	0.001522	2.25	43.19	26.70	0.31
Reach	9255	100-Yr	97.00	2225.99	2228.61	2227.46	2228.70	0.001686	2.37	40.90	25.04	0.33
Reach	9250		Inl Struct									
Reach	9245	100-Yr	97.00	2225.73	2228.02		2228.16	0.003177	3.01	32.27	22.28	0.44
Reach	9105	100-Yr	97.00	2225.12	2227.77	2226.58	2227.85	0.001473	2.20	43.99	27.25	0.31
Reach	9100		Inl Struct									
Reach	9095	100-Yr	97.00	2224.84	2227.26		2227.36	0.002211	2.57	37.70	25.12	0.37
Reach	8955	100-Yr	97.00	2224.47	2227.01	2225.91	2227.09	0.001652	2.27	42.81	27.85	0.32
Reach	8950		Inl Struct									
Reach	8945	100-Yr	97.00	2224.09	2226.53		2226.62	0.002002	2.45	39.54	26.35	0.35
Reach	8805	100-Yr	97.00	2223.71	2226.29	2225.16	2226.37	0.001625	2.27	42.65	27.22	0.32
Reach	8800		Inl Struct									
Reach	8795	100-Yr	97.00	2223.34	2225.83		2225.93	0.002001	2.49	38.95	25.31	0.35
Reach	8655	100-Yr	97.00	2222.93	2225.59	2224.41	2225.67	0.001571	2.28	42.48	26.18	0.32
Reach	8650		Inl Struct									
Reach	8645	100-Yr	97.00	2222.59	2224.99		2225.11	0.002518	2.76	35.17	23.21	0.39
Reach	8505	100-Yr	97.00	2222.16	2224.76	2223.61	2224.83	0.001487	2.19	44.20	27.79	0.31
Reach	8500		Inl Struct									
Reach	8495	100-Yr	97.00	2221.78	2224.21		2224.30	0.002041	2.45	39.56	26.80	0.36
Reach	8450	100-Yr	97.00	2221.62	2224.12	2223.08	2224.21	0.001907	2.43	39.86	25.89	0.35


4RTSUN Sunset Road Silverbell to I-10 Plan: East Roadside Channel n=0.035 9/19/2014
Stream Reach
Legend
EG 100-Yr
WS 100-Yr
Crit 100-Yr
Ground
Elevation (ft)
2230
2228
2226
2224
2222
2220
8400
8600
8800
9000
9200
9400
9600
Main Channel Distance (ft)

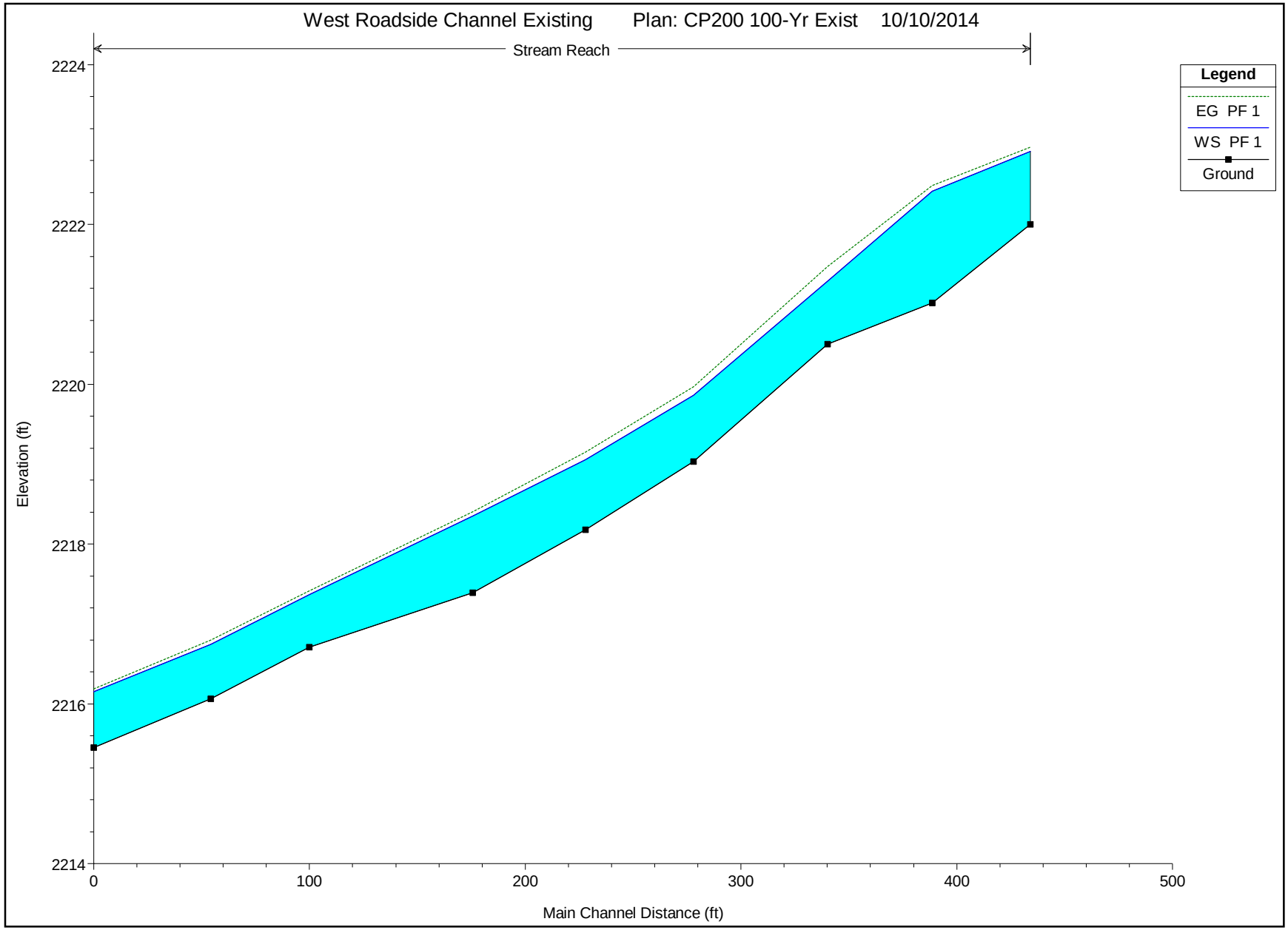
4RTSUN Sunset Road Silverbell to I-10 Plan: East Roadside Channel n=0.035 9/19/2014

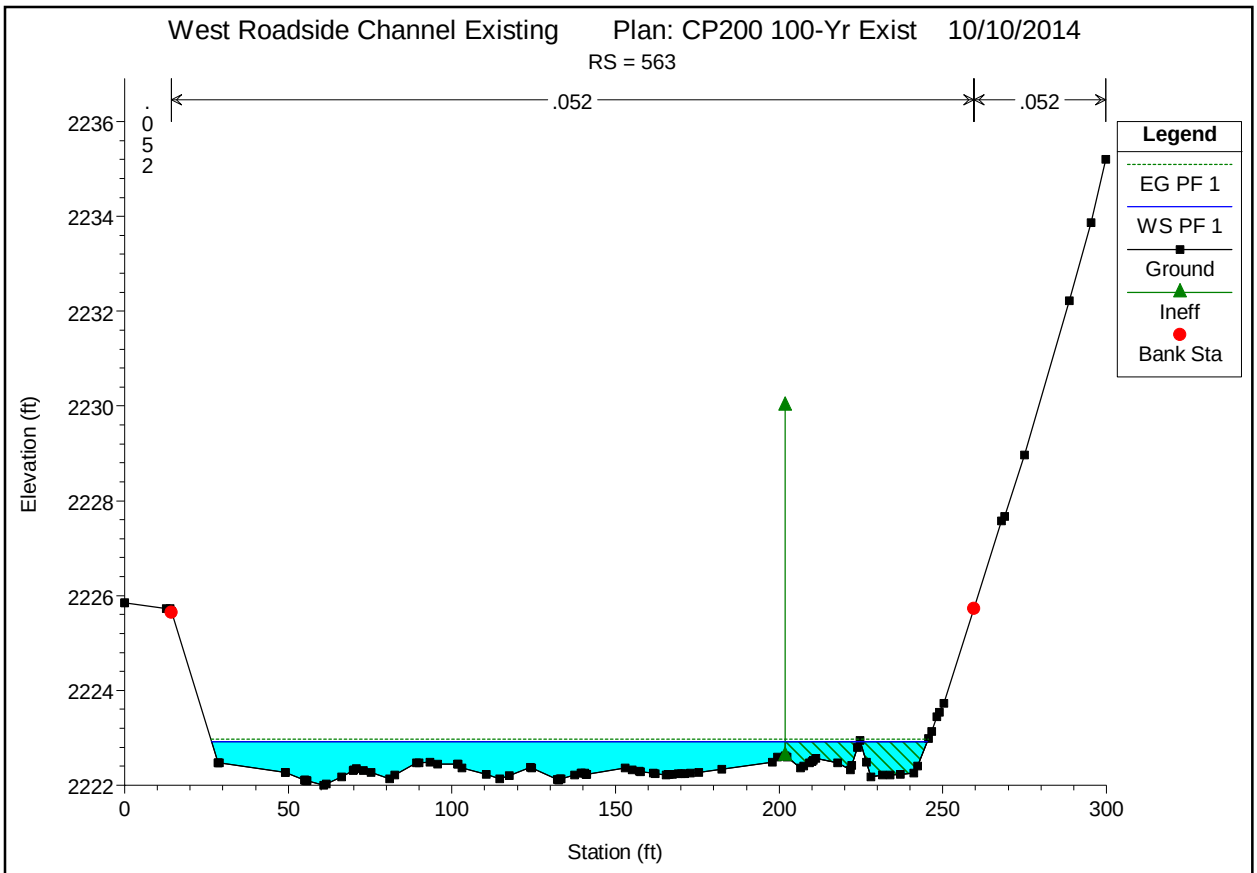


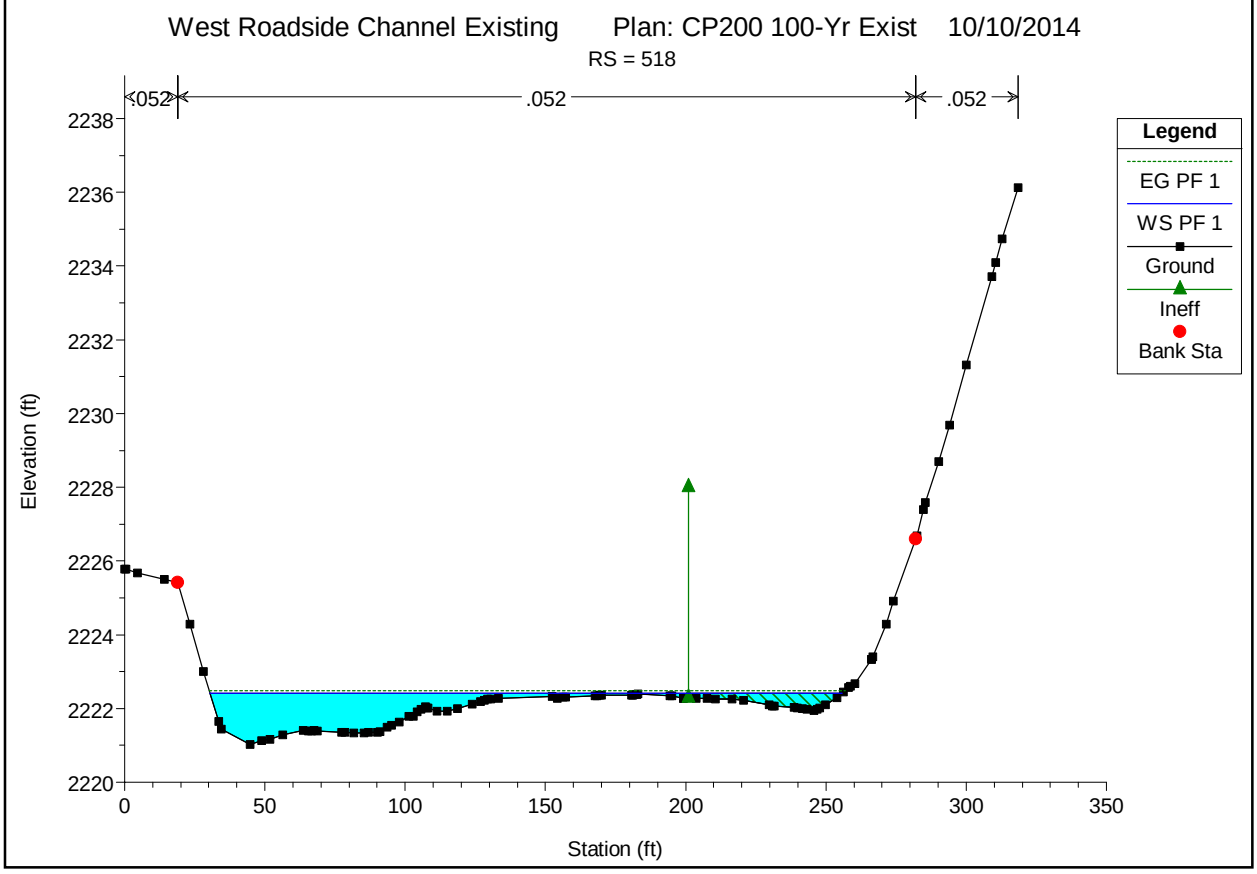
POC 200 (WEST OFFSITE DRAINAGE)

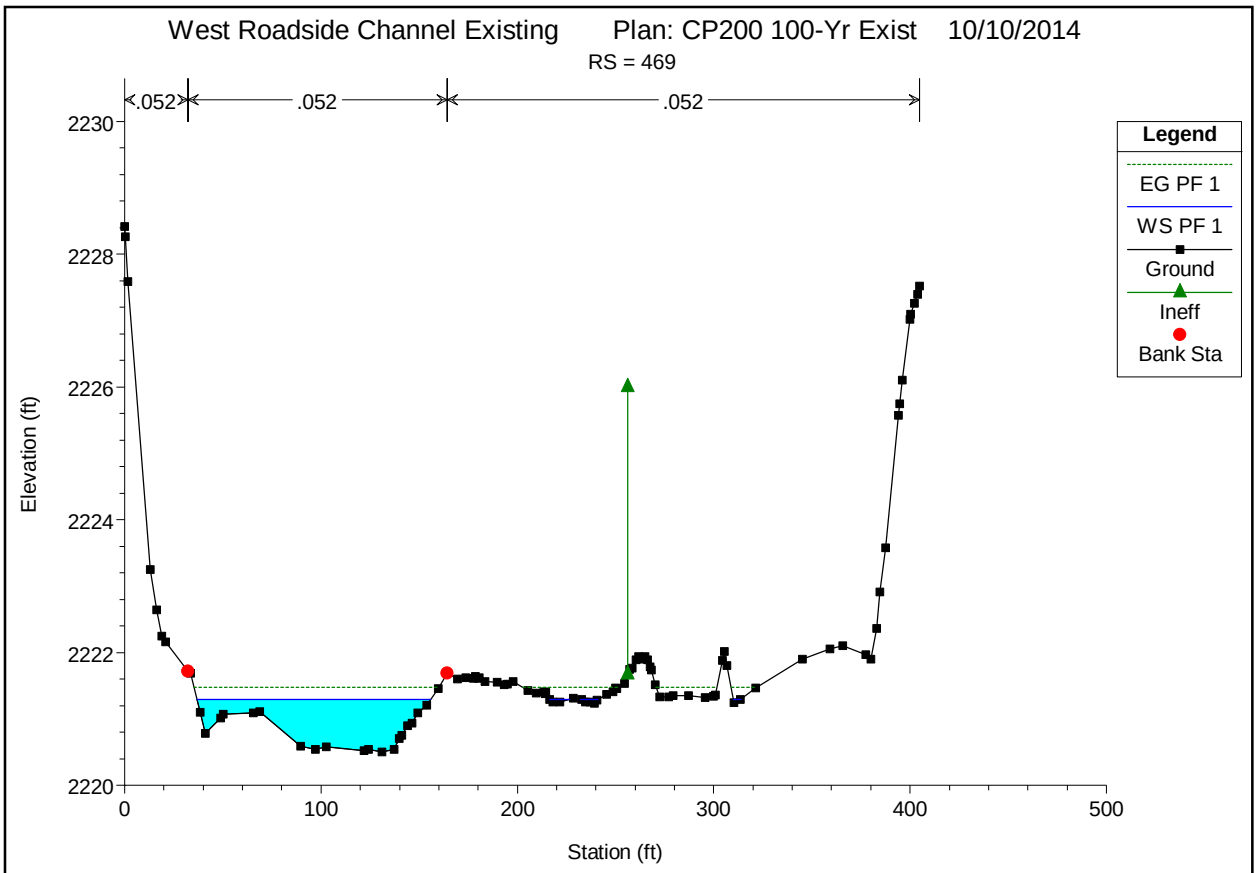
HEC-RAS Plan: CP200Exst River: Stream Reach: Reach Profile: PF 1

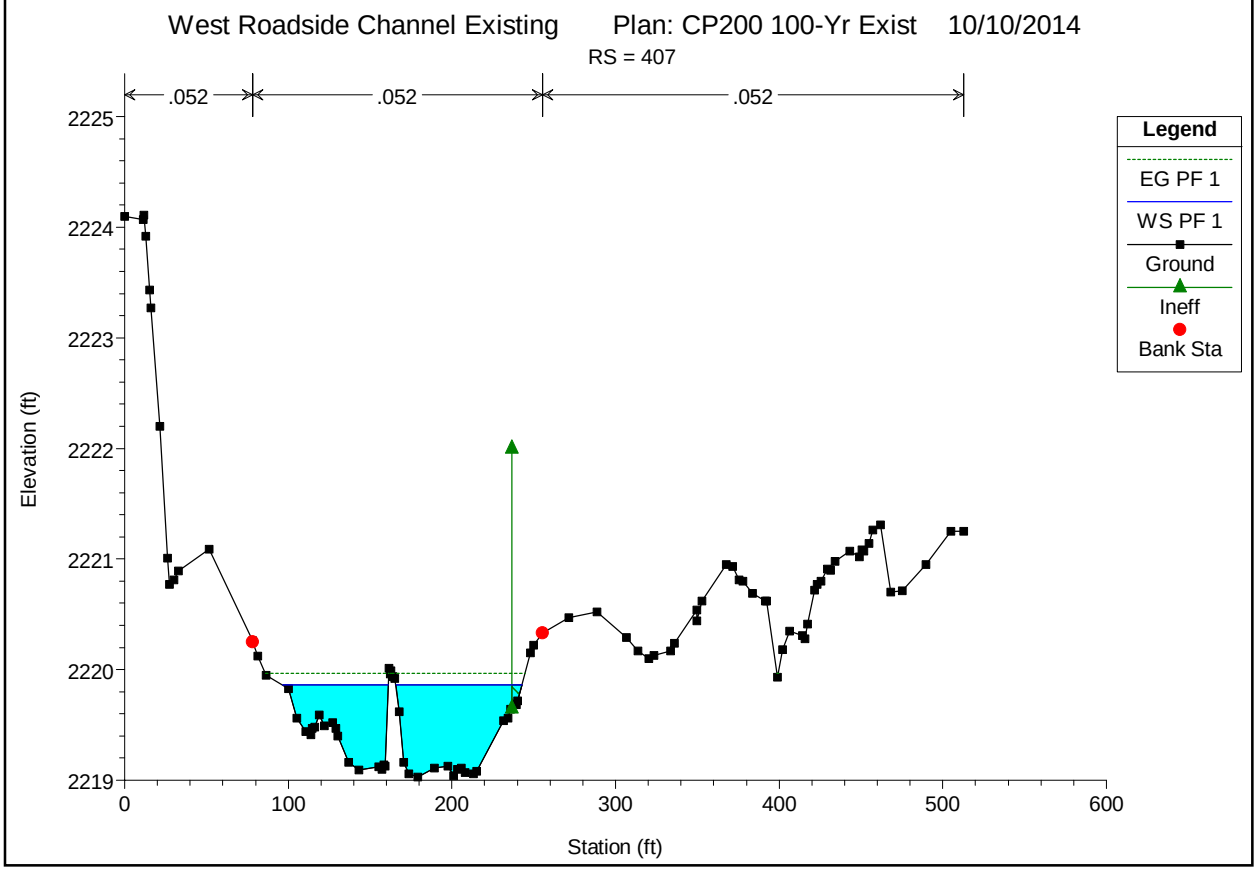
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	563	PF 1	203.00	2222.00	2222.91		2222.97	0.008507	1.90	107.03	218.50	0.43
Reach	518	PF 1	203.00	2221.02	2222.42		2222.49	0.013618	2.21	91.98	225.39	0.53
Reach	469	PF 1	203.00	2220.50	2221.29	2221.24	2221.47	0.035817	3.41	60.11	141.87	0.85
Reach	407	PF 1	203.00	2219.03	2219.86		2219.97	0.017205	2.59	78.26	141.70	0.60
Reach	357	PF 1	203.00	2218.18	2219.06		2219.15	0.015557	2.42	84.02	217.76	0.57
Reach	305	PF 1	203.00	2217.39	2218.35		2218.41	0.012648	1.85	109.55	447.06	0.49
Reach	229	PF 1	203.00	2216.71	2217.37		2217.42	0.013627	1.79	113.16	318.20	0.50
Reach	184	PF 1	203.00	2216.06	2216.75		2216.80	0.013869	1.83	110.90	276.44	0.51
Reach	129	PF 1	203.00	2215.45	2216.15	2215.91	2216.19	0.009170	1.53	132.31	420.16	0.42

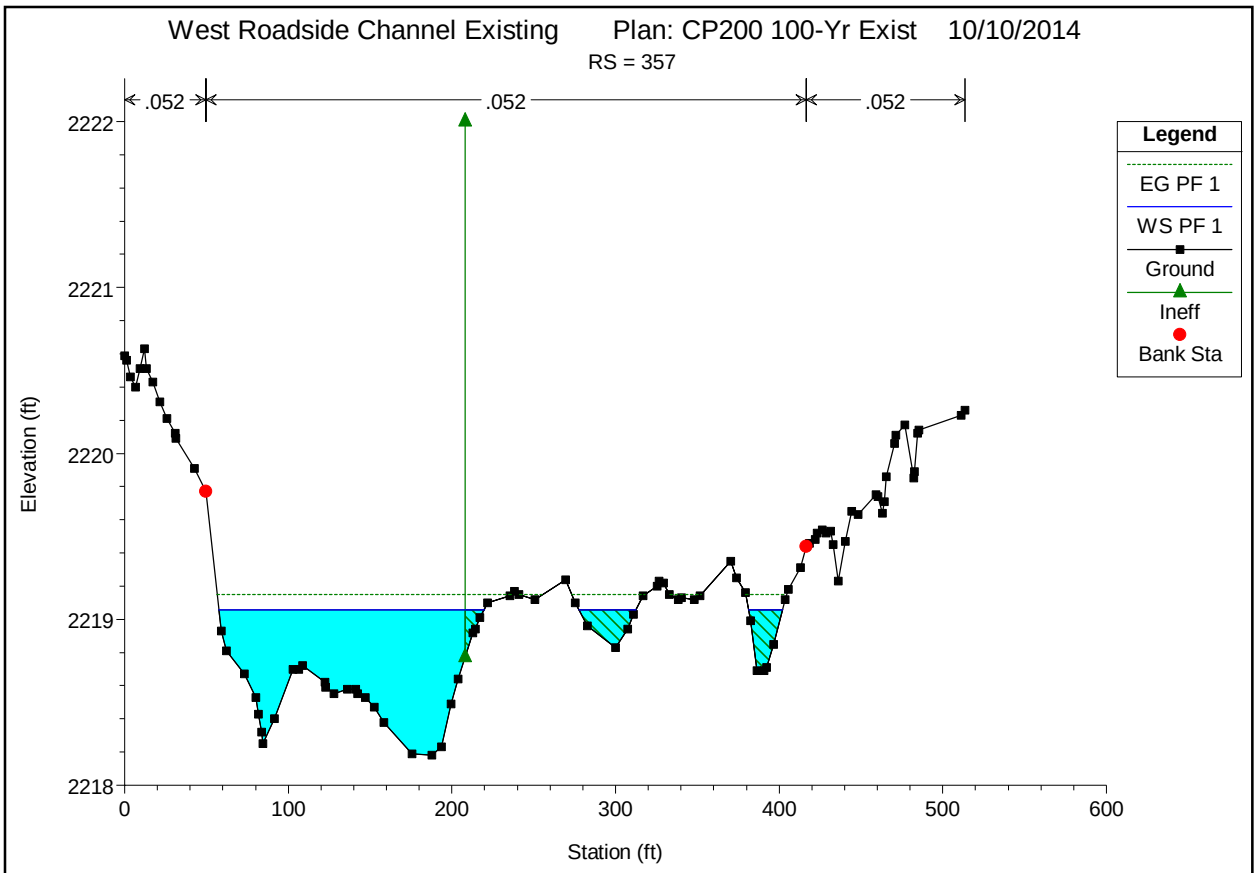

West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
Stream Reach
Legend
EG PF 1
WS PF 1
Ground
Elevation (ft)
2224
2222
2220
2218
2216
2214
0
100
200
300
400
500
Main Channel Distance (ft)

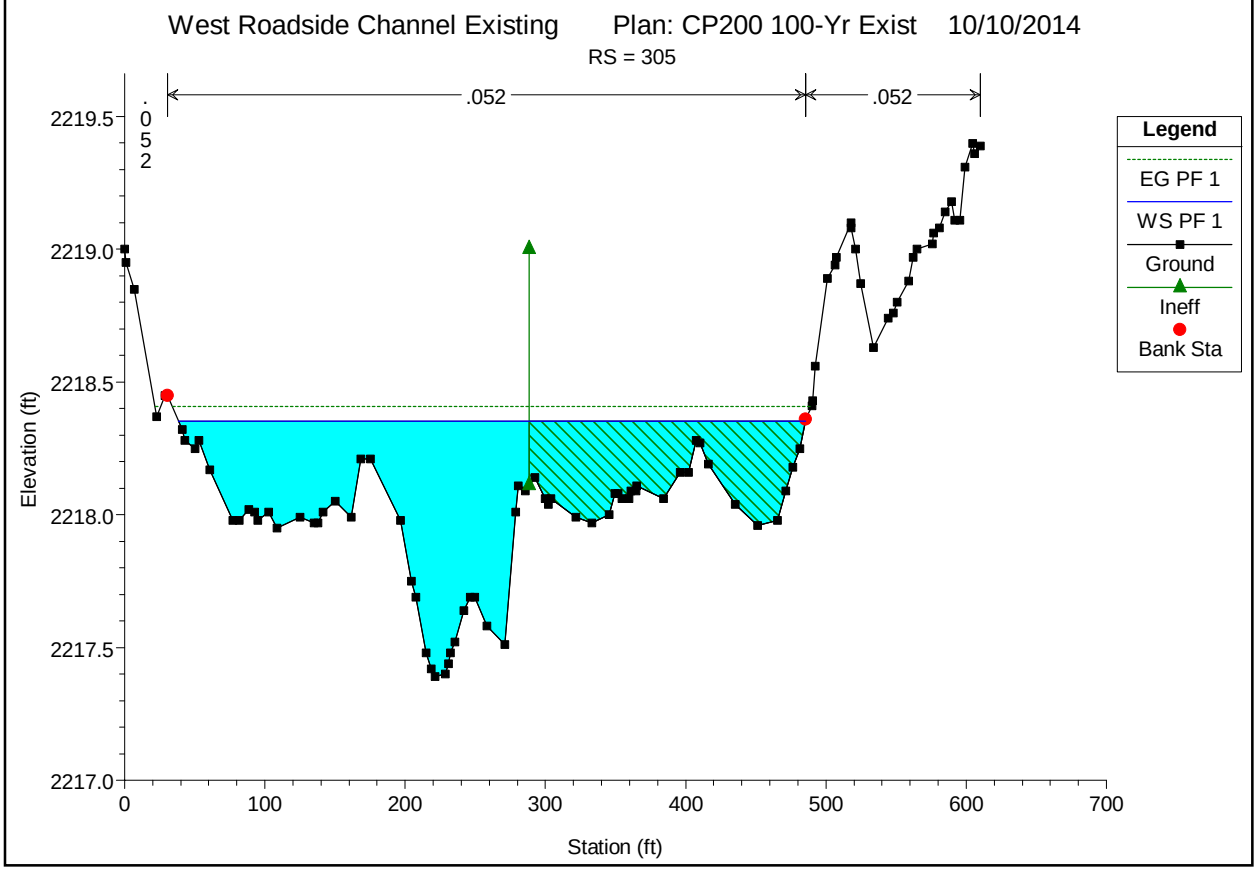

West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 563
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2222
2224
2226
2228
2230
2232
2234
2236
0
50
100
150
200
250
300

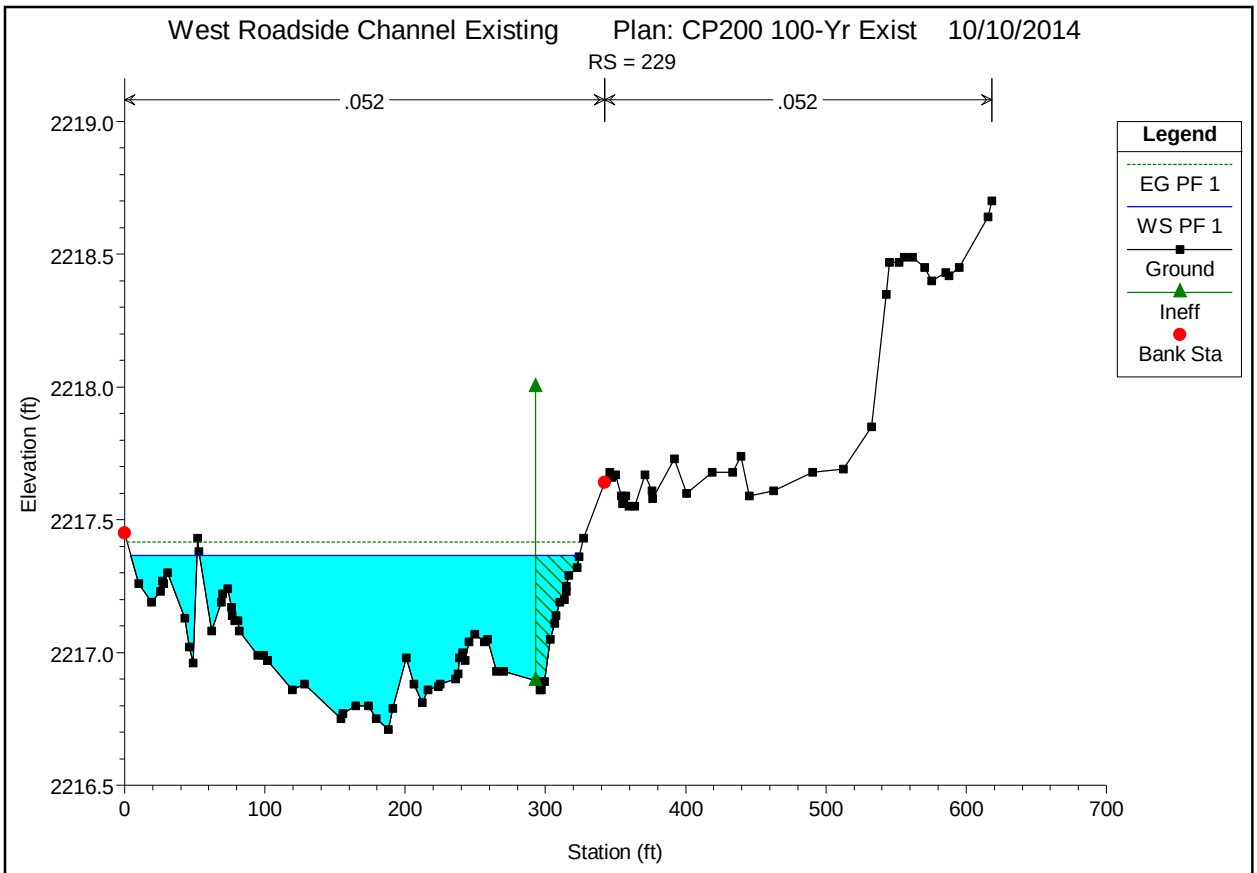

West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 518
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2220
2222
2224
2226
2228
2230
2232
2234
2236
2238
0
50
100
150
200
250
300
350

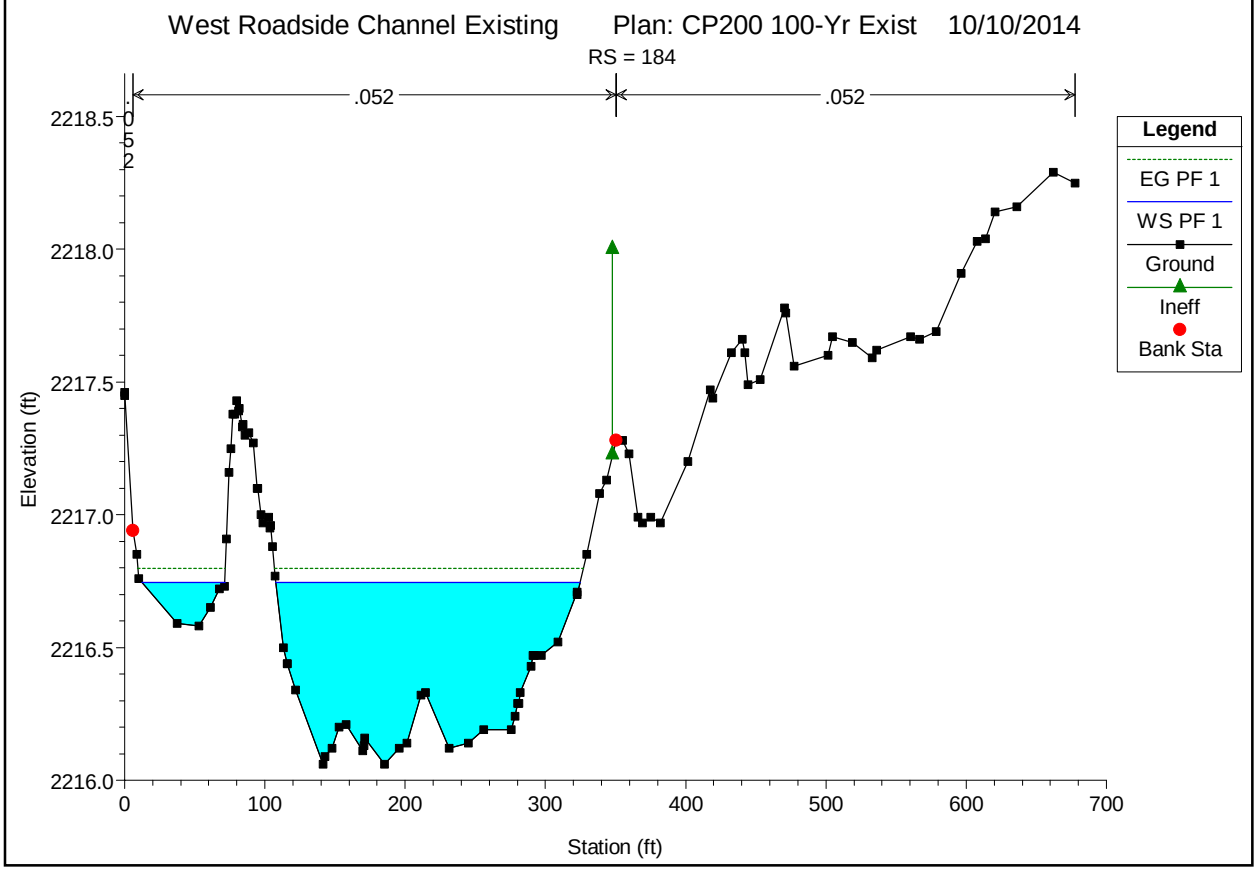

West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 469
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

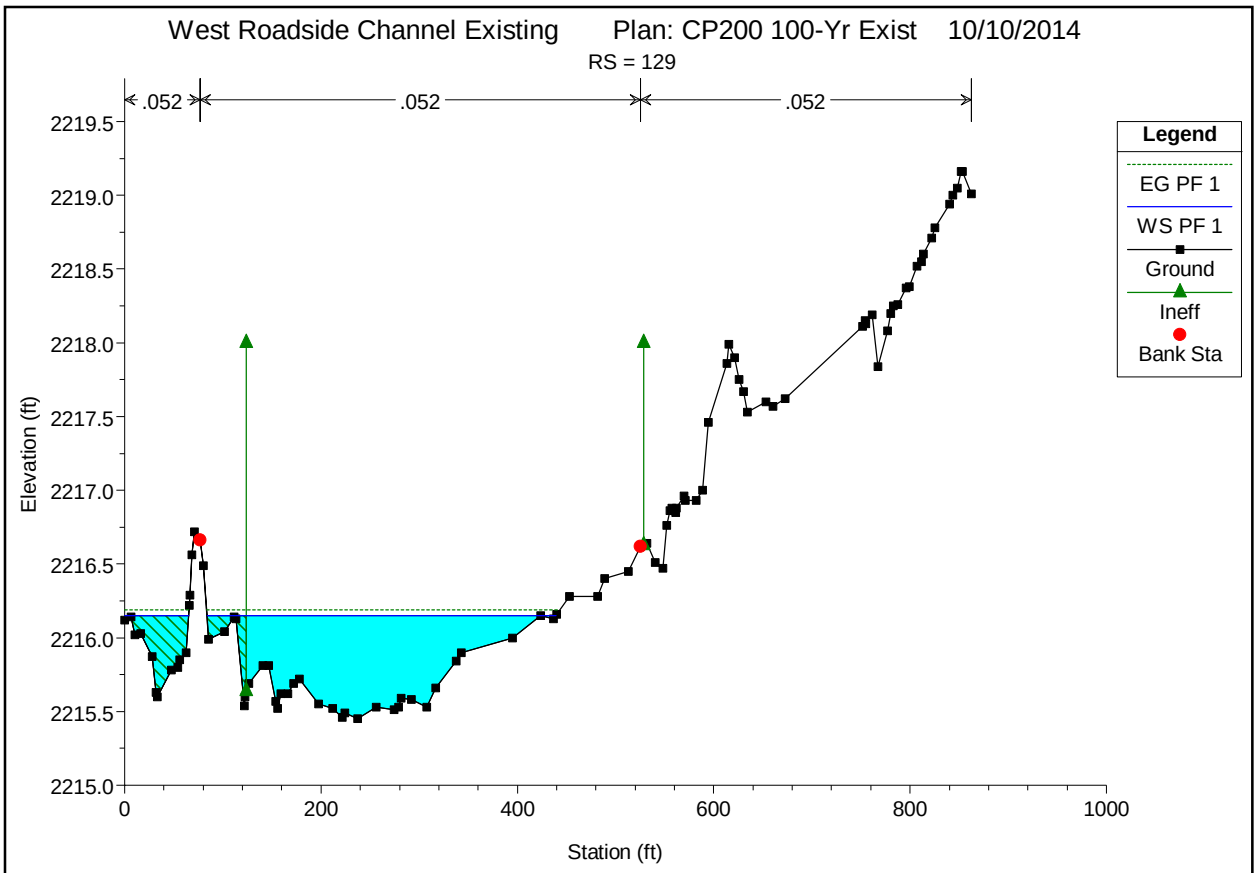

West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 407
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 357
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
2222
2221
2220
2219
2218
0
100
200
300
400
500
600
Station (ft)


West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 305
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
2219.5
2219.0
2218.5
2218.0
2217.5
2217.0
0
100
200
300
400
500
600
700
Station (ft)

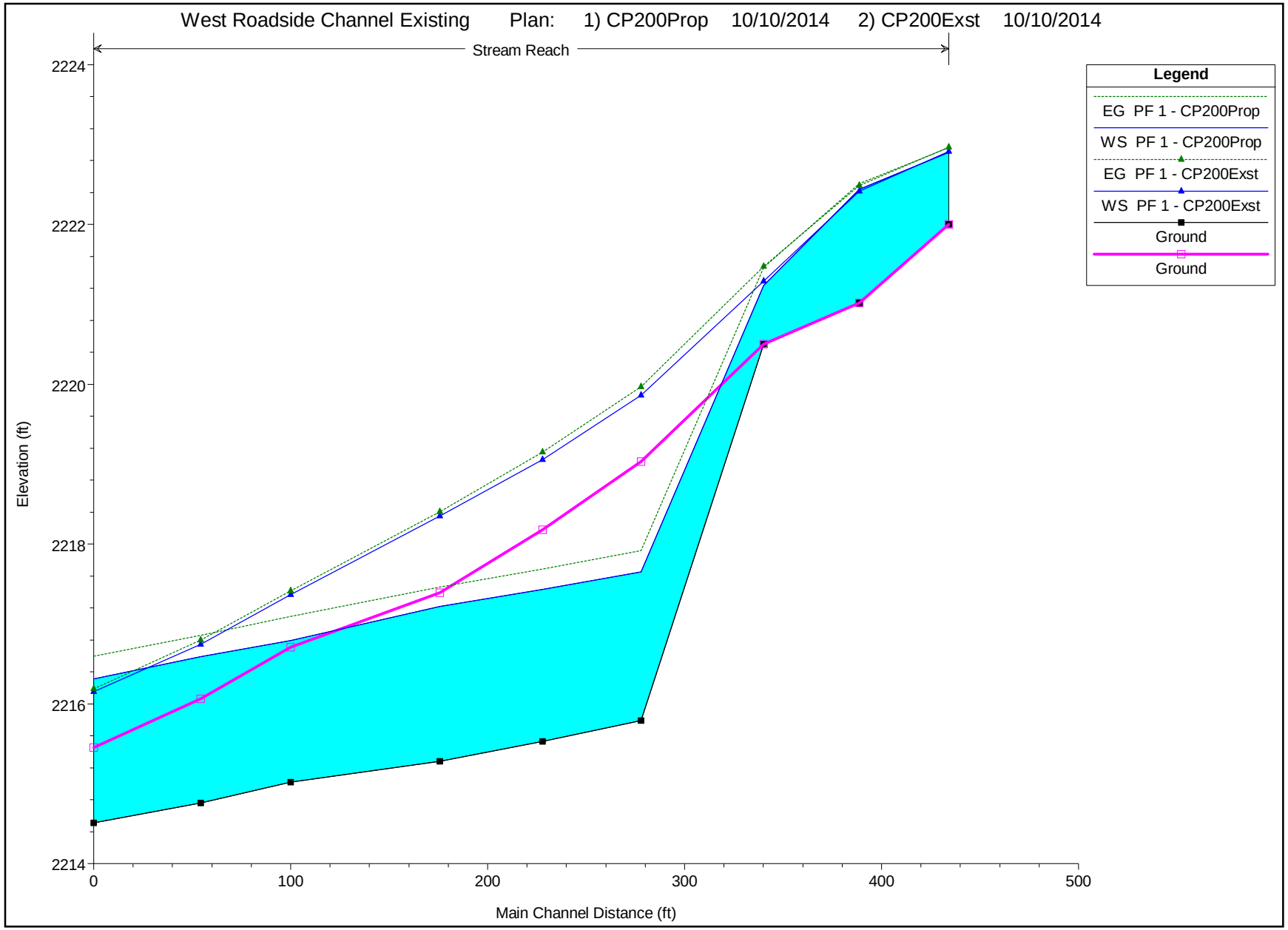

West Roadside Channel Existing
Plan: CP200 100-Yr Exist
10/10/2014
RS = 229
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2219.0
2218.5
2218.0
2217.5
2217.0
2216.5
0
100
200
300
400
500
600
700

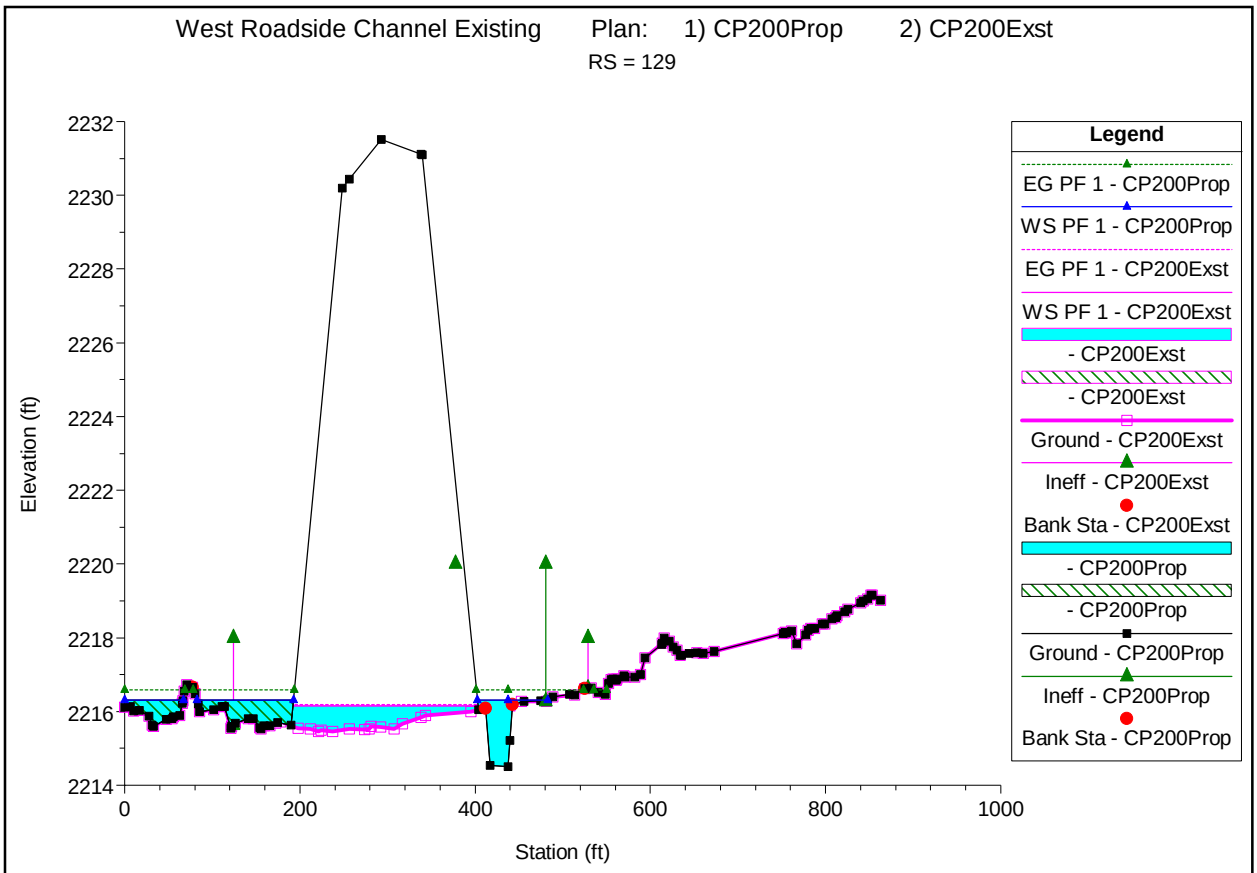

West Roadside Channel Existing
Plan: CP200 100-Yr Exist
10/10/2014
RS = 184
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2218.5
2218.0
2217.5
2217.0
2216.5
2216.0
0
100
200
300
400
500
600
700

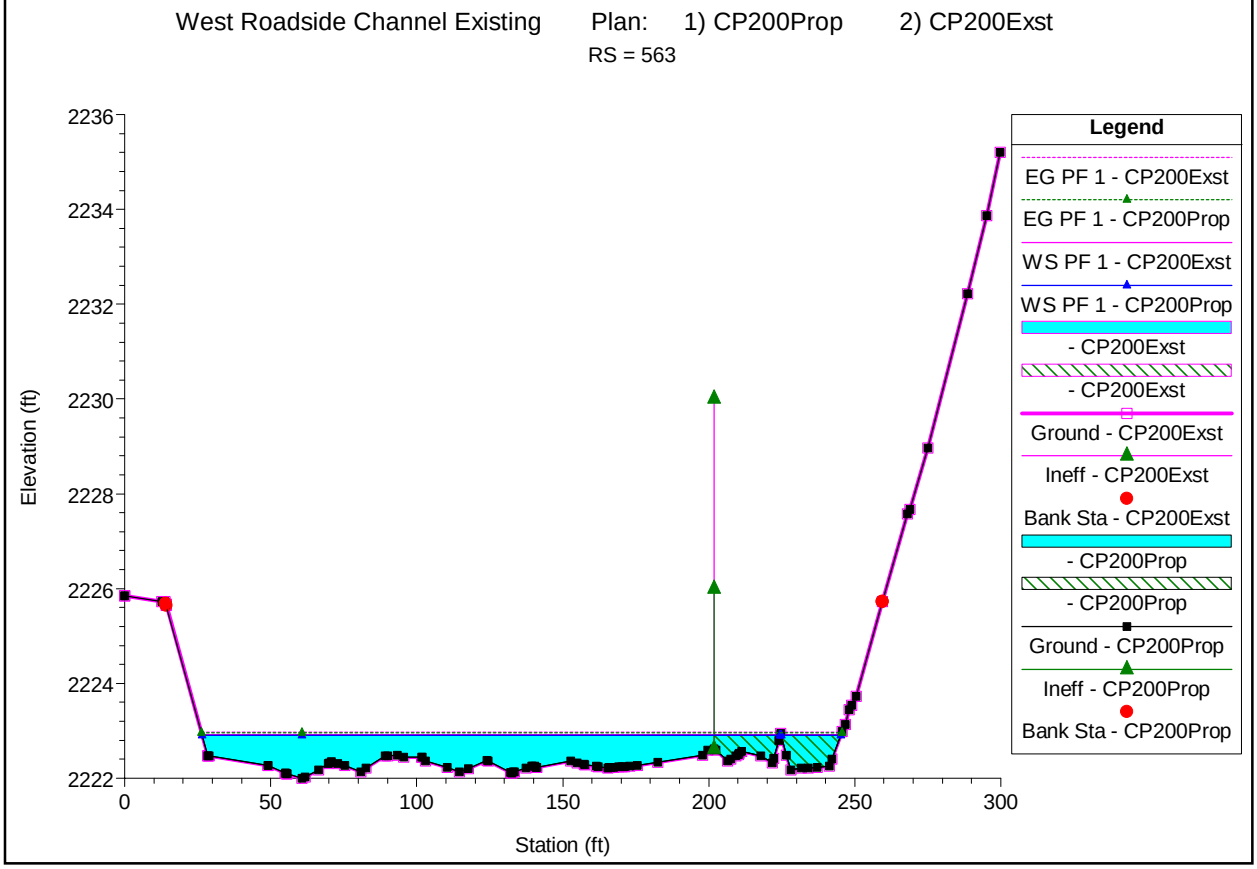

West Roadside Channel Existing Plan: CP200 100-Yr Exist 10/10/2014
RS = 129
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
2219.5
2219.0
2218.5
2218.0
2217.5
2217.0
2216.5
2216.0
2215.5
2215.0
0
200
400
600
800
1000
Station (ft)

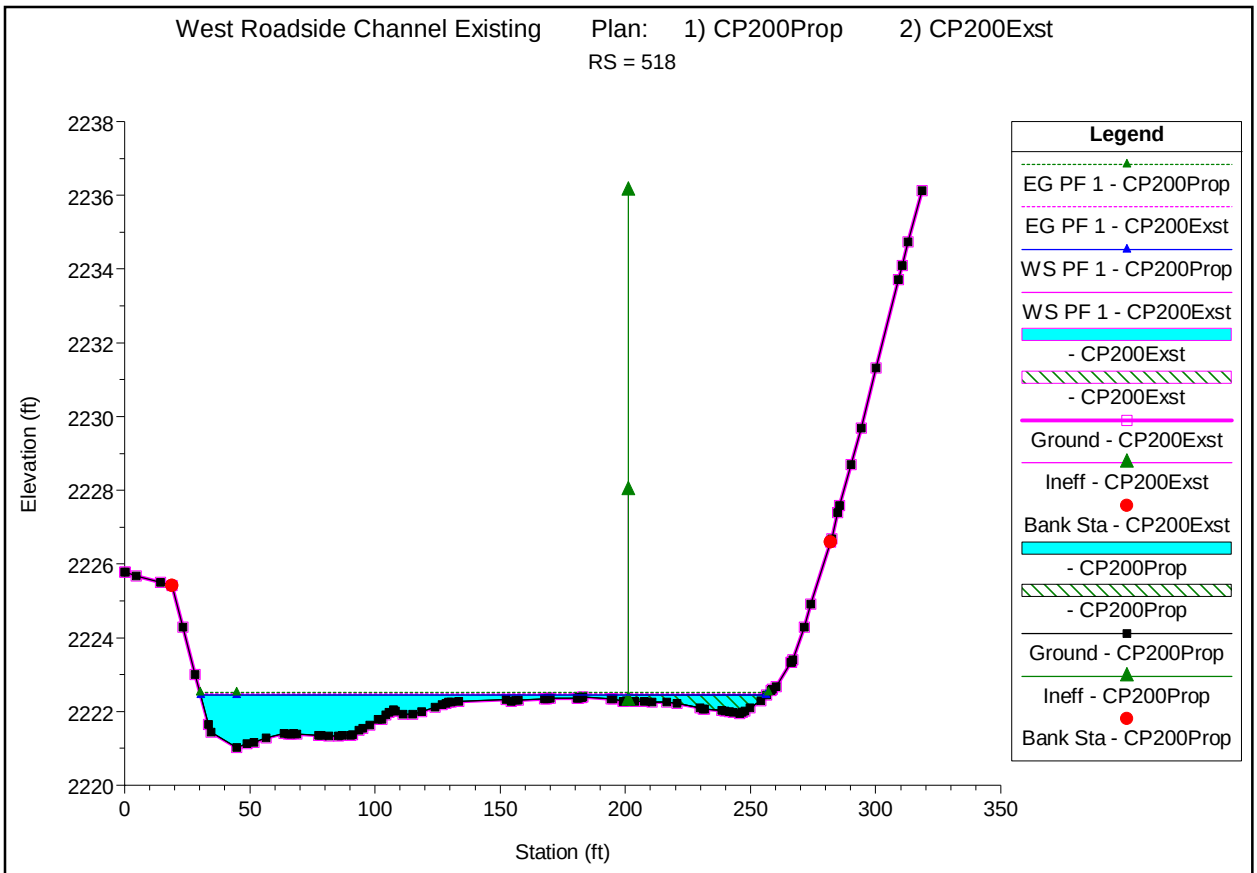
HEC-RAS River: Stream Reach: Reach Profile: PF 1

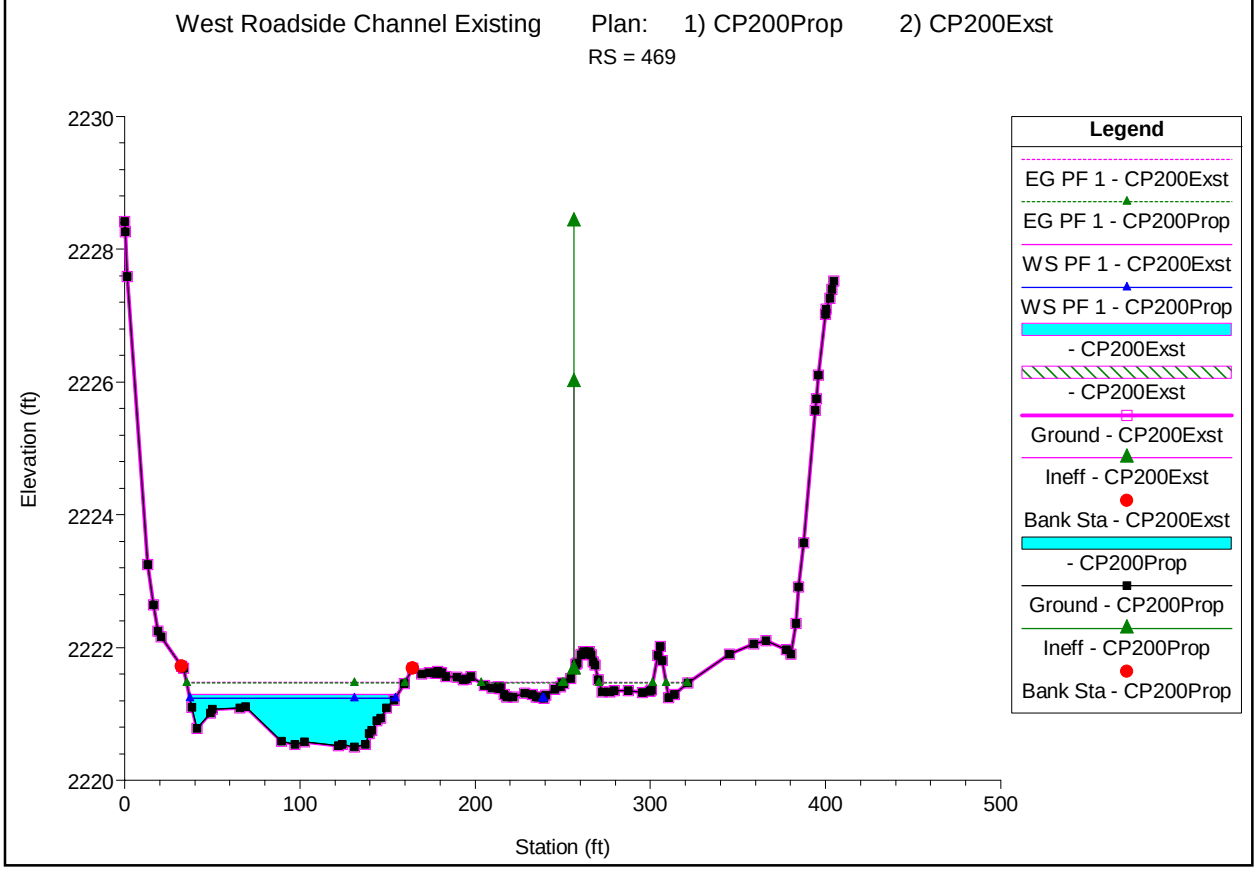
Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	563	PF 1	CP200Prop	203.00	2222.00	2222.91		2222.96	0.008831	1.92	105.84	218.39	0.43
Reach	563	PF 1	CP200Exst	203.00	2222.00	2222.91		2222.97	0.008507	1.90	107.03	218.50	0.43
Reach	518	PF 1	CP200Prop	203.00	2221.02	2222.44	2222.02	2222.51	0.011557	2.10	96.65	225.89	0.49
Reach	518	PF 1	CP200Exst	203.00	2221.02	2222.42		2222.49	0.013618	2.21	91.98	225.39	0.53
Reach	469	PF 1	CP200Prop	203.00	2220.50	2221.24	2221.24	2221.47	0.052028	3.84	52.93	118.23	1.01
Reach	469	PF 1	CP200Exst	203.00	2220.50	2221.29	2221.24	2221.47	0.035817	3.41	60.11	141.87	0.85
Reach	407	PF 1	CP200Prop	203.00	2215.79	2217.65		2217.92	0.004725	4.17	48.72	32.08	0.60
Reach	407	PF 1	CP200Exst	203.00	2219.03	2219.86		2219.97	0.017205	2.59	78.26	141.70	0.60
Reach	357	PF 1	CP200Prop	203.00	2215.53	2217.43		2217.69	0.004419	4.07	49.84	32.29	0.58
Reach	357	PF 1	CP200Exst	203.00	2218.18	2219.06		2219.15	0.015557	2.42	84.02	217.76	0.57
Reach	305	PF 1	CP200Prop	203.00	2215.28	2217.22		2217.46	0.004073	3.96	51.26	33.66	0.56
Reach	305	PF 1	CP200Exst	203.00	2217.39	2218.35		2218.41	0.012648	1.85	109.55	447.06	0.49
Reach	229	PF 1	CP200Prop	203.00	2215.02	2216.79		2217.10	0.005637	4.43	45.86	31.50	0.65
Reach	229	PF 1	CP200Exst	203.00	2216.71	2217.37		2217.42	0.013627	1.79	113.16	318.20	0.50
Reach	184	PF 1	CP200Prop	203.00	2214.76	2216.59		2216.86	0.004516	4.18	53.28	83.72	0.59
Reach	184	PF 1	CP200Exst	203.00	2216.06	2216.75		2216.80	0.013869	1.83	110.90	276.44	0.51
Reach	129	PF 1	CP200Prop	203.00	2214.51	2216.31	2215.86	2216.60	0.005005	4.31	50.66	256.99	0.61
Reach	129	PF 1	CP200Exst	203.00	2215.45	2216.15	2215.91	2216.19	0.009170	1.53	132.31	420.16	0.42

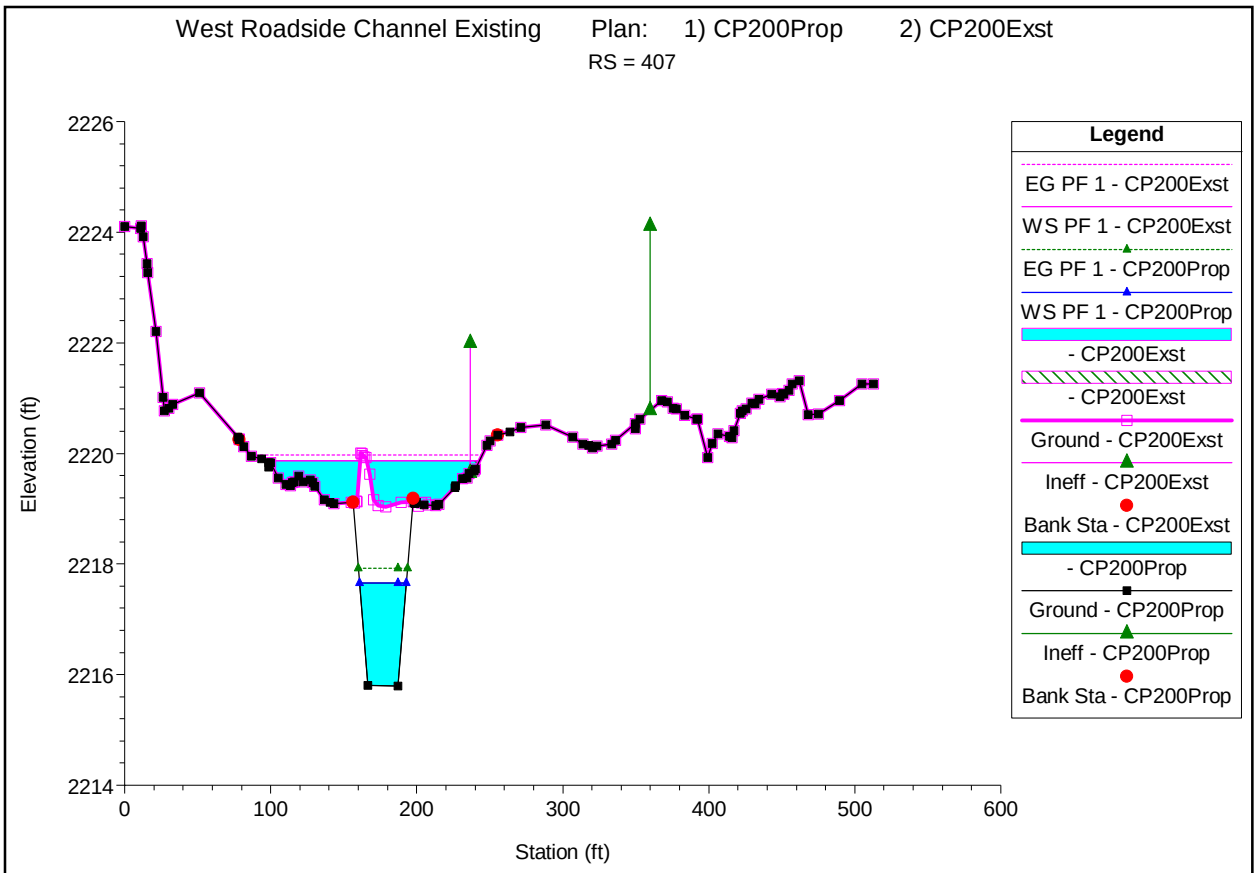

West Roadside Channel Existing Plan: 1) CP200Prop 10/10/2014 2) CP200Exst 10/10/2014
Stream Reach
Legend
EG PF 1 - CP200Prop
WS PF 1 - CP200Prop
EG PF 1 - CP200Exst
WS PF 1 - CP200Exst
Ground
Ground
Elevation (ft)
2224
2222
2220
2218
2216
2214
0
100
200
300
400
500
Main Channel Distance (ft)

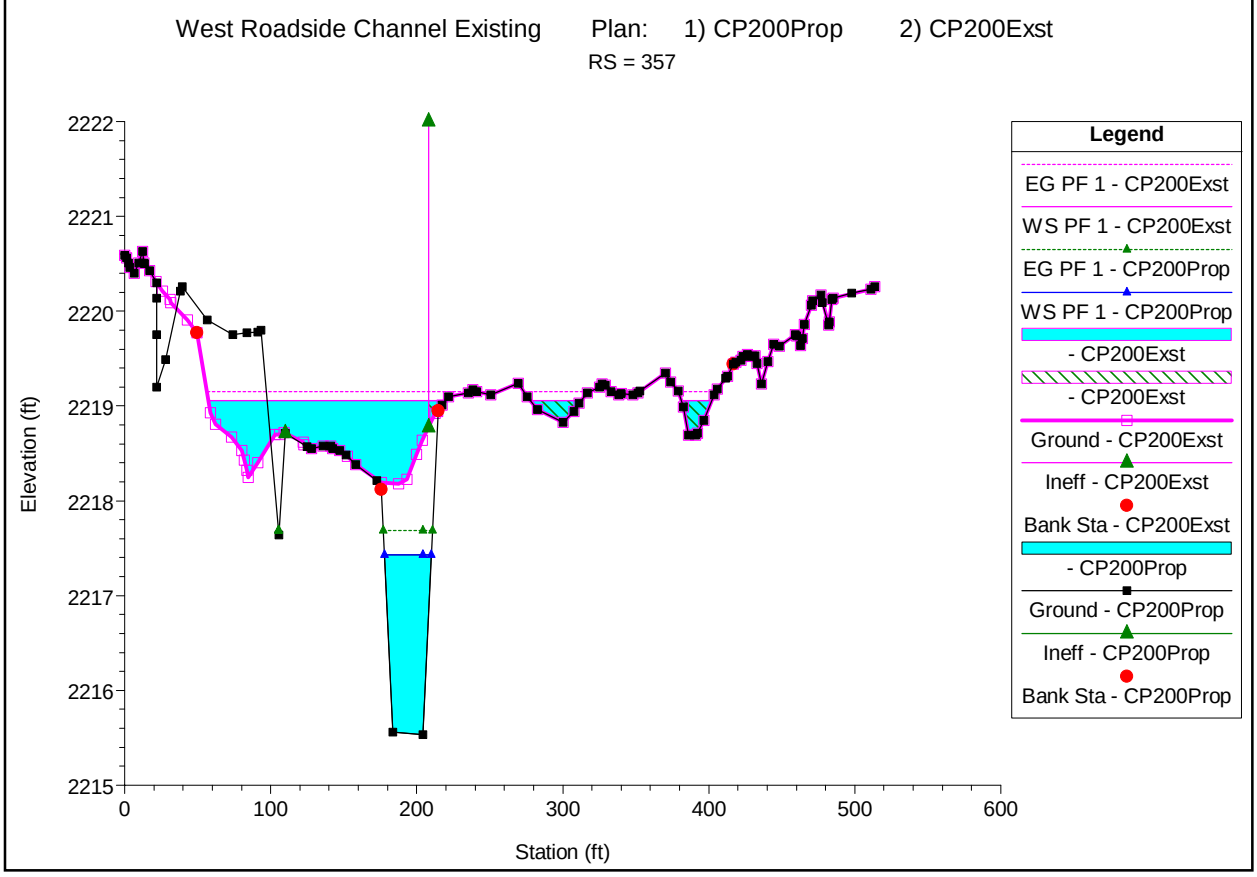

West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 129
Elevation (ft)
Station (ft)
Legend
EG PF 1 - CP200Prop
WS PF 1 - CP200Prop
EG PF 1 - CP200Exst
WS PF 1 - CP200Exst
- CP200Exst
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop


West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 563
Elevation (ft)
Station (ft)
Legend
EG PF 1 - CP200Exst
EG PF 1 - CP200Prop
WS PF 1 - CP200Exst
WS PF 1 - CP200Prop
- CP200Exst
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop


West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 518
Elevation (ft)
Station (ft)
Legend
EG PF 1 - CP200Prop
EG PF 1 - CP200Exst
WS PF 1 - CP200Prop
WS PF 1 - CP200Exst
- CP200Exst
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop

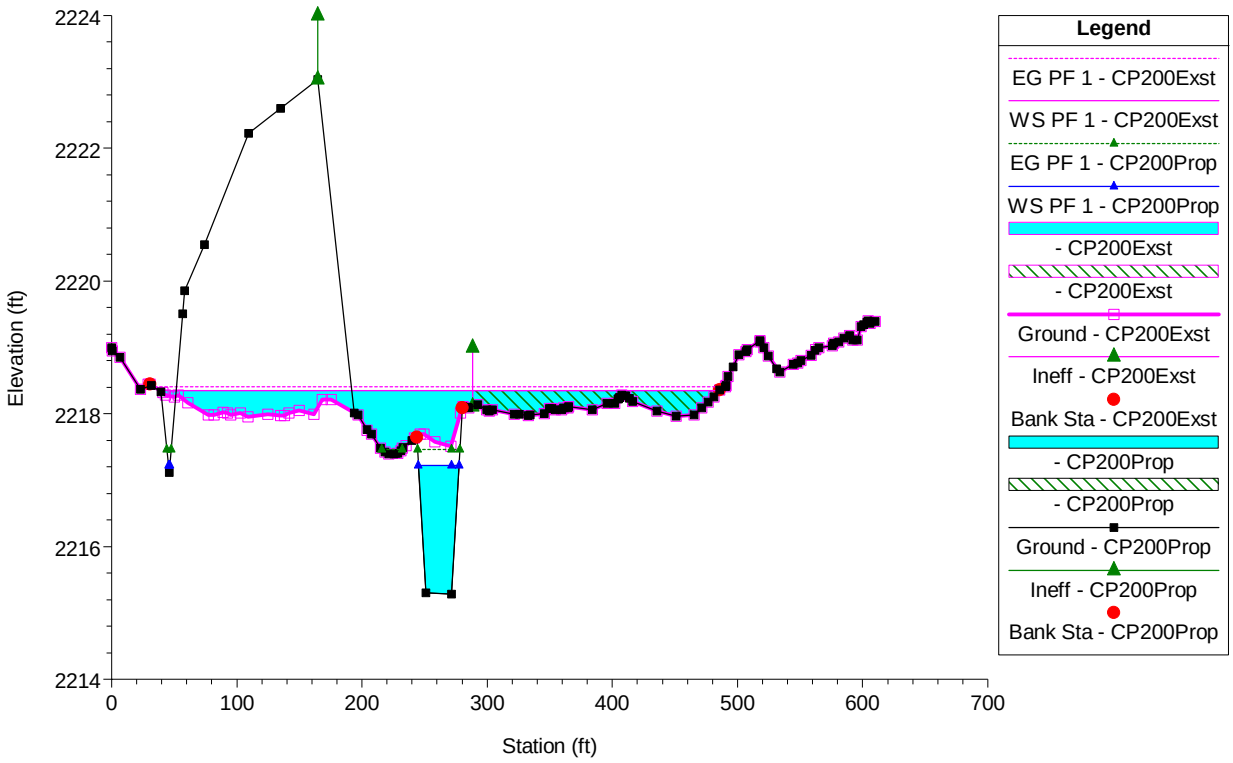

West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 469
Elevation (ft)
Station (ft)
Legend
EG PF 1 - CP200Exst
EG PF 1 - CP200Prop
WS PF 1 - CP200Exst
WS PF 1 - CP200Prop
- CP200Exst
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop


West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 407
Elevation (ft)
Station (ft)
Legend
EG PF 1 - CP200Exst
WS PF 1 - CP200Exst
EG PF 1 - CP200Prop
WS PF 1 - CP200Prop
- CP200Exst
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop


West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 357
Elevation (ft)
Station (ft)
Legend
EG PF 1 - CP200Exst
WS PF 1 - CP200Exst
EG PF 1 - CP200Prop
WS PF 1 - CP200Prop
- CP200Exst
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop

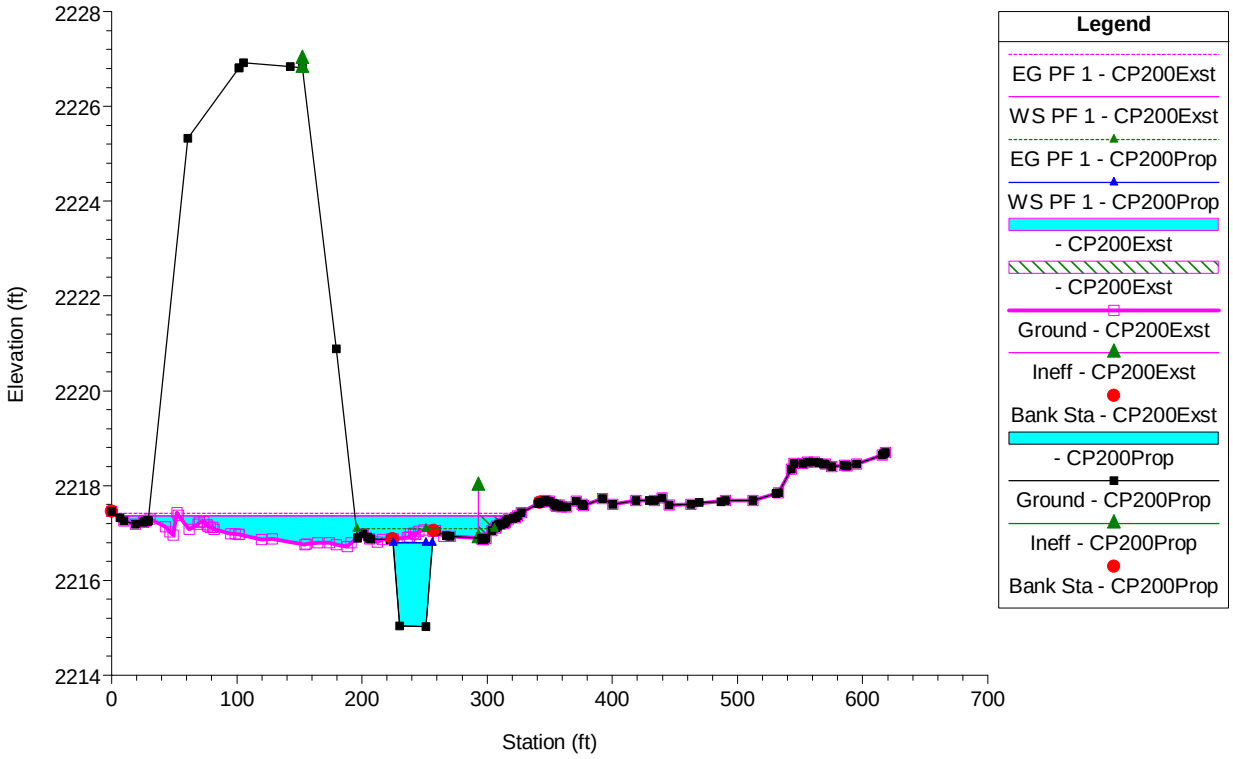
West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst

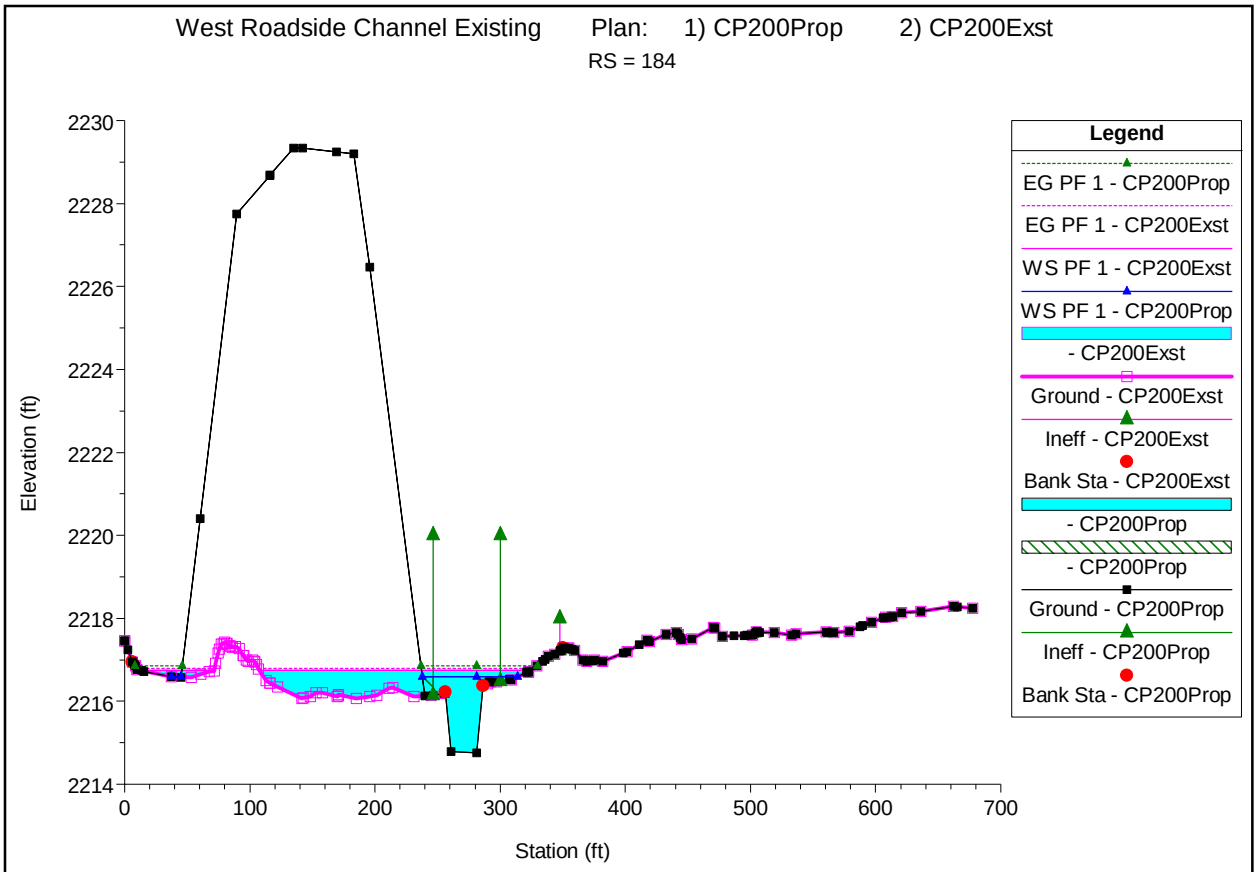
RS = 305



West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst

RS = 229




West Roadside Channel Existing Plan: 1) CP200Prop 2) CP200Exst
RS = 184
Elevation (ft)
Station (ft)
2230
2228
2226
2224
2222
2220
2218
2216
2214
0
100
200
300
400
500
600
700
Legend
EG PF 1 - CP200Prop
EG PF 1 - CP200Exst
WS PF 1 - CP200Exst
WS PF 1 - CP200Prop
- CP200Exst
Ground - CP200Exst
Ineff - CP200Exst
Bank Sta - CP200Exst
- CP200Prop
- CP200Prop
Ground - CP200Prop
Ineff - CP200Prop
Bank Sta - CP200Prop

PARSONS BRINCKERHOFF Computation Sheet

page of

made by D. Ruvalcaba

date 10/29/14

checked by

date

subject Sunset Road, Silverbell to River
Scour Downstream of Silverbell Road

Compute General Scour Off Silverbell Road @ POC 200

$$z_{gs} = y_{MAX}\left(\frac{0.0685\ V_m^{0.8}}{y_h^{0.4}\ S_e^{0.3}} - 1\right);$$

z_{gs} = General Scour
V_m = Average Velocity
y_{MAX} = Max Depth
y_h = Hydraulic Depth
S_e = Energy Slope

RS 469

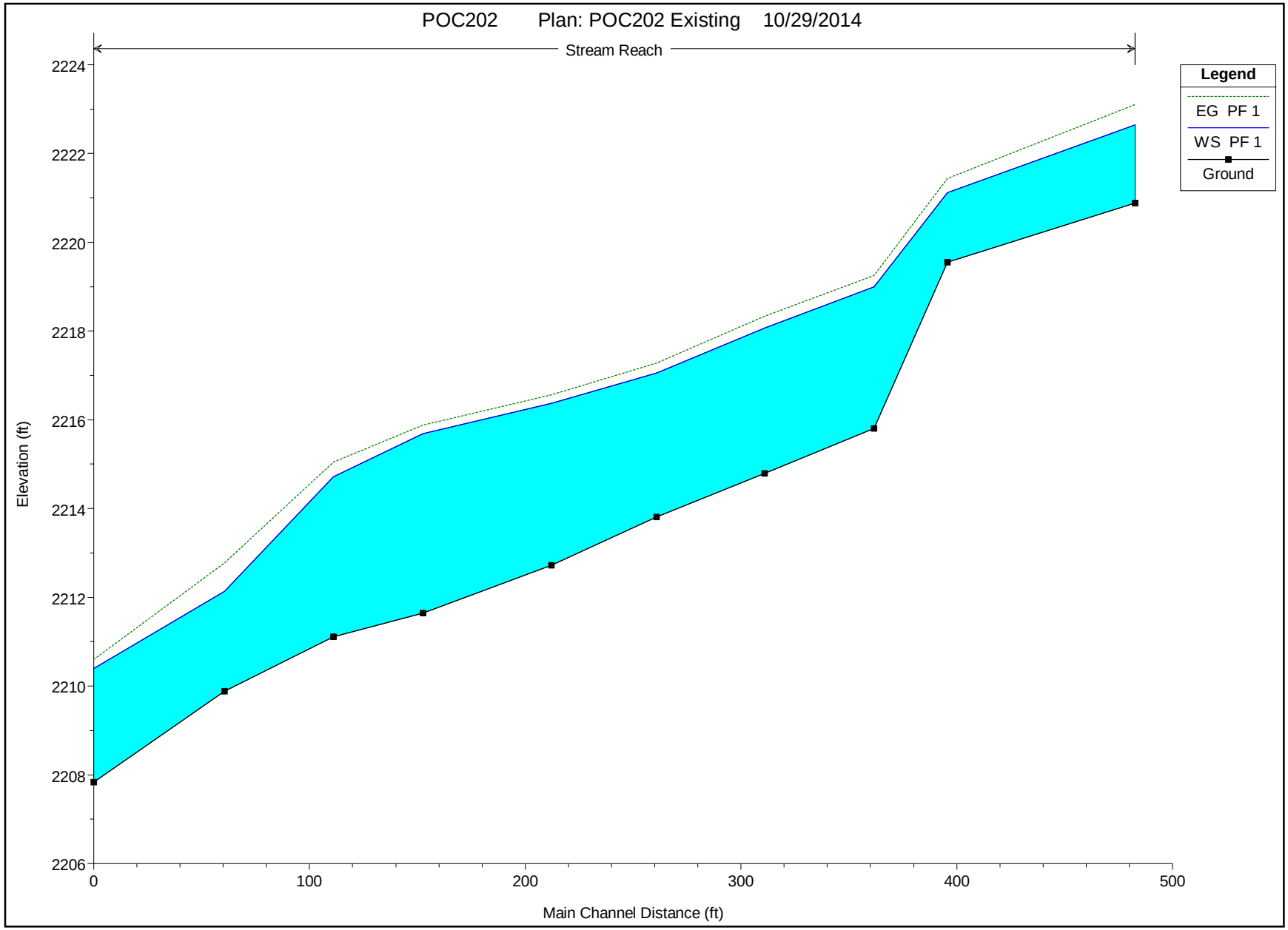
$V_m = Q/A = 3.84$ fps
$y_{MAX} = 0.74'$
$y_h = A/TW = 52.9/118.23 = 0.45$
$S_e = 0.052$ 1/ft

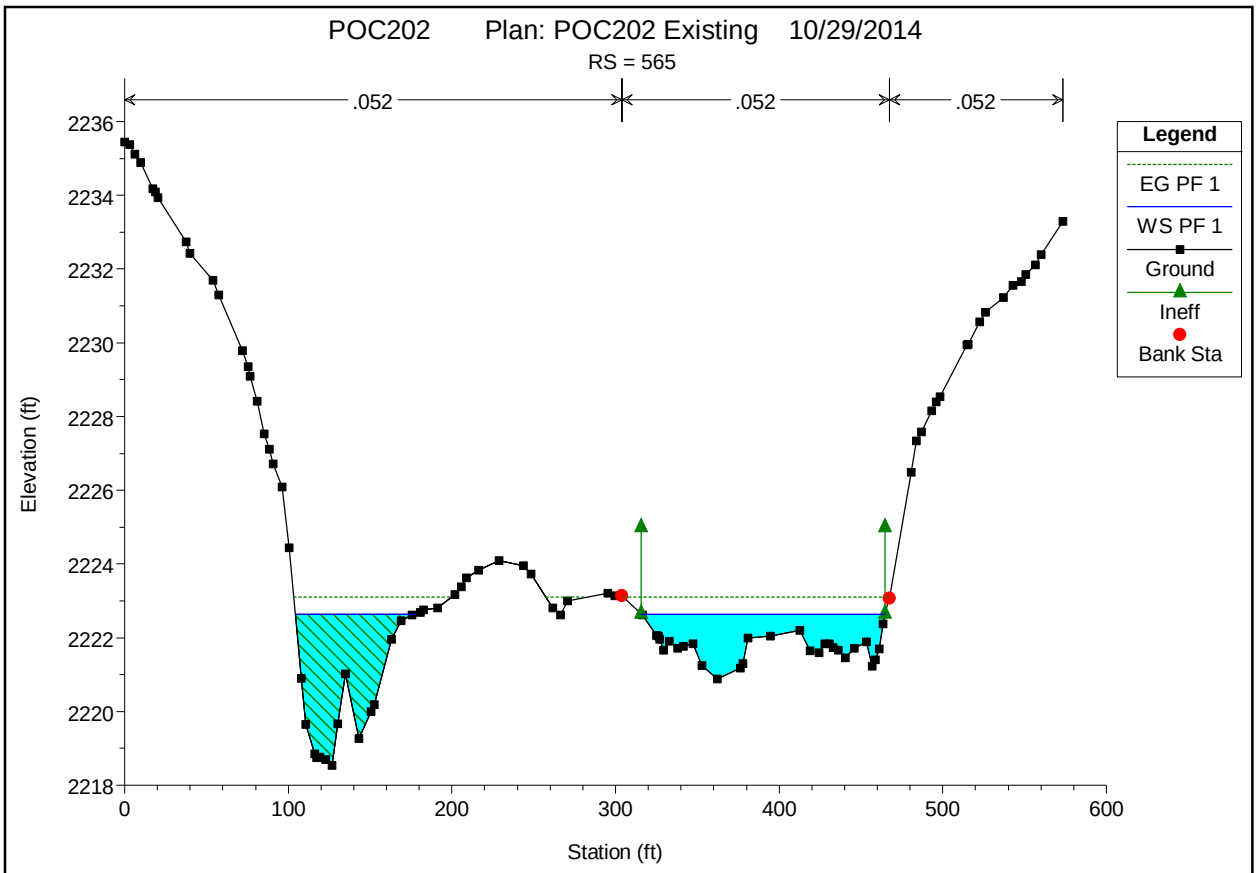
$$z_{gs} = 0.74\left(\frac{0.0685 * 3.84^{0.8}}{0.45^{0.4} * 0.052^{0.3}} - 1\right) = \emptyset'$$ No Scour off Roadway

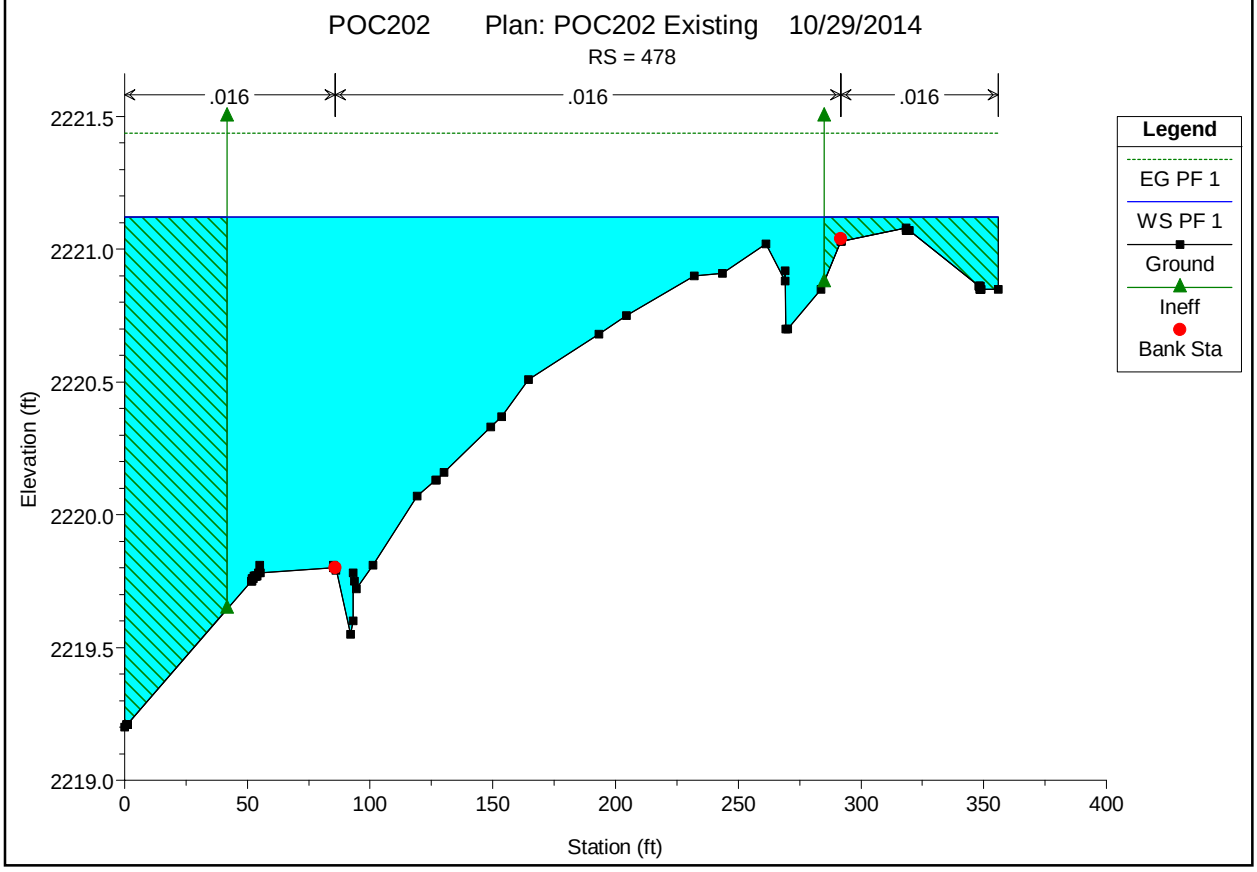
POC 202 (WEST OFFSITE DRAINAGE)

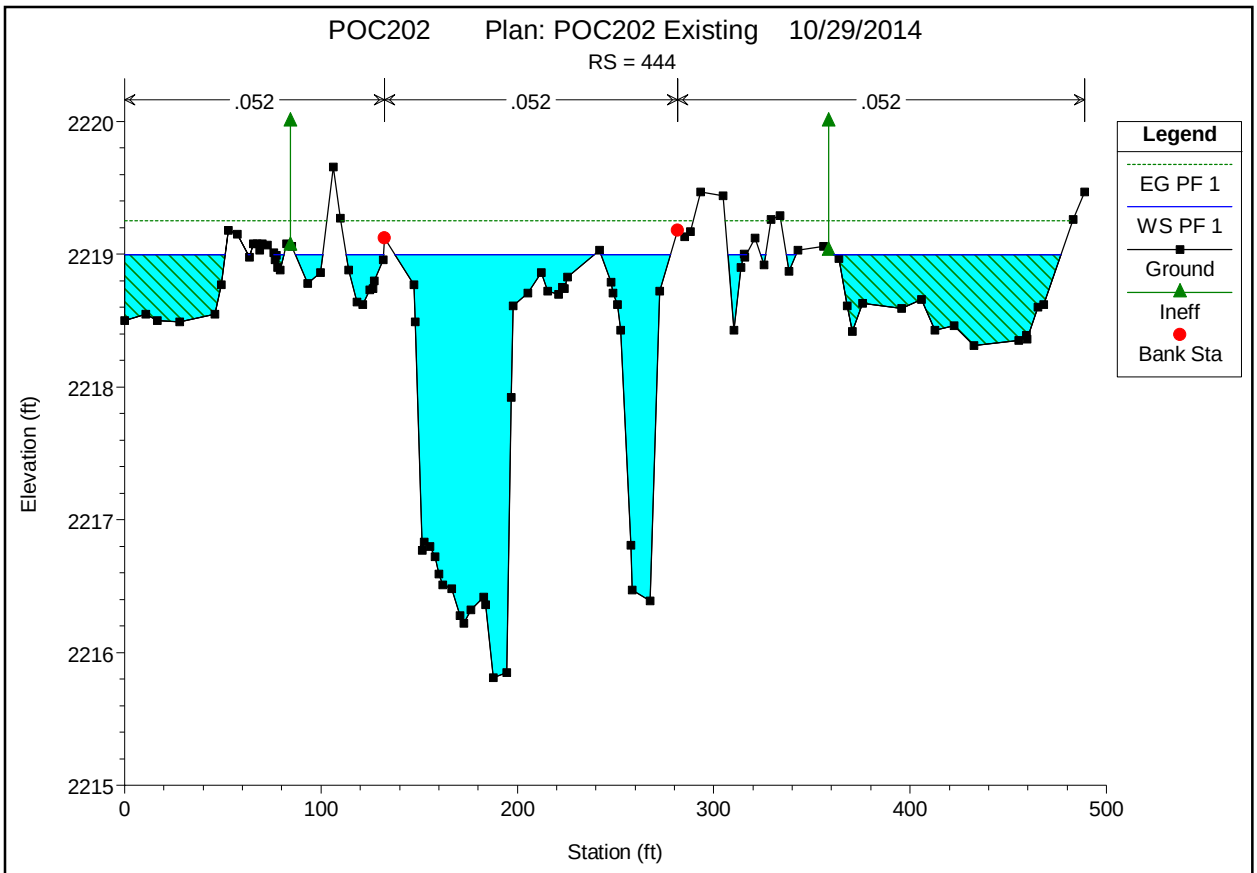
HEC-RAS Plan: 202EX River: Stream Reach: Reach Profile: PF 1

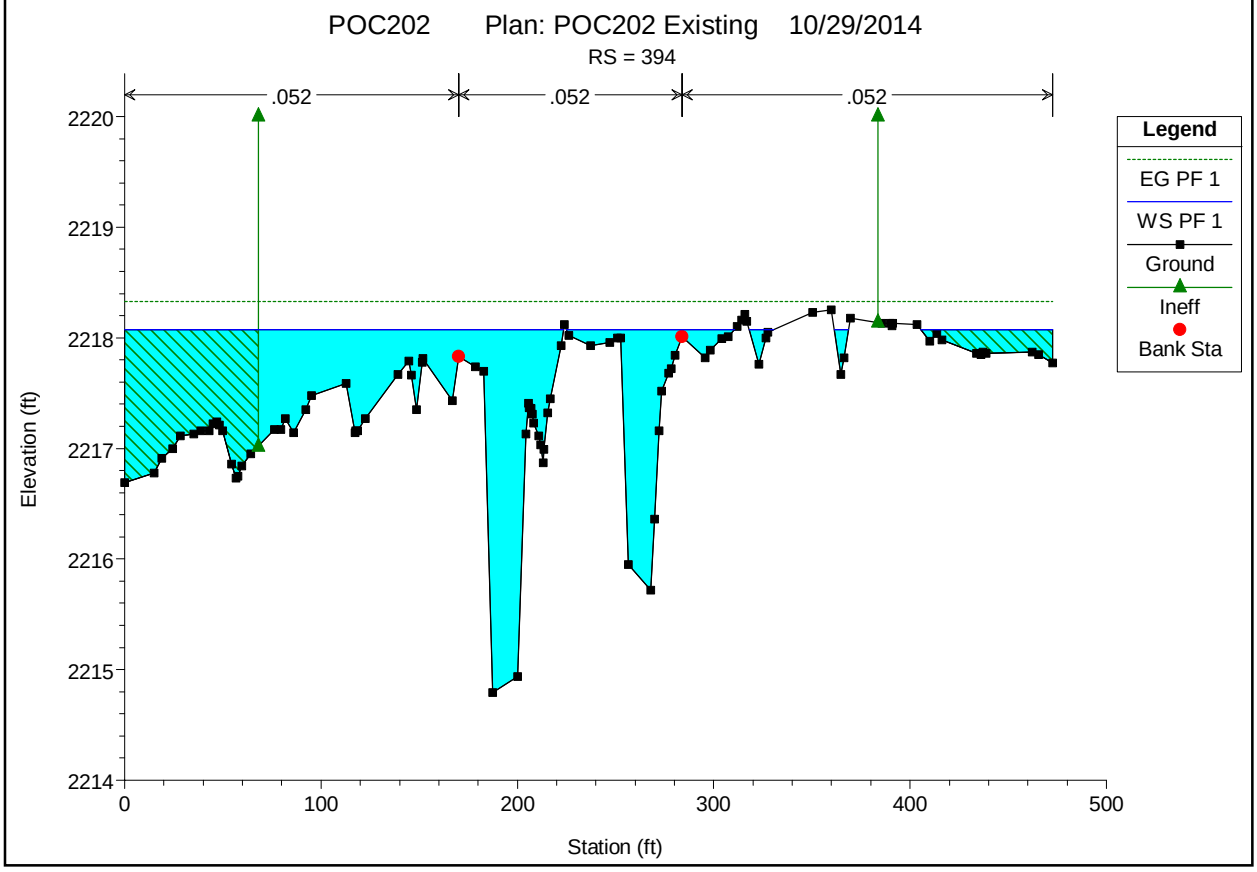
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	565	PF 1	735.00	2220.88	2222.64	2222.64	2223.10	0.041411	5.44	135.16	223.11	1.01
Reach	478	PF 1	735.00	2219.55	2221.12	2221.12	2221.44	0.002450	3.30	180.81	355.81	0.74
Reach	444	PF 1	735.00	2215.81	2219.00		2219.25	0.014813	4.08	186.36	360.09	0.63
Reach	394	PF 1	735.00	2214.79	2218.07		2218.33	0.022775	4.40	189.71	396.24	0.76
Reach	344	PF 1	735.00	2213.81	2217.05		2217.28	0.019123	4.12	197.36	250.94	0.70
Reach	295	PF 1	735.00	2212.72	2216.37		2216.56	0.011388	3.74	224.98	271.23	0.56
Reach	235	PF 1	735.00	2211.64	2215.69		2215.88	0.011563	3.59	238.07	451.11	0.56
Reach	194	PF 1	735.00	2211.11	2214.71	2214.71	2215.04	0.040310	4.67	162.43	274.62	0.96
Reach	144	PF 1	735.00	2209.88	2212.14	2212.14	2212.77	0.038267	6.38	115.13	93.09	1.01
Reach	83	PF 1	735.00	2207.83	2210.40	2209.94	2210.60	0.013997	3.67	200.38	175.40	0.60

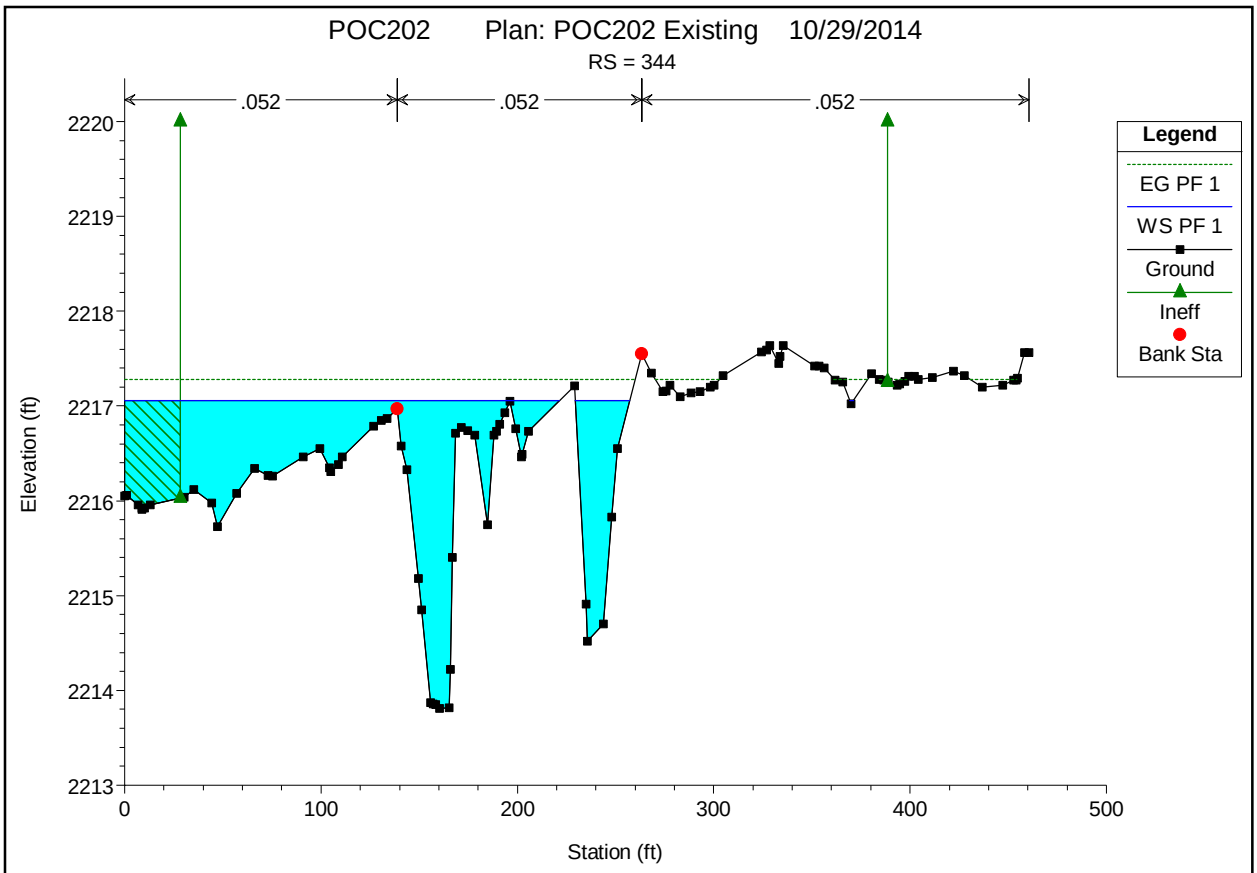

POC202 Plan: POC202 Existing 10/29/2014
Stream Reach
Legend
EG PF 1
WS PF 1
Ground
Elevation (ft)
2224
2222
2220
2218
2216
2214
2212
2210
2208
2206
0
100
200
300
400
500
Main Channel Distance (ft)

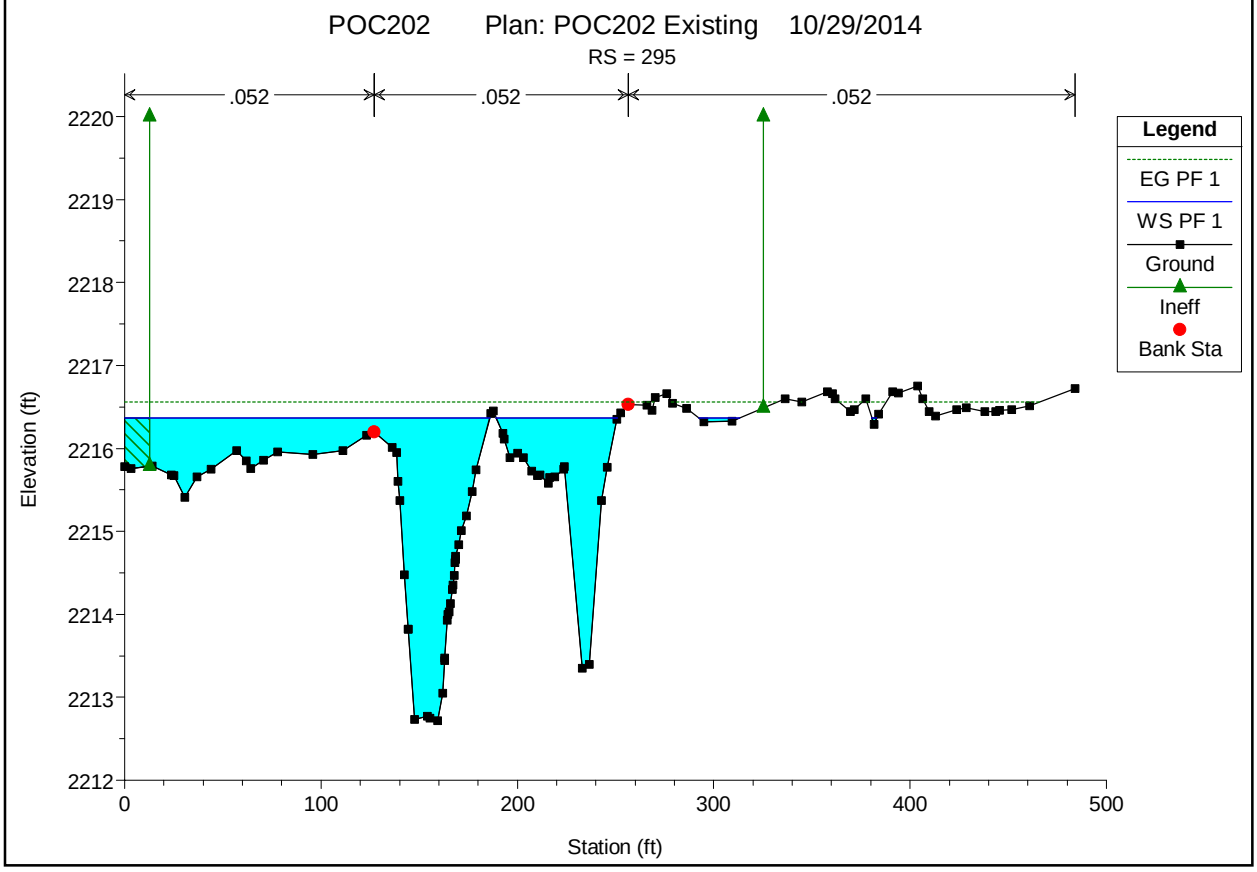

POC202 Plan: POC202 Existing 10/29/2014
RS = 565
.052
.052
.052
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta

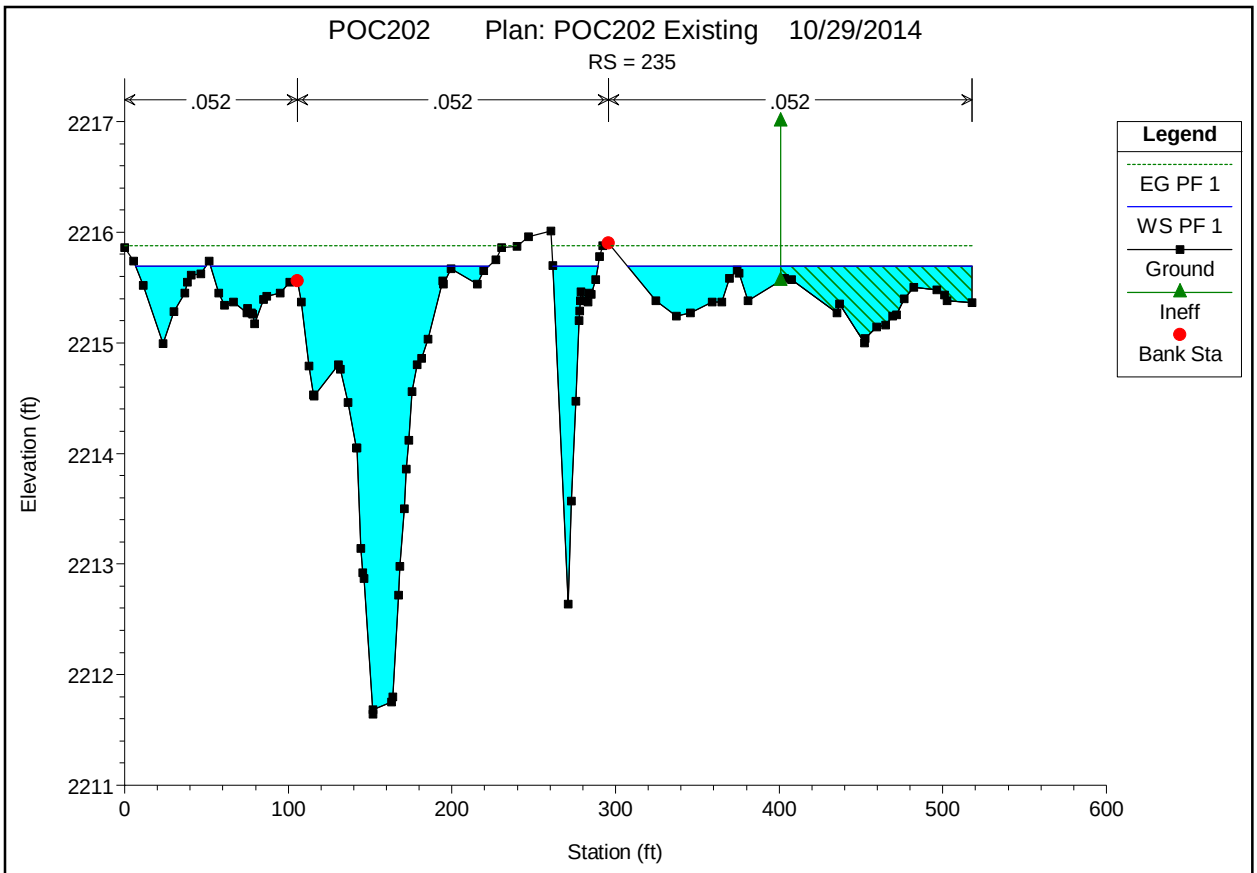

POC202 Plan: POC202 Existing 10/29/2014
RS = 478
.016
.016
.016
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta

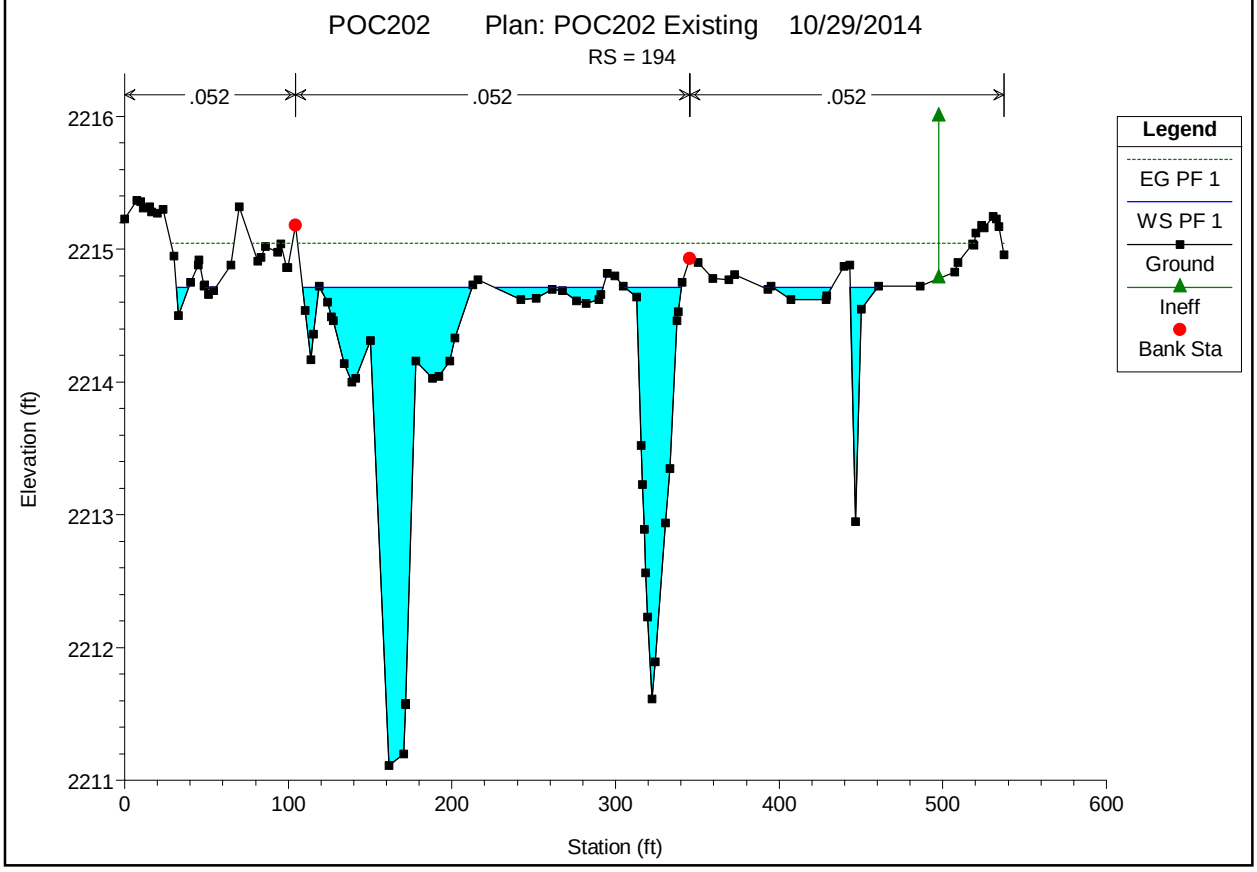

POC202 Plan: POC202 Existing 10/29/2014
RS = 444
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2220
2219
2218
2217
2216
2215
0
100
200
300
400
500

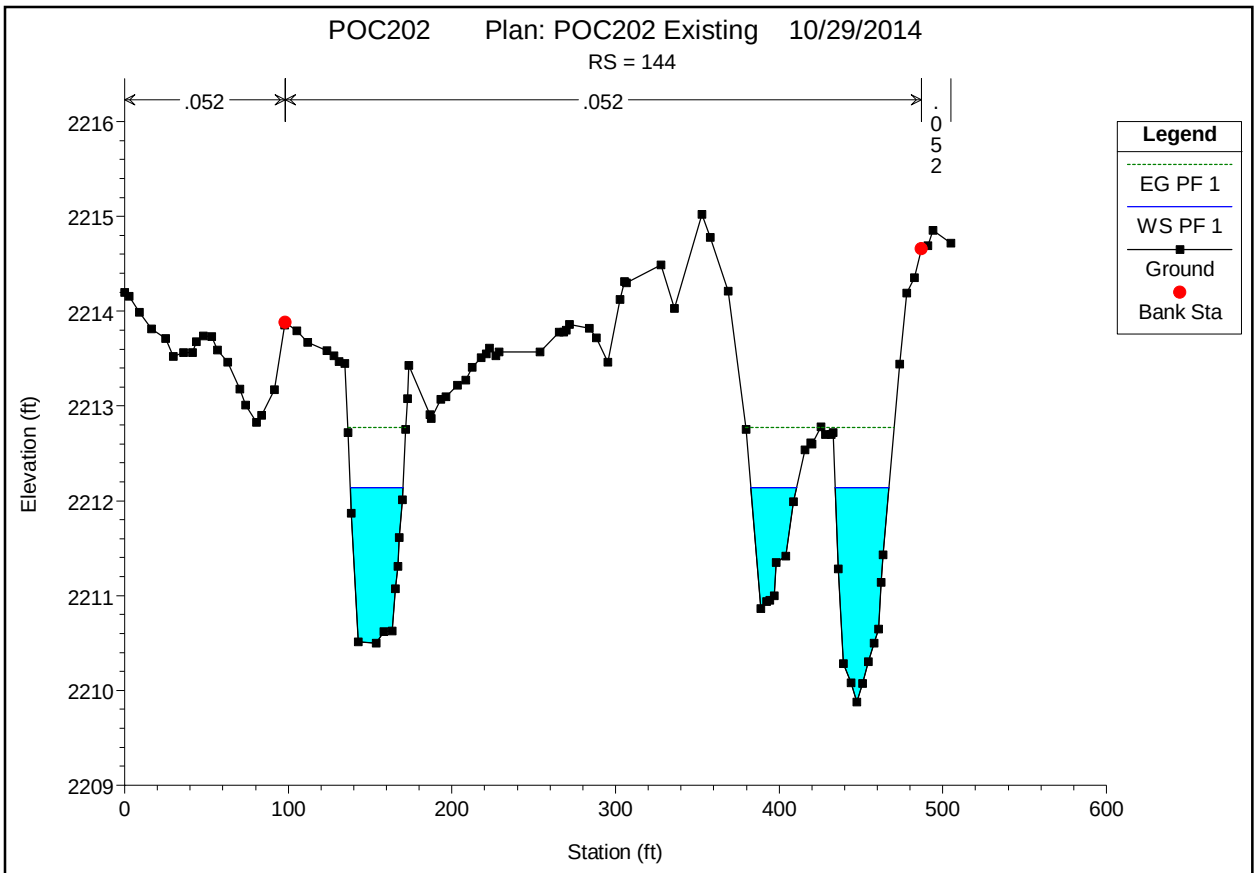

POC202 Plan: POC202 Existing 10/29/2014
RS = 394
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2220
2219
2218
2217
2216
2215
2214
0
100
200
300
400
500

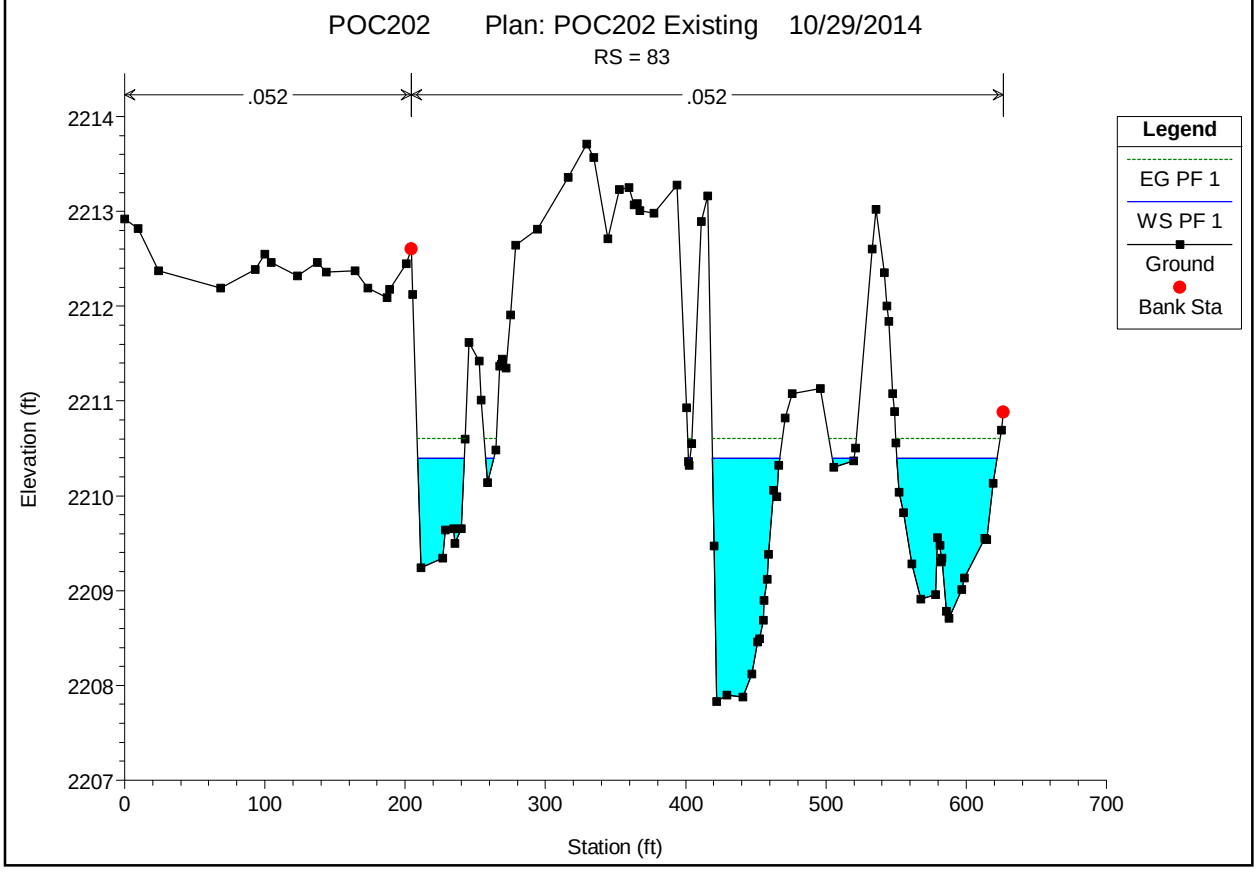

POC202 Plan: POC202 Existing 10/29/2014
RS = 344
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2220
2219
2218
2217
2216
2215
2214
2213
0
100
200
300
400
500


POC202 Plan: POC202 Existing 10/29/2014
RS = 295
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
2220
2219
2218
2217
2216
2215
2214
2213
2212
0
100
200
300
400
500


POC202 Plan: POC202 Existing 10/29/2014
RS = 235
.052
.052
.052
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta

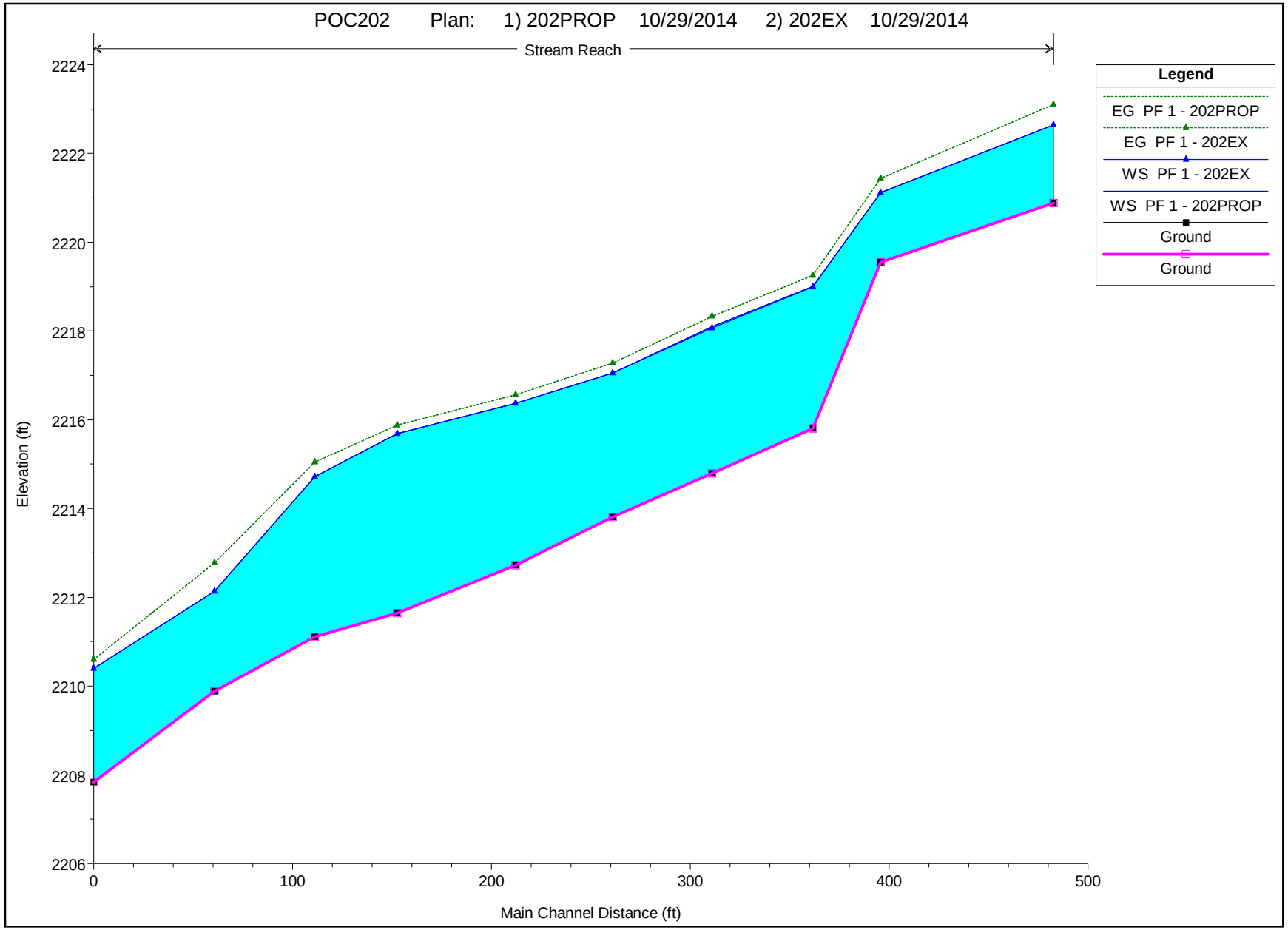

POC202 Plan: POC202 Existing 10/29/2014
RS = 194
.052
.052
.052
Elevation (ft)
Station (ft)
Legend
EG PF 1
WS PF 1
Ground
Ineff
Bank Sta

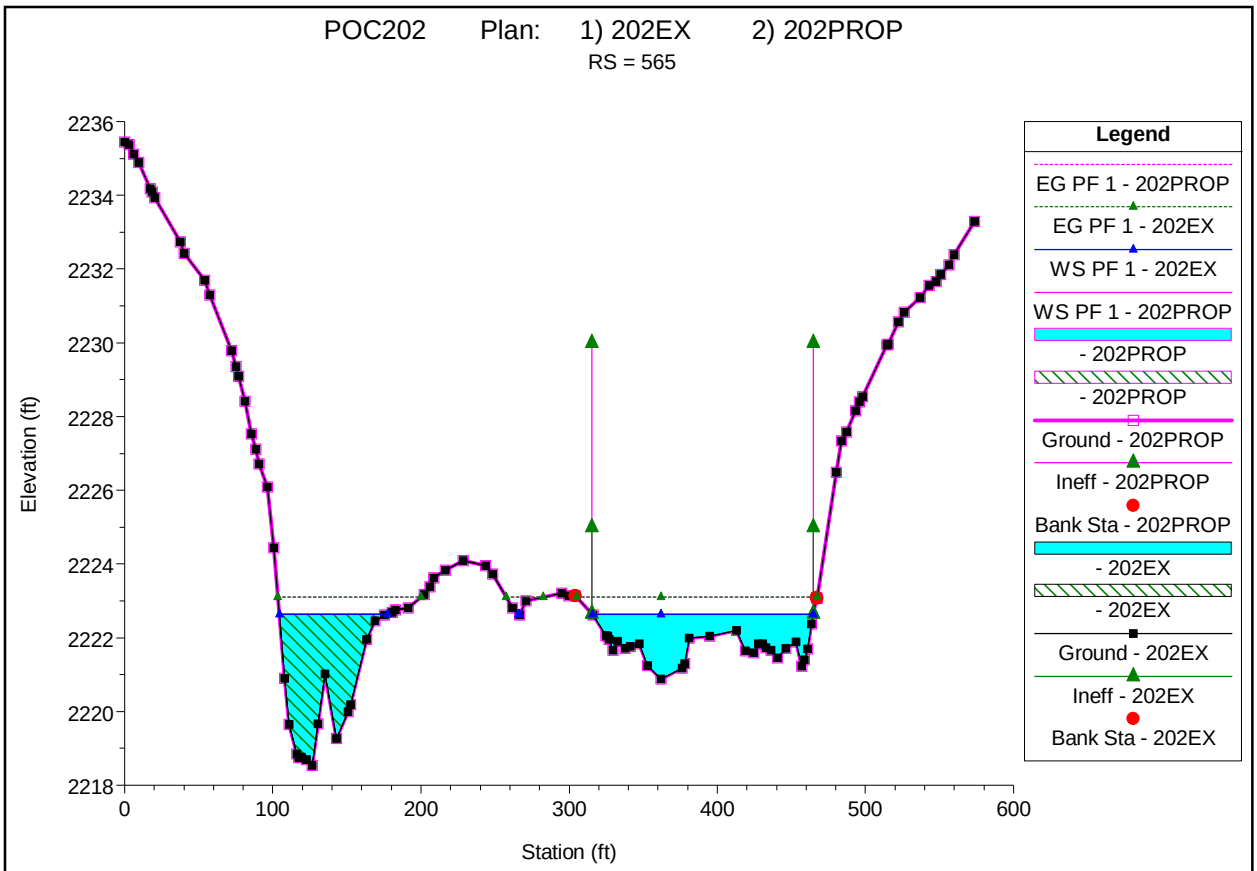

POC202 Plan: POC202 Existing 10/29/2014
RS = 144
.052
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
2216
2215
2214
2213
2212
2211
2210
2209
0
100
200
300
400
500
600

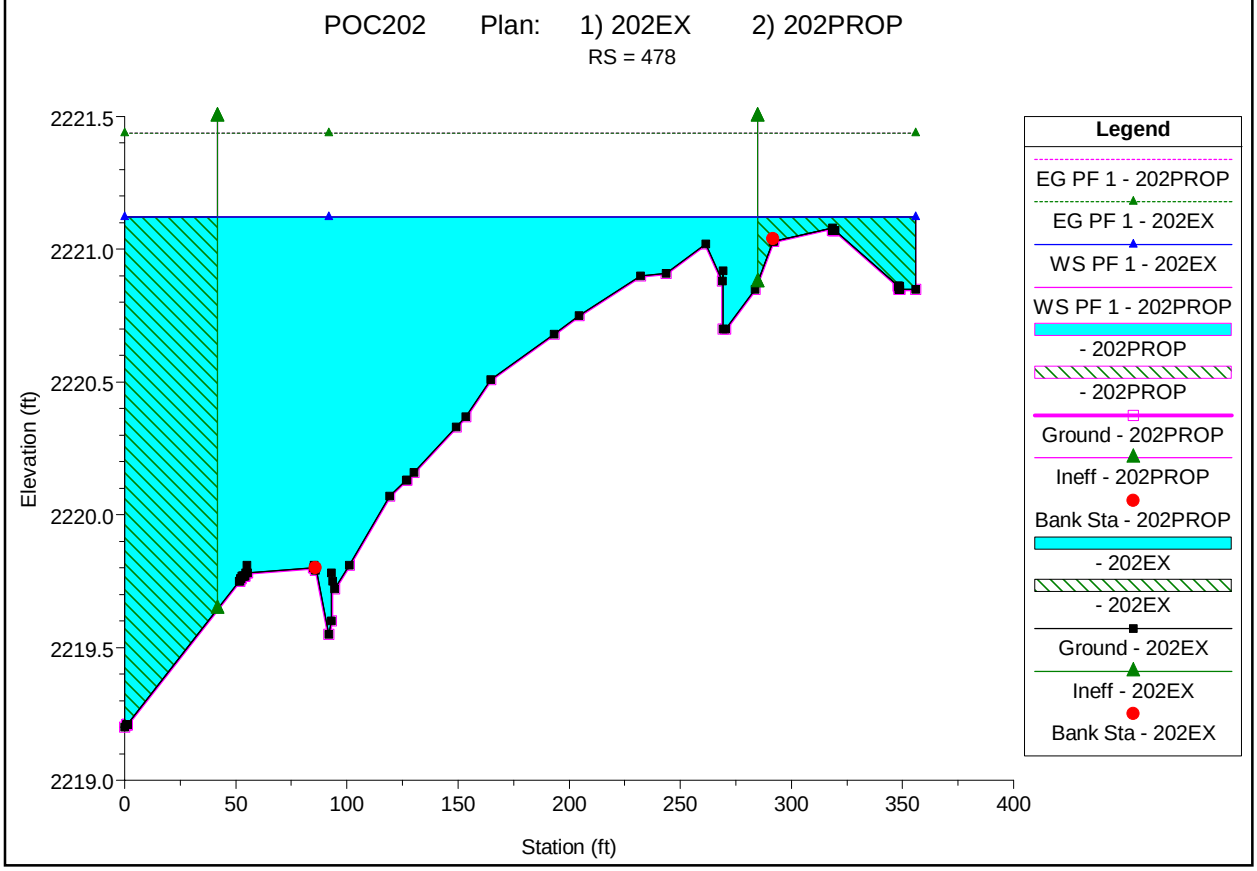

POC202 Plan: POC202 Existing 10/29/2014
RS = 83
.052
.052
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
2214
2213
2212
2211
2210
2209
2208
2207
0
100
200
300
400
500
600
700

HEC-RAS River: Stream Reach: Reach Profile: PF 1

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	565	PF 1	202PROP	735.00	2220.88	2222.64	2222.64	2223.10	0.041411	5.44	135.16	223.11	1.01
Reach	565	PF 1	202EX	735.00	2220.88	2222.64	2222.64	2223.10	0.041411	5.44	135.16	223.11	1.01
Reach	478	PF 1	202PROP	735.00	2219.55	2221.12	2221.12	2221.44	0.002449	3.30	180.82	355.81	0.74
Reach	478	PF 1	202EX	735.00	2219.55	2221.12	2221.12	2221.44	0.002450	3.30	180.81	355.81	0.74
Reach	444	PF 1	202PROP	735.00	2215.81	2219.01		2219.26	0.014641	4.05	188.19	353.35	0.63
Reach	444	PF 1	202EX	735.00	2215.81	2219.00		2219.25	0.014813	4.08	186.36	360.09	0.63
Reach	394	PF 1	202PROP	735.00	2214.79	2218.11		2218.33	0.023205	3.99	198.20	399.02	0.74
Reach	394	PF 1	202EX	735.00	2214.79	2218.07		2218.33	0.022775	4.40	189.71	396.24	0.76
Reach	344	PF 1	202PROP	735.00	2213.81	2217.05		2217.28	0.019131	4.12	197.33	250.94	0.70
Reach	344	PF 1	202EX	735.00	2213.81	2217.05		2217.28	0.019123	4.12	197.36	250.94	0.70
Reach	295	PF 1	202PROP	735.00	2212.72	2216.37		2216.56	0.011380	3.74	225.05	271.29	0.56
Reach	295	PF 1	202EX	735.00	2212.72	2216.37		2216.56	0.011388	3.74	224.98	271.23	0.56
Reach	235	PF 1	202PROP	735.00	2211.64	2215.69		2215.88	0.011607	3.60	237.63	423.80	0.56
Reach	235	PF 1	202EX	735.00	2211.64	2215.69		2215.88	0.011563	3.59	238.07	451.11	0.56
Reach	194	PF 1	202PROP	735.00	2211.11	2214.71	2214.71	2215.04	0.040122	4.66	163.03	276.92	0.95
Reach	194	PF 1	202EX	735.00	2211.11	2214.71	2214.71	2215.04	0.040310	4.67	162.43	274.62	0.96
Reach	144	PF 1	202PROP	735.00	2209.88	2212.14	2212.14	2212.77	0.038267	6.38	115.13	93.09	1.01
Reach	144	PF 1	202EX	735.00	2209.88	2212.14	2212.14	2212.77	0.038267	6.38	115.13	93.09	1.01
Reach	83	PF 1	202PROP	735.00	2207.83	2210.40	2209.94	2210.60	0.013997	3.67	200.38	175.40	0.60
Reach	83	PF 1	202EX	735.00	2207.83	2210.40	2209.94	2210.60	0.013997	3.67	200.38	175.40	0.60


POC202 Plan: 1) 202PROP 10/29/2014 2) 202EX 10/29/2014
Stream Reach
Legend
EG PF 1 - 202PROP
EG PF 1 - 202EX
WS PF 1 - 202EX
WS PF 1 - 202PROP
Ground
Ground
Elevation (ft)
2224
2222
2220
2218
2216
2214
2212
2210
2208
2206
0
100
200
300
400
500
Main Channel Distance (ft)


POC202 Plan: 1) 202EX 2) 202PROP
RS = 565
Elevation (ft)
Station (ft)
Legend
EG PF 1 - 202PROP
EG PF 1 - 202EX
WS PF 1 - 202EX
WS PF 1 - 202PROP
- 202PROP
- 202PROP
Ground - 202PROP
Ineff - 202PROP
Bank Sta - 202PROP
- 202EX
- 202EX
Ground - 202EX
Ineff - 202EX
Bank Sta - 202EX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Elevation (ft)
Station (ft)
Legend
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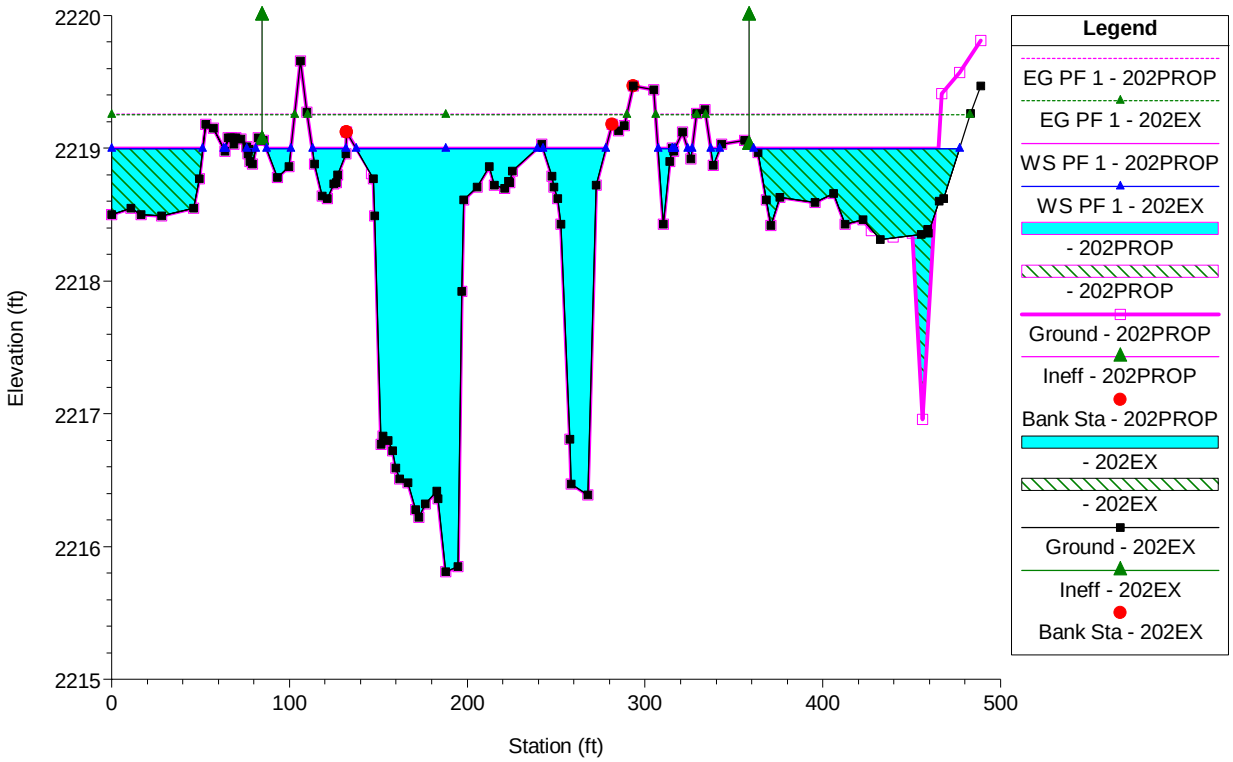
EG PF 1 - 202EX
WS PF 1 - 202EX
WS PF 1 - 202PROP
- 202PROP
- 202PROP
Ground - 202PROP
Ineff - 202PROP
Bank Sta - 202PROP
- 202EX
- 202EX
Ground - 202EX
Ineff - 202EX
Bank Sta - 202EX

POC202 Plan: 1) 202EX 2) 202PROP

RS = 444



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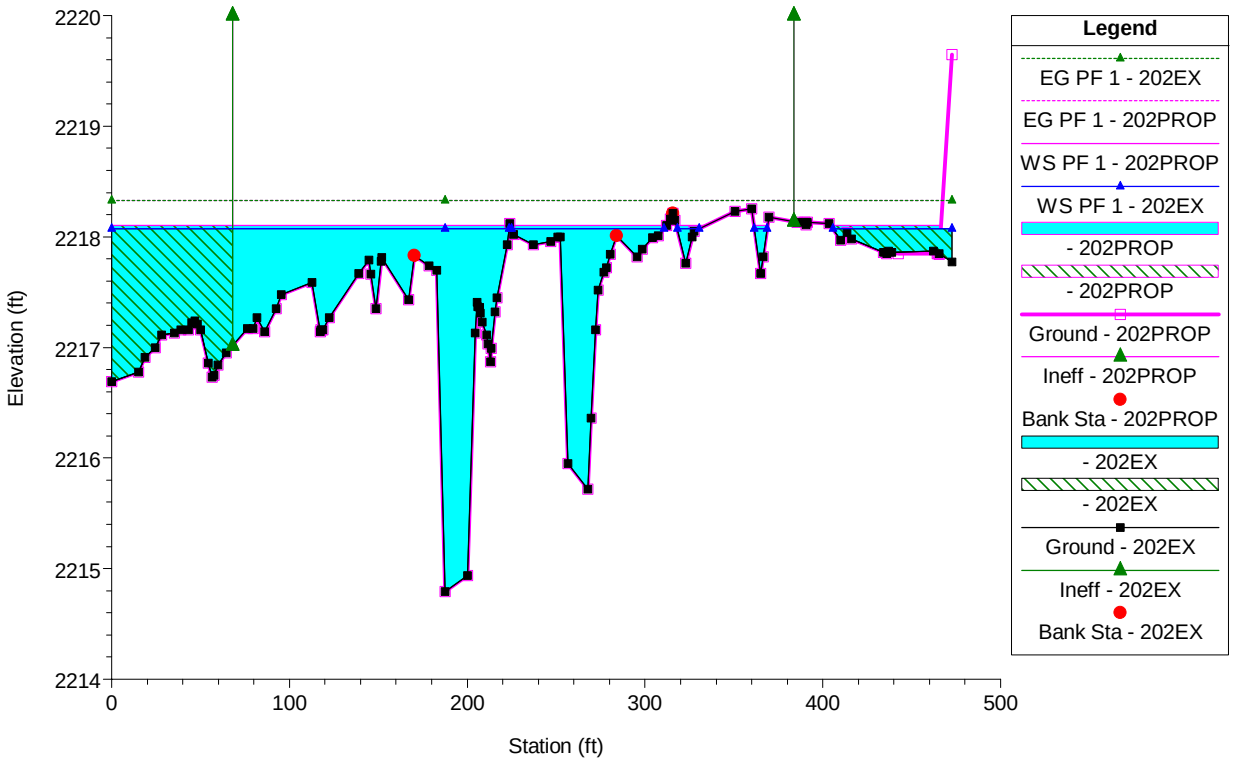
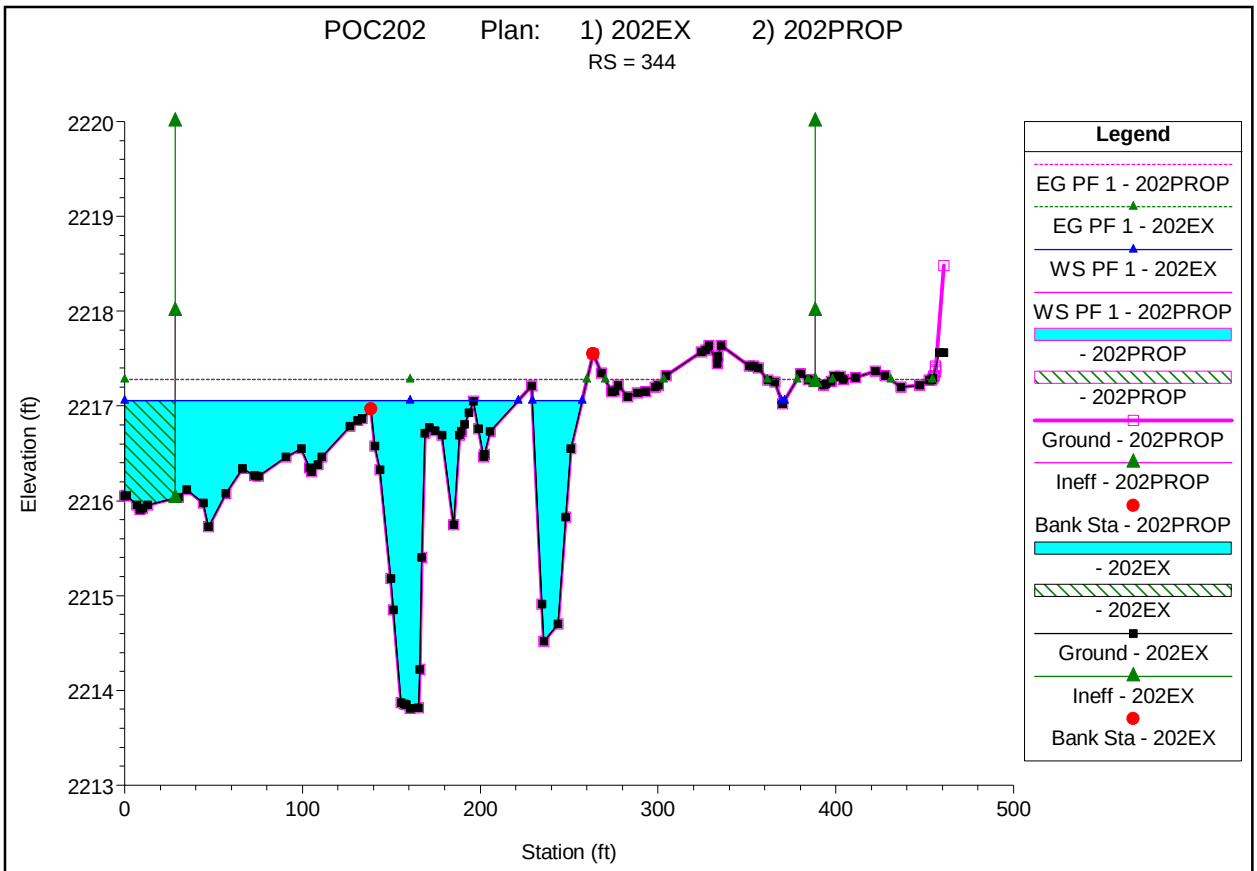
RS = 394

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Elevation (ft)
Station (ft)
Legend
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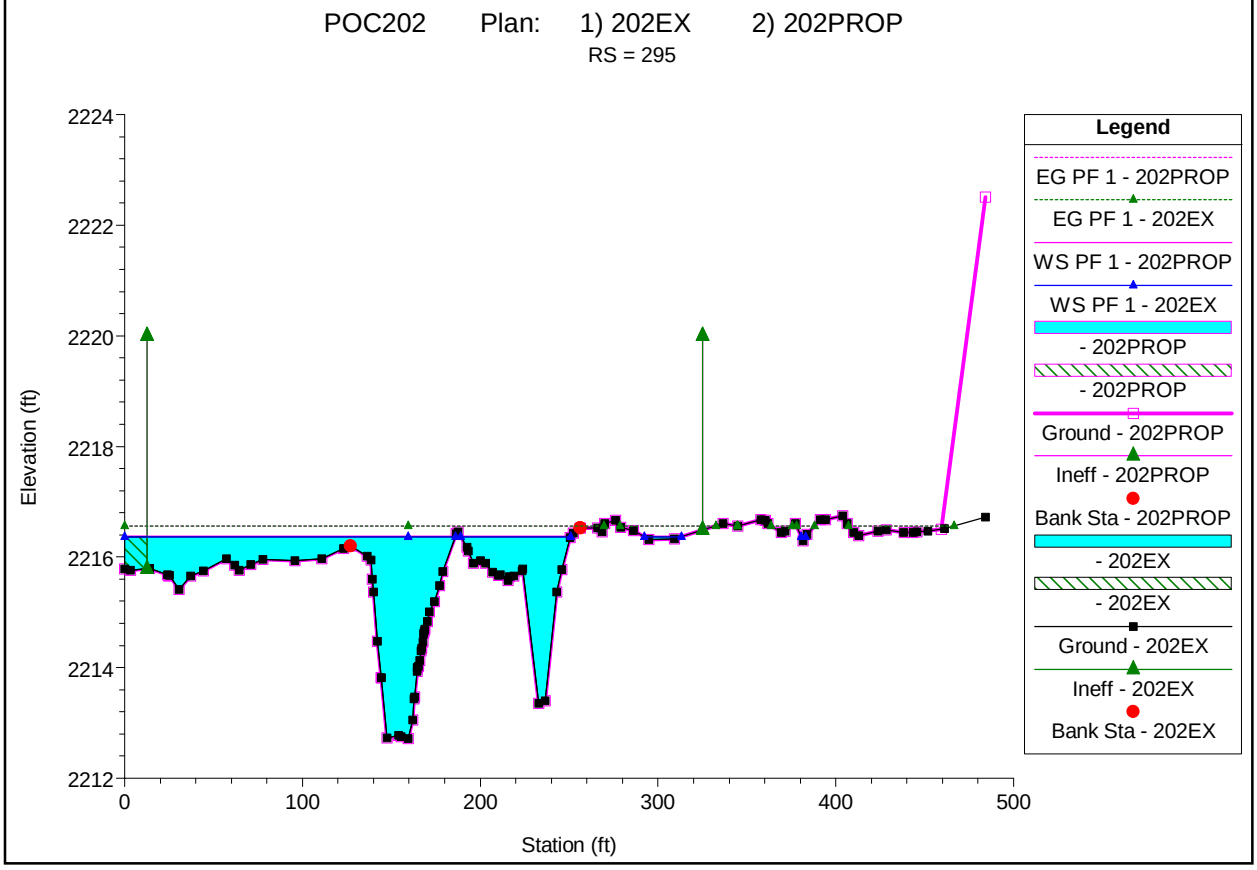
EG PF 1 - 202EX
WS PF 1 - 202EX
WS PF 1 - 202PROP
- 202PROP
- 202PROP
Ground - 202PROP
Ineff - 202PROP
Bank Sta - 202PROP
- 202EX
- 202EX
Ground - 202EX
Ineff - 202EX
Bank Sta - 202EX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RS = 295
Elevation (ft)
Station (ft)
Legend
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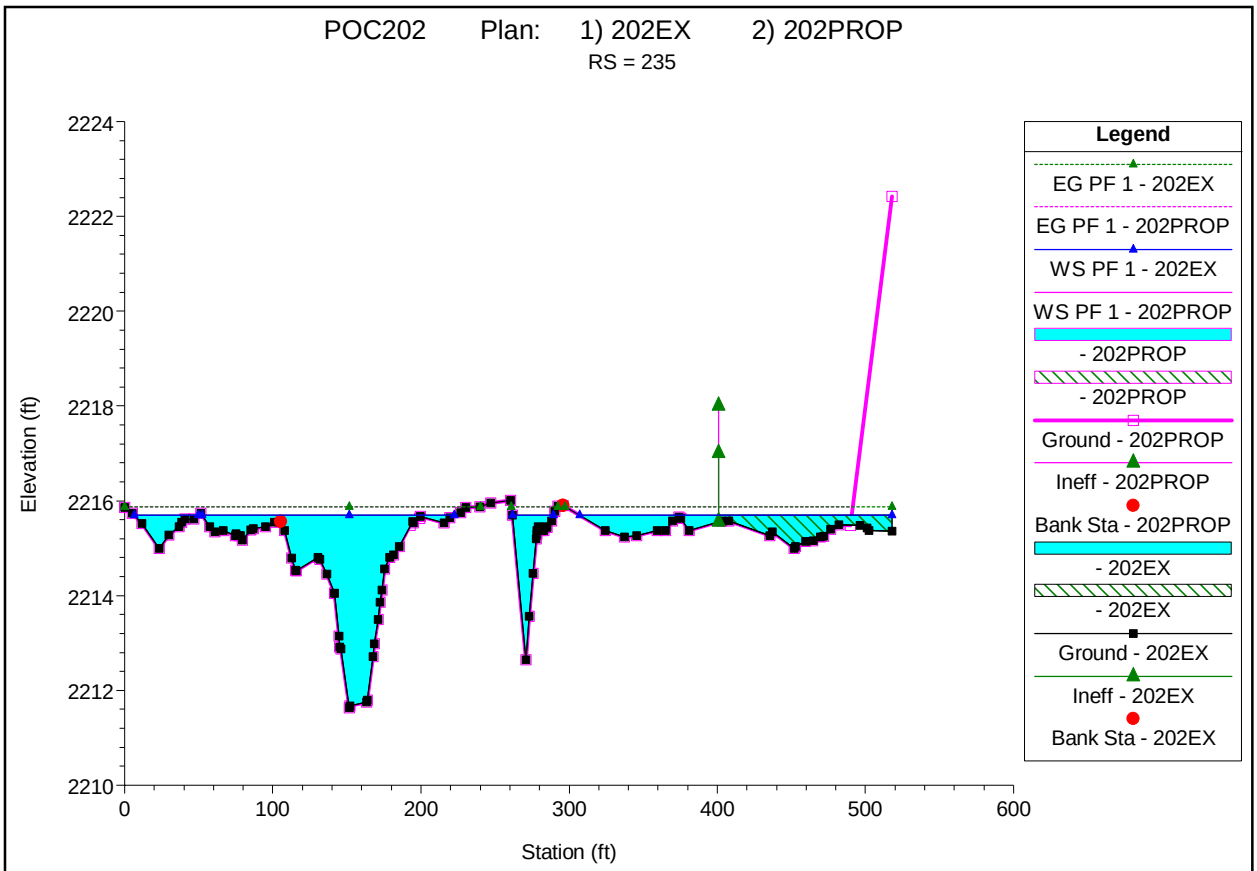
EG PF 1 - 202EX
WS PF 1 - 202PROP
WS PF 1 - 202EX
- 202PROP
- 202PROP
Ground - 202PROP
Ineff - 202PROP
Bank Sta - 202PROP
- 202EX
- 202EX
Ground - 202EX
Ineff - 202EX
Bank Sta - 202EX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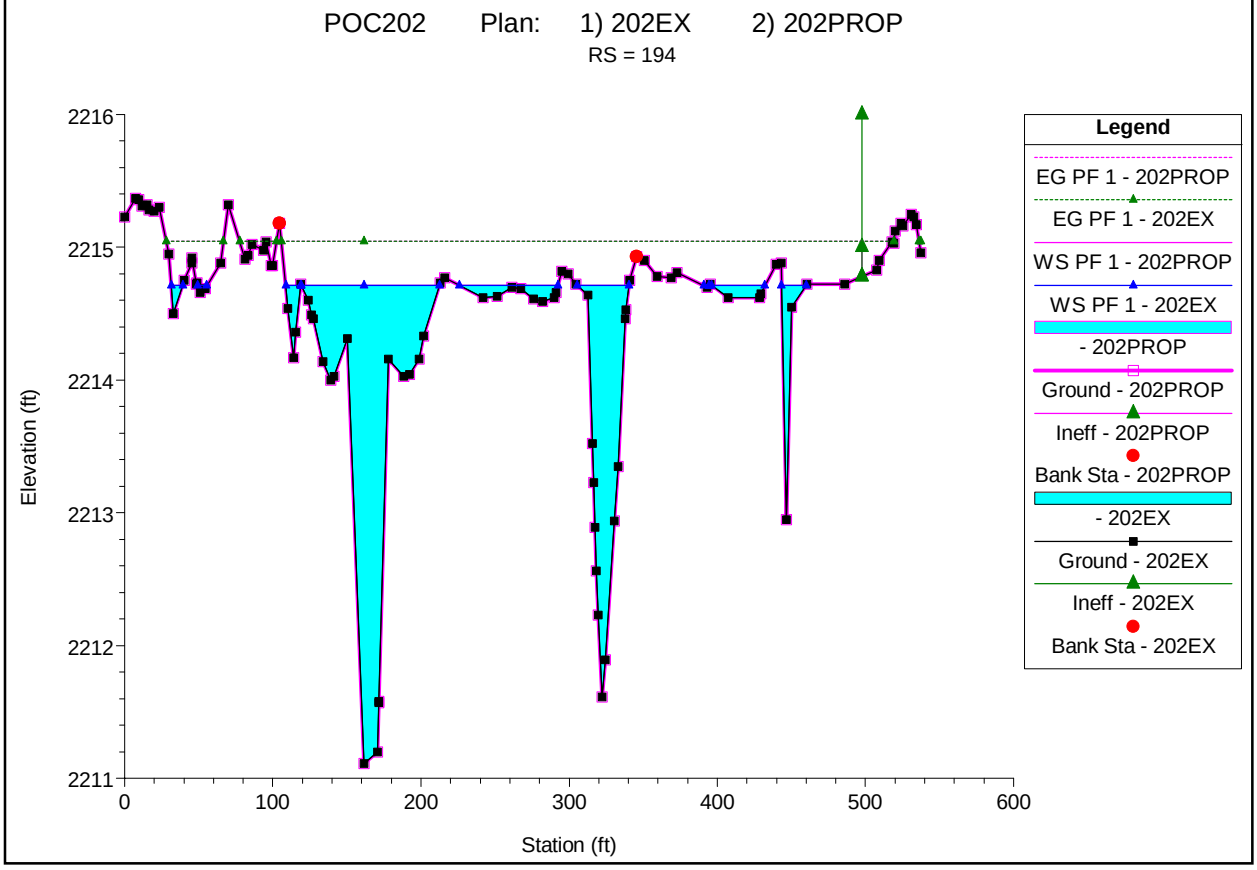
RS = 235
Elevation (ft)
Station (ft)
Legend
EG PF 1 - 202EX
EG PF 1 - 202PROP
WS PF 1 - 202EX
WS PF 1 - 202PROP
- 202PROP
- 202PROP
Ground - 202PROP
Ineff - 202PROP
Bank Sta - 202PROP
- 202EX
- 202EX
Ground - 202EX
Ineff - 202EX
Bank Sta - 202EX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Elevation (ft)
Station (ft)
Legend
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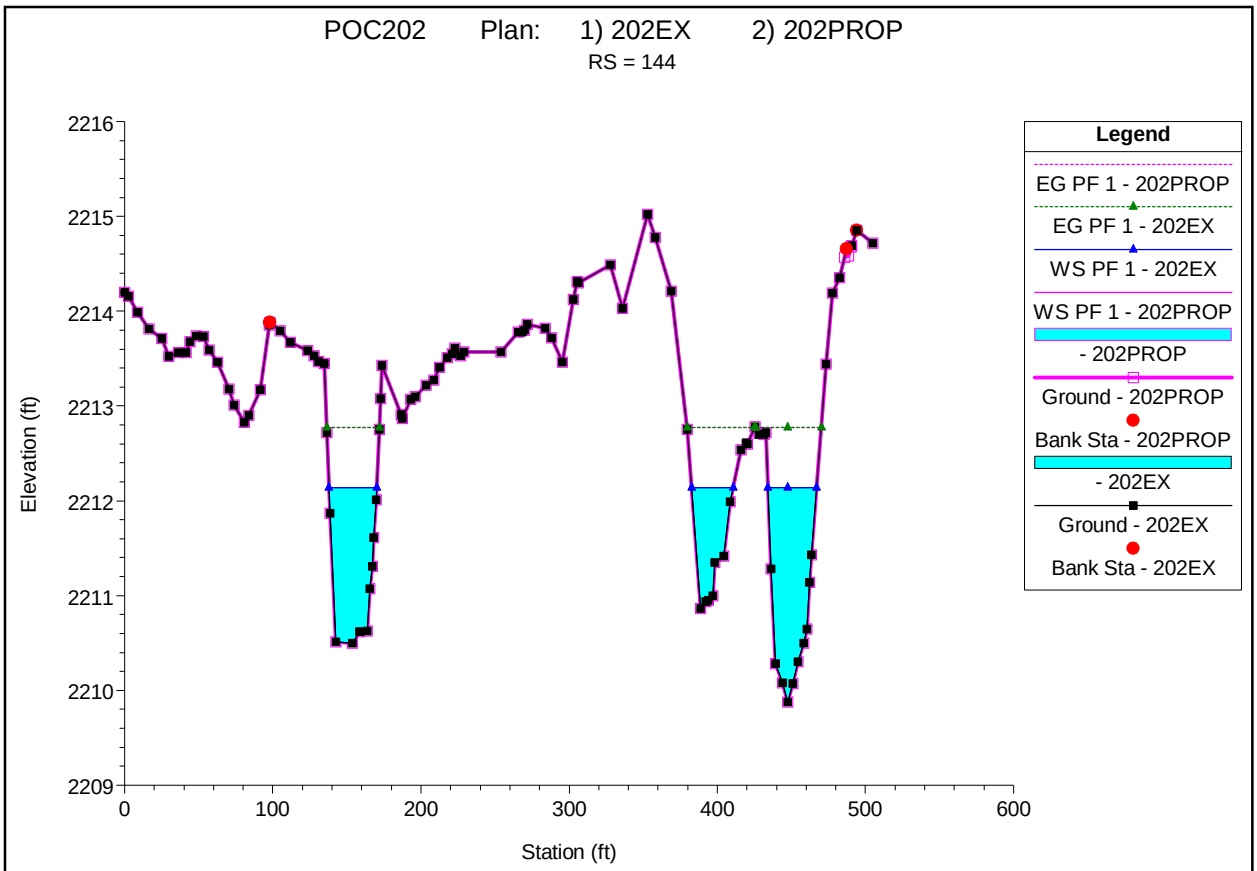
EG PF 1 - 202EX
WS PF 1 - 202PROP
WS PF 1 - 202EX
- 202PROP
Ground - 202PROP
Ineff - 202PROP
Bank Sta - 202PROP
- 202EX
Ground - 202EX
Ineff - 202EX
Bank Sta - 202EX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Elevation (ft)
Station (ft)
Legend
EG PF 1 - 202PROP
EG PF 1 - 202EX
WS PF 1 - 202EX
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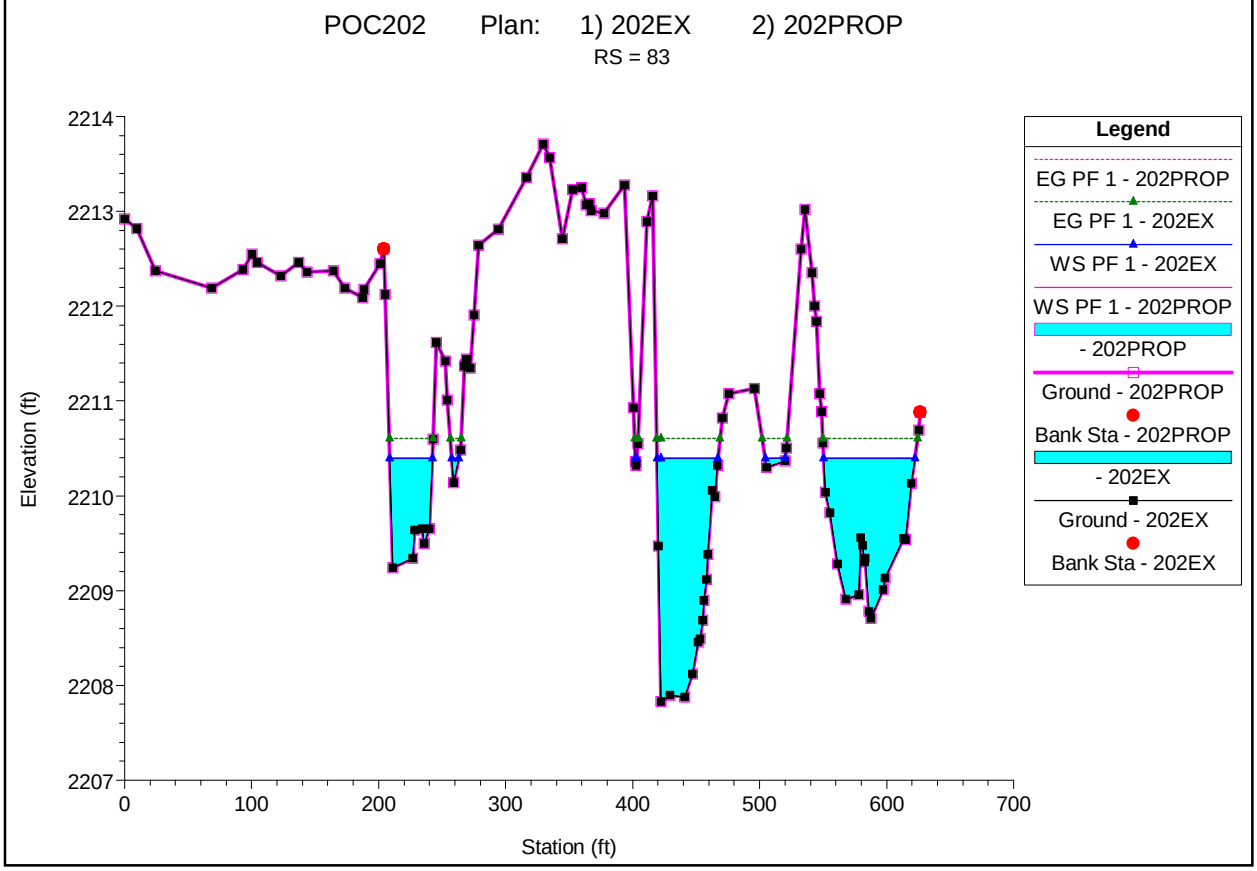
- 202PROP
Ground - 202PROP
Bank Sta - 202PROP
- 202EX
Ground - 202EX
Bank Sta - 202EX


POC202 Plan: 1) 202EX 2) 202PROP
RS = 83
Elevation (ft)
Station (ft)
Legend
EG PF 1 - 202PROP
EG PF 1 - 202EX
WS PF 1 - 202EX
WS PF 1 - 202PROP
- 202PROP
Ground - 202PROP
Bank Sta - 202PROP
- 202EX
Ground - 202EX
Bank Sta - 202EX

PARSONS BRINCKERHOFF Computation Sheet

page of

made by D. Rivalcaba

date 10/29/14

checked by

date

subject Sunset Road, Silverbell to River
Scour Downstream of Silverbell Road

Compute General Scour Off Silverbell Road @ POC 202

$$z_{gs} = y_{MAX}\left(\frac{0.0685\ V_m^{0.8}}{y_h^{0.4}\ S_e^{0.3}} - 1\right);$$

z_{gs} = General Scour
V_m = Average Velocity
y_{MAX} = Max Depth
y_h = Hydraulic Depth
S_e = Energy Slope

RS 478

V_m = 3.30 fps
y_{MAX} = 1.57'
y_h = A/TW = 180.82/355.81 = 0.51
S_e = 0.002

$$Z_{gs} = 1.57\left(\frac{0.0685 * 3.3^{0.8}}{0.51^{0.4} * 0.02^{0.3}} - 1\right) = \emptyset'$$ No Scour Off Roadway

APPENDECIES

APPENDIX A PROJECT MAPPING AND SURVEY CONTROL

APPENDIX B ONSITE DRAINAGE

APPENDIX C OFFSITE DRAINAGE

APPENDIX D SANTA CRUZ HYDRAULICS

APPENDIX E DCR LEVEL CONSTRUCTION PLANS

PARAMETERS

The following steps were used to establish the roughness coefficients for the hydraulic model of the Santa Cruz River. The roughness coefficients were used for both tying into the existing LOMR as well as developing the effect of the proposed bridge.

1. The photo log was translated into the numerical factors to develop roughnesses according to the document "Verification of Roughness Coefficients for selected natural and constructed channels in Arizona". Please refer to document to obtain formula used.

2. There are several factors that the document above uses to describe and calculate the manning's roughness in each identified areas.

    a. The base roughness used for the project site is a 0.022. On the document shown above, Table 2 describes (based from Chow's *Open Channel Hydraulics* 1959) firm earth as 0.020, and fine gravel as 0.024. Since the ground is somewhere between firm earth and fine gravel, 0.022 was used as the base Manning's roughness.

    b. The first roughness adjustment is based on degree of irregularity. This describes roughness caused by any projecting points, such as exposed tree roots, or scoured and eroded channel and banks.

    c. The second roughness adjustment is based on variation in channel cross section. This roughness adjusts for changes in cross section shape and shifts. This describes how rapidly the changes occur, the harshest and most abrupt changes results in the biggest adjustment. For the majority of the observed reach, the channels showed gradual transition.

    d. The third roughness adjustment is due to obstructions. This adjustment includes obstructions ranging from something small such as isolated boulders to something big that could obstruct the flow of the channel more than 50%. There were some areas where small obstructions covered the ground.

    e. The fourth adjustment is based on vegetation. Two characteristics of the vegetation were used to appropriately estimate the roughness adjustment. The first characteristic is the vegetation height; this was a factor because it is compared to the flow height. The document uses this height ratio as a measure of flow disruption. The second aspect to be considered is the width of the vegetation, this provides how much percentage of the flow it is going to affect. This study reach ranges from "Negligible Small" to "Extremely Large".

    f. The last roughness adjustment is based on river meandering, it is not an adjustment that is added, but a factor. This is the factor that is multiplied to the sum of the base roughness and the roughness adjustments. This is computed as a ratio of the channel length to valley length; throughout this project reach this ratio was less than 1.2, therefore the factor to this study reach is 1.0.

3. There are three areas that did not use the above method directly.

    a. The first area was the riparian area. The riparian area is described as two parts, first the stream portion which is cobble bottom. The second portion of the riparian area is the banks with dense and "extremely large" vegetation. These two were then averaged to obtain a roughness for this area.

    b. The second area was an area on the downstream side that contains urban landscape. This also started with the method described above but then accounted for the obstruction of the buildings residing in the area.

    c. The third area is that of a golf course. This area was just described as a 0.010; this was done to reflect the slickness that will occur as water starts to flow above the grass.

4. Once each roughness area was calculated, the study reach was evaluated on a cross section by cross section basis. Manning's roughness coefficients were selected by overlaying cross sections on delineated roughness areas. In accordance with PCRFCD, the roughness coefficients were averaged using equation 6-17 from Chow's *Open Channel Hydraulics* 1959 for over banks and main channel. This method was compared to the HEC-RAS averaging when entered as horizontally varying roughness, and the results show that the methods are comparable.

5. For the areas within the channel, during events larger than the 10-year, the vegetation is assumed to be removed from scour. Therefore, the vegetation roughness component was eliminated. This change lowers the main channel roughness by significant amount.

    a. Upon review of the scoured condition of the main channel, portions along the river seemed to be similar; therefore an average roughness value was used for similar sub reaches within the main channel.

6. Manning's roughness coefficient near the bridge at Station 51000 (El Camino Del Cerro Bridge), was based on the assumption of fully established vegetation.

Photo 1. Desert Bloom 6’ tall, surrounded by grass downstream of Ina Road Bridge. Right Ovebank. n=0.036

Photo 2. Mesquite Trees also in the channel with surrounded by grass . Right Overbank.

n=0.036

Photo 3. Natural vegetation downstream of the Ina Road Bridge. Right Overbank.

n=0.036

Photo 4. Shotcrete downstream of Ina Road channel. Main Channel. n=0.026

Photo 5. The right side of the picture shows the right overbank downstream of Ina Road Bridge.

n=0.036

Photo 6. Large trees, including Mesquite Trees in the main channel, upstream of Ina Road Bridge.

n=0.140

Photo 7. A lot of open areas with short grass in main channel just upstream of Ina Road Bridge .

n=0.033

Photo 8. Very dense Mesquite Trees and grass in the right overbank.

n=0.105

Photo 9. Very dense area of Mesquite Trees with debris and grass in right overbank.

n=0.105

Photo 10. Channel bottom is overgrown with about 3’ tall grass in the right overbank.

n=0.033

Photo 11. Right Overbank with clusters of trees and several obstructions not in picture.

n=0.050

Photo 12. Overlooking at grown vegetation in the right overbank.

n=0.033

Photo 13. 5’ average height of Creosote Bush in the left overbank.

n=0.059

Photo 14. Higher density of Creosote Bushes in the left overbank.

n=0.059

Photo 15. Area littered with Desert Broom in the area where is there is very little grass. Left Overbank.

n=0.052

Photo 16. Very dense vegetation of tall trees blocks a big portion of flow area. In Left overbank.

n=0.180

Photo 17. Variety of vegetation which may include Desert Broom and Net-Leaf Hackberry along banks of the main channel. n=0.140

Photo 18. Edge of the riparian area (main channel) lined with large trees.

n=0.140

Photo 19. Area contains plenty of Creosote Bushes and Mesquite Trees. Left overbank.

n=0.052

Photo 20. Left overbank populated with several 4' Creosote Bushes.

n=0.059

Photo 21. Pecan tree orchard, on the right overbank. Canopy is about 5’ above ground.

n=0.029

Photo 22. Very bare ground on the right overbank of the bank.

n=0.027

Photo 23. Bare ground on the right overbank of the main channel.

n=0.027

Photo 24. Bare ground near channel at the site of a local park. Left Overbank.

n=0.027

Photo 25. In the background, dense area of smaller bushes and several tall Mesquite Trees. Left Overbank. n=0.059

Photo 26. Very high density of Mesquite Trees, a lot of overlap in this small and isolated area.

n=0.237

Photo 27. Sparse trees located in the vicinity of Columbus Park in the left overbank of the channel. n=0.044

Photo 28. Looking at the Santa Cruz River channel, high density of short vegetation.

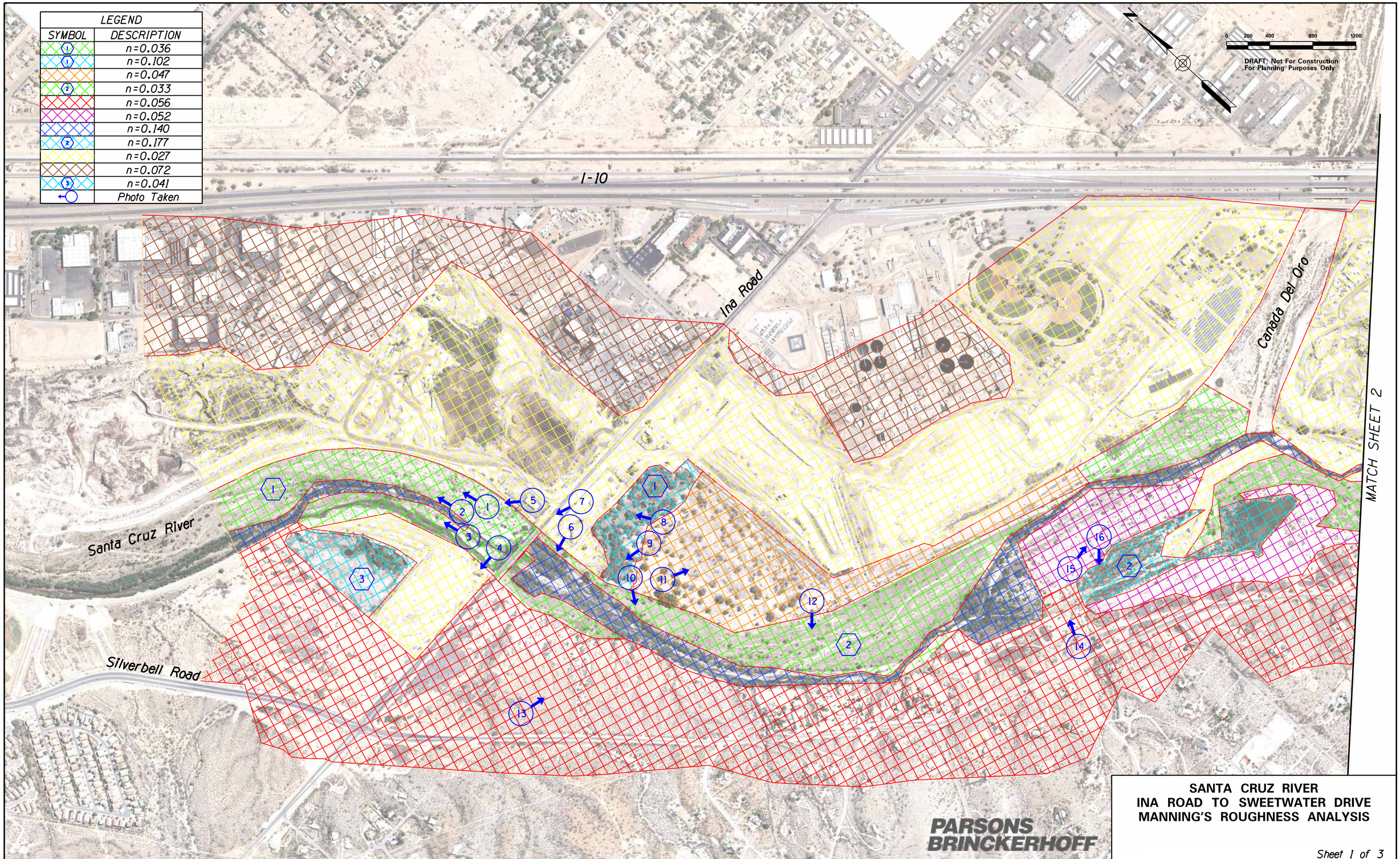
n=0.033

Photo 29. A large number of rocks in the main channel of the Santa Cruz River.

n=0.033

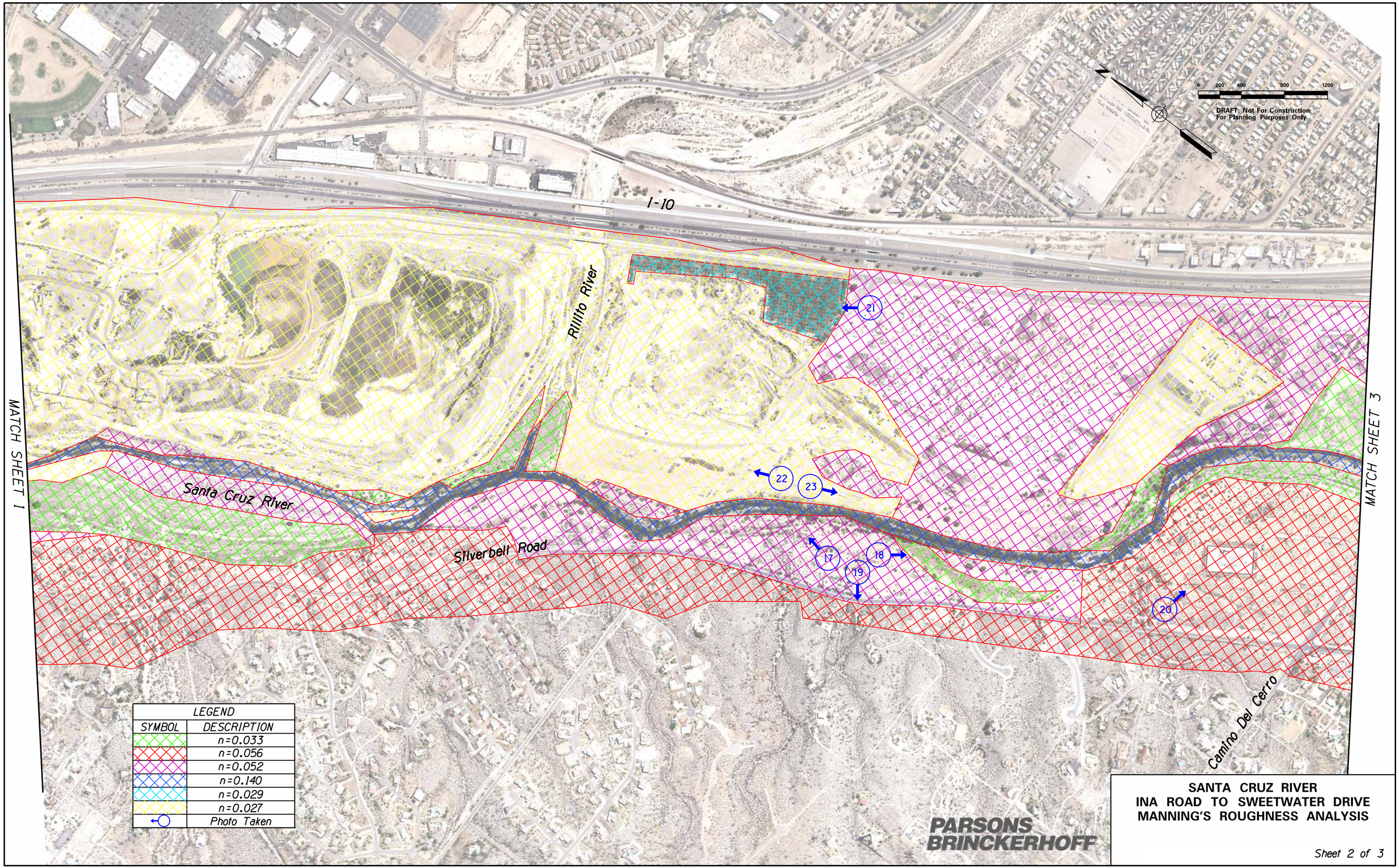
Photo 30. Looking at the Santa Cruz River channel, high density short vegetation.

n=0.033



SANTA CRUZ RIVER
INA ROAD TO SWEETWATER DRIVE
MANNING'S ROUGHNESS ANALYSIS

Sheet 1 of 3



SANTA CRUZ RIVER
INA ROAD TO SWEETWATER DRIVE
MANNING'S ROUGHNESS ANALYSIS

Sheet 2 of 3

SANTA CRUZ RIVER
INA ROAD TO SWEETWATER DRIVE
MANNING'S ROUGHNESS ANALYSIS

Sheet 3 of 3

Proj. No.:	11542	Calculated By:	D. Ruvalcaba	Date:	8/1/2014
Proj. Name:	4RTSUN Sunset Road, Silverbell to River	Checked By:		Date:	
Description:	Roughness per Area and Vegetation				

Area	Base n	Irregularity	Variation	Obstructions	Vegetation	Meandering	Total
A	0.022	0.005	0.000	0.004	0.005	1.0	0.036
B	0.022	0.005	0.000	0.000	0.075	1.0	0.102
C	0.022	0.005	0.000	0.010	0.010	1.0	0.047
D	0.022	0.005	0.000	0.004	0.002	1.0	0.033
E	0.022	0.005	0.000	0.004	0.025	1.0	0.056
F	0.022	0.005	0.000	0.005	0.020	1.0	0.052
**G							0.140
H	0.022	0.005	0.000	0.000	0.150	1.0	0.177
I	0.022	0.005	0.000	0.004	0.010	1.0	0.041
J	0.022	0.005	0.000	0.000	0.002	1.0	0.029
K	0.022	0.005	0.000	0.000	0.000	1.0	0.027
L	0.022	0.005	0.000	0.004	0.002	1.0	0.033
M	0.022	0.005	0.000	0.010	0.200	1.0	0.237
O							*0.072
****P	0.010	0.000	0.000	0.000	0.000	1.0	0.010
***Q	0.026	0.000	0.000	0.000	0.000	1.0	0.026
A'	0.022	0.005	0.000	0.004	0.000	1.0	0.031
C'	0.022	0.005	0.000	0.010	0.000	1.0	0.037
D'	0.022	0.005	0.000	0.004	0.000	1.0	0.031
E'	0.022	0.005	0.000	0.004	0.000	1.0	0.031
F'	0.022	0.005	0.000	0.005	0.000	1.0	0.032
**G'							0.028
H'	0.022	0.005	0.000	0.000	0.000	1.0	0.027
I'	0.022	0.005	0.000	0.004	0.000	1.0	0.031
L'	0.022	0.005	0.000	0.004	0.000	1.0	0.031

Manning's Roughness for areas were based on the document named "Selection of Manning's Roughness Coefficient for Natural and Constructed Vegetated and Non-Vegetated Channels, and Vegetation Maintenance Plan Guidelines

for Vegetated Channels in Central Arizona"
Base n was taken from Chow in Table 2 from document by mentioned above.
The 0.022 correlates the soil being half firm earth (0.020) and half fine gravel (0.024).
*Mannings roughness for area O was developed for an urban area, as described in "Determination of Roughness Coefficients For Streams in Colorado"
**G is based on external hand calculation
***Q is based on roughness on shotcrete surface
****P base mannings of 0.010 is due to area being a golf course. Grass that will be slick when water is present.

PARSONS BRINCKERHOFF Computation Sheet

page 1 of 2

made by D. Ruvalcaba

date 8/4/14

checked by

date

subject 11542 Sunset

Manning's Calculation for Riparian Area (10 Yr Event)

The document:

Selection of Manning's Roughness Coefficient for Natural and Constructed Vegetated and Non-Vegetated Channels, and Vegetation Maintenance Plan Guidelines for Vegetated Channels in Central Arizona

describes how to obtain the Roughness coefficient with the main channel

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)\, m \qquad \text{(Eqn 5)}$$

n_0 = Base Manning's roughness

n_1 = Degree of Irregularity

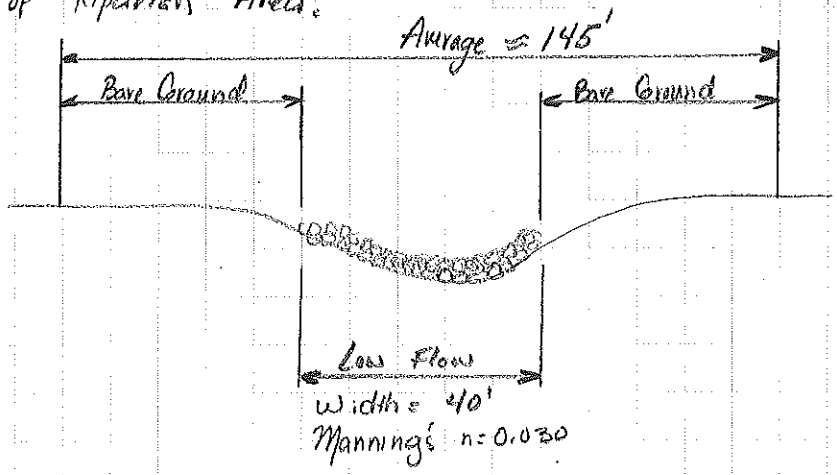
n_2 = Variation in Channel cross section

n_3 = Effect of Obstructions

n_4 = Amount of vegetation

m = Degree of meandering

Area of Riparian Area:



PARSONS BRINCKERHOFF Computation Sheet

made by D. Ruvalcaba

date 8/4/14

checked by

date

subject 1542 Sunset

Manning's Calculation for Riparian Area

For Bare ground along banks:

$$n = (n_0 + n_1 + n_2 + n_3 + n_4)\, m$$

Bare ground due to storm event

$n_0 = 0.022$, $n_1 = 0.005$, $n_2 = 0.000$, $n_3 = 0.000$, $n_4 = 0.000$, $m = 1.0$

$$n = (0.022 + 0.005 + 0.000 + 0.000 + 0.000)\, 1.0 = 0.027$$

Average n:

$$n = \frac{(40 \times 0.030) + (105 \times 0.027)}{145} = 0.028$$

PARSONS BRINCKERHOFF Computation Sheet

page 1 of 1

made by D. Ruvalcaba

date 6/23/14

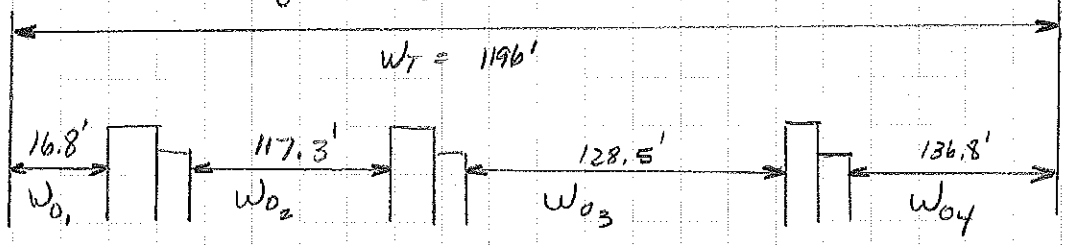
checked by

date

subject 11542 Sunset

Manning's Calculation for urban developed

Formula for obtaining Manning's Roughness as described in the document.



$W_O = 16.8 + 117.3 + 128.5 + 136.8 = 399.4'$

$n_O = 0.027$

$L_O = 282.8 + 256.8 + 341.8 + 379.5 + 329.8 + 245.0 + 95.0 + 652.6 + 282.6 + 109.5 + 262.9 = 3438.3$

$L_T = 5232.8$

Formula from document

$$n_u = n_O \left[\frac{3}{2}\left(\frac{W_T}{\Sigma W_O}\right) + \left(1 - \frac{W_T}{\Sigma W_O}\right) \frac{\Sigma L_O}{L_T} - \frac{1}{2} \right]$$

$$n_u = 0.027 \left[\frac{3}{2}\left(\frac{1196}{399.4}\right) + \left(1 - \frac{1196}{399.4}\right) \frac{3438.3}{5232.8} - \frac{1}{2} \right]$$

$$n_u = 0.027 \left[2.68 \right] = 0.072$$

Proj. No.:	11542	Calculated By:	D. Ruvalcaba	Date:	8/19/2014
Proj. Name:	4RTSUN Sunset Road, Silverbell to River	Checked By:		Date:	
Description:	Roughness (10-Yr Event)				

River Sta	Left Overbank	Main Channel	Right Overbank Horz "n": Sta_1/n_1; Sta_2/n_2
61000	0.041	0.057	0.041
60523	0.041	0.069	0.041
60070	0.041	0.065	0.041
59588	0.109	0.067	0.041
59088	0.128	0.075	0.041
58533	0.041	0.083	0.041
57982	0.047	0.054	0.041
57561	0.046	0.071	0.041
57165	0.037	0.066	0.041
56836	0.034	0.072	0.041
56608	0.040	0.071	0.040
56440	0.041	0.068	0.040
**55999	0.053	0.086	2100/0.033;2701/0.022;2754/0.041
**55499	0.056	0.080	2050/0.033;2617/0.025;2694/0.041
54999	0.056	0.085	0.041
54499	0.056	0.095	0.041
53999	0.056	0.087	0.041
53499	0.056	0.071	0.041
52999	0.042	0.072	0.041
52499	0.038	0.069	0.041
51999	0.041	0.077	0.041
51499	0.041	0.075	0.041
51057	0.042	0.071	1330/0.041;1634/0.027;2243/0.041
50945	0.041	0.073	1129/0.041;1500/0.027;2170/0.041
50500	0.041	0.067	0.027
49996	0.044	0.061	0.027
49501	0.042	0.062	0.029
48999	0.041	0.060	0.029
48499	0.041	0.055	0.027
47499	0.050	0.101	0.027
46999	0.053	0.134	0.027
46499	0.056	0.096	0.031
45999	0.050	0.064	0.027
45499	*0.056	0.063	0.027
44999	*0.056	0.067	0.027
44499	*0.056	0.056	0.027
43999	0.056	0.048	0.027

Proj. No.:	11542	Calculated By:	D. Ruvalcaba	Date:	8/19/2014
Proj. Name:	4RTSUN Sunset Road, Silverbell to River	Checked By:		Date:	
Description:	Roughness (10-Yr Event)				

River Sta	Left Overbank	Main Channel	Right Overbank Horz "n": Sta_1/n_1; Sta_2/n_2
43499	0.056	0.044	0.027
42999	0.056	0.042	0.027
42499	0.053	0.095	0.027
41999	0.054	0.094	0.027
41499	0.054	0.079	0.029
40999	0.055	0.115	0.033
40499	0.055	0.100	0.047
39999	0.056	0.131	0.047
39499	0.056	0.127	0.047
38999	0.056	0.048	0.047
38499	0.056	0.044	0.047
37999	0.056	0.048	0.047
37499	0.056	0.065	0.047
36999	0.056	0.064	0.047
36499	0.056	0.091	0.047
35999	0.056	0.100	0.095
35499	0.056	0.100	0.048
34960	0.056	0.069	0.027
34890	0.027	0.026	0.027
34500	0.027	0.035	0.027
34000	0.027	0.047	0.027
33500	0.041	0.052	0.027
33000	0.041	0.065	0.027
32501	0.056	0.062	0.027
32000	0.057	0.081	0.043

Notes:

Cross Sections 56836 through 68087 were imported directly from the LOMR River Model. This was done to facilitate the comparison to the LOMR Model.

Manning's Roughnesses in the overbanks were a result of the floodplain extent, if no flow in the overbank then the highest value present in the cross section was used for the entire overbank.

*Manually overwritten to more accurately portray overbank roughness

**Crossection will have to be coded as horizontally varying manning's roughness

Proj. No.:	11542	Calculated By:	D. Ruvalcaba	Date:	10/30/2014
Proj. Name:	4RTSUN Sunset Road, Silverbell to River	Checked By:		Date:	
Description:	Roughness per Area and Vegetation (>10-Yr Event)				

River Sta	Left Overbank	Main Channel	Value Used	Right Overbank Horz "n": Sta_1/n_1; Sta_2/n_2
56608	0.040	0.030	0.025	0.040
56440	0.041	0.030	0.030	0.040
**55999	0.053	0.030	0.030	2100/0.033,2701/0.022,2754/0.041
**55499	0.056	0.030	0.030	2617/0.025,2694/0.041
54999	0.056	0.030	0.030	0.041
54499	0.056	0.030	0.030	0.041
53999	0.056	0.030	0.030	0.041
53499	0.056	0.030	0.030	0.041
52999	0.042	0.030	0.030	0.041
52499	0.038	0.030	0.030	0.041
51999	0.041	0.030	0.030	0.041
51499	0.041	0.030	0.030	0.041
51057	0.042	0.027	0.035	1330/0.041;1634/0.027;2243/0.041
50945	0.041	0.027	0.035	1129/0.041;1500/0.027;2170/0.041
50500	0.041	0.027	0.030	0.027
49996	0.044	0.027	0.030	0.027
49501	0.042	0.027	0.030	0.029
48999	0.041	0.028	0.030	0.029
48499	0.041	0.027	0.030	0.027
47499	0.050	0.029	0.030	0.027
46999	0.053	0.028	0.030	0.027
46499	0.056	0.028	0.030	0.031
45999	0.050	0.030	0.030	0.027
45499	*0.056	0.030	0.030	0.027
44999	*0.056	0.030	0.030	0.027
44499	*0.056	0.031	0.030	0.027
43999	0.056	0.031	0.030	0.027
43499	0.056	0.029	0.030	0.027
42999	0.056	0.029	0.030	0.027
42499	0.053	0.030	0.030	0.027
41999	0.054	0.029	0.030	0.027

Proj. No.:	11542	Calculated By:	D. Ruvalcaba	Date:	10/30/2014
Proj. Name:	4RTSUN Sunset Road, Silverbell to River	Checked By:		Date:	
Description:	Roughness per Area and Vegetation (>10-Yr Event)				

River Sta	Left Overbank	Main Channel	Value Used	Right Overbank Horz "n": Sta_1/n_1; Sta_2/n_2
41499	0.054	0.030	0.030	0.029
40999	0.055	0.030	0.030	0.033
40499	0.055	0.030	0.030	0.047
39999	0.056	0.028	0.030	0.047
39499	0.056	0.029	0.035	0.047
38999	0.056	0.032	0.035	0.047
38499	0.056	0.032	0.035	0.047
37999	0.056	0.033	0.035	0.047
37499	0.056	0.033	0.035	0.047
36999	0.056	0.032	0.035	0.047
36499	0.056	0.030	0.035	0.047
35999	0.056	0.029	0.035	0.095
35499	0.056	0.029	0.035	0.048
34960	0.056	0.030	0.035	0.027
34890	***0.056	0.026	0.035	0.027
34500	***0.056	0.031	0.025	0.027
34000	***0.056	0.030	0.025	0.027
33500	***0.056	0.030	0.025	0.027
33000	***0.056	0.030	0.025	0.027
32501	0.056	0.030	0.025	***0.072
32000	0.057	0.030	0.025	***0.072

Notes:

Cross Sections 56843 through 68087 were imported directly from the LOMR River Model. This was done to facilitate the comparison to the LOMR Model.

Manning's Roughnesses in the overbanks were a result of the floodplain extent, if no flow in the overbank then the highest value present in the cross section was used for the entire overbank.

*Manually overwritten to more accurately portray overbank roughness

**Crossection will have to be coded as horizontally varying manning's roughness

***Manning's roughness was adjusted for the extent of the 500-Yr event

HYDRAULICS

FEMA

4RTSUN FEMA CLOMR HEC-RAS MODELS BASED ON FEMA FLOW RATE

- FEMA Flow Rates in Accordance with FIS
- No Debris Loading on Bridge Piers (All Bridges) in accordance with PCRFCD Direction
- Interim Condition Includes @ Grade Connection to Silverbell Road
- Ultimate Condition – Approximate Silverbell Road Full Build Out with Ineffective and Blocked Flow Regions

HEC-RAS FEMA MODELS:

Run	Plan	Geometry	Flow	Description
1.	10-50-100 Existing FEMA	100-Yr Exist Geometry SCR FEMA	10-50-100Yr FEMA	Existing Condition
2.	500-Yr Existing FEMA	500-Yr Exist Geometry SCR FEMA	500-Yr	Existing Condition
3.	10-100 Yr Exist Cond SCR No Levee FEMA	100-Yr Exist Geometry SCR No Levee FEMA	10-50-100Yr FEMA	Existing No Levee Run
4.	500-Yr Existing No Levee FEMA	500-Yr Exist Geometry SCR No Levee FEMA	500-Yr	Existing No Levee Run
5.	100-Yr Existing Condition Floodway	100-Yr Exist Geometry SCR FEMA	100-Yr Floodway	Existing Floodway Run
6.	10-50-100-Yr Prop Int Grade Alt-2 FEMA	100-Yr Prop Int Geo SCR Bdg & Grd-2 FEMA	10-50-100Yr FEMA	Proposed Floodplain Run
7.	500-Yr Int Brg_Grd Alt-2 FEMA	500-Yr Int Brg_Grd Alt-2 FEMA	500-Yr	Proposed 500-Yr Floodplain
8.	10-100 Yr Int Brg_Grd Alt-2 No Levee FEMA	10-100 Yr Int Brg_Grd Alt-2 No Levee FEMA	10-50-100Yr FEMA	Proposed No Levee Run
9.	500-Yr Int Brg_Grd Alt-2 No Levee FEMA	500-Yr Int Brg_Grd Alt-2 No Levee FEMA	500-Yr	Proposed 500-Yr No Levee Run
10.	100-Yr Int Sunset Brg_Grd Alt-2 FW	100-Yr Prop Int Geo SCR Bdg & Grd-2 FEMA	100-Yr Floodway	Proposed 100-Yr Floodway Run
11.	10-50-100-Yr Prop Ult FEMA	100-Yr Prop Ult Bdg & Grd-2 FEMA	10-50-100Yr FEMA	Ultimate Condition Evaluation
12.	500-Yr Prop Ult Brg_Grd Alt-2 FEMA	500-Yr Prop Ult Brg_Grd Alt-2 FEMA	500-Yr	Ultimate Condition Evaluation
13.	100-Yr Int Sunset Bridge Only	100-Yr Int Geometry SCR Bridge Only	100-Yr	Alternative Run
14.	100-Yr Ult Sunset Bridge Only	100-Yr Prop Ult Geometry SCR Bridge Only	100-Yr	Alternative Run
15.	100-Yr Int Brg_Grd Alt-1	100-Yr Prop Int Geometry SCR Bdg & Grd-1	100-Yr	Alternative Run
16.	10-50-100-Yr Prop Int Grade Alt-2 VrtAbt	100-Yr Prop Int Vertabut SCR Bdg & Grd-2	10-50-100Yr FEMA	Alternative Run

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: 10-50-100-Yr Ex River: Santa Cruz Reach: Sunset

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	10-Yr	16800.00	2255.61	2265.49	2264.51	2267.38	0.003109	11.04	1522.15	244.01	0.78
Sunset	68977	50-Yr	41000.00	2255.61	2270.78	2268.89	2274.02	0.002504	14.46	2835.48	254.66	0.76
Sunset	68977	100-Yr	60000.00	2255.61	2274.22	2271.67	2278.25	0.002294	16.11	3724.63	269.76	0.75
Sunset	68588	10-Yr	16800.00	2253.49	2264.65	2263.16	2266.23	0.002387	10.10	1663.78	248.65	0.69
Sunset	68588	50-Yr	41000.00	2253.49	2270.30	2267.49	2273.01	0.001935	13.20	3105.40	273.16	0.67
Sunset	68588	100-Yr	60000.00	2253.49	2273.88	2270.22	2277.28	0.001796	14.79	4057.93	661.89	0.67
Sunset	68087	10-Yr	16800.00	2250.70	2264.38	2260.73	2265.31	0.000974	7.72	2177.44	250.52	0.46
Sunset	68087	50-Yr	41000.00	2250.70	2270.10	2265.16	2272.05	0.001137	11.22	3653.81	280.96	0.53
Sunset	68087	100-Yr	60000.00	2250.70	2273.71	2267.92	2276.27	0.001289	12.84	4678.36	1010.43	0.58
Sunset	67552	10-Yr	16800.00	2250.55	2262.97	2261.19	2264.51	0.002115	9.97	1685.81	236.39	0.66
Sunset	67552	50-Yr	41000.00	2250.55	2268.10	2265.71	2271.13	0.002174	13.95	2938.89	307.05	0.72
Sunset	67552	100-Yr	60000.00	2250.55	2271.44	2268.53	2275.27	0.002124	15.73	3907.53	767.04	0.73
Sunset	67038	10-Yr	16800.00	2249.72	2261.55	2260.13	2263.30	0.002530	10.61	1583.13	408.63	0.71
Sunset	67038	50-Yr	41000.00	2249.72	2266.07	2264.70	2269.77	0.002921	15.43	2657.76	702.37	0.82
Sunset	67038	100-Yr	60000.00	2249.72	2268.96	2267.55	2273.87	0.003047	17.78	3374.39	883.92	0.87
Sunset	66600	10-Yr	16800.00	2249.10	2259.76	2259.02	2261.76	0.004996	11.35	1479.85	375.59	0.82
Sunset	66600	50-Yr	41000.00	2249.10	2264.78	2263.32	2268.19	0.004024	14.83	2763.85	956.61	0.81
Sunset	66600	100-Yr	60000.00	2249.10	2267.85	2266.06	2272.20	0.003857	16.74	3585.23	1132.33	0.81
Sunset	66255	10-Yr	16800.00	2248.50	2259.73	2256.52	2260.75	0.001135	8.11	2072.66	250.57	0.50
Sunset	66255	50-Yr	41000.00	2248.50	2264.77	2260.91	2267.07	0.001467	12.17	3368.35	265.03	0.60
Sunset	66255	100-Yr	60000.00	2248.50	2267.88	2263.67	2271.00	0.001658	14.19	4273.50	418.82	0.65
Sunset	65763	10-Yr	16800.00	2247.09	2258.18	2256.99	2259.86	0.002738	10.40	1614.66	257.19	0.73
Sunset	65763	50-Yr	41000.00	2247.09	2262.52	2261.18	2265.96	0.002948	14.89	2753.80	608.22	0.82
Sunset	65763	100-Yr	60000.00	2247.09	2265.15	2263.98	2269.76	0.003156	17.22	3483.47	986.18	0.87
Sunset	65255	10-Yr	16800.00	2246.28	2256.48	2255.42	2258.16	0.004167	10.39	1617.60	269.31	0.75
Sunset	65255	50-Yr	41000.00	2246.28	2260.88	2259.53	2264.12	0.004259	14.43	2840.33	325.99	0.82
Sunset	65255	100-Yr	60000.00	2246.28	2263.62	2262.23	2267.79	0.004176	16.39	3660.42	596.17	0.83
Sunset	64585	10-Yr	16800.00	2244.01	2254.80	2253.15	2256.13	0.002098	9.23	1820.41	285.10	0.64
Sunset	64585	50-Yr	41000.00	2244.01	2259.25	2257.12	2261.89	0.002294	13.06	3140.20	397.07	0.72
Sunset	64585	100-Yr	60000.00	2244.01	2261.99	2259.69	2265.47	0.002461	14.96	4009.68	883.13	0.77
Sunset	64087	10-Yr	16800.00	2242.46	2252.84	2252.24	2254.71	0.003755	10.97	1531.20	285.73	0.84
Sunset	64087	50-Yr	41000.00	2242.46	2257.12	2256.20	2260.46	0.003362	14.65	2798.49	331.48	0.86
Sunset	64087	100-Yr	60000.00	2242.46	2259.78	2258.68	2264.01	0.003158	16.52	3632.24	1071.10	0.86
Sunset	63622	10-Yr	16800.00	2241.64	2251.66	2250.44	2253.15	0.002597	9.81	1712.44	288.60	0.71
Sunset	63622	50-Yr	41000.00	2241.64	2256.11	2254.35	2258.94	0.002582	13.49	3038.22	347.73	0.76
Sunset	63622	100-Yr	60000.00	2241.64	2258.90	2256.87	2262.52	0.002537	15.27	3929.75	1232.77	0.78
Sunset	62978	10-Yr	16800.00	2240.25	2249.67	2248.70	2251.33	0.003027	10.34	1624.21	283.27	0.76
Sunset	62978	50-Yr	41000.00	2240.25	2254.07	2252.64	2257.17	0.002837	14.12	2903.61	315.61	0.80
Sunset	62978	100-Yr	60000.00	2240.25	2256.61	2255.29	2260.70	0.002948	16.24	3695.07	952.54	0.84
Sunset	62453	10-Yr	16800.00	2239.00	2248.37	2247.01	2249.85	0.002465	9.76	1721.76	280.96	0.69
Sunset	62453	50-Yr	41000.00	2239.00	2252.82	2251.01	2255.71	0.002498	13.65	3004.47	320.12	0.76
Sunset	62453	100-Yr	60000.00	2239.00	2255.09	2253.64	2259.17	0.002880	16.21	3701.01	761.48	0.83
Sunset	61960	10-Yr	16800.00	2234.74	2247.37	2245.60	2248.70	0.002031	9.26	1815.15	278.23	0.64
Sunset	61960	50-Yr	41000.00	2234.74	2251.99	2249.80	2254.49	0.002038	12.81	3518.46	494.12	0.69
Sunset	61960	100-Yr	60000.00	2234.74	2254.49	2252.62	2257.70	0.002112	14.72	4669.43	930.59	0.73
Sunset	61436	10-Yr	16800.00	2233.28	2246.20	2244.75	2247.57	0.002296	9.37	1793.36	294.44	0.67
Sunset	61436	50-Yr	41000.00	2233.28	2250.93	2248.68	2253.36	0.002174	12.53	3340.64	410.52	0.70
Sunset	61436	100-Yr	60000.00	2233.28	2253.20	2251.33	2256.52	0.002335	14.73	4380.56	1737.89	0.75
Sunset	61000	10-Yr	16800.00	2229.63	2245.62	2243.25	2246.67	0.001506	8.26	2033.94	293.16	0.55
Sunset	61000	50-Yr	41000.00	2229.63	2250.36	2247.33	2252.41	0.001707	11.51	3599.09	400.21	0.63
Sunset	61000	100-Yr	60000.00	2229.63	2252.54	2249.87	2255.49	0.001935	13.82	4535.67	1248.36	0.69
Sunset	60523	10-Yr	16800.00	2229.89	2244.40	2242.83	2245.77	0.002270	9.41	1785.78	287.36	0.67
Sunset	60523	50-Yr	41000.00	2229.89	2249.05	2247.08	2251.42	0.002438	12.35	3339.62	420.86	0.73
Sunset	60523	100-Yr	60000.00	2229.89	2251.16	2249.56	2254.40	0.002558	14.49	4282.36	1375.58	0.78
Sunset	60070	10-Yr	16800.00	2228.19	2243.02	2241.42	2244.38	0.004299	9.36	1795.50	284.37	0.66
Sunset	60070	50-Yr	41000.00	2228.19	2247.37	2245.93	2249.84	0.005219	12.69	3380.18	530.91	0.76
Sunset	60070	100-Yr	60000.00	2228.19	2249.93	2248.44	2252.79	0.004450	13.83	4796.40	745.33	0.73
Sunset	59588	10-Yr	16800.00	2226.99	2241.67	2239.93	2242.86	0.002288	8.76	1916.96	344.63	0.65
Sunset	59588	50-Yr	41000.00	2226.99	2246.58	2243.84	2248.28	0.001703	10.58	4362.71	809.39	0.61
Sunset	59588	100-Yr	60000.00	2226.99	2249.78	2246.59	2251.43	0.001208	10.73	7087.43	961.79	0.54
Sunset	59088	10-Yr	16800.00	2226.21	2239.44	2238.81	2241.33	0.003865	11.03	1523.27	287.38	0.84
Sunset	59088	50-Yr	41000.00	2226.21	2244.87	2242.96	2247.25	0.002256	12.43	3570.85	739.74	0.71
Sunset	59088	100-Yr	60000.00	2226.21	2248.49	2245.74	2250.72	0.001496	12.38	5904.29	1117.19	0.61

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: 10-50-100-Yr Ex River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	58533	10-Yr	16800.00	2224.44	2238.06	2236.22	2239.63	0.002235	10.05	1671.74	242.37	0.67
Sunset	58533	50-Yr	41000.00	2224.44	2242.73	2240.96	2245.82	0.002621	14.11	2907.01	293.62	0.78
Sunset	58533	100-Yr	60000.00	2224.44	2245.07	2243.77	2249.38	0.002860	16.70	3721.74	408.13	0.84
Sunset	57982	10-Yr	16800.00	2224.20	2236.24	2234.44	2237.72	0.005867	9.74	1724.65	265.16	0.67
Sunset	57982	50-Yr	41000.00	2224.20	2240.25	2238.93	2243.43	0.008417	14.32	2866.70	340.78	0.85
Sunset	57982	100-Yr	60000.00	2224.20	2244.28	2242.20	2246.84	0.004802	13.23	5478.37	980.85	0.67
Sunset	57561	10-Yr	16800.00	2222.54	2234.63	2233.32	2236.06	0.002781	9.59	1750.93	320.72	0.72
Sunset	57561	50-Yr	41000.00	2222.54	2239.00	2237.22	2241.51	0.002404	12.72	3222.11	344.10	0.73
Sunset	57561	100-Yr	60000.00	2222.54	2243.29	2239.48	2245.76	0.001529	12.63	4830.66	801.63	0.62
Sunset	57165	10-Yr	16800.00	2221.13	2233.56	2232.52	2234.94	0.002814	9.42	1784.32	339.74	0.72
Sunset	57165	50-Yr	41000.00	2221.13	2238.31	2236.03	2240.48	0.002277	11.83	3470.71	418.11	0.71
Sunset	57165	100-Yr	60000.00	2221.13	2243.42	2238.57	2245.02	0.000984	10.38	7055.01	943.85	0.50
Sunset	56836	10-Yr	16800.00	2221.00	2232.86	2231.28	2234.09	0.002139	8.91	1886.43	315.56	0.64
Sunset	56836	50-Yr	41000.00	2221.00	2237.51	2235.00	2239.79	0.001890	12.12	3424.87	346.37	0.66
Sunset	56836	100-Yr	60000.00	2221.00	2242.61	2237.35	2244.64	0.001055	11.59	6217.47	924.29	0.52
Sunset	56608	10-Yr	16800.00	2221.00	2232.65	2230.13	2233.53	0.001290	7.54	2227.99	328.14	0.51
Sunset	56608	50-Yr	41000.00	2221.00	2237.40	2233.80	2239.14	0.001394	10.60	3872.48	427.98	0.57
Sunset	56608	100-Yr	60000.00	2221.00	2243.02	2236.13	2243.90	0.000501	8.26	11448.52	1878.41	0.36
Sunset	56526 El Camino Del Ce		Bridge									
Sunset	56440	10-Yr	16800.00	2220.50	2231.36	2229.20	2232.37	0.002286	8.07	2081.22	322.58	0.56
Sunset	56440	50-Yr	41000.00	2220.50	2235.85	2232.87	2237.89	0.002378	11.46	3636.27	389.42	0.62
Sunset	56440	100-Yr	60000.00	2220.50	2239.09	2235.25	2241.17	0.001853	12.01	6478.95	1593.18	0.57
Sunset	55999	10-Yr	16800.00	2217.00	2229.77	2228.35	2231.07	0.003435	9.15	1836.65	318.29	0.67
Sunset	55999	50-Yr	41000.00	2217.00	2233.68	2232.02	2236.38	0.003757	13.21	3116.76	360.83	0.76
Sunset	55999	100-Yr	60000.00	2217.00	2235.68	2234.59	2239.47	0.004290	15.72	3928.40	466.47	0.83
Sunset	55499	10-Yr	16800.00	2216.00	2228.28	2226.66	2229.39	0.002931	8.44	1989.78	343.89	0.62
Sunset	55499	50-Yr	41000.00	2216.00	2232.19	2230.14	2234.44	0.003138	12.09	3499.47	497.44	0.69
Sunset	55499	100-Yr	60000.00	2216.00	2234.18	2232.90	2237.16	0.003392	14.13	4737.97	817.81	0.74
Sunset	54999	10-Yr	16800.00	2214.00	2226.26	2225.23	2227.62	0.004172	9.38	1791.17	344.50	0.72
Sunset	54999	50-Yr	41000.00	2214.00	2230.67	2228.73	2232.84	0.003172	11.94	3772.54	730.29	0.69
Sunset	54999	100-Yr	60000.00	2214.00	2233.15	2231.71	2235.47	0.002647	12.78	5992.87	1018.42	0.66
Sunset	54499	10-Yr	16800.00	2213.00	2224.20	2222.83	2225.65	0.003729	9.65	1740.34	296.31	0.70
Sunset	54499	50-Yr	41000.00	2213.00	2227.88	2226.99	2230.89	0.004418	14.03	3070.71	481.90	0.82
Sunset	54499	100-Yr	60000.00	2213.00	2230.00	2230.00	2233.65	0.004441	15.81	4624.36	858.66	0.84
Sunset	53999	10-Yr	16800.00	2211.00	2223.75	2219.86	2224.40	0.001260	6.47	2597.00	353.20	0.42
Sunset	53999	50-Yr	41000.00	2211.00	2227.32	2223.91	2229.04	0.002075	10.56	3948.03	515.83	0.57
Sunset	53999	100-Yr	60000.00	2211.00	2228.98	2226.11	2231.62	0.002724	13.14	5052.63	783.02	0.67
Sunset	53499	10-Yr	16800.00	2207.00	2222.86	2218.32	2223.62	0.001893	7.03	2391.33	394.04	0.50
Sunset	53499	50-Yr	41000.00	2207.00	2226.36	2224.13	2227.80	0.002604	9.64	4318.14	737.96	0.62
Sunset	53499	100-Yr	60000.00	2207.00	2228.06	2225.85	2230.04	0.002799	11.37	5730.42	948.42	0.66
Sunset	52999	10-Yr	16800.00	2205.00	2221.44	2220.29	2222.35	0.003427	7.99	2366.50	620.84	0.65
Sunset	52999	50-Yr	41000.00	2205.00	2225.55	2223.38	2226.46	0.002089	8.20	5745.53	1083.55	0.55
Sunset	52999	100-Yr	60000.00	2205.00	2227.48	2224.51	2228.53	0.002080	8.85	7614.61	1177.95	0.56
Sunset	52499	10-Yr	16800.00	2204.00	2218.67	2217.95	2220.24	0.004759	10.59	1776.56	442.58	0.78
Sunset	52499	50-Yr	41000.00	2204.00	2222.72	2221.98	2224.71	0.005262	12.13	3744.61	811.59	0.84
Sunset	52499	100-Yr	60000.00	2204.00	2224.81	2223.80	2226.83	0.004983	12.18	5392.04	1013.33	0.83
Sunset	51999	10-Yr	16800.00	2203.00	2217.26	2215.54	2218.16	0.002904	8.29	2392.16	498.98	0.62
Sunset	51999	50-Yr	41000.00	2203.00	2221.82	2218.98	2222.78	0.002075	8.73	5564.55	900.36	0.55
Sunset	51999	100-Yr	60000.00	2203.00	2223.82	2219.81	2225.03	0.002002	9.78	7173.08	962.47	0.56
Sunset	51499	10-Yr	16800.00	2201.00	2216.30	2213.93	2216.94	0.001831	6.41	2620.20	490.47	0.49
Sunset	51499	50-Yr	41000.00	2201.00	2221.20	2217.00	2221.96	0.001159	7.27	6467.18	1153.52	0.42
Sunset	51499	100-Yr	60000.00	2201.00	2223.27	2218.88	2224.17	0.001197	8.06	8638.81	1240.78	0.44
Sunset	51057	10-Yr	16800.00	2199.00	2214.26	2212.74	2215.77	0.003420	9.87	1702.89	265.78	0.69
Sunset	51057	50-Yr	41000.00	2199.00	2219.15	2218.14	2221.06	0.003156	11.50	4255.68	870.75	0.69
Sunset	51057	100-Yr	60000.00	2199.00	2221.35	2220.03	2223.30	0.002783	12.04	6154.22	1006.76	0.67
Sunset	50945	10-Yr	16800.00	2199.00	2214.04	2211.88	2215.39	0.002714	9.31	1804.79	257.53	0.62
Sunset	50945	50-Yr	41000.00	2199.00	2218.75	2217.47	2220.71	0.002987	11.58	4131.52	777.04	0.68
Sunset	50945	100-Yr	60000.00	2199.00	2219.81	2219.73	2222.81	0.004161	14.56	5004.01	920.47	0.81
Sunset	50500	10-Yr	16800.00	2198.00	2211.88	2211.28	2213.74	0.004965	11.17	1616.24	324.80	0.81
Sunset	50500	50-Yr	41000.00	2198.00	2217.76	2214.93	2218.94	0.004136	9.37	5040.57	1147.21	0.73
Sunset	50500	100-Yr	60000.00	2198.00	2219.26	2218.10	2220.65	0.003548	10.20	6796.25	1206.52	0.71

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: 10-50-100-Yr Ex River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	49996	10-Yr	16800.00	2197.00	2210.25	2208.48	2211.68	0.003031	9.76	1848.06	327.64	0.65
Sunset	49996	50-Yr	41000.00	2197.00	2216.53	2213.80	2217.36	0.002156	7.71	5898.82	1140.33	0.55
Sunset	49996	100-Yr	60000.00	2197.00	2218.07	2215.50	2219.17	0.002177	8.89	7463.84	1206.83	0.57
Sunset	49501	10-Yr	16800.00	2197.00	2207.17	2206.63	2209.60	0.005533	12.51	1343.13	211.63	0.87
Sunset	49501	50-Yr	41000.00	2197.00	2213.92	2213.38	2215.66	0.005594	10.58	3900.11	883.39	0.84
Sunset	49501	100-Yr	60000.00	2197.00	2215.42	2214.76	2217.52	0.004954	11.67	5217.25	1002.79	0.83
Sunset	48999	10-Yr	16800.00	2196.00	2206.97	2203.99	2207.77	0.001580	7.16	2346.45	333.10	0.48
Sunset	48999	50-Yr	41000.00	2196.00	2213.07	2207.76	2213.91	0.001805	7.35	5625.60	927.91	0.50
Sunset	48999	100-Yr	60000.00	2196.00	2214.62	2211.36	2215.78	0.001919	8.66	7031.17	977.26	0.54
Sunset	48499	10-Yr	16800.00	2195.00	2203.32	2203.32	2206.09	0.007475	13.34	1259.50	225.01	0.99
Sunset	48499	50-Yr	41000.00	2195.00	2208.87	2208.87	2212.07	0.007236	14.36	2854.27	446.43	1.00
Sunset	48499	100-Yr	60000.00	2195.00	2211.39	2211.39	2214.02	0.006506	13.12	4789.60	986.75	0.94
Sunset	47499	10-Yr	21800.00	2193.11	2202.06	2199.34	2202.63	0.001346	6.03	3618.78	603.61	0.43
Sunset	47499	50-Yr	48000.00	2193.11	2206.76	2201.87	2207.62	0.000985	7.45	6530.16	654.61	0.40
Sunset	47499	100-Yr	70000.00	2193.11	2209.95	2203.57	2210.97	0.000880	8.21	9060.64	1002.32	0.39
Sunset	46999	10-Yr	21800.00	2191.00	2200.39	2198.40	2201.65	0.002594	9.00	2423.29	354.91	0.61
Sunset	46999	50-Yr	48000.00	2191.00	2204.14	2201.88	2206.66	0.003003	12.74	3769.10	364.73	0.70
Sunset	46999	100-Yr	70000.00	2191.00	2206.38	2204.24	2209.95	0.003343	15.20	4820.86	698.71	0.76
Sunset	46499	10-Yr	21800.00	2189.00	2198.42	2197.30	2200.02	0.004022	10.14	2150.80	367.76	0.74
Sunset	46499	50-Yr	48000.00	2189.00	2201.13	2200.84	2204.52	0.005963	14.76	3253.03	425.11	0.94
Sunset	46499	100-Yr	70000.00	2189.00	2203.07	2203.07	2207.61	0.006348	17.09	4095.08	482.39	1.00
Sunset	45999	10-Yr	21800.00	2189.00	2196.95	2195.72	2198.00	0.003430	8.20	2659.37	559.85	0.66
Sunset	45999	50-Yr	48000.00	2189.00	2199.09	2198.37	2201.47	0.005066	12.40	3871.15	597.53	0.85
Sunset	45999	100-Yr	70000.00	2189.00	2200.41	2200.26	2203.89	0.006434	14.96	4680.32	678.29	0.97
Sunset	45499	10-Yr	21800.00	2187.00	2195.63	2194.30	2196.30	0.002935	6.61	3298.07	846.53	0.59
Sunset	45499	50-Yr	48000.00	2187.00	2197.82	2196.36	2199.16	0.003244	9.29	5167.96	857.17	0.67
Sunset	45499	100-Yr	70000.00	2187.00	2199.25	2197.68	2201.11	0.003426	10.93	6403.69	866.07	0.71
Sunset	44999	10-Yr	21800.00	2186.00	2194.03	2193.02	2194.73	0.003369	6.70	3252.63	907.02	0.62
Sunset	44999	50-Yr	48000.00	2186.00	2196.14	2194.88	2197.45	0.003544	9.20	5217.78	939.08	0.69
Sunset	44999	100-Yr	70000.00	2186.00	2197.60	2196.13	2199.35	0.003496	10.62	6588.29	944.69	0.71
Sunset	44499	10-Yr	21800.00	2184.00	2192.06	2191.22	2192.84	0.004222	7.11	3066.02	926.23	0.69
Sunset	44499	50-Yr	48000.00	2184.00	2194.40	2193.09	2195.69	0.003470	9.14	5253.09	939.00	0.68
Sunset	44499	100-Yr	70000.00	2184.00	2195.94	2194.34	2197.63	0.003292	10.44	6706.55	942.60	0.69
Sunset	43999	10-Yr	21800.00	2183.00	2190.92	2189.26	2191.40	0.001876	5.54	3936.16	942.90	0.48
Sunset	43999	50-Yr	48000.00	2183.00	2193.40	2191.08	2194.31	0.001943	7.64	6284.03	953.07	0.52
Sunset	43999	100-Yr	70000.00	2183.00	2194.97	2192.34	2196.23	0.002040	8.99	7785.96	957.95	0.56
Sunset	43499	10-Yr	21800.00	2181.00	2189.73	2188.38	2190.31	0.002511	6.09	3580.41	925.42	0.55
Sunset	43499	50-Yr	48000.00	2181.00	2192.16	2190.25	2193.21	0.002426	8.21	5847.96	940.45	0.58
Sunset	43499	100-Yr	70000.00	2181.00	2193.58	2191.52	2195.05	0.002629	9.75	7181.63	947.27	0.62
Sunset	42999	10-Yr	21800.00	2180.00	2186.52	2186.52	2188.06	0.009007	9.96	2189.34	702.32	0.99
Sunset	42999	50-Yr	48000.00	2180.00	2188.86	2188.86	2191.08	0.007943	11.95	4015.23	890.28	0.99
Sunset	42999	100-Yr	70000.00	2180.00	2190.49	2190.15	2193.03	0.006116	12.79	5473.12	900.56	0.91
Sunset	42499	10-Yr	21800.00	2175.00	2184.93	2182.00	2185.41	0.001584	5.57	3910.74	812.56	0.45
Sunset	42499	50-Yr	48000.00	2175.00	2187.98	2184.90	2188.83	0.001573	7.40	6482.16	873.77	0.48
Sunset	42499	100-Yr	70000.00	2175.00	2190.18	2186.28	2191.23	0.001507	8.25	8485.38	1482.34	0.48
Sunset	41999	10-Yr	21800.00	2176.00	2184.51	2181.49	2184.75	0.000904	3.92	5556.70	1292.37	0.33
Sunset	41999	50-Yr	48000.00	2176.00	2187.85	2183.55	2188.20	0.000652	4.77	10069.14	1366.50	0.31
Sunset	41999	100-Yr	70000.00	2176.00	2190.18	2184.73	2190.62	0.000557	5.28	13265.44	1674.49	0.30
Sunset	41499	10-Yr	21800.00	2175.00	2183.58	2181.79	2184.09	0.001945	5.68	3835.68	904.71	0.49
Sunset	41499	50-Yr	48000.00	2175.00	2186.97	2183.80	2187.70	0.001451	6.84	7016.18	1002.03	0.46
Sunset	41499	100-Yr	70000.00	2175.00	2189.35	2185.08	2190.16	0.001389	7.24	9663.21	1559.94	0.45
Sunset	40999	10-Yr	21800.00	2174.00	2182.74	2180.28	2183.22	0.001532	5.58	3906.47	789.41	0.44
Sunset	40999	50-Yr	48000.00	2174.00	2186.21	2182.66	2186.97	0.001453	7.00	6856.86	1017.77	0.46
Sunset	40999	100-Yr	70000.00	2174.00	2188.59	2184.13	2189.47	0.001331	7.53	9294.77	1351.79	0.45
Sunset	40499	10-Yr	21800.00	2172.00	2181.22	2179.64	2182.17	0.002771	7.78	2800.52	657.05	0.60
Sunset	40499	50-Yr	48000.00	2172.00	2183.38	2182.35	2185.64	0.004519	12.05	3983.94	712.47	0.80
Sunset	40499	100-Yr	70000.00	2172.00	2185.33	2184.61	2188.01	0.006971	13.13	5330.00	1094.76	0.97
Sunset	39999	10-Yr	21800.00	2171.00	2179.42	2178.70	2180.34	0.004963	7.72	2824.02	847.92	0.75
Sunset	39999	50-Yr	48000.00	2171.00	2182.04	2180.77	2183.37	0.003526	9.25	5189.68	924.04	0.69
Sunset	39999	100-Yr	70000.00	2171.00	2184.07	2182.07	2185.60	0.002721	9.91	7064.61	1134.82	0.63
Sunset	39399	10-Yr	21800.00	2168.00	2177.34	2175.80	2177.95	0.003051	6.29	3463.14	857.00	0.53
Sunset	39399	50-Yr	48000.00	2168.00	2180.52	2177.80	2181.53	0.002436	8.04	5967.40	868.79	0.51
Sunset	39399	100-Yr	70000.00	2168.00	2182.81	2179.21	2184.07	0.002165	9.01	7768.16	1034.61	0.51

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: 10-50-100-Yr Ex River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	38909	10-Yr	21800.00	2168.00	2176.20	2174.18	2176.67	0.002121	5.60	4023.09	880.24	0.45
Sunset	38909	50-Yr	48000.00	2168.00	2179.78	2176.22	2180.50	0.001570	6.93	7246.50	909.22	0.42
Sunset	38909	100-Yr	70000.00	2168.00	2182.21	2177.56	2183.11	0.001413	7.76	9477.44	967.97	0.42
Sunset	38409	10-Yr	21800.00	2168.00	2175.32	2172.77	2175.74	0.001589	5.23	4166.37	763.75	0.39
Sunset	38409	50-Yr	48000.00	2168.00	2179.04	2174.85	2179.76	0.001379	6.82	7040.71	834.10	0.40
Sunset	38409	100-Yr	70000.00	2168.00	2181.47	2176.28	2182.42	0.001325	7.83	9009.86	903.09	0.41
Sunset	37929	10-Yr	21800.00	2166.00	2174.64	2171.40	2175.06	0.001285	5.22	4173.63	662.38	0.36
Sunset	37929	50-Yr	48000.00	2166.00	2178.25	2173.76	2179.08	0.001407	7.32	6630.18	802.44	0.41
Sunset	37929	100-Yr	70000.00	2166.00	2180.60	2175.35	2181.73	0.001467	8.57	8373.77	882.06	0.43
Sunset	37509	10-Yr	21800.00	2166.00	2174.01	2171.06	2174.48	0.001478	5.49	4093.99	1126.33	0.39
Sunset	37509	50-Yr	48000.00	2166.00	2177.61	2173.51	2178.46	0.001513	7.51	6679.28	1183.38	0.42
Sunset	37509	100-Yr	70000.00	2166.00	2179.93	2175.09	2181.09	0.001567	8.78	8352.85	1212.38	0.45
Sunset	36859	10-Yr	21800.00	2164.00	2172.62	2170.20	2173.31	0.002156	6.71	3524.71	1286.81	0.47
Sunset	36859	50-Yr	48000.00	2164.00	2176.25	2173.14	2177.34	0.001977	8.71	6437.65	1312.85	0.49
Sunset	36859	100-Yr	70000.00	2164.00	2178.57	2174.81	2179.95	0.001959	9.97	8368.88	1353.36	0.50
Sunset	36439	10-Yr	21800.00	2162.00	2171.20	2169.40	2172.16	0.003342	7.88	2793.86	771.56	0.58
Sunset	36439	50-Yr	48000.00	2162.00	2174.80	2172.61	2176.29	0.002891	10.07	5335.94	1398.68	0.58
Sunset	36439	100-Yr	70000.00	2162.00	2177.15	2174.45	2178.94	0.002681	11.21	7102.78	1403.98	0.58
Sunset	36049	10-Yr	21800.00	2162.00	2170.19	2167.76	2171.02	0.002431	7.29	2991.61	1030.55	0.50
Sunset	36049	50-Yr	48000.00	2162.00	2173.47	2170.71	2175.12	0.002928	10.43	4913.32	1506.63	0.59
Sunset	36049	100-Yr	70000.00	2162.00	2175.49	2173.02	2177.73	0.003178	12.28	6209.23	1517.79	0.63
Sunset	35639	10-Yr	21800.00	2160.00	2168.80	2167.11	2169.80	0.003598	8.03	2739.53	1551.71	0.60
Sunset	35639	50-Yr	48000.00	2160.00	2171.74	2170.00	2173.66	0.004158	11.26	4542.20	1699.92	0.68
Sunset	35639	100-Yr	70000.00	2160.00	2173.71	2172.12	2176.18	0.004303	12.92	5865.07	1721.05	0.72
Sunset	35095	10-Yr	21800.00	2158.00	2166.96	2165.42	2167.78	0.003624	7.26	3003.40	1659.56	0.58
Sunset	35095	50-Yr	48000.00	2158.00	2169.86	2167.86	2171.37	0.003833	9.87	4865.52	1720.09	0.64
Sunset	35095	100-Yr	70000.00	2158.00	2171.80	2169.55	2173.78	0.004023	11.28	6207.09	2520.71	0.68
Sunset	34808	10-Yr	21800.00	2158.00	2164.23	2164.23	2165.96	0.011841	10.58	2061.44	592.54	1.00
Sunset	34808	50-Yr	48000.00	2158.00	2166.66	2166.66	2169.56	0.009914	13.67	3511.19	599.48	1.00
Sunset	34808	100-Yr	70000.00	2158.00	2168.80	2168.34	2172.10	0.007546	14.58	4801.57	1908.37	0.91
Sunset	34568	10-Yr	21800.00	2157.92	2163.17	2161.60	2164.01	0.003486	7.38	2952.76	581.57	0.58
Sunset	34568	50-Yr	48000.00	2157.92	2166.26	2164.06	2167.84	0.003502	10.07	4766.64	589.25	0.62
Sunset	34568	100-Yr	70000.00	2157.92	2168.54	2165.77	2170.58	0.003298	11.45	6114.08	1179.90	0.63
Sunset	34556	10-Yr	21800.00	2157.92	2163.09	2161.60	2163.96	0.003634	7.48	2915.38	581.29	0.59
Sunset	34556	50-Yr	48000.00	2157.92	2166.19	2164.05	2167.79	0.003596	10.15	4728.50	589.21	0.63
Sunset	34556	100-Yr	70000.00	2157.92	2168.47	2165.78	2170.53	0.003362	11.52	6079.01	594.56	0.63
Sunset	34529 Ina Road (LOMR)		Bridge									
Sunset	34502	10-Yr	21800.00	2155.79	2161.36	2160.55	2162.53	0.003056	8.70	2506.59	579.04	0.74
Sunset	34502	50-Yr	48000.00	2155.79	2164.25	2163.04	2166.29	0.002721	11.44	4194.18	586.25	0.75
Sunset	34502	100-Yr	70000.00	2155.79	2166.31	2164.75	2168.91	0.002523	12.96	5403.03	590.98	0.76
Sunset	34494	10-Yr	21800.00	2155.79	2160.57	2160.57	2162.32	0.005899	10.61	2054.16	577.03	0.99
Sunset	34494	50-Yr	48000.00	2155.79	2163.04	2163.04	2165.99	0.004997	13.77	3485.90	583.28	0.99
Sunset	34494	100-Yr	70000.00	2155.79	2164.75	2164.75	2168.53	0.004643	15.61	4485.16	587.39	1.00
Sunset	34294	10-Yr	21800.00	2146.87	2155.30	2153.72	2156.16	0.001797	7.45	2925.62	570.91	0.58
Sunset	34294	50-Yr	48000.00	2146.87	2157.90	2156.20	2159.73	0.002240	10.86	4419.96	576.35	0.69
Sunset	34294	100-Yr	70000.00	2146.87	2159.39	2157.91	2162.12	0.002656	13.25	5282.73	579.66	0.77
Sunset	34054	10-Yr	21800.00	2146.44	2154.52	2153.57	2155.61	0.002766	8.36	2607.02	592.03	0.70
Sunset	34054	50-Yr	48000.00	2146.44	2157.16	2156.12	2159.11	0.002976	11.19	4291.17	664.40	0.78
Sunset	34054	100-Yr	70000.00	2146.44	2158.77	2157.70	2161.41	0.003054	13.06	5359.50	669.57	0.81
Sunset	33594	10-Yr	21800.00	2145.96	2153.11	2152.33	2154.25	0.003105	8.58	2539.82	1274.47	0.74
Sunset	33594	50-Yr	48000.00	2145.96	2155.72	2154.84	2157.74	0.002951	11.49	4311.14	1410.33	0.78
Sunset	33594	100-Yr	70000.00	2145.96	2157.50	2156.47	2160.05	0.002780	12.99	5631.49	1444.37	0.78
Sunset	33332	10-Yr	21800.00	2145.72	2152.44	2151.46	2153.47	0.002650	8.14	2677.31	1229.10	0.69
Sunset	33332	50-Yr	48000.00	2145.72	2155.09	2153.84	2156.97	0.002611	11.04	4443.47	1338.87	0.74
Sunset	33332	100-Yr	70000.00	2145.72	2156.93	2155.57	2159.32	0.002481	12.54	5770.92	1346.91	0.75
Sunset	33162	10-Yr	21800.00	2145.21	2151.04	2151.04	2152.75	0.006108	10.47	2081.60	1171.82	1.00
Sunset	33162	50-Yr	48000.00	2145.21	2153.42	2153.42	2156.27	0.005120	13.56	3545.09	1205.64	1.00
Sunset	33162	100-Yr	70000.00	2145.21	2155.17	2155.17	2158.66	0.004445	15.05	4747.74	1287.87	0.97
Sunset	32680	10-Yr	21800.00	2143.52	2149.82	2148.44	2150.69	0.001979	7.47	2918.87	989.90	0.60
Sunset	32680	50-Yr	48000.00	2143.52	2152.77	2150.79	2154.37	0.001952	10.15	4739.36	1021.17	0.65
Sunset	32680	100-Yr	70000.00	2143.52	2154.65	2152.46	2156.83	0.002002	11.86	5941.79	1112.01	0.68

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: 10-50-100-Yr Ex River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	32153	10-Yr	21800.00	2142.51	2148.80	2147.29	2149.67	0.001882	7.50	2906.04	1283.01	0.59
Sunset	32153	50-Yr	48000.00	2142.51	2151.42	2149.77	2153.22	0.002364	10.78	4452.25	1326.51	0.71
Sunset	32153	100-Yr	70000.00	2142.51	2153.05	2151.55	2155.59	0.002620	12.81	5465.57	1347.60	0.77
Sunset	31655	10-Yr	21800.00	2141.12	2146.40	2146.36	2148.06	0.005873	10.34	2107.80	1667.82	0.98
Sunset	31655	50-Yr	48000.00	2141.12	2149.09	2148.71	2151.61	0.004191	12.76	3775.04	1725.43	0.91
Sunset	31655	100-Yr	70000.00	2141.12	2151.26	2150.38	2154.12	0.003204	13.62	5201.07	1774.06	0.84
Sunset	31182	10-Yr	21800.00	2139.64	2145.72	2144.02	2146.48	0.001608	7.01	3111.40	1851.19	0.55
Sunset	31182	50-Yr	48000.00	2139.64	2148.54	2146.39	2150.06	0.001806	9.90	4848.55	1884.13	0.62
Sunset	31182	100-Yr	70000.00	2139.64	2150.87	2148.04	2152.79	0.001635	11.13	6289.89	1913.03	0.62
Sunset	30846	10-Yr	21800.00	2138.32	2143.72	2143.72	2145.44	0.006110	10.54	2068.88	1964.34	1.00
Sunset	30846	50-Yr	48000.00	2138.32	2147.73	2146.08	2149.38	0.002214	10.32	4653.30	2058.18	0.68
Sunset	30846	100-Yr	70000.00	2138.32	2150.33	2147.65	2152.22	0.001696	11.02	6351.66	2201.63	0.62
Sunset	30571	10-Yr	21800.00	2135.91	2143.79	2141.41	2144.35	0.001038	6.00	3634.09	1988.61	0.45
Sunset	30571	50-Yr	48000.00	2135.91	2147.91	2143.71	2148.81	0.000810	7.57	6337.27	2252.98	0.43
Sunset	30571	100-Yr	70000.00	2135.91	2150.53	2145.33	2151.70	0.000781	8.67	8074.72	2405.90	0.44
Sunset	30211	10-Yr	21800.00	2134.31	2143.47	2140.85	2143.99	0.000919	5.80	3757.17	1835.11	0.42
Sunset	30211	50-Yr	48000.00	2134.31	2147.67	2143.22	2148.51	0.000740	7.40	6489.46	1947.08	0.41
Sunset	30211	100-Yr	70000.00	2134.31	2150.29	2144.84	2151.41	0.000728	8.52	8213.72	2037.29	0.43
Sunset	29689	10-Yr	21800.00	2133.83	2142.47	2139.88	2143.40	0.001251	7.70	2831.87	1258.30	0.51
Sunset	29689	50-Yr	48000.00	2133.83	2145.70	2143.01	2147.78	0.002114	11.58	4145.10	1346.57	0.68
Sunset	29689	100-Yr	70000.00	2133.83	2147.74	2145.70	2150.61	0.002387	13.59	5150.64	1568.14	0.75
Sunset	29333	10-Yr	21800.00	2133.19	2141.65	2140.02	2142.80	0.002135	8.60	2534.64	1221.51	0.64
Sunset	29333	50-Yr	48000.00	2133.19	2144.48	2143.14	2146.88	0.002866	12.44	3859.17	1461.94	0.78
Sunset	29333	100-Yr	70000.00	2133.19	2146.31	2145.41	2149.56	0.003413	14.46	4840.06	1576.09	0.87
Sunset	29145	10-Yr	21800.00	2133.23	2141.40	2139.84	2142.35	0.002065	7.83	2784.66	1393.81	0.62
Sunset	29145	50-Yr	48000.00	2133.23	2144.53	2142.60	2146.20	0.002110	10.38	4626.14	1614.61	0.67
Sunset	29145	100-Yr	70000.00	2133.23	2146.57	2144.41	2148.76	0.002040	11.87	5895.69	1708.86	0.68
Sunset	28850	10-Yr	21800.00	2133.13	2140.93	2139.33	2141.75	0.001750	7.28	2996.17	1428.36	0.57
Sunset	28850	50-Yr	48000.00	2133.13	2144.09	2141.74	2145.59	0.001696	9.82	4888.37	1573.22	0.61
Sunset	28850	100-Yr	70000.00	2133.13	2146.12	2143.42	2148.16	0.001738	11.46	6110.04	1595.21	0.64
Sunset	28513	10-Yr	21800.00	2132.91	2140.69	2138.25	2141.23	0.000977	5.88	3707.60	1288.63	0.44
Sunset	28513	50-Yr	48000.00	2132.91	2143.97	2140.50	2145.01	0.001051	8.19	5862.36	1344.69	0.48
Sunset	28513	100-Yr	70000.00	2132.91	2146.07	2142.09	2147.51	0.001111	9.64	7261.95	1454.63	0.52
Sunset	28332	10-Yr	21800.00	2132.32	2140.64	2137.66	2141.05	0.000678	5.13	4249.05	1046.62	0.37
Sunset	28332	50-Yr	48000.00	2132.32	2143.96	2139.84	2144.77	0.000826	7.22	6646.41	1132.93	0.43
Sunset	28332	100-Yr	70000.00	2132.32	2146.13	2141.37	2147.24	0.000844	8.44	8294.16	1144.03	0.45
Sunset	28037	10-Yr	21800.00	2131.16	2140.52	2137.26	2140.84	0.000550	4.50	4847.53	827.73	0.33
Sunset	28037	50-Yr	48000.00	2131.16	2143.90	2139.38	2144.51	0.000592	6.27	7651.66	835.43	0.37
Sunset	28037	100-Yr	70000.00	2131.16	2146.10	2140.70	2146.94	0.000632	7.35	9518.06	859.32	0.39
Sunset	27481	10-Yr	21800.00	2130.71	2139.80	2137.97	2140.36	0.001336	6.01	3629.34	784.06	0.49
Sunset	27481	50-Yr	48000.00	2130.71	2143.13	2140.03	2144.04	0.001075	7.68	6251.21	791.32	0.48
Sunset	27481	100-Yr	70000.00	2130.71	2145.26	2141.43	2146.46	0.001041	8.82	7938.93	795.59	0.49
Sunset	27120	10-Yr	21800.00	2130.71	2139.47	2137.04	2139.93	0.000928	5.47	3987.72	757.53	0.42
Sunset	27120	50-Yr	48000.00	2130.71	2142.84	2139.21	2143.67	0.000875	7.33	6550.05	764.27	0.44
Sunset	27120	100-Yr	70000.00	2130.71	2144.95	2140.66	2146.09	0.000899	8.56	8173.50	768.83	0.46
Sunset	27119	10-Yr	21800.00	2130.58	2139.52	2136.59	2139.91	0.000708	5.04	4325.82	758.13	0.37
Sunset	27119	50-Yr	48000.00	2130.58	2142.89	2138.78	2143.65	0.000737	6.96	6896.35	764.75	0.41
Sunset	27119	100-Yr	70000.00	2130.58	2145.02	2140.22	2146.06	0.000781	8.21	8526.23	769.15	0.43
Sunset	27054 Cortaro Road (LO		Bridge									
Sunset	26989	10-Yr	21800.00	2130.16	2139.18	2136.97	2139.69	0.001109	5.75	3794.12	760.48	0.45
Sunset	26989	50-Yr	48000.00	2130.16	2142.49	2139.13	2143.38	0.000997	7.60	6319.95	766.10	0.47
Sunset	26989	100-Yr	70000.00	2130.16	2144.53	2140.57	2145.75	0.001021	8.87	7890.21	769.69	0.49
Sunset	26977	10-Yr	21800.00	2130.27	2139.12	2137.04	2139.67	0.001230	5.94	3667.12	756.51	0.48
Sunset	26977	50-Yr	48000.00	2130.27	2142.42	2139.24	2143.36	0.001066	7.76	6181.78	764.54	0.48
Sunset	26977	100-Yr	70000.00	2130.27	2144.46	2140.68	2145.73	0.001081	9.04	7743.33	769.12	0.50
Sunset	26837	10-Yr	21800.00	2130.30	2139.05	2136.22	2139.46	0.000772	5.16	4222.81	759.16	0.39
Sunset	26837	50-Yr	48000.00	2130.30	2142.37	2138.45	2143.15	0.000795	7.11	6754.51	765.93	0.42
Sunset	26837	100-Yr	70000.00	2130.30	2144.41	2139.87	2145.51	0.000852	8.41	8321.10	770.09	0.45

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: Exist 500 River: Santa Cruz Reach: Sunset Profile: 500-Yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	500-Yr	93000.00	2255.61	2278.06	2278.06	2282.67	0.002119	17.96	7290.03	1191.06	0.75
Sunset	68588	500-Yr	93000.00	2253.49	2278.46	2275.66	2281.54	0.001363	15.09	8685.07	1184.24	0.61
Sunset	68087	500-Yr	93000.00	2250.70	2278.65	2274.81	2280.69	0.000856	12.47	10527.74	1323.86	0.49
Sunset	67552	500-Yr	93000.00	2250.55	2274.29	2274.29	2279.62	0.002516	19.09	6088.85	1231.53	0.82
Sunset	67038	500-Yr	93000.00	2249.72	2273.62	2272.58	2278.15	0.002217	17.94	6582.21	1924.19	0.77
Sunset	66600	500-Yr	93000.00	2249.10	2273.66	2271.13	2276.77	0.002153	15.05	7623.26	2358.07	0.64
Sunset	66255	500-Yr	93000.00	2248.50	2271.67	2268.45	2275.98	0.001806	16.90	6257.72	1248.87	0.70
Sunset	65763	500-Yr	93000.00	2247.09	2268.79	2268.79	2274.67	0.003113	19.77	5359.30	1679.76	0.89
Sunset	65255	500-Yr	93000.00	2246.28	2266.34	2266.34	2271.33	0.004480	18.70	6163.70	906.30	0.88
Sunset	64585	500-Yr	93000.00	2244.01	2264.40	2264.40	2268.51	0.002569	17.16	7313.85	1099.54	0.81
Sunset	64087	500-Yr	93000.00	2242.46	2262.87	2262.87	2266.66	0.002568	16.91	8519.65	1246.53	0.80
Sunset	63622	500-Yr	93000.00	2241.64	2262.95	2261.12	2265.28	0.001467	13.70	11125.59	1412.96	0.62
Sunset	62978	500-Yr	93000.00	2240.25	2261.36	2259.65	2264.21	0.001645	14.73	9619.33	1170.95	0.66
Sunset	62453	500-Yr	93000.00	2239.00	2257.97	2256.02	2262.87	0.002898	18.50	6823.73	935.51	0.86
Sunset	61960	500-Yr	93000.00	2234.74	2257.01	2256.98	2261.40	0.002477	17.76	7526.40	983.79	0.81
Sunset	61436	500-Yr	93000.00	2233.28	2258.06	2255.83	2259.79	0.001042	12.15	14059.18	1854.52	0.53
Sunset	61000	500-Yr	93000.00	2229.63	2254.88	2254.86	2258.93	0.002300	16.77	7934.30	1392.28	0.77
Sunset	60523	500-Yr	93000.00	2229.89	2254.99	2253.84	2257.58	0.001643	14.03	10639.78	1559.05	0.65
Sunset	60070	500-Yr	93000.00	2228.19	2254.70	2252.37	2256.50	0.002163	12.08	11965.73	1687.52	0.54
Sunset	59588	500-Yr	93000.00	2226.99	2254.13	2249.45	2255.84	0.000923	11.35	12995.01	1727.22	0.50
Sunset	59088	500-Yr	93000.00	2226.21	2253.91	2249.24	2255.38	0.000769	11.01	14165.90	1453.10	0.46
Sunset	58533	500-Yr	93000.00	2224.44	2248.80	2248.80	2254.23	0.002713	19.08	6029.85	790.18	0.85
Sunset	57982	500-Yr	93000.00	2224.20	2248.59	2246.10	2250.61	0.002982	12.57	9786.33	1160.45	0.56
Sunset	57561	500-Yr	93000.00	2222.54	2246.59	2243.91	2249.60	0.001566	14.45	8299.59	916.40	0.64
Sunset	57165	500-Yr	93000.00	2221.13	2246.79	2242.47	2248.81	0.001001	12.03	10537.69	1094.21	0.52
Sunset	56836	500-Yr	93000.00	2221.00	2245.48	2241.51	2248.35	0.001278	14.19	8980.60	990.13	0.59
Sunset	56608	500-Yr	93000.00	2221.00	2246.31	2239.54	2247.19	0.000451	8.88	17949.54	2541.34	0.36
Sunset	56526 El Camino Del Ce		Bridge									
Sunset	56440	500-Yr	93000.00	2220.50	2244.33	2240.71	2245.31	0.000752	9.48	15793.50	2317.21	0.38
Sunset	55999	500-Yr	93000.00	2217.00	2239.00	2239.00	2243.59	0.003864	17.70	6104.91	897.59	0.82
Sunset	55499	500-Yr	93000.00	2216.00	2236.80	2236.80	2240.45	0.003430	16.25	7302.58	1231.94	0.77
Sunset	54999	500-Yr	93000.00	2214.00	2235.30	2234.64	2238.54	0.003131	15.56	8377.13	1215.02	0.74
Sunset	54499	500-Yr	93000.00	2213.00	2233.62	2232.99	2236.92	0.003317	15.91	8301.50	1084.88	0.76
Sunset	53999	500-Yr	93000.00	2211.00	2231.07	2230.44	2235.12	0.003581	16.63	6816.94	929.57	0.78
Sunset	53499	500-Yr	93000.00	2207.00	2230.23	2228.73	2233.05	0.003197	13.78	7874.41	1076.85	0.73
Sunset	52999	500-Yr	93000.00	2205.00	2229.93	2226.61	2231.35	0.001987	10.25	10130.82	1198.25	0.57
Sunset	52499	500-Yr	93000.00	2204.00	2227.45	2225.86	2229.84	0.003904	13.17	7645.31	1038.83	0.77
Sunset	51999	500-Yr	93000.00	2203.00	2226.49	2222.80	2228.15	0.002118	11.40	9357.51	1158.79	0.59
Sunset	51499	500-Yr	93000.00	2201.00	2226.05	2221.79	2227.21	0.001227	9.26	11632.63	1282.98	0.46
Sunset	51057	500-Yr	93000.00	2199.00	2223.88	2222.20	2226.30	0.002764	13.75	8384.16	1066.68	0.69
Sunset	50945	500-Yr	93000.00	2199.00	2222.01	2222.01	2225.78	0.004418	16.86	6935.84	1070.62	0.86
Sunset	50500	500-Yr	93000.00	2198.00	2221.53	2219.62	2223.20	0.002946	11.26	9475.20	1335.28	0.67
Sunset	49996	500-Yr	93000.00	2197.00	2220.36	2217.39	2221.88	0.002163	10.43	9827.84	1318.48	0.59
Sunset	49501	500-Yr	93000.00	2197.00	2217.39	2216.61	2220.23	0.004713	13.62	6957.90	1027.74	0.84
Sunset	48999	500-Yr	93000.00	2196.00	2216.57	2213.80	2218.34	0.002220	10.73	8817.67	1072.04	0.60
Sunset	48499	500-Yr	93000.00	2195.00	2215.02	2213.39	2217.05	0.002887	11.82	8669.49	1212.27	0.68
Sunset	47499	500-Yr	107400.00	2193.11	2214.21	2206.02	2215.44	0.000853	9.07	12811.81	1149.46	0.40
Sunset	46999	500-Yr	107400.00	2191.00	2208.57	2208.57	2214.18	0.004400	19.31	6275.73	806.18	0.89
Sunset	46499	500-Yr	107400.00	2189.00	2206.81	2206.81	2211.55	0.004583	17.74	6524.58	787.68	0.89
Sunset	45999	500-Yr	107400.00	2189.00	2203.11	2203.11	2207.25	0.005452	16.44	6791.39	882.93	0.93
Sunset	45499	500-Yr	107400.00	2187.00	2201.32	2199.67	2203.97	0.003570	13.07	8266.64	944.05	0.75
Sunset	44999	500-Yr	107400.00	2186.00	2199.75	2197.97	2202.15	0.003386	12.44	8633.09	953.01	0.73
Sunset	44499	500-Yr	107400.00	2184.00	2198.20	2196.21	2200.49	0.003142	12.12	8858.00	959.72	0.70
Sunset	43999	500-Yr	107400.00	2183.00	2197.28	2194.11	2199.07	0.002106	10.74	9999.75	963.48	0.59
Sunset	43499	500-Yr	107400.00	2181.00	2195.77	2193.38	2197.85	0.002682	11.59	9265.94	955.84	0.66
Sunset	42999	500-Yr	107400.00	2180.00	2192.58	2192.05	2195.88	0.005416	14.59	7363.67	906.56	0.90
Sunset	42499	500-Yr	107400.00	2175.00	2192.29	2188.39	2193.90	0.001854	10.19	10534.98	1635.41	0.55
Sunset	41999	500-Yr	107400.00	2176.00	2192.43	2186.26	2193.10	0.000657	6.57	16365.87	1843.12	0.34
Sunset	41499	500-Yr	107400.00	2175.00	2191.37	2187.06	2192.57	0.001529	8.79	12361.50	1772.97	0.49
Sunset	40999	500-Yr	107400.00	2174.00	2190.28	2186.34	2191.73	0.001746	9.64	11182.61	1480.91	0.53
Sunset	40499	500-Yr	107400.00	2172.00	2188.24	2186.97	2190.40	0.003882	12.16	9667.86	1330.92	0.76
Sunset	39999	500-Yr	107400.00	2171.00	2187.32	2183.93	2188.93	0.001876	10.31	11191.69	1212.90	0.56
Sunset	39399	500-Yr	107400.00	2168.00	2186.13	2181.31	2187.78	0.001928	10.31	10465.59	1196.13	0.50
Sunset	38909	500-Yr	107400.00	2168.00	2185.71	2179.53	2186.88	0.001276	8.90	13010.93	1101.67	0.41
Sunset	38409	500-Yr	107400.00	2168.00	2184.94	2178.42	2186.23	0.001272	9.15	12085.48	1024.42	0.42
Sunset	37929	500-Yr	107400.00	2166.00	2183.93	2177.77	2185.53	0.001531	10.23	10916.58	959.49	0.46
Sunset	37509	500-Yr	107400.00	2166.00	2183.19	2177.39	2184.85	0.001651	10.51	10717.78	1270.82	0.48
Sunset	36859	500-Yr	107400.00	2164.00	2181.88	2177.11	2183.70	0.001927	11.59	11248.66	1413.76	0.52
Sunset	36439	500-Yr	107400.00	2162.00	2180.42	2176.84	2182.70	0.002582	12.82	9576.31	1552.41	0.59
Sunset	36049	500-Yr	107400.00	2162.00	2178.10	2175.75	2181.37	0.003666	14.99	7881.46	1540.45	0.70
Sunset	35639	500-Yr	107400.00	2160.00	2176.43	2174.70	2179.72	0.004279	15.07	7981.50	1903.70	0.74
Sunset	35095	500-Yr	107400.00	2158.00	2175.16	2172.12	2177.45	0.003116	12.22	8998.92	3846.09	0.63
Sunset	34808	500-Yr	107400.00	2158.00	2173.07	2170.84	2176.31	0.004301	14.46	7485.40	2680.81	0.74
Sunset	34568	500-Yr	107400.00	2157.92	2174.44	2168.33	2175.13	0.000933	7.64	19101.10	3185.41	0.35
Sunset	34556	500-Yr	107400.00	2157.92	2171.67	2168.32	2174.47	0.003249	13.43	7996.99	694.34	0.65
Sunset	34529 Ina Road (LOMR)		Bridge									
Sunset	34502	500-Yr	107400.00	2155.79	2169.34	2167.30	2172.79	0.002323	14.91	7204.29	1779.71	0.76
Sunset	34494	500-Yr	107400.00	2155.79	2167.27	2167.27	2172.29	0.004282	17.98	5971.85	593.19	1.00
Sunset	34294	500-Yr	107400.00	2146.87	2161.44	2160.46	2165.71	0.003220	16.59	6473.85	584.36	0.88
Sunset	34054	500-Yr	107400.00	2146.44	2160.99	2160.03	2164.80	0.003204	15.66	6858.53	675.12	0.87
Sunset	33594	500-Yr	107400.00	2145.96	2159.90	2158.78	2163.34	0.002753	15.19	7438.96	1551.48	0.81
Sunset	33332	500-Yr	107400.00	2145.72	2159.27	2157.88	2162.63	0.002589	14.94	7472.27	1401.49	0.79
Sunset	33162	500-Yr	107400.00	2145.21	2157.91	2157.54	2162.04	0.003552	16.51	6748.67	1301.59	0.91
Sunset	32680	500-Yr	107400.00	2143.52	2157.42	2154.92	2160.46	0.002013	14.03	7748.72	1304.35	0.71
Sunset	32153	500-Yr	107400.00	2142.51	2155.77	2154.03	2159.22	0.002580	14.90	7209.08	1381.42	0.79
Sunset	31655	500-Yr	107400.00	2141.12	2154.70	2152.82	2157.95	0.002321	14.57	7544.97	1867.72	0.75
Sunset	31182	500-Yr	107400.00	2139.64	2154.38	2150.50	2156.87	0.001446	12.65	8490.60	2059.96	0.61

4RTSUN FEMA Existing Condition Results, SCR

HEC-RAS Plan: Exist 500 River: Santa Cruz Reach: Sunset Profile: 500-Yr (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	30846	500-Yr	107400.00	2138.32	2154.02	2150.04	2156.34	0.001384	12.23	8784.89	2380.37	0.59
Sunset	30571	500-Yr	107400.00	2135.91	2154.25	2147.67	2155.85	0.000765	10.16	10578.54	2485.50	0.45
Sunset	30211	500-Yr	107400.00	2134.31	2154.00	2147.19	2155.57	0.000727	10.05	10681.84	2319.03	0.44
Sunset	29689	500-Yr	107400.00	2133.83	2150.43	2148.77	2154.63	0.002979	16.46	6538.78	1754.33	0.85
Sunset	29333	500-Yr	107400.00	2133.19	2149.51	2148.41	2153.46	0.003161	15.94	6737.90	1839.84	0.87
Sunset	29145	500-Yr	107400.00	2133.23	2152.05	2146.88	2152.26	0.000156	3.89	31096.80	4033.43	0.20
Sunset	28850	500-Yr	107400.00	2133.13	2148.96	2145.91	2151.87	0.001816	13.69	7858.65	1915.33	0.68
Sunset	28513	500-Yr	107400.00	2132.91	2149.10	2144.47	2151.12	0.001131	11.45	9702.35	2263.27	0.54
Sunset	28332	500-Yr	107400.00	2132.32	2149.25	2143.76	2150.81	0.000855	10.04	10887.30	1945.90	0.47
Sunset	28037	500-Yr	107400.00	2131.16	2149.33	2142.76	2150.46	0.000665	8.54	12933.01	1745.74	0.41
Sunset	27481	500-Yr	107400.00	2130.71	2148.28	2143.48	2149.94	0.001050	10.34	10389.39	1169.11	0.51
Sunset	27120	500-Yr	107400.00	2130.71	2147.95	2142.79	2149.58	0.000936	10.24	10485.30	775.36	0.49
Sunset	27119	500-Yr	107400.00	2130.58	2148.02	2142.34	2149.54	0.000837	9.90	10846.72	775.97	0.47
Sunset	27054 Cortaro Road (LO		Bridge									
Sunset	26989	500-Yr	107400.00	2130.16	2147.40	2142.70	2149.15	0.001068	10.63	10103.48	774.62	0.52
Sunset	26977	500-Yr	107400.00	2130.27	2147.31	2142.81	2149.12	0.001120	10.80	9948.48	775.65	0.53
Sunset	26837	500-Yr	107400.00	2130.30	2147.27	2142.01	2148.88	0.000926	10.19	10561.26	798.46	0.49

4RTSUN FEMA PROPOSED CONDITION (INTERIM) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPINT River: Santa Cruz Reach: Sunset

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	10-Yr	16800.00	2255.61	2265.49	2264.51	2267.38	0.003109	11.04	1522.15	244.01	0.78
Sunset	68977	50-Yr	41000.00	2255.61	2270.78	2268.89	2274.02	0.002504	14.46	2835.48	254.66	0.76
Sunset	68977	100-Yr	60000.00	2255.61	2274.22	2271.67	2278.25	0.002294	16.11	3724.63	269.76	0.75
Sunset	68588	10-Yr	16800.00	2253.49	2264.65	2263.16	2266.23	0.002387	10.10	1663.78	248.65	0.69
Sunset	68588	50-Yr	41000.00	2253.49	2270.30	2267.49	2273.01	0.001935	13.20	3105.40	273.16	0.67
Sunset	68588	100-Yr	60000.00	2253.49	2273.88	2270.22	2277.28	0.001796	14.79	4057.93	661.89	0.67
Sunset	68087	10-Yr	16800.00	2250.70	2264.38	2260.73	2265.31	0.000974	7.72	2177.44	250.52	0.46
Sunset	68087	50-Yr	41000.00	2250.70	2270.10	2265.16	2272.05	0.001137	11.22	3653.81	280.96	0.53
Sunset	68087	100-Yr	60000.00	2250.70	2273.71	2267.92	2276.27	0.001289	12.84	4678.36	1010.43	0.58
Sunset	67552	10-Yr	16800.00	2250.55	2262.97	2261.19	2264.51	0.002115	9.97	1685.81	236.39	0.66
Sunset	67552	50-Yr	41000.00	2250.55	2268.10	2265.71	2271.13	0.002174	13.95	2938.89	307.05	0.72
Sunset	67552	100-Yr	60000.00	2250.55	2271.44	2268.53	2275.27	0.002124	15.73	3907.53	767.04	0.73
Sunset	67038	10-Yr	16800.00	2249.72	2261.55	2260.13	2263.30	0.002530	10.61	1583.13	408.63	0.71
Sunset	67038	50-Yr	41000.00	2249.72	2266.07	2264.70	2269.77	0.002921	15.43	2657.76	702.37	0.82
Sunset	67038	100-Yr	60000.00	2249.72	2268.96	2267.55	2273.87	0.003047	17.78	3374.39	883.92	0.87
Sunset	66600	10-Yr	16800.00	2249.10	2259.76	2259.02	2261.76	0.004996	11.35	1479.85	375.59	0.82
Sunset	66600	50-Yr	41000.00	2249.10	2264.78	2263.32	2268.19	0.004024	14.83	2763.85	956.61	0.81
Sunset	66600	100-Yr	60000.00	2249.10	2267.85	2266.06	2272.20	0.003857	16.74	3585.23	1132.33	0.81
Sunset	66255	10-Yr	16800.00	2248.50	2259.73	2256.52	2260.75	0.001135	8.11	2072.66	250.57	0.50
Sunset	66255	50-Yr	41000.00	2248.50	2264.77	2260.91	2267.07	0.001467	12.17	3368.35	265.03	0.60
Sunset	66255	100-Yr	60000.00	2248.50	2267.88	2263.67	2271.00	0.001658	14.19	4273.50	418.82	0.65
Sunset	65763	10-Yr	16800.00	2247.09	2258.18	2256.99	2259.86	0.002738	10.40	1614.66	257.19	0.73
Sunset	65763	50-Yr	41000.00	2247.09	2262.52	2261.18	2265.96	0.002948	14.89	2753.80	608.22	0.82
Sunset	65763	100-Yr	60000.00	2247.09	2265.15	2263.98	2269.76	0.003156	17.22	3483.47	986.18	0.87
Sunset	65255	10-Yr	16800.00	2246.28	2256.48	2255.42	2258.16	0.004167	10.39	1617.60	269.31	0.75
Sunset	65255	50-Yr	41000.00	2246.28	2260.88	2259.53	2264.12	0.004259	14.43	2840.33	325.99	0.82
Sunset	65255	100-Yr	60000.00	2246.28	2263.62	2262.23	2267.79	0.004176	16.39	3660.42	596.17	0.83
Sunset	64585	10-Yr	16800.00	2244.01	2254.80	2253.15	2256.13	0.002098	9.23	1820.41	285.10	0.64
Sunset	64585	50-Yr	41000.00	2244.01	2259.25	2257.12	2261.89	0.002294	13.06	3140.20	397.07	0.72
Sunset	64585	100-Yr	60000.00	2244.01	2261.99	2259.69	2265.47	0.002461	14.96	4009.68	883.13	0.77
Sunset	64087	10-Yr	16800.00	2242.46	2252.84	2252.24	2254.71	0.003755	10.97	1531.20	285.73	0.84
Sunset	64087	50-Yr	41000.00	2242.46	2257.12	2256.20	2260.46	0.003362	14.65	2798.49	331.48	0.86
Sunset	64087	100-Yr	60000.00	2242.46	2259.78	2258.68	2264.01	0.003158	16.52	3632.24	1071.10	0.86
Sunset	63622	10-Yr	16800.00	2241.64	2251.66	2250.44	2253.15	0.002597	9.81	1712.44	288.60	0.71
Sunset	63622	50-Yr	41000.00	2241.64	2256.11	2254.35	2258.94	0.002582	13.49	3038.22	347.73	0.76
Sunset	63622	100-Yr	60000.00	2241.64	2258.90	2256.87	2262.52	0.002537	15.27	3929.75	1232.77	0.78
Sunset	62978	10-Yr	16800.00	2240.25	2249.67	2248.70	2251.33	0.003027	10.34	1624.21	283.27	0.76
Sunset	62978	50-Yr	41000.00	2240.25	2254.07	2252.64	2257.17	0.002837	14.12	2903.61	315.61	0.80
Sunset	62978	100-Yr	60000.00	2240.25	2256.61	2255.29	2260.70	0.002948	16.24	3695.07	952.54	0.84
Sunset	62453	10-Yr	16800.00	2239.00	2248.37	2247.01	2249.85	0.002465	9.76	1721.76	280.96	0.69
Sunset	62453	50-Yr	41000.00	2239.00	2252.82	2251.01	2255.71	0.002498	13.65	3004.47	320.12	0.76
Sunset	62453	100-Yr	60000.00	2239.00	2255.09	2253.64	2259.17	0.002880	16.21	3701.01	761.48	0.83
Sunset	61960	10-Yr	16800.00	2234.74	2247.37	2245.60	2248.70	0.002031	9.26	1815.15	278.23	0.64
Sunset	61960	50-Yr	41000.00	2234.74	2251.99	2249.80	2254.49	0.002038	12.81	3518.46	494.12	0.69
Sunset	61960	100-Yr	60000.00	2234.74	2254.49	2252.62	2257.70	0.002112	14.72	4669.43	930.59	0.73
Sunset	61436	10-Yr	16800.00	2233.28	2246.20	2244.75	2247.57	0.002296	9.37	1793.36	294.44	0.67
Sunset	61436	50-Yr	41000.00	2233.28	2250.93	2248.68	2253.36	0.002174	12.53	3340.64	410.52	0.70
Sunset	61436	100-Yr	60000.00	2233.28	2253.20	2251.33	2256.52	0.002335	14.73	4380.56	1737.89	0.75
Sunset	61000	10-Yr	16800.00	2229.63	2245.62	2243.25	2246.67	0.001506	8.26	2033.94	293.16	0.55
Sunset	61000	50-Yr	41000.00	2229.63	2250.36	2247.33	2252.41	0.001707	11.51	3599.09	400.21	0.63
Sunset	61000	100-Yr	60000.00	2229.63	2252.54	2249.87	2255.49	0.001935	13.82	4535.67	1248.36	0.69
Sunset	60523	10-Yr	16800.00	2229.89	2244.40	2242.83	2245.77	0.002270	9.41	1785.78	287.36	0.67
Sunset	60523	50-Yr	41000.00	2229.89	2249.05	2247.08	2251.42	0.002438	12.35	3339.62	420.86	0.73
Sunset	60523	100-Yr	60000.00	2229.89	2251.16	2249.56	2254.40	0.002558	14.49	4282.36	1375.58	0.78
Sunset	60070	10-Yr	16800.00	2228.19	2243.02	2241.42	2244.38	0.004299	9.36	1795.50	284.37	0.66
Sunset	60070	50-Yr	41000.00	2228.19	2247.37	2245.93	2249.84	0.005219	12.69	3380.18	530.91	0.76
Sunset	60070	100-Yr	60000.00	2228.19	2249.93	2248.44	2252.79	0.004450	13.83	4796.40	745.33	0.73
Sunset	59588	10-Yr	16800.00	2226.99	2241.67	2239.93	2242.86	0.002288	8.76	1916.96	344.63	0.65
Sunset	59588	50-Yr	41000.00	2226.99	2246.58	2243.84	2248.28	0.001703	10.58	4362.71	809.39	0.61
Sunset	59588	100-Yr	60000.00	2226.99	2249.78	2246.59	2251.43	0.001208	10.73	7087.43	961.79	0.54
Sunset	59088	10-Yr	16800.00	2226.21	2239.44	2238.81	2241.33	0.003865	11.03	1523.27	287.38	0.84
Sunset	59088	50-Yr	41000.00	2226.21	2244.87	2242.96	2247.25	0.002256	12.43	3570.85	739.74	0.71
Sunset	59088	100-Yr	60000.00	2226.21	2248.49	2245.74	2250.72	0.001496	12.38	5904.29	1117.19	0.61

4RTSUN FEMA PROPOSED CONDITION (INTERIM) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPINT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	58533	10-Yr	16800.00	2224.44	2238.06	2236.22	2239.63	0.002235	10.05	1671.74	242.37	0.67
Sunset	58533	50-Yr	41000.00	2224.44	2242.73	2240.96	2245.82	0.002621	14.11	2907.01	293.62	0.78
Sunset	58533	100-Yr	60000.00	2224.44	2245.07	2243.77	2249.38	0.002860	16.70	3721.74	408.13	0.84
Sunset	57982	10-Yr	16800.00	2224.20	2236.24	2234.44	2237.72	0.005867	9.74	1724.65	265.16	0.67
Sunset	57982	50-Yr	41000.00	2224.20	2240.25	2238.93	2243.43	0.008417	14.32	2866.70	340.78	0.85
Sunset	57982	100-Yr	60000.00	2224.20	2244.28	2242.20	2246.84	0.004802	13.23	5478.37	980.85	0.67
Sunset	57561	10-Yr	16800.00	2222.54	2234.63	2233.32	2236.06	0.002781	9.59	1750.93	320.72	0.72
Sunset	57561	50-Yr	41000.00	2222.54	2239.00	2237.22	2241.51	0.002404	12.72	3222.11	344.10	0.73
Sunset	57561	100-Yr	60000.00	2222.54	2243.29	2239.48	2245.76	0.001529	12.63	4830.66	801.63	0.62
Sunset	57165	10-Yr	16800.00	2221.13	2233.56	2232.52	2234.94	0.002814	9.42	1784.32	339.74	0.72
Sunset	57165	50-Yr	41000.00	2221.13	2238.31	2236.03	2240.48	0.002277	11.83	3470.71	418.11	0.71
Sunset	57165	100-Yr	60000.00	2221.13	2243.42	2238.57	2245.02	0.000984	10.38	7055.01	943.85	0.50
Sunset	56836	10-Yr	16800.00	2221.00	2232.86	2231.28	2234.09	0.002139	8.91	1886.43	315.56	0.64
Sunset	56836	50-Yr	41000.00	2221.00	2237.51	2235.00	2239.79	0.001890	12.12	3424.87	346.37	0.66
Sunset	56836	100-Yr	60000.00	2221.00	2242.61	2237.35	2244.64	0.001055	11.59	6217.47	924.29	0.52
Sunset	56608	10-Yr	16800.00	2221.00	2232.65	2230.13	2233.53	0.001290	7.54	2227.99	328.14	0.51
Sunset	56608	50-Yr	41000.00	2221.00	2237.40	2233.80	2239.14	0.001394	10.60	3872.48	427.98	0.57
Sunset	56608	100-Yr	60000.00	2221.00	2243.02	2236.13	2243.90	0.000501	8.26	11448.52	1878.41	0.36
Sunset	56526 El Camino Del Ce		Bridge									
Sunset	56440	10-Yr	16800.00	2220.50	2231.36	2229.20	2232.37	0.002286	8.07	2081.22	322.58	0.56
Sunset	56440	50-Yr	41000.00	2220.50	2235.85	2232.87	2237.89	0.002378	11.46	3636.27	389.42	0.62
Sunset	56440	100-Yr	60000.00	2220.50	2239.09	2235.25	2241.17	0.001853	12.01	6478.95	1593.18	0.57
Sunset	55999	10-Yr	16800.00	2217.00	2229.77	2228.35	2231.07	0.003435	9.15	1836.65	318.29	0.67
Sunset	55999	50-Yr	41000.00	2217.00	2233.68	2232.02	2236.38	0.003757	13.21	3116.76	360.83	0.76
Sunset	55999	100-Yr	60000.00	2217.00	2235.68	2234.59	2239.47	0.004290	15.72	3928.40	466.47	0.83
Sunset	55499	10-Yr	16800.00	2216.00	2228.28	2226.67	2229.39	0.002931	8.44	1989.78	343.89	0.62
Sunset	55499	50-Yr	41000.00	2216.00	2232.19	2230.14	2234.44	0.003138	12.09	3499.59	497.46	0.69
Sunset	55499	100-Yr	60000.00	2216.00	2234.18	2232.90	2237.16	0.003392	14.13	4737.97	817.81	0.74
Sunset	54999	10-Yr	16800.00	2214.00	2226.26	2225.23	2227.62	0.004172	9.38	1791.17	344.50	0.72
Sunset	54999	50-Yr	41000.00	2214.00	2230.67	2228.73	2232.84	0.003171	11.93	3772.90	730.34	0.69
Sunset	54999	100-Yr	60000.00	2214.00	2233.15	2231.71	2235.47	0.002647	12.78	5992.87	1018.42	0.66
Sunset	54499	10-Yr	16800.00	2213.00	2224.20	2222.83	2225.65	0.003729	9.65	1740.27	296.31	0.70
Sunset	54499	50-Yr	41000.00	2213.00	2227.89	2226.99	2230.89	0.004415	14.02	3071.63	482.29	0.82
Sunset	54499	100-Yr	60000.00	2213.00	2230.00	2230.00	2233.65	0.004441	15.81	4624.36	858.66	0.84
Sunset	53999	10-Yr	16800.00	2211.00	2223.75	2219.86	2224.40	0.001260	6.47	2596.91	353.20	0.42
Sunset	53999	50-Yr	41000.00	2211.00	2227.32	2223.91	2229.05	0.002073	10.56	3949.66	516.22	0.57
Sunset	53999	100-Yr	60000.00	2211.00	2228.99	2226.11	2231.62	0.002721	13.14	5055.88	783.19	0.67
Sunset	53499	10-Yr	16800.00	2207.00	2222.86	2218.32	2223.62	0.001893	7.03	2391.24	393.99	0.50
Sunset	53499	50-Yr	41000.00	2207.00	2226.36	2224.13	2227.80	0.002597	9.63	4323.01	738.69	0.61
Sunset	53499	100-Yr	60000.00	2207.00	2228.07	2225.85	2230.04	0.002789	11.35	5739.22	948.69	0.66
Sunset	52999	10-Yr	16800.00	2205.00	2221.43	2220.29	2222.35	0.003434	8.00	2364.69	620.72	0.65
Sunset	52999	50-Yr	41000.00	2205.00	2225.56	2223.38	2226.46	0.002077	8.18	5756.90	1083.89	0.54
Sunset	52999	100-Yr	60000.00	2205.00	2227.49	2224.51	2228.54	0.002066	8.83	7630.78	1178.09	0.55
Sunset	52499	10-Yr	16800.00	2204.00	2218.69	2217.95	2220.24	0.004719	10.56	1782.15	443.17	0.78
Sunset	52499	50-Yr	41000.00	2204.00	2222.56	2221.98	2224.67	0.005642	12.50	3640.12	799.04	0.87
Sunset	52499	100-Yr	60000.00	2204.00	2224.56	2223.80	2226.75	0.005660	12.70	5179.23	1009.82	0.88
Sunset	51999	10-Yr	16800.00	2203.00	2217.34	2215.54	2218.20	0.002795	8.15	2430.67	502.84	0.60
Sunset	51999	50-Yr	41000.00	2203.00	2221.38	2218.98	2222.48	0.002543	9.35	5212.81	872.80	0.60
Sunset	51999	100-Yr	60000.00	2203.00	2223.28	2219.81	2224.66	0.002439	10.44	6739.43	940.69	0.61
Sunset	51499	10-Yr	16800.00	2201.00	2216.45	2213.93	2217.05	0.001696	6.24	2691.09	495.33	0.47
Sunset	51499	50-Yr	41000.00	2201.00	2220.52	2217.00	2221.47	0.001517	8.02	5783.04	1090.61	0.48
Sunset	51499	100-Yr	60000.00	2201.00	2222.49	2218.88	2223.60	0.001609	8.89	7805.31	1235.58	0.50
Sunset	51057	10-Yr	16800.00	2199.00	2215.49	2213.08	2216.26	0.001636	7.38	2577.31	491.35	0.48
Sunset	51057	50-Yr	41000.00	2199.00	2219.53	2216.85	2220.66	0.001926	9.13	5006.75	891.84	0.54
Sunset	51057	100-Yr	60000.00	2199.00	2221.61	2218.61	2222.82	0.001803	9.84	7357.28	1024.97	0.54
Sunset	51000 Proposed Sunset		Bridge									
Sunset	50945	10-Yr	16800.00	2199.00	2214.34	2211.88	2215.32	0.002033	8.23	2301.83	462.91	0.54
Sunset	50945	50-Yr	41000.00	2199.00	2219.04	2216.29	2220.20	0.001832	9.23	4951.02	889.69	0.53
Sunset	50945	100-Yr	60000.00	2199.00	2220.53	2217.96	2222.03	0.002187	10.90	6599.99	953.19	0.59
Sunset	50500	10-Yr	16800.00	2198.00	2211.96	2211.28	2213.76	0.004766	11.01	1641.29	326.76	0.80
Sunset	50500	50-Yr	41000.00	2198.00	2217.81	2214.93	2219.03	0.004108	9.39	4821.17	1147.94	0.73
Sunset	50500	100-Yr	60000.00	2198.00	2219.29	2217.97	2220.80	0.003754	10.51	6334.44	1207.12	0.73

HEC-RAS Plan: 10-50-100-YrPINT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	49996	10-Yr	16800.00	2197.00	2210.25	2208.48	2211.68	0.003031	9.76	1848.06	327.64	0.65
Sunset	49996	50-Yr	41000.00	2197.00	2216.53	2213.80	2217.36	0.002156	7.71	5898.82	1140.33	0.55
Sunset	49996	100-Yr	60000.00	2197.00	2218.07	2215.50	2219.17	0.002177	8.89	7463.84	1206.83	0.57
Sunset	49501	10-Yr	16800.00	2197.00	2207.17	2206.63	2209.60	0.005533	12.51	1343.13	211.63	0.87
Sunset	49501	50-Yr	41000.00	2197.00	2213.92	2213.38	2215.66	0.005594	10.58	3900.11	883.39	0.84
Sunset	49501	100-Yr	60000.00	2197.00	2215.42	2214.76	2217.52	0.004954	11.67	5217.25	1002.79	0.83
Sunset	48999	10-Yr	16800.00	2196.00	2206.97	2203.99	2207.77	0.001580	7.16	2346.45	333.10	0.48
Sunset	48999	50-Yr	41000.00	2196.00	2213.07	2207.76	2213.91	0.001805	7.35	5625.60	927.91	0.50
Sunset	48999	100-Yr	60000.00	2196.00	2214.62	2211.36	2215.78	0.001919	8.66	7031.17	977.26	0.54
Sunset	48499	10-Yr	16800.00	2195.00	2203.32	2203.32	2206.09	0.007475	13.34	1259.50	225.01	0.99
Sunset	48499	50-Yr	41000.00	2195.00	2208.87	2208.87	2212.07	0.007236	14.36	2854.27	446.43	1.00
Sunset	48499	100-Yr	60000.00	2195.00	2211.39	2211.39	2214.02	0.006506	13.12	4789.60	986.75	0.94
Sunset	47499	10-Yr	21800.00	2193.11	2202.06	2199.34	2202.63	0.001346	6.03	3618.78	603.61	0.43
Sunset	47499	50-Yr	48000.00	2193.11	2206.76	2201.87	2207.62	0.000985	7.45	6530.16	654.61	0.40
Sunset	47499	100-Yr	70000.00	2193.11	2209.95	2203.57	2210.97	0.000880	8.21	9060.64	1002.32	0.39
Sunset	46999	10-Yr	21800.00	2191.00	2200.39	2198.40	2201.65	0.002594	9.00	2423.29	354.91	0.61
Sunset	46999	50-Yr	48000.00	2191.00	2204.14	2201.88	2206.66	0.003003	12.74	3769.10	364.73	0.70
Sunset	46999	100-Yr	70000.00	2191.00	2206.38	2204.24	2209.95	0.003343	15.20	4820.86	698.71	0.76
Sunset	46499	10-Yr	21800.00	2189.00	2198.42	2197.30	2200.02	0.004022	10.14	2150.80	367.76	0.74
Sunset	46499	50-Yr	48000.00	2189.00	2201.13	2200.84	2204.52	0.005963	14.76	3253.03	425.11	0.94
Sunset	46499	100-Yr	70000.00	2189.00	2203.07	2203.07	2207.61	0.006348	17.09	4095.08	482.39	1.00
Sunset	45999	10-Yr	21800.00	2189.00	2196.95	2195.72	2198.00	0.003430	8.20	2659.37	559.85	0.66
Sunset	45999	50-Yr	48000.00	2189.00	2199.09	2198.37	2201.47	0.005066	12.40	3871.15	597.53	0.85
Sunset	45999	100-Yr	70000.00	2189.00	2200.41	2200.26	2203.89	0.006434	14.96	4680.32	678.29	0.97
Sunset	45499	10-Yr	21800.00	2187.00	2195.63	2194.30	2196.30	0.002935	6.61	3298.07	846.53	0.59
Sunset	45499	50-Yr	48000.00	2187.00	2197.82	2196.36	2199.16	0.003244	9.29	5167.96	857.17	0.67
Sunset	45499	100-Yr	70000.00	2187.00	2199.25	2197.68	2201.11	0.003426	10.93	6403.69	866.07	0.71
Sunset	44999	10-Yr	21800.00	2186.00	2194.03	2193.02	2194.73	0.003369	6.70	3252.63	907.02	0.62
Sunset	44999	50-Yr	48000.00	2186.00	2196.14	2194.88	2197.45	0.003544	9.20	5217.78	939.08	0.69
Sunset	44999	100-Yr	70000.00	2186.00	2197.60	2196.13	2199.35	0.003496	10.62	6588.29	944.69	0.71
Sunset	44499	10-Yr	21800.00	2184.00	2192.06	2191.22	2192.84	0.004222	7.11	3066.02	926.23	0.69
Sunset	44499	50-Yr	48000.00	2184.00	2194.40	2193.09	2195.69	0.003470	9.14	5253.09	939.00	0.68
Sunset	44499	100-Yr	70000.00	2184.00	2195.94	2194.34	2197.63	0.003292	10.44	6706.55	942.60	0.69
Sunset	43999	10-Yr	21800.00	2183.00	2190.92	2189.26	2191.40	0.001876	5.54	3936.16	942.90	0.48
Sunset	43999	50-Yr	48000.00	2183.00	2193.40	2191.08	2194.31	0.001943	7.64	6284.03	953.07	0.52
Sunset	43999	100-Yr	70000.00	2183.00	2194.97	2192.34	2196.23	0.002040	8.99	7785.96	957.95	0.56
Sunset	43499	10-Yr	21800.00	2181.00	2189.73	2188.38	2190.31	0.002511	6.09	3580.41	925.42	0.55
Sunset	43499	50-Yr	48000.00	2181.00	2192.16	2190.25	2193.21	0.002426	8.21	5847.96	940.45	0.58
Sunset	43499	100-Yr	70000.00	2181.00	2193.58	2191.52	2195.05	0.002629	9.75	7181.63	947.27	0.62
Sunset	42999	10-Yr	21800.00	2180.00	2186.52	2186.52	2188.06	0.009007	9.96	2189.34	702.32	0.99
Sunset	42999	50-Yr	48000.00	2180.00	2188.86	2188.86	2191.08	0.007943	11.95	4015.23	890.28	0.99
Sunset	42999	100-Yr	70000.00	2180.00	2190.49	2190.15	2193.03	0.006116	12.79	5473.12	900.56	0.91
Sunset	42499	10-Yr	21800.00	2175.00	2184.93	2182.00	2185.41	0.001584	5.57	3910.74	812.56	0.45
Sunset	42499	50-Yr	48000.00	2175.00	2187.98	2184.90	2188.83	0.001573	7.40	6482.16	873.77	0.48
Sunset	42499	100-Yr	70000.00	2175.00	2190.18	2186.28	2191.23	0.001507	8.25	8485.38	1482.34	0.48
Sunset	41999	10-Yr	21800.00	2176.00	2184.51	2181.49	2184.75	0.000904	3.92	5556.70	1292.37	0.33
Sunset	41999	50-Yr	48000.00	2176.00	2187.85	2183.55	2188.20	0.000652	4.77	10069.14	1366.50	0.31
Sunset	41999	100-Yr	70000.00	2176.00	2190.18	2184.73	2190.62	0.000557	5.28	13265.44	1674.49	0.30
Sunset	41499	10-Yr	21800.00	2175.00	2183.58	2181.79	2184.09	0.001945	5.68	3835.68	904.71	0.49
Sunset	41499	50-Yr	48000.00	2175.00	2186.97	2183.80	2187.70	0.001451	6.84	7016.18	1002.03	0.46
Sunset	41499	100-Yr	70000.00	2175.00	2189.35	2185.08	2190.16	0.001389	7.24	9663.21	1559.94	0.45
Sunset	40999	10-Yr	21800.00	2174.00	2182.74	2180.28	2183.22	0.001532	5.58	3906.47	789.41	0.44
Sunset	40999	50-Yr	48000.00	2174.00	2186.21	2182.66	2186.97	0.001453	7.00	6856.86	1017.77	0.46
Sunset	40999	100-Yr	70000.00	2174.00	2188.59	2184.13	2189.47	0.001331	7.53	9294.77	1351.79	0.45
Sunset	40499	10-Yr	21800.00	2172.00	2181.22	2179.64	2182.17	0.002771	7.78	2800.52	657.05	0.60
Sunset	40499	50-Yr	48000.00	2172.00	2183.38	2182.35	2185.64	0.004519	12.05	3983.94	712.47	0.80
Sunset	40499	100-Yr	70000.00	2172.00	2185.33	2184.61	2188.01	0.006971	13.13	5330.00	1094.76	0.97
Sunset	39999	10-Yr	21800.00	2171.00	2179.42	2178.70	2180.34	0.004963	7.72	2824.02	847.92	0.75
Sunset	39999	50-Yr	48000.00	2171.00	2182.04	2180.77	2183.37	0.003526	9.25	5189.68	924.04	0.69
Sunset	39999	100-Yr	70000.00	2171.00	2184.07	2182.07	2185.60	0.002721	9.91	7064.61	1134.82	0.63
Sunset	39399	10-Yr	21800.00	2168.00	2177.34	2175.80	2177.95	0.003051	6.29	3463.14	857.00	0.53
Sunset	39399	50-Yr	48000.00	2168.00	2180.52	2177.80	2181.53	0.002436	8.04	5967.40	868.79	0.51
Sunset	39399	100-Yr	70000.00	2168.00	2182.81	2179.21	2184.07	0.002165	9.01	7768.16	1034.61	0.51

4RTSUN FEMA PROPOSED CONDITION (INTERIM) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPINT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	38909	10-Yr	21800.00	2168.00	2176.20	2174.18	2176.67	0.002121	5.60	4023.09	880.24	0.45
Sunset	38909	50-Yr	48000.00	2168.00	2179.78	2176.22	2180.50	0.001570	6.93	7246.50	909.22	0.42
Sunset	38909	100-Yr	70000.00	2168.00	2182.21	2177.56	2183.11	0.001413	7.76	9477.44	967.97	0.42
Sunset	38409	10-Yr	21800.00	2168.00	2175.32	2172.77	2175.74	0.001589	5.23	4166.37	763.75	0.39
Sunset	38409	50-Yr	48000.00	2168.00	2179.04	2174.85	2179.76	0.001379	6.82	7040.71	834.10	0.40
Sunset	38409	100-Yr	70000.00	2168.00	2181.47	2176.28	2182.42	0.001325	7.83	9009.86	903.09	0.41
Sunset	37929	10-Yr	21800.00	2166.00	2174.64	2171.40	2175.06	0.001285	5.22	4173.63	662.38	0.36
Sunset	37929	50-Yr	48000.00	2166.00	2178.25	2173.76	2179.08	0.001407	7.32	6630.18	802.44	0.41
Sunset	37929	100-Yr	70000.00	2166.00	2180.60	2175.35	2181.73	0.001467	8.57	8373.77	882.06	0.43
Sunset	37509	10-Yr	21800.00	2166.00	2174.01	2171.06	2174.48	0.001478	5.49	4093.99	1126.33	0.39
Sunset	37509	50-Yr	48000.00	2166.00	2177.61	2173.51	2178.46	0.001513	7.51	6679.28	1183.38	0.42
Sunset	37509	100-Yr	70000.00	2166.00	2179.93	2175.09	2181.09	0.001567	8.78	8352.85	1212.38	0.45
Sunset	36859	10-Yr	21800.00	2164.00	2172.62	2170.20	2173.31	0.002156	6.71	3524.71	1286.81	0.47
Sunset	36859	50-Yr	48000.00	2164.00	2176.25	2173.14	2177.34	0.001977	8.71	6437.65	1312.85	0.49
Sunset	36859	100-Yr	70000.00	2164.00	2178.57	2174.81	2179.95	0.001959	9.97	8368.88	1353.36	0.50
Sunset	36439	10-Yr	21800.00	2162.00	2171.20	2169.40	2172.16	0.003342	7.88	2793.86	771.56	0.58
Sunset	36439	50-Yr	48000.00	2162.00	2174.80	2172.61	2176.29	0.002891	10.07	5335.94	1398.68	0.58
Sunset	36439	100-Yr	70000.00	2162.00	2177.15	2174.45	2178.94	0.002681	11.21	7102.78	1403.98	0.58
Sunset	36049	10-Yr	21800.00	2162.00	2170.19	2167.76	2171.02	0.002431	7.29	2991.61	1030.55	0.50
Sunset	36049	50-Yr	48000.00	2162.00	2173.47	2170.71	2175.12	0.002928	10.43	4913.32	1506.63	0.59
Sunset	36049	100-Yr	70000.00	2162.00	2175.49	2173.02	2177.73	0.003178	12.28	6209.23	1517.79	0.63
Sunset	35639	10-Yr	21800.00	2160.00	2168.80	2167.11	2169.80	0.003598	8.03	2739.53	1551.71	0.60
Sunset	35639	50-Yr	48000.00	2160.00	2171.74	2170.00	2173.66	0.004158	11.26	4542.20	1699.92	0.68
Sunset	35639	100-Yr	70000.00	2160.00	2173.71	2172.12	2176.18	0.004303	12.92	5865.07	1721.05	0.72
Sunset	35095	10-Yr	21800.00	2158.00	2166.96	2165.42	2167.78	0.003624	7.26	3003.40	1659.56	0.58
Sunset	35095	50-Yr	48000.00	2158.00	2169.86	2167.86	2171.37	0.003833	9.87	4865.52	1720.09	0.64
Sunset	35095	100-Yr	70000.00	2158.00	2171.80	2169.55	2173.78	0.004023	11.28	6207.09	2520.71	0.68
Sunset	34808	10-Yr	21800.00	2158.00	2164.23	2164.23	2165.96	0.011841	10.58	2061.44	592.54	1.00
Sunset	34808	50-Yr	48000.00	2158.00	2166.66	2166.66	2169.56	0.009914	13.67	3511.19	599.48	1.00
Sunset	34808	100-Yr	70000.00	2158.00	2168.80	2168.34	2172.10	0.007546	14.58	4801.57	1908.37	0.91
Sunset	34568	10-Yr	21800.00	2157.92	2163.17	2161.60	2164.01	0.003486	7.38	2952.76	581.57	0.58
Sunset	34568	50-Yr	48000.00	2157.92	2166.26	2164.06	2167.84	0.003502	10.07	4766.64	589.25	0.62
Sunset	34568	100-Yr	70000.00	2157.92	2168.54	2165.77	2170.58	0.003298	11.45	6114.08	1179.90	0.63
Sunset	34556	10-Yr	21800.00	2157.92	2163.09	2161.60	2163.96	0.003634	7.48	2915.38	581.29	0.59
Sunset	34556	50-Yr	48000.00	2157.92	2166.19	2164.05	2167.79	0.003596	10.15	4728.50	589.21	0.63
Sunset	34556	100-Yr	70000.00	2157.92	2168.47	2165.78	2170.53	0.003362	11.52	6079.01	594.56	0.63
Sunset	34529		Bridge									
Sunset	34502	10-Yr	21800.00	2155.79	2161.36	2160.55	2162.53	0.003056	8.70	2506.59	579.04	0.74
Sunset	34502	50-Yr	48000.00	2155.79	2164.25	2163.04	2166.29	0.002721	11.44	4194.18	586.25	0.75
Sunset	34502	100-Yr	70000.00	2155.79	2166.31	2164.75	2168.91	0.002523	12.96	5403.03	590.98	0.76
Sunset	34494	10-Yr	21800.00	2155.79	2160.57	2160.57	2162.32	0.005899	10.61	2054.16	577.03	0.99
Sunset	34494	50-Yr	48000.00	2155.79	2163.04	2163.04	2165.99	0.004997	13.77	3485.90	583.28	0.99
Sunset	34494	100-Yr	70000.00	2155.79	2164.75	2164.75	2168.53	0.004643	15.61	4485.16	587.39	1.00
Sunset	34294	10-Yr	21800.00	2146.87	2155.30	2153.72	2156.16	0.001797	7.45	2925.62	570.91	0.58
Sunset	34294	50-Yr	48000.00	2146.87	2157.90	2156.20	2159.73	0.002240	10.86	4419.96	576.35	0.69
Sunset	34294	100-Yr	70000.00	2146.87	2159.39	2157.91	2162.12	0.002656	13.25	5282.73	579.66	0.77
Sunset	34054	10-Yr	21800.00	2146.44	2154.52	2153.57	2155.61	0.002766	8.36	2607.02	592.03	0.70
Sunset	34054	50-Yr	48000.00	2146.44	2157.16	2156.12	2159.11	0.002976	11.19	4291.17	664.40	0.78
Sunset	34054	100-Yr	70000.00	2146.44	2158.77	2157.70	2161.41	0.003054	13.06	5359.50	669.57	0.81
Sunset	33594	10-Yr	21800.00	2145.96	2153.11	2152.33	2154.25	0.003105	8.58	2539.82	1274.47	0.74
Sunset	33594	50-Yr	48000.00	2145.96	2155.72	2154.84	2157.74	0.002951	11.49	4311.14	1410.33	0.78
Sunset	33594	100-Yr	70000.00	2145.96	2157.50	2156.47	2160.05	0.002780	12.99	5631.49	1444.37	0.78
Sunset	33332	10-Yr	21800.00	2145.72	2152.44	2151.46	2153.47	0.002650	8.14	2677.31	1229.10	0.69
Sunset	33332	50-Yr	48000.00	2145.72	2155.09	2153.84	2156.97	0.002611	11.04	4443.47	1338.87	0.74
Sunset	33332	100-Yr	70000.00	2145.72	2156.93	2155.57	2159.32	0.002481	12.54	5770.92	1346.91	0.75
Sunset	33162	10-Yr	21800.00	2145.21	2151.04	2151.04	2152.75	0.006108	10.47	2081.60	1171.82	1.00
Sunset	33162	50-Yr	48000.00	2145.21	2153.42	2153.42	2156.27	0.005120	13.56	3545.09	1205.64	1.00
Sunset	33162	100-Yr	70000.00	2145.21	2155.17	2155.17	2158.66	0.004445	15.05	4747.74	1287.87	0.97
Sunset	32680	10-Yr	21800.00	2143.52	2149.82	2148.44	2150.69	0.001979	7.47	2918.87	989.90	0.60
Sunset	32680	50-Yr	48000.00	2143.52	2152.77	2150.79	2154.37	0.001952	10.15	4739.36	1021.17	0.65
Sunset	32680	100-Yr	70000.00	2143.52	2154.65	2152.46	2156.83	0.002002	11.86	5941.79	1112.01	0.68
Sunset	32153	10-Yr	21800.00	2142.51	2148.80	2147.29	2149.67	0.001882	7.50	2906.04	1283.01	0.59
Sunset	32153	50-Yr	48000.00	2142.51	2151.42	2149.77	2153.22	0.002364	10.78	4452.25	1326.51	0.71

4RTSUN FEMA PROPOSED CONDITION (INTERIM) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPINT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	32153	100-Yr	70000.00	2142.51	2153.05	2151.55	2155.59	0.002620	12.81	5465.57	1347.60	0.77
Sunset	31655	10-Yr	21800.00	2141.12	2146.40	2146.36	2148.06	0.005873	10.34	2107.80	1667.82	0.98
Sunset	31655	50-Yr	48000.00	2141.12	2149.09	2148.71	2151.61	0.004191	12.76	3775.04	1725.43	0.91
Sunset	31655	100-Yr	70000.00	2141.12	2151.26	2150.38	2154.12	0.003204	13.62	5201.07	1774.06	0.84
Sunset	31182	10-Yr	21800.00	2139.64	2145.72	2144.02	2146.48	0.001608	7.01	3111.40	1851.19	0.55
Sunset	31182	50-Yr	48000.00	2139.64	2148.54	2146.39	2150.06	0.001806	9.90	4848.55	1884.13	0.62
Sunset	31182	100-Yr	70000.00	2139.64	2150.87	2148.04	2152.79	0.001635	11.13	6289.89	1913.03	0.62
Sunset	30846	10-Yr	21800.00	2138.32	2143.72	2143.72	2145.44	0.006110	10.54	2068.88	1964.34	1.00
Sunset	30846	50-Yr	48000.00	2138.32	2147.73	2146.08	2149.38	0.002214	10.32	4653.30	2058.18	0.68
Sunset	30846	100-Yr	70000.00	2138.32	2150.33	2147.65	2152.22	0.001696	11.02	6351.66	2201.63	0.62
Sunset	30571	10-Yr	21800.00	2135.91	2143.79	2141.41	2144.35	0.001038	6.00	3634.09	1988.61	0.45
Sunset	30571	50-Yr	48000.00	2135.91	2147.91	2143.71	2148.81	0.000810	7.57	6337.27	2252.98	0.43
Sunset	30571	100-Yr	70000.00	2135.91	2150.53	2145.33	2151.70	0.000781	8.67	8074.72	2405.90	0.44
Sunset	30211	10-Yr	21800.00	2134.31	2143.47	2140.85	2143.99	0.000919	5.80	3757.17	1835.11	0.42
Sunset	30211	50-Yr	48000.00	2134.31	2147.67	2143.22	2148.51	0.000740	7.40	6489.46	1947.08	0.41
Sunset	30211	100-Yr	70000.00	2134.31	2150.29	2144.84	2151.41	0.000728	8.52	8213.72	2037.29	0.43
Sunset	29689	10-Yr	21800.00	2133.83	2142.47	2139.88	2143.40	0.001251	7.70	2831.87	1258.30	0.51
Sunset	29689	50-Yr	48000.00	2133.83	2145.70	2143.01	2147.78	0.002113	11.58	4145.45	1346.63	0.68
Sunset	29689	100-Yr	70000.00	2133.83	2147.74	2145.70	2150.61	0.002387	13.59	5150.77	1568.14	0.75
Sunset	29333	10-Yr	21800.00	2133.19	2141.65	2140.02	2142.80	0.002135	8.60	2534.75	1221.52	0.64
Sunset	29333	50-Yr	48000.00	2133.19	2144.48	2143.14	2146.88	0.002865	12.44	3859.65	1462.02	0.78
Sunset	29333	100-Yr	70000.00	2133.19	2146.32	2145.41	2149.56	0.003410	14.46	4841.29	1576.17	0.87
Sunset	29145	10-Yr	21800.00	2133.23	2141.40	2139.84	2142.35	0.002064	7.83	2784.93	1393.82	0.62
Sunset	29145	50-Yr	48000.00	2133.23	2144.53	2142.60	2146.20	0.002109	10.37	4626.74	1614.66	0.67
Sunset	29145	100-Yr	70000.00	2133.23	2146.57	2144.41	2148.76	0.002039	11.87	5896.91	1708.95	0.68
Sunset	28850	10-Yr	21800.00	2133.13	2140.93	2139.33	2141.75	0.001749	7.27	2996.61	1428.38	0.57
Sunset	28850	50-Yr	48000.00	2133.13	2144.10	2141.74	2145.59	0.001695	9.82	4889.10	1573.23	0.61
Sunset	28850	100-Yr	70000.00	2133.13	2146.12	2143.42	2148.16	0.001737	11.45	6111.52	1595.29	0.64
Sunset	28513	10-Yr	21800.00	2132.91	2140.70	2138.25	2141.23	0.000977	5.88	3708.24	1288.65	0.44
Sunset	28513	50-Yr	48000.00	2132.91	2143.97	2140.50	2145.01	0.001050	8.19	5863.17	1344.70	0.48
Sunset	28513	100-Yr	70000.00	2132.91	2146.07	2142.09	2147.52	0.001110	9.64	7263.84	1455.13	0.52
Sunset	28332	10-Yr	21800.00	2132.32	2140.64	2137.66	2141.05	0.000678	5.13	4249.56	1046.63	0.37
Sunset	28332	50-Yr	48000.00	2132.32	2143.96	2139.84	2144.77	0.000825	7.22	6647.15	1132.94	0.43
Sunset	28332	100-Yr	70000.00	2132.32	2146.13	2141.37	2147.24	0.000844	8.44	8296.20	1144.04	0.45
Sunset	28037	10-Yr	21800.00	2131.16	2140.53	2137.26	2140.84	0.000550	4.50	4847.93	827.73	0.33
Sunset	28037	50-Yr	48000.00	2131.16	2143.90	2139.38	2144.51	0.000592	6.27	7652.48	835.44	0.37
Sunset	28037	100-Yr	70000.00	2131.16	2146.11	2140.70	2146.95	0.000633	7.35	9520.16	860.10	0.39
Sunset	27481	10-Yr	21800.00	2130.71	2139.80	2137.97	2140.36	0.001334	6.00	3630.49	784.07	0.49
Sunset	27481	50-Yr	48000.00	2130.71	2143.13	2140.03	2144.05	0.001074	7.68	6252.17	791.32	0.48
Sunset	27481	100-Yr	70000.00	2130.71	2145.26	2141.43	2146.46	0.001040	8.81	7941.07	795.60	0.49
Sunset	27120	10-Yr	21800.00	2130.71	2139.47	2137.04	2139.93	0.000927	5.46	3989.20	757.54	0.42
Sunset	27120	50-Yr	48000.00	2130.71	2142.84	2139.21	2143.67	0.000874	7.33	6551.36	764.27	0.44
Sunset	27120	100-Yr	70000.00	2130.71	2144.96	2140.66	2146.10	0.000898	8.56	8175.56	768.84	0.46
Sunset	27119	10-Yr	21800.00	2130.58	2139.52	2136.59	2139.91	0.000707	5.04	4327.12	758.13	0.37
Sunset	27119	50-Yr	48000.00	2130.58	2142.89	2138.78	2143.65	0.000737	6.96	6897.66	764.75	0.41
Sunset	27119	100-Yr	70000.00	2130.58	2145.02	2140.22	2146.07	0.000781	8.21	8528.11	769.16	0.43
Sunset	27054		Bridge									
Sunset	26989	10-Yr	21800.00	2130.16	2139.18	2136.97	2139.69	0.001109	5.75	3794.12	760.48	0.45
Sunset	26989	50-Yr	48000.00	2130.16	2142.49	2139.13	2143.38	0.000997	7.60	6319.95	766.10	0.47
Sunset	26989	100-Yr	70000.00	2130.16	2144.53	2140.57	2145.75	0.001021	8.87	7890.21	769.69	0.49
Sunset	26977	10-Yr	21800.00	2130.27	2139.12	2137.04	2139.67	0.001230	5.94	3667.12	756.51	0.48
Sunset	26977	50-Yr	48000.00	2130.27	2142.42	2139.24	2143.36	0.001066	7.76	6181.78	764.54	0.48
Sunset	26977	100-Yr	70000.00	2130.27	2144.46	2140.68	2145.73	0.001081	9.04	7743.33	769.12	0.50
Sunset	26837	10-Yr	21800.00	2130.30	2139.05	2136.22	2139.46	0.000772	5.16	4222.81	759.16	0.39
Sunset	26837	50-Yr	48000.00	2130.30	2142.37	2138.45	2143.15	0.000795	7.11	6754.51	765.93	0.42
Sunset	26837	100-Yr	70000.00	2130.30	2144.41	2139.87	2145.51	0.000852	8.41	8321.10	770.09	0.45

4RTSUN FEMA PROPOSED CONDITION (INTERIM) RESULTS, SCR

HEC-RAS Plan: 500YrINTAlt-2 River: Santa Cruz Reach: Sunset Profile: 500-Yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	500-Yr	93000.00	2255.61	2278.15	2278.06	2282.67	0.002068	17.81	7390.14	1196.25	0.74
Sunset	68588	500-Yr	93000.00	2253.49	2278.58	2275.66	2281.58	0.001322	14.92	8810.93	1192.16	0.60
Sunset	68087	500-Yr	93000.00	2250.70	2278.76	2274.81	2280.76	0.000834	12.36	10645.00	1333.25	0.49
Sunset	67552	500-Yr	93000.00	2250.55	2274.32	2274.29	2279.69	0.002522	19.13	6117.61	1254.83	0.82
Sunset	67038	500-Yr	93000.00	2249.72	2273.90	2272.58	2278.20	0.002068	17.52	6817.96	2013.76	0.75
Sunset	66600	500-Yr	93000.00	2249.10	2273.95	2271.13	2276.91	0.002013	14.71	7823.82	2462.98	0.62
Sunset	66255	500-Yr	93000.00	2248.50	2271.16	2268.24	2276.02	0.002074	17.77	5468.57	961.45	0.75
Sunset	65763	500-Yr	93000.00	2247.09	2268.79	2268.79	2274.67	0.003113	19.77	5359.30	1679.76	0.89
Sunset	65255	500-Yr	93000.00	2246.28	2266.34	2266.34	2271.33	0.004480	18.70	6163.70	906.30	0.88
Sunset	64585	500-Yr	93000.00	2244.01	2264.40	2264.40	2268.51	0.002569	17.16	7313.85	1099.54	0.81
Sunset	64087	500-Yr	93000.00	2242.46	2262.87	2262.87	2266.66	0.002568	16.91	8519.65	1246.53	0.80
Sunset	63622	500-Yr	93000.00	2241.64	2262.95	2261.12	2265.28	0.001467	13.70	11125.59	1412.96	0.62
Sunset	62978	500-Yr	93000.00	2240.25	2261.36	2259.65	2264.21	0.001645	14.73	9619.33	1170.95	0.66
Sunset	62453	500-Yr	93000.00	2239.00	2257.97	2256.02	2262.87	0.002898	18.50	6823.73	935.51	0.86
Sunset	61960	500-Yr	93000.00	2234.74	2257.01	2256.98	2261.40	0.002477	17.76	7526.40	983.79	0.81
Sunset	61436	500-Yr	93000.00	2233.28	2258.06	2255.83	2259.79	0.001042	12.15	14059.18	1854.52	0.53
Sunset	61000	500-Yr	93000.00	2229.63	2254.88	2254.86	2258.93	0.002300	16.77	7934.30	1392.28	0.77
Sunset	60523	500-Yr	93000.00	2229.89	2254.99	2253.84	2257.58	0.001643	14.03	10639.78	1559.05	0.65
Sunset	60070	500-Yr	93000.00	2228.19	2254.70	2252.37	2256.50	0.002163	12.08	11965.73	1687.52	0.54
Sunset	59588	500-Yr	93000.00	2226.99	2254.13	2249.45	2255.84	0.000923	11.35	12995.01	1727.22	0.50
Sunset	59088	500-Yr	93000.00	2226.21	2253.91	2249.24	2255.38	0.000769	11.01	14165.90	1453.10	0.46
Sunset	58533	500-Yr	93000.00	2224.44	2248.80	2248.80	2254.23	0.002713	19.08	6029.85	790.18	0.85
Sunset	57982	500-Yr	93000.00	2224.20	2248.59	2246.10	2250.61	0.002982	12.57	9786.33	1160.45	0.56
Sunset	57561	500-Yr	93000.00	2222.54	2246.59	2243.91	2249.60	0.001566	14.45	8299.59	916.40	0.64
Sunset	57165	500-Yr	93000.00	2221.13	2246.79	2242.47	2248.81	0.001001	12.03	10537.69	1094.21	0.52
Sunset	56836	500-Yr	93000.00	2221.00	2245.48	2241.51	2248.35	0.001278	14.19	8980.60	990.13	0.59
Sunset	56608	500-Yr	93000.00	2221.00	2246.31	2239.54	2247.19	0.000451	8.88	17949.54	2541.34	0.36
Sunset	56526 El Camino Del Ce		Bridge									
Sunset	56440	500-Yr	93000.00	2220.50	2244.33	2240.71	2245.31	0.000752	9.48	15793.50	2317.21	0.38
Sunset	55999	500-Yr	93000.00	2217.00	2239.00	2239.00	2243.59	0.003864	17.70	6104.91	897.59	0.82
Sunset	55499	500-Yr	93000.00	2216.00	2236.80	2236.80	2240.45	0.003430	16.25	7302.58	1231.94	0.77
Sunset	54999	500-Yr	93000.00	2214.00	2235.29	2234.64	2238.54	0.003137	15.58	8369.12	1214.93	0.74
Sunset	54499	500-Yr	93000.00	2213.00	2233.64	2232.99	2236.92	0.003294	15.87	8325.13	1085.21	0.76
Sunset	53999	500-Yr	93000.00	2211.00	2231.05	2230.44	2235.12	0.003598	16.65	6801.82	929.32	0.79
Sunset	53499	500-Yr	93000.00	2207.00	2230.19	2228.72	2233.03	0.003243	13.85	7827.89	1075.81	0.73
Sunset	52999	500-Yr	93000.00	2205.00	2229.88	2226.61	2231.31	0.002023	10.31	10073.91	1197.82	0.57
Sunset	52499	500-Yr	93000.00	2204.00	2227.05	2225.86	2229.67	0.004528	13.80	7304.75	1036.36	0.83
Sunset	51999	500-Yr	93000.00	2203.00	2225.86	2222.80	2227.75	0.002477	12.20	8832.51	1133.59	0.64
Sunset	51499	500-Yr	93000.00	2201.00	2225.27	2221.79	2226.64	0.001516	10.02	10778.58	1265.67	0.51
Sunset	51057	500-Yr	93000.00	2199.00	2224.44	2220.96	2225.90	0.001679	11.01	10355.75	1076.90	0.54
Sunset	51000 Proposed Sunset		Bridge									
Sunset	50945	500-Yr	93000.00	2199.00	2222.65	2220.64	2224.77	0.002507	13.16	8755.45	1085.17	0.66
Sunset	50500	500-Yr	93000.00	2198.00	2221.49	2219.73	2223.44	0.003318	11.91	8622.43	1334.72	0.72
Sunset	49996	500-Yr	93000.00	2197.00	2220.36	2217.39	2221.88	0.002163	10.43	9827.84	1318.48	0.59
Sunset	49501	500-Yr	93000.00	2197.00	2217.39	2216.61	2220.23	0.004713	13.62	6957.90	1027.74	0.84
Sunset	48999	500-Yr	93000.00	2196.00	2216.57	2213.80	2218.34	0.002220	10.73	8817.67	1072.04	0.60
Sunset	48499	500-Yr	93000.00	2195.00	2215.02	2213.39	2217.05	0.002887	11.82	8669.49	1212.27	0.68
Sunset	47499	500-Yr	107400.00	2193.11	2214.21	2206.02	2215.44	0.000853	9.07	12811.81	1149.46	0.40
Sunset	46999	500-Yr	107400.00	2191.00	2208.57	2208.57	2214.18	0.004400	19.31	6275.73	806.18	0.89
Sunset	46499	500-Yr	107400.00	2189.00	2206.81	2206.81	2211.55	0.004583	17.74	6524.58	787.68	0.89
Sunset	45999	500-Yr	107400.00	2189.00	2203.11	2203.11	2207.25	0.005452	16.44	6791.39	882.93	0.93
Sunset	45499	500-Yr	107400.00	2187.00	2201.32	2199.67	2203.97	0.003570	13.07	8266.64	944.05	0.75
Sunset	44999	500-Yr	107400.00	2186.00	2199.75	2197.97	2202.15	0.003386	12.44	8633.09	953.01	0.73
Sunset	44499	500-Yr	107400.00	2184.00	2198.20	2196.21	2200.49	0.003142	12.12	8858.00	959.72	0.70
Sunset	43999	500-Yr	107400.00	2183.00	2197.28	2194.11	2199.07	0.002106	10.74	9999.75	963.48	0.59
Sunset	43499	500-Yr	107400.00	2181.00	2195.77	2193.38	2197.85	0.002682	11.59	9265.94	955.84	0.66
Sunset	42999	500-Yr	107400.00	2180.00	2192.58	2192.05	2195.88	0.005416	14.59	7363.67	906.56	0.90
Sunset	42499	500-Yr	107400.00	2175.00	2192.29	2188.39	2193.90	0.001854	10.19	10534.98	1635.41	0.55
Sunset	41999	500-Yr	107400.00	2176.00	2192.43	2186.26	2193.10	0.000657	6.57	16365.87	1843.12	0.34
Sunset	41499	500-Yr	107400.00	2175.00	2191.37	2187.06	2192.57	0.001529	8.79	12361.50	1772.97	0.49
Sunset	40999	500-Yr	107400.00	2174.00	2190.28	2186.34	2191.73	0.001746	9.64	11182.61	1480.91	0.53
Sunset	40499	500-Yr	107400.00	2172.00	2188.24	2186.97	2190.40	0.003882	12.16	9667.86	1330.92	0.76
Sunset	39999	500-Yr	107400.00	2171.00	2187.32	2183.93	2188.93	0.001876	10.31	11191.69	1212.90	0.56
Sunset	39399	500-Yr	107400.00	2168.00	2186.13	2181.31	2187.78	0.001928	10.31	10465.59	1196.13	0.50
Sunset	38909	500-Yr	107400.00	2168.00	2185.71	2179.53	2186.88	0.001276	8.90	13010.93	1101.67	0.41
Sunset	38409	500-Yr	107400.00	2168.00	2184.94	2178.42	2186.23	0.001272	9.15	12085.48	1024.42	0.42
Sunset	37929	500-Yr	107400.00	2166.00	2183.93	2177.77	2185.53	0.001531	10.23	10916.58	959.49	0.46
Sunset	37509	500-Yr	107400.00	2166.00	2183.19	2177.39	2184.85	0.001651	10.51	10717.78	1270.82	0.48
Sunset	36859	500-Yr	107400.00	2164.00	2181.88	2177.11	2183.70	0.001927	11.59	11248.66	1413.76	0.52
Sunset	36439	500-Yr	107400.00	2162.00	2180.42	2176.84	2182.70	0.002582	12.82	9576.31	1552.41	0.59
Sunset	36049	500-Yr	107400.00	2162.00	2178.10	2175.75	2181.37	0.003666	14.99	7881.46	1540.45	0.70
Sunset	35639	500-Yr	107400.00	2160.00	2176.43	2174.70	2179.72	0.004279	15.07	7981.50	1903.70	0.74
Sunset	35095	500-Yr	107400.00	2158.00	2175.16	2172.12	2177.45	0.003116	12.22	8998.92	3846.09	0.63
Sunset	34808	500-Yr	107400.00	2158.00	2173.07	2170.84	2176.31	0.004301	14.46	7485.40	2680.81	0.74
Sunset	34568	500-Yr	107400.00	2157.92	2174.44	2168.33	2175.13	0.000933	7.64	19101.10	3185.41	0.35
Sunset	34556	500-Yr	107400.00	2157.92	2171.67	2168.32	2174.47	0.003249	13.43	7996.99	694.34	0.65
Sunset	34529 Ina Road (LOMR)		Bridge									
Sunset	34502	500-Yr	107400.00	2155.79	2169.34	2167.30	2172.79	0.002323	14.91	7204.29	1779.71	0.76
Sunset	34494	500-Yr	107400.00	2155.79	2167.27	2167.27	2172.29	0.004282	17.98	5971.85	593.19	1.00
Sunset	34294	500-Yr	107400.00	2146.87	2161.44	2160.46	2165.71	0.003220	16.59	6473.85	584.36	0.88
Sunset	34054	500-Yr	107400.00	2146.44	2160.99	2160.03	2164.80	0.003204	15.66	6858.53	675.12	0.87
Sunset	33594	500-Yr	107400.00	2145.96	2159.90	2158.78	2163.34	0.002753	15.19	7438.96	1551.48	0.81
Sunset	33332	500-Yr	107400.00	2145.72	2159.27	2157.88	2162.63	0.002589	14.94	7472.27	1401.49	0.79
Sunset	33162	500-Yr	107400.00	2145.21	2157.91	2157.54	2162.04	0.003552	16.51	6748.67	1301.59	0.91
Sunset	32680	500-Yr	107400.00	2143.52	2157.42	2154.92	2160.46	0.002013	14.03	7748.72	1304.35	0.71
Sunset	32153	500-Yr	107400.00	2142.51	2155.77	2154.03	2159.22	0.002580	14.90	7209.08	1381.42	0.79
Sunset	31655	500-Yr	107400.00	2141.12	2154.70	2152.82	2157.95	0.002321	14.57	7544.97	1867.72	0.75

4RTSUN FEMA PROPOSED CONDITION (INTERIM) RESULTS, SCR

HEC-RAS Plan: 500YrINTAlt-2 River: Santa Cruz Reach: Sunset Profile: 500-Yr (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	31182	500-Yr	107400.00	2139.64	2154.38	2150.50	2156.87	0.001446	12.65	8490.60	2059.96	0.61
Sunset	30846	500-Yr	107400.00	2138.32	2154.02	2150.04	2156.34	0.001384	12.23	8784.89	2380.37	0.59
Sunset	30571	500-Yr	107400.00	2135.91	2154.25	2147.67	2155.85	0.000765	10.16	10578.54	2485.50	0.45
Sunset	30211	500-Yr	107400.00	2134.31	2154.00	2147.19	2155.57	0.000727	10.05	10681.84	2319.03	0.44
Sunset	29689	500-Yr	107400.00	2133.83	2150.43	2148.77	2154.63	0.002979	16.46	6538.78	1754.33	0.85
Sunset	29333	500-Yr	107400.00	2133.19	2149.51	2148.41	2153.46	0.003161	15.94	6737.90	1839.84	0.87
Sunset	29145	500-Yr	107400.00	2133.23	2152.05	2146.88	2152.26	0.000156	3.89	31096.80	4033.43	0.20
Sunset	28850	500-Yr	107400.00	2133.13	2148.96	2145.91	2151.87	0.001816	13.69	7858.65	1915.33	0.68
Sunset	28513	500-Yr	107400.00	2132.91	2149.10	2144.47	2151.12	0.001131	11.45	9702.35	2263.27	0.54
Sunset	28332	500-Yr	107400.00	2132.32	2149.25	2143.76	2150.81	0.000855	10.04	10887.30	1945.90	0.47
Sunset	28037	500-Yr	107400.00	2131.16	2149.33	2142.76	2150.46	0.000665	8.54	12933.01	1745.74	0.41
Sunset	27481	500-Yr	107400.00	2130.71	2148.28	2143.48	2149.94	0.001050	10.34	10389.39	1169.11	0.51
Sunset	27120	500-Yr	107400.00	2130.71	2147.95	2142.79	2149.58	0.000936	10.24	10485.30	775.36	0.49
Sunset	27119	500-Yr	107400.00	2130.58	2148.02	2142.34	2149.54	0.000837	9.90	10846.72	775.97	0.47
Sunset	27054 Cortaro Road (LO		Bridge									
Sunset	26989	500-Yr	107400.00	2130.16	2147.40	2142.70	2149.15	0.001068	10.63	10103.48	774.62	0.52
Sunset	26977	500-Yr	107400.00	2130.27	2147.31	2142.81	2149.12	0.001120	10.80	9948.48	775.65	0.53
Sunset	26837	500-Yr	107400.00	2130.30	2147.27	2142.01	2148.88	0.000926	10.19	10561.26	798.46	0.49

4RTSUN FEMA PROPOSED FLOODWAY RESULTS (INTERIM), SCR

HEC-RAS Plan: INTPROPGRD-2FW River: Santa Cruz Reach: Sunset

Reach	River Sta	Profile	W.S. Elev	Prof Delta WS	E.G. Elev	Top Wdth Act	Q Left	Q Channel	Q Right	Enc Sta L	Ch Sta L	Ch Sta R	Enc Sta R
			(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)
Sunset	68977	100-Yr	2274.22		2278.25	263.16		60000.00			169.92	438.85	
Sunset	68977	FW1	2274.23	0.01	2278.26	263.17		60000.00		169.92	169.92	438.85	438.85
Sunset	68588	100-Yr	2273.88		2277.28	270.57		60000.00			158.92	439.44	
Sunset	68588	FW1	2273.89	0.01	2277.28	270.59		60000.00		158.92	158.92	439.44	439.44
Sunset	68087	100-Yr	2273.71		2276.27	312.99	3.83	59996.16			134.34	446.02	
Sunset	68087	FW1	2273.72	0.00	2276.27	305.40		60000.00		134.34	134.34	446.02	446.02
Sunset	67552	100-Yr	2271.44		2275.27	345.06	224.23	59775.77			385.77	657.56	
Sunset	67552	FW1	2271.44	0.00	2275.27	336.52	218.88	59781.12		315.00	385.77	657.56	657.56
Sunset	67038	100-Yr	2268.96		2273.87	257.28		60000.00			1255.68	1531.56	
Sunset	67038	FW1	2268.96	0.00	2273.87	257.31		60000.00		1255.68	1255.68	1531.56	1531.56
Sunset	66600	100-Yr	2267.85		2272.20	273.53		60000.00			1351.19	1661.67	
Sunset	66600	FW1	2267.86	0.00	2272.20	273.55		60000.00		1351.19	1351.19	1661.67	1661.67
Sunset	66255	100-Yr	2267.88		2271.00	341.09	61.52	59938.48			1378.58	1684.85	
Sunset	66255	FW1	2267.88	0.00	2271.00	341.12	61.86	59938.14		1320.00	1378.58	1684.85	1684.85
Sunset	65763	100-Yr	2265.15		2269.76	285.76		60000.00			1568.13	1878.02	
Sunset	65763	FW1	2265.15	0.00	2269.76	285.76		60000.00		1568.13	1568.13	1878.02	1878.02
Sunset	65255	100-Yr	2263.62		2267.79	304.85		60000.00			907.16	1244.55	
Sunset	65255	FW1	2263.62	0.00	2267.79	304.87		60000.00		907.16	907.16	1244.55	1244.55
Sunset	64585	100-Yr	2261.99		2265.47	340.23		60000.00			1182.20	1538.87	
Sunset	64585	FW1	2261.99	0.00	2265.47	340.23		60000.00		1182.20	1182.20	1538.87	1538.87
Sunset	64087	100-Yr	2259.78		2264.01	319.40		60000.00			944.22	1303.70	
Sunset	64087	FW1	2259.77	0.00	2264.01	319.39		60000.00		944.22	944.22	1303.70	1303.70
Sunset	63622	100-Yr	2258.90		2262.52	332.06		60000.00			1230.80	1599.17	
Sunset	63622	FW1	2258.89	0.00	2262.51	332.06		60000.00		1230.80	1230.80	1599.17	1599.17
Sunset	62978	100-Yr	2256.61		2260.70	318.11		60000.00			1030.19	1377.26	
Sunset	62978	FW1	2256.70	0.09	2260.73	318.34		60000.00		1030.19	1030.19	1377.26	1377.26
Sunset	62453	100-Yr	2255.09		2259.17	313.80		60000.00			844.61	1175.43	
Sunset	62453	FW1	2255.29	0.20	2259.24	313.66		60000.00		575.00	844.61	1175.43	1160.00
Sunset	61960	100-Yr	2254.49		2257.70	464.82	2797.68	57202.32			759.79	1084.65	
Sunset	61960	FW1	2254.71	0.22	2257.84	440.50	2619.31	57380.69		625.00	759.79	1084.65	1090.00
Sunset	61436	100-Yr	2253.20		2256.52	526.79	706.59	59293.42			1505.79	1861.37	
Sunset	61436	FW1	2253.46	0.27	2256.73	360.00	350.32	59649.68		1475.00	1505.79	1861.37	1835.00
Sunset	61000	100-Yr	2252.54		2255.49	456.85	424.27	59575.73			1172.91	1531.08	
Sunset	61000	FW1	2252.89	0.35	2255.76	345.00	66.52	59933.48		1165.00	1172.91	1531.08	1510.00
Sunset	60523	100-Yr	2251.16		2254.40	463.31	360.01	59639.99			1209.08	1605.77	
Sunset	60523	FW1	2251.49	0.33	2254.75	350.00		60000.00		1235.00	1209.08	1605.77	1585.00
Sunset	60070	100-Yr	2249.93		2252.79	580.39	2443.78	57556.22			1326.69	1729.88	
Sunset	60070	FW1	2250.28	0.36	2253.26	398.70	333.52	59666.48		1305.00	1326.69	1729.88	1720.00
Sunset	59588	100-Yr	2249.78		2251.43	862.67	4954.32	55045.69			1376.79	1819.79	
Sunset	59588	FW1	2249.85	0.07	2251.90	459.14	501.53	59498.48		1340.00	1376.79	1819.79	1830.00
Sunset	59088	100-Yr	2248.49		2250.72	650.80	4002.72	55997.29			1274.34	1650.65	
Sunset	59088	FW1	2248.84	0.36	2251.17	495.00	2415.77	57584.23		1120.00	1274.34	1650.65	1615.00
Sunset	58533	100-Yr	2245.07		2249.38	408.44	237.62	59762.38			707.97	1024.88	
Sunset	58533	FW1	2245.39	0.31	2249.87	264.34		60000.00		735.00	707.97	1024.88	1030.00
Sunset	57982	100-Yr	2244.30		2246.85	981.35	3566.95	56433.05			815.61	1192.65	
Sunset	57982	FW1	2244.33	0.03	2247.39	350.00	3.44	59996.55		815.00	815.61	1192.65	1165.00
Sunset	57561	100-Yr	2243.31		2245.77	396.43	212.04	59787.96			535.82	921.77	
Sunset	57561	FW1	2243.30	-0.01	2246.14	328.63		60000.00		570.00	535.82	921.77	915.00
Sunset	57165	100-Yr	2243.44		2245.04	944.82	2660.18	57339.82			676.77	1099.71	
Sunset	57165	FW1	2243.44	0.00	2245.31	398.02		60000.00		690.00	676.77	1099.71	1090.00
Sunset	56836	100-Yr	2242.64		2244.66	925.54	1678.66	58321.34			1114.62	1450.40	
Sunset	56836	FW1	2243.13	0.49	2244.97	646.92	2245.14	57754.86		800.00	1114.62	1450.40	1450.40
Sunset	56608	100-Yr	2243.05		2243.92	1882.57	4340.08	48935.75	6724.16		1427.22	1798.17	
Sunset	56608	FW1	2243.52	0.47	2244.30	1350.00	4845.93	48075.19	7078.88	1025.00	1427.22	1798.17	2375.00
Sunset	56526 El Camino Del CeBR U	100-Yr	2243.05		2243.92	972.59	1148.32	51253.51	7599.63		1427.22	1798.17	
Sunset	56526 El Camino Del CeBR U	FW1	2243.52	0.47	2244.30	609.08	1207.10	54582.29	4197.85	1025.00	1427.22	1798.17	2375.00
Sunset	56526 El Camino Del CeBR D	100-Yr	2242.13		2243.07	646.40	1230.46	51139.23	7631.77		1559.21	1896.04	
Sunset	56526 El Camino Del CeBR D	FW1	2243.07	0.94	2243.83	553.77	1294.58	54460.57	4232.07	1200.00	1559.21	1896.04	2575.00
Sunset	56440	100-Yr	2239.09		2241.17	1593.18	2521.91	55830.36	1647.73		1559.21	1896.04	
Sunset	56440	FW1	2239.56	0.48	2241.34	1374.19	3350.88	54113.13	2535.99	1200.00	1559.21	1896.04	2575.00
Sunset	55999	100-Yr	2235.68		2239.47	466.47	37.08	59299.04	663.88		1758.15	2100.07	
Sunset	55999	FW1	2236.26	0.58	2239.80	340.93		60000.00		1758.15	1758.15	2100.07	2100.07
Sunset	55499	100-Yr	2234.18		2237.16	817.81	299.78	57426.89	2273.33		1688.77	2049.92	
Sunset	55499	FW1	2234.80	0.62	2237.84	359.55		60000.00		1688.77	1688.77	2049.92	2049.92
Sunset	54999	100-Yr	2233.15		2235.47	1018.42	2614.29	54565.37	2820.34		1774.58	2140.37	

4RTSUN FEMA PROPOSED FLOODWAY RESULTS (INTERIM), SCR

HEC-RAS Plan: INTPROPGRD-2FW River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	W.S. Elev	Prof Delta WS	E.G. Elev	Top Wdth Act	Q Left	Q Channel	Q Right	Enc Sta L	Ch Sta L	Ch Sta R	Enc Sta R
			(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)
Sunset	54999	FW1	2233.69	0.55	2236.27	490.37	1666.95	58333.05		1650.00	1774.58	2140.37	2140.37
Sunset	54499	100-Yr	2230.00		2233.65	844.08	2027.51	56149.92	1822.58		1801.69	2154.32	
Sunset	54499	FW1	2229.98	-0.01	2234.33	472.26	452.45	59547.55		1650.00	1801.69	2154.32	2154.32
Sunset	53999	100-Yr	2228.99		2231.62	783.19	971.76	59028.23			1641.00	2041.06	
Sunset	53999	FW1	2229.59	0.60	2232.10	374.67		60000.00		1641.00	1641.00	2041.06	2041.06
Sunset	53499	100-Yr	2228.07		2230.04	948.69	933.28	59066.72			1144.91	1734.08	
Sunset	53499	FW1	2229.04	0.97	2230.73	568.69	2.64	59997.36		1144.00	1144.91	1734.08	1734.08
Sunset	52999	100-Yr	2227.49		2228.54	1019.03	13637.02	46362.98			798.52	1499.10	
Sunset	52999	FW1	2228.30	0.80	2229.57	769.13	6267.62	53732.38		700.00	798.52	1499.10	1499.10
Sunset	52499	100-Yr	2224.56		2226.75	837.32	16144.38	43855.62			753.71	1336.82	
Sunset	52499	FW1	2224.77	0.21	2227.66	765.05	8867.84	51132.16		525.00	753.71	1336.82	1336.82
Sunset	51999	100-Yr	2223.28		2224.66	806.81	19635.12	40364.88			827.39	1296.86	
Sunset	51999	FW1	2223.70	0.41	2225.12	703.82	18038.81	41961.19		550.00	827.39	1296.86	1296.86
Sunset	51499	100-Yr	2222.49		2223.60	1062.98	6818.50	53181.50			809.02	1522.22	
Sunset	51499	FW1	2223.02	0.53	2224.12	855.22	4982.04	55017.96		575.00	809.02	1522.22	1522.22
Sunset	51057	100-Yr	2221.61		2222.82	1024.89	17876.26	42123.74			890.95	1329.62	
Sunset	51057	FW1	2221.82	0.21	2223.28	667.07	14855.40	45144.60		642.00	890.95	1329.62	1329.62
Sunset	51000 Proposed Sunset BR U	100-Yr	2220.57		2222.54	652.44	14354.20	44807.25			890.95	1329.62	
Sunset	51000 Proposed Sunset BR U	FW1	2221.55	0.98	2223.18	645.64	15023.37	44976.62		642.00	890.95	1329.62	1329.62
Sunset	51000 Proposed Sunset BR D	100-Yr	2220.38		2222.30	619.20	14349.39	44812.06			745.13	1129.54	
Sunset	51000 Proposed Sunset BR D	FW1	2220.60	0.22	2222.50	612.20	14620.31	45379.69		495.00	745.13	1129.54	1129.54
Sunset	50945	100-Yr	2220.53		2222.03	953.19	16554.77	43445.23			745.13	1129.54	
Sunset	50945	FW1	2220.69	0.16	2222.44	633.62	14143.80	45856.20		495.00	745.13	1129.54	1129.54
Sunset	50500	100-Yr	2219.29		2220.80	1030.72	11700.57	48299.43			806.26	1525.37	
Sunset	50500	FW1	2219.37	0.09	2221.11	903.58	8588.61	51411.39		610.00	806.26	1525.37	1525.37
Sunset	49996	100-Yr	2218.07		2219.17	1021.75	9853.54	50146.46			765.88	1530.25	
Sunset	49996	FW1	2218.07	0.00	2219.31	933.76	7532.97	52467.03		570.00	765.88	1530.25	1530.25
Sunset	49501	100-Yr	2215.42		2217.52	881.72	471.96	59528.04			763.27	1640.65	
Sunset	49501	FW1	2215.44	0.02	2217.58	823.54		60000.00		763.27	763.27	1640.65	1640.65
Sunset	48999	100-Yr	2214.62		2215.78	913.57	476.02	59523.98			676.11	1571.76	
Sunset	48999	FW1	2214.62	0.00	2215.80	855.46		60000.00		676.11	676.11	1571.76	1571.76
Sunset	48499	100-Yr	2211.39		2214.02	985.87	1085.98	58914.02			965.34	1765.51	
Sunset	48499	FW1	2211.38	-0.01	2214.02	916.13	1048.11	58951.90		797.00	965.34	1765.51	1765.00
Sunset	47499	100-Yr	2209.95		2210.97	820.06	1438.45	68561.55			846.82	1636.25	
Sunset	47499	FW1	2209.94	-0.01	2210.98	767.94	1155.20	68844.80		700.00	846.82	1636.25	1636.00
Sunset	46999	100-Yr	2206.38		2209.95	663.72	329.31	69670.69			863.80	1231.28	
Sunset	46999	FW1	2206.37	-0.01	2209.95	593.71	294.52	69705.48		635.00	863.80	1231.28	1231.28
Sunset	46499	100-Yr	2203.07		2207.61	449.49		70000.00			700.59	1175.42	
Sunset	46499	FW1	2203.07	0.00	2207.61	449.09		70000.00		720.00	700.59	1175.42	1175.42
Sunset	45999	100-Yr	2200.41		2203.89	635.43		70000.00			705.28	1375.66	
Sunset	45999	FW1	2200.41	0.00	2203.89	635.43		70000.00		705.00	705.28	1375.66	1375.66
Sunset	45499	100-Yr	2199.25		2201.11	866.07		70000.00			594.38	1469.45	
Sunset	45499	FW1	2199.25	0.00	2201.11	866.08		70000.00		594.38	594.38	1469.45	1469.45
Sunset	44999	100-Yr	2197.60		2199.35	944.69		70000.00			610.96	1637.36	
Sunset	44999	FW1	2197.60	0.00	2199.35	944.69		70000.00		610.90	610.96	1637.36	1638.00
Sunset	44499	100-Yr	2195.94		2197.63	942.60		70000.00			1132.81	2134.38	
Sunset	44499	FW1	2195.94	0.00	2197.63	942.60		70000.00		1132.80	1132.81	2134.38	2135.00
Sunset	43999	100-Yr	2194.97		2196.23	957.95		70000.00			1190.04	2173.86	
Sunset	43999	FW1	2194.97	0.00	2196.23	957.95		70000.00		1190.00	1190.04	2173.86	2174.00
Sunset	43499	100-Yr	2193.58		2195.05	947.27		70000.00			1196.61	2216.98	
Sunset	43499	FW1	2193.58	0.00	2195.05	947.28		70000.00		1196.60	1196.61	2216.98	2217.00
Sunset	42999	100-Yr	2190.49		2193.03	900.56		70000.00			1179.96	2178.60	
Sunset	42999	FW1	2190.48	-0.01	2193.03	900.54		70000.00		1179.90	1179.96	2178.60	2179.00
Sunset	42499	100-Yr	2190.18		2191.23	940.93		70000.00			1352.45	2477.80	
Sunset	42499	FW1	2190.17	-0.01	2191.23	940.76		70000.00		1352.40	1352.45	2477.80	2478.00
Sunset	41999	100-Yr	2190.18		2190.62	1371.80		70000.00			1224.20	2601.33	
Sunset	41999	FW1	2190.17	-0.01	2190.61	1371.78		70000.00		1224.20	1224.20	2601.33	2601.33
Sunset	41499	100-Yr	2189.35		2190.16	1226.96		70000.00			631.50	1880.57	
Sunset	41499	FW1	2189.33	-0.01	2190.15	1226.73		70000.00		631.50	631.50	1880.57	1880.57
Sunset	40999	100-Yr	2188.59		2189.47	1074.48		70000.00			1129.21	2234.39	
Sunset	40999	FW1	2188.57	-0.02	2189.46	1074.15		70000.00		1129.00	1129.21	2234.39	2234.39
Sunset	40499	100-Yr	2185.33		2188.01	930.02		70000.00			811.03	1917.57	
Sunset	40499	FW1	2185.44	0.11	2188.01	934.78		70000.00		815.00	811.03	1917.57	1978.00
Sunset	39999	100-Yr	2184.07		2185.60	927.40		70000.00			1345.67	2297.81	
Sunset	39999	FW1	2184.42	0.35	2185.82	928.97		70000.00		1346.00	1345.67	2297.81	2298.00

4RTSUN FEMA PROPOSED FLOODWAY RESULTS (INTERIM), SCR

HEC-RAS Plan: INTPROPGRD-2FW River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	W.S. Elev	Prof Delta WS	E.G. Elev	Top Wdth Act	Q Left	Q Channel	Q Right	Enc Sta L	Ch Sta L	Ch Sta R	Enc Sta R
			(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)
Sunset	39399	100-Yr	2182.81		2184.07	790.79		70000.00			1746.84	2637.01	
Sunset	39399	FW1	2183.39	0.58	2184.51	791.60		70000.00		1746.84	1746.84	2637.01	2637.01
Sunset	38909	100-Yr	2182.21		2183.11	933.53	3846.03	66153.81	0.17		1683.14	2472.95	
Sunset	38909	FW1	2182.74	0.53	2183.69	789.81		70000.00		1683.14	1683.14	2472.95	2472.95
Sunset	38409	100-Yr	2181.47		2182.42	837.97	104.42	69879.56	16.01		1722.73	2500.65	
Sunset	38409	FW1	2182.21	0.74	2183.05	777.92		70000.00		1722.73	1722.73	2500.65	2500.65
Sunset	37929	100-Yr	2180.60		2181.73	754.04		69468.34	531.65		1857.59	2537.78	
Sunset	37929	FW1	2181.48	0.87	2182.48	664.09		70000.00		1857.59	1857.59	2537.78	2537.78
Sunset	37509	100-Yr	2179.93		2181.09	722.32		67327.05	2672.96		1723.91	2375.05	
Sunset	37509	FW1	2180.81	0.88	2181.94	637.69		70000.00		1723.91	1723.91	2375.05	2375.05
Sunset	36859	100-Yr	2178.57		2179.95	851.59	884.94	61587.25	7527.82		1759.42	2263.84	
Sunset	36859	FW1	2179.05	0.48	2180.77	547.28		68372.44	1627.56	1759.42	1759.42	2263.84	2306.70
Sunset	36439	100-Yr	2177.15		2178.94	752.79		62801.54	7198.46		2106.25	2612.34	
Sunset	36439	FW1	2177.14	0.00	2179.57	479.13		70000.00		2106.25	2106.25	2612.34	2612.34
Sunset	36049	100-Yr	2175.49		2177.73	640.79		66432.38	3567.62		2414.69	2884.12	
Sunset	36049	FW1	2175.78	0.29	2178.26	458.03		70000.00		2414.69	2414.69	2884.12	2884.12
Sunset	35639	100-Yr	2173.71		2176.18	682.43		66210.47	3789.53		2719.94	3230.99	
Sunset	35639	FW1	2173.55	-0.16	2176.54	506.96		70000.00		2719.94	2719.94	3230.99	3230.99
Sunset	35095	100-Yr	2171.80		2173.78	735.90	1.18	69998.82			3049.61	3784.84	
Sunset	35095	FW1	2171.80	0.00	2173.78	719.18		70000.00		3049.61	3049.61	3784.84	3784.84
Sunset	34808	100-Yr	2168.80		2172.10	605.27		70000.00			3232.17	3853.56	
Sunset	34808	FW1	2168.80	0.00	2172.10	605.27		70000.00		3232.17	3232.17	3853.56	3853.56
Sunset	34568	100-Yr	2168.54		2170.58	594.37		70000.00			2999.40	3671.96	
Sunset	34568	FW1	2168.54	0.00	2170.58	594.37		70000.00		2999.40	2999.40	3671.96	3671.96
Sunset	34556	100-Yr	2168.47		2170.53	594.56		70000.00			3038.00	3659.11	
Sunset	34556	FW1	2168.47	0.00	2170.53	594.56		70000.00		1025.51	3038.00	3659.11	4929.76
Sunset	34529 Ina Road (LOMR) BR U	100-Yr	2166.07		2169.97	559.92		70000.00			3038.00	3659.11	
Sunset	34529 Ina Road (LOMR) BR U	FW1	2166.07	0.00	2169.97	559.92		70000.00		1025.51	3038.00	3659.11	4929.76
Sunset	34529 Ina Road (LOMR) BR D	100-Yr	2166.10		2169.13	561.50		70000.00			3007.82	3638.28	
Sunset	34529 Ina Road (LOMR) BR D	FW1	2166.10	0.00	2169.13	561.50		70000.00		1000.00	3007.82	3638.28	4904.25
Sunset	34502	100-Yr	2166.31		2168.91	590.98		70000.00			3007.82	3638.28	
Sunset	34502	FW1	2166.31	0.00	2168.91	590.98		70000.00		1000.00	3007.82	3638.28	4904.25
Sunset	34494	100-Yr	2164.75		2168.53	587.39		70000.00			3007.82	3638.28	
Sunset	34494	FW1	2164.75	0.00	2168.53	587.39		70000.00		3007.82	3007.82	3638.28	3638.28
Sunset	34294	100-Yr	2159.39		2162.12	579.66		70000.00			3319.24	3917.94	
Sunset	34294	FW1	2159.71	0.31	2162.25	580.35		70000.00		3319.24	3319.24	3917.94	3917.94
Sunset	34054	100-Yr	2158.77		2161.41	669.57		70000.00			3185.43	3970.93	
Sunset	34054	FW1	2159.26	0.49	2161.61	670.81		70000.00		3185.43	3185.43	3970.93	3970.93
Sunset	33594	100-Yr	2157.50		2160.05	747.05	2368.42	67631.58			2913.64	3531.86	
Sunset	33594	FW1	2157.40	-0.10	2160.28	609.77	0.00	70000.00		2913.64	2913.64	3531.86	3531.86
Sunset	33332	100-Yr	2156.93		2159.32	725.41	1681.21	68318.78			2828.48	3457.27	
Sunset	33332	FW1	2156.80	-0.13	2159.44	619.86		70000.00		2828.48	2828.48	3457.27	3457.27
Sunset	33162	100-Yr	2155.17		2158.66	723.65	491.59	69508.41			2806.24	3432.46	
Sunset	33162	FW1	2155.04	-0.12	2158.73	618.31		70000.00		2806.24	2806.24	3432.46	3432.46
Sunset	32680	100-Yr	2154.65		2156.83	644.67	202.56	69797.45			2672.46	3300.61	
Sunset	32680	FW1	2154.66	0.01	2156.85	617.12	0.00	70000.00		2672.46	2672.46	3300.61	3300.61
Sunset	32153	100-Yr	2153.05		2155.59	628.07		70000.00			2156.78	2860.09	
Sunset	32153	FW1	2153.16	0.12	2155.64	629.08		70000.00		2156.78	2156.78	2860.09	2860.09
Sunset	31655	100-Yr	2151.26		2154.12	666.32	436.11	69563.90			1864.78	2492.66	
Sunset	31655	FW1	2151.22	-0.04	2154.16	620.65		70000.00		1864.78	1864.78	2492.66	2492.66
Sunset	31182	100-Yr	2150.87		2152.79	622.21		70000.00			1736.49	2382.91	
Sunset	31182	FW1	2150.86	0.00	2152.79	622.21		70000.00		1736.49	1736.49	2382.91	2382.91
Sunset	30846	100-Yr	2150.33		2152.22	655.23		70000.00			1668.45	2334.27	
Sunset	30846	FW1	2150.33	0.00	2152.22	655.23		70000.00		1668.45	1668.45	2334.27	2334.27
Sunset	30571	100-Yr	2150.53		2151.70	667.52		70000.00			2014.22	2694.89	
Sunset	30571	FW1	2150.53	0.00	2151.70	667.52		70000.00		2014.22	2014.22	2694.89	2694.89
Sunset	30211	100-Yr	2150.29		2151.41	660.41		70000.00			2238.54	2905.18	
Sunset	30211	FW1	2150.29	0.00	2151.41	660.41		70000.00		2238.54	2238.54	2905.18	2905.18
Sunset	29689	100-Yr	2147.74		2150.61	499.34		70000.00			2028.94	2653.34	
Sunset	29689	FW1	2147.74	0.00	2150.61	499.34		70000.00		2028.94	2028.94	2653.34	2653.34
Sunset	29333	100-Yr	2146.32		2149.56	563.00		70000.00			2819.84	3597.49	
Sunset	29333	FW1	2146.31	0.00	2149.56	562.99		70000.00		2819.84	2819.84	3597.49	3597.49
Sunset	29145	100-Yr	2146.57		2148.76	626.60		70000.00			2982.02	3791.91	
Sunset	29145	FW1	2146.57	0.00	2148.76	626.61		70000.00		2982.02	2982.02	3791.91	3791.91

4RTSUN FEMA PROPOSED FLOODWAY RESULTS (INTERIM), SCR

HEC-RAS Plan: INTPROPGRD-2FW River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	W.S. Elev	Prof Delta WS	E.G. Elev	Top Wdth Act	Q Left	Q Channel	Q Right	Enc Sta L	Ch Sta L	Ch Sta R	Enc Sta R
			(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)
Sunset	28850	100-Yr	2146.12		2148.16	606.09		70000.00			2457.90	3080.25	
Sunset	28850	FW1	2146.12	0.00	2148.16	606.10		70000.00		2457.90	2457.90	3080.25	3080.25
Sunset	28513	100-Yr	2146.07		2147.52	704.40		69999.42	0.58		1523.68	2192.48	
Sunset	28513	FW1	2146.07	0.00	2147.52	667.88		70000.00		1523.68	1523.68	2192.48	2192.48
Sunset	28332	100-Yr	2146.13		2147.24	760.93		70000.00			1507.08	2268.53	
Sunset	28332	FW1	2146.14	0.00	2147.24	760.93		70000.00		1507.08	1507.08	2268.53	2268.53
Sunset	28037	100-Yr	2146.11		2146.95	860.10		70000.00			1677.12	2616.55	
Sunset	28037	FW1	2146.11	0.00	2146.95	860.10		70000.00		1677.12	1677.12	2616.55	2616.55
Sunset	27481	100-Yr	2145.26		2146.46	795.60		70000.00			1601.41	2433.61	
Sunset	27481	FW1	2145.26	0.00	2146.46	795.60		70000.00		1601.41	1601.41	2433.61	2433.61
Sunset	27120	100-Yr	2144.96		2146.10	768.84		70000.00			1055.49	1830.96	
Sunset	27120	FW1	2144.96	0.00	2146.10	768.84		70000.00		1055.49	1055.49	1830.96	1830.96
Sunset	27119	100-Yr	2145.02		2146.07	769.16		70000.00			1032.01	1807.72	
Sunset	27119	FW1	2145.02	0.00	2146.07	769.16		70000.00		1032.01	1032.01	1807.72	1807.72
Sunset	27054 Cortaro Road (LOBR U	100-Yr	2144.86		2146.03	736.23		70000.00			1032.01	1807.72	
Sunset	27054 Cortaro Road (LOBR U	FW1	2144.86	0.00	2146.03	736.23		70000.00		1032.01	1032.01	1807.72	1807.72
Sunset	27054 Cortaro Road (LOBR D	100-Yr	2144.47		2145.82	739.58		70000.00			1020.12	1795.80	
Sunset	27054 Cortaro Road (LOBR D	FW1	2144.47	0.00	2145.82	739.58		70000.00		1020.12	1020.12	1795.80	1795.80
Sunset	26989	100-Yr	2144.53		2145.75	769.69		70000.00			1020.12	1795.80	
Sunset	26989	FW1	2144.53	0.00	2145.75	769.69		70000.00		1020.12	1020.12	1795.80	1795.80
Sunset	26977	100-Yr	2144.46		2145.73	769.12		70000.00			0.00	823.29	
Sunset	26977	FW1	2144.46	0.00	2145.73	769.12		70000.00		0.00	0.00	823.29	823.29
Sunset	26837	100-Yr	2144.41		2145.51	770.09		70000.00			1056.94	1834.90	
Sunset	26837	FW1	2144.41	0.00	2145.51	770.09		70000.00		1056.94	1056.94	1834.90	1834.90

4RTSUN FEMA PROPOSED BRIDGE RESULTS (INTERIM), SUNSET ROAD BRIDGE

Plan: 10-50-100-YrPINT Santa Cruz Sunset RS: 51000 Profile: 100-Yr

E.G. US. (ft)	2222.82	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2221.61	E.G. Elev (ft)	2222.54	2222.30
Q Total (cfs)	60000.00	W.S. Elev (ft)	2220.57	2220.38
Q Bridge (cfs)	59160.93	Crit W.S. (ft)	2218.76	2218.18
Q Weir (cfs)	839.07	Max Chl Dpth (ft)	21.57	21.38
Weir Sta Lft (ft)	251.44	Vel Total (ft/s)	10.95	10.84
Weir Sta Rgt (ft)	410.45	Flow Area (sq ft)	5403.82	5458.82
Weir Submerg	0.02	Froude # Chl	0.69	0.65
Weir Max Depth (ft)	2.61	Specif Force (cu ft)	50824.14	52354.68
Min El Weir Flow (ft)	2220.22	Hydr Depth (ft)	8.28	8.82
Min El Prs (ft)	2232.16	W.P. Total (ft)	737.01	718.10
Delta EG (ft)	0.79	Conv. Total (cfs)	998096.4	1039061.0
Delta WS (ft)	1.08	Top Width (ft)	652.43	619.19
BR Open Area (sq ft)	12133.99	Frctn Loss (ft)	0.22	0.06
BR Open Vel (ft/s)	10.95	C & E Loss (ft)	0.02	0.21
Coef of Q		Shear Total (lb/sq ft)	1.65	1.58
Br Sel Method	Energy/Weir	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Yarnell answer is not valid if the water surface is above the low chord or if there is weir flow. The Yarnell answer has
	been disregarded.
Note:	Momentum answer is not valid if the water surface is above the low chord or if there is weir flow. The momentum
	answer has been disregarded.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.

4RTSUN FEMA PROPOSED BRIDGE RESULTS (INTERIM), SUNSET ROAD BRIDGE

Plan: 500YrINTAlt-2 Santa Cruz Sunset RS: 51000 Profile: 500-Yr

E.G. US. (ft)	2225.90	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2224.44	E.G. Elev (ft)	2225.48	2225.19
Q Total (cfs)	93000.00	W.S. Elev (ft)	2222.78	2222.37
Q Bridge (cfs)	88557.82	Crit W.S. (ft)	2221.26	2220.81
Q Weir (cfs)	4442.18	Max Chl Dpth (ft)	23.78	23.37
Weir Sta Lft (ft)	221.62	Vel Total (ft/s)	12.89	13.09
Weir Sta Rgt (ft)	468.00	Flow Area (sq ft)	6871.68	6767.23
Weir Submerg	0.25	Froude # Chl	0.73	0.72
Weir Max Depth (ft)	5.69	Specif Force (cu ft)	79873.98	81005.71
Min El Weir Flow (ft)	2220.22	Hydr Depth (ft)	10.25	9.98
Min El Prs (ft)	2232.16	W.P. Total (ft)	779.07	797.34
Delta EG (ft)	1.13	Conv. Total (cfs)	1418084.0	1409535.0
Delta WS (ft)	1.78	Top Width (ft)	670.29	678.05
BR Open Area (sq ft)	12133.99	Frctn Loss (ft)	0.25	0.07
BR Open Vel (ft/s)	13.09	C & E Loss (ft)	0.03	0.35
Coef of Q		Shear Total (lb/sq ft)	2.37	2.31
Br Sel Method	Energy/Weir	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Yarnell answer is not valid if the water surface is above the low chord or if there is weir flow. The Yarnell answer has
	been disregarded.
Note:	Momentum answer is not valid if the water surface is above the low chord or if there is weir flow. The momentum
	answer has been disregarded.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.

4RTSUN FEMA PROPOSED CONDITION (ULTIMATE) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPULT River: Santa Cruz Reach: Sunset

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	10-Yr	16800.00	2255.61	2265.49	2264.51	2267.38	0.003109	11.04	1522.15	244.01	0.78
Sunset	68977	50-Yr	41000.00	2255.61	2270.78	2268.89	2274.02	0.002504	14.46	2835.48	254.66	0.76
Sunset	68977	100-Yr	60000.00	2255.61	2274.22	2271.67	2278.25	0.002294	16.11	3724.63	269.76	0.75
Sunset	68588	10-Yr	16800.00	2253.49	2264.65	2263.16	2266.23	0.002387	10.10	1663.78	248.65	0.69
Sunset	68588	50-Yr	41000.00	2253.49	2270.30	2267.49	2273.01	0.001935	13.20	3105.40	273.16	0.67
Sunset	68588	100-Yr	60000.00	2253.49	2273.88	2270.22	2277.28	0.001796	14.79	4057.93	661.89	0.67
Sunset	68087	10-Yr	16800.00	2250.70	2264.38	2260.73	2265.31	0.000974	7.72	2177.44	250.52	0.46
Sunset	68087	50-Yr	41000.00	2250.70	2270.10	2265.16	2272.05	0.001137	11.22	3653.81	280.96	0.53
Sunset	68087	100-Yr	60000.00	2250.70	2273.71	2267.92	2276.27	0.001289	12.84	4678.36	1010.43	0.58
Sunset	67552	10-Yr	16800.00	2250.55	2262.97	2261.19	2264.51	0.002115	9.97	1685.81	236.39	0.66
Sunset	67552	50-Yr	41000.00	2250.55	2268.10	2265.71	2271.13	0.002174	13.95	2938.89	307.05	0.72
Sunset	67552	100-Yr	60000.00	2250.55	2271.44	2268.53	2275.27	0.002124	15.73	3907.53	767.04	0.73
Sunset	67038	10-Yr	16800.00	2249.72	2261.55	2260.13	2263.30	0.002530	10.61	1583.13	408.63	0.71
Sunset	67038	50-Yr	41000.00	2249.72	2266.07	2264.70	2269.77	0.002921	15.43	2657.76	702.37	0.82
Sunset	67038	100-Yr	60000.00	2249.72	2268.96	2267.55	2273.87	0.003047	17.78	3374.39	883.92	0.87
Sunset	66600	10-Yr	16800.00	2249.10	2259.76	2259.02	2261.76	0.004996	11.35	1479.85	375.59	0.82
Sunset	66600	50-Yr	41000.00	2249.10	2264.78	2263.32	2268.19	0.004024	14.83	2763.85	956.61	0.81
Sunset	66600	100-Yr	60000.00	2249.10	2267.85	2266.06	2272.20	0.003857	16.74	3585.23	1132.33	0.81
Sunset	66255	10-Yr	16800.00	2248.50	2259.73	2256.52	2260.75	0.001135	8.11	2072.66	250.57	0.50
Sunset	66255	50-Yr	41000.00	2248.50	2264.77	2260.91	2267.07	0.001467	12.17	3368.35	265.03	0.60
Sunset	66255	100-Yr	60000.00	2248.50	2267.88	2263.67	2271.00	0.001658	14.19	4273.50	418.82	0.65
Sunset	65763	10-Yr	16800.00	2247.09	2258.18	2256.99	2259.86	0.002738	10.40	1614.66	257.19	0.73
Sunset	65763	50-Yr	41000.00	2247.09	2262.52	2261.18	2265.96	0.002948	14.89	2753.80	608.22	0.82
Sunset	65763	100-Yr	60000.00	2247.09	2265.15	2263.98	2269.76	0.003156	17.22	3483.47	986.18	0.87
Sunset	65255	10-Yr	16800.00	2246.28	2256.48	2255.42	2258.16	0.004167	10.39	1617.60	269.31	0.75
Sunset	65255	50-Yr	41000.00	2246.28	2260.88	2259.53	2264.12	0.004259	14.43	2840.33	325.99	0.82
Sunset	65255	100-Yr	60000.00	2246.28	2263.62	2262.23	2267.79	0.004176	16.39	3660.42	596.17	0.83
Sunset	64585	10-Yr	16800.00	2244.01	2254.80	2253.15	2256.13	0.002098	9.23	1820.41	285.10	0.64
Sunset	64585	50-Yr	41000.00	2244.01	2259.25	2257.12	2261.89	0.002294	13.06	3140.20	397.07	0.72
Sunset	64585	100-Yr	60000.00	2244.01	2261.99	2259.69	2265.47	0.002461	14.96	4009.68	883.13	0.77
Sunset	64087	10-Yr	16800.00	2242.46	2252.84	2252.24	2254.71	0.003755	10.97	1531.20	285.73	0.84
Sunset	64087	50-Yr	41000.00	2242.46	2257.12	2256.20	2260.46	0.003362	14.65	2798.49	331.48	0.86
Sunset	64087	100-Yr	60000.00	2242.46	2259.78	2258.68	2264.01	0.003158	16.52	3632.24	1071.10	0.86
Sunset	63622	10-Yr	16800.00	2241.64	2251.66	2250.44	2253.15	0.002597	9.81	1712.44	288.60	0.71
Sunset	63622	50-Yr	41000.00	2241.64	2256.11	2254.35	2258.94	0.002582	13.49	3038.22	347.73	0.76
Sunset	63622	100-Yr	60000.00	2241.64	2258.90	2256.87	2262.52	0.002537	15.27	3929.75	1232.77	0.78
Sunset	62978	10-Yr	16800.00	2240.25	2249.67	2248.70	2251.33	0.003027	10.34	1624.21	283.27	0.76
Sunset	62978	50-Yr	41000.00	2240.25	2254.07	2252.64	2257.17	0.002837	14.12	2903.61	315.61	0.80
Sunset	62978	100-Yr	60000.00	2240.25	2256.61	2255.29	2260.70	0.002948	16.24	3695.07	952.54	0.84
Sunset	62453	10-Yr	16800.00	2239.00	2248.37	2247.01	2249.85	0.002465	9.76	1721.76	280.96	0.69
Sunset	62453	50-Yr	41000.00	2239.00	2252.82	2251.01	2255.71	0.002498	13.65	3004.47	320.12	0.76
Sunset	62453	100-Yr	60000.00	2239.00	2255.09	2253.64	2259.17	0.002880	16.21	3701.01	761.48	0.83
Sunset	61960	10-Yr	16800.00	2234.74	2247.37	2245.60	2248.70	0.002031	9.26	1815.15	278.23	0.64
Sunset	61960	50-Yr	41000.00	2234.74	2251.99	2249.80	2254.49	0.002038	12.81	3518.46	494.12	0.69
Sunset	61960	100-Yr	60000.00	2234.74	2254.49	2252.62	2257.70	0.002112	14.72	4669.43	930.59	0.73
Sunset	61436	10-Yr	16800.00	2233.28	2246.20	2244.75	2247.57	0.002296	9.37	1793.36	294.44	0.67
Sunset	61436	50-Yr	41000.00	2233.28	2250.93	2248.68	2253.36	0.002174	12.53	3340.64	410.52	0.70
Sunset	61436	100-Yr	60000.00	2233.28	2253.20	2251.33	2256.52	0.002335	14.73	4380.56	1737.89	0.75
Sunset	61000	10-Yr	16800.00	2229.63	2245.62	2243.25	2246.67	0.001506	8.26	2033.94	293.16	0.55
Sunset	61000	50-Yr	41000.00	2229.63	2250.36	2247.33	2252.41	0.001707	11.51	3599.09	400.21	0.63
Sunset	61000	100-Yr	60000.00	2229.63	2252.54	2249.87	2255.49	0.001935	13.82	4535.67	1248.36	0.69
Sunset	60523	10-Yr	16800.00	2229.89	2244.40	2242.83	2245.77	0.002270	9.41	1785.78	287.36	0.67
Sunset	60523	50-Yr	41000.00	2229.89	2249.05	2247.08	2251.42	0.002438	12.35	3339.62	420.86	0.73
Sunset	60523	100-Yr	60000.00	2229.89	2251.16	2249.56	2254.40	0.002558	14.49	4282.36	1375.58	0.78
Sunset	60070	10-Yr	16800.00	2228.19	2243.02	2241.42	2244.38	0.004299	9.36	1795.50	284.37	0.66
Sunset	60070	50-Yr	41000.00	2228.19	2247.37	2245.93	2249.84	0.005219	12.69	3380.18	530.91	0.76
Sunset	60070	100-Yr	60000.00	2228.19	2249.93	2248.44	2252.79	0.004450	13.83	4796.40	745.33	0.73
Sunset	59588	10-Yr	16800.00	2226.99	2241.67	2239.93	2242.86	0.002288	8.76	1916.96	344.63	0.65
Sunset	59588	50-Yr	41000.00	2226.99	2246.58	2243.84	2248.28	0.001703	10.58	4362.71	809.39	0.61
Sunset	59588	100-Yr	60000.00	2226.99	2249.78	2246.59	2251.43	0.001208	10.73	7087.43	961.79	0.54
Sunset	59088	10-Yr	16800.00	2226.21	2239.44	2238.81	2241.33	0.003865	11.03	1523.27	287.38	0.84
Sunset	59088	50-Yr	41000.00	2226.21	2244.87	2242.96	2247.25	0.002256	12.43	3570.85	739.74	0.71
Sunset	59088	100-Yr	60000.00	2226.21	2248.49	2245.74	2250.72	0.001496	12.38	5904.29	1117.19	0.61

4RTSUN FEMA PROPOSED CONDITION (ULTIMATE) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPULT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	58533	10-Yr	16800.00	2224.44	2238.06	2236.22	2239.63	0.002235	10.05	1671.74	242.37	0.67
Sunset	58533	50-Yr	41000.00	2224.44	2242.73	2240.96	2245.82	0.002621	14.11	2907.01	293.62	0.78
Sunset	58533	100-Yr	60000.00	2224.44	2245.07	2243.77	2249.38	0.002860	16.70	3721.74	408.13	0.84
Sunset	57982	10-Yr	16800.00	2224.20	2236.24	2234.44	2237.72	0.005867	9.74	1724.65	265.16	0.67
Sunset	57982	50-Yr	41000.00	2224.20	2240.25	2238.93	2243.43	0.008417	14.32	2866.70	340.78	0.85
Sunset	57982	100-Yr	60000.00	2224.20	2244.28	2242.20	2246.84	0.004802	13.23	5478.37	980.85	0.67
Sunset	57561	10-Yr	16800.00	2222.54	2234.63	2233.32	2236.06	0.002781	9.59	1750.93	320.72	0.72
Sunset	57561	50-Yr	41000.00	2222.54	2239.00	2237.22	2241.51	0.002404	12.72	3222.11	344.10	0.73
Sunset	57561	100-Yr	60000.00	2222.54	2243.29	2239.48	2245.76	0.001529	12.63	4830.66	801.63	0.62
Sunset	57165	10-Yr	16800.00	2221.13	2233.56	2232.52	2234.94	0.002814	9.42	1784.32	339.74	0.72
Sunset	57165	50-Yr	41000.00	2221.13	2238.31	2236.03	2240.48	0.002277	11.83	3470.71	418.11	0.71
Sunset	57165	100-Yr	60000.00	2221.13	2243.42	2238.57	2245.02	0.000984	10.38	7055.01	943.85	0.50
Sunset	56836	10-Yr	16800.00	2221.00	2232.86	2231.28	2234.09	0.002139	8.91	1886.43	315.56	0.64
Sunset	56836	50-Yr	41000.00	2221.00	2237.51	2235.00	2239.79	0.001890	12.12	3424.87	346.37	0.66
Sunset	56836	100-Yr	60000.00	2221.00	2242.61	2237.35	2244.64	0.001055	11.59	6217.47	924.29	0.52
Sunset	56608	10-Yr	16800.00	2221.00	2232.65	2230.13	2233.53	0.001290	7.54	2227.99	328.14	0.51
Sunset	56608	50-Yr	41000.00	2221.00	2237.40	2233.80	2239.14	0.001394	10.60	3872.48	427.98	0.57
Sunset	56608	100-Yr	60000.00	2221.00	2243.02	2236.13	2243.90	0.000501	8.26	11448.52	1878.41	0.36
Sunset	56526 El Camino Del Ce		Bridge									
Sunset	56440	10-Yr	16800.00	2220.50	2231.36	2229.20	2232.37	0.002286	8.07	2081.22	322.58	0.56
Sunset	56440	50-Yr	41000.00	2220.50	2235.85	2232.87	2237.89	0.002378	11.46	3636.27	389.42	0.62
Sunset	56440	100-Yr	60000.00	2220.50	2239.09	2235.25	2241.17	0.001853	12.01	6478.95	1593.18	0.57
Sunset	55999	10-Yr	16800.00	2217.00	2229.77	2228.35	2231.07	0.003435	9.15	1836.65	318.29	0.67
Sunset	55999	50-Yr	41000.00	2217.00	2233.68	2232.02	2236.38	0.003757	13.21	3116.76	360.83	0.76
Sunset	55999	100-Yr	60000.00	2217.00	2235.68	2234.59	2239.47	0.004290	15.72	3928.40	466.47	0.83
Sunset	55499	10-Yr	16800.00	2216.00	2228.28	2226.67	2229.39	0.002931	8.44	1989.78	343.89	0.62
Sunset	55499	50-Yr	41000.00	2216.00	2232.19	2230.14	2234.44	0.003138	12.09	3499.47	497.44	0.69
Sunset	55499	100-Yr	60000.00	2216.00	2234.18	2232.90	2237.16	0.003392	14.13	4737.97	817.81	0.74
Sunset	54999	10-Yr	16800.00	2214.00	2226.26	2225.23	2227.62	0.004172	9.38	1791.17	344.50	0.72
Sunset	54999	50-Yr	41000.00	2214.00	2230.67	2228.73	2232.84	0.003172	11.94	3772.54	730.29	0.69
Sunset	54999	100-Yr	60000.00	2214.00	2233.15	2231.71	2235.47	0.002647	12.78	5992.87	1018.42	0.66
Sunset	54499	10-Yr	16800.00	2213.00	2224.20	2222.83	2225.65	0.003729	9.65	1740.27	296.31	0.70
Sunset	54499	50-Yr	41000.00	2213.00	2227.89	2226.99	2230.89	0.004409	14.02	3073.13	482.92	0.82
Sunset	54499	100-Yr	60000.00	2213.00	2230.00	2230.00	2233.65	0.004441	15.81	4624.36	858.66	0.84
Sunset	53999	10-Yr	16800.00	2211.00	2223.75	2219.86	2224.40	0.001260	6.47	2597.09	353.20	0.42
Sunset	53999	50-Yr	41000.00	2211.00	2227.32	2223.91	2229.05	0.002070	10.55	3951.93	516.76	0.57
Sunset	53999	100-Yr	60000.00	2211.00	2228.99	2226.11	2231.62	0.002717	13.13	5059.13	783.36	0.67
Sunset	53499	10-Yr	16800.00	2207.00	2222.86	2218.32	2223.62	0.001893	7.02	2391.62	394.18	0.50
Sunset	53499	50-Yr	41000.00	2207.00	2226.37	2224.18	2227.81	0.002587	9.62	4328.96	739.58	0.61
Sunset	53499	100-Yr	60000.00	2207.00	2228.08	2225.81	2230.05	0.002780	11.34	5747.33	948.93	0.66
Sunset	52999	10-Yr	16800.00	2205.00	2221.44	2220.29	2222.35	0.003406	7.97	2371.96	621.20	0.65
Sunset	52999	50-Yr	41000.00	2205.00	2225.57	2223.38	2226.47	0.002064	8.16	5770.31	931.64	0.54
Sunset	52999	100-Yr	60000.00	2205.00	2227.50	2224.65	2228.55	0.002063	8.83	7639.49	1019.07	0.55
Sunset	52499	10-Yr	16800.00	2204.00	2218.69	2217.93	2220.25	0.004748	10.59	1781.61	369.47	0.78
Sunset	52499	50-Yr	41000.00	2204.00	2222.62	2222.00	2224.70	0.005548	12.42	3680.96	633.72	0.86
Sunset	52499	100-Yr	60000.00	2204.00	2224.69	2223.82	2226.81	0.005358	12.50	5288.50	839.00	0.86
Sunset	51999	10-Yr	16800.00	2203.00	2217.34	2215.54	2218.20	0.002795	8.15	2430.79	502.85	0.60
Sunset	51999	50-Yr	41000.00	2203.00	2221.57	2218.98	2222.61	0.002325	9.08	5370.16	795.37	0.58
Sunset	51999	100-Yr	60000.00	2203.00	2223.57	2219.81	2224.86	0.002205	10.11	6969.30	808.20	0.58
Sunset	51499	10-Yr	16800.00	2201.00	2216.45	2213.93	2217.05	0.001696	6.24	2691.58	495.36	0.47
Sunset	51499	50-Yr	41000.00	2201.00	2220.84	2217.00	2221.70	0.001334	7.66	6103.78	1007.19	0.45
Sunset	51499	100-Yr	60000.00	2201.00	2222.92	2218.88	2223.91	0.001364	8.42	8264.87	1063.99	0.47
Sunset	51057	10-Yr	16800.00	2199.00	2215.49	2213.03	2216.27	0.001635	7.38	2578.15	491.42	0.48
Sunset	51057	50-Yr	41000.00	2199.00	2220.02	2216.85	2221.01	0.001614	8.54	5339.81	857.81	0.50
Sunset	51057	100-Yr	60000.00	2199.00	2221.65	2218.57	2223.07	0.001948	10.25	6480.74	880.16	0.56
Sunset	51000 Proposed Sunset		Bridge									
Sunset	50945	10-Yr	16800.00	2199.00	2214.34	2211.89	2215.32	0.002033	8.23	2301.83	462.91	0.54
Sunset	50945	50-Yr	41000.00	2199.00	2219.04	2216.30	2220.20	0.001832	9.23	4950.86	826.26	0.53
Sunset	50945	100-Yr	60000.00	2199.00	2220.46	2217.94	2222.21	0.002388	11.37	5866.12	858.42	0.62
Sunset	50500	10-Yr	16800.00	2198.00	2211.96	2211.28	2213.76	0.004766	11.01	1641.29	326.76	0.80
Sunset	50500	50-Yr	41000.00	2198.00	2217.81	2214.93	2219.03	0.004101	9.39	4823.88	1147.98	0.73

4RTSUN FEMA PROPOSED CONDITION (ULTIMATE) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPULT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	50500	100-Yr	60000.00	2198.00	2219.29	2217.97	2220.81	0.003745	10.50	6339.22	1176.77	0.73
Sunset	49996	10-Yr	16800.00	2197.00	2210.25	2208.48	2211.68	0.003031	9.76	1848.06	327.64	0.65
Sunset	49996	50-Yr	41000.00	2197.00	2216.53	2213.79	2217.36	0.002162	7.72	5898.82	1009.72	0.55
Sunset	49996	100-Yr	60000.00	2197.00	2218.07	2215.71	2219.18	0.002185	8.91	7464.09	1021.75	0.57
Sunset	49501	10-Yr	16800.00	2197.00	2207.17	2206.63	2209.60	0.005533	12.51	1343.13	211.63	0.87
Sunset	49501	50-Yr	41000.00	2197.00	2213.92	2213.38	2215.66	0.005592	10.58	3900.53	851.31	0.84
Sunset	49501	100-Yr	60000.00	2197.00	2215.42	2214.77	2217.52	0.004954	11.68	5217.68	881.72	0.83
Sunset	48999	10-Yr	16800.00	2196.00	2206.97	2203.99	2207.77	0.001580	7.16	2346.45	333.10	0.48
Sunset	48999	50-Yr	41000.00	2196.00	2213.07	2207.76	2213.91	0.001806	7.35	5625.60	902.19	0.51
Sunset	48999	100-Yr	60000.00	2196.00	2214.62	2211.36	2215.78	0.001920	8.66	7030.94	913.56	0.54
Sunset	48499	10-Yr	16800.00	2195.00	2203.32	2203.32	2206.09	0.007475	13.34	1259.50	225.01	0.99
Sunset	48499	50-Yr	41000.00	2195.00	2208.87	2208.87	2212.07	0.007236	14.36	2854.27	446.43	1.00
Sunset	48499	100-Yr	60000.00	2195.00	2211.39	2211.39	2214.02	0.006506	13.12	4789.60	985.87	0.94
Sunset	47499	10-Yr	21800.00	2193.11	2202.06	2199.34	2202.63	0.001346	6.03	3618.78	603.61	0.43
Sunset	47499	50-Yr	48000.00	2193.11	2206.76	2201.87	2207.62	0.000985	7.45	6530.16	654.61	0.40
Sunset	47499	100-Yr	70000.00	2193.11	2209.95	2203.57	2210.97	0.000881	8.21	9060.24	820.05	0.39
Sunset	46999	10-Yr	21800.00	2191.00	2200.39	2198.40	2201.65	0.002594	9.00	2423.29	354.91	0.61
Sunset	46999	50-Yr	48000.00	2191.00	2204.14	2201.88	2206.66	0.003003	12.74	3769.10	364.73	0.70
Sunset	46999	100-Yr	70000.00	2191.00	2206.38	2204.24	2209.95	0.003344	15.20	4820.54	663.72	0.76
Sunset	46499	10-Yr	21800.00	2189.00	2198.42	2197.30	2200.02	0.004022	10.14	2150.80	367.76	0.74
Sunset	46499	50-Yr	48000.00	2189.00	2201.13	2200.84	2204.52	0.005963	14.76	3253.03	425.11	0.94
Sunset	46499	100-Yr	70000.00	2189.00	2203.07	2203.07	2207.61	0.006348	17.09	4095.08	482.39	1.00
Sunset	45999	10-Yr	21800.00	2189.00	2196.95	2195.72	2198.00	0.003430	8.20	2659.37	559.85	0.66
Sunset	45999	50-Yr	48000.00	2189.00	2199.09	2198.37	2201.47	0.005066	12.40	3871.15	597.53	0.85
Sunset	45999	100-Yr	70000.00	2189.00	2200.41	2200.26	2203.89	0.006434	14.96	4680.32	678.29	0.97
Sunset	45499	10-Yr	21800.00	2187.00	2195.63	2194.30	2196.30	0.002935	6.61	3298.07	846.53	0.59
Sunset	45499	50-Yr	48000.00	2187.00	2197.82	2196.36	2199.16	0.003244	9.29	5167.96	857.17	0.67
Sunset	45499	100-Yr	70000.00	2187.00	2199.25	2197.68	2201.11	0.003426	10.93	6403.69	866.07	0.71
Sunset	44999	10-Yr	21800.00	2186.00	2194.03	2193.02	2194.73	0.003369	6.70	3252.63	907.02	0.62
Sunset	44999	50-Yr	48000.00	2186.00	2196.14	2194.88	2197.45	0.003544	9.20	5217.78	939.08	0.69
Sunset	44999	100-Yr	70000.00	2186.00	2197.60	2196.13	2199.35	0.003496	10.62	6588.29	944.69	0.71
Sunset	44499	10-Yr	21800.00	2184.00	2192.06	2191.22	2192.84	0.004222	7.11	3066.02	926.23	0.69
Sunset	44499	50-Yr	48000.00	2184.00	2194.40	2193.09	2195.69	0.003470	9.14	5253.09	939.00	0.68
Sunset	44499	100-Yr	70000.00	2184.00	2195.94	2194.34	2197.63	0.003292	10.44	6706.55	942.60	0.69
Sunset	43999	10-Yr	21800.00	2183.00	2190.92	2189.26	2191.40	0.001876	5.54	3936.16	942.90	0.48
Sunset	43999	50-Yr	48000.00	2183.00	2193.40	2191.08	2194.31	0.001943	7.64	6284.03	953.07	0.52
Sunset	43999	100-Yr	70000.00	2183.00	2194.97	2192.34	2196.23	0.002040	8.99	7785.96	957.95	0.56
Sunset	43499	10-Yr	21800.00	2181.00	2189.73	2188.38	2190.31	0.002511	6.09	3580.41	925.42	0.55
Sunset	43499	50-Yr	48000.00	2181.00	2192.16	2190.25	2193.21	0.002426	8.21	5847.96	940.45	0.58
Sunset	43499	100-Yr	70000.00	2181.00	2193.58	2191.52	2195.05	0.002629	9.75	7181.63	947.27	0.62
Sunset	42999	10-Yr	21800.00	2180.00	2186.52	2186.52	2188.06	0.009007	9.96	2189.34	702.32	0.99
Sunset	42999	50-Yr	48000.00	2180.00	2188.86	2188.86	2191.08	0.007943	11.95	4015.23	890.28	0.99
Sunset	42999	100-Yr	70000.00	2180.00	2190.49	2190.15	2193.03	0.006116	12.79	5473.12	900.56	0.91
Sunset	42499	10-Yr	21800.00	2175.00	2184.93	2182.00	2185.41	0.001584	5.57	3910.74	812.56	0.45
Sunset	42499	50-Yr	48000.00	2175.00	2187.98	2184.90	2188.83	0.001573	7.40	6482.16	873.77	0.48
Sunset	42499	100-Yr	70000.00	2175.00	2190.18	2186.28	2191.23	0.001507	8.25	8485.38	1434.63	0.48
Sunset	41999	10-Yr	21800.00	2176.00	2184.51	2181.49	2184.75	0.000904	3.92	5556.70	1292.37	0.33
Sunset	41999	50-Yr	48000.00	2176.00	2187.85	2183.55	2188.20	0.000652	4.77	10069.14	1366.50	0.31
Sunset	41999	100-Yr	70000.00	2176.00	2190.18	2184.73	2190.62	0.000557	5.28	13265.44	1616.62	0.30
Sunset	41499	10-Yr	21800.00	2175.00	2183.58	2181.79	2184.09	0.001945	5.68	3835.68	904.71	0.49
Sunset	41499	50-Yr	48000.00	2175.00	2186.97	2183.80	2187.70	0.001451	6.84	7016.18	1002.03	0.46
Sunset	41499	100-Yr	70000.00	2175.00	2189.35	2185.08	2190.16	0.001389	7.24	9663.21	1487.51	0.45
Sunset	40999	10-Yr	21800.00	2174.00	2182.74	2180.28	2183.22	0.001532	5.58	3906.47	789.41	0.44
Sunset	40999	50-Yr	48000.00	2174.00	2186.21	2182.66	2186.97	0.001453	7.00	6856.86	1017.77	0.46
Sunset	40999	100-Yr	70000.00	2174.00	2188.59	2184.13	2189.47	0.001331	7.53	9294.77	1317.12	0.45
Sunset	40499	10-Yr	21800.00	2172.00	2181.22	2179.64	2182.17	0.002771	7.78	2800.52	657.05	0.60
Sunset	40499	50-Yr	48000.00	2172.00	2183.38	2182.35	2185.64	0.004519	12.05	3983.94	712.47	0.80
Sunset	40499	100-Yr	70000.00	2172.00	2185.33	2184.61	2188.01	0.006971	13.13	5330.00	1094.76	0.97
Sunset	39999	10-Yr	21800.00	2171.00	2179.42	2178.70	2180.34	0.004963	7.72	2824.02	847.92	0.75
Sunset	39999	50-Yr	48000.00	2171.00	2182.04	2180.77	2183.37	0.003526	9.25	5189.68	924.04	0.69
Sunset	39999	100-Yr	70000.00	2171.00	2184.07	2182.07	2185.60	0.002721	9.91	7064.61	1134.82	0.63
Sunset	39399	10-Yr	21800.00	2168.00	2177.34	2175.80	2177.95	0.003051	6.29	3463.14	857.00	0.53

4RTSUN FEMA PROPOSED CONDITION (ULTIMATE) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPULT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	39399	50-Yr	48000.00	2168.00	2180.52	2177.80	2181.53	0.002436	8.04	5967.40	868.79	0.51
Sunset	39399	100-Yr	70000.00	2168.00	2182.81	2179.21	2184.07	0.002165	9.01	7768.16	1034.61	0.51
Sunset	38909	10-Yr	21800.00	2168.00	2176.20	2174.18	2176.67	0.002121	5.60	4023.09	880.24	0.45
Sunset	38909	50-Yr	48000.00	2168.00	2179.78	2176.22	2180.50	0.001570	6.93	7246.50	909.22	0.42
Sunset	38909	100-Yr	70000.00	2168.00	2182.21	2177.56	2183.11	0.001413	7.76	9477.44	967.97	0.42
Sunset	38409	10-Yr	21800.00	2168.00	2175.32	2172.77	2175.74	0.001589	5.23	4166.37	763.75	0.39
Sunset	38409	50-Yr	48000.00	2168.00	2179.04	2174.85	2179.76	0.001379	6.82	7040.71	834.10	0.40
Sunset	38409	100-Yr	70000.00	2168.00	2181.47	2176.28	2182.42	0.001325	7.83	9009.86	903.09	0.41
Sunset	37929	10-Yr	21800.00	2166.00	2174.64	2171.40	2175.06	0.001285	5.22	4173.63	662.38	0.36
Sunset	37929	50-Yr	48000.00	2166.00	2178.25	2173.76	2179.08	0.001407	7.32	6630.18	802.44	0.41
Sunset	37929	100-Yr	70000.00	2166.00	2180.60	2175.35	2181.73	0.001467	8.57	8373.77	882.06	0.43
Sunset	37509	10-Yr	21800.00	2166.00	2174.01	2171.06	2174.48	0.001478	5.49	4093.99	1126.33	0.39
Sunset	37509	50-Yr	48000.00	2166.00	2177.61	2173.51	2178.46	0.001513	7.51	6679.28	1183.38	0.42
Sunset	37509	100-Yr	70000.00	2166.00	2179.93	2175.09	2181.09	0.001567	8.78	8352.85	1212.38	0.45
Sunset	36859	10-Yr	21800.00	2164.00	2172.62	2170.20	2173.31	0.002156	6.71	3524.71	1286.81	0.47
Sunset	36859	50-Yr	48000.00	2164.00	2176.25	2173.14	2177.34	0.001977	8.71	6437.65	1312.85	0.49
Sunset	36859	100-Yr	70000.00	2164.00	2178.57	2174.81	2179.95	0.001959	9.97	8368.88	1353.36	0.50
Sunset	36439	10-Yr	21800.00	2162.00	2171.20	2169.40	2172.16	0.003342	7.88	2793.86	771.56	0.58
Sunset	36439	50-Yr	48000.00	2162.00	2174.80	2172.61	2176.29	0.002891	10.07	5335.94	1398.68	0.58
Sunset	36439	100-Yr	70000.00	2162.00	2177.15	2174.45	2178.94	0.002681	11.21	7102.78	1403.98	0.58
Sunset	36049	10-Yr	21800.00	2162.00	2170.19	2167.76	2171.02	0.002431	7.29	2991.61	1030.55	0.50
Sunset	36049	50-Yr	48000.00	2162.00	2173.47	2170.71	2175.12	0.002928	10.43	4913.32	1506.63	0.59
Sunset	36049	100-Yr	70000.00	2162.00	2175.49	2173.02	2177.73	0.003178	12.28	6209.23	1517.79	0.63
Sunset	35639	10-Yr	21800.00	2160.00	2168.80	2167.11	2169.80	0.003598	8.03	2739.53	1551.71	0.60
Sunset	35639	50-Yr	48000.00	2160.00	2171.74	2170.00	2173.66	0.004158	11.26	4542.20	1699.92	0.68
Sunset	35639	100-Yr	70000.00	2160.00	2173.71	2172.12	2176.18	0.004303	12.92	5865.07	1721.05	0.72
Sunset	35095	10-Yr	21800.00	2158.00	2166.96	2165.42	2167.78	0.003624	7.26	3003.40	1659.56	0.58
Sunset	35095	50-Yr	48000.00	2158.00	2169.86	2167.86	2171.37	0.003833	9.87	4865.52	1720.09	0.64
Sunset	35095	100-Yr	70000.00	2158.00	2171.80	2169.55	2173.78	0.004023	11.28	6207.09	2520.71	0.68
Sunset	34808	10-Yr	21800.00	2158.00	2164.23	2164.23	2165.96	0.011841	10.58	2061.44	592.54	1.00
Sunset	34808	50-Yr	48000.00	2158.00	2166.66	2166.66	2169.56	0.009914	13.67	3511.19	599.48	1.00
Sunset	34808	100-Yr	70000.00	2158.00	2168.80	2168.34	2172.10	0.007546	14.58	4801.57	1908.37	0.91
Sunset	34568	10-Yr	21800.00	2157.92	2163.17	2161.60	2164.01	0.003486	7.38	2952.76	581.57	0.58
Sunset	34568	50-Yr	48000.00	2157.92	2166.26	2164.06	2167.84	0.003502	10.07	4766.64	589.25	0.62
Sunset	34568	100-Yr	70000.00	2157.92	2168.54	2165.77	2170.58	0.003298	11.45	6114.08	1179.90	0.63
Sunset	34556	10-Yr	21800.00	2157.92	2163.09	2161.60	2163.96	0.003634	7.48	2915.38	581.29	0.59
Sunset	34556	50-Yr	48000.00	2157.92	2166.19	2164.05	2167.79	0.003596	10.15	4728.50	589.21	0.63
Sunset	34556	100-Yr	70000.00	2157.92	2168.47	2165.78	2170.53	0.003362	11.52	6079.01	594.56	0.63
Sunset	34529 Ina Road (LOMR)		Bridge									
Sunset	34502	10-Yr	21800.00	2155.79	2161.36	2160.55	2162.53	0.003056	8.70	2506.59	579.04	0.74
Sunset	34502	50-Yr	48000.00	2155.79	2164.25	2163.04	2166.29	0.002721	11.44	4194.18	586.25	0.75
Sunset	34502	100-Yr	70000.00	2155.79	2166.31	2164.75	2168.91	0.002523	12.96	5403.03	590.98	0.76
Sunset	34494	10-Yr	21800.00	2155.79	2160.57	2160.57	2162.32	0.005899	10.61	2054.16	577.03	0.99
Sunset	34494	50-Yr	48000.00	2155.79	2163.04	2163.04	2165.99	0.004997	13.77	3485.90	583.28	0.99
Sunset	34494	100-Yr	70000.00	2155.79	2164.75	2164.75	2168.53	0.004643	15.61	4485.16	587.39	1.00
Sunset	34294	10-Yr	21800.00	2146.87	2155.30	2153.72	2156.16	0.001797	7.45	2925.62	570.91	0.58
Sunset	34294	50-Yr	48000.00	2146.87	2157.90	2156.20	2159.73	0.002240	10.86	4419.96	576.35	0.69
Sunset	34294	100-Yr	70000.00	2146.87	2159.39	2157.91	2162.12	0.002656	13.25	5282.73	579.66	0.77
Sunset	34054	10-Yr	21800.00	2146.44	2154.52	2153.57	2155.61	0.002766	8.36	2607.02	592.03	0.70
Sunset	34054	50-Yr	48000.00	2146.44	2157.16	2156.12	2159.11	0.002976	11.19	4291.17	664.40	0.78
Sunset	34054	100-Yr	70000.00	2146.44	2158.77	2157.70	2161.41	0.003054	13.06	5359.50	669.57	0.81
Sunset	33594	10-Yr	21800.00	2145.96	2153.11	2152.33	2154.25	0.003105	8.58	2539.82	1274.47	0.74
Sunset	33594	50-Yr	48000.00	2145.96	2155.72	2154.84	2157.74	0.002951	11.49	4311.14	1410.33	0.78
Sunset	33594	100-Yr	70000.00	2145.96	2157.50	2156.47	2160.05	0.002780	12.99	5631.49	1444.37	0.78
Sunset	33332	10-Yr	21800.00	2145.72	2152.44	2151.46	2153.47	0.002650	8.14	2677.31	1229.10	0.69
Sunset	33332	50-Yr	48000.00	2145.72	2155.09	2153.84	2156.97	0.002611	11.04	4443.47	1338.87	0.74
Sunset	33332	100-Yr	70000.00	2145.72	2156.93	2155.57	2159.32	0.002481	12.54	5770.92	1346.91	0.75
Sunset	33162	10-Yr	21800.00	2145.21	2151.04	2151.04	2152.75	0.006108	10.47	2081.60	1171.82	1.00
Sunset	33162	50-Yr	48000.00	2145.21	2153.42	2153.42	2156.27	0.005120	13.56	3545.09	1205.64	1.00
Sunset	33162	100-Yr	70000.00	2145.21	2155.17	2155.17	2158.66	0.004445	15.05	4747.74	1287.87	0.97
Sunset	32680	10-Yr	21800.00	2143.52	2149.82	2148.44	2150.69	0.001979	7.47	2918.87	989.90	0.60
Sunset	32680	50-Yr	48000.00	2143.52	2152.77	2150.79	2154.37	0.001952	10.15	4739.36	1021.17	0.65

4RTSUN FEMA PROPOSED CONDITION (ULTIMATE) RESULTS, SCR

HEC-RAS Plan: 10-50-100-YrPULT River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	32680	100-Yr	70000.00	2143.52	2154.65	2152.46	2156.83	0.002002	11.86	5941.79	1112.01	0.68
Sunset	32153	10-Yr	21800.00	2142.51	2148.80	2147.29	2149.67	0.001882	7.50	2906.04	1283.01	0.59
Sunset	32153	50-Yr	48000.00	2142.51	2151.42	2149.77	2153.22	0.002364	10.78	4452.25	1326.51	0.71
Sunset	32153	100-Yr	70000.00	2142.51	2153.05	2151.55	2155.59	0.002620	12.81	5465.57	1347.60	0.77
Sunset	31655	10-Yr	21800.00	2141.12	2146.40	2146.36	2148.06	0.005873	10.34	2107.80	1667.82	0.98
Sunset	31655	50-Yr	48000.00	2141.12	2149.09	2148.71	2151.61	0.004191	12.76	3775.04	1725.43	0.91
Sunset	31655	100-Yr	70000.00	2141.12	2151.26	2150.38	2154.12	0.003204	13.62	5201.07	1774.06	0.84
Sunset	31182	10-Yr	21800.00	2139.64	2145.72	2144.02	2146.48	0.001608	7.01	3111.40	1851.19	0.55
Sunset	31182	50-Yr	48000.00	2139.64	2148.54	2146.39	2150.06	0.001806	9.90	4848.55	1884.13	0.62
Sunset	31182	100-Yr	70000.00	2139.64	2150.87	2148.04	2152.79	0.001635	11.13	6289.89	1913.03	0.62
Sunset	30846	10-Yr	21800.00	2138.32	2143.72	2143.72	2145.44	0.006110	10.54	2068.88	1964.34	1.00
Sunset	30846	50-Yr	48000.00	2138.32	2147.73	2146.08	2149.38	0.002214	10.32	4653.30	2058.18	0.68
Sunset	30846	100-Yr	70000.00	2138.32	2150.33	2147.65	2152.22	0.001696	11.02	6351.66	2201.63	0.62
Sunset	30571	10-Yr	21800.00	2135.91	2143.79	2141.41	2144.35	0.001038	6.00	3634.09	1988.61	0.45
Sunset	30571	50-Yr	48000.00	2135.91	2147.91	2143.71	2148.81	0.000810	7.57	6337.27	2252.98	0.43
Sunset	30571	100-Yr	70000.00	2135.91	2150.53	2145.33	2151.70	0.000781	8.67	8074.72	2405.90	0.44
Sunset	30211	10-Yr	21800.00	2134.31	2143.47	2140.85	2143.99	0.000919	5.80	3757.17	1835.11	0.42
Sunset	30211	50-Yr	48000.00	2134.31	2147.67	2143.22	2148.51	0.000740	7.40	6489.46	1947.08	0.41
Sunset	30211	100-Yr	70000.00	2134.31	2150.29	2144.84	2151.41	0.000728	8.52	8213.72	2037.29	0.43
Sunset	29689	10-Yr	21800.00	2133.83	2142.47	2139.88	2143.40	0.001251	7.70	2831.87	1258.30	0.51
Sunset	29689	50-Yr	48000.00	2133.83	2145.70	2143.01	2147.78	0.002114	11.58	4145.10	1346.57	0.68
Sunset	29689	100-Yr	70000.00	2133.83	2147.74	2145.70	2150.61	0.002387	13.59	5150.64	1568.14	0.75
Sunset	29333	10-Yr	21800.00	2133.19	2141.65	2140.02	2142.80	0.002135	8.60	2534.64	1221.51	0.64
Sunset	29333	50-Yr	48000.00	2133.19	2144.48	2143.14	2146.88	0.002866	12.44	3859.17	1461.94	0.78
Sunset	29333	100-Yr	70000.00	2133.19	2146.31	2145.41	2149.56	0.003413	14.46	4840.06	1576.09	0.87
Sunset	29145	10-Yr	21800.00	2133.23	2141.40	2139.84	2142.35	0.002065	7.83	2784.66	1393.81	0.62
Sunset	29145	50-Yr	48000.00	2133.23	2144.53	2142.60	2146.20	0.002110	10.38	4626.14	1614.61	0.67
Sunset	29145	100-Yr	70000.00	2133.23	2146.57	2144.41	2148.76	0.002040	11.87	5895.69	1708.86	0.68
Sunset	28850	10-Yr	21800.00	2133.13	2140.93	2139.33	2141.75	0.001750	7.28	2996.17	1428.36	0.57
Sunset	28850	50-Yr	48000.00	2133.13	2144.09	2141.74	2145.59	0.001696	9.82	4888.37	1573.22	0.61
Sunset	28850	100-Yr	70000.00	2133.13	2146.12	2143.42	2148.16	0.001738	11.46	6110.04	1595.21	0.64
Sunset	28513	10-Yr	21800.00	2132.91	2140.69	2138.25	2141.23	0.000977	5.88	3707.60	1288.63	0.44
Sunset	28513	50-Yr	48000.00	2132.91	2143.97	2140.50	2145.01	0.001051	8.19	5862.36	1344.69	0.48
Sunset	28513	100-Yr	70000.00	2132.91	2146.07	2142.09	2147.51	0.001111	9.64	7261.95	1454.63	0.52
Sunset	28332	10-Yr	21800.00	2132.32	2140.64	2137.66	2141.05	0.000678	5.13	4249.05	1046.62	0.37
Sunset	28332	50-Yr	48000.00	2132.32	2143.96	2139.84	2144.77	0.000826	7.22	6646.41	1132.93	0.43
Sunset	28332	100-Yr	70000.00	2132.32	2146.13	2141.37	2147.24	0.000844	8.44	8294.16	1144.03	0.45
Sunset	28037	10-Yr	21800.00	2131.16	2140.52	2137.26	2140.84	0.000550	4.50	4847.53	827.73	0.33
Sunset	28037	50-Yr	48000.00	2131.16	2143.90	2139.38	2144.51	0.000592	6.27	7651.66	835.43	0.37
Sunset	28037	100-Yr	70000.00	2131.16	2146.10	2140.70	2146.94	0.000632	7.35	9518.06	859.32	0.39
Sunset	27481	10-Yr	21800.00	2130.71	2139.80	2137.97	2140.36	0.001336	6.01	3629.34	784.06	0.49
Sunset	27481	50-Yr	48000.00	2130.71	2143.13	2140.03	2144.04	0.001075	7.68	6251.21	791.32	0.48
Sunset	27481	100-Yr	70000.00	2130.71	2145.26	2141.43	2146.46	0.001041	8.82	7938.93	795.59	0.49
Sunset	27120	10-Yr	21800.00	2130.71	2139.47	2137.04	2139.93	0.000928	5.47	3987.72	757.53	0.42
Sunset	27120	50-Yr	48000.00	2130.71	2142.84	2139.21	2143.67	0.000875	7.33	6550.05	764.27	0.44
Sunset	27120	100-Yr	70000.00	2130.71	2144.95	2140.66	2146.09	0.000899	8.56	8173.50	768.83	0.46
Sunset	27119	10-Yr	21800.00	2130.58	2139.52	2136.59	2139.91	0.000708	5.04	4325.82	758.13	0.37
Sunset	27119	50-Yr	48000.00	2130.58	2142.89	2138.78	2143.65	0.000737	6.96	6896.35	764.75	0.41
Sunset	27119	100-Yr	70000.00	2130.58	2145.02	2140.22	2146.06	0.000781	8.21	8526.23	769.15	0.43
Sunset	27054 Cortaro Road (LO		Bridge									
Sunset	26989	10-Yr	21800.00	2130.16	2139.18	2136.97	2139.69	0.001109	5.75	3794.12	760.48	0.45
Sunset	26989	50-Yr	48000.00	2130.16	2142.49	2139.13	2143.38	0.000997	7.60	6319.95	766.10	0.47
Sunset	26989	100-Yr	70000.00	2130.16	2144.53	2140.57	2145.75	0.001021	8.87	7890.21	769.69	0.49
Sunset	26977	10-Yr	21800.00	2130.27	2139.12	2137.04	2139.67	0.001230	5.94	3667.12	756.51	0.48
Sunset	26977	50-Yr	48000.00	2130.27	2142.42	2139.24	2143.36	0.001066	7.76	6181.78	764.54	0.48
Sunset	26977	100-Yr	70000.00	2130.27	2144.46	2140.68	2145.73	0.001081	9.04	7743.33	769.12	0.50
Sunset	26837	10-Yr	21800.00	2130.30	2139.05	2136.22	2139.46	0.000772	5.16	4222.81	759.16	0.39
Sunset	26837	50-Yr	48000.00	2130.30	2142.37	2138.45	2143.15	0.000795	7.11	6754.51	765.93	0.42
Sunset	26837	100-Yr	70000.00	2130.30	2144.41	2139.87	2145.51	0.000852	8.41	8321.10	770.09	0.45

4RTSUN FEMA PROPOSED CONDITION (ULTIMATE) RESULTS, SCR

HEC-RAS Plan: 500ULTBRGGRD2 River: Santa Cruz Reach: Sunset Profile: 500-Yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	500-Yr	93000.00	2255.61	2278.15	2278.06	2282.67	0.002068	17.81	7390.14	1196.25	0.74
Sunset	68588	500-Yr	93000.00	2253.49	2278.58	2275.66	2281.58	0.001322	14.92	8810.93	1192.16	0.60
Sunset	68087	500-Yr	93000.00	2250.70	2278.76	2274.81	2280.76	0.000834	12.36	10645.00	1333.25	0.49
Sunset	67552	500-Yr	93000.00	2250.55	2274.32	2274.29	2279.69	0.002522	19.13	6117.61	1254.83	0.82
Sunset	67038	500-Yr	93000.00	2249.72	2273.90	2272.58	2278.20	0.002068	17.52	6817.96	2013.76	0.75
Sunset	66600	500-Yr	93000.00	2249.10	2273.95	2271.13	2276.91	0.002013	14.71	7823.82	2462.98	0.62
Sunset	66255	500-Yr	93000.00	2248.50	2271.16	2268.24	2276.02	0.002074	17.77	5468.57	961.45	0.75
Sunset	65763	500-Yr	93000.00	2247.09	2268.79	2268.79	2274.67	0.003113	19.77	5359.30	1679.76	0.89
Sunset	65255	500-Yr	93000.00	2246.28	2266.34	2266.34	2271.33	0.004480	18.70	6163.70	906.30	0.88
Sunset	64585	500-Yr	93000.00	2244.01	2264.40	2264.40	2268.51	0.002569	17.16	7313.85	1099.54	0.81
Sunset	64087	500-Yr	93000.00	2242.46	2262.87	2262.87	2266.66	0.002568	16.91	8519.65	1246.53	0.80
Sunset	63622	500-Yr	93000.00	2241.64	2262.95	2261.12	2265.28	0.001467	13.70	11125.59	1412.96	0.62
Sunset	62978	500-Yr	93000.00	2240.25	2261.36	2259.65	2264.21	0.001645	14.73	9619.33	1170.95	0.66
Sunset	62453	500-Yr	93000.00	2239.00	2257.97	2256.02	2262.87	0.002898	18.50	6823.73	935.51	0.86
Sunset	61960	500-Yr	93000.00	2234.74	2257.01	2256.98	2261.40	0.002477	17.76	7526.40	983.79	0.81
Sunset	61436	500-Yr	93000.00	2233.28	2258.06	2255.83	2259.79	0.001042	12.15	14059.18	1854.52	0.53
Sunset	61000	500-Yr	93000.00	2229.63	2254.88	2254.86	2258.93	0.002300	16.77	7934.30	1392.28	0.77
Sunset	60523	500-Yr	93000.00	2229.89	2254.99	2253.84	2257.58	0.001643	14.03	10639.78	1559.05	0.65
Sunset	60070	500-Yr	93000.00	2228.19	2254.70	2252.37	2256.50	0.002163	12.08	11965.73	1687.52	0.54
Sunset	59588	500-Yr	93000.00	2226.99	2254.13	2249.45	2255.84	0.000923	11.35	12995.01	1727.22	0.50
Sunset	59088	500-Yr	93000.00	2226.21	2253.91	2249.24	2255.38	0.000769	11.01	14165.90	1453.10	0.46
Sunset	58533	500-Yr	93000.00	2224.44	2248.80	2248.80	2254.23	0.002713	19.08	6029.85	790.18	0.85
Sunset	57982	500-Yr	93000.00	2224.20	2248.59	2246.10	2250.61	0.002982	12.57	9786.33	1160.45	0.56
Sunset	57561	500-Yr	93000.00	2222.54	2246.59	2243.91	2249.60	0.001566	14.45	8299.59	916.40	0.64
Sunset	57165	500-Yr	93000.00	2221.13	2246.79	2242.47	2248.81	0.001001	12.03	10537.69	1094.21	0.52
Sunset	56836	500-Yr	93000.00	2221.00	2245.48	2241.51	2248.35	0.001278	14.19	8980.60	990.13	0.59
Sunset	56608	500-Yr	93000.00	2221.00	2246.31	2239.54	2247.19	0.000451	8.88	17949.54	2541.34	0.36
Sunset	56526 El Camino Del Ce		Bridge									
Sunset	56440	500-Yr	93000.00	2220.50	2244.33	2240.71	2245.31	0.000752	9.48	15793.50	2317.21	0.38
Sunset	55999	500-Yr	93000.00	2217.00	2239.00	2239.00	2243.59	0.003864	17.70	6104.91	897.59	0.82
Sunset	55499	500-Yr	93000.00	2216.00	2236.80	2236.80	2240.45	0.003430	16.25	7302.58	1231.94	0.77
Sunset	54999	500-Yr	93000.00	2214.00	2235.30	2234.64	2238.54	0.003130	15.56	8377.43	1215.02	0.74
Sunset	54499	500-Yr	93000.00	2213.00	2233.61	2232.99	2236.92	0.003318	15.91	8300.46	1084.87	0.76
Sunset	53999	500-Yr	93000.00	2211.00	2231.07	2230.44	2235.12	0.003577	16.62	6819.67	929.61	0.78
Sunset	53499	500-Yr	93000.00	2207.00	2230.24	2228.72	2233.05	0.003189	13.77	7882.82	1077.04	0.73
Sunset	52999	500-Yr	93000.00	2205.00	2229.93	2226.60	2231.35	0.001997	10.27	10129.30	1031.46	0.57
Sunset	52499	500-Yr	93000.00	2204.00	2227.27	2225.86	2229.78	0.004228	13.54	7494.19	861.71	0.80
Sunset	51999	500-Yr	93000.00	2203.00	2226.20	2222.79	2227.97	0.002309	11.80	9112.05	829.60	0.61
Sunset	51499	500-Yr	93000.00	2201.00	2225.69	2222.06	2226.94	0.001355	9.62	11233.82	1090.31	0.48
Sunset	51057	500-Yr	93000.00	2199.00	2224.65	2220.90	2226.19	0.001664	11.07	9828.66	892.65	0.54
Sunset	51000 Proposed Sunset		Bridge									
Sunset	50945	500-Yr	93000.00	2199.00	2222.62	2220.55	2224.85	0.002580	13.33	8351.34	931.83	0.67
Sunset	50500	500-Yr	93000.00	2198.00	2221.50	2219.73	2223.44	0.003306	11.90	8632.34	1186.60	0.71
Sunset	49996	500-Yr	93000.00	2197.00	2220.37	2217.37	2221.88	0.002174	10.46	9830.12	1037.98	0.59
Sunset	49501	500-Yr	93000.00	2197.00	2217.39	2216.62	2220.24	0.004713	13.62	6960.29	888.55	0.84
Sunset	48999	500-Yr	93000.00	2196.00	2216.57	2213.80	2218.34	0.002221	10.73	8820.13	917.65	0.60
Sunset	48499	500-Yr	93000.00	2195.00	2215.02	2213.41	2217.06	0.002889	11.82	8671.36	1095.73	0.68
Sunset	47499	500-Yr	107400.00	2193.11	2214.21	2206.02	2215.44	0.000855	9.08	12809.83	902.70	0.40
Sunset	46999	500-Yr	107400.00	2191.00	2208.58	2208.58	2214.18	0.004384	19.29	6286.30	665.87	0.89
Sunset	46499	500-Yr	107400.00	2189.00	2206.81	2206.81	2211.55	0.004583	17.74	6524.58	787.68	0.89
Sunset	45999	500-Yr	107400.00	2189.00	2203.11	2203.11	2207.25	0.005452	16.44	6791.39	882.93	0.93
Sunset	45499	500-Yr	107400.00	2187.00	2201.32	2199.67	2203.97	0.003570	13.07	8266.64	944.05	0.75
Sunset	44999	500-Yr	107400.00	2186.00	2199.75	2197.97	2202.15	0.003386	12.44	8633.09	953.01	0.73
Sunset	44499	500-Yr	107400.00	2184.00	2198.20	2196.21	2200.49	0.003142	12.12	8858.00	959.72	0.70
Sunset	43999	500-Yr	107400.00	2183.00	2197.28	2194.11	2199.07	0.002106	10.74	9999.75	963.48	0.59
Sunset	43499	500-Yr	107400.00	2181.00	2195.77	2193.38	2197.85	0.002682	11.59	9265.94	955.84	0.66
Sunset	42999	500-Yr	107400.00	2180.00	2192.58	2192.05	2195.88	0.005416	14.59	7363.67	906.56	0.90
Sunset	42499	500-Yr	107400.00	2175.00	2192.29	2188.39	2193.90	0.001853	10.19	10535.22	1549.20	0.55
Sunset	41999	500-Yr	107400.00	2176.00	2192.43	2186.26	2193.10	0.000656	6.57	16366.56	1730.23	0.34
Sunset	41499	500-Yr	107400.00	2175.00	2191.37	2187.06	2192.57	0.001528	8.79	12361.85	1691.64	0.49
Sunset	40999	500-Yr	107400.00	2174.00	2190.29	2186.34	2191.73	0.001746	9.64	11183.17	1383.34	0.53
Sunset	40499	500-Yr	107400.00	2172.00	2188.24	2186.97	2190.40	0.003884	12.17	9661.01	1302.46	0.76
Sunset	39999	500-Yr	107400.00	2171.00	2187.32	2183.93	2188.93	0.001876	10.31	11191.69	1212.90	0.56
Sunset	39399	500-Yr	107400.00	2168.00	2186.13	2181.31	2187.78	0.001928	10.31	10465.59	1196.13	0.50
Sunset	38909	500-Yr	107400.00	2168.00	2185.71	2179.53	2186.88	0.001276	8.90	13010.93	1101.67	0.41
Sunset	38409	500-Yr	107400.00	2168.00	2184.94	2178.42	2186.23	0.001272	9.15	12085.48	1024.42	0.42
Sunset	37929	500-Yr	107400.00	2166.00	2183.93	2177.77	2185.53	0.001531	10.23	10916.58	959.49	0.46
Sunset	37509	500-Yr	107400.00	2166.00	2183.19	2177.39	2184.85	0.001651	10.51	10717.78	1270.82	0.48
Sunset	36859	500-Yr	107400.00	2164.00	2181.88	2177.11	2183.70	0.001927	11.59	11248.66	1413.76	0.52
Sunset	36439	500-Yr	107400.00	2162.00	2180.42	2176.84	2182.70	0.002582	12.82	9576.31	1552.41	0.59
Sunset	36049	500-Yr	107400.00	2162.00	2178.10	2175.75	2181.37	0.003666	14.99	7881.46	1540.45	0.70
Sunset	35639	500-Yr	107400.00	2160.00	2176.43	2174.70	2179.72	0.004279	15.07	7981.50	1903.70	0.74
Sunset	35095	500-Yr	107400.00	2158.00	2175.16	2172.12	2177.45	0.003116	12.22	8998.92	3846.09	0.63
Sunset	34808	500-Yr	107400.00	2158.00	2173.07	2170.84	2176.31	0.004301	14.46	7485.40	2680.81	0.74
Sunset	34568	500-Yr	107400.00	2157.92	2174.44	2168.33	2175.13	0.000933	7.64	19101.10	3185.41	0.35
Sunset	34556	500-Yr	107400.00	2157.92	2171.67	2168.32	2174.47	0.003249	13.43	7996.99	694.34	0.65
Sunset	34529 Ina Road (LOMR)		Bridge									
Sunset	34502	500-Yr	107400.00	2155.79	2169.34	2167.30	2172.79	0.002323	14.91	7204.29	1779.71	0.76
Sunset	34494	500-Yr	107400.00	2155.79	2167.27	2167.27	2172.29	0.004282	17.98	5971.85	593.19	1.00
Sunset	34294	500-Yr	107400.00	2146.87	2161.44	2160.46	2165.71	0.003220	16.59	6473.85	584.36	0.88
Sunset	34054	500-Yr	107400.00	2146.44	2160.99	2160.03	2164.80	0.003204	15.66	6858.53	675.12	0.87
Sunset	33594	500-Yr	107400.00	2145.96	2159.90	2158.78	2163.34	0.002753	15.19	7438.96	1551.48	0.81
Sunset	33332	500-Yr	107400.00	2145.72	2159.27	2157.88	2162.63	0.002589	14.94	7472.27	1401.49	0.79

HEC-RAS Plan: 500ULTBRGGRD2 River: Santa Cruz Reach: Sunset Profile: 500-Yr (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	33162	500-Yr	107400.00	2145.21	2157.91	2157.54	2162.04	0.003552	16.51	6748.67	1301.59	0.91
Sunset	32680	500-Yr	107400.00	2143.52	2157.42	2154.92	2160.46	0.002013	14.03	7748.72	1304.35	0.71
Sunset	32153	500-Yr	107400.00	2142.51	2155.77	2154.03	2159.22	0.002580	14.90	7209.08	1381.42	0.79
Sunset	31655	500-Yr	107400.00	2141.12	2154.70	2152.82	2157.95	0.002321	14.57	7544.97	1867.72	0.75
Sunset	31182	500-Yr	107400.00	2139.64	2154.38	2150.50	2156.87	0.001446	12.65	8490.60	2059.96	0.61
Sunset	30846	500-Yr	107400.00	2138.32	2154.02	2150.04	2156.34	0.001384	12.23	8784.89	2380.37	0.59
Sunset	30571	500-Yr	107400.00	2135.91	2154.25	2147.67	2155.85	0.000765	10.16	10578.54	2485.50	0.45
Sunset	30211	500-Yr	107400.00	2134.31	2154.00	2147.19	2155.57	0.000727	10.05	10681.84	2319.03	0.44
Sunset	29689	500-Yr	107400.00	2133.83	2150.43	2148.77	2154.63	0.002979	16.46	6538.78	1754.33	0.85
Sunset	29333	500-Yr	107400.00	2133.19	2149.51	2148.41	2153.46	0.003161	15.94	6737.90	1839.84	0.87
Sunset	29145	500-Yr	107400.00	2133.23	2152.05	2146.88	2152.26	0.000156	3.89	31096.80	4033.43	0.20
Sunset	28850	500-Yr	107400.00	2133.13	2148.96	2145.91	2151.87	0.001816	13.69	7858.65	1915.33	0.68
Sunset	28513	500-Yr	107400.00	2132.91	2149.10	2144.47	2151.12	0.001131	11.45	9702.35	2263.27	0.54
Sunset	28332	500-Yr	107400.00	2132.32	2149.25	2143.76	2150.81	0.000855	10.04	10887.30	1945.90	0.47
Sunset	28037	500-Yr	107400.00	2131.16	2149.33	2142.76	2150.46	0.000665	8.54	12933.01	1745.74	0.41
Sunset	27481	500-Yr	107400.00	2130.71	2148.28	2143.48	2149.94	0.001050	10.34	10389.39	1169.11	0.51
Sunset	27120	500-Yr	107400.00	2130.71	2147.95	2142.79	2149.58	0.000936	10.24	10485.30	775.36	0.49
Sunset	27119	500-Yr	107400.00	2130.58	2148.02	2142.34	2149.54	0.000837	9.90	10846.72	775.97	0.47
Sunset	27054 Cortaro Road (LO		Bridge									
Sunset	26989	500-Yr	107400.00	2130.16	2147.40	2142.70	2149.15	0.001068	10.63	10103.48	774.62	0.52
Sunset	26977	500-Yr	107400.00	2130.27	2147.31	2142.81	2149.12	0.001120	10.80	9948.48	775.65	0.53
Sunset	26837	500-Yr	107400.00	2130.30	2147.27	2142.01	2148.88	0.000926	10.19	10561.26	798.46	0.49

4RTSUN FEMA PROPOSED BRIDGE RESULTS (ULTIMATE), SUNSET ROAD BRIDGE

Plan: 10-50-100-YrPULT Santa Cruz Sunset RS: 51000 Profile: 100-Yr

E.G. US. (ft)	2223.07	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2221.65	E.G. Elev (ft)	2222.98	2222.28
Q Total (cfs)	60000.00	W.S. Elev (ft)	2221.27	2220.24
Q Bridge (cfs)	60000.00	Crit W.S. (ft)	2218.75	2218.18
Q Weir (cfs)		Max Chl Dpth (ft)	22.27	21.24
Weir Sta Lft (ft)		Vel Total (ft/s)	10.23	11.17
Weir Sta Rgt (ft)		Flow Area (sq ft)	5863.28	5372.35
Weir Submerg		Froude # Chl	0.62	0.67
Weir Max Depth (ft)		Specif Force (cu ft)	53662.03	52519.98
Min El Weir Flow (ft)	2226.68	Hydr Depth (ft)	8.83	8.74
Min El Prs (ft)	2232.16	W.P. Total (ft)	756.03	712.38
Delta EG (ft)	0.86	Conv. Total (cfs)	1122044.0	1016914.0
Delta WS (ft)	1.19	Top Width (ft)	664.05	614.94
BR Open Area (sq ft)	12133.99	Frctn Loss (ft)		
BR Open Vel (ft/s)	11.17	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)	1.38	1.64
Br Sel Method	Momentum	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

4RTSUN FEMA PROPOSED (ULTIMATE) BRIDGE RESULTS, SUNSET ROAD BRIDGE

Plan: 500ULTBRGGRD2 Santa Cruz Sunset RS: 51000 Profile: 500-Yr

E.G. US. (ft)	2226.19	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2224.65	E.G. Elev (ft)	2225.76	2225.41
Q Total (cfs)	93000.00	W.S. Elev (ft)	2222.81	2222.24
Q Bridge (cfs)	92841.20	Crit W.S. (ft)	2221.13	2220.69
Q Weir (cfs)	158.80	Max Chl Dpth (ft)	23.81	23.24
Weir Sta Lft (ft)	428.00	Vel Total (ft/s)	13.47	13.91
Weir Sta Rgt (ft)	473.48	Flow Area (sq ft)	6892.63	6676.42
Weir Submerg	0.00	Froude # Chl	0.77	0.77
Weir Max Depth (ft)	2.43	Specif Force (cu ft)	83534.14	84282.61
Min El Weir Flow (ft)	2223.77	Hydr Depth (ft)	10.28	9.86
Min El Prs (ft)	2232.16	W.P. Total (ft)	779.52	794.92
Delta EG (ft)	1.35	Conv. Total (cfs)	1424526.0	1382698.0
Delta WS (ft)	2.03	Top Width (ft)	670.38	676.98
BR Open Area (sq ft)	12133.99	Frctn Loss (ft)	0.28	0.07
BR Open Vel (ft/s)	13.91	C & E Loss (ft)	0.07	0.45
Coef of Q		Shear Total (lb/sq ft)	2.35	2.37
Br Sel Method	Energy/Weir	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Yarnell answer is not valid if the water surface is above the low chord or if there is weir flow. The Yarnell answer has
	been disregarded.
Note:	Momentum answer is not valid if the water surface is above the low chord or if there is weir flow. The momentum
	answer has been disregarded.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.

JE Fuller 100-Yr Floodway Run (Case No.10-09-2016P)										Sunset 100-Yr Proposed Floodway Interim									Comparison		
River Sta	Equal River Sta	Profile	W.S. Elev	Prof Delta WS	Q Left	Q Channel	Q Right	Enc Sta L	Enc Sta R	River Sta	Profile	W.S. Elev	Prof Delta WS	Q Left	Q Channel	Q Right	Enc Sta L	Enc Sta R	Δ WSE	Δ Enc Sta Lt	Δ Enc Sta Rt
	(Feet)		(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)			(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)
27.445	65255	Floodway	2263.62	0		60000		907.16	1244.55	65255	FW1	2263.62	0	0	60000	0	907.16	1244.55	0	0	0
27.319	64585	Floodway	2261.99	0		60000		1182.2	1538.87	64585	FW1	2261.99	0	0	60000	0	1182.2	1538.87	0	0	0
27.224	64087	Floodway	2259.77	0		60000		944.22	1303.7	64087	FW1	2259.77	0	0	60000	0	944.22	1303.7	0	0	0
27.136	63622	Floodway	2258.9	0		60000		1230.8	1599.17	63622	FW1	2258.89	0	0	60000	0	1230.8	1599.17	-0.01	0	0
27.014	62978	Floodway	2256.7	0.09		60000		1030.19	1377.26	62978	FW1	2256.7	0.09	0	60000	0	1030.19	1377.26	0	0	0
26.915	62453	Floodway	2255.29	0.2		60000		575	1160	62453	FW1	2255.29	0.2	0	60000	0	575	1160	0	0	0
26.822	61960	Floodway	2254.7	0.22	2617.06	57382.95		625	1090	61960	FW1	2254.71	0.22	2619.31	57380.69	0	625	1090	0.01	0	0
26.722	61436	Floodway	2253.45	0.26	349.43	59650.57		1475	1835	61436	FW1	2253.46	0.27	350.32	59649.68	0	1475	1835	0.01	0	0
26.64	61000	Floodway	2252.88	0.34	66.33	59933.67		1165	1510	61000	FW1	2252.89	0.35	66.52	59933.48	0	1165	1510	0.01	0	0
26.549	60523	Floodway	2251.47	0.33		60000		1235	1585	60523	FW1	2251.49	0.33	0	60000	0	1235	1585	0.02	0	0
26.463	60070	Floodway	2250.28	0.32	521.95	59478.05		1305	1720	60070	FW1	2250.28	0.36	333.52	59666.48	0	1305	1720	0	0	0
26.372	59588	Floodway	2249.82	0.04	498.46	59501.54		1340	1830	59588	FW1	2249.85	0.07	501.53	59498.48	0	1340	1830	0.03	0	0
26.278	59088	Floodway	2248.8	0.31	2393.75	57606.25		1120	1615	59088	FW1	2248.84	0.36	2415.77	57584.23	0	1120	1615	0.04	0	0
26.172	58533	Floodway	2245.12	0.19		60000		735	1030	58533	FW1	2245.39	0.31	0	60000	0	735	1030	0.27	0	0
26.068	57982	Floodway	2243.43	0.69		60000		840	1165	57982	FW1	2244.33	0.03	3.44	59996.55	0	815	1165	0.9	-25	0
25.988	57561	Floodway	2241.58	0.29		60000		580	915	57561	FW1	2243.3	-0.01	0	60000	0	570	915	1.72	-10	0
25.913	57165	Floodway	2240.94	-0.03		60000		760	1090	57165	FW1	2243.44	0	0	60000	0	690	1090	2.5	-70	0
25.851	56836	Floodway	2240.86	0.19		60000		620	930	56836	FW1	2243.13	0.49	2245.14	57754.86	0	800	1450.4	2.27	180	520.4
										56608	FW1	2243.52	0.47	4845.93	48075.19	7078.88	1025	2375			
										56526 El	FW1	2243.52	0.47	1207.1	54582.29	4197.85	1025	2375			
										56526 El	FW1	2243.07	0.94	1294.58	54460.57	4232.07	1200	2575			
										56440	FW1	2239.56	0.48	3350.88	54113.13	2535.99	1200	2575			
										55999	FW1	2236.26	0.58	0	60000	0	1758.15	2100.07			
										55499	FW1	2234.8	0.62	0	60000	0	1688.77	2049.92			
										54999	FW1	2233.69	0.55	1666.95	58333.05	0	1650	2140.37			
										54499	FW1	2229.98	-0.01	452.45	59547.55	0	1650	2154.32			
										53999	FW1	2229.59	0.6	0	60000	0	1641	2041.06			
										53499	FW1	2229.04	0.97	2.64	59997.36	0	1144	1734.08			
										52999	FW1	2228.3	0.8	6267.62	53732.38	0	700	1499.1			
										52499	FW1	2224.77	0.21	8867.84	51132.16	0	525	1336.82			
										51999	FW1	2223.7	0.41	18038.81	41961.19	0	550	1296.86			
										51499	FW1	2223.02	0.53	4982.04	55017.96	0	575	1522.22			
										51057	FW1	2221.82	0.21	14855.4	45144.6	0	642	1329.62			
										51000 Pr	FW1	2221.55	0.98	15023.37	44976.62	0	642	1329.62			
										51000 Pr	FW1	2220.6	0.22	14620.31	45379.69	0	495	1129.54			
										50945	FW1	2220.69	0.16	14143.8	45856.2	0	495	1129.54			
										50500	FW1	2219.37	0.09	8588.61	51411.39	0	610	1525.37			
										49996	FW1	2218.07	0	7532.97	52467.03	0	570	1530.25			
										49501	FW1	2215.44	0.02	0	60000	0	763.27	1640.65			
										48999	FW1	2214.62	0	0	60000	0	676.11	1571.76			
										48499	FW1	2211.38	-0.01	1048.11	58951.9	0	797	1765			
										47499	FW1	2209.94	-0.01	1155.2	68844.8	0	700	1636			
										46999	FW1	2206.37	-0.01	294.52	69705.48	0	635	1231.28			
										46499	FW1	2203.07	0	0	70000	0	720	1175.42			

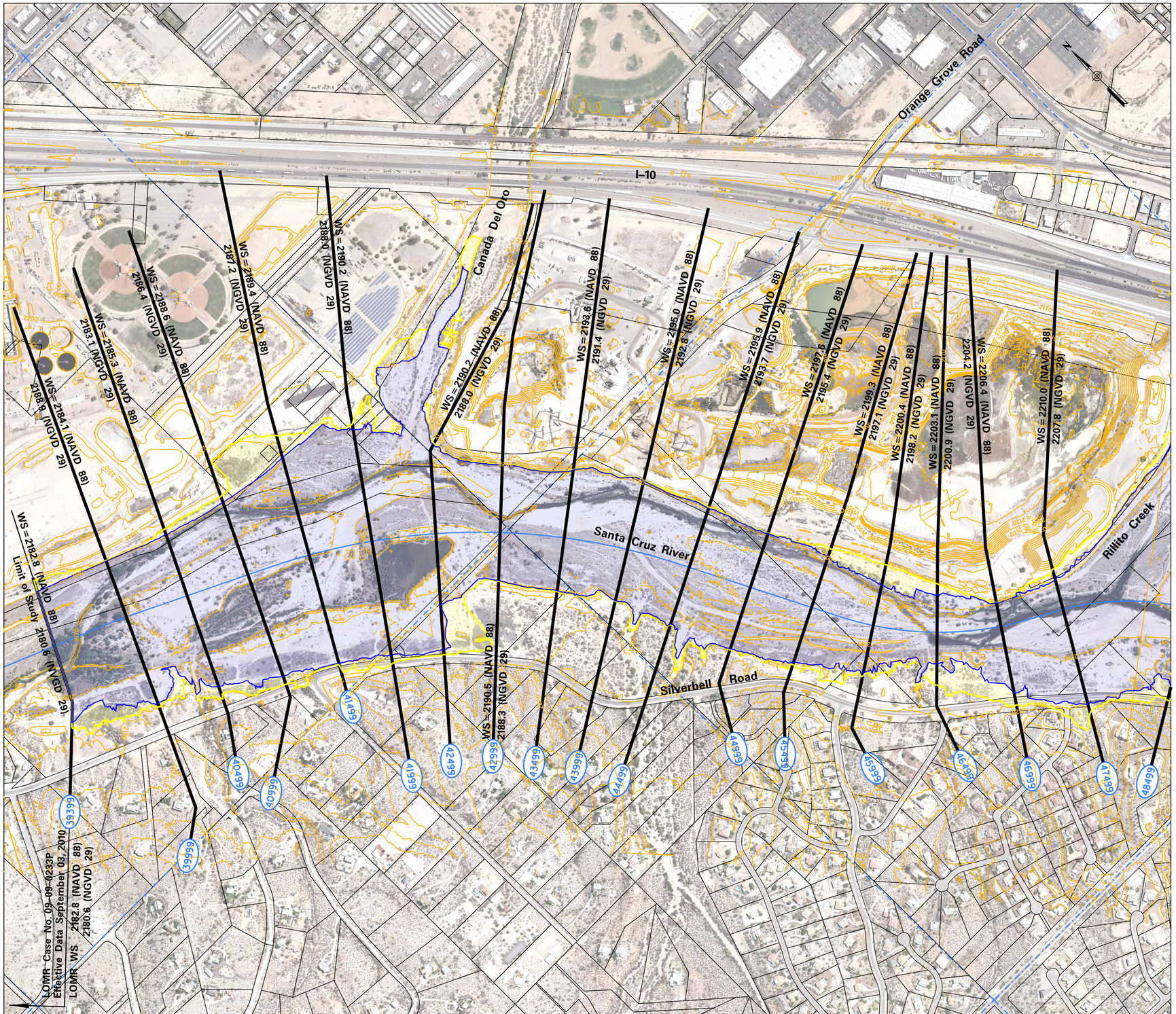
JE Fuller 100-Yr Floodway Run (Case No.10-09-2016P)										Sunset 100-Yr Proposed Floodway Interim									Comparison		
River Sta	Equal River Sta	Profile	W.S. Elev	Prof Delta WS	Q Left	Q Channel	Q Right	Enc Sta L	Enc Sta R	River Sta	Profile	W.S. Elev	Prof Delta WS	Q Left	Q Channel	Q Right	Enc Sta L	Enc Sta R	Δ WSE	Δ Enc Sta Lt	Δ Enc Sta Rt
	(Feet)		(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)			(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)
										45999	FW1	2200.41	0	0	70000	0	705	1375.66			
										45499	FW1	2199.25	0	0	70000	0	594.38	1469.45			
										44999	FW1	2197.6	0	0	70000	0	610.9	1638			
										44499	FW1	2195.94	0	0	70000	0	1132.8	2135			
										43999	FW1	2194.97	0	0	70000	0	1190	2174			
										43499	FW1	2193.58	0	0	70000	0	1196.6	2217			
										42999	FW1	2190.48	-0.01	0	70000	0	1179.9	2179			
										42499	FW1	2190.17	-0.01	0	70000	0	1352.4	2478			
										41999	FW1	2190.17	-0.01	0	70000	0	1224.2	2601.33			
										41499	FW1	2189.33	-0.01	0	70000	0	631.5	1880.57			
										40999	FW1	2188.57	-0.02	0	70000	0	1129	2234.39			
										40499	FW1	2185.44	0.11	0	70000	0	815	1978			
										39999	FW1	2184.42	0.35	0	70000	0	1346	2298			

Tetra Tech 100-Yr Floodway Run (Case No. 09-09-0233P)										Sunset 100-Yr Proposed Floodway Interim									Comparison		
River Sta	Equal River Sta	Profile	W.S. Elev	Prof Delta WS	Q Left	Q Channel	Q Right	Enc Sta L	Enc Sta R	River Sta	Profile	W.S. Elev	Prof Delta WS	Q Left	Q Channel	Q Right	Enc Sta L	Enc Sta R	Δ WSE	Δ Enc Sta Lt	Δ Enc Sta Rt
	(Feet)		(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)			(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)
22.5	39399	PF 2	2183.39	0.58		70000		1746.84	2637.01	39399	FW1	2183.39	0.58	0	70000	0	1746.84	2637.01	0	0	0
22.4	38909	PF 2	2182.74	0.53		70000		1683.14	2472.95	38909	FW1	2182.74	0.53	0	70000	0	1683.14	2472.95	0	0	0
22.31	38409	PF 2	2182.21	0.74		70000		1722.73	2500.65	38409	FW1	2182.21	0.74	0	70000	0	1722.73	2500.65	0	0	0
22.21	37929	PF 2	2181.48	0.87		70000		1857.59	2537.78	37929	FW1	2181.48	0.87	0	70000	0	1857.59	2537.78	0	0	0
22.12	37509	PF 2	2180.81	0.88		70000		1723.91	2375.05	37509	FW1	2180.81	0.88	0	70000	0	1723.91	2375.05	0	0	0
22.02	36859	PF 2	2179.05	0.48		68372.33	1627.67	1759.42	2306.7	36859	FW1	2179.05	0.48	0	68372.44	1627.56	1759.42	2306.7	0	0	0

JE Fuller 500-Yr Run (Case No. 10-09-2016P)								Sunset Existing 500-Yr Run							Comparison		
Reach	River Sta	Equal River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Δ Froude	Δ Min Ch	Δ WSE
	(miles)	(ft)		(cfs)	(ft)	(ft)					(cfs)	(ft)	(ft)			(ft)	(ft)
1	26.278	59088	500-year	93000	2226.21	2253.89	0.46	Sunset	59088	500-Yr	93000	2226.21	2253.91	0.46	0	0	0.02
1	26.172	58533	500-year	93000	2224.44	2248.8	0.85	Sunset	58533	500-Yr	93000	2224.44	2248.8	0.85	0	0	0
1	26.068	57982	500-year	93000	2224.2	2245.95	0.84	Sunset	57982	500-Yr	93000	2224.2	2248.59	0.56	-0.28	0	2.64
1	25.988	57561	500-year	93000	2222.54	2244.18	0.85	Sunset	57561	500-Yr	93000	2222.54	2246.59	0.64	-0.21	0	2.41
1	25.913	57165	500-year	93000	2221.13	2244.42	0.68	Sunset	57165	500-Yr	93000	2221.13	2246.79	0.52	-0.16	0	2.37
1	25.851	56836	500-year	93000	2220.88	2244.11	0.61	Sunset	56836	500-Yr	93000	2221	2245.48	0.59	-0.02	0.12	1.37
								Sunset	56608	500-Yr	93000	2221	2246.31	0.36			
								Sunset	56526 El	0	Bridge	0	0	0			
								Sunset	56440	500-Yr	93000	2220.5	2244.33	0.38			
								Sunset	55999	500-Yr	93000	2217	2239	0.82			
								Sunset	55499	500-Yr	93000	2216	2236.8	0.77			
								Sunset	54999	500-Yr	93000	2214	2235.3	0.74			
								Sunset	54499	500-Yr	93000	2213	2233.62	0.76			
								Sunset	53999	500-Yr	93000	2211	2231.07	0.78			
								Sunset	53499	500-Yr	93000	2207	2230.23	0.73			
								Sunset	52999	500-Yr	93000	2205	2229.93	0.57			
								Sunset	52499	500-Yr	93000	2204	2227.45	0.77			
								Sunset	51999	500-Yr	93000	2203	2226.49	0.59			
								Sunset	51499	500-Yr	93000	2201	2226.05	0.46			
								Sunset	51057	500-Yr	93000	2199	2223.88	0.69			
								Sunset	50945	500-Yr	93000	2199	2222.01	0.86			
								Sunset	50500	500-Yr	93000	2198	2221.53	0.67			
								Sunset	49996	500-Yr	93000	2197	2220.36	0.59			
								Sunset	49501	500-Yr	93000	2197	2217.39	0.84			
								Sunset	48999	500-Yr	93000	2196	2216.57	0.6			
								Sunset	48499	500-Yr	93000	2195	2215.02	0.68			
								Sunset	47499	500-Yr	107400	2193.11	2214.21	0.4			
								Sunset	46999	500-Yr	107400	2191	2208.57	0.89			
								Sunset	46499	500-Yr	107400	2189	2206.81	0.89			
								Sunset	45999	500-Yr	107400	2189	2203.11	0.93			
								Sunset	45499	500-Yr	107400	2187	2201.32	0.75			
								Sunset	44999	500-Yr	107400	2186	2199.75	0.73			
								Sunset	44499	500-Yr	107400	2184	2198.2	0.7			
								Sunset	43999	500-Yr	107400	2183	2197.28	0.59			
								Sunset	43499	500-Yr	107400	2181	2195.77	0.66			
								Sunset	42999	500-Yr	107400	2180	2192.58	0.9			
								Sunset	42499	500-Yr	107400	2175	2192.29	0.55			
								Sunset	41999	500-Yr	107400	2176	2192.43	0.34			
								Sunset	41499	500-Yr	107400	2175	2191.37	0.49			
Tetra Tech 100-Yr Run (Case No. 09-09-0233P)								Sunset	40999	500-Yr	107400	2174	2190.28	0.53			

Reach	River Sta	Equal River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl										
Sunset	40499	500-Yr	107400	2172	2188.24	0.76											
		(ft)		(cfs)	(ft)	(ft)		Sunset	39999	500-Yr	107400	2171	2187.32	0.56			
Reach #1	22.5	39399	PF 4	107400	2168	2186.13	0.5	Sunset	39399	500-Yr	107400	2168	2186.13	0.5	0	0	0
Reach #1	22.4	38909	PF 4	107400	2168	2185.71	0.41	Sunset	38909	500-Yr	107400	2168	2185.71	0.41	0	0	0
Reach #1	22.31	38409	PF 4	107400	2168	2184.94	0.42	Sunset	38409	500-Yr	107400	2168	2184.94	0.42	0	0	0
Reach #1	22.21	37929	PF 4	107400	2166	2183.93	0.46	Sunset	37929	500-Yr	107400	2166	2183.93	0.46	0	0	0
Reach #1	22.12	37509	PF 4	107400	2166	2183.19	0.48	Sunset	37509	500-Yr	107400	2166	2183.19	0.48	0	0	0
Reach #1	22.02	36859	PF 4	107400	2164	2181.87	0.52	Sunset	36859	500-Yr	107400	2164	2181.88	0.52	0	0	0.01

Sunset 500-Yr Existing Condition							Sunset 500-Yr Proposed Interim Alt-2							Comparison		
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Froude # Chl	Δ Froude	Δ Min Ch	Δ WSE
			(cfs)	(ft)	(ft)					(cfs)	(ft)	(ft)			(ft)	(ft)
Sunset	58533	500-Yr	93000	2224.44	2248.8	0.85	Sunset	58533	500-Yr	93000	2224.44	2248.8	0.85	0	0	0
Sunset	57982	500-Yr	93000	2224.2	2248.59	0.56	Sunset	57982	500-Yr	93000	2224.2	2248.59	0.56	0	0	0
Sunset	57561	500-Yr	93000	2222.54	2246.59	0.64	Sunset	57561	500-Yr	93000	2222.54	2246.59	0.64	0	0	0
Sunset	57165	500-Yr	93000	2221.13	2246.79	0.52	Sunset	57165	500-Yr	93000	2221.13	2246.79	0.52	0	0	0
Sunset	56836	500-Yr	93000	2221	2245.48	0.59	Sunset	56836	500-Yr	93000	2221	2245.48	0.59	0	0	0
Sunset	56608	500-Yr	93000	2221	2246.31	0.36	Sunset	56608	500-Yr	93000	2221	2246.31	0.36	0	0	0
Sunset	56526	El Camino Del Ce					Sunset	56526	El Camino Del Ce					0	0	0
Sunset	56440	500-Yr	93000	2220.5	2244.33	0.38	Sunset	56440	500-Yr	93000	2220.5	2244.33	0.38	0	0	0
Sunset	55999	500-Yr	93000	2217	2239	0.82	Sunset	55999	500-Yr	93000	2217	2239	0.82	0	0	0
Sunset	55499	500-Yr	93000	2216	2236.8	0.77	Sunset	55499	500-Yr	93000	2216	2236.8	0.77	0	0	0
Sunset	54999	500-Yr	93000	2214	2235.3	0.74	Sunset	54999	500-Yr	93000	2214	2235.29	0.74	0	0	-0.01
Sunset	54499	500-Yr	93000	2213	2233.62	0.76	Sunset	54499	500-Yr	93000	2213	2233.64	0.76	0	0	0.02
Sunset	53999	500-Yr	93000	2211	2231.07	0.78	Sunset	53999	500-Yr	93000	2211	2231.05	0.79	0.01	0	-0.02
Sunset	53499	500-Yr	93000	2207	2230.23	0.73	Sunset	53499	500-Yr	93000	2207	2230.19	0.73	0	0	-0.04
Sunset	52999	500-Yr	93000	2205	2229.93	0.57	Sunset	52999	500-Yr	93000	2205	2229.88	0.57	0	0	-0.05
Sunset	52499	500-Yr	93000	2204	2227.45	0.77	Sunset	52499	500-Yr	93000	2204	2227.05	0.83	0.06	0	-0.4
Sunset	51999	500-Yr	93000	2203	2226.49	0.59	Sunset	51999	500-Yr	93000	2203	2225.86	0.64	0.05	0	-0.63
Sunset	51499	500-Yr	93000	2201	2226.05	0.46	Sunset	51499	500-Yr	93000	2201	2225.27	0.51	0.05	0	-0.78
Sunset	51057	500-Yr	93000	2199	2223.88	0.69	Sunset	51057	500-Yr	93000	2199	2224.44	0.54	-0.15	0	0.56
							Sunset	51000	Proposed Sunset					0	0	0
Sunset	50945	500-Yr	93000	2199	2222.01	0.86	Sunset	50945	500-Yr	93000	2199	2222.65	0.66	-0.2	0	0.64
Sunset	50500	500-Yr	93000	2198	2221.53	0.67	Sunset	50500	500-Yr	93000	2198	2221.49	0.72	0.05	0	-0.04
Sunset	49996	500-Yr	93000	2197	2220.36	0.59	Sunset	49996	500-Yr	93000	2197	2220.36	0.59	0	0	0
Sunset	49501	500-Yr	93000	2197	2217.39	0.84	Sunset	49501	500-Yr	93000	2197	2217.39	0.84	0	0	0
Sunset	48999	500-Yr	93000	2196	2216.57	0.6	Sunset	48999	500-Yr	93000	2196	2216.57	0.6	0	0	0
Sunset	48499	500-Yr	93000	2195	2215.02	0.68	Sunset	48499	500-Yr	93000	2195	2215.02	0.68	0	0	0
Sunset	47499	500-Yr	107400	2193.11	2214.21	0.4	Sunset	47499	500-Yr	107400	2193.11	2214.21	0.4	0	0	0
Sunset	46999	500-Yr	107400	2191	2208.57	0.89	Sunset	46999	500-Yr	107400	2191	2208.57	0.89	0	0	0
Sunset	46499	500-Yr	107400	2189	2206.81	0.89	Sunset	46499	500-Yr	107400	2189	2206.81	0.89	0	0	0
Sunset	45999	500-Yr	107400	2189	2203.11	0.93	Sunset	45999	500-Yr	107400	2189	2203.11	0.93	0	0	0
Sunset	45499	500-Yr	107400	2187	2201.32	0.75	Sunset	45499	500-Yr	107400	2187	2201.32	0.75	0	0	0
Sunset	44999	500-Yr	107400	2186	2199.75	0.73	Sunset	44999	500-Yr	107400	2186	2199.75	0.73	0	0	0
Sunset	44499	500-Yr	107400	2184	2198.2	0.7	Sunset	44499	500-Yr	107400	2184	2198.2	0.7	0	0	0
Sunset	43999	500-Yr	107400	2183	2197.28	0.59	Sunset	43999	500-Yr	107400	2183	2197.28	0.59	0	0	0
Sunset	43499	500-Yr	107400	2181	2195.77	0.66	Sunset	43499	500-Yr	107400	2181	2195.77	0.66	0	0	0
Sunset	42999	500-Yr	107400	2180	2192.58	0.9	Sunset	42999	500-Yr	107400	2180	2192.58	0.9	0	0	0
Sunset	42499	500-Yr	107400	2175	2192.29	0.55	Sunset	42499	500-Yr	107400	2175	2192.29	0.55	0	0	0
Sunset	41999	500-Yr	107400	2176	2192.43	0.34	Sunset	41999	500-Yr	107400	2176	2192.43	0.34	0	0	0
Sunset	41499	500-Yr	107400	2175	2191.37	0.49	Sunset	41499	500-Yr	107400	2175	2191.37	0.49	0	0	0
Sunset	40999	500-Yr	107400	2174	2190.28	0.53	Sunset	40999	500-Yr	107400	2174	2190.28	0.53	0	0	0
Sunset	40499	500-Yr	107400	2172	2188.24	0.76	Sunset	40499	500-Yr	107400	2172	2188.24	0.76	0	0	0
Sunset	39999	500-Yr	107400	2171	2187.32	0.56	Sunset	39999	500-Yr	107400	2171	2187.32	0.56	0	0	0



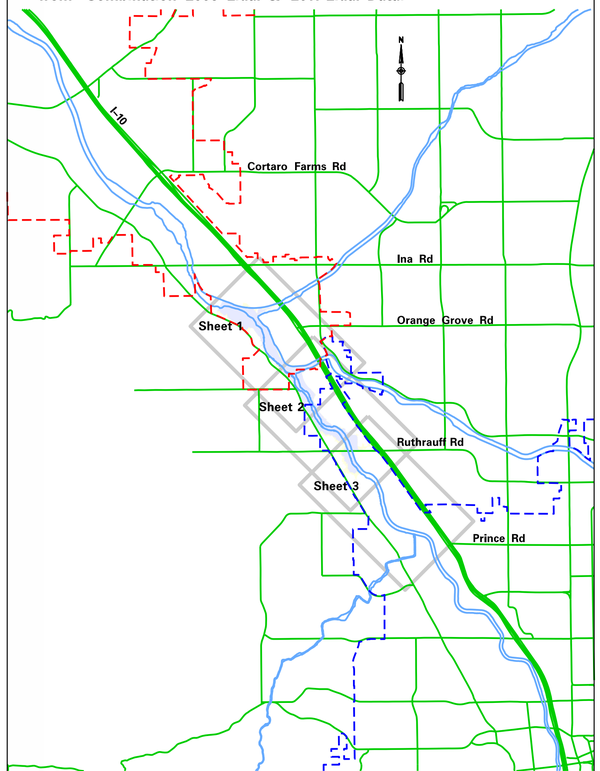
Santa Cruz River CLOMR
Ina Rd. to Sweetwater Dr.

Plate 1 – Floodplain and Cross Section Workmap Existing Conditions

LEGEND

- Major Streets
- Centerline
- 10ft Contour
- Cross Section
- Town of Marana
- City of Tucson
- Flood sheet line
- Parcels
- Section line
- 100-year
- 500-year

Aerial Photos are 2011 PAG Topo Developed from Combination 2008 Lidar & 2011 Lidar Data.



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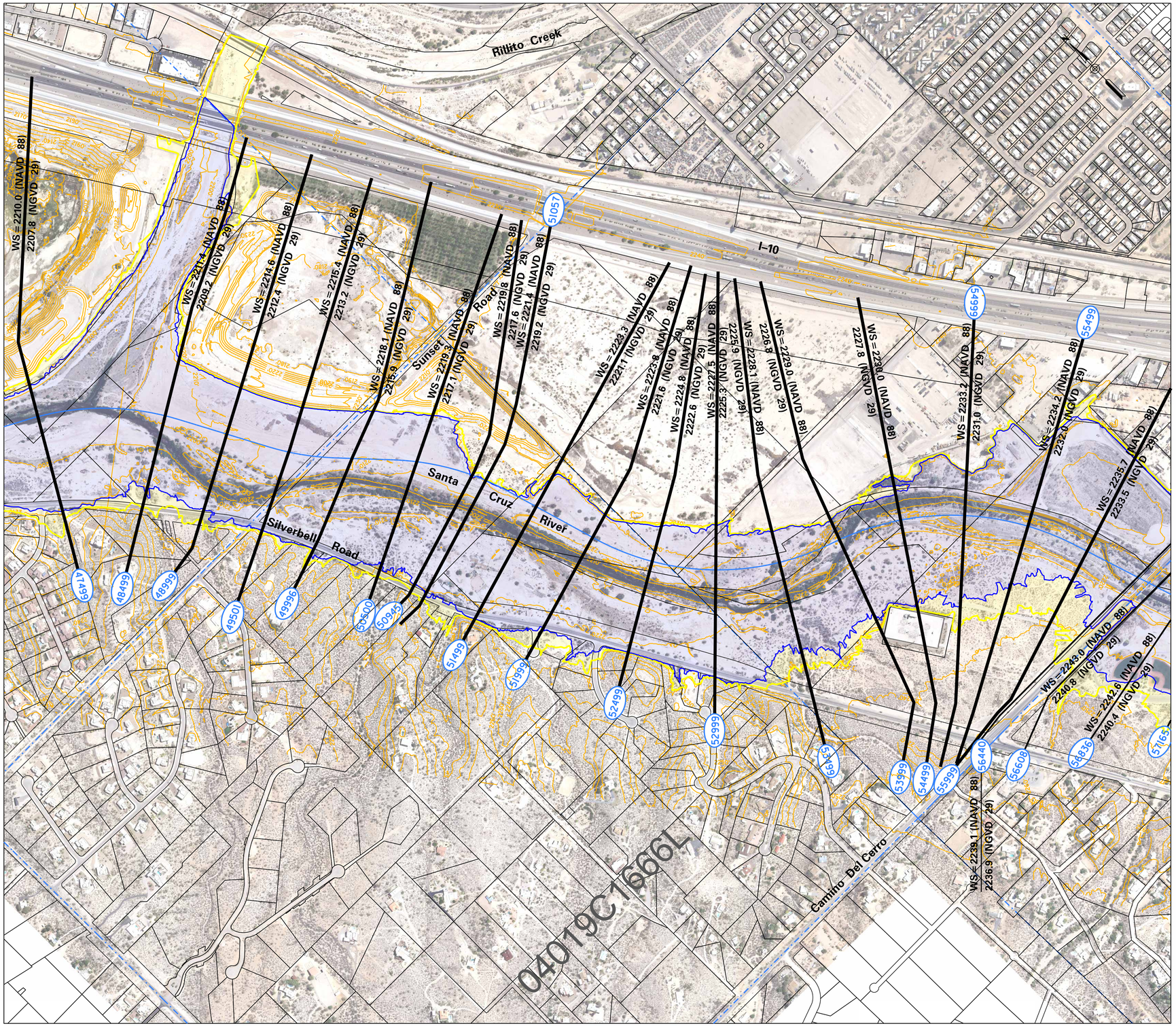
SHEET 1 OF 3



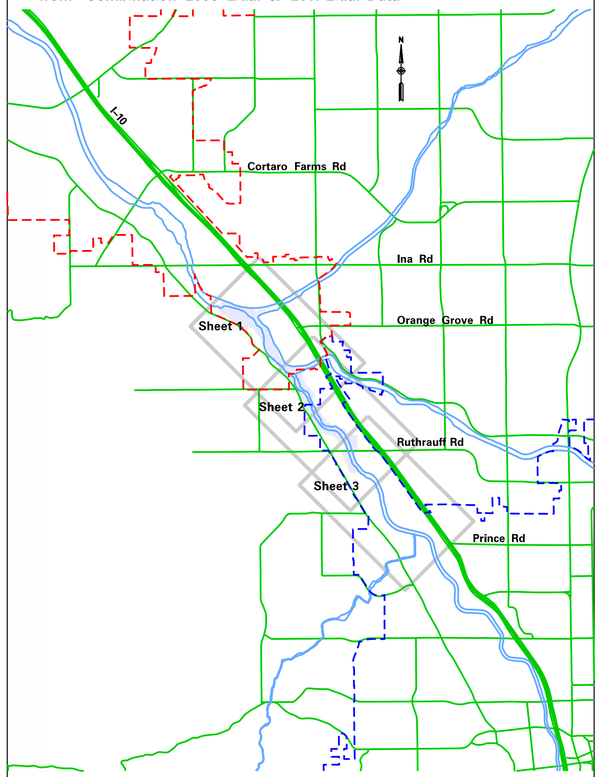
Santa Cruz River CLOMR
Ina Rd. to Sweetwater Dr.

Plate 1 – Floodplain and Cross Section Workmap Existing Conditions

LEGEND

- Major Streets
- Centerline
- 10ft Contour
- Cross Section
- Town of Marana
- City of Tucson
- Flood sheet line
- Parcels
- Section line
- 100-year
- 500-year

Aerial Photos are 2011 PAG Topo Developed from Combination 2008 Lidar & 2011 Lidar Data.



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Scale: 1" = 400'

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July 20, 2014

SHEET 2 OF 3

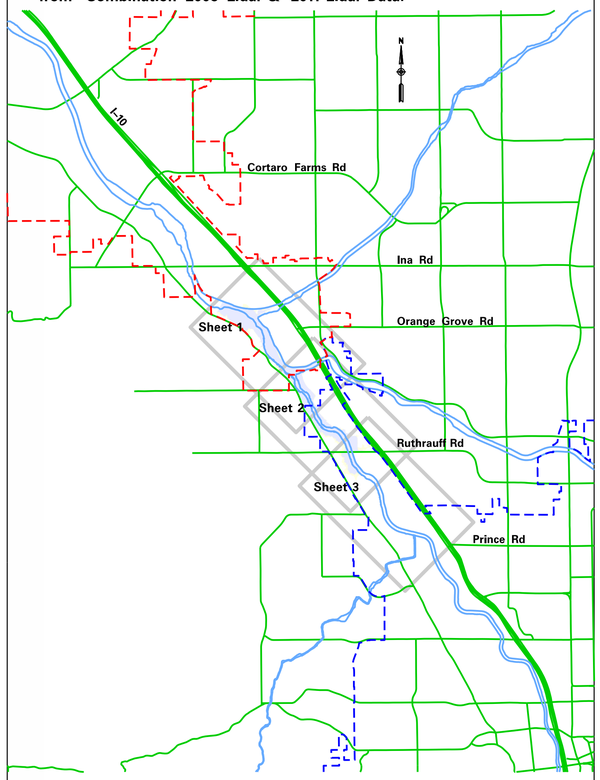
Santa Cruz River CLOMR
Ina Rd. to Sweetwater Dr.

Plate 1 – Floodplain and Cross Section Workmap Existing Conditions

LEGEND

- Major Streets
- Centerline
- 10ft Contour
- Cross Section
- Town of Marana
- City of Tucson
- Flood sheet line
- Parcels
- Section line
- 100-year
- 500-year

Aerial Photos are 2011 PAG Topo Developed from Combination 2008 Lidar & 2011 Lidar Data.



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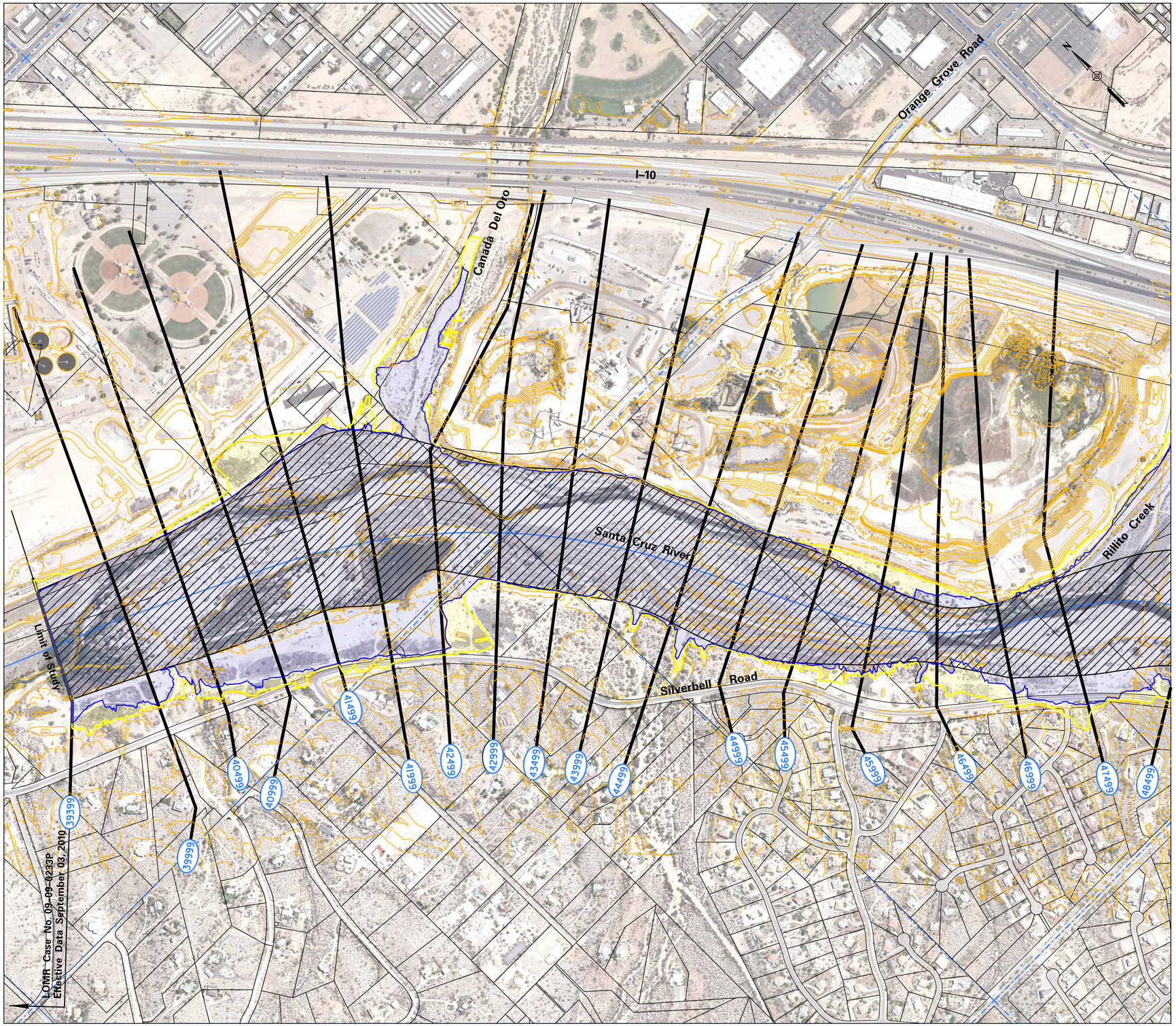
SHEET 3 OF 3

Santa Cruz River CLOMR
Ina Rd. to Sweetwater Dr.

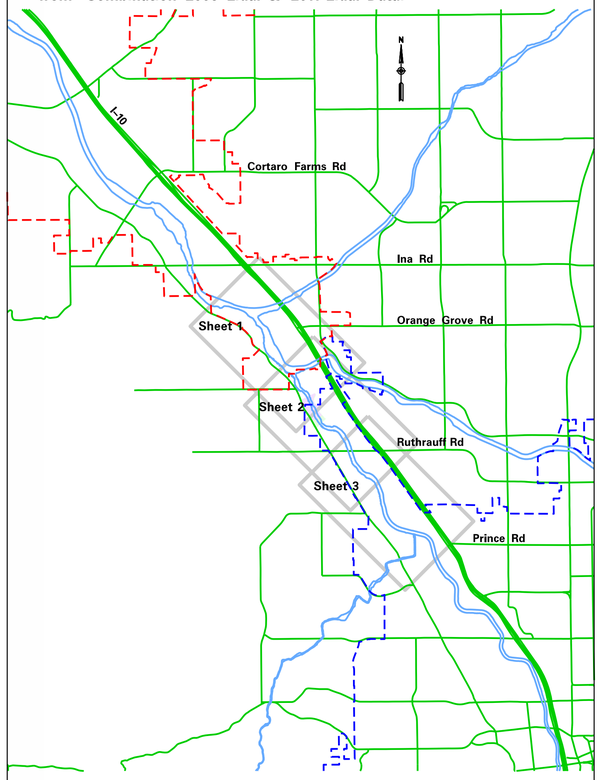
Plate 1 – Floodplain and Cross Section Workmap Proposed Conditions



LEGEND

Major Streets	Proposed Floodway
Centerline	Flood sheet line
10ft Contour	Section line
Cross Section	Prop 100-year
Town of Marana	Prop 500-year
City of Tucson	100-year (Existing)
Parcels	500-year (Existing)

Aerial Photos are 2011 PAG Topo Developed from Combination 2008 Lidar & 2011 Lidar Data.



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Scale: 1" = 400'

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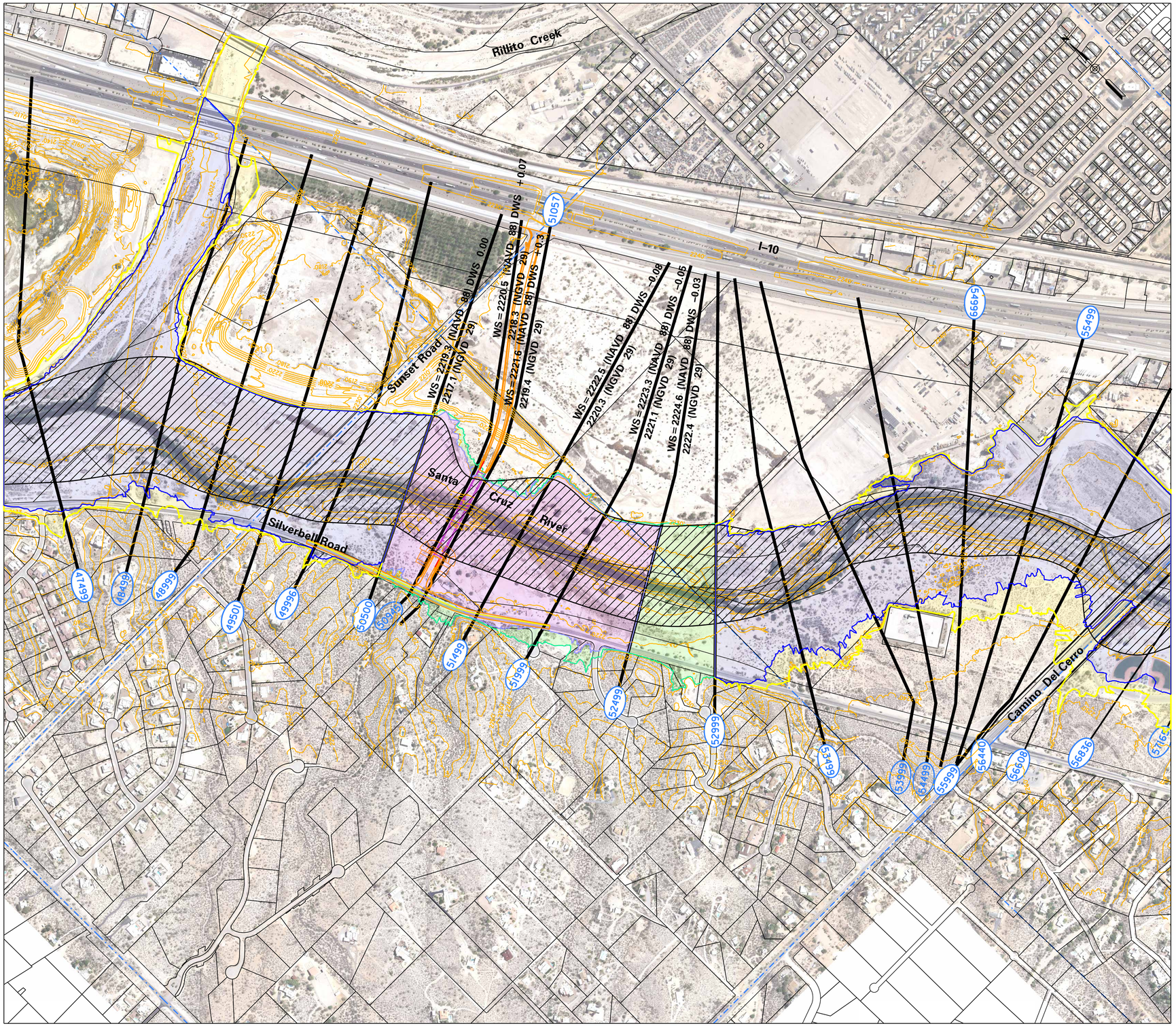


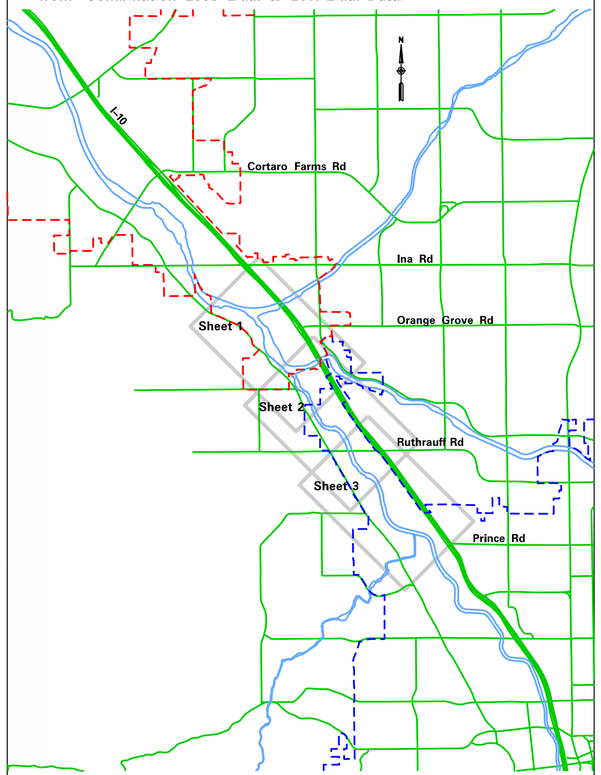
Santa Cruz River CLOMR
Ina Rd. to Sweetwater Dr.

Plate 1 – Floodplain and Cross Section Workmap Proposed Conditions

LEGEND

- Major Streets
- Centerline
- 10ft Contour
- Cross Section
- Town of Marana
- City of Tucson
- Parcels
- Proposed Floodway
- Flood sheet line
- Section line
- Prop 100-year
- Prop 500-year
- 100-year (Existing)
- 500-year (Existing)

Aerial Photos are 2011 PAG Topo Developed from Combination 2008 Lidar & 2011 Lidar Data.



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Scale: 1" = 400'

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SHEET 2 OF 3

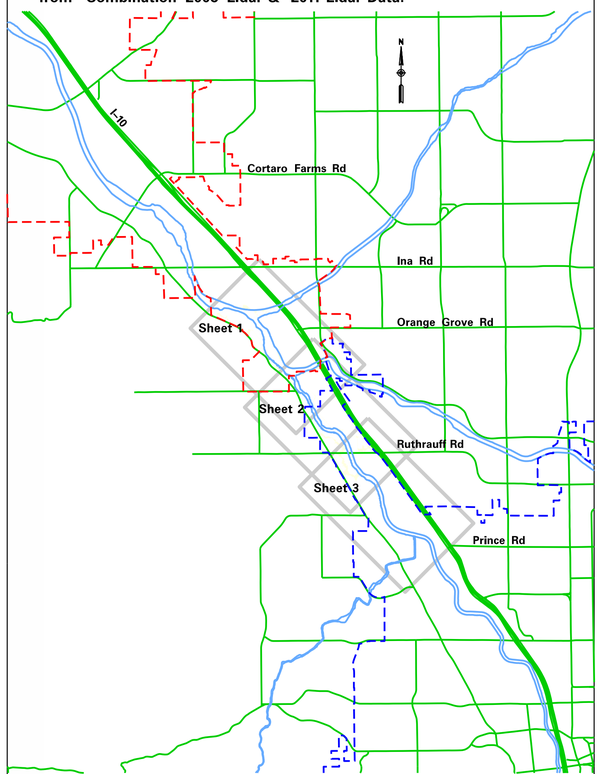
Santa Cruz River CLOMR
Ina Rd. to Sweetwater Dr.

Plate 1 – Floodplain and Cross Section Workmap Proposed Conditions

LEGEND

Major Streets	Proposed Floodway
Centerline	Flood sheet line
10ft Contour	Section line
Cross Section	Prop 100-year
Town of Marana	Prop 500-year
City of Tucson	100-year (Existing)
Parcels	500-year (Existing)

Aerial Photos are 2011 PAG Topo Developed from Combination 2008 Lidar & 2011 Lidar Data.



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Scale: 1" = 400'

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SHEET 3 OF 3

HYDRAULICS

DESIGN

4RTSUN DESIGN HEC-RAS MODELS BASED ON DESIGN FLOW RATE & DESIGN CONTRAINTS

- 100-Year Discharge 70,000 ft^3/sec @ Proposed Bridge Site
- Full Debris Loading on Bridge Piers (All Bridges) in accordance with PCRFCD Memorandum
- Interim Condition Includes @ Grade Connection to Silverbell Road
- Ultimate Condition – Approximate Silverbell Road Full Build Out with Ineffective and Blocked Flow Regions

HEC-RAS MODELS:

Run	Plan	Geometry	Flow	Description
1.	DES EXIST COND	EXIST GEO SCR DES	100Yr & 500Yr DES	Existing Condition
2.	DES Int Brg Grd Alt-2	Int Brg Grd-2 DES	100Yr & 500Yr DES	Interim Design w/ Sloping Abutment
3.	DES Ult Brg Grd Alt-2	Ult Brg Grd-2 DES	100Yr & 500Yr DES	Ultimate Design w/ Sloping Abutment
4.	DES Int Brg No Grd (Alt)	Int Brg No Grd DES	100Yr & 500Yr DES	Interim Design (Alt) w/ Vert Abut No Grade
5.	DES Ult Brg No Grd (Alt)	Ult Brg No Grd DES	100Yr & 500Yr DES	Ultimate Design (Alt) w/ Vert Abut No Grade
6.	DES Int Brg VrtSbut Grd-2 (Alt)	Int Brg No Grd DES	100Yr & 500Yr DES	Interim Design (Alt) w/ Vert Abut Grade Alt2
7.	DES Ult Brg VrtAbut Grd-2 (Alt)	Ult Brg No Grd DES	100Yr & 500Yr DES	Ultimate Design (Alt) w/ Vert Abut Grade Alt2
8.	DES Int Brg Grd-1 (Alt)	Int Brg Grd-1 DES	100Yr & 500Yr DES	Interim Design (Alt) w/ Sloping Abutment Grade Alt1

4RTSUN DESIGN PROPOSED (INTERIM) CONDITION RESULTS, SCR

HEC-RAS Plan: INTBRGGRD-2 River: Santa Cruz Reach: Sunset

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	100-Yr	70000.00	2255.61	2275.79	2273.02	2280.15	0.002225	16.80	4392.94	981.95	0.75
Sunset	68977	500-Yr	93000.00	2255.61	2281.75	2276.77	2283.78	0.000831	12.77	12427.02	1595.10	0.49
Sunset	68588	100-Yr	70000.00	2253.49	2275.40	2271.56	2279.21	0.001808	15.65	4472.53	984.19	0.68
Sunset	68588	500-Yr	93000.00	2253.49	2278.06	2274.37	2283.01	0.001957	17.86	5207.87	1168.04	0.73
Sunset	68087	100-Yr	70000.00	2250.70	2275.32	2269.24	2278.16	0.001283	13.52	5194.55	1124.65	0.58
Sunset	68087	500-Yr	93000.00	2250.70	2279.97	2272.48	2281.47	0.000611	11.00	13144.99	1389.29	0.42
Sunset	67552	100-Yr	70000.00	2250.55	2273.14	2269.97	2277.19	0.002006	16.25	4507.35	913.42	0.72
Sunset	67552	500-Yr	93000.00	2250.55	2274.60	2273.36	2280.43	0.002584	19.58	5039.34	1297.64	0.83
Sunset	67038	100-Yr	70000.00	2249.72	2270.12	2269.08	2275.73	0.003359	19.00	3683.83	1102.63	0.91
Sunset	67038	500-Yr	93000.00	2249.72	2277.90	2272.02	2278.51	0.000345	8.23	23436.22	2718.42	0.32
Sunset	66600	100-Yr	70000.00	2249.10	2267.39	2267.39	2273.75	0.005843	20.23	3459.55	1107.81	1.00
Sunset	66600	500-Yr	93000.00	2249.10	2270.54	2270.54	2277.49	0.005548	21.16	4410.02	1518.21	0.99
Sunset	66255	100-Yr	70000.00	2248.50	2267.13	2265.06	2271.86	0.002676	17.45	4021.70	375.11	0.82
Sunset	66255	500-Yr	93000.00	2248.50	2268.24	2268.24	2275.37	0.003681	21.45	4395.85	446.02	0.98
Sunset	65763	100-Yr	70000.00	2247.09	2267.86	2265.31	2270.15	0.001538	13.38	8467.06	1556.77	0.62
Sunset	65763	500-Yr	93000.00	2247.09	2270.67	2267.11	2272.51	0.001132	12.78	13351.71	1872.14	0.55
Sunset	65255	100-Yr	70000.00	2246.28	2265.74	2263.42	2268.99	0.003029	14.97	5682.89	882.69	0.72
Sunset	65255	500-Yr	93000.00	2246.28	2268.67	2266.35	2271.59	0.002329	14.80	8497.60	1083.97	0.65
Sunset	64585	100-Yr	70000.00	2244.01	2263.33	2260.87	2267.15	0.002362	15.67	4466.80	983.88	0.76
Sunset	64585	500-Yr	93000.00	2244.01	2268.72	2264.44	2270.32	0.000822	11.40	12774.28	1376.64	0.47
Sunset	64087	100-Yr	70000.00	2242.46	2260.62	2259.87	2265.61	0.003547	17.91	3907.34	1159.91	0.92
Sunset	64087	500-Yr	93000.00	2242.46	2262.38	2262.38	2269.03	0.003988	20.69	4495.27	1230.12	1.00
Sunset	63622	100-Yr	70000.00	2241.64	2262.16	2258.12	2263.76	0.001044	11.20	10093.69	1311.90	0.52
Sunset	63622	500-Yr	93000.00	2241.64	2264.41	2261.13	2266.14	0.001012	12.02	13267.75	1454.63	0.52
Sunset	62978	100-Yr	70000.00	2240.25	2257.94	2256.47	2262.40	0.002933	16.95	4130.92	1025.20	0.85
Sunset	62978	500-Yr	93000.00	2240.25	2264.38	2259.59	2265.42	0.000603	9.89	20313.97	2811.08	0.41
Sunset	62453	100-Yr	70000.00	2239.00	2255.99	2254.86	2260.78	0.003126	17.57	3985.51	857.44	0.88
Sunset	62453	500-Yr	93000.00	2239.00	2257.67	2257.36	2264.23	0.003668	20.55	4526.55	934.10	0.97
Sunset	61960	100-Yr	70000.00	2234.74	2255.51	2253.72	2259.15	0.002205	15.74	5144.99	963.82	0.75
Sunset	61960	500-Yr	93000.00	2234.74	2257.64	2255.98	2262.20	0.002357	17.75	6145.23	991.88	0.79
Sunset	61436	100-Yr	70000.00	2233.28	2253.96	2252.45	2257.88	0.002564	16.02	4786.42	1799.27	0.80
Sunset	61436	500-Yr	93000.00	2233.28	2259.35	2255.86	2260.58	0.000715	10.53	16792.63	1857.30	0.44
Sunset	61000	100-Yr	70000.00	2229.63	2253.10	2251.01	2256.75	0.002276	15.40	4803.39	1315.61	0.75
Sunset	61000	500-Yr	93000.00	2229.63	2254.89	2253.60	2259.69	0.002582	17.77	5683.56	1392.43	0.82
Sunset	60523	100-Yr	70000.00	2229.89	2252.71	2250.66	2255.48	0.001974	13.84	7138.09	1517.04	0.70
Sunset	60523	500-Yr	93000.00	2229.89	2256.08	2253.84	2258.05	0.001187	12.47	12347.07	1571.72	0.56
Sunset	60070	100-Yr	70000.00	2228.19	2251.35	2249.40	2254.24	0.003933	14.04	5639.91	1389.61	0.70
Sunset	60070	500-Yr	93000.00	2228.19	2253.84	2251.40	2257.06	0.003572	15.00	7235.02	1662.12	0.69
Sunset	59588	100-Yr	70000.00	2226.99	2251.39	2247.48	2253.00	0.001031	10.72	8484.18	1134.67	0.51
Sunset	59588	500-Yr	93000.00	2226.99	2254.13	2249.40	2255.84	0.000923	11.35	12995.43	1727.22	0.50
Sunset	59088	100-Yr	70000.00	2226.21	2250.18	2246.81	2252.38	0.001300	12.44	7007.17	1281.40	0.58
Sunset	59088	500-Yr	93000.00	2226.21	2253.89	2248.79	2255.38	0.000782	11.09	14152.95	1452.00	0.46
Sunset	58533	100-Yr	70000.00	2224.44	2245.74	2245.17	2250.98	0.003270	18.43	4016.92	480.42	0.90
Sunset	58533	500-Yr	93000.00	2224.44	2248.80	2248.80	2254.23	0.002714	19.08	6029.28	790.16	0.85
Sunset	57982	100-Yr	70000.00	2224.20	2245.90	2243.56	2248.13	0.003782	12.70	7112.94	1039.09	0.61
Sunset	57982	500-Yr	93000.00	2224.20	2247.59	2246.02	2250.16	0.003986	14.01	8945.00	1131.30	0.64
Sunset	57561	100-Yr	70000.00	2222.54	2243.93	2240.61	2246.98	0.001803	14.03	5087.62	838.70	0.67
Sunset	57561	500-Yr	93000.00	2222.54	2248.24	2242.99	2249.14	0.000570	9.24	20362.67	2477.30	0.39
Sunset	57165	100-Yr	70000.00	2221.13	2244.22	2239.67	2246.08	0.001077	11.26	7836.47	1006.73	0.53
Sunset	57165	500-Yr	93000.00	2221.13	2246.63	2242.47	2248.72	0.001041	12.20	10411.57	1093.70	0.53
Sunset	56836	100-Yr	70000.00	2221.00	2243.11	2238.47	2245.63	0.001271	12.96	6688.68	942.61	0.58
Sunset	56836	500-Yr	93000.00	2221.00	2245.26	2241.51	2248.24	0.001346	14.44	8758.72	985.61	0.61
Sunset	56608	100-Yr	70000.00	2221.00	2243.69	2237.25	2244.68	0.000549	8.89	12736.27	1968.89	0.38
Sunset	56608	500-Yr	93000.00	2221.00	2246.07	2239.54	2247.06	0.000508	9.35	17999.49	2535.38	0.38
Sunset	56526 El Camino Del Ce		Bridge									

4RTSUN DESIGN PROPOSED (INTERIM) CONDITION RESULTS, SCR

HEC-RAS Plan: INTBRGGRD-2 River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	56440	100-Yr	70000.00	2220.50	2241.28	2237.27	2242.67	0.001157	10.46	10220.02	1776.55	0.46
Sunset	56440	500-Yr	93000.00	2220.50	2244.20	2240.68	2245.28	0.000828	9.90	16102.58	2304.04	0.40
Sunset	55999	100-Yr	70000.00	2217.00	2236.42	2235.94	2240.85	0.004646	17.04	4282.14	484.88	0.87
Sunset	55999	500-Yr	93000.00	2217.00	2239.22	2239.22	2243.61	0.003643	17.36	6318.71	987.88	0.80
Sunset	55499	100-Yr	70000.00	2216.00	2234.95	2234.00	2238.27	0.003558	15.08	5391.06	901.55	0.77
Sunset	55499	500-Yr	93000.00	2216.00	2236.62	2236.62	2240.49	0.003669	16.65	7175.30	1216.18	0.79
Sunset	54999	100-Yr	70000.00	2214.00	2233.89	2232.76	2236.49	0.002786	13.66	6767.77	1064.20	0.68
Sunset	54999	500-Yr	93000.00	2214.00	2235.29	2234.64	2238.54	0.003137	15.58	8369.12	1214.93	0.74
Sunset	54499	100-Yr	70000.00	2213.00	2231.34	2231.34	2234.75	0.004022	15.59	5923.71	1022.48	0.81
Sunset	54499	500-Yr	93000.00	2213.00	2233.64	2232.99	2236.92	0.003296	15.87	8323.05	1085.18	0.76
Sunset	53999	100-Yr	70000.00	2211.00	2229.66	2227.36	2232.76	0.003030	14.34	5619.02	851.36	0.71
Sunset	53999	500-Yr	93000.00	2211.00	2231.05	2230.44	2235.12	0.003595	16.65	6804.34	929.36	0.79
Sunset	53499	100-Yr	70000.00	2207.00	2228.75	2226.77	2231.00	0.002962	12.21	6388.73	968.03	0.68
Sunset	53499	500-Yr	93000.00	2207.00	2230.19	2228.72	2233.04	0.003235	13.84	7835.78	1075.98	0.73
Sunset	52999	100-Yr	70000.00	2205.00	2228.25	2225.33	2229.42	0.002062	9.34	8400.48	1185.23	0.56
Sunset	52999	500-Yr	93000.00	2205.00	2229.89	2226.59	2231.32	0.002017	10.30	10083.73	1197.89	0.57
Sunset	52499	100-Yr	70000.00	2204.00	2225.40	2224.59	2227.70	0.005131	12.96	5889.68	1021.50	0.85
Sunset	52499	500-Yr	93000.00	2204.00	2227.15	2225.86	2229.71	0.004362	13.64	7389.24	1036.97	0.81
Sunset	51999	100-Yr	70000.00	2203.00	2224.20	2221.46	2225.71	0.002385	10.92	7479.71	1047.55	0.61
Sunset	51999	500-Yr	93000.00	2203.00	2226.02	2222.80	2227.84	0.002394	11.97	8963.59	1142.90	0.62
Sunset	51499	100-Yr	70000.00	2201.00	2223.51	2220.28	2224.67	0.001495	9.14	8893.38	1242.37	0.49
Sunset	51499	500-Yr	93000.00	2201.00	2225.47	2221.79	2226.78	0.001435	9.82	10991.76	1269.55	0.50
Sunset	51057	100-Yr	70000.00	2199.00	2222.72	2219.37	2223.95	0.001653	10.02	8523.08	1060.48	0.53
Sunset	51057	500-Yr	93000.00	2199.00	2224.72	2220.96	2226.10	0.001546	10.70	10657.25	1085.09	0.52
Sunset	51000 Proposed Sunset		Bridge									
Sunset	50945	100-Yr	70000.00	2199.00	2221.21	2218.73	2222.91	0.002322	11.67	7265.76	1012.81	0.62
Sunset	50945	500-Yr	93000.00	2199.00	2222.65	2220.64	2224.77	0.002507	13.16	8755.45	1085.17	0.66
Sunset	50500	100-Yr	70000.00	2198.00	2220.00	2218.59	2221.65	0.003602	10.97	7067.95	1255.83	0.72
Sunset	50500	500-Yr	93000.00	2198.00	2221.49	2219.73	2223.44	0.003318	11.91	8622.43	1334.72	0.72
Sunset	49996	100-Yr	70000.00	2197.00	2218.81	2216.21	2220.04	0.002179	9.41	8216.29	1253.50	0.58
Sunset	49996	500-Yr	93000.00	2197.00	2220.36	2217.39	2221.88	0.002163	10.43	9827.84	1318.48	0.59
Sunset	49501	100-Yr	70000.00	2197.00	2216.09	2215.36	2218.40	0.004787	12.26	5806.92	1016.39	0.83
Sunset	49501	500-Yr	93000.00	2197.00	2217.39	2216.61	2220.23	0.004713	13.62	6957.90	1027.74	0.84
Sunset	48999	100-Yr	70000.00	2196.00	2215.30	2212.51	2216.63	0.001987	9.29	7654.60	1001.28	0.55
Sunset	48999	500-Yr	93000.00	2196.00	2216.57	2213.80	2218.34	0.002220	10.73	8817.67	1072.04	0.60
Sunset	48499	100-Yr	70000.00	2195.00	2212.11	2212.11	2214.88	0.006028	13.54	5510.79	1057.80	0.92
Sunset	48499	500-Yr	93000.00	2195.00	2215.02	2213.39	2217.05	0.002887	11.82	8669.49	1212.27	0.68
Sunset	47499	100-Yr	80000.00	2193.11	2211.21	2204.27	2212.29	0.000906	8.45	10135.50	1074.68	0.40
Sunset	47499	500-Yr	107400.00	2193.11	2214.21	2206.02	2215.44	0.000853	9.07	12811.81	1149.46	0.40
Sunset	46999	100-Yr	80000.00	2191.00	2207.25	2205.40	2211.21	0.003440	16.09	5398.58	753.39	0.77
Sunset	46999	500-Yr	107400.00	2191.00	2208.57	2208.57	2214.18	0.004400	19.31	6275.73	806.18	0.89
Sunset	46499	100-Yr	80000.00	2189.00	2204.00	2204.00	2208.87	0.006169	17.70	4519.52	583.72	1.00
Sunset	46499	500-Yr	107400.00	2189.00	2206.81	2206.81	2211.55	0.004583	17.74	6524.58	787.68	0.89
Sunset	45999	100-Yr	80000.00	2189.00	2200.98	2200.98	2204.89	0.006650	15.86	5045.42	688.44	1.00
Sunset	45999	500-Yr	107400.00	2189.00	2203.11	2203.11	2207.25	0.005452	16.44	6791.39	882.93	0.93
Sunset	45499	100-Yr	80000.00	2187.00	2199.85	2198.23	2201.92	0.003495	11.56	6919.40	873.17	0.72
Sunset	45499	500-Yr	107400.00	2187.00	2201.32	2199.67	2203.97	0.003570	13.07	8266.64	944.05	0.75
Sunset	44999	100-Yr	80000.00	2186.00	2198.21	2196.65	2200.14	0.003465	11.17	7164.91	947.04	0.72
Sunset	44999	500-Yr	107400.00	2186.00	2199.75	2197.97	2202.15	0.003386	12.44	8633.09	953.01	0.73
Sunset	44499	100-Yr	80000.00	2184.00	2196.58	2194.87	2198.44	0.003250	10.94	7309.30	947.35	0.69
Sunset	44499	500-Yr	107400.00	2184.00	2198.20	2196.21	2200.49	0.003142	12.12	8858.00	959.72	0.70
Sunset	43999	100-Yr	80000.00	2183.00	2195.62	2192.82	2197.02	0.002069	9.52	8406.29	959.69	0.57
Sunset	43999	500-Yr	107400.00	2183.00	2197.28	2194.11	2199.07	0.002106	10.74	9999.75	963.48	0.59
Sunset	43499	100-Yr	80000.00	2181.00	2194.17	2192.05	2195.83	0.002679	10.33	7745.22	949.60	0.64
Sunset	43499	500-Yr	107400.00	2181.00	2195.77	2193.38	2197.85	0.002682	11.59	9265.94	955.84	0.66

4RTSUN DESIGN PROPOSED (INTERIM) CONDITION RESULTS, SCR

HEC-RAS Plan: INTBRGGRD-2 River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	42999	100-Yr	80000.00	2180.00	2191.17	2190.67	2193.85	0.005613	13.14	6090.41	902.26	0.89
Sunset	42999	500-Yr	107400.00	2180.00	2192.58	2192.05	2195.88	0.005416	14.59	7363.67	906.56	0.90
Sunset	42499	100-Yr	80000.00	2175.00	2190.88	2186.89	2192.07	0.001558	8.74	9148.10	1545.88	0.50
Sunset	42499	500-Yr	107400.00	2175.00	2192.29	2188.39	2193.90	0.001854	10.19	10534.98	1635.41	0.55
Sunset	41999	100-Yr	80000.00	2176.00	2190.92	2185.21	2191.41	0.000570	5.60	14281.79	1744.64	0.31
Sunset	41999	500-Yr	107400.00	2176.00	2192.43	2186.26	2193.10	0.000657	6.57	16365.87	1843.12	0.34
Sunset	41499	100-Yr	80000.00	2175.00	2190.05	2185.63	2190.95	0.001376	7.59	10539.68	1648.80	0.46
Sunset	41499	500-Yr	107400.00	2175.00	2191.37	2187.06	2192.57	0.001529	8.79	12361.50	1772.97	0.49
Sunset	40999	100-Yr	80000.00	2174.00	2189.26	2184.72	2190.25	0.001366	7.98	10029.21	1457.27	0.46
Sunset	40999	500-Yr	107400.00	2174.00	2190.28	2186.34	2191.73	0.001746	9.64	11182.61	1480.91	0.53
Sunset	40499	100-Yr	80000.00	2172.00	2186.02	2185.74	2188.79	0.006440	13.36	5988.54	1167.18	0.94
Sunset	40499	500-Yr	107400.00	2172.00	2188.24	2186.97	2190.40	0.003882	12.16	9667.86	1330.92	0.76
Sunset	39999	100-Yr	80000.00	2171.00	2184.96	2182.58	2186.55	0.002479	10.14	7885.77	1151.78	0.61
Sunset	39999	500-Yr	107400.00	2171.00	2187.32	2183.93	2188.93	0.001876	10.31	11191.39	1212.90	0.56
Sunset	39399	100-Yr	80000.00	2168.00	2183.76	2179.81	2185.13	0.002084	9.39	8519.81	1062.01	0.50
Sunset	39399	500-Yr	107400.00	2168.00	2186.13	2181.31	2187.78	0.001928	10.32	10464.97	1196.11	0.50
Sunset	38909	100-Yr	80000.00	2168.00	2183.20	2178.14	2184.19	0.001378	8.13	10429.96	1028.75	0.42
Sunset	38909	500-Yr	107400.00	2168.00	2185.71	2179.53	2186.88	0.001276	8.90	13009.90	1101.66	0.41
Sunset	38409	100-Yr	80000.00	2168.00	2182.46	2176.88	2183.51	0.001308	8.22	9865.51	954.67	0.41
Sunset	38409	500-Yr	107400.00	2168.00	2184.94	2178.42	2186.23	0.001272	9.15	12084.13	1024.37	0.42
Sunset	37929	100-Yr	80000.00	2166.00	2181.56	2176.04	2182.82	0.001486	9.06	9097.27	903.06	0.44
Sunset	37929	500-Yr	107400.00	2166.00	2183.93	2177.77	2185.53	0.001532	10.23	10914.88	959.44	0.46
Sunset	37509	100-Yr	80000.00	2166.00	2180.87	2175.74	2182.17	0.001591	9.28	9032.09	1225.27	0.45
Sunset	37509	500-Yr	107400.00	2166.00	2183.19	2177.39	2184.85	0.001652	10.52	10715.65	1270.75	0.48
Sunset	36859	100-Yr	80000.00	2164.00	2179.51	2175.46	2181.02	0.001950	10.45	9180.07	1367.59	0.51
Sunset	36859	500-Yr	107400.00	2164.00	2181.87	2177.11	2183.70	0.001929	11.59	11244.77	1413.71	0.52
Sunset	36439	100-Yr	80000.00	2162.00	2178.09	2175.16	2180.01	0.002633	11.68	7812.43	1411.26	0.58
Sunset	36439	500-Yr	107400.00	2162.00	2180.41	2176.84	2182.69	0.002586	12.82	9571.11	1552.28	0.59
Sunset	36049	100-Yr	80000.00	2162.00	2176.28	2173.82	2178.78	0.003297	13.04	6711.07	1519.96	0.65
Sunset	36049	500-Yr	107400.00	2162.00	2178.08	2175.75	2181.36	0.003683	15.01	7868.96	1539.58	0.70
Sunset	35639	100-Yr	80000.00	2160.00	2174.47	2172.87	2177.19	0.004353	13.60	6400.02	1771.64	0.73
Sunset	35639	500-Yr	107400.00	2160.00	2176.17	2174.70	2179.63	0.004618	15.44	7756.64	1896.54	0.77
Sunset	35095	100-Yr	80000.00	2158.00	2172.69	2170.27	2174.79	0.003834	11.66	6912.72	3685.26	0.67
Sunset	35095	500-Yr	107400.00	2158.00	2174.50	2172.12	2177.10	0.003804	12.99	8425.09	3832.29	0.69
Sunset	34808	100-Yr	80000.00	2158.00	2170.63	2169.06	2173.47	0.004996	13.54	5910.30	2363.27	0.77
Sunset	34808	500-Yr	107400.00	2158.00	2175.69	2170.84	2176.09	0.000609	6.19	24514.84	3843.28	0.29
Sunset	34568	100-Yr	80000.00	2157.92	2170.49	2166.50	2172.37	0.002442	10.99	7277.88	2033.83	0.56
Sunset	34568	500-Yr	107400.00	2157.92	2175.43	2168.33	2175.93	0.000638	6.60	22415.90	3488.19	0.30
Sunset	34556	100-Yr	80000.00	2157.92	2170.44	2166.49	2172.33	0.002468	11.02	7257.11	599.48	0.56
Sunset	34556	500-Yr	107400.00	2157.92	2173.10	2168.32	2175.38	0.002365	12.12	8861.36	2134.71	0.56
Sunset	34529		Bridge									
Sunset	34502	100-Yr	80000.00	2155.79	2167.17	2165.46	2170.01	0.002453	13.53	5913.49	592.97	0.75
Sunset	34502	500-Yr	107400.00	2155.79	2169.34	2167.30	2172.79	0.002323	14.91	7204.29	1779.71	0.76
Sunset	34494	100-Yr	80000.00	2155.79	2165.45	2165.45	2169.59	0.004540	16.33	4899.03	589.01	1.00
Sunset	34494	500-Yr	107400.00	2155.79	2167.27	2167.27	2172.29	0.004282	17.98	5971.85	593.19	1.00
Sunset	34294	100-Yr	80000.00	2146.87	2160.00	2158.62	2163.13	0.002806	14.19	5637.23	581.02	0.80
Sunset	34294	500-Yr	107400.00	2146.87	2161.44	2160.46	2165.71	0.003220	16.59	6473.85	584.36	0.88
Sunset	34054	100-Yr	80000.00	2146.44	2159.42	2158.36	2162.38	0.003083	13.80	5797.32	671.22	0.83
Sunset	34054	500-Yr	107400.00	2146.44	2160.99	2160.03	2164.80	0.003204	15.66	6858.36	675.12	0.87
Sunset	33594	100-Yr	80000.00	2145.96	2158.21	2157.13	2160.99	0.002749	13.61	6163.40	1532.95	0.79
Sunset	33594	500-Yr	107400.00	2145.96	2159.90	2158.78	2163.34	0.002753	15.19	7438.77	1551.48	0.81
Sunset	33332	100-Yr	80000.00	2145.72	2157.64	2156.23	2160.27	0.002482	13.19	6283.79	1349.81	0.76
Sunset	33332	500-Yr	107400.00	2145.72	2159.26	2157.88	2162.63	0.002589	14.94	7471.91	1401.48	0.79
Sunset	33162	100-Yr	80000.00	2145.21	2155.87	2155.86	2159.62	0.004266	15.64	5256.08	1292.26	0.96
Sunset	33162	500-Yr	107400.00	2145.21	2157.91	2157.54	2162.04	0.003554	16.51	6747.95	1301.58	0.91

4RTSUN DESIGN PROPOSED (INTERIM) CONDITION RESULTS, SCR

HEC-RAS Plan: INTBRGGRD-2 River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	32680	100-Yr	80000.00	2143.52	2155.43	2153.15	2157.85	0.002016	12.52	6441.95	1188.58	0.69
Sunset	32680	500-Yr	107400.00	2143.52	2157.42	2154.92	2160.46	0.002014	14.04	7748.07	1304.33	0.71
Sunset	32153	100-Yr	80000.00	2142.51	2153.73	2152.24	2156.59	0.002689	13.56	5899.12	1355.80	0.78
Sunset	32153	500-Yr	107400.00	2142.51	2155.77	2154.03	2159.22	0.002584	14.91	7205.58	1381.36	0.79
Sunset	31655	100-Yr	80000.00	2141.12	2152.20	2151.06	2155.19	0.002903	13.92	5834.89	1823.11	0.81
Sunset	31655	500-Yr	107400.00	2141.12	2154.69	2152.82	2157.94	0.002328	14.58	7538.17	1866.20	0.75
Sunset	31182	100-Yr	80000.00	2139.64	2151.84	2148.74	2153.93	0.001578	11.59	6899.87	1922.98	0.61
Sunset	31182	500-Yr	107400.00	2139.64	2154.37	2150.50	2156.86	0.001450	12.66	8483.51	2059.01	0.61
Sunset	30846	100-Yr	80000.00	2138.32	2151.37	2148.31	2153.38	0.001589	11.38	7029.98	2250.77	0.61
Sunset	30846	500-Yr	107400.00	2138.32	2154.01	2150.04	2156.34	0.001388	12.24	8776.31	2379.75	0.59
Sunset	30571	100-Yr	80000.00	2135.91	2151.57	2145.98	2152.86	0.000779	9.12	8771.91	2429.10	0.44
Sunset	30571	500-Yr	107400.00	2135.91	2154.24	2147.67	2155.84	0.000766	10.17	10569.90	2484.94	0.45
Sunset	30211	100-Yr	80000.00	2134.31	2151.33	2145.50	2152.58	0.000731	8.99	8902.29	2076.48	0.43
Sunset	30211	500-Yr	107400.00	2134.31	2153.99	2147.19	2155.56	0.000729	10.06	10673.21	2266.54	0.44
Sunset	29689	100-Yr	80000.00	2133.83	2148.47	2146.69	2151.74	0.002500	14.50	5517.15	1595.69	0.77
Sunset	29689	500-Yr	107400.00	2133.83	2150.34	2148.77	2154.61	0.003037	16.58	6489.96	1751.18	0.86
Sunset	29333	100-Yr	80000.00	2133.19	2146.73	2146.30	2150.59	0.003829	15.77	5073.43	1591.98	0.93
Sunset	29333	500-Yr	107400.00	2133.19	2148.57	2148.41	2153.31	0.004106	17.48	6145.65	1764.34	0.98
Sunset	29145	100-Yr	80000.00	2133.23	2147.10	2145.13	2149.66	0.002229	12.85	6228.07	1734.06	0.72
Sunset	29145	500-Yr	107400.00	2133.23	2149.12	2146.88	2152.30	0.002191	14.32	7502.15	1853.57	0.73
Sunset	28850	100-Yr	80000.00	2133.13	2146.56	2144.11	2149.01	0.001971	12.54	6380.62	1609.75	0.68
Sunset	28850	500-Yr	107400.00	2133.13	2148.55	2145.91	2151.66	0.002020	14.15	7596.28	1898.05	0.71
Sunset	28513	100-Yr	80000.00	2132.91	2146.53	2142.77	2148.27	0.001264	10.56	7604.48	1509.66	0.55
Sunset	28513	500-Yr	107400.00	2132.91	2148.67	2144.47	2150.84	0.001266	11.86	9275.05	2217.60	0.57
Sunset	28332	100-Yr	80000.00	2132.32	2146.62	2141.99	2147.94	0.000954	9.23	8666.97	1146.20	0.48
Sunset	28332	500-Yr	107400.00	2132.32	2148.82	2143.76	2150.49	0.000950	10.37	10480.80	1808.90	0.50
Sunset	28037	100-Yr	80000.00	2131.16	2146.59	2141.31	2147.59	0.000774	8.03	9961.61	918.05	0.43
Sunset	28037	500-Yr	107400.00	2131.16	2148.89	2142.76	2150.10	0.000747	8.85	12370.76	1697.32	0.43
Sunset	27481	100-Yr	80000.00	2130.71	2145.50	2142.01	2147.01	0.001254	9.83	8136.53	796.08	0.54
Sunset	27481	500-Yr	107400.00	2130.71	2147.69	2143.48	2149.52	0.001223	10.84	9903.42	832.71	0.55
Sunset	27120	100-Yr	80000.00	2130.71	2145.12	2141.24	2146.56	0.001116	9.64	8300.23	769.20	0.52
Sunset	27120	500-Yr	107400.00	2130.71	2147.30	2142.79	2149.09	0.001101	10.76	9979.40	773.94	0.53
Sunset	27119	100-Yr	80000.00	2130.58	2145.20	2140.82	2146.52	0.000967	9.23	8667.67	769.55	0.48
Sunset	27119	500-Yr	107400.00	2130.58	2147.38	2142.34	2149.05	0.000975	10.38	10351.34	774.34	0.50
Sunset	27054		Bridge									
Sunset	26989	100-Yr	80000.00	2130.16	2144.42	2141.17	2146.05	0.001384	10.25	7802.09	769.49	0.57
Sunset	26989	500-Yr	107400.00	2130.16	2146.50	2142.70	2148.52	0.001350	11.42	9405.79	773.03	0.58
Sunset	26977	100-Yr	80000.00	2130.27	2144.30	2141.29	2146.01	0.001489	10.50	7619.05	768.75	0.59
Sunset	26977	500-Yr	107400.00	2130.27	2146.37	2142.81	2148.48	0.001437	11.65	9219.67	773.50	0.59
Sunset	26837	100-Yr	80000.00	2130.30	2144.23	2140.50	2145.71	0.001177	9.78	8179.37	769.72	0.53
Sunset	26837	500-Yr	107400.00	2130.30	2146.31	2142.02	2148.18	0.001177	10.97	9798.82	789.30	0.54

4RTSUN DESIGN PROPOSED (INTERIM) BRIDGE RESULTS, SUNSET ROAD BRIDGE

Plan: INTBRGGRD-2 Santa Cruz Sunset RS: 51000 Profile: 100-Yr

E.G. US. (ft)	2223.95	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2222.72	E.G. Elev (ft)	2223.55	2223.23
Q Total (cfs)	70000.00	W.S. Elev (ft)	2221.20	2221.02
Q Bridge (cfs)	68153.15	Crit W.S. (ft)	2219.67	2218.99
Q Weir (cfs)	1846.85	Max Chl Dpth (ft)	22.20	22.02
Weir Sta Lft (ft)	248.86	Vel Total (ft/s)	12.06	11.62
Weir Sta Rgt (ft)	431.60	Flow Area (sq ft)	5651.93	5864.18
Weir Submerg	0.10	Froude # Chl	0.73	0.68
Weir Max Depth (ft)	3.74	Specif Force (cu ft)	58963.45	60755.06
Min El Weir Flow (ft)	2220.22	Hydr Depth (ft)	8.78	8.84
Min El Prs (ft)	2232.16	W.P. Total (ft)	763.30	769.11
Delta EG (ft)	1.04	Conv. Total (cfs)	1051700.0	1149228.0
Delta WS (ft)	1.51	Top Width (ft)	643.66	663.49
BR Open Area (sq ft)	11775.37	Frctn Loss (ft)	0.25	0.06
BR Open Vel (ft/s)	12.06	C & E Loss (ft)	0.08	0.25
Coef of Q		Shear Total (lb/sq ft)	2.05	1.77
Br Sel Method	Energy/Weir	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Yarnell answer is not valid if the water surface is above the low chord or if there is weir flow. The Yarnell answer has
	been disregarded.
Note:	Momentum answer is not valid if the water surface is above the low chord or if there is weir flow. The momentum
	answer has been disregarded.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.

Plan: INTBRGGRD-2 Santa Cruz Sunset RS: 51000 Profile: 500-Yr

E.G. US. (ft)	2226.10	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2224.72	E.G. Elev (ft)	2225.50	2225.16
Q Total (cfs)	93000.00	W.S. Elev (ft)	2222.56	2222.35
Q Bridge (cfs)	88235.73	Crit W.S. (ft)	2221.46	2220.81
Q Weir (cfs)	4764.27	Max Chl Dpth (ft)	23.56	23.35
Weir Sta Lft (ft)	221.36	Vel Total (ft/s)	13.50	13.07
Weir Sta Rgt (ft)	471.65	Flow Area (sq ft)	6534.94	6752.33
Weir Submerg	0.24	Froude # Chl	0.77	0.72
Weir Max Depth (ft)	5.89	Specif Force (cu ft)	78863.21	80669.14
Min El Weir Flow (ft)	2220.22	Hydr Depth (ft)	10.06	9.96
Min El Prs (ft)	2232.16	W.P. Total (ft)	787.16	796.94
Delta EG (ft)	1.33	Conv. Total (cfs)	1300951.0	1405121.0
Delta WS (ft)	2.06	Top Width (ft)	649.62	677.88
BR Open Area (sq ft)	11775.37	Frctn Loss (ft)	0.28	0.07
BR Open Vel (ft/s)	13.50	C & E Loss (ft)	0.07	0.37
Coef of Q		Shear Total (lb/sq ft)	2.65	2.32
Br Sel Method	Energy/Weir	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Yarnell answer is not valid if the water surface is above the low chord or if there is weir flow. The Yarnell answer has
	been disregarded.
Note:	Momentum answer is not valid if the water surface is above the low chord or if there is weir flow. The momentum
	answer has been disregarded.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.
Warning:	The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Notes(60): This is an inside cross section of a perched bridge that has energy, low flow inside of the bridge and weir
	flow over the embankment. The reported hydraulics are based on the flow and area inside of the bridge.

4RTSUN DESIGN PROPOSED (ULTIMATE) CONDITION RESULTS, SCR

HEC-RAS Plan: DESULTBRGGRD-2 River: Santa Cruz Reach: Sunset

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	68977	100-Yr	70000.00	2255.61	2275.79	2273.02	2280.15	0.002225	16.80	4392.94	981.95	0.75
Sunset	68977	500-Yr	93000.00	2255.61	2281.75	2276.77	2283.78	0.000831	12.77	12427.02	1595.10	0.49
Sunset	68588	100-Yr	70000.00	2253.49	2275.40	2271.56	2279.21	0.001808	15.65	4472.53	984.19	0.68
Sunset	68588	500-Yr	93000.00	2253.49	2278.06	2274.37	2283.01	0.001957	17.86	5207.87	1168.04	0.73
Sunset	68087	100-Yr	70000.00	2250.70	2275.32	2269.24	2278.16	0.001283	13.52	5194.55	1124.65	0.58
Sunset	68087	500-Yr	93000.00	2250.70	2279.97	2272.48	2281.47	0.000611	11.00	13144.99	1389.29	0.42
Sunset	67552	100-Yr	70000.00	2250.55	2273.14	2269.97	2277.19	0.002006	16.25	4507.35	913.42	0.72
Sunset	67552	500-Yr	93000.00	2250.55	2274.60	2273.36	2280.43	0.002584	19.58	5039.34	1297.64	0.83
Sunset	67038	100-Yr	70000.00	2249.72	2270.12	2269.08	2275.73	0.003359	19.00	3683.83	1102.63	0.91
Sunset	67038	500-Yr	93000.00	2249.72	2277.90	2272.02	2278.51	0.000345	8.23	23436.22	2718.42	0.32
Sunset	66600	100-Yr	70000.00	2249.10	2267.39	2267.39	2273.75	0.005843	20.23	3459.55	1107.81	1.00
Sunset	66600	500-Yr	93000.00	2249.10	2270.54	2270.54	2277.49	0.005548	21.16	4410.02	1518.21	0.99
Sunset	66255	100-Yr	70000.00	2248.50	2267.13	2265.06	2271.86	0.002676	17.45	4021.70	375.11	0.82
Sunset	66255	500-Yr	93000.00	2248.50	2268.24	2268.24	2275.37	0.003681	21.45	4395.85	446.02	0.98
Sunset	65763	100-Yr	70000.00	2247.09	2267.86	2265.31	2270.15	0.001538	13.38	8467.06	1556.77	0.62
Sunset	65763	500-Yr	93000.00	2247.09	2270.67	2267.11	2272.51	0.001132	12.78	13351.71	1872.14	0.55
Sunset	65255	100-Yr	70000.00	2246.28	2265.74	2263.42	2268.99	0.003029	14.97	5682.89	882.69	0.72
Sunset	65255	500-Yr	93000.00	2246.28	2268.67	2266.35	2271.59	0.002329	14.80	8497.60	1083.97	0.65
Sunset	64585	100-Yr	70000.00	2244.01	2263.33	2260.87	2267.15	0.002362	15.67	4466.80	983.88	0.76
Sunset	64585	500-Yr	93000.00	2244.01	2268.72	2264.44	2270.32	0.000822	11.40	12774.28	1376.64	0.47
Sunset	64087	100-Yr	70000.00	2242.46	2260.62	2259.87	2265.61	0.003547	17.91	3907.34	1159.91	0.92
Sunset	64087	500-Yr	93000.00	2242.46	2262.38	2262.38	2269.03	0.003988	20.69	4495.27	1230.12	1.00
Sunset	63622	100-Yr	70000.00	2241.64	2262.16	2258.12	2263.76	0.001044	11.20	10093.69	1311.90	0.52
Sunset	63622	500-Yr	93000.00	2241.64	2264.41	2261.13	2266.14	0.001012	12.02	13267.75	1454.63	0.52
Sunset	62978	100-Yr	70000.00	2240.25	2257.94	2256.47	2262.40	0.002933	16.95	4130.92	1025.20	0.85
Sunset	62978	500-Yr	93000.00	2240.25	2264.38	2259.59	2265.42	0.000603	9.89	20313.97	2811.08	0.41
Sunset	62453	100-Yr	70000.00	2239.00	2255.99	2254.86	2260.78	0.003126	17.57	3985.51	857.44	0.88
Sunset	62453	500-Yr	93000.00	2239.00	2257.67	2257.36	2264.23	0.003668	20.55	4526.55	934.10	0.97
Sunset	61960	100-Yr	70000.00	2234.74	2255.51	2253.72	2259.15	0.002205	15.74	5144.99	963.82	0.75
Sunset	61960	500-Yr	93000.00	2234.74	2257.64	2255.98	2262.20	0.002357	17.75	6145.23	991.88	0.79
Sunset	61436	100-Yr	70000.00	2233.28	2253.96	2252.45	2257.88	0.002564	16.02	4786.42	1799.27	0.80
Sunset	61436	500-Yr	93000.00	2233.28	2259.35	2255.86	2260.58	0.000715	10.53	16792.63	1857.30	0.44
Sunset	61000	100-Yr	70000.00	2229.63	2253.10	2251.01	2256.75	0.002276	15.40	4803.39	1315.61	0.75
Sunset	61000	500-Yr	93000.00	2229.63	2254.89	2253.60	2259.69	0.002582	17.77	5683.56	1392.43	0.82
Sunset	60523	100-Yr	70000.00	2229.89	2252.71	2250.66	2255.48	0.001974	13.84	7138.09	1517.04	0.70
Sunset	60523	500-Yr	93000.00	2229.89	2256.08	2253.84	2258.05	0.001187	12.47	12347.07	1571.72	0.56
Sunset	60070	100-Yr	70000.00	2228.19	2251.35	2249.40	2254.24	0.003933	14.04	5639.91	1389.61	0.70
Sunset	60070	500-Yr	93000.00	2228.19	2253.84	2251.40	2257.06	0.003572	15.00	7235.02	1662.12	0.69
Sunset	59588	100-Yr	70000.00	2226.99	2251.39	2247.48	2253.00	0.001031	10.72	8484.18	1134.67	0.51
Sunset	59588	500-Yr	93000.00	2226.99	2254.13	2249.40	2255.84	0.000923	11.35	12995.43	1727.22	0.50
Sunset	59088	100-Yr	70000.00	2226.21	2250.18	2246.81	2252.38	0.001300	12.44	7007.17	1281.40	0.58
Sunset	59088	500-Yr	93000.00	2226.21	2253.89	2248.79	2255.38	0.000782	11.09	14152.95	1452.00	0.46
Sunset	58533	100-Yr	70000.00	2224.44	2245.74	2245.17	2250.98	0.003270	18.43	4016.92	480.42	0.90
Sunset	58533	500-Yr	93000.00	2224.44	2248.80	2248.80	2254.23	0.002714	19.08	6029.28	790.16	0.85
Sunset	57982	100-Yr	70000.00	2224.20	2245.90	2243.56	2248.13	0.003782	12.70	7112.94	1039.09	0.61
Sunset	57982	500-Yr	93000.00	2224.20	2247.59	2246.02	2250.16	0.003986	14.01	8945.00	1131.30	0.64
Sunset	57561	100-Yr	70000.00	2222.54	2243.93	2240.61	2246.98	0.001803	14.03	5087.62	838.70	0.67
Sunset	57561	500-Yr	93000.00	2222.54	2248.24	2242.99	2249.14	0.000570	9.24	20362.67	2477.30	0.39
Sunset	57165	100-Yr	70000.00	2221.13	2244.22	2239.67	2246.08	0.001077	11.26	7836.47	1006.73	0.53
Sunset	57165	500-Yr	93000.00	2221.13	2246.63	2242.47	2248.72	0.001041	12.20	10411.57	1093.70	0.53
Sunset	56836	100-Yr	70000.00	2221.00	2243.11	2238.47	2245.63	0.001271	12.96	6688.68	942.61	0.58
Sunset	56836	500-Yr	93000.00	2221.00	2245.26	2241.51	2248.24	0.001346	14.44	8758.72	985.61	0.61
Sunset	56608	100-Yr	70000.00	2221.00	2243.69	2237.25	2244.68	0.000549	8.89	12736.27	1968.89	0.38
Sunset	56608	500-Yr	93000.00	2221.00	2246.07	2239.54	2247.06	0.000508	9.35	17999.49	2535.38	0.38
Sunset	56526 El Camino Del Ce		Bridge									

4RTSUN DESIGN PROPOSED (ULTIMATE) CONDITION RESULTS, SCR

HEC-RAS Plan: DESULTBRGGRD-2 River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	56440	100-Yr	70000.00	2220.50	2241.28	2237.27	2242.67	0.001157	10.46	10220.02	1776.55	0.46
Sunset	56440	500-Yr	93000.00	2220.50	2244.20	2240.68	2245.28	0.000828	9.90	16102.58	2304.04	0.40
Sunset	55999	100-Yr	70000.00	2217.00	2236.42	2235.94	2240.85	0.004646	17.04	4282.14	484.88	0.87
Sunset	55999	500-Yr	93000.00	2217.00	2239.22	2239.22	2243.61	0.003643	17.36	6318.71	987.88	0.80
Sunset	55499	100-Yr	70000.00	2216.00	2234.95	2234.00	2238.27	0.003558	15.08	5391.06	901.55	0.77
Sunset	55499	500-Yr	93000.00	2216.00	2236.62	2236.62	2240.49	0.003669	16.65	7175.30	1216.18	0.79
Sunset	54999	100-Yr	70000.00	2214.00	2233.89	2232.76	2236.49	0.002786	13.66	6767.77	1064.20	0.68
Sunset	54999	500-Yr	93000.00	2214.00	2235.30	2234.64	2238.54	0.003127	15.56	8381.58	1215.07	0.74
Sunset	54499	100-Yr	70000.00	2213.00	2231.34	2231.34	2234.75	0.004022	15.59	5923.71	1022.48	0.81
Sunset	54499	500-Yr	93000.00	2213.00	2233.61	2232.99	2236.91	0.003323	15.92	8295.79	1084.81	0.76
Sunset	53999	100-Yr	70000.00	2211.00	2229.67	2227.36	2232.76	0.003021	14.32	5627.25	851.58	0.71
Sunset	53999	500-Yr	93000.00	2211.00	2231.08	2230.44	2235.13	0.003563	16.60	6832.27	929.81	0.78
Sunset	53499	100-Yr	70000.00	2207.00	2228.77	2226.77	2231.01	0.002941	12.18	6408.59	968.61	0.68
Sunset	53499	500-Yr	93000.00	2207.00	2230.27	2228.72	2233.06	0.003155	13.72	7919.38	1077.86	0.72
Sunset	52999	100-Yr	70000.00	2205.00	2228.27	2225.32	2229.44	0.002049	9.32	8424.70	1022.99	0.56
Sunset	52999	500-Yr	93000.00	2205.00	2229.97	2226.60	2231.38	0.001968	10.23	10174.64	1031.68	0.56
Sunset	52499	100-Yr	70000.00	2204.00	2225.61	2224.59	2227.79	0.004731	12.65	6067.22	850.86	0.82
Sunset	52499	500-Yr	93000.00	2204.00	2227.52	2225.86	2229.89	0.003864	13.17	7705.55	862.84	0.77
Sunset	51999	100-Yr	70000.00	2203.00	2224.58	2221.46	2225.98	0.002107	10.50	7792.80	812.36	0.58
Sunset	51999	500-Yr	93000.00	2203.00	2226.58	2222.79	2228.22	0.002090	11.35	9429.96	836.64	0.59
Sunset	51499	100-Yr	70000.00	2201.00	2224.05	2220.26	2225.07	0.001246	8.61	9464.73	1067.30	0.45
Sunset	51499	500-Yr	93000.00	2201.00	2226.16	2221.81	2227.30	0.001195	9.18	11746.34	1098.68	0.46
Sunset	51057	100-Yr	70000.00	2199.00	2222.69	2219.37	2224.24	0.001897	10.71	7216.87	884.10	0.56
Sunset	51057	500-Yr	93000.00	2199.00	2224.35	2220.89	2226.36	0.002069	12.18	8408.00	889.18	0.60
Sunset	51000 Proposed Sunset		Bridge									
Sunset	50945	100-Yr	70000.00	2199.00	2221.13	2218.73	2223.17	0.002614	12.32	6313.42	905.43	0.66
Sunset	50945	500-Yr	93000.00	2199.00	2222.47	2220.43	2225.22	0.003025	14.32	7257.81	929.27	0.72
Sunset	50500	100-Yr	70000.00	2198.00	2220.00	2218.59	2221.65	0.003592	10.96	7074.29	1183.82	0.72
Sunset	50500	500-Yr	93000.00	2198.00	2221.50	2219.73	2223.44	0.003306	11.90	8632.34	1186.60	0.71
Sunset	49996	100-Yr	70000.00	2197.00	2218.81	2216.22	2220.04	0.002188	9.43	8217.29	1027.47	0.58
Sunset	49996	500-Yr	93000.00	2197.00	2220.37	2217.37	2221.88	0.002174	10.46	9830.12	1037.98	0.59
Sunset	49501	100-Yr	70000.00	2197.00	2216.09	2215.36	2218.40	0.004790	12.26	5806.92	884.80	0.83
Sunset	49501	500-Yr	93000.00	2197.00	2217.39	2216.62	2220.24	0.004713	13.62	6960.29	888.55	0.84
Sunset	48999	100-Yr	70000.00	2196.00	2215.30	2212.51	2216.63	0.001989	9.29	7653.03	914.99	0.56
Sunset	48999	500-Yr	93000.00	2196.00	2216.57	2213.80	2218.34	0.002221	10.73	8820.13	917.65	0.60
Sunset	48499	100-Yr	70000.00	2195.00	2212.11	2212.11	2214.88	0.006015	13.53	5515.16	1052.25	0.92
Sunset	48499	500-Yr	93000.00	2195.00	2215.02	2213.41	2217.06	0.002889	11.82	8671.36	1095.73	0.68
Sunset	47499	100-Yr	80000.00	2193.11	2211.21	2204.27	2212.29	0.000907	8.46	10135.71	866.68	0.40
Sunset	47499	500-Yr	107400.00	2193.11	2214.21	2206.02	2215.44	0.000855	9.08	12809.83	902.70	0.40
Sunset	46999	100-Yr	80000.00	2191.00	2207.25	2205.40	2211.21	0.003436	16.08	5401.83	664.57	0.77
Sunset	46999	500-Yr	107400.00	2191.00	2208.58	2208.58	2214.18	0.004384	19.29	6286.30	665.87	0.89
Sunset	46499	100-Yr	80000.00	2189.00	2204.00	2204.00	2208.87	0.006169	17.70	4519.52	583.72	1.00
Sunset	46499	500-Yr	107400.00	2189.00	2206.81	2206.81	2211.55	0.004583	17.74	6524.58	787.68	0.89
Sunset	45999	100-Yr	80000.00	2189.00	2200.98	2200.98	2204.89	0.006650	15.86	5045.42	688.44	1.00
Sunset	45999	500-Yr	107400.00	2189.00	2203.11	2203.11	2207.25	0.005452	16.44	6791.39	882.93	0.93
Sunset	45499	100-Yr	80000.00	2187.00	2199.85	2198.23	2201.92	0.003495	11.56	6919.40	873.17	0.72
Sunset	45499	500-Yr	107400.00	2187.00	2201.32	2199.67	2203.97	0.003570	13.07	8266.64	944.05	0.75
Sunset	44999	100-Yr	80000.00	2186.00	2198.21	2196.65	2200.14	0.003465	11.17	7164.91	947.04	0.72
Sunset	44999	500-Yr	107400.00	2186.00	2199.75	2197.97	2202.15	0.003386	12.44	8633.09	953.01	0.73
Sunset	44499	100-Yr	80000.00	2184.00	2196.58	2194.87	2198.44	0.003250	10.94	7309.30	947.35	0.69
Sunset	44499	500-Yr	107400.00	2184.00	2198.20	2196.21	2200.49	0.003142	12.12	8858.00	959.72	0.70
Sunset	43999	100-Yr	80000.00	2183.00	2195.62	2192.82	2197.02	0.002069	9.52	8406.29	959.69	0.57
Sunset	43999	500-Yr	107400.00	2183.00	2197.28	2194.11	2199.07	0.002106	10.74	9999.75	963.48	0.59
Sunset	43499	100-Yr	80000.00	2181.00	2194.17	2192.05	2195.83	0.002679	10.33	7745.22	949.60	0.64
Sunset	43499	500-Yr	107400.00	2181.00	2195.77	2193.38	2197.85	0.002682	11.59	9265.94	955.84	0.66

4RTSUN DESIGN PROPOSED (ULTIMATE) CONDITION RESULTS, SCR

HEC-RAS Plan: DESULTBRGGRD-2 River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	42999	100-Yr	80000.00	2180.00	2191.17	2190.67	2193.85	0.005613	13.14	6090.41	902.26	0.89
Sunset	42999	500-Yr	107400.00	2180.00	2192.58	2192.05	2195.88	0.005416	14.59	7363.67	906.56	0.90
Sunset	42499	100-Yr	80000.00	2175.00	2190.88	2186.89	2192.07	0.001558	8.74	9148.10	1484.07	0.50
Sunset	42499	500-Yr	107400.00	2175.00	2192.29	2188.39	2193.90	0.001853	10.19	10535.22	1549.20	0.55
Sunset	41999	100-Yr	80000.00	2176.00	2190.92	2185.21	2191.41	0.000570	5.60	14281.79	1668.62	0.31
Sunset	41999	500-Yr	107400.00	2176.00	2192.43	2186.26	2193.10	0.000656	6.57	16366.56	1730.23	0.34
Sunset	41499	100-Yr	80000.00	2175.00	2190.05	2185.63	2190.95	0.001376	7.59	10539.68	1573.25	0.46
Sunset	41499	500-Yr	107400.00	2175.00	2191.37	2187.06	2192.57	0.001528	8.79	12361.85	1691.64	0.49
Sunset	40999	100-Yr	80000.00	2174.00	2189.26	2184.72	2190.25	0.001366	7.98	10029.21	1369.93	0.46
Sunset	40999	500-Yr	107400.00	2174.00	2190.29	2186.34	2191.73	0.001746	9.64	11183.17	1383.34	0.53
Sunset	40499	100-Yr	80000.00	2172.00	2186.02	2185.74	2188.79	0.006440	13.36	5988.54	1167.18	0.94
Sunset	40499	500-Yr	107400.00	2172.00	2188.24	2186.97	2190.40	0.003884	12.17	9661.01	1302.46	0.76
Sunset	39999	100-Yr	80000.00	2171.00	2184.96	2182.58	2186.55	0.002479	10.14	7885.77	1151.78	0.61
Sunset	39999	500-Yr	107400.00	2171.00	2187.32	2183.93	2188.93	0.001876	10.31	11191.39	1212.90	0.56
Sunset	39399	100-Yr	80000.00	2168.00	2183.76	2179.81	2185.13	0.002084	9.39	8519.81	1062.01	0.50
Sunset	39399	500-Yr	107400.00	2168.00	2186.13	2181.31	2187.78	0.001928	10.32	10464.97	1196.11	0.50
Sunset	38909	100-Yr	80000.00	2168.00	2183.20	2178.14	2184.19	0.001378	8.13	10429.96	1028.75	0.42
Sunset	38909	500-Yr	107400.00	2168.00	2185.71	2179.53	2186.88	0.001276	8.90	13009.90	1101.66	0.41
Sunset	38409	100-Yr	80000.00	2168.00	2182.46	2176.88	2183.51	0.001308	8.22	9865.51	954.67	0.41
Sunset	38409	500-Yr	107400.00	2168.00	2184.94	2178.42	2186.23	0.001272	9.15	12084.13	1024.37	0.42
Sunset	37929	100-Yr	80000.00	2166.00	2181.56	2176.04	2182.82	0.001486	9.06	9097.27	903.06	0.44
Sunset	37929	500-Yr	107400.00	2166.00	2183.93	2177.77	2185.53	0.001532	10.23	10914.88	959.44	0.46
Sunset	37509	100-Yr	80000.00	2166.00	2180.87	2175.74	2182.17	0.001591	9.28	9032.09	1225.27	0.45
Sunset	37509	500-Yr	107400.00	2166.00	2183.19	2177.39	2184.85	0.001652	10.52	10715.65	1270.75	0.48
Sunset	36859	100-Yr	80000.00	2164.00	2179.51	2175.46	2181.02	0.001950	10.45	9180.07	1367.59	0.51
Sunset	36859	500-Yr	107400.00	2164.00	2181.87	2177.11	2183.70	0.001929	11.59	11244.77	1413.71	0.52
Sunset	36439	100-Yr	80000.00	2162.00	2178.09	2175.16	2180.01	0.002633	11.68	7812.43	1411.26	0.58
Sunset	36439	500-Yr	107400.00	2162.00	2180.41	2176.84	2182.69	0.002586	12.82	9571.11	1552.28	0.59
Sunset	36049	100-Yr	80000.00	2162.00	2176.28	2173.82	2178.78	0.003297	13.04	6711.07	1519.96	0.65
Sunset	36049	500-Yr	107400.00	2162.00	2178.08	2175.75	2181.36	0.003683	15.01	7868.96	1539.58	0.70
Sunset	35639	100-Yr	80000.00	2160.00	2174.47	2172.87	2177.19	0.004353	13.60	6400.02	1771.64	0.73
Sunset	35639	500-Yr	107400.00	2160.00	2176.17	2174.70	2179.63	0.004618	15.44	7756.64	1896.54	0.77
Sunset	35095	100-Yr	80000.00	2158.00	2172.69	2170.27	2174.79	0.003834	11.66	6912.72	3685.26	0.67
Sunset	35095	500-Yr	107400.00	2158.00	2174.50	2172.12	2177.10	0.003804	12.99	8425.09	3832.29	0.69
Sunset	34808	100-Yr	80000.00	2158.00	2170.63	2169.06	2173.47	0.004996	13.54	5910.30	2363.27	0.77
Sunset	34808	500-Yr	107400.00	2158.00	2175.69	2170.84	2176.09	0.000609	6.19	24514.84	3843.28	0.29
Sunset	34568	100-Yr	80000.00	2157.92	2170.49	2166.50	2172.37	0.002442	10.99	7277.88	2033.83	0.56
Sunset	34568	500-Yr	107400.00	2157.92	2175.43	2168.33	2175.93	0.000638	6.60	22415.90	3488.19	0.30
Sunset	34556	100-Yr	80000.00	2157.92	2170.44	2166.49	2172.33	0.002468	11.02	7257.11	599.48	0.56
Sunset	34556	500-Yr	107400.00	2157.92	2173.10	2168.32	2175.38	0.002365	12.12	8861.36	2134.71	0.56
Sunset	34529		Bridge									
Sunset	34502	100-Yr	80000.00	2155.79	2167.17	2165.46	2170.01	0.002453	13.53	5913.49	592.97	0.75
Sunset	34502	500-Yr	107400.00	2155.79	2169.34	2167.30	2172.79	0.002323	14.91	7204.29	1779.71	0.76
Sunset	34494	100-Yr	80000.00	2155.79	2165.45	2165.45	2169.59	0.004540	16.33	4899.03	589.01	1.00
Sunset	34494	500-Yr	107400.00	2155.79	2167.27	2167.27	2172.29	0.004282	17.98	5971.85	593.19	1.00
Sunset	34294	100-Yr	80000.00	2146.87	2160.00	2158.62	2163.13	0.002806	14.19	5637.23	581.02	0.80
Sunset	34294	500-Yr	107400.00	2146.87	2161.44	2160.46	2165.71	0.003220	16.59	6473.85	584.36	0.88
Sunset	34054	100-Yr	80000.00	2146.44	2159.42	2158.36	2162.38	0.003083	13.80	5797.32	671.22	0.83
Sunset	34054	500-Yr	107400.00	2146.44	2160.99	2160.03	2164.80	0.003204	15.66	6858.36	675.12	0.87
Sunset	33594	100-Yr	80000.00	2145.96	2158.21	2157.13	2160.99	0.002749	13.61	6163.40	1532.95	0.79
Sunset	33594	500-Yr	107400.00	2145.96	2159.90	2158.78	2163.34	0.002753	15.19	7438.77	1551.48	0.81
Sunset	33332	100-Yr	80000.00	2145.72	2157.64	2156.23	2160.27	0.002482	13.19	6283.79	1349.81	0.76
Sunset	33332	500-Yr	107400.00	2145.72	2159.26	2157.88	2162.63	0.002589	14.94	7471.91	1401.48	0.79
Sunset	33162	100-Yr	80000.00	2145.21	2155.87	2155.86	2159.62	0.004266	15.64	5256.08	1292.26	0.96
Sunset	33162	500-Yr	107400.00	2145.21	2157.91	2157.54	2162.04	0.003554	16.51	6747.95	1301.58	0.91

4RTSUN DESIGN PROPOSED (ULTIMATE) CONDITION RESULTS, SCR

HEC-RAS Plan: DESULTBRGGRD-2 River: Santa Cruz Reach: Sunset (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Sunset	32680	100-Yr	80000.00	2143.52	2155.43	2153.15	2157.85	0.002016	12.52	6441.95	1188.58	0.69
Sunset	32680	500-Yr	107400.00	2143.52	2157.42	2154.92	2160.46	0.002014	14.04	7748.07	1304.33	0.71
Sunset	32153	100-Yr	80000.00	2142.51	2153.73	2152.24	2156.59	0.002689	13.56	5899.12	1355.80	0.78
Sunset	32153	500-Yr	107400.00	2142.51	2155.77	2154.03	2159.22	0.002584	14.91	7205.58	1381.36	0.79
Sunset	31655	100-Yr	80000.00	2141.12	2152.20	2151.06	2155.19	0.002903	13.92	5834.89	1823.11	0.81
Sunset	31655	500-Yr	107400.00	2141.12	2154.69	2152.82	2157.94	0.002328	14.58	7538.17	1866.20	0.75
Sunset	31182	100-Yr	80000.00	2139.64	2151.84	2148.74	2153.93	0.001578	11.59	6899.87	1922.98	0.61
Sunset	31182	500-Yr	107400.00	2139.64	2154.37	2150.50	2156.86	0.001450	12.66	8483.51	2059.01	0.61
Sunset	30846	100-Yr	80000.00	2138.32	2151.37	2148.31	2153.38	0.001589	11.38	7029.98	2250.77	0.61
Sunset	30846	500-Yr	107400.00	2138.32	2154.01	2150.04	2156.34	0.001388	12.24	8776.31	2379.75	0.59
Sunset	30571	100-Yr	80000.00	2135.91	2151.57	2145.98	2152.86	0.000779	9.12	8771.91	2429.10	0.44
Sunset	30571	500-Yr	107400.00	2135.91	2154.24	2147.67	2155.84	0.000766	10.17	10569.90	2484.94	0.45
Sunset	30211	100-Yr	80000.00	2134.31	2151.33	2145.50	2152.58	0.000731	8.99	8902.29	2076.48	0.43
Sunset	30211	500-Yr	107400.00	2134.31	2153.99	2147.19	2155.56	0.000729	10.06	10673.21	2266.54	0.44
Sunset	29689	100-Yr	80000.00	2133.83	2148.47	2146.69	2151.74	0.002500	14.50	5517.27	1595.71	0.77
Sunset	29689	500-Yr	107400.00	2133.83	2150.34	2148.77	2154.61	0.003036	16.57	6490.96	1751.24	0.86
Sunset	29333	100-Yr	80000.00	2133.19	2146.73	2146.30	2150.59	0.003830	15.77	5073.02	1591.95	0.93
Sunset	29333	500-Yr	107400.00	2133.19	2148.57	2148.41	2153.31	0.004113	17.49	6141.88	1763.85	0.98
Sunset	29145	100-Yr	80000.00	2133.23	2147.10	2145.13	2149.66	0.002229	12.85	6227.61	1734.03	0.72
Sunset	29145	500-Yr	107400.00	2133.23	2149.11	2146.88	2152.30	0.002193	14.32	7499.36	1853.42	0.73
Sunset	28850	100-Yr	80000.00	2133.13	2146.56	2144.11	2149.00	0.001972	12.54	6379.88	1609.71	0.68
Sunset	28850	500-Yr	107400.00	2133.13	2148.54	2145.91	2151.65	0.002023	14.16	7593.03	1897.84	0.71
Sunset	28513	100-Yr	80000.00	2132.91	2146.53	2142.77	2148.26	0.001264	10.57	7603.21	1509.61	0.55
Sunset	28513	500-Yr	107400.00	2132.91	2148.66	2144.47	2150.83	0.001267	11.86	9270.12	2216.62	0.57
Sunset	28332	100-Yr	80000.00	2132.32	2146.62	2141.99	2147.94	0.000954	9.23	8665.66	1146.11	0.48
Sunset	28332	500-Yr	107400.00	2132.32	2148.82	2143.76	2150.49	0.000952	10.37	10476.15	1807.65	0.50
Sunset	28037	100-Yr	80000.00	2131.16	2146.59	2141.31	2147.59	0.000775	8.03	9960.04	918.02	0.43
Sunset	28037	500-Yr	107400.00	2131.16	2148.89	2142.76	2150.10	0.000748	8.85	12364.58	1696.78	0.43
Sunset	27481	100-Yr	80000.00	2130.71	2145.50	2142.01	2147.00	0.001255	9.83	8134.78	796.07	0.54
Sunset	27481	500-Yr	107400.00	2130.71	2147.69	2143.48	2149.51	0.001225	10.85	9897.61	832.60	0.55
Sunset	27120	100-Yr	80000.00	2130.71	2145.12	2141.24	2146.56	0.001117	9.64	8298.35	769.19	0.52
Sunset	27120	500-Yr	107400.00	2130.71	2147.29	2142.79	2149.09	0.001103	10.77	9973.54	773.93	0.53
Sunset	27119	100-Yr	80000.00	2130.58	2145.20	2140.82	2146.52	0.000968	9.23	8665.97	769.54	0.48
Sunset	27119	500-Yr	107400.00	2130.58	2147.38	2142.34	2149.05	0.000977	10.38	10345.86	774.32	0.50
Sunset	27054		Bridge									
Sunset	26989	100-Yr	80000.00	2130.16	2144.42	2141.17	2146.05	0.001384	10.25	7802.09	769.49	0.57
Sunset	26989	500-Yr	107400.00	2130.16	2146.50	2142.70	2148.52	0.001350	11.42	9405.79	773.03	0.58
Sunset	26977	100-Yr	80000.00	2130.27	2144.30	2141.29	2146.01	0.001489	10.50	7619.05	768.75	0.59
Sunset	26977	500-Yr	107400.00	2130.27	2146.37	2142.81	2148.48	0.001437	11.65	9219.67	773.50	0.59
Sunset	26837	100-Yr	80000.00	2130.30	2144.23	2140.50	2145.71	0.001177	9.78	8179.37	769.72	0.53
Sunset	26837	500-Yr	107400.00	2130.30	2146.31	2142.02	2148.18	0.001177	10.97	9798.82	789.30	0.54

4RTSUN DESIGN PROPOSED (ULTIMATE) BRIDGE RESULTS, SUNSET ROAD BRIDGE

Plan: DESULTBRGGRD-2 Santa Cruz Sunset RS: 51000 Profile: 100-Yr

E.G. US. (ft)	2224.24	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2222.69	E.G. Elev (ft)	2224.11	2223.26
Q Total (cfs)	70000.00	W.S. Elev (ft)	2222.05	2220.83
Q Bridge (cfs)	70000.00	Crit W.S. (ft)	2219.66	2218.99
Q Weir (cfs)		Max Chl Dpth (ft)	23.05	21.83
Weir Sta Lft (ft)		Vel Total (ft/s)	11.28	12.19
Weir Sta Rgt (ft)		Flow Area (sq ft)	6204.97	5744.19
Weir Submerg		Froude # Chl	0.66	0.72
Weir Max Depth (ft)		Specif Force (cu ft)	62997.07	61585.21
Min El Weir Flow (ft)	2226.68	Hydr Depth (ft)	9.57	9.14
Min El Prs (ft)	2232.16	W.P. Total (ft)	778.92	731.86
Delta EG (ft)	1.06	Conv. Total (cfs)	1204927.0	1115381.0
Delta WS (ft)	1.56	Top Width (ft)	648.07	628.18
BR Open Area (sq ft)	11775.37	Frctn Loss (ft)		
BR Open Vel (ft/s)	12.19	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)	1.68	1.93
Br Sel Method	Momentum	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

4RTSUN DESIGN PROPOSED (ULTIMATE) BRIDGE RESULTS, SUNSET ROAD BRIDGE

Plan: DESULTBRGGRD-2 Santa Cruz Sunset RS: 51000 Profile: 500-Yr

E.G. US. (ft)	2226.36	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	2224.35	E.G. Elev (ft)	2226.21	2225.33
Q Total (cfs)	93000.00	W.S. Elev (ft)	2223.46	2221.97
Q Bridge (cfs)	93000.00	Crit W.S. (ft)	2221.25	2220.70
Q Weir (cfs)		Max Chl Dpth (ft)	24.46	22.97
Weir Sta Lft (ft)		Vel Total (ft/s)	13.06	14.32
Weir Sta Rgt (ft)		Flow Area (sq ft)	7119.33	6492.85
Weir Submerg		Froude # Chl	0.72	0.80
Weir Max Depth (ft)		Specif Force (cu ft)	85695.48	83758.23
Min El Weir Flow (ft)	2226.68	Hydr Depth (ft)	10.91	9.74
Min El Prs (ft)	2232.16	W.P. Total (ft)	801.71	782.14
Delta EG (ft)	1.14	Conv. Total (cfs)	1476909.0	1329055.0
Delta WS (ft)	1.88	Top Width (ft)	652.35	666.94
BR Open Area (sq ft)	11775.37	Frctn Loss (ft)		
BR Open Vel (ft/s)	14.32	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)	2.20	2.54
Br Sel Method	Momentum	Power Total (lb/ft s)	0.00	0.00

Errors Warnings and Notes

Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.
Note:	Multiple critical depths were found at this location. The critical depth with the lowest, valid, water surface was used.

PARSONS BRINCKERHOFF Computation Sheet

page of

made by D. Ruvalcaba

date 10/29/14

checked by

date

subject Sunset Road, Silverbell to River
Scour Downstream of Sunset Road

Compute General Scour from Sunset Road

$$z_{gs} = y_{max}\left(\frac{0.0685\ V_m^{0.8}}{y_h^{0.4}\ S_e^{0.3}} - 1\right);$$

z_{gs} = General Scour
V_m = Average Velocity
y_{max} = Max Depth
y_h = Hydraulic Depth
S_e = Energy Slope

$V_m = Q/A = 1846.85/236.5 = 7.8$ fps
$y_{max} = 2.5'$
$y_h = A/TW = 236.5/137.2 = 1.7'$
$S_e = \Delta EG/L = 1.04/46 = 0.023$ '/ft

$$z_{gs} = 2.5\left(\frac{0.0685 * 7.8^{0.8}}{1.7^{0.4} * 0.023^{0.3}} - 1\right) = \emptyset$$

No Scour Off Roadway

SCOUR AND SEDIMENT ANALYSIS

DRAFT

Bridge Scour Report
For
The Proposed Sunset Bridge

Submitted to:

PIMA COUNTY
TRANSPORTATION

Pima County Department of Transportation
201 N Stone Ave
Tucson, AZ 85701

PCDOT Job No. 4RTSUN

Submitted By:

The University of Arizona
Tucson Arizona

1209 E 2ND Street, Room 206
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October 2014

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1 Introduction

1.1 Project Description

The project is to provide bridge scour analysis at the proposed Sunset Road bridge site, and evaluate the stability of the reach of Santa Cruz River after the bridge construction. The objective is to model sediment transport in the Santa Cruz River at the proposed sunset bridge site and provide long-term bed degradation and general scour calculations for three different bridge design alternatives, determine bank erosion rates, identify locations of spur dikes that can ensure flow pathway and reduce local scour depth, recommend possible counter-scour measures at the bridge site and evaluate their effectiveness, provide construction specifications of proposed spur dike and counter-scour measurements.

1.2 Key Points of Interest

The key interests are three-folds: 1) the total scour depth at the proposed bridge piers and both abutment; 2) channel stability of the Santa Cruz River reach after the construction of bridge; 3) if spur dikes or counter scour measures are needed, the location and specifications of those structures.

1.3 Scope of Work

To achieve these objectives, the following tasks are proposed:

1.3.1 Data Collection

The model domain starts at 2000 ft upstream from the bridge site to the grade control structure at Ina Road on the Santa Cruz River and 2000 ft of the Rillito River. Sediment data includes sediment in the main channel and floodplains. Bed and bank sediment samples at the study site will be collected at about 200 ft intervals. Bed sediment samples will include surface and substrate material to determine which sediment transport formula is appropriate for the study site. Bank material samples are needed for bank erosion analysis including basal erosion and bank failure. Vegetation data include vegetation density and coverage. The data will be used to determine channel roughness and its impacts on sediment transport.

1.3.2 Long-term Channel Degradation/Aggradation

Level 1 analysis needs to determine the long-term degradation qualitatively based on general geomorphic and river mechanics relationships, such as regime relations between flow discharge and channel geometry.

Level 2 analysis needs to use established qualitative and quantitative relationships to estimate the probable behavior of the stream system to various scenarios or future conditions. Since the current reach is experiencing over 3 ft degradation in 2005-2008, and the treatment plant will upgrades its capacity to 82 cfs from current 46 cfs, the base flow channel is expected to continue degrading and consequently bank failure will occur. The equilibrium channel geometry including longitudinal slope, channel width, depth, and sinuosity will be determined using HEC-20 recommended regime relations.

Level 3 analysis needs to use physical process based computer modeling using mathematical models such as USACE HEC-RAS to make predictions of quantitative changes in streambed elevation due to changes in the stream and watershed. HEC-RAS sediment transport model will be used to determine general erosion depth at the study site

1.3.3 HEC-RAS Sediment Transport Model

HEC-RAS quasi-unsteady flow model input files include the geometry file, sediment data file, and flow file. Two flow scenarios will be simulated: one is 100-year design flow, and the other is an extreme event. Both flow data are provided by the PCFCD. Several model runs will be performed to evaluate the differences of using different sediment transport formulas. PCFCD recommends the use of Yang's equation and Laursen's sediment transport formula. We will compare the results of different sediment equations, and select the one that yields the maximum erosion depth. Specifically, the following tasks will be performed:

1) General erosion and deposition over the bridge reach will be calculated from the model. The results will include the averaged erosion/deposition at each subreach between two consecutive cross sections. This will be used as a reference for general scour depth at the sub-reach.
2) Determine bank erosion rates at the study sites using the empirical relations and results from 1D sediment transport model. This analysis only applies to the Santa Cruz River.
3) Based on bed degradation and bank erosion rate, sites that needs spur dike structures to reduce general scour at the bridge will be identified. Three alternative dike locations and

placements will be simulated using HEC-RAS. The differences in general scour depth with and without dikes may not be reflected in the simulation results.

4) Possible counter-scour measurements, such as rip-rap around pier will be simulated. Their effectiveness in reducing the reach averaged flow velocity and general scour will be approximately estimated. Optimal counter-scour measurements based on the analysis will be recommended to PB. Coordinate with PB to design scour countermeasures based on the sediment modeling results.

2 Overview of Channel Stability

The reach of Santa Cruz River from Roger Road to Ina Road is a small effluent dominated perennial river. Fig.2.1 is the merged aerial photo taken in 2011, which is also the modeling boundary covered by the HEC-RAS model. The base flow was discharged from the Roger Road and the Ina Road wastewater treatment plants. The effluent discharge was approximately 46 cfs, and has increased to 80 cfs since Jan 2014. Flood flows often occur during the summer and winter Monsoon seasons. The dominant discharge is flow with a return period of 5 to 10 years. The bankfull flow in this reach is nearly 10 year return flow. The 100-year design flow is 70,000 cfs, while the 500-year design discharge is 104,700 cfs.

The main channel width is nearly constant, and is less than 100 ft. This reach is a mild sinuous channel with a sinuosity from 1.06 to1.25. Several reaches are ana-branched, where 2-3 branches are observed. Sand bars occasionally appeared on the convex banks in meandering reaches. Historical data showed that the channel platform has migrated slightly in the past decades. The averaged migration rate is xxx. Section 3 used the historical channel platform analyzed the lateral stability of base flow channel. Because of low sinuosity, sand bars are not the dominant feature in this reach. There are two locations: one is about 1500 ft upstream from the bridge site, and the other is downstream from the outlet of Ina Road treatment plant, bars existed in channel center that separate the river into two branches.

Fig.2.1 Aerial photo of the study reach in 2011

Bed and bank material in this reach are sand and gravel, predominately coarse or medium sand. Sediment samples are collected in the main channel, the left, and the right floodplains for the sediment transport model. Section 2.2 is the detailed summary of bed and floodplain sediment compositions. Although this reach is alluvial channel, many segments, especially the east banks near bridge sites, were engineered with cement banks. The base flow channel has been moderately incised in the past decade (Pima 2012). Headcuts were observed in multiple locations along both sides of banks.

The banks of base flow channel on both sides are covered with dense vegetation, including sparse mature willow and cottonwood trees, shrubs, and weeds. The tree coverage is less than

50% of banklines. Both sides of floodplains are covered with vegetation, typically shrubs and weeds. The vegetation coverages are analyzed using the aerial photos taken in 2011. The averaged vegetation density on floodplain is 23%. Section 2.1 describes the vegetation density calculation.

The historical landuse during 1800s in this area is agriculture, so ancient irrigation canals may exist in the floodplain deposits. The current landuse on both sides of the floodplain is natural land with sparse desert vegetation. Two large gravel pits existed on the east side floodplain. The pit on the North side of the Sunset Road is still operating, while the one at the South side has been abandoned. The proposed Sunset Road centerline will pass through the pit at the South side.

2.1 Vegetation Coverage

The 2011 aerial photos for vegetation coverage analysis were provided by PB World. Those photos were loaded into ARCGIS. Then, the photos were overlapped with the HEC-RAS model. The land areas outside the boundaries of HEC-RAS model were deleted. The processed photos only show the areas covered by the HEC-RAS model (Fig.2.1). The total area covered by HEC-RAS model is 2642.04 acres.

The combined aerial photo was classified using six color groups in ARCGIS: white, blue, red, purple, green, and brown (Fig.2.2). The detailed classifications are shown in Figs.2.3-2.6. In those figures, white is background, brown is bare land, and blue is the tree shadow or water surface. Red and purple colors are mostly vegetation, while green is the areas with sparse vegetation. This classification is not perfectly accurate because some features on land surface have the same color as the vegetation in the photo. For example, the roof top is green, but no vegetation was seen on the roof top; the road surface is purple, but no vegetation. However, those areas are very small compared to the vegetated area in purple, red, or green. Therefore, we gave the vegetation coverage in a range with uncertainties.

The pixel numbers of six classified colors are shown in Table 2.1. The percentage of coverage is calculated by using the pixel numbers. If counting the green color as the vegetated area, the vegetation coverage is 55.35%; without the green color, the coverage is 29.03%. The

realistic vegetation coverage is between those two numbers. By using the median value, the approximate vegetation coverage is 42.19%, the median of 29.03% and 55.35%.

Table 2.1 Vegetation coverage

Type	Color	Number of Pixels	Percentage
Shadow, Water	Blue	7423752	6.45%
Vegetation 1	Red	12521037	10.88%
Vegetation 2	Purple	20889314	18.15%
Partial Vegetation	Green	30292245	26.32%
Land	Brown	43962697	38.20%
Total		115089045	100.00%
Vegetation 1 + 2	Red + Purple	33410351	**29.03%**
Vegetation + Partial	Red+Purple+Green	63702596	**55.35%**

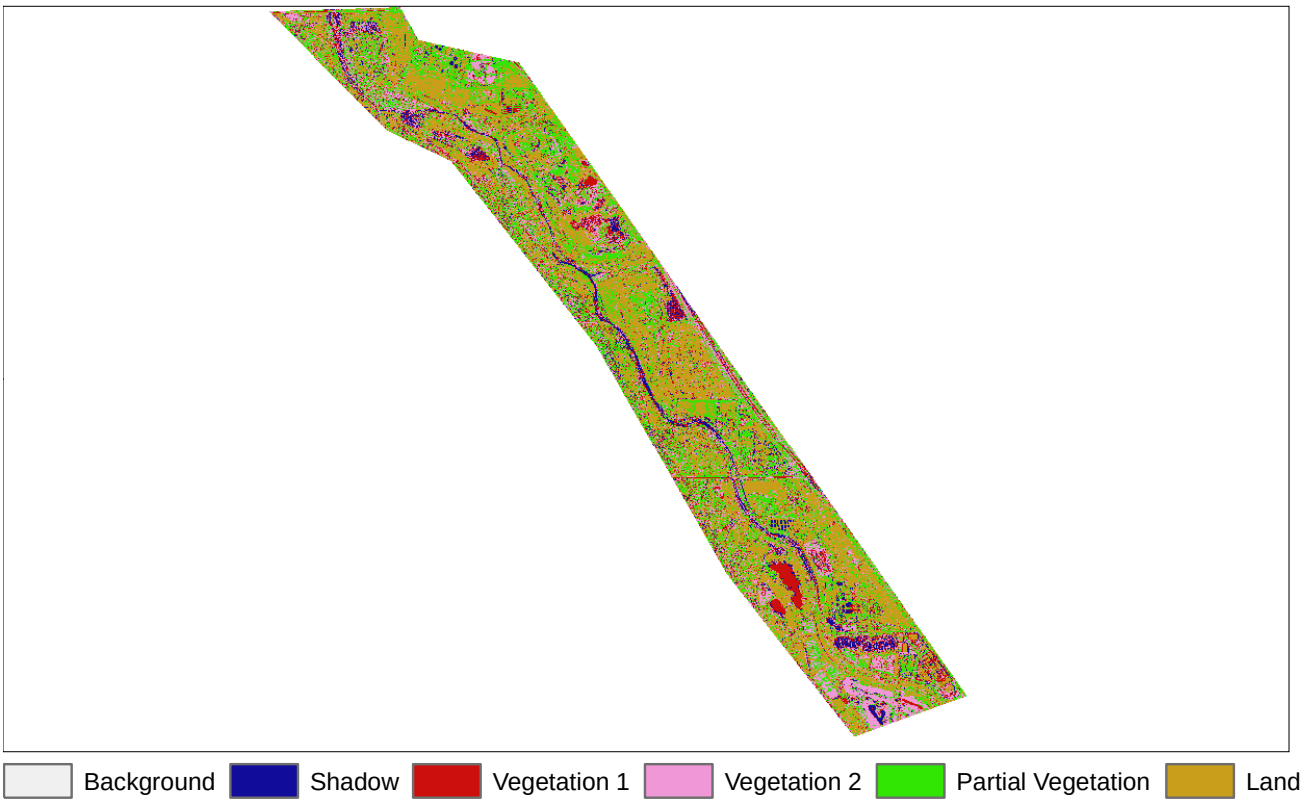


Fig.2.2 Classified image using six color schemes

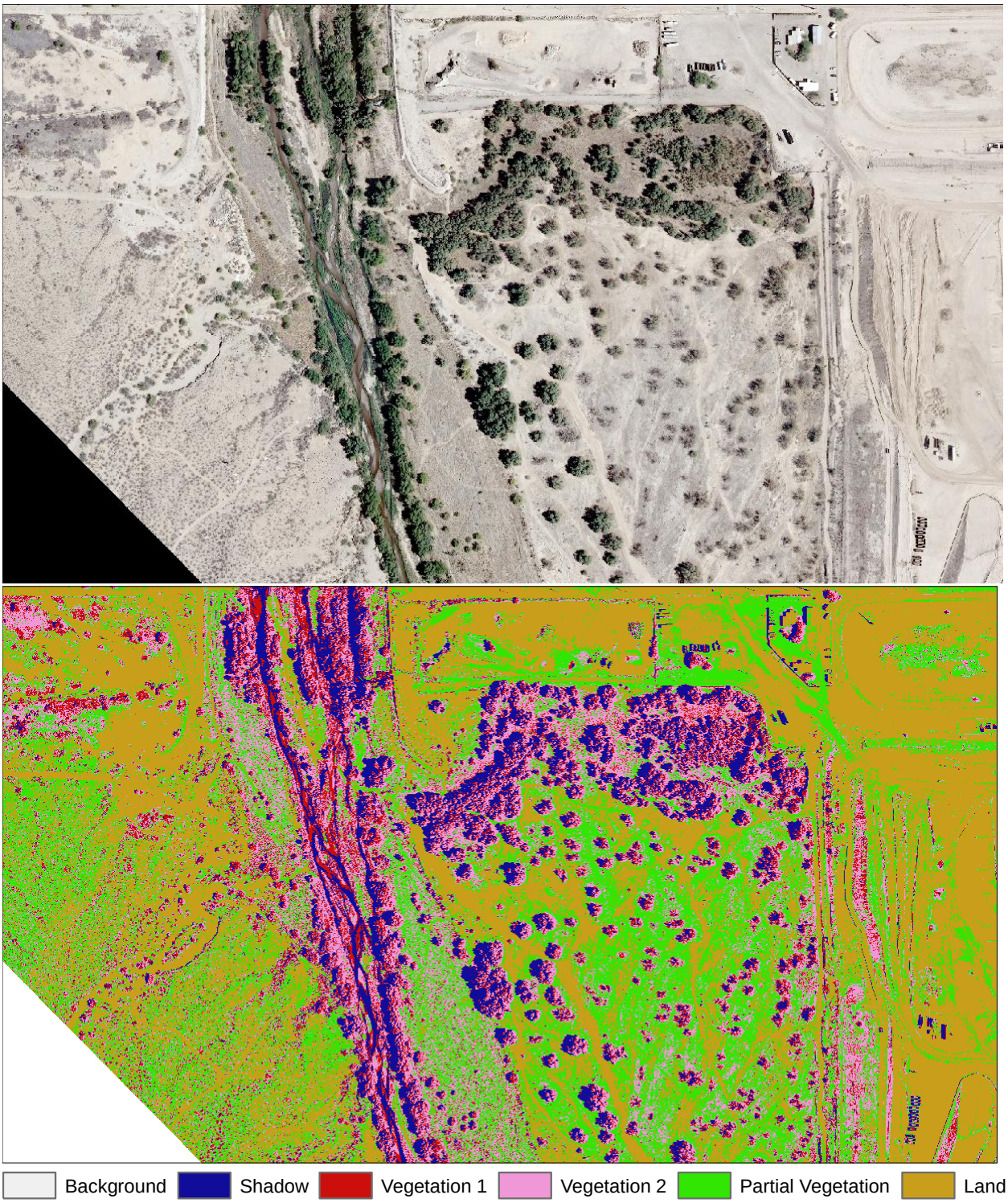


Fig. 2.3 Detailed classified images near Ina Road.

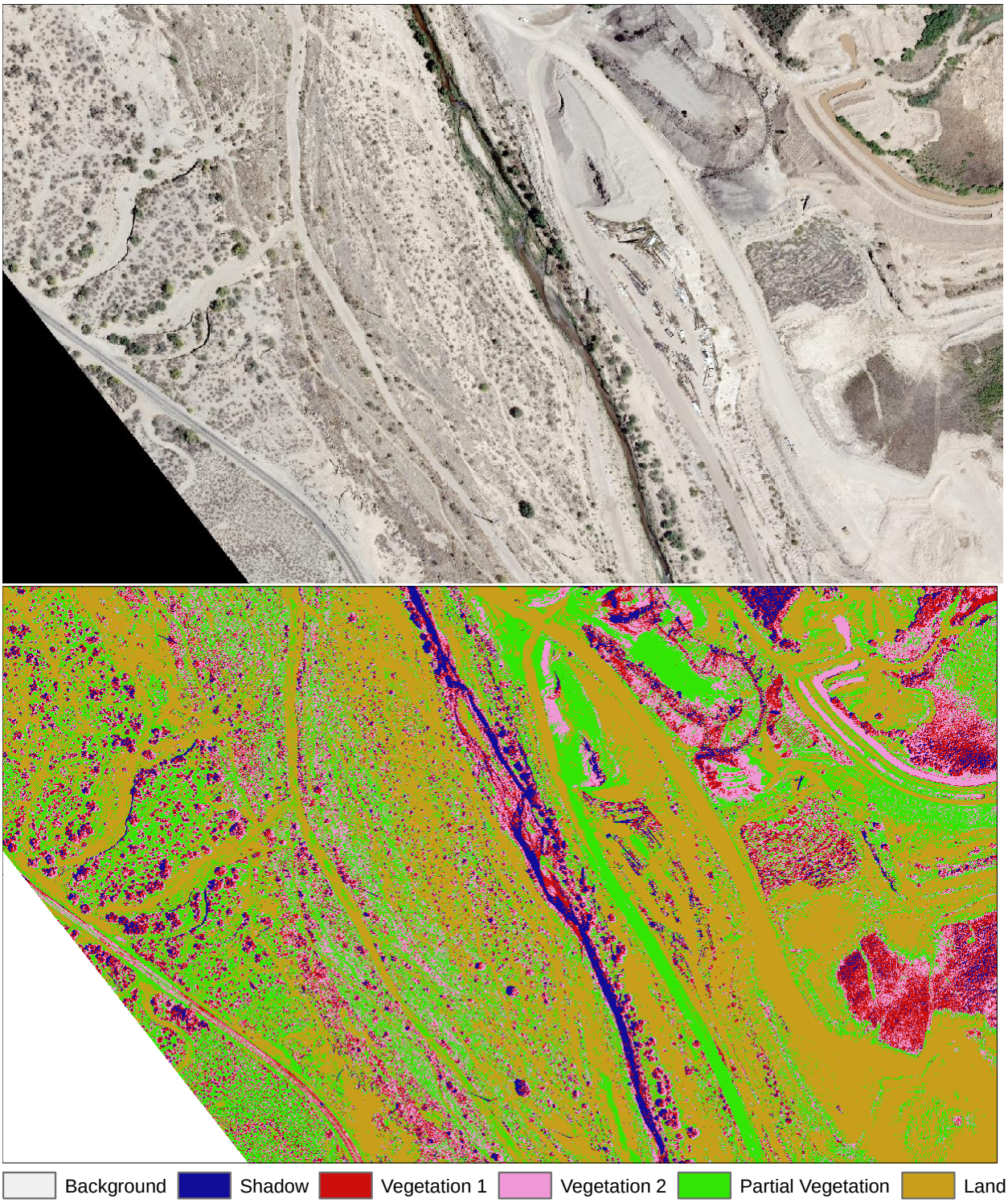


Fig.2.4 Detailed classified images between Ina and Sunset Road.

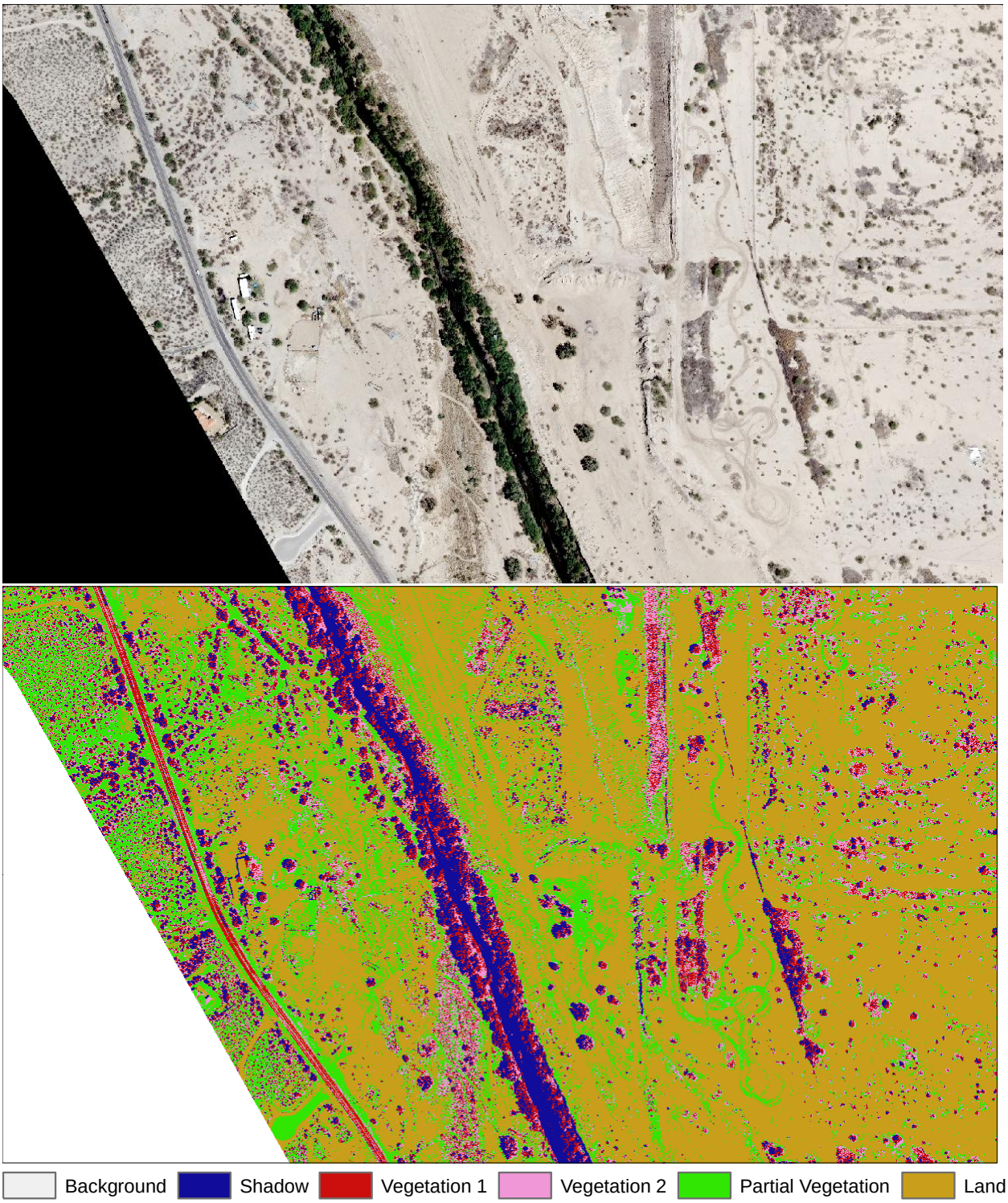


Fig.2.5 Detailed classified image near Sunset Road.

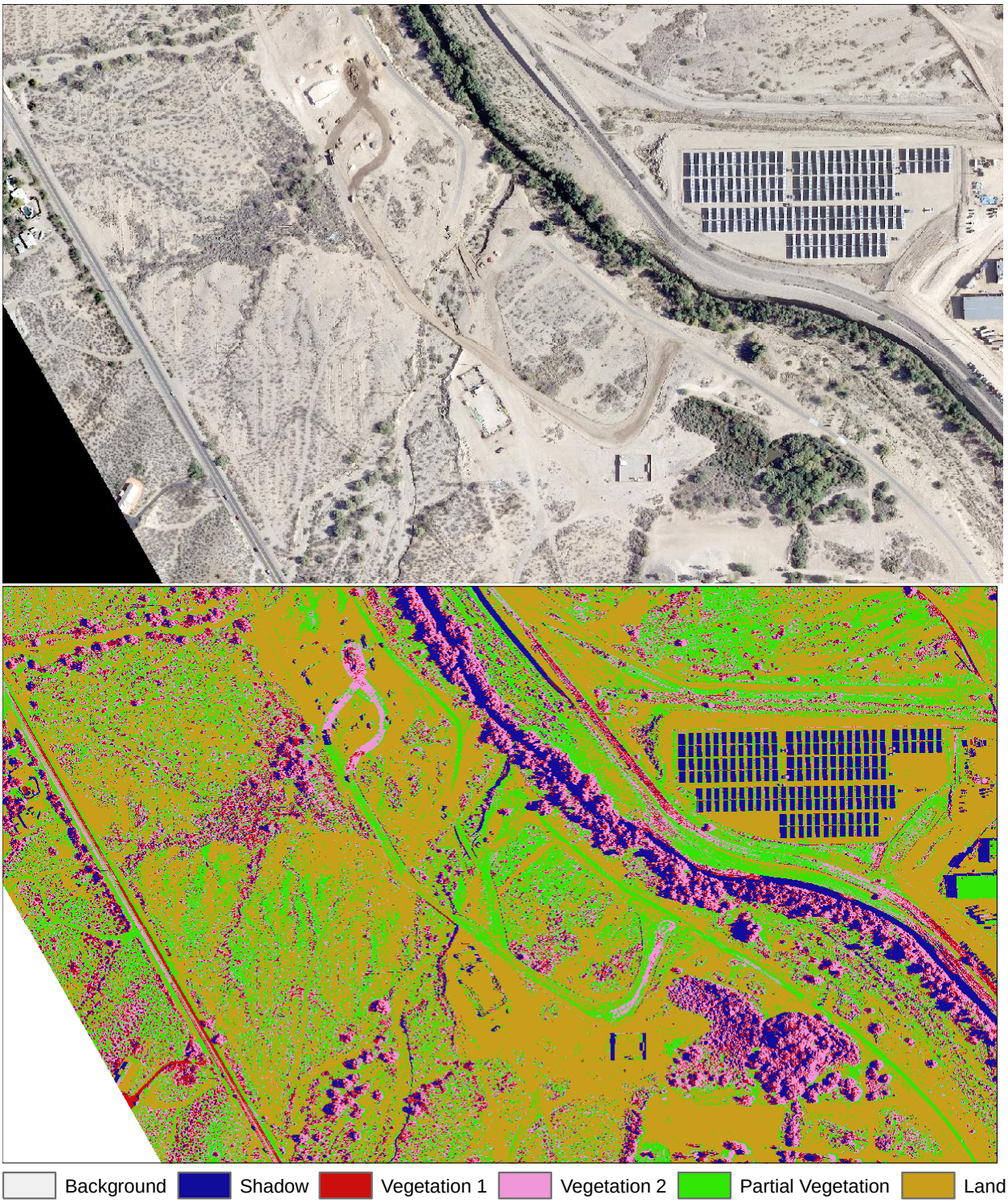


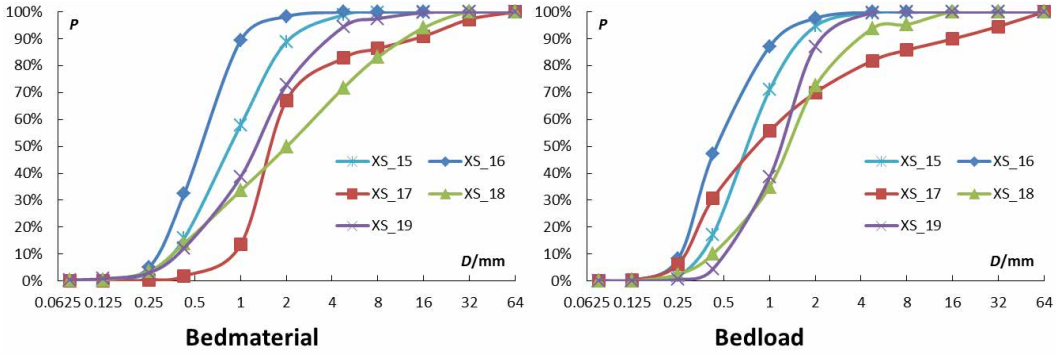
Fig.2.6 Detailed classified images near Roger Road WWTP.

2.2 Sediment Size Distribution

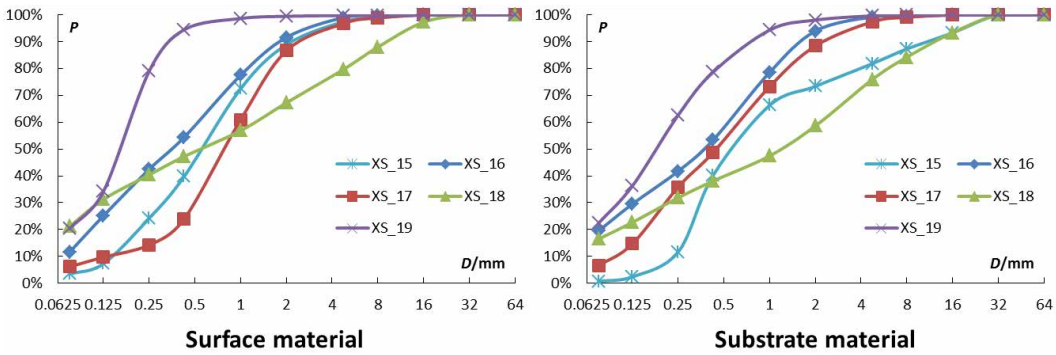
Sediment samples are collected from the Prince Road Bridge to the Ina Road Bridge. At the bridge site, which is defined as 2000 ft upstream and downstream from the proposed bridge centerline, samples are collected at 500 ft interval. At the upstream and downstream from the bridge site, sediment samples are collected at 2000 ft interval. The sampling sites are shown as distance from the bridge centerline in Fig.2.7. At each site, sediment samples are collected at the main channel, left and right floodplains. On the floodplain, both surface and substrate sediment are sampled. Bed load transport rate are also measured using the Helley-Smith bed load sampler.

Sediment gradation (SG) curves for the sediment downstream from the bridge (positive distance) are shown in Fig.2.8, at the bridge site shown in Fig.2.9, and at the upstream from the bridge site (negative distance) shown in Fig.2.10.

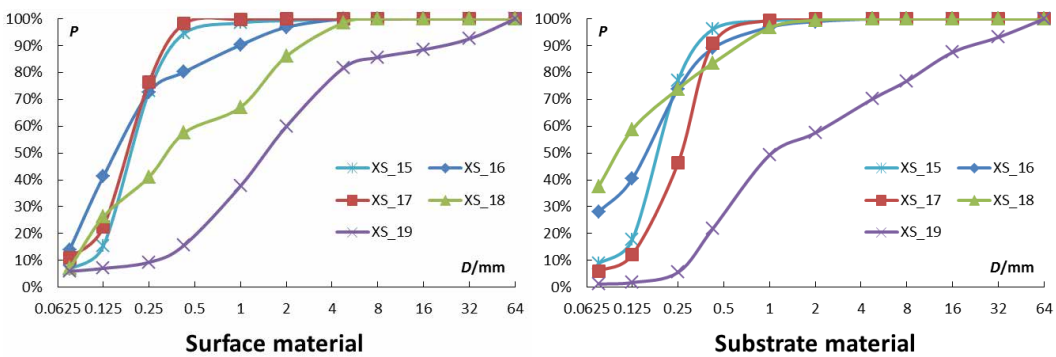
Fig.2.7 Locations of each sampling site along the study reach



(a) Main channel

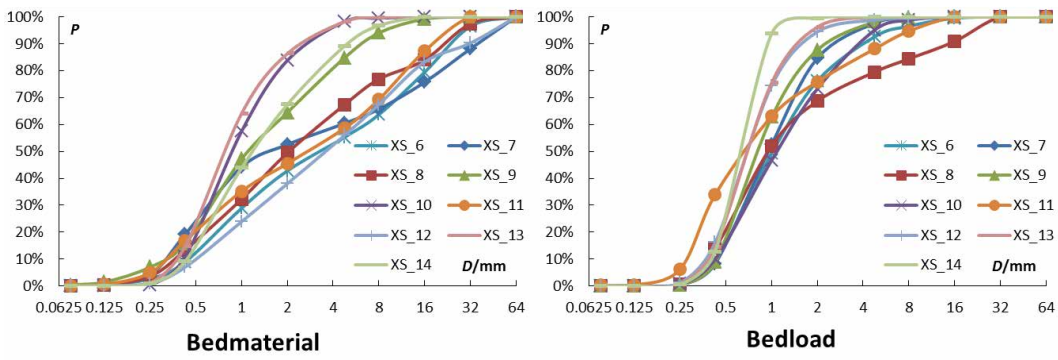


(b) Left floodplain

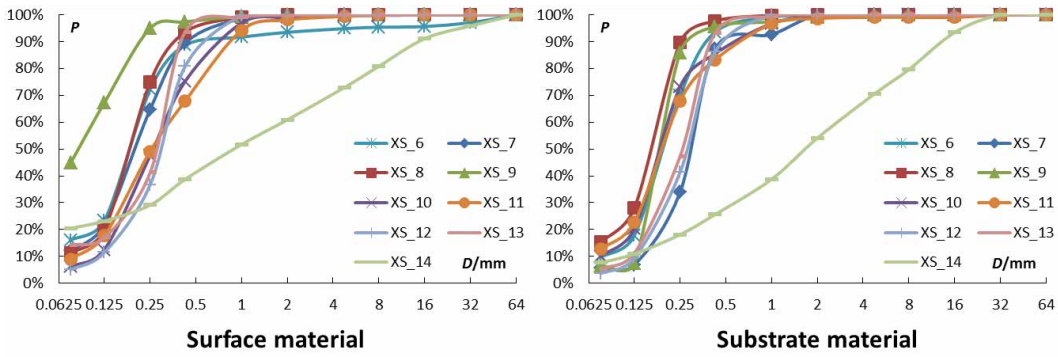


(c) Right floodplain

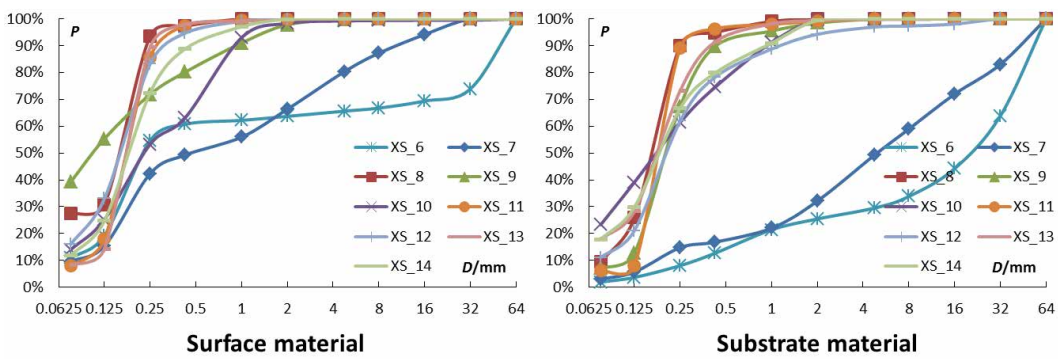
Fig.2.8 Sediment gradations at the downstream sites



(a) Main channel

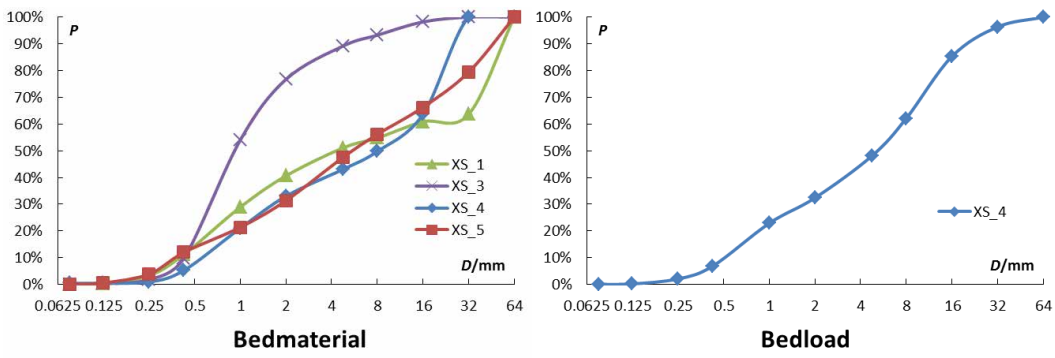


(b) Left floodplain

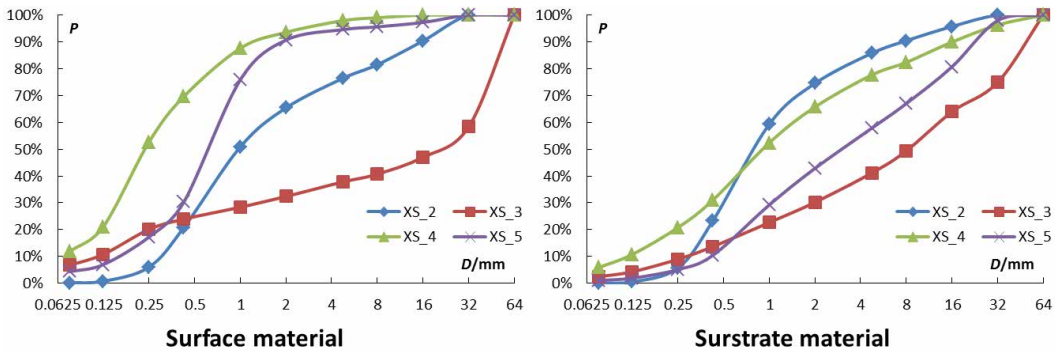


(c) Right floodplain

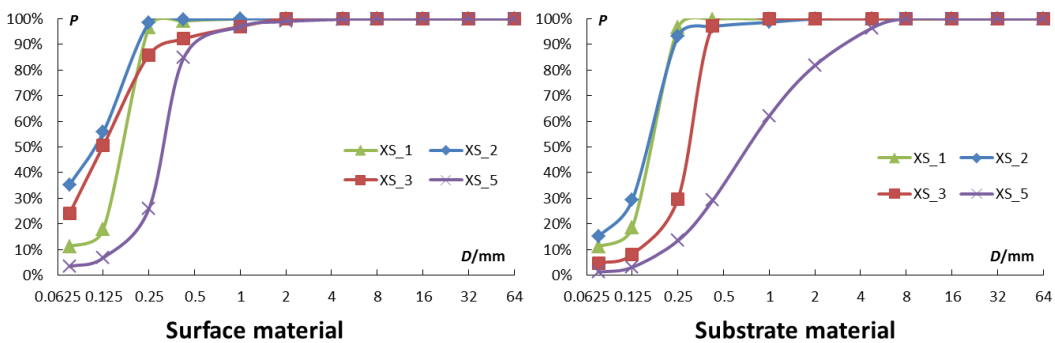
Fig.2.9 Sediment gradations at the bridge site



(a) Main channel



(b) Left floodplain



(c) Right floodplain

Fig.2.10 Sediment gradations at the upstream sites

Based on the sediment gradation curves, the median sediment size (D_{50}) and 90% percent finer sediment size, D_{90}, for the bed material and bed load are summarized in Table 2.2, for the surface and substrate material on the left floodplain in Table 2.3 for the surface and substrate material on the right floodplain in Table 2.4.

Table 2.2 Bed material and bed load D_{50} and D_{90} sizes at sampling sites

Sections	Bed Material		Bedload	
	D50 (mm)	D90 (mm)	D50 (mm)	D90 (mm)
XS_1	4.35	52.88		
XS_2				
XS_3	0.92	5.28		
XS_4	8.10	26.45	5.10	21.47
XS_5	5.52	45.69		
XS_6	3.29	24.57	1.02	4.13
XS_7	1.61	35.65	0.95	2.85
XS_8	2.05	21.77	0.95	14.50
XS_9	1.12	6.37	0.82	2.41
XS_10	0.87	2.89	1.09	3.88
XS_11	2.69	18.51	0.68	5.51
XS_12	3.56	31.14	0.18	0.55
XS_13	0.78	2.60	0.70	1.62
XS_14	1.20	5.03	0.63	0.96
XS_15	0.85	2.21	0.72	1.74
XS_16	0.55	1.04	0.45	1.20
XS_17	1.60	13.85	0.82	16.10
XS_18	2.02	12.35	1.32	4.06
XS_19a	1.26	3.97	1.18	2.42

Note ①: Values in this low was obtained by averaging data from two samples.

Table 2.3 D_{50} and D_{90} sizes of surface and substrate sediment at left floodplain

Sections	Left Surface		Left Substrate	
	D50 (mm)	D90 (mm)	D50 (mm)	D90 (mm)
XS_1				
XS_2	0.98	15.53	0.80	7.60
XS_3	19.25	54.19	8.24	48.54
XS_4	0.24	1.32	0.91	16.08
XS_5	0.61	1.93	3.02	23.24
XS_6	0.18	0.61	0.19	0.39
XS_7	0.20	0.45	0.29	0.64
XS_8	0.18	0.38	0.16	0.25
XS_9	0.08	0.22	0.18	0.31
XS_10	0.26	0.76	0.18	0.60
XS_11	0.26	0.87	0.19	0.65
XS_12	0.29	0.64	0.28	0.54
XS_13	0.27	0.41	0.26	0.41
XS_14	0.89	14.80	1.66	13.45
XS_15	0.56	2.23	0.59	10.89
XS_16	0.35	1.85	0.36	1.67
XS_17	0.78	2.66	0.44	2.32
XS_18	0.54	9.28	1.17	12.38
XS_19	0.16	0.36	0.18	0.79

Table 2.4 D_{50} and D_{90} sizes of surface and substrate sediment at right floodplain

Sections	Right Surface		Right Substrate	
	D50 (mm)	D90 (mm)	D50 (mm)	D90 (mm)
XS_1	0.17	0.24	0.17	0.24
XS_2	0.11	0.22	0.16	0.24
XS_3	0.12	0.35	0.29	0.40
XS_4				
XS_5	0.31	0.61	0.73	3.26
XS_6	0.23	49.08	19.62	52.83
XS_7	0.47	10.54	4.94	42.52
XS_8	0.15	0.24	0.16	0.25
XS_9	0.11	0.92	0.20	0.44
XS_10	0.23	0.92	0.18	0.94
XS_11	0.17	0.30	0.18	0.26
XS_12	0.16	0.34	0.20	1.17
XS_13	0.17	0.26	0.17	0.41
XS_14	0.18	0.48	0.18	0.92
XS_15	0.19	0.38	0.18	0.36
XS_16	0.15	0.98	0.15	0.47
XS_17	0.18	0.35	0.26	0.42
XS_18	0.33	2.63	0.10	0.65
XS_19	1.47	20.64	1.07	21.72

Note ②: Values in this low was obtained by averaging data from two samples.

Bed load are sampled at main channel where flow is present. The measured bedload transport rates are summarized in Table 2.5.

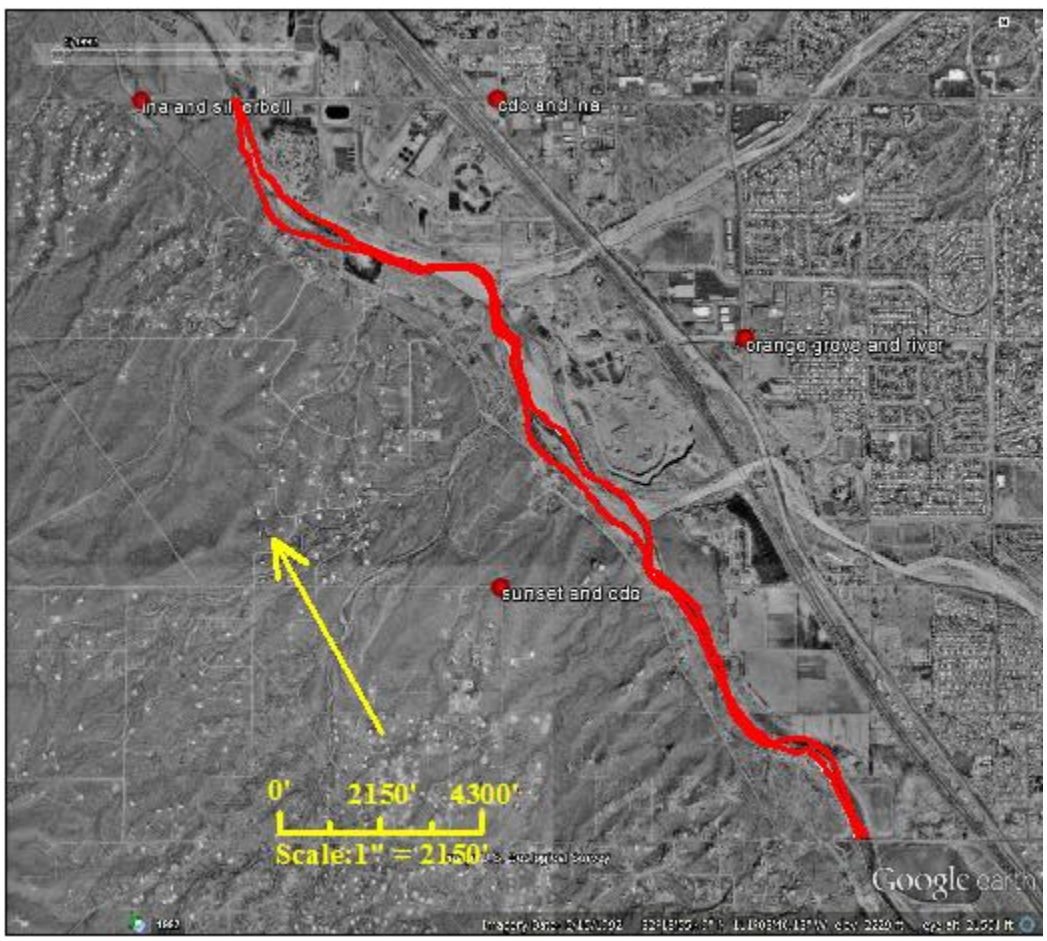
Table 2.5 Bed load transport rate at sampling sites

Section	Weight (g)	Sampling Time (min)	Qb (g/min)	D50 (mm)	D90 (mm)
XS_1	0.00		0.00		
XS_2	0.00		0.00		
XS_3	0.00		0.00		
XS_4	3039.00	3.00	1013.00	5.10	21.47
XS_5					
XS_6	1540.00	3.00	513.33	1.02	4.13
XS_7	2027.00	3.00	675.67	0.95	2.85
XS_8	2566.00	3.00	855.33	0.95	14.50
XS_9	2747.00	3.00	915.67	0.82	2.41
XS_10	1363.50	3.00	454.50	1.09	3.88
XS_11	2309.50	3.00	769.83	0.68	5.51
XS_12	2411.50	3.00	803.83	0.18	0.55
XS_13	2159.00	3.00	719.67	0.70	1.62
XS_14	2484.00	3.00	828.00	0.63	0.96
XS_15	1369.50	3.00	456.50	0.72	1.74
XS_16	2055.00	3.00	685.00	0.45	1.20
XS_17	1724.50	3.00	574.83	0.82	16.10
XS_18	1842.50	3.00	614.17	1.32	4.06
XS_19	1540.00	3.00	513.33	1.18	2.42

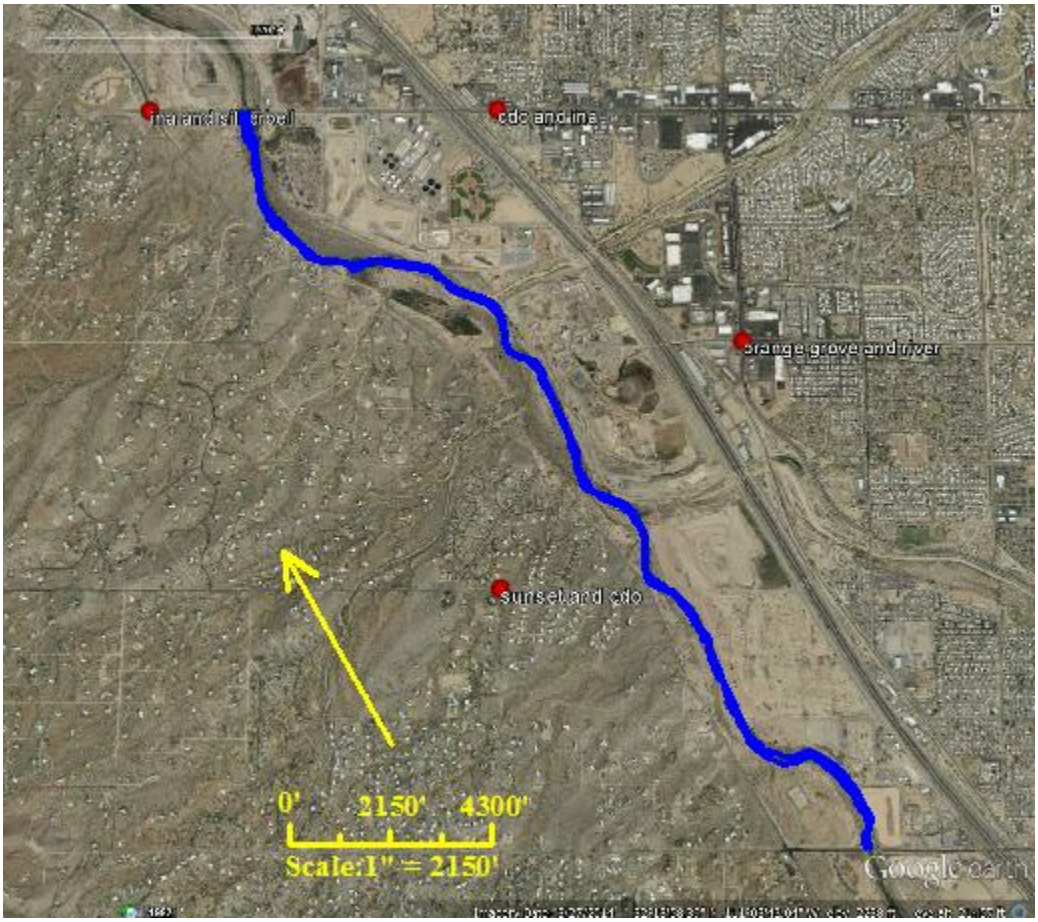
2.3 Lateral Migration Analysis

2.3.1 Lateral Migration of Existing Base Flow Channel

The lateral migration rate of base flow channel was calculated based on HEC-20. The aerial photographs of the base flow channel in May 1992 and Jan 2014 were obtained from Google Earth (Installation of Google Earth: https://www.google.com/earth/explore/products/). In Google Earth, and these two images can be found at "Viewer -> Historical Imagery". The study zone and years of interest were chosen by using the small black slider on the upper left corner of the map. In each map, four intersections of streets were defined as the registration points shown in Fig.2.11a. Then, the bank line of the Santa Cruz River in May 1992 was drawn using the drawing tools provided by Google Earth. Similarly, the bank lines of Santa Cruz River on Jan 2014 using the same drawing tools were drawn in the same figure. The map with 2014 channel banklines was shown in Fig.2.11b.



(a) 1992 base flow channel



(b) 2014 base flow channel

Fig.2.11 Registration points and 1991 and 2014 base flow channel from Google Earth

Then, Figure 2.11(a) and (b) were imported into AutoCAD. When overlaying these two base flow channels, all the registration points were matched exactly. The bank lines for 1992 and 2014 photos were delineated in AutoCAD. After removing the photo layers, the outer bank lines of meandering loops were fitted with circles as shown in Fig.2.12. Those circles are the best-fit to each bend, which are tangential to the outer banklines. Detailed descriptions of the curve fitting are available on Page 6.20 in HEC20. The red circles are for 1992 bank lines, and the blue ones are for 2014 bankline. At each bend, the center of each circle was identified, and an arrow line were drawn from the circular centers in 1992 to those in 2014. The arrow directions are the migration directions of the curvature center of each bend. The changes of the radius of the fitting circles represent the changes of the radius of curvature for each bend.

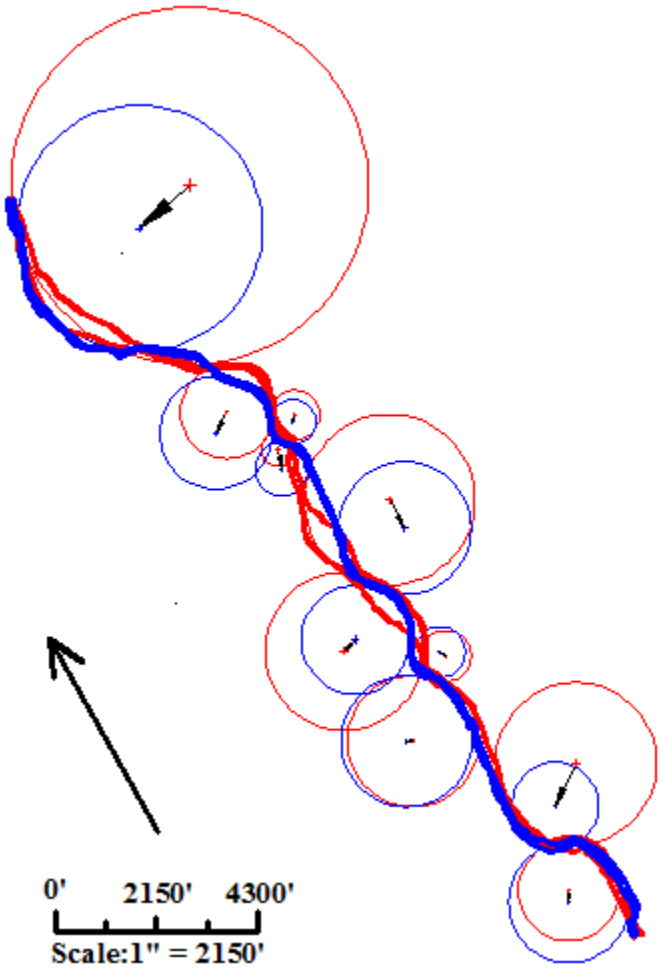


Fig.2.12 1992 and 2014 bank line and fitting circles (red: 1992, blue: 2014)

After deactivated the bank line layers in AutoCAD, the diameters of those fitting circles and the distances between the curvature centers in 1992 and 2014 were calculated and shown in Fig.2.13. The distance of arrow line between two circular centers is the migration distance for a bend from May 1992 to Jan 2014. The arrow represents the direction of channel migration.

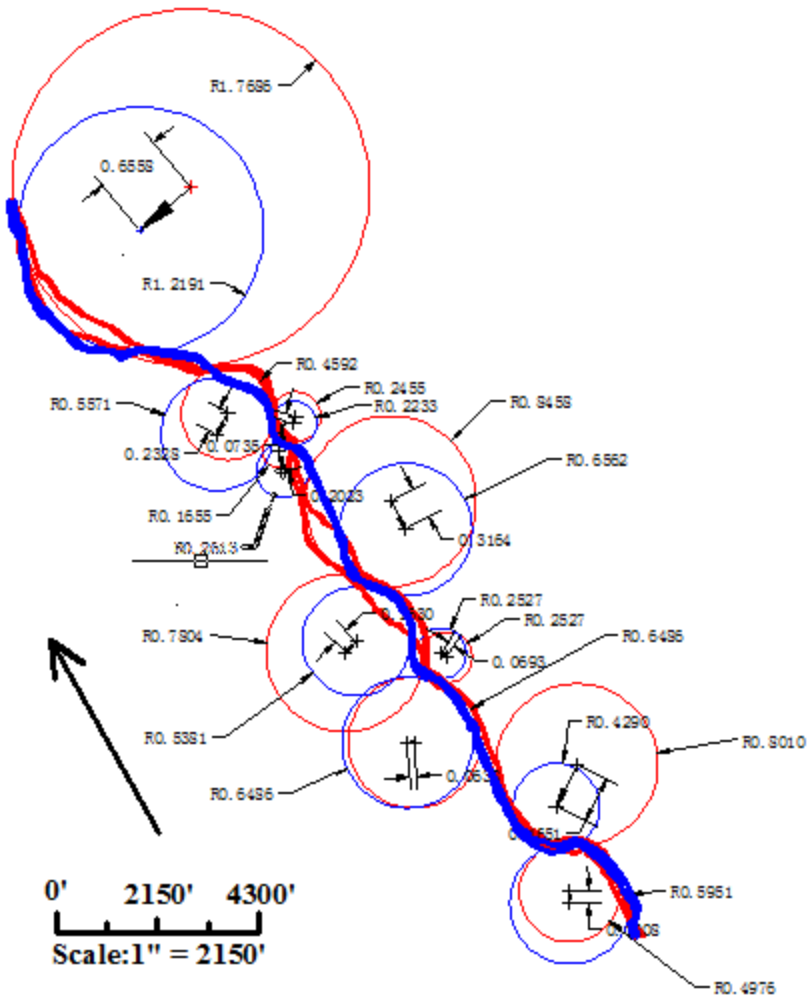


Fig.2.13 Diameters of each circle (in map distance) and the circle center change from 1992 to 2014 (red: 1992, blue: 2014)

Then, the changing ratio of radius of curvature for each bend was found by dividing the difference between the radius of curvatures in 1992 and 2014 by the time period. The migration rate of each bend was calculated by dividing the distance between two circular centers by the time period from 1992 to 2014.

2.3.2 Lateral Migration in Ten Years

In ten years (2024), the center of each bend will migrate to a new location, and the radius of bend curvature will also change to a new value based on the calculated results shown in Table 2.6. The location of each bend in 2024 was found by moving the circular center to the projected location, and re-drawing the circles using the predicted radius.

Table 2.6 Radius and migration distance of circular centers, and 2024 projections

Circles ID	Radius(R) (ft)		Distance between Centers (ft)	Change of Radius (ft)	Radius Change per Year (ft)	Center Migration per Year (ft)	New Center and Raius In 10 years (2024) (ft)	
	1992	2014					Radius	Distance
1	1069.84	1279.47	259.72	209.63	9.53	11.81	1374.75	118.05
2	1722.15	922.35	999.97	-799.80	-36.35	45.45	558.80	454.53
3	1394.49	1394.49	137.17	0.00	0.00	6.24	1394.49	62.35
4	543.31	543.31	149.00	0.00	0.00	6.77	543.31	67.73
5	1677.86	1156.92	350.45	-520.95	-23.68	15.93	920.12	159.30
6	1818.47	1410.83	680.26	-407.64	-18.53	30.92	1225.54	309.21
7	355.83	561.80	434.95	205.97	9.36	19.77	655.42	197.70
8	527.83	480.10	158.03	-47.73	-2.17	7.18	458.40	71.83
9	987.28	1197.77	500.52	210.49	9.57	22.75	1293.44	227.51
10	3802.49	2621.07	1409.97	-1181.43	-53.70	64.09	2084.05	640.90

To obtain new channel banklines in 2024, the center of the fitted circle should move along the arrow to the projected location in Table 2.6. At the projected center, a new circle was drawn using the projected diameter for the bend. The projected fitted circles for all the bend in the study are shown in Fig.2.14 as orange circles. The new channel bank line in 2024 was obtained by connecting the outlayers of the fitted circles. The predicted bank line in 2024 and the current channel in 2014 were shown in Fig.2.15. It apprarently that this low-sinouous base flow channel is moderately active, the maximum migration distance of bend curvature center is about 640.90 ft in 10 years, and the channel sinuosity decreases.

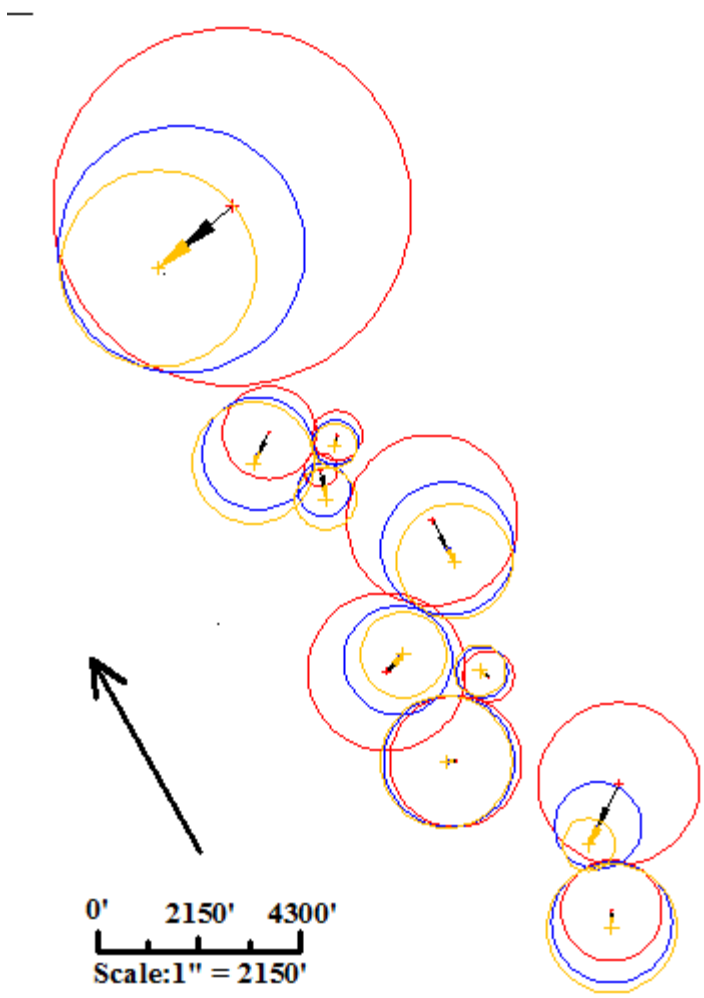


Fig.2.14 Fitted circles for 1992, 2014 and 2024 channels (red:1992, blue:2014, orange:2024)

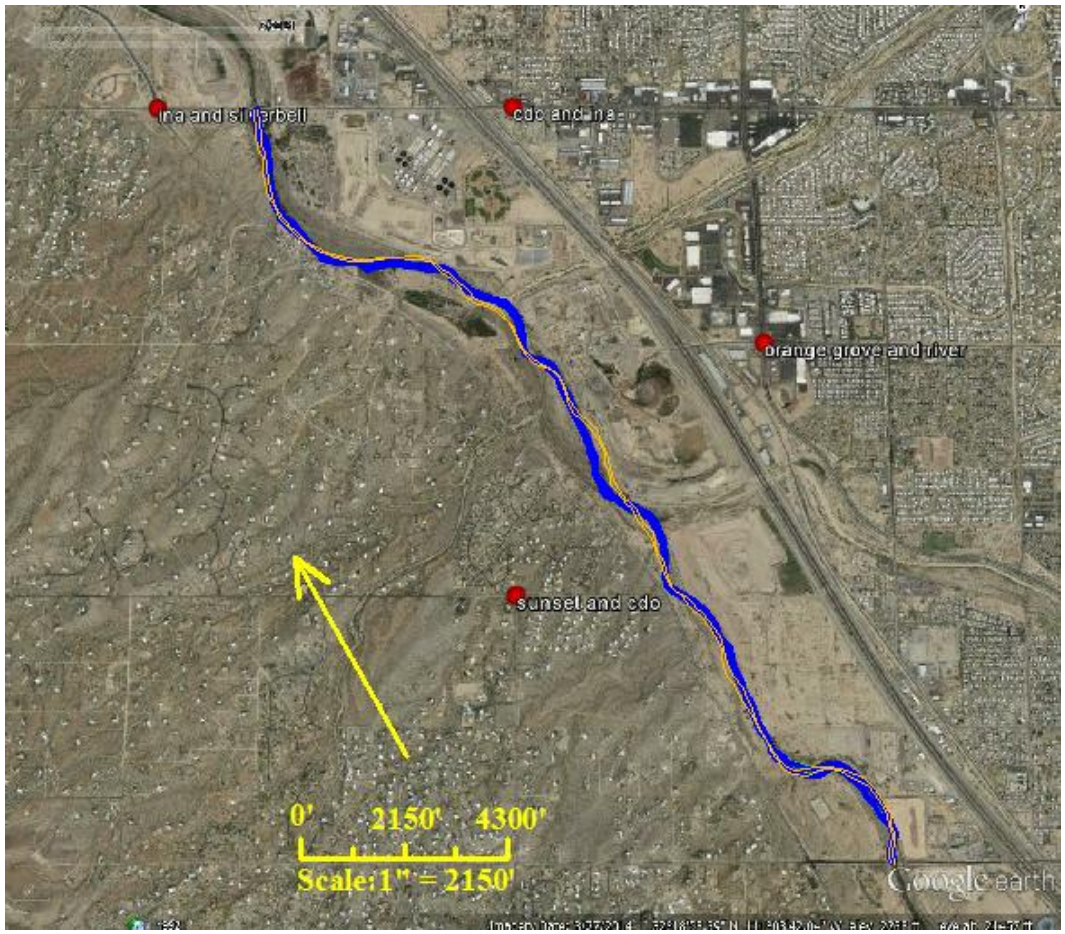


Fig.2.15 Bank line change from 2014 to 2024(blue: 2014, orange: 2024)

2.3.3 Lateral Migration in Seventy-five Years

The same procedure was applied to estimate the channel location in 75 years (Year 2089). The new center migration and radius in 75 years are listed in Table 2.7. It is noticed that the radius of some circles are negative. Because the radius of fitted circles are assumed to change the same way as observed from 1992 to 2014, this results in the radius of some fitted circles become negative if the radius is decreasing at a large rate. In fact, as radius of curvature decreases, the sinuosity of the bend is increasing. When the sinuosity reaches approximately 3.7, cutoff will occur so the bend will become a straight reach. Therefore, when the radius of curvature approaches zero, a cutoff was assumed at that bend. After the cutoff, the bend will disappear. In 75 years, cutoff will occur at bend 2 and 6 corresponding to the fitted circle NO. 2 and NO. 6. The migration of channel bank lines are also controlled by bridges, roads, and soil cement banks. For this reach, the east banks are mostly soil cemented, Ina Road Bridge controls the downstream end, and the Silverbell Road is the west limit. If the channel migrates to those un-

erodible control points, the channel migration will stop. With the considerations of meandering cutoff and non-erodible controls, the predicted curvature centers and fitted circles in 2089 were shown in Fig. 2.16. Connecting the arcs of those fitted circles, the predicted bank line in 2089 and the current channel in 2014 were shown in Fig.2.17. The maximum migration rate of curvature center is about 2320 ft.

Table 2.7 Radius and migration distance of circle centers, and 2089 projections

Circles ID	Radius(R) (ft)		Distance between Centers (ft)	Change of Radius (ft)	Radius Change per Year (ft)	Center Migration per Year (ft)	New Center and Radius in 75 years (2089) (ft)	
	1992	2014					Radius	Distance
1	1069.84	1279.47	259.72	209.63	9.53	11.81	1994.10	885.41
2	1722.15	922.35	999.97	-799.80	-36.35	45.45	-1804.24	3408.97
3	1394.49	1394.49	137.17	0.00	0.00	6.24	1394.49	467.63
4	543.31	543.31	149.00	0.00	0.00	6.77	543.31	507.94
5	1677.86	1156.92	350.45	-520.95	-23.68	15.93	-619.03	1194.72
6	1818.47	1410.83	680.26	-407.64	-18.53	30.92	21.15	2319.07
7	355.83	561.80	434.95	205.97	9.36	19.77	1263.97	1482.77
8	527.83	480.10	158.03	-47.73	-2.17	7.18	317.38	538.72
9	987.28	1197.77	500.52	210.49	9.57	22.75	1915.33	1706.32
10	3802.49	2621.07	1409.97	-1181.43	-53.70	64.09	-1406.52	4806.72

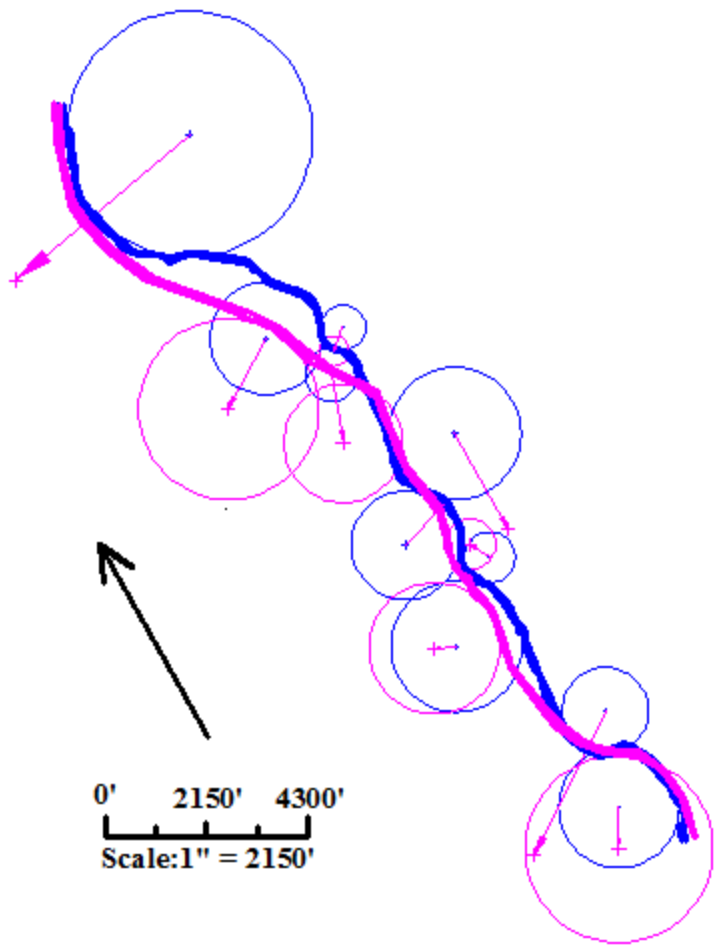


Fig.2.16 Fitted circles and channel banks for 2014 and 2089 channels (blue: 2014, purple: 2089)

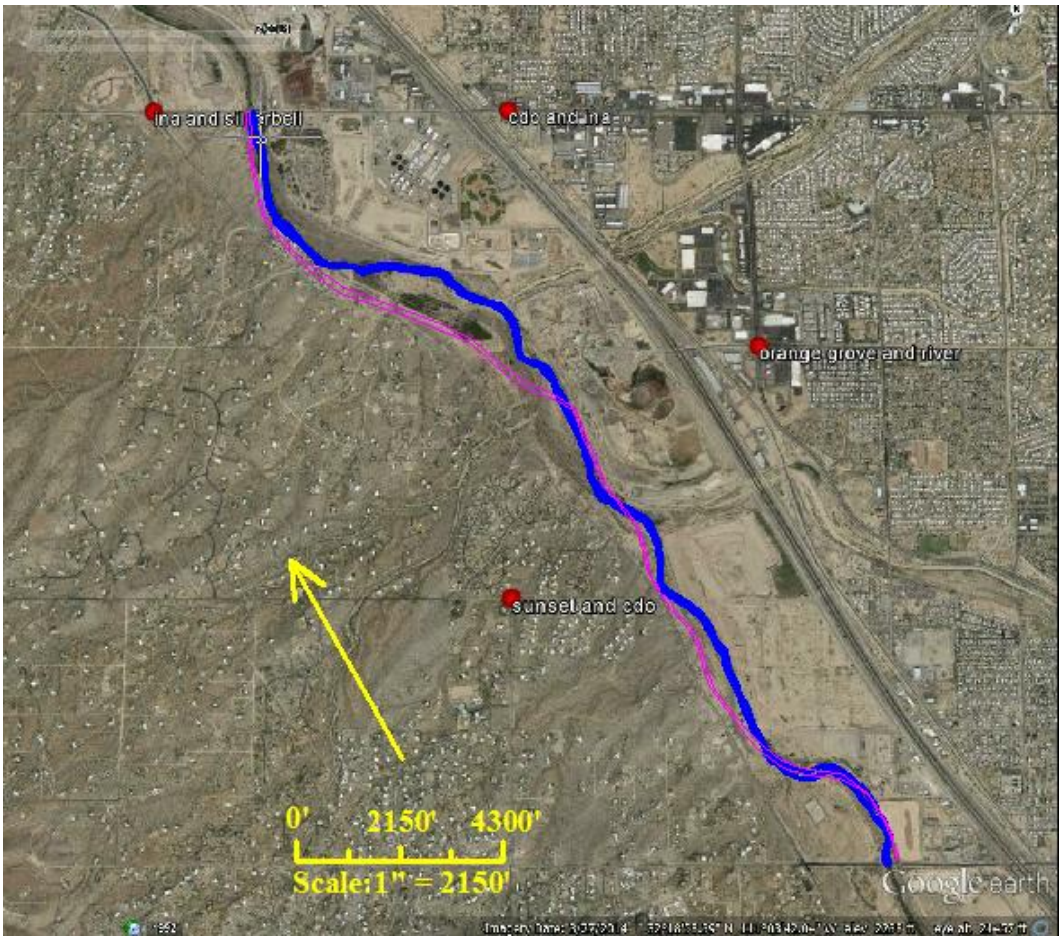


Fig.2.17 Bank line change from 2014 to 2089 (blue: 2014, purple: 2089)

2.4 SRH2D Model Analysis of Skewness Angle

A preliminary two dimensional model analysis was conducted to determine flow attack angles on bridge piers and abutment. The bridge centerline was aligned perpendicular to bathymetry contour lines as shown in Fig.2.16. The SRH-2D, Sedimentation and River Hydraulics – Two Dimensional model, is adopted in this study. SRH2D is a two-dimensional hydraulic, sediment, temperature, and vegetation model for river systems developed at the Bureau of Reclamation. The model is authorized by Federal Highway administration for hydraulics and sediment transport analysis. A constant discharge of 70,000 cfs at the upstream and a constant water surface elevation of xxx at the downstream are the boundary conditions. Those conditions are exactly the same as those in the HEC-RAS model.

The simulated velocity field at each pier location and both abutments are shown in Fig.2.16. The attack angles between the velocity vector and the normal to the bridge alignment were calculated using the simulated results. The attack angles are summarized in Table 2.7.

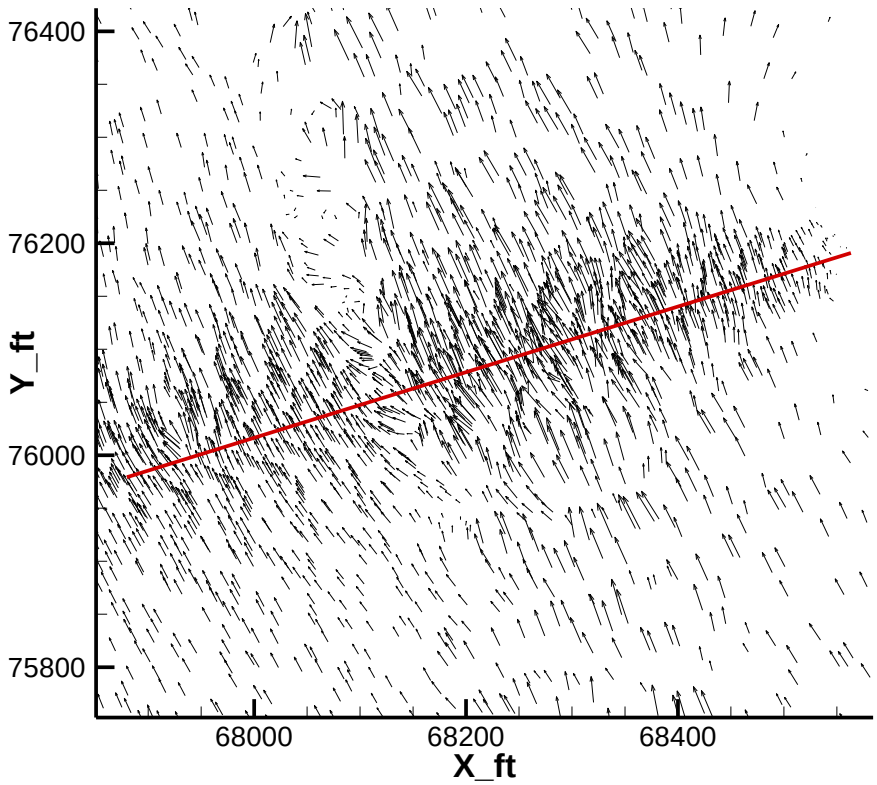


Fig.2.16 The velocity field near the center line

Table 2.7 Attack Angles at Pier and Abutment

Location	Center X (ft)	Center Y (ft)	Velocity X (m/s)	Velocity Y (m/s)	Skewness (degree)
West Abutment	67878.64	75978.60	-4.38	7.90	-11.73
Pier (West)	67991.17	76013.57	-3.38	7.54	-6.90
Pier	68106.16	76049.31	-3.37	4.49	-19.64
Pier (center)	68221.23	76085.07	-6.34	13.72	-7.53
Pier	68336.30	76120.83	0.44	6.72	21.01
Pier (East)	68451.29	76156.56	-3.43	8.50	-4.74
East Abutment	68563.82	76191.53	0.00	0.00	N/A

Table 2.7 showed the attack angles at the west abutment is -11.73 degree. This angle is less than the angle (±15º) for calculating the maximum abutment scour depth. Although the attack angles at two piers are greater than 15º, the piers are circular shaped so that the attack angle doesn't affect the scour depth.

3 Bridge Scour Calculation

Pima County requires the bridge scour shall be calculated for the 100-year design flow event and an extreme event, called the check flood event that is not exceed the 500-year flood flow. In some case, smaller flows, such as bankfull flow, can cause larger scour depth than the 100-year design flow. In those cases, the largest value of the total scour depth should be used for the applicable strength and service limit states for the bridge design.

The 100-year design flow for the Sunset Reach of the Santa Cruz River (SCR) is 70,000 cfs, and the 500-year flood flow is estimated to be 93,000 cfs. SCR is a major water course, and the required free board is 3 feet above the 100-year water surface elevation.

3.1 Long-term Degradation Rate

The long-term bed degradation depth is calculated based on the City of Tucson Drainage Manual and Stream Stability at Highway Structures Manual (HEC 20). The base elevation control is chosen as the top of soil cement at the Ina Road Bridge. The south end of soil cement cap is approximately at the elevation of as-built bridge pier bottom, 2158.0 ft (NAVD88). This elevation is shown in HEC-RAS model, and also the recent survey at the soil cement sections. Therefore, 2158.0 ft is used as the control elevation. In the City of Tucson Drainage Manual, two scenarios are recommended to calculate the long-term bed degradation depth: one is clear water scour using Equation 6.25 (Page 6.32) to calculate the equilibrium channel slope; the other is to assume an urban growth scenario that will cause channel incision and storm flow increase. 10-year flow is recommended for the long-term degradation analysis. Table 3.1.1 lists the hydraulic and sediment variables obtained from HEC-RAS model using 10 year flow.

Table 3.1.1 Hydraulic and Sediment Variables for Selected Sections

HEC-RAS Section ID	Distance (ft)	Bed elevation (ft)	Q (cfs)	Top width (ft)	n	q (ft^2/s)	Velocity (ft/s)	Water depth (ft)	D_{50} (mm)	D_{90} (mm)
68087	6126.77	2250.7	16800	250.52	0.025	67.06	7.72	8.69	4.35	52.88
61960	2872.25	2234.74	16800	278.23	0.025	60.38	9.26	6.52	0.92	5.28
59088	3096.34	2226.21	16800	287.39	0.025	58.46	11.03	5.3	8.10	26.45
55999	3000	2217	16800	318.29	0.03	52.78	9.15	5.77	5.52	45.69
52999	500	2205	16800	621.13	0.03	27.04	7.98	4.68	3.29	24.57
52499	500	2204	16800	369.74	0.03	45.47	10.57	5.71	1.61	35.65
51999	500	2203	16800	505.08	0.032	33.41	8.09	5.63	2.05	21.77
51499	442	2201	16800	497.04	0.03	33.91	6.18	5.48	1.12	6.37
51057	112	2199	16800	496.22	0.028	34.19	7.23	7.29	0.87	2.89
50945 (Bridge)	445	2199	16800	462.91	0.026	36.29	8.23	7.24	0.13	10.58
50500	505	2198	16800	326.76	0.029	51.41	11.01	5.88	2.69	18.51
49996	495	2197	16800	327.64	0.028	51.28	9.76	6.96	3.56	31.14
49501	502	2197	16800	211.63	0.03	79.38	12.51	6.35	0.78	2.60
48999	3000	2196	16800	333.1	0.03	50.44	7.16	7.04	1.20	5.03
45999	3000	2189	21800	559.85	0.03	38.94	8.2	4.79	0.85	2.21
42999	3000	2180	21800	702.32	0.03	31.04	9.96	3.12	0.55	1.04
39999	3140	2171	21800	847.92	0.03	25.71	7.72	3.33	1.60	13.85
36859	2290	2165	21800	1286.81	0.035	16.94	6.71	6.31	2.02	12.35
34569		2158								

3.1.1 Clear Water Scour Scenario Based on City of Tucson Drainage Manual

Clear water scenario assumes sediment concentration is nearly zero, so channel bed is incised to achieve an equilibrium slope. The equilibrium slope is calculated as

$$S_{eq} = \left[\frac{1.45n}{q^{0.11}}\right]^2 \tag{3.1.1}$$

where S_{eq} = Equilibrium slope after urbanization, in feet per foot;

n = Manning's roughness coefficient;

q = Channel unit discharge (ft^2/s).

Table 3.1.2 Clear Water Scour Scenario Results Based on City of Tucson Drainage Manual

HEC-RAS Section ID	Distance (ft)	Bed elevation (ft)	Total Q (cfs)	Top width (ft)	n	Unit Q (ft^2/s)	S_{equ} x 10^3	Z_{equ} (ft)	Long-term degradation (ft)
68087	6126.77	2250.7	16800.00	250.52	0.025	67.06	0.52	2183.6	-67.07
61960	2872.25	2234.74	16800.00	278.23	0.025	60.38	0.53	2180.4	-54.30
59088	3096.34	2226.21	16800.00	287.39	0.025	58.46	0.54	2178.9	-47.30
55999	3000	2217	16800.00	318.29	0.03	52.78	0.79	2177.2	-39.75
52999	500	2205	16800.00	621.13	0.03	27.04	0.92	2174.9	-30.13
52499	500	2204	16800.00	369.74	0.03	45.47	0.82	2174.4	-29.58
51999	500	2203	16800.00	505.08	0.032	33.41	0.99	2174.0	-28.99
51499	442	2201	16800.00	497.04	0.03	33.91	0.87	2173.5	-27.49
51057	112	2199	16800.00	496.22	0.028	34.19	0.76	2173.1	-25.87
50945 (bridge)	445	2199	16800.00	462.91	0.026	36.29	0.64	2173.0	**-25.96**
50500	505	2198	16800.00	326.76	0.029	51.41	0.74	2172.8	-25.25
49996	495	2197	16800.00	327.64	0.028	51.28	0.69	2172.4	-24.62
49501	502	2197	16800.00	211.63	0.03	79.38	0.72	2172.0	-24.97
48999	3000	2196	16800.00	333.1	0.03	50.44	0.80	2171.7	-24.33
45999	3000	2189	21800.00	559.85	0.03	38.94	0.85	2169.3	-19.72
42999	3000	2180	21800.00	702.32	0.03	31.04	0.89	2166.7	-13.26
39999	3140	2171	21800	847.92	0.03	25.71	0.93	2164.1	-6.93
36859	2290	2165	21800	1286.81	0.035	16.94	1.38	2161.2	-3.84
34569		2158						2158.0	0.00

Note: S_{equ} = Equilibrium bed slope; Z_{equ} = Equilibrium bed elevation; n = Manning's roughness

3.1.2 Urban Growth Scenario Based on City of Tucson Drainage Manual

An aggressive urban growth scenario is assumed, that channel thalweg will be incised 20 ft, and 10-year flow will increase by 5000 cfs. The equilibrium slope is computed by Eq.6.26 (page 6.32) as

$$S_{eq} = \left[\left(\frac{n_u}{n_n} \right)^2 \left(\frac{Q_{u,10}}{Q_{n,10}} \right)^{-1.1} \left(\frac{b_u}{b_n} \right)^{0.4} (1 - R_s)^{0.7} \right] S_n \qquad (3.1.2)$$

where n_u and n_n =Manning's roughness coefficients for an urban and a natural/existing channel, respectively;

$Q_{u,10}$ and $Q_{n,10}$ = Ten-year discharges under urbanized and natural/existing conditions (cfs), respectively;

b_u and b_n = bottom width of channel under urbanized and natural/existing conditions (ft), respectively;

S_n = Natural/existing channel slope, in feet per foot;

Both methods yielded an deEgradation at the bridge site. The clear water assumption predicted 0.71 ft erosion, while the urban model predicted 0.17 ft erosion.

Table 3.1.3 Urban Growth Scenario Results Based on City of Tucson Drainage Manual

HEC-RAS Section ID	Distance (ft)	Bed elevation (ft)	Bed elevation - 20ft (ft)	Total Q (cfs)	Top width (ft)	n	Unit Q (ft2/s)	S_{equ} x 10^3	Z_{equ}(ft)	Long-term degradation (ft)
68087	6126.77	2250.7	2230.7	16800	250.52	0.025	67.06	2.13	2215.2	-15.49
61960	2872.25	2234.74	2214.74	16800	278.23	0.025	60.38	2.44	2202.2	-12.58
59088	3096.34	2226.21	2206.21	16800	287.39	0.025	58.46	2.44	2195.2	-11.05
55999	3000	2217	2197	16800	318.29	0.03	52.78	3.30	2187.6	-9.41
52999	500	2205	2185	16800	621.13	0.03	27.04	1.67	2177.7	-7.29
52499	500	2204	2184	16800	369.74	0.03	45.47	1.65	2176.9	-7.13
51999	500	2203	2183	16800	505.08	0.032	33.41	3.33	2176.0	-6.96
51499	442	2201	2181	16800	497.04	0.03	33.91	3.76	2174.4	-6.62
51057	112	2199	2179	16800	496.22	0.028	34.19	0.00	2172.7	-6.28
50945 (bridge)	445	2199	2179	16800	462.91	0.026	36.29	1.87	2172.7	**-6.28**
50500	505	2198	2178	16800	326.76	0.029	51.41	1.63	2171.9	-6.11
49996	495	2197	2177	16800	327.64	0.028	51.28	0.00	2171.1	-5.94
49501	502	2197	2177	16800	211.63	0.03	79.38	1.62	2171.1	-5.94
48999	3000	2196	2176	16800	333.1	0.03	50.44	1.92	2170.2	-5.75
45999	3000	2189	2169	21800	559.85	0.03	38.94	2.55	2164.5	-4.53
42999	3000	2180	2160	21800	702.32	0.03	31.04	2.56	2156.8	-3.18
39999	3140	2171	2151	21800	847.92	0.03	25.70	1.63	2149.1	-1.86
36859	2290	2165	2145	21800	1286.81	0.035	16.94	3.41	2144.0	-0.99
34569		2158	2138						2138.0	0.00

Note: *Q*= Channel discharge; *n* = Manning's roughness; *q* = Channel unit discharge.

S_{equ} = Equilibrium bed slope; Z_{equ} = Equilibrium bed elevation; *n* = Manning's roughness

3.1.3 Clear Water Scour Scenario Based on HEC 20 Shields Approach

In addition to methods recommended COT manual, in HEC 20 Manual, two situations were considered to calculate the long-term bed degradation depth: one is clear water; the other is to assume a reduction in sediment supply that will cause channel incision. 10-year flow is also recommended for the long-term degradation analysis.

Clear water scenario assumes sediment concentration is nearly zero, so channel bed is incised to achieve an equilibrium slope. The equilibrium slope can be calculated from two approaches, the Shields parameter approach (Equation 6.17 in HEC 20) and Meyer-Peter Muller equation approach (Equation 6.18 in HEC 20). The Shields parameter approach calculates the equilibrium slope as:

$$S_{eq} = \left[K_s D_c \left(\frac{\gamma_s - \gamma}{\gamma} \right) \right]^{(10/7)} \left(\frac{K_u}{qn} \right)^{(6/7)} \tag{3.1.3}$$

where S_{eq} = Equilibrium slope, in feet per foot;

n = Manning's roughness coefficient;

q = Channel unit discharge (ft^2/s);

K_s = Shields parameter;

K_s = 1.486 in English Unit and 1.0 in SI;

D_c = Critical bed material size (ft).

The Shields parameter ranges from 0.03 to 0.1 for natural sediment. 0.047 is recommended for sand sizes and 0.03 for gravel and cobble sizes (HEC 20, page 6.27). The critical size (D_c) used in the equation should be D_{90} because the bed will coarsen as degradation occurs (HEC 20, page 6.29). The long-term degradation results using Equation 3.1.3 under clear water scenario are shown in Table 3.1.4.

Table 3.1.4 Clear Water Scenario Results Based on HEC 20 Shields Approach (Equation 6.17)

HEC-RAS Section ID	Distance (ft)	Bed elevation (ft)	n	q (ft^2/s)	K_s	D_c (ft)	S_{equ} (x 10^3)	Z_{equ} (ft)	Long-term degradation (ft)
68087	6126.77	2250.7	0.025	67.06	0.030	0.17	1.91	2172.83	-77.87
61960	2872.25	2234.74	0.025	60.38	0.047	0.02	0.08	2166.65	-68.09
59088	3096.34	2226.21	0.025	58.46	0.030	0.09	0.42	2166.43	-59.78
55999	3000	2217	0.03	52.78	0.030	0.15	1.63	2165.12	-51.88
52999	500	2205	0.03	27.04	0.030	0.08	1.19	2162.55	-42.45
52499	500	2204	0.03	45.47	0.047	0.12	1.30	2162.23	-41.77
51999	500	2203	0.032	33.41	0.030	0.07	0.79	2161.58	-41.42
51499	442	2201	0.03	33.91	0.047	0.02	0.14	2161.38	-39.62
51057	112	2199	0.028	34.19	0.047	0.01	0.05	2161.31	-37.69
50945 (Bridge)	445	2199	0.026	36.29	0.047	0.03	0.31	2161.31	**-37.69**
50500	505	2198	0.029	51.41	0.030	0.06	0.47	2161.17	-36.83
49996	495	2197	0.028	51.28	0.030	0.10	1.03	2161.04	-35.96
49501	502	2197	0.03	79.38	0.047	0.01	0.02	2160.77	-36.23
48999	3000	2196	0.03	50.44	0.047	0.02	0.07	2160.76	-35.24
45999	3000	2189	0.03	38.94	0.047	0.01	0.03	2160.55	-28.45
42999	3000	2180	0.03	31.04	0.047	0.00	0.01	2160.46	-19.54
39999	3140	2171	0.03	25.71	0.047	0.05	0.55	2160.43	-10.57
36859	2290	2165	0.035	16.94	0.030	0.04	0.58	2158.70	-6.30
34569		2158						2158.00	0.00

Note: *n* = Manning's roughness; *q* = Channel unit discharge; K_s = Shields parameter; D_c = Critical bed material size; S_{equ} = Equilibrium bed slope; Z_{equ} = Equilibrium bed elevation.

3.1.4 Clear Water Scour Scenario Based on HEC 20 Meyer-Peter Muller Approach

The Meyer-Peter Muller equation approach (Equation 6.18 in HEC 20) is calculated as:

$$S_{eq} = K_u \frac{\left(D_{50}\right)^{10/7} n^{9/7}}{\left(D_{90}\right)^{5/14} q^{6/7}} \tag{3.1.4}$$

where K_s = 60.1 in English Unit and 28..0 in SI.

Table 3.1.5 Clear Water Scenario Results Based on HEC 20 Meyer-Peter Muller Approach (Equation 6.18)

HEC-RAS Section ID	Distance (ft)	Bed elevation (ft)	n	q (ft^2/s)	D_{50} (mm)	D_{90} (mm)	S_{equ} (x 10^3)	Z_{equ} (ft)	Long-term degradation (ft)
68087	6126.77	2250.7	0.025	67.06	4.35	52.88	0.06	2160.7	-90.03
61960	2872.25	2234.74	0.025	60.38	0.92	5.28	0.02	2160.3	-74.44
59088	3096.34	2226.21	0.025	58.46	8.10	26.45	0.22	2160.3	-65.96
55999	3000	2217	0.03	52.78	5.52	45.69	0.14	2159.6	-57.42
52999	500	2205	0.03	27.04	3.29	24.57	0.15	2159.2	-45.84
52499	500	2204	0.03	45.47	1.61	35.65	0.03	2159.1	-44.91
51999	500	2203	0.032	33.41	2.05	21.77	0.07	2159.1	-43.93
51499	442	2201	0.03	33.91	1.12	6.37	0.04	2159.0	-41.96
51057	112	2199	0.028	34.19	0.87	2.89	0.04	2159.0	-39.98
50945 (Bridge)	445	2199	0.026	36.29	0.13	10.58	0.00	2159.0	**-39.99**
50500	505	2198	0.029	51.41	2.69	18.51	0.07	2159.0	-38.99
49996	495	2197	0.028	51.28	3.56	31.14	0.08	2159.0	-38.02
49501	502	2197	0.03	79.38	0.78	2.60	0.02	2158.9	-38.06
48999	3000	2196	0.03	50.44	1.20	5.03	0.04	2158.9	-37.07
45999	3000	2189	0.03	38.94	0.85	2.21	0.04	2158.8	-30.18
42999	3000	2180	0.03	31.04	0.55	1.04	0.03	2158.7	-21.29
39999	3140	2171	0.03	25.71	1.60	13.85	0.07	2158.6	-12.39
36859	2290	2165	0.035	16.94	2.02	12.35	0.17	2158.4	-6.60
34569		2158						2158.0	0.00

Note: n = Manning's roughness; q = Channel unit discharge; S_{equ} = Equilibrium bed slope; Z_{equ} = Equilibrium bed elevation.

3.1.5 Sediment Supply Reduced Based on HEC 20 Shields Approach

Another situation involves a reduction in sediment supply. In this case, a reduction in sediment supply or an increase in discharge can cause a reduction in channel slope and degradation. The new equilibrium slope will produce hydraulic conditions where the channel sediment transport capacity matches the upstream sediment supply. Two equations in HEC 20 can be used to calculate equilibrium slope, Equation 6.23 and Equation 6.24. Eq. 6.23 will need the definition of sediment transport capacity equation. According HEC-20, the sediment capacity equation (Eq. 6.19 - 6.22 in HEC-20) is developed for channel slope less than 0.002. Its applicability to this reach, which has an averaged channel slope of 0.0025, has not been verified.

Therefore, the results by using Eq. 6.23 in HEC-20 are for reference only. Two scenarios with sediment supply reduced by 10% and 30% in the future, respectively, are assumed. The equations to compute equilibrium slope using Equation 6.23 are listed as:

$$q_s = aV^b Y^c \tag{3.1.5}$$

$$a = 0.025n^{(2.39-0.8\log(D_{50}))}(D_{50} - 0.07)^{-14} \tag{3.1.6}$$

$$b = 4.93 - 0.74\log(D_{50}) \tag{3.1.7}$$

$$c = -0.46 + 0.65\log(D_{50}) \tag{3.1.8}$$

where q_s = Sediment transport capacity per unit width or existing sediment supply (ft^2/s);

V = Channel average velocity (ft/s);

Y = Channel average depth (ft);

a,b,c = Coefficient and exponents;

n = Manning's roughness coefficient;

$$S_{eq} = \left(\frac{a}{q_s}\right)^{\frac{10}{3(c-b)}} q^{\frac{2(2b+3c)}{3(c-b)}} \left(\frac{n}{K_u}\right)^2 \tag{3.1.9}$$

where S_{eq} = Equilibrium slope, in feet per foot;

q_s = Upstream sediment supply per unit width or future sediment supply (ft^2/s);

q = Channel unit discharge (ft^2/s);

K_s = 1.486 in English Unit and 1.0 in SI.

Table 3.1.6 lists the hydraulic variables, sediment variables, the calculation of coefficient and existing sediment supply (sediment transport capacity). Results of two scenarios with sediment supply reduced by 30% and 50% in the future are listed in Table 3.1.7 and Table 3.1.8.

Table 3.16. Variables and Coefficient

HEC-RAS Section ID	Distance (ft)	n	V (ft/s)	Y (ft)	q (ft^2/s)	D_{50} (mm)	Coefficient			Existing q_s (ft^2/s)
							a	b	c	
68087	0	0.025	7.72	8.69	67.06	4.35	3.2E-06	4.46	-0.05	0.026
61960	6126.77	0.025	9.26	6.52	60.38	0.92	4.2E-06	4.96	-0.48	0.104
59088	8999.02	0.025	11.03	5.3	58.46	8.10	2.9E-06	4.26	0.13	0.100
55999	12095.36	0.03	9.15	5.77	52.78	5.52	4.3E-06	4.38	0.02	0.072
52999	15095.36	0.03	7.98	4.68	27.05	3.29	4.8E-06	4.55	-0.12	0.050
52499	15595.36	0.03	10.57	5.71	45.44	1.61	5.6E-06	4.78	-0.33	0.247
51999	16095.36	0.032	8.09	5.63	33.26	2.05	6.1E-06	4.70	-0.26	0.072
51499	16595.36	0.03	6.18	5.48	33.80	1.12	6.1E-06	4.89	-0.43	0.022
51057	17037.36	0.028	7.23	7.29	33.86	0.87	5.6E-06	4.97	-0.50	0.039
50945 (Bridge)	17149.36	0.026	8.23	7.24	36.29	0.13	2.0E-05	5.59	-1.04	0.263
50500	17594.36	0.029	11.01	5.88	51.41	2.69	4.6E-06	4.61	-0.18	0.215
49996	18099.36	0.028	9.76	6.96	51.28	3.56	4.1E-06	4.52	-0.10	0.100
49501	18594.36	0.03	12.51	6.35	79.38	0.78	6.8E-06	5.01	-0.53	0.805
48999	19096.36	0.03	7.16	7.04	50.44	1.20	6.0E-06	4.87	-0.41	0.040
45999	22096.36	0.03	8.2	4.79	38.94	0.85	0.000	4.98	-0.51	0.108
42999	25096.36	0.03	9.96	3.12	31.04	0.55	0.000	5.12	-0.63	0.488
39999	28096.36	0.03	7.72	3.33	25.71	1.60	0.000	4.78	-0.33	0.066
36859	31236.36	0.035	6.71	6.31	16.94	2.02	0.000	4.70	-0.26	0.035
34569	33526.36									

Note: n = Manning's roughness; V = Channel average velocity; Y = Channel average depth; q = Channel unit discharge; q_s= Sediment transport capacity per unit width or existing sediment supply.

Table 3.1.7 Sediment Supply Reduced by 10% and 30% Results Using HEC 20 Equation (6.23)

HEC-RAS Section ID	Bed elevation (ft)	Sediment supply reduced by 10%				Sediment supply reduced by 30%			
		Future q_s (ft^2/s)	S_{equ} (x 10^3)	Z_{equ} (ft)	Long-term degradation (ft)	Future q_s (ft^2/s)	S_{equ} (x 10^3)	Z_{equ} (ft)	Long-term degradation (ft)
68087	2250.7	0.02	0.87	2270.92	20.22	0.02	0.73	2253.66	2.96
61960	2234.74	0.09	1.87	2265.57	30.83	0.07	1.60	2249.21	14.47
59088	2226.21	0.09	3.42	2260.21	34.00	0.07	2.79	2244.62	18.41
55999	2217	0.07	3.04	2249.61	32.61	0.05	2.51	2235.96	18.96
52999	2205	0.04	4.60	2240.48	35.48	0.03	3.84	2228.43	23.43
52499	2204	0.22	5.73	2238.18	34.18	0.17	4.86	2226.51	22.51
51999	2203	0.06	4.07	2235.32	32.32	0.05	3.43	2224.08	21.08
51499	2201	0.02	1.51	2233.29	32.29	0.02	1.29	2222.37	21.37
51057	2199	0.04	1.94	2232.62	33.62	0.03	1.67	2221.79	22.79
50945 (Bridge)	2199	0.24	2.10	2232.40	33.40	0.18	1.85	2221.61	22.61
50500	2198	0.19	5.34	2231.47	33.47	0.15	4.48	2220.78	22.78
49996	2197	0.09	3.36	2228.77	31.77	0.07	2.81	2218.52	21.52
49501	2197	0.72	5.09	2227.11	30.11	0.56	4.38	2217.13	20.13
48999	2196	0.04	1.45	2224.55	28.55	0.03	1.24	2214.93	18.93
45999	2189	0.10	3.21	2220.20	31.20	0.08	2.76	2211.23	22.23
42999	2180	0.44	8.35	2210.57	30.57	0.34	7.22	2202.95	22.95
39999	2171	0.06	4.56	2185.51	14.51	0.05	3.87	2181.30	10.30
36859	2165	0.03	5.76	2171.20	6.20	0.02	4.87	2169.15	4.15
34569	2158	0.02		2158.00	0.00			2158.00	0.00

Note: S_{equ} = Equilibrium bed slope; Z_{equ} = Equilibrium bed elevation.

In the case of a reduction in sediment supply to a reach that was previously in equilibrium and with all other characteristics remaining constant, the equilibrium slope can be related to the existing channel slope by simplifying Equation 6.23 to Equation 6.24:

$$S_{eq} = S_{ex}\left(\frac{Q_{s(future)}}{Q_{s(existing)}}\right)^{\frac{10}{3(c-b)}} \tag{3.1.10}$$

where S_{ex} = Existing channel slope;

Q_s = Sediment supply (ft^3/s).

Table 3.1.8 Sediment Supply Reduced by 10% and 30% Results Using HEC 20 Equation 6.24

HEC-RAS Section ID	Z_b (ft)	Existing		Sediment supply reduced by 10%				Sediment supply reduced by 30%			
		Slope	q_s (ft^2/s)	Future q_s (ft^2/s)	S_{equ} (x 10^3)	Z_{equ} (ft)	ΔZ (ft)	Future q_s (ft^2/s)	S_{equ} (x 10^3)	Z_{equ} (ft)	ΔZ (ft)
68087	2251	0.0026	0.03	0.02	2.41	2244.28	-6.42	0.02	2.00	2230.73	-19.97
61960	2235	0.0030	0.10	0.09	2.78	2229.52	-5.22	0.07	2.39	2218.48	-16.26
59088	2226	0.0030	0.10	0.09	2.73	2221.52	-4.69	0.07	2.23	2211.62	-14.59
55999	2217	0.0040	0.07	0.07	3.69	2213.07	-3.93	0.05	3.05	2204.72	-12.28
52999	2205	0.0020	0.05	0.04	1.86	2201.99	-3.01	0.03	1.55	2195.58	-9.42
52499	2204	0.0020	0.25	0.22	1.87	2201.07	-2.93	0.17	1.58	2194.81	-9.19
51999	2203	0.0040	0.07	0.06	3.73	2200.13	-2.87	0.05	3.15	2194.01	-8.99
51499	2201	0.0045	0.02	0.02	4.24	2198.27	-2.73	0.02	3.62	2192.44	-8.56
51057	2199	0.0000	0.04	0.04	0.00	2196.40	-2.60	0.03	0.00	2190.84	-8.16
50945 (Bridge)	2199	0.0022	0.26	0.24	2.13	2196.40	-2.60	0.18	1.88	2190.84	-8.16
50500	2198	0.0020	0.21	0.19	1.84	2195.45	-2.55	0.15	1.55	2190.00	-8.00
49996	2197	0.0000	0.10	0.09	0.00	2194.52	-2.48	0.07	0.00	2189.22	-7.78
49501	2197	0.0020	0.80	0.72	1.87	2194.52	-2.48	0.56	1.61	2189.22	-7.78
48999	2196	0.0023	0.04	0.04	2.18	2193.58	-2.42	0.03	1.86	2188.42	-7.58
45999	2189	0.0030	0.11	0.10	2.81	2187.03	-1.97	0.08	2.42	2182.83	-6.17
42999	2180	0.0030	0.49	0.44	2.82	2178.59	-1.41	0.34	2.44	2175.58	-4.42
39999	2171	0.0019	0.07	0.06	1.78	2170.12	-0.88	0.05	1.51	2168.26	-2.74
36859	2165	0.0031	0.04	0.03	2.85	2164.52	-0.48	0.02	2.41	2163.51	-1.49
34569	2158					2158.00	0.00			2158.00	0.00

Note: z_b = Existing bed elevation; q_s = sediment supply per unit width; S_{equ} = Equilibrium bed slope; Z_{equ} = Equilibrium bed elevation; ΔZ = long-term degradation.

In summary, using the Ina Bridge soil cement as the grade control of this reach, if assuming clear water scour, the maximum long-term degradation rate ranges from 25.96 ft from COT Drainage Manual to 39.99 ft from Eq. 6.18 in HEC-20. Since it's unlikely clear water scour situation will occur in this reach of Santa Cruz River, the equilibrium slope method using sediment reduction assumption is more realistic. Therefore, Eq.6.23 and 6.24 in HEC-20 are chosen for long-term degradation estimation. Table 3.1.7 showed aggradation at the study reach because the predicted equilibrium slope is steeper than the current slope. Since the validity of Eq.6.23 to this reach is not verified, results in Table 3.1.7 were neglected. Table 3.1.8 showed

the long term scour depth at the bridge section is 2.6 ft for 10% sediment reduction and 8.16 ft for 30% sediment reduction. This study assumes minor sediment load reduction in the bridge reach, the long-term degradation rate is 2.6 ft. ***This estimation is optimistic because there is no grade control structure in this 17,000 ft river reach from the bridge site to the Ina Road Bridge. If sediment supply will significantly reduce in the future, a system wide incision will occur in this reach, which may result in a considerable incision at the bridge site. Therefore, periodic monitoring of bed elevation changes near the bridge site should be carried on to ensure stable bed elevation. In case of incision, a grade control structure should be built at the bridge site or within 2000 ft downstream from the bridge site.***

3.2 Bend Scour Depth

The bend scour is calculated by using the method in the City of Tucson Drainage Manual. The bend scour depth relates to the channel curvature, flow depth, and velocity as follows.

$$Z_{be} = \frac{0.0685 Y_{\max} V_m^{0.8}}{Y_h^{0.4} S_e^{0.3}} \left[2.1 \left(\frac{\sin^2(\alpha/2)}{\cos\alpha} \right)^{0.2} - 1 \right] \tag{3.2.1}$$

Z_{be} = bend scour component of total scour depth in ft, α=23.98°.

V_m = averaged velocity (ft/s);

$Y_{\max}$ =maximum flow depth (ft);

Y_h = hydraulic depth (ft);

S_e = energy slope;

The attack angle is calculated as the angle between flow and the tangential of the outer bank line as below:

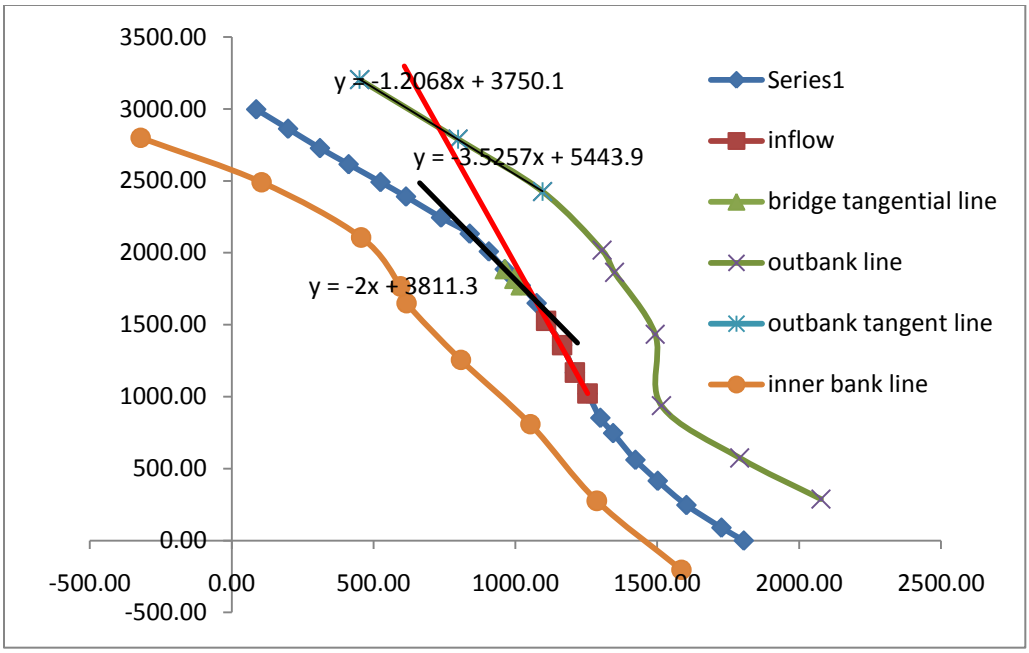


Fig.3.2.1 Tangential lines at the neighborhood of the bridge

10-year flow is used for the calculation. Flow properties from HEC-RAS model were shown below. The calculated bend scour depth is 2.21 ft for both interim and ultimate geometry.

Table 3.2.1 Calculation of Bend Scour Depth

Flow Properties	interim geometry	ultimate geometry
Flow Area, A=	2691.09	2691.58
Energy Slope, Se=	0.001696	0.001696
Hydraulic Depth, yh=	5.43	5.43
Mean Velocity, Vm=	6.24	6.24
Maximum Flow Depth, Ymax	15.45	15.45
Bend Scour Depth, Zbe=	2.21	2.21

3.3 General/Contraction Scour

This section details the calculations of local scour and contraction scour at piers and abutment. PDOT requires bridge scour calculation to follow the "Guidelines for Establishing Scour and Freeboard for Bridges in Pima County, August 2012" (Guidelines). 100-year design flood is required for determining the scour depth, and an extreme flood event is required to check the calculated scour depth. The 100-year flow for the design reach is 70,000 cfs at the bridge site, and increases to 80,000 cfs downstream from the confluence to the Rillito River. The extreme event is 500 year flood event. The design flow is 94,700 cfs at the bridge site, and increases to 104,700 cfs downstream from the confluence to the Rillito River.

HEC-RAS steady flow model for these two floods at the bridge reach developed by the PB World, Inc. was used for bridge scour analysis. The model simulated 100-year and 500-year flood flows for two geometries: one is the interim geometry, and the other is the ultimate geometry, The interim geometry reflects the topographic condition before upgrading the Silver Road, while the ultimate geometry includes the proposed upgrading of Silverbell Road. Additionally, three pier diameters were assumed: 4 ft, 6 ft, and 8 ft. Therefore, the scour depths were calculated for three pier diameters, two geometric settings, and two flood flows.

3.3.1 Sediment Fall Velocity

Sediment fall velocity is determined by using the Federal Highway Administration's "Evaluating Scour at Bridges, 5th edition, Hydraulic Engineering Circular No. 18, 2012" (HEC-18). HEC-18 Figure 6.8 shows fall velocity is a function of particle diameter and temperature. Temperature is chosen as 20°. D_{50} at seven boring sites are used as the mean sediment sizes. The bed material size distributions are provided by NCS Consultants, LLC. The data are separated into two groups: the top layer (0.0 ft – 20.0 ft), and the bottom layer (40.0 ft). The fall velocities at each boring sites were determined by using 0-20 ft and 40 ft soil data, respectively. The results of fall velocity calculated using the top and bottom layer soils are summarized in Table 3.3.1 and 3.3.2, respectively.

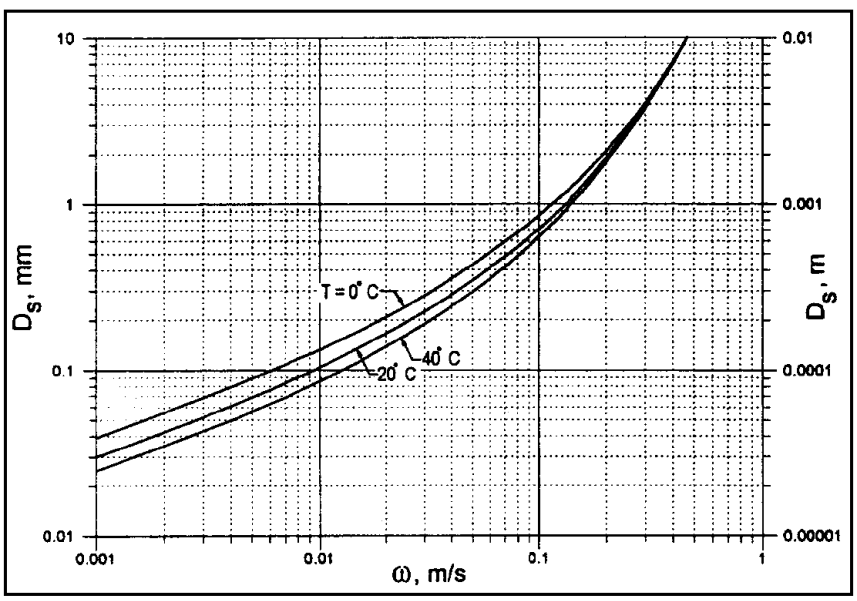


Fig.3.3.1 Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units (HEC-18 Figure 6.8)

Table 3.3.1 Fall Velocity of Top Layer

	Boring	Depth (ft)	D_{50} (mm)	Averaged D_{50} (mm)	Fall Velocity (m/s)
LOB	B-01	0.0 – 20.0	0.299	0.36	0.06
	B-02	0.0 – 20.0	0.270		
	B-03	0.0 – 20.0	0.721		
Channel	B-04	0.0 – 20.0	0.191	0.13	0.02
	B-05	0.0 – 20.0	0.121		
	B-06	0.0 – 20.0	0.015		
ROB	B-07	0.0 – 20.0	0.034	0.03	0.002

Table 3.3.2 Fall Velocity of Bottom Layer (40.0 ft)

	Boring	Depth (ft)	D_{50} (mm)	Averaged D_{50} (mm)	Fall Velocity (m/s)
LOB	B-01	35.0 – 36.0	2.151	1.87	0.20
	B-02	40.0 – 41.0	1.094		
	B-03	35.0 – 36.0	2.118		
Channel	B-04	40.0 – 40.9	2.188	2.24	0.22
	B-05	40.0 – 41.5	2.147		
	B-06	45.0 – 46.0	2.155		
ROB	B-07	30.0 – 31.5	5.654	5.56	0.35

Table 3.3.1 and 3.3.2 showed there are three bore holes on the left floodplain, three in the channel, and one on the right floodplain. Sediment samples on the left floodplain were mixed to obtain the average sediment size gradation, and sediment samples in the channel were also mixed to obtain the averaged gradation curve. To obtain the averaged grain size distribution, we first interpolate grain size distributions to standard gradations for Sieve Number #200 – 3", then the sample gradations were mixed to obtain the algebra average. At last, the averaged D_{50} was calculated. The cubic interpolation was used in the calculation.

3.3.2 Live Bed Contraction Scour

The contraction scour is the scour caused by the contraction of cross section at the bridge section. Two flow conditions are commonly assumed: one is clear water, and the other is live bed. Both methods were used for calculating contraction scour at the bridge site.

The Live-bed scour relation, Equation 3.3.2 and 3.3.3 in HEC-18, is written as:

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1} \tag{3.3.1}$$

$$y_s = y_2 - y_0 \tag{3.3.2}$$

where:

y_s is the average contraction scour depth (ft);

y_0 is the existing depth in the contracted section before scour (ft);

y_1 is the average depth in the upstream main channel (ft);

y_2 is the average depth in the contracted section (ft);

Q_1 is the flow in the upstream channel transporting sediment (ft);

Q_2 is the flow in the contracted channel (ft^3/s);

W_1 is the bottom width of the upstream main channel that is transporting bed material (ft);

W_2 is the bottom width of main channel in contracted section less pier width (ft);

k_1 is the exponent coefficient (-) determined below

V_* / T	k_1
< 0.5	0.59
0.5 ~ 2.0	0.64
> 2.0	0.69

V_* is the shear velocity (ft/s);

T is the fall velocity of bed material based on D_{50} (m/s);

The hydraulic parameters needed in Eq. (3.3.1) and (3.3.2) for contraction scour calculation were obtained from HEC-RAS model for 100-year and 500-year design flows. The calculation results are presented from Table 3.3.3 to Table 3.3.6.

Table 3.3.3 Live-Bed Contraction Scour Depth for 100-year Design Flow and Interim Geometry

100-Year Design Flow (Q = 70,000 cfs), Interim Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	9510.70	60489.30	9602.22	60397.77	9714.10	60285.90
Q_2	17410.33	50742.82	17603.72	50474.90	17604.80	50379.46
W_1	443.02	622.35	443.02	622.50	443.02	622.69
W_2	252.85	390.81	248.85	384.70	244.85	378.56
k_1	0.69	0.69	0.69	0.69	0.69	0.69
y_1	5.14	10.63	5.21	10.69	5.29	10.77
y_0	6.98	9.95	6.97	9.94	6.95	9.92
y_2	12.71	12.61	13.04	12.78	13.26	13.02
y_s	5.73	2.66	6.07	2.84	6.31	3.10
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	9510.70	60489.30	9602.22	60397.77	9714.10	60285.90
Q_2	17410.33	50742.82	17603.72	50474.90	17604.80	50379.46
W_1	443.02	622.35	443.02	622.50	443.02	622.69
W_2	252.85	390.81	248.85	384.70	244.85	378.56
k_1	0.64	0.64	0.64	0.64	0.64	0.64
y_1	5.14	10.63	5.21	10.69	5.29	10.77
y_0	6.98	9.95	6.97	9.94	6.95	9.92
y_2	12.36	12.32	12.67	12.47	12.87	12.70
y_s	5.38	2.37	5.70	2.53	5.92	2.78

Table 3.3.4 Live-Bed Contraction Scour Depth for 100-year Design Flow and Ultimate Geometry

100-Year Design Flow (Q = 70,000 cfs), Ultimate Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	10169.35	59830.65	10190.61	59809.39	10209.62	59790.38
Q_2	18514.12	51485.88	18705.18	51294.81	18675.75	51324.25
W_1	443.02	624.28	443.02	624.36	443.02	624.43
W_2	252.85	395.22	248.85	388.87	244.85	382.30
k_1	0.69	0.69	0.69	0.69	0.69	0.69
y_1	5.68	11.13	5.70	11.15	5.71	11.16
y_0	7.84	10.69	7.76	10.61	7.66	10.53
y_2	13.98	13.41	14.28	13.55	14.43	13.74
y_s	6.14	2.72	6.52	2.94	6.77	3.21
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	10169.35	59830.65	10190.61	59809.39	10209.62	59790.38
Q_2	18514.12	51485.88	18705.18	51294.81	18675.75	51324.25
W_1	443.02	624.28	443.02	624.36	443.02	624.43
W_2	252.85	395.22	248.85	388.87	244.85	382.30
k_1	0.64	0.64	0.64	0.64	0.64	0.64
y_1	5.68	11.13	5.70	11.15	5.71	11.16
y_0	7.84	10.69	7.76	10.61	7.66	10.53
y_2	13.59	13.11	13.88	13.23	14.00	13.40
y_s	5.75	2.42	6.12	2.62	6.34	2.87

Table 3.3.5 Live-Bed Contraction Scour Depth for 500-year Design Flow and Interim Geometry

500-Year Design Flow (Q = 93,000 cfs), Interim Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	15855.51	77144.48	15992.67	77007.34	16150.06	76849.95
Q_2	23778.84	64555.83	24055.88	64131.96	24042.08	63959.52
W_1	443.02	642.35	443.02	643.89	443.02	645.68
W_2	252.85	396.84	248.85	390.78	244.85	384.68
k_1	0.69	0.69	0.69	0.69	0.69	0.69
y_1	7.04	12.15	7.13	12.21	7.23	12.28
y_0	8.37	11.17	8.36	11.16	8.34	11.14
y_2	14.67	14.54	15.06	14.73	15.31	15.00
y_s	6.30	3.37	6.70	3.57	6.97	3.86
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	15855.51	77144.48	15992.67	77007.34	16150.06	76849.95
Q_2	23778.84	64555.83	24055.88	64131.96	24042.08	63959.52
W_1	443.02	642.35	443.02	643.89	443.02	645.68
W_2	252.85	396.84	248.85	390.78	244.85	384.68
k_1	0.64	0.64	0.64	0.64	0.64	0.64
y_1	7.04	12.15	7.13	12.21	7.23	12.28
y_0	8.37	11.17	8.36	11.16	8.34	11.14
y_2	14.27	14.19	14.63	14.37	14.86	14.61
y_s	5.90	3.02	6.27	3.21	6.52	3.47

Table 3.3.6 Live-Bed Contraction Scour Depth for 500-year Design Flow and Ultimate Geometry

500-Year Design Flow (Q = 93,000 cfs), Ultimate Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	17472.22	75527.78	17558.13	75441.88	17616.61	75383.37
Q_2	25593.00	67407.00	25246.51	67753.49	25952.86	67047.15
W_1	473.02	655.61	473.02	655.82	473.02	655.94
W_2	252.85	399.13	248.85	390.33	244.85	386.82
k_1	0.69	0.69	0.69	0.69	0.69	0.69
y_1	7.69	12.64	7.76	12.70	7.81	12.75
y_0	9.12	11.86	8.21	11.03	9.04	11.78
y_2	16.43	16.15	16.50	16.57	17.15	16.60
y_s	7.31	4.29	8.29	5.54	8.11	4.82
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q_1	17472.22	75527.78	17558.13	75441.88	17616.61	75383.37
Q_2	25593.00	67407.00	25246.51	67753.49	25952.86	67047.15
W_1	473.02	655.61	473.02	655.82	473.02	655.94
W_2	252.85	399.13	248.85	390.33	244.85	386.82
k_1	0.64	0.64	0.64	0.64	0.64	0.64
y_1	7.69	12.64	7.76	12.70	7.81	12.75
y_0	9.12	11.86	8.21	11.03	9.04	11.78
y_2	15.93	15.75	15.98	16.14	16.59	16.17
y_s	6.81	3.89	7.77	5.11	7.55	4.39

3.3.3 Clear-Water Contraction Scour

The clear water contraction scour depth is calculated by using Equation (HEC-18 equation 3.3.4):

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2} \right]^{3/7} \tag{3.3.3}$$

$$y_s = y_2 - y_0 \tag{3.3.4}$$

where:

y_s is the average contraction scour depth (ft);

y_2 is the average equilibrium depth in the contracted section after contraction scour (ft);

Q is the discharge through the bridge (ft^3/s);

D_m is the diameter of the smallest nontransportable particle in the bed material ($1.25D_{50}$) in the contracted section (ft);

D_{50} is the median diameter of bed material (ft);

W is the bottom width of the contracted section less pier widths (ft);

K_u equals 0.0077 for English units;

The calculation results are presented from Table 3.3.7 to Table 3.3.10.

Table 3.3.7 Clear-Water Contraction Scour Depth for 100-year Design Flow and Interim Geometry

100-Year Design Flow (Q = 70,000 cfs), Interim Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	17410.33	50742.82	17603.72	50474.90	17604.80	50379.46
D_{50}	0.36	0.13	0.36	0.13	0.36	0.13
W	252.85	390.81	248.85	384.70	244.85	378.56
y_0	6.98	9.95	6.97	9.94	6.95	9.92
y_2	30.09	69.33	30.79	69.95	31.22	70.81
y_s	23.11	59.38	23.82	60.01	24.27	60.89
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	17410.33	50742.82	17603.72	50474.90	17604.80	50379.46
D_{50}	1.87	2.24	1.87	2.24	1.87	2.24
W	252.85	390.81	248.85	384.70	244.85	378.56
y_0	6.98	9.95	6.97	9.94	6.95	9.92
y_2	18.79	30.74	19.23	31.01	19.50	31.39
y_s	11.81	20.79	12.26	21.07	12.55	21.47

Table 3.3.8 Clear-Water Contraction Scour Depth for 100-year Design Flow and Ultimate Geometry

100-Year Design Flow (Q = 70,000 cfs), Ultimate Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	18514.12	51485.88	18705.18	51294.81	18675.75	51324.25
D_{50}	0.36	0.13	0.36	0.13	0.36	0.13
W	252.85	395.22	248.85	388.87	244.85	382.30
y_0	7.84	10.69	7.76	10.61	7.66	10.53
y_2	31.72	69.52	32.44	70.27	32.85	71.34
y_s	23.88	58.83	24.68	59.66	25.19	60.81
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	18514.12	51485.88	18705.18	51294.81	18675.75	51324.25
D_{50}	1.87	2.24	1.87	2.24	1.87	2.24
W	252.85	395.22	248.85	388.87	244.85	382.30
y_0	7.84	10.69	7.76	10.61	7.66	10.53
y_2	19.81	30.82	20.26	31.16	20.51	31.63
y_s	11.97	20.13	12.50	20.55	12.85	21.10

Table 3.3.9 Clear-Water Contraction Scour Depth for 500-year Design Flow and Interim Geometry

500-Year Design Flow (Q = 93,000 cfs), Interim Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	23778.84	64555.83	24055.88	64131.96	24042.08	63959.52
D_{50}	0.36	0.13	0.36	0.13	0.36	0.13
W	252.85	396.84	248.85	390.78	244.85	384.68
y_0	8.37	11.17	8.36	11.16	8.34	11.14
y_2	39.30	84.10	40.24	84.74	40.79	85.69
y_s	30.93	72.93	31.88	73.58	32.45	74.55
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	23778.84	64555.83	24055.88	64131.96	24042.08	63959.52
D_{50}	1.87	2.24	1.87	2.24	1.87	2.24
W	252.85	396.84	248.85	390.78	244.85	384.68
y_0	8.37	11.17	8.36	11.16	8.34	11.14
y_2	24.55	37.29	25.13	37.57	25.47	37.99
y_s	16.18	26.12	16.77	26.41	17.13	26.85

Table 3.3.10 Clear-Water Contraction Scour Depth for 500-year Design Flow and Ultimate Geometry

500-Year Design Flow (Q = 93,000 cfs), Ultimate Geometry						
Soil Data	0-20 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	25593.00	67407.00	25246.51	67753.49	25952.86	67047.15
D_{50}	0.36	0.13	0.36	0.13	0.36	0.13
W	252.85	399.13	248.85	390.33	244.85	386.82
y_0	9.12	11.86	8.21	11.03	9.04	11.78
y_2	41.86	86.85	41.94	88.91	43.55	88.80
y_s	32.74	74.99	33.73	77.88	34.51	77.02
Soil Data	40 ft					
Pier Diameter	4 ft		6 ft		8 ft	
	West	Channel	West	Channel	West	Channel
Q	25593.00	67407.00	25246.51	67753.49	25952.86	67047.15
D_{50}	1.87	2.24	1.87	2.24	1.87	2.24
W	252.85	399.13	248.85	390.33	244.85	386.82
y_0	9.12	11.86	8.21	11.03	9.04	11.78
y_2	26.14	38.51	26.20	39.42	27.20	39.37
y_s	17.02	26.65	17.99	28.39	18.16	27.59

The method using clear water assumption always predicts larger contraction scour depth than the method using the live bed method. At the bridge site, suspended sediment concentration is very high during flood events, and significant sediment transport were also observed in this reach during flood events. Therefore, live-bed scour assumption is most suitable for predicting contraction scour in this reach. Besides, HEC-18 also recommends the adaption of smaller contraction scour depths from both methods. Therefore, the contraction scour depth is the results using the Live-Bed scour relation in HEC-18.

3.4 Local Scour

3.4.1 CSU Equation in HEC-18

The HEC-18 recommended CSU equation is:

$$y_s = 2.0 K_1 K_2 K_3 y_1^{0.35} a^{0.65} Fr_1^{0.43} \tag{3.4.1}$$

where:

y_s is the scour depth (ft);

y_1 is the flow depth directly upstream of the pier (ft);

a is the pier width (ft);

L is the length of pier (ft);

Fr_1 is the Froude number directly upstream of the pier ($Fr_1 = \frac{V_1}{\sqrt{gy_1}}$);

V_1 is the velocity of flow directly upstream of the pier (ft/s);

g is the acceleration of gravity ($g = 32.2$ ft/s^2);

K_1 is the correction factor for pier nose shape ($K_1 = 1.0$ for group of cylinders);

K_2 is the correction factor for attack angle of flow ($K_2 = (\cos\theta + \min(12, \frac{L}{a})\sin\theta)^{0.65}$);

θ is the attack angle of flow;

K_3 is the correction factor for bed condition ($K_3 = 1.1$ for plane bed condition, which is typical of most bridge sites for the flood frequencies employed in scour design);

With the consideration of debris accumulation, the pier width can be replaced by the equivalent pier width:

$$a^* = \frac{K^*(HW) + (y - K^*H)a}{y} \quad \text{.....(3.4.2)}$$

where:

a^* is the equivalent pier width (ft) (for maximum pier scour, $a^* = a + 4$);

K^* is the debris shape factor ($K^* = 0.21$ for triangular debris, $K^* = 0.79$ for rectangular debris);

H is the height of the debris (ft);

W is the width of debris (ft);

y is the depth of approach flow (ft);

The pier scour depth was calculated using the maximum velocity and flow depth in the pier section. The debris was assumed to be triangular or rectangular shaped. The pier scour depth for the triangular shape debris is summarized in Table 3.4.1; and for the rectangular debris in Table 3.4.2. Additionally, the maximum scour depth if adding the full width of debris to the pier diameter is summarized in Table 3.4.3.

Table 3.4.1 Pier Scour Depth (CSU Equation) for Triangular Debris Shape

Deisgn Flow	100-Year Design Flow (Q = 70,000 cfs)					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
a	4.00	6.00	8.00	4.00	6.00	8.00
W	8.00	10.00	12.00	8.00	10.00	12.00
H	23.37	23.47	23.60	23.34	23.37	23.39
*a**	4.84	6.84	8.84	4.84	6.84	8.84
S/a	4.13	2.92	2.26	4.13	2.92	2.26
L	9.68	13.68	17.68	9.68	13.68	17.68
y1	23.37	23.47	23.60	23.34	23.37	23.39
V1	14.24	14.06	13.85	15.23	15.19	15.15
Fr1	0.52	0.51	0.50	0.56	0.55	0.55
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.29	1.29	1.29	1.29	1.29	1.29
K3	1.10	1.10	1.10	1.10	1.10	1.10
ys	20.33	28.59	36.74	20.92	29.54	38.14
Design Flow	500-Year Design Flow (Q = 93,000 cfs)					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
a	4.00	6.00	8.00	4.00	6.00	8.00
W	8.00	10.00	12.00	8.00	10.00	12.00
H	25.29	25.41	25.55	24.92	25.04	25.13
*a**	4.84	6.84	8.84	4.84	6.84	8.84
S/a	4.13	2.92	2.26	4.13	2.92	2.26
L	9.68	13.68	17.68	9.68	13.68	17.68
y1	25.29	25.41	25.55	24.92	25.04	25.13
V1	15.10	14.90	14.68	17.23	17.02	16.89
Fr1	0.53	0.52	0.51	0.61	0.60	0.59
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.29	1.29	1.29	1.29	1.29	1.29
K3	1.10	1.10	1.10	1.10	1.10	1.10
ys	21.07	29.63	38.07	22.26	31.31	40.35

Table 3.4.2 Pier Scour Depth (CSU Equation) for Rectangular Debris Shape

Deisgn Flow	100-Year Design Flow (Q = 70,000 cfs)					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
a	4.00	6.00	8.00	4.00	6.00	8.00
W	8.00	10.00	12.00	8.00	10.00	12.00
H	23.37	23.47	23.60	23.34	23.37	23.39
*a**	7.16	9.16	11.16	7.16	9.16	11.16
S/a	2.79	2.18	1.79	2.79	2.18	1.79
L	14.32	18.32	22.32	14.32	18.32	22.32
y1	23.37	23.47	23.60	23.34	23.37	23.39
V1	14.24	14.06	13.85	15.23	15.19	15.15
Fr1	0.52	0.51	0.50	0.56	0.55	0.55
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.29	1.29	1.29	1.29	1.29	1.29
K3	1.10	1.10	1.10	1.10	1.10	1.10
ys	30.07	38.29	46.38	30.95	39.56	48.15
Design Flow	500-Year Design Flow (Q = 93,000 cfs)					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
a	4.00	6.00	8.00	4.00	6.00	8.00
W	8.00	10.00	12.00	8.00	10.00	12.00
H	25.29	25.41	25.55	24.92	25.04	25.13
*a**	7.16	9.16	11.16	7.16	9.16	11.16
S/a	2.79	2.18	1.79	2.79	2.18	1.79
L	14.32	18.32	22.32	14.32	18.32	22.32
y1	25.29	25.41	25.55	24.92	25.04	25.13
V1	15.10	14.90	14.68	17.23	17.02	16.89
Fr1	0.53	0.52	0.51	0.61	0.60	0.59
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.29	1.29	1.29	1.29	1.29	1.29
K3	1.10	1.10	1.10	1.10	1.10	1.10
ys	31.17	39.68	48.07	32.93	41.93	50.94

Table 3.4.3 Pier Scour Depth (CSU Equation) for Maximum Pier Scour

Deisgn Flow	100-Year Design Flow (Q = 70,000 cfs)					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
a	4.00	6.00	8.00	4.00	6.00	8.00
W	8.00	10.00	12.00	8.00	10.00	12.00
H	23.37	23.47	23.60	23.34	23.37	23.39
*a**	8.00	10.00	12.00	8.00	10.00	12.00
S/a	2.50	2.00	1.67	2.50	2.00	1.67
L	16.00	20.00	24.00	16.00	20.00	24.00
y1	23.37	23.47	23.60	23.34	23.37	23.39
V1	14.24	14.06	13.85	15.23	15.19	15.15
Fr1	0.52	0.51	0.50	0.56	0.55	0.55
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.29	1.29	1.29	1.29	1.29	1.29
K3	1.10	1.10	1.10	1.10	1.10	1.10
ys	33.60	41.80	49.87	34.58	43.19	51.77
Design Flow	500-Year Design Flow (Q = 93,000 cfs)					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
a	4.00	6.00	8.00	4.00	6.00	8.00
W	8.00	10.00	12.00	8.00	10.00	12.00
H	25.29	25.41	25.55	24.92	25.04	25.13
*a**	8.00	10.00	12.00	8.00	10.00	12.00
S/a	2.50	2.00	1.67	2.50	2.00	1.67
L	16.00	20.00	24.00	16.00	20.00	24.00
y1	25.29	25.41	25.55	24.92	25.04	25.13
V1	15.10	14.90	14.68	17.23	17.02	16.89
Fr1	0.53	0.52	0.51	0.61	0.60	0.59
K1	1.00	1.00	1.00	1.00	1.00	1.00
K2	1.29	1.29	1.29	1.29	1.29	1.29
K3	1.10	1.10	1.10	1.10	1.10	1.10
ys	34.83	43.32	51.69	36.79	45.77	54.78

3.4.2 Abutment Scour (Froehlich Equation)

The calculations of abutment scour depth used both the Froehlich's equation and the HIRE equation. Two skewness angles, +15° and -15°, are considered in the calculations. Froehlich Equation (Equation 8.1 in HEC-18) is written as:

$$\frac{y_s}{y_a} = 2.27 K_1 K_2 \left(\frac{L'}{y_a} \right)^{0.43} Fr^{0.61} + 1 \qquad (3.4.3)$$

where:

K_1 is the coefficient for abutment shape (-);

$K_2 = (\theta / 90)^{0.13}$ is the coefficient for angle of embankment to flow (-);

θ is the skewness angle (degree);

L' is the length of active flow obstructed by the embankment (ft);

$Fr = V_e / (g y_a)^{1/2}$ is the Froude number of approach flow upstream of the abutment (-);

$V_e = Q_e / A_e$ is the velocity of approach flow (ft/s);

Q_e is the flow obstructed by the abutment and approach embankment (ft^3/s);

A_e is the flow area of the approach cross section obstructed by the embankment (ft^2);

$y_a = A_e / L$ is the average depth of flow on the floodplain (ft);

L is the length of embankment projected normal to the flow (ft);

y_s is the scour depth (ft);

The calculation results are presented in Table 3.4.4 and Table 3.4.5.

Table 3.4.4 Abutment Scour Depth (Froehlich Equation) for 100-year Design Flow

100-Year Design Flow (Q = 70,000 cfs)						
Soil Data	0-20 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
L'	379.25	379.53	379.87	208.28	208.28	208.28
y_a	3.85	3.92	3.99	5.16	5.18	5.19
Q_e	3867.34	3914.04	3971.20	4178.35	4189.07	4198.67
A_e	1512.81	1538.70	1570.75	1112.81	1116.39	1119.60
Fr	0.23	0.23	0.22	0.29	0.29	0.29
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	17.67	17.77	17.86	19.75	19.78	19.79
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	18.23	18.33	18.42	20.35	20.38	20.39
Soil Data	~40 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
L'	379.25	379.53	379.87	208.28	208.28	208.28
y_a	3.85	3.92	3.99	5.16	5.18	5.19
Q_e	3867.34	3914.04	3971.20	4178.35	4189.07	4198.67
A_e	1512.81	1538.70	1570.75	1112.81	1116.39	1119.60
Fr	0.23	0.23	0.22	0.29	0.29	0.29
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	17.67	17.77	17.86	19.75	19.78	19.79
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	18.23	18.33	18.42	20.35	20.38	20.39

Table 3.4.5 Abutment Scour Depth (Froehlich Equation) for 500-year Design Flow

500-Year Design Flow (Q = 93,000 cfs)						
Soil Data	0-20 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
L'	385.05	385.26	385.51	237.26	237.26	237.26
y_a	5.68	5.77	5.87	7.15	7.22	7.27
Q_e	6783.76	6854.08	6934.84	7980.41	8028.38	8061.07
A_e	2263.97	2299.60	2341.09	1756.86	1774.13	1786.01
Fr	0.22	0.22	0.22	0.30	0.30	0.29
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	22.67	22.78	22.90	26.05	26.12	26.18
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	23.36	23.47	23.59	26.82	26.89	26.95
Soil Data	~40 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
L'	385.05	385.26	385.51	237.26	237.26	237.26
y_a	5.68	5.77	5.87	7.15	7.22	7.27
Q_e	6783.76	6854.08	6934.84	7980.41	8028.38	8061.07
A_e	2263.97	2299.60	2341.09	1756.86	1774.13	1786.01
Fr	0.22	0.22	0.22	0.30	0.30	0.29
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	22.67	22.78	22.90	26.05	26.12	26.18
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	23.36	23.47	23.59	26.82	26.89	26.95

3.4.3 Abutment Scour (HIRE Equation)

The HIRE Equation (Eq.8.2 in HEC-18) is written as:

$$\frac{y_s}{y_1} = 4Fr^{0.33}\frac{K_1}{0.55}K_2 \tag{3.4.4}$$

where:

y_s is the scour depth (ft);

y_1 is the depth of flow at the abutment on the overbank or in the main channel (ft);

F_r is the Froude number based on the velocity and depth adjacent to and upstream of the abutment (-);

K_1 is the abutment shape coefficient (-);

K_2 is the coefficient for skew angle of abutment to flow calculated as for Froehlich's equation (-);

The calculation results are presented in Table 3.4.6 and Table 3.4.7.

Table 3.4.6 Abutment Scour Depth (HIRE Equation) for 100-year Design Flow

100-Year Design Flow (Q = 70,000 cfs)						
Soil Data	0-20 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
V_1	6.91	6.85	6.77	7.57	7.55	7.54
y_1	9.95	10.05	10.17	9.92	9.94	9.97
Fr	0.39	0.38	0.37	0.42	0.42	0.42
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	28.49	28.65	28.82	29.29	29.31	29.37
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	29.65	29.82	30.00	30.48	30.51	30.57
Soil Data	~40 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
V_1	6.91	6.85	6.77	7.57	7.55	7.54
y_1	9.95	10.05	10.17	9.92	9.94	9.97
Fr	0.39	0.38	0.37	0.42	0.42	0.42
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	28.49	28.65	28.82	29.29	29.31	29.37
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	29.65	29.82	30.00	30.48	30.51	30.57

Table 3.4.7 Abutment Scour Depth (HIRE Equation) for 500-year Design Flow

500-Year Design Flow (Q = 93,000 cfs)						
Soil Data	0-20 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
V_1	7.73	7.65	7.56	8.87	8.79	8.74
y_1	11.85	11.98	12.12	11.49	11.62	11.70
Fr	0.40	0.39	0.38	0.46	0.45	0.45
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	34.21	34.40	34.60	34.89	35.11	35.25
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	35.61	35.81	36.02	36.31	36.54	36.69
Soil Data	40 ft					
Geometry	West of Interim Geometry			West of Ultimate Geometry		
Pier Diameter (ft)	4	6	8	4	6	8
K_1	0.55	0.55	0.55	0.55	0.55	0.55
V_1	7.73	7.65	7.56	8.87	8.79	8.74
y_1	11.85	11.98	12.12	11.49	11.62	11.70
Fr	0.40	0.39	0.38	0.46	0.45	0.45
θ	75.00	75.00	75.00	75.00	75.00	75.00
K_2	0.98	0.98	0.98	0.98	0.98	0.98
y_s	34.21	34.40	34.60	34.89	35.11	35.25
θ	105.00	105.00	105.00	105.00	105.00	105.00
K_2	1.02	1.02	1.02	1.02	1.02	1.02
y_s	35.61	35.81	36.02	36.31	36.54	36.69

3.5 Total Bridge Scour Depth

The total bridge scour depth consists of general/contraction scour, local scour, long-term degradation scour, and bend scour.

$$Z_t = Z_{gs} + Z_{ls} + Z_{lt} + Z_{bs} \tag{3.5.1}$$

The long-term degradation depth is 2.6 ft assuming 10% sediment load reduction. The bend scour depth for both the interim and ultimate geometry is 2.21 ft. The contraction scour depth are determined based on the Live-bed scour equation, while the local scour depth at piers is calculated by using the CSU equation in HEC-18. The abutment scour depth is the larger scour

depth calculated from the Froehlich equation and the HIRE equation. The total scour depths are summarized from Table 3.5.1 to Table 3.5.4 for 100-year and 500 year flows, the top and bottom soil, and two different geometries.

Table 3.5.1 Total Scour Depth Using 0-20 ft Soil Data (Maximum Possible Scour Depth#)

Flow and Geometry Condition		100-year design flow Q=70,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	44.14	52.68	60.99	45.53	54.52	63.34
	channel	41.07	49.44	57.78	42.12	50.94	59.79
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	39.03	39.53	39.94	40.24	40.64	40.95
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	40.19	40.70	41.11	41.43	41.84	42.15
	east	no flow					
Flow and Geometry Condition		500-year design flow Q=93,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	45.94	54.83	63.46	48.91	58.88	67.69
	channel	43.01	51.70	60.35	45.89	56.12	64.41
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	45.32	45.92	46.38	47.01	48.21	48.16
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	46.72	47.32	46.80	48.43	49.65	49.61
	east	no flow					

the full debris width (4 ft) was added to the pier diameter

Table 3.5.2 Total Scour Depth Using 0-20 ft Soil Data (Triangular Debris#)

Flow and Geometry Condition		100-year design flow Q=70,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	30.87	39.47	47.86	31.87	40.87	49.71
	channel	27.79	36.24	44.65	28.46	37.29	46.15
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	39.03	39.53	39.94	40.24	40.64	40.95
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	40.19	40.70	41.11	41.43	41.84	42.15
	east	no flow					
Flow and Geometry Condition		500-year design flow Q=93,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	32.18	41.14	49.85	34.38	44.41	53.27
	channel	29.25	38.01	46.74	31.36	41.66	49.98
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	45.32	45.92	46.38	47.01	48.21	48.16
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	46.72	47.32	46.80	48.43	49.65	49.61
	east	no flow					

Equivalent pier diameter is calculated from Eq.3.4.2

Table 3.5.3 Total Scour Depth Using 40 ft Soil Data (Maximum Possible Scour Depth)

Flow and Geometry Condition		100-year design flow Q=70,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	43.79	52.31	60.60	45.14	54.11	62.92
	channel	40.78	49.14	57.46	41.81	50.62	59.45
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	38.68	39.16	39.55	39.85	40.24	40.53
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	39.84	40.33	40.73	41.04	41.43	41.72
	east	no flow					
Flow and Geometry Condition		500-year design flow Q=93,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	45.54	54.40	63.02	48.41	58.35	67.14
	channel	42.66	51.33	59.97	45.49	55.70	63.97
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	44.92	45.49	45.94	46.50	47.69	47.61
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	46.31	46.89	47.35	47.93	49.12	49.06
	east	no flow					

Table 3.5.4 Total Scour Depth Using 40 ft Soil Data (Triangular Debris)

Flow and Geometry Condition		100-year design flow Q=70,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	30.52	39.10	47.47	31.48	40.46	49.29
	channel	27.50	35.93	44.33	28.13	36.97	45.82
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	38.68	39.16	39.55	39.85	40.24	40.53
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	39.84	40.33	40.73	41.04	41.43	41.72
	east	no flow					
Flow and Geometry Condition		500-year design flow Q=93,000 cfs					
		Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)		4.00	6.00	8.00	4.00	6.00	8.00
Max Pier Scour Depth (ft)	west floodplain	31.78	40.71	49.41	33.87	43.89	52.71
	channel	28.91	37.65	46.36	30.96	41.23	49.55
	east Floodplain	no flow					
Max Abutment Scour Depth -15 (ft)	west	44.92	45.49	45.94	46.50	47.69	47.61
	east	no flow					
Max Abutment Scour Depth +15 (ft)	west	46.31	46.89	47.35	47.93	49.12	49.06
	east	no flow					

Table 3.5.3 and 3.5.4 indicated that the total scour depth calculated using soil data at 40 ft deep is slightly smaller than the surface soil. However, the total scour depth in the channel for two 4-ft piers is about 25-28 ft. Therefore, the results using 0-20 ft soil data is more suitable for this scour depth. The total scour depth in the channel is estimated using 0-20 ft soil data, which are summarized in Table 3.5.1 and 3.5.2. For two 4-ft piers spacing at 20 ft, the total scour depth using 0-20 ft soil samples are the results using the ultimate design geometry. The maximum scour depth if assuming the full debris width is 40.12 ft, and the scour depth assuming triangular debris is about 28.46 ft for 100-year design flow.

3.6 Bed and Abutment Elevations after Scour

Although the base flow channel is relatively stable based on the historical data, this reach of Santa Cruz River experienced severe incision in an unprecedented flood event (larger than

100-year flow) in 1983. To ensure the bridge safety, this study assumes that the channel thalweg may migrate across the bridge section. The proposed Sunset bridge has five piers, and three of them on the west floodplain and two in the main channel. The most likely scour depth for the thalweg location is the maximum scour depth for the two piers in the main channel. The thalweg elevation is 2197.5 ft. The lowest scoured bed elevation is obtained by subtracting the total scour depth for 4-ft pier in the channel from the thalweg elevation.

However, none of the piers is located at the thalweg currently. The realistic bed elevation after scour is the elevation after subtracting the total scour depth from the toe elevation of the lowest pier. The lowest pier is at elevation 2211 ft. The channel elevation after scour is at 2182.54 ft.

The east abutment is above 100-year and 500-year flood level. Abutment scour will only occur at the west abutment. The base of West Abutment is at 2212.49 ft. The scoured abutment elevation is obtained by subtracting the abutment scour depth from the current base elevation. Assuming the debris is triangular shaped, Table 3.6.1 (using 0-20 ft soil) and Table 3.6.2 (using 40 ft soil) are the scoured bed elevations for two 4 ft piers for 100-year and 500-year flows.

Table 3.6.1 Thalweg and Abutment Elevation Using 0-20 ft Soil Sample (Triangular Debris)

Flow Condition	100-year design flow Q=70,000 cfs					
	Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)	4.00	6.00	8.00	4.00	6.00	8.00
Thalweg Elevation (ft)	2197.50					
channel scour depth (ft)	27.79	36.24	44.65	28.46	37.29	46.15
Thalweg elevation after scour (ft)	2169.71	2161.26	2152.85	2169.04	2160.21	2151.35
Lowest Pier Bottom Elevation (ft)	2211.00					
channel scour depth (ft)	27.79	36.24	44.65	28.46	37.29	46.15
Thalweg elevation after scour (ft)	**2183.21**	**2174.76**	**2166.35**	**2182.54**	**2173.71**	**2164.85**
West Abutment Elevation (ft)	2212.49					
Abutment Scour Depth (ft)	40.19	40.70	41.11	41.43	41.84	42.15
Abutment Scoured Elevation (ft)	2172.30	2171.79	2171.38	2171.06	2170.65	2170.34
Flow Condition	500-year design flow Q=93,000 cfs					
	Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)	4.00	6.00	8.00	4.00	6.00	8.00
Thalweg Elevation (ft)	2197.50					
Channel scour depth (ft)	29.25	38.01	46.74	31.36	41.66	49.98
Thalweg Elevation After Scour (ft)	2168.25	2159.49	2150.76	2166.14	2155.84	2147.52
West Abutment Elevation (ft)	2212.49					
Abutment Scour Depth (ft)	46.72	47.32	46.80	48.43	49.65	49.61
West Abutment Scoured Elevation (ft)	2165.77	2165.17	2165.69	2164.06	2162.84	2162.88

Table 3.6.2 Thalweg and Abutment Elevation Using 40 ft Soil Sample (Triangular Debris)

Flow Condition	100-year design flow Q=70,000 cfs					
	Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)	4.00	6.00	8.00	4.00	6.00	8.00
Thalweg Elevation (ft)	2197.50					
channel scour depth (ft)	27.50	35.93	44.33	28.13	36.97	45.82
Thalweg elevation after scour (ft)	**2170.00**	**2161.57**	**2153.17**	**2169.37**	**2160.53**	**2151.68**
West Abutment Elevation (ft)	2212.49					
Abutment Scour Depth (ft)	39.84	40.33	40.73	41.04	41.43	41.72
Abutment Scoured Elevation (ft)	**2172.65**	**2172.16**	**2171.76**	**2171.45**	**2171.06**	**2170.77**
Flow Condition	500-year design flow Q=93,000 cfs					
	Interim Geometry			Ultimate Geometry		
Pier Diameter (ft)	4.00	6.00	8.00	4.00	6.00	8.00
Thalweg Elevation (ft)	2197.50					
Channel scour depth (ft)	28.91	37.65	46.36	30.96	41.23	49.55
Thalweg Elevation After Scour (ft)	2168.59	2159.85	2151.14	2166.54	2156.27	2147.95
West Abutment Elevation (ft)	2212.49					
Abutment Scour Depth (ft)	46.31	46.89	47.35	47.93	49.12	49.06
West Abutment Scoured Elevation (ft)	2166.18	2165.60	2165.14	2164.56	2163.37	2163.43

4 Sediment Transport Model Analysis Using HEC-RAS Model

The latest version of HEC-RAS 4.1 was employed. The sediment transport module in HEC-RAS model was used to simulate flow and sediment transport in the study reach for 100-year and 500-year design flows. The objective is to quantify channel changes (e.g., bed degradation, aggradation) near the bridge site after the bridge is constructed. This study simulated the 100-year and 500-year flood for the current channel condition without bridge, the intermediate geometry with bridge, and the ultimate geometry with bridge.

4.1 Model Input Data

The HEC-RAS quasi-unsteady flow model simulates sediment transport and bed changes using quasi-unsteady flow hydrograph. The model input includes geometry data, hydrology data and sediment data.

4.1.1 Geometry Data

The study reach of the Santa Cruz River was divided into 105 sub-reaches. The distance between two cross sections is about 200-600 ft, and each cross section has about 150 to 300 stations. The geometric data including current, interim, and ultimate were provided by PB World, Inc. For hydraulic analysis, many ineffective flow areas were specified because flood are ponded on the floodplain. For sediment transport analysis, the mobile bed boundaries at each cross section were extended into the ineffective flow area to allow sediment deposition on the floodplains.

4.1.2 Hydrology Data

The hydrographs for 100-year and 500-year events were acquired from the Pima County Regional Flood Control District as shown in Figure 4. 1. Those two flow hydrographs were used as the upstream boundary conditions.

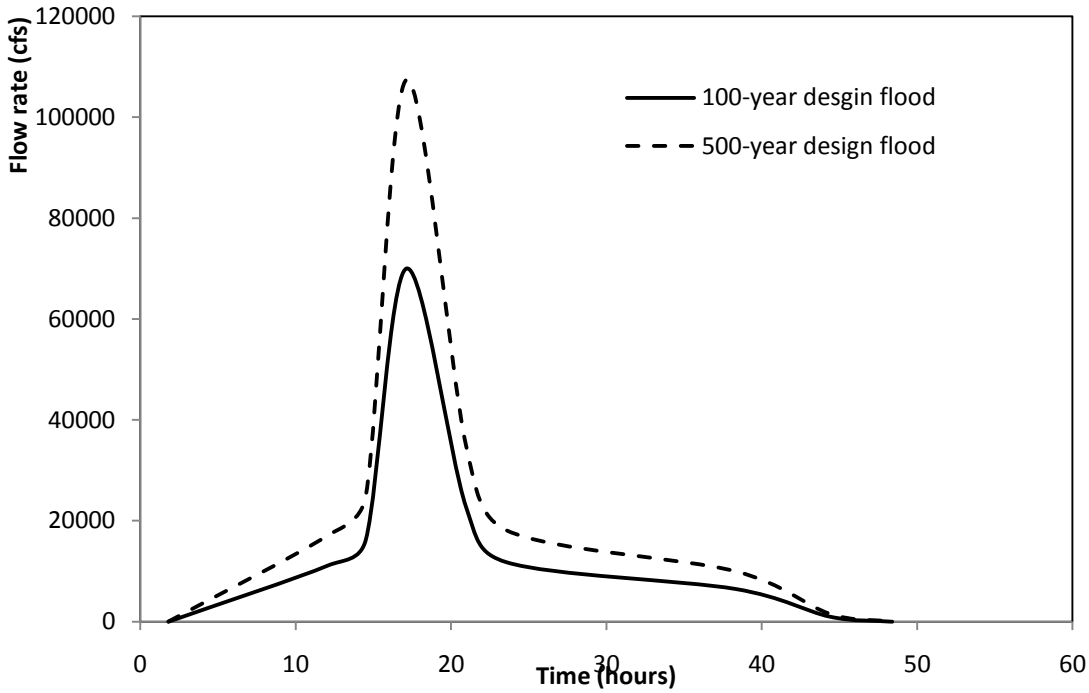


Fig. 4. 1 100-Year and 500-Year design flow hydrograph

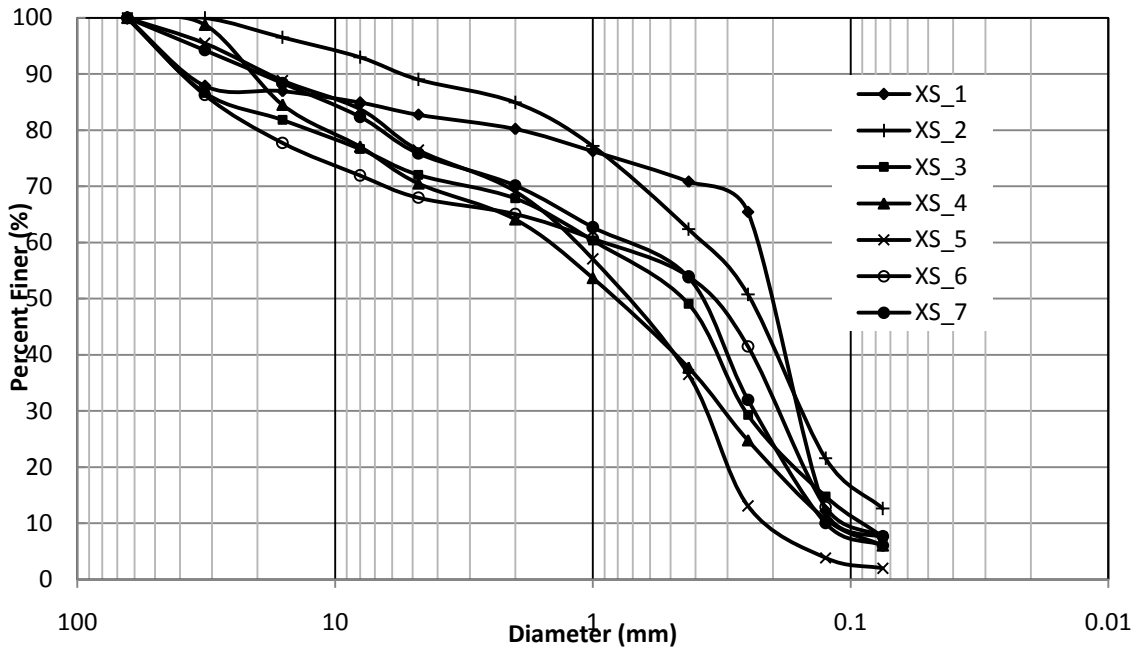
The downstream boundary condition is "normal depth", which indicates that Manning's equation is valid at the downstream boundary. The corresponding friction slope was chosen as 0.003, the same as the bed slope. Water temperate is chosen as 68°F. Manning's n values range from 0.025 to 0.04 in the main channel, and from 0.022 to 0.06 on the floodplain. The simulation time step is 4.8 minutes (0.08 hour).

Table 4. 1 Locations of Sediment Sampling Site

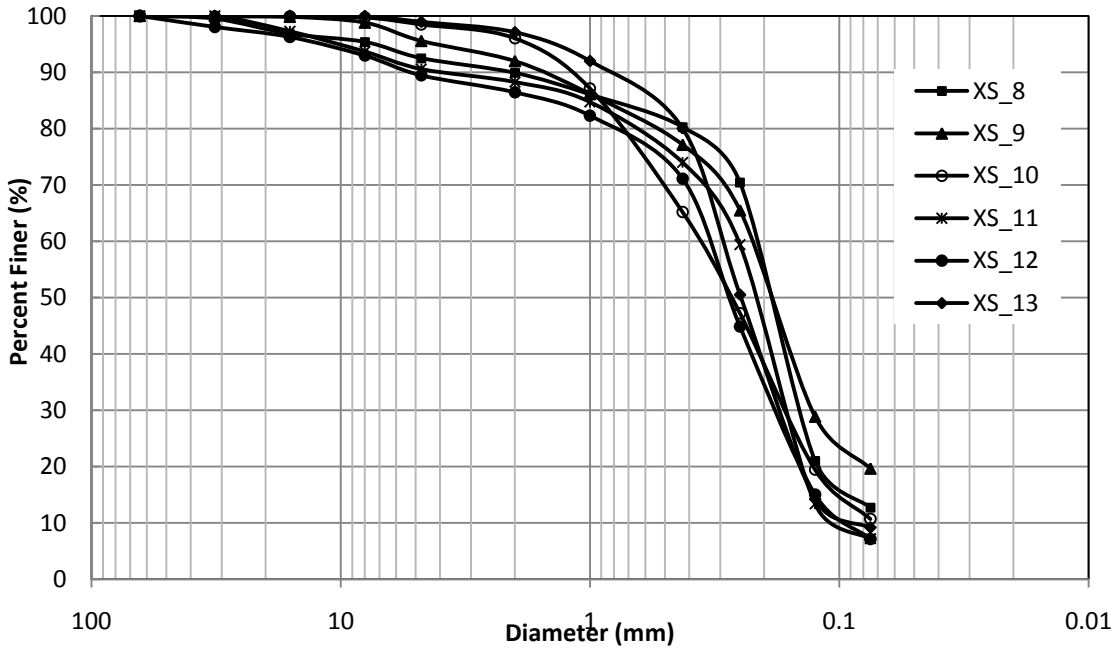
CS NO.	Location (ft)	Distance to Downstream Section (ft)	Note
1	67798	2800	
2	64998	3000	
3	61999	3000	
4	58999	3000	
5	55999	3000	
6	52999	500	
7	52499	500	
8	51999	500	
9	51499	459	
10	51040	39	
*****	**51000**	502	**Sunset Bridge Location**
11	50499	503	
12	49996	495	
13	49501	502	
14	48999	3000	
15	45999	3000	
16	42999	3000	
17	39999	3000	
18	36999	2200	
19	34800		

4.1.3 Sediment Data

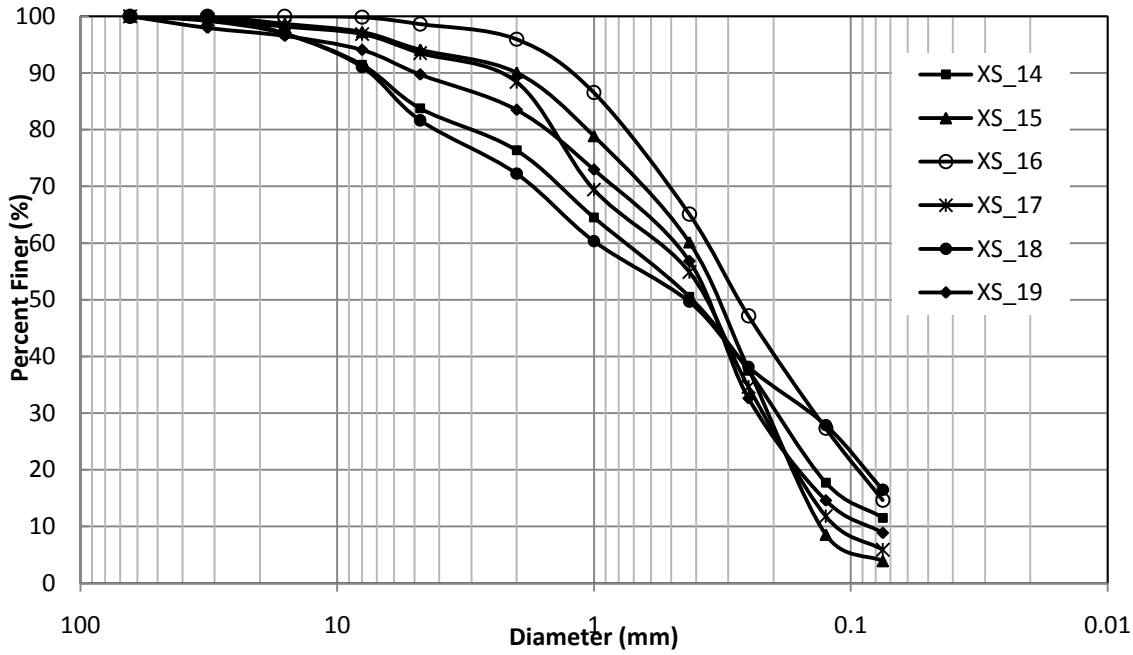
Bed material and bed load samples were collected in the main channel at 19 cross sections within the study reach. Both surface and substrate (defined as one foot below ground surface) bed materials were sampled at the left and right floodplain at the same 19 cross sections. Sediment sampling locations were listed in Table 4. 1. HEC-RAS model only allows on sediment size distribution at each cross section. Therefore, the averaged sediment size distribution for all the samples collected at one cross section was used as the sediment size distribution curve for that cross section. At cross sections without measured sediment data, the size distribution of bed material was interpolated based on available data at the nearby sampled cross sections. Figures 4. 2(a) to 4. 2(c) are the average size gradation curves at all the sampled cross sections.



(a) Section 1-7



(b) Section 8-13



(c) Section 14-19

Fig. 4. 2 Size distribution of bed material at sampled cross sections

Besides sediment data at the sampled cross sections along the channel, sediment size gradation at different depth were obtained at the boring holes at the proposed bridge site. Soil size distribution data at seven boring holes from the left to the right floodplain along the bridge centerline were used. Boring holes #1 to #3 are located on the left floodplain, #4 to #6 are located in the main channel, and # 7 is located in the right floodplain. Bulk soil samples from 0 to 10 feet, and 10 to 20 feet were used for size distribution analysis. Hydraulic modeling results showed water surface will not reach boring hole #7 in 100-year and 500-year event. Therefore, sediment size distribution is averaged among soil data sampled at the surface (0-10 ft) from #1 to # 6 bore holes. The average of the soil size distributions at these six boring sites was the sediment size distribution at the bridge location. No sediment data input is required at the bridge cross section, the sediment size distribution at the bridge section was used at the cross sections immediately upstream and downstream from the bridge section. Figure 4. 3 is the soil size distributions at boring site #1 to #6, and also the average of these six soil data.

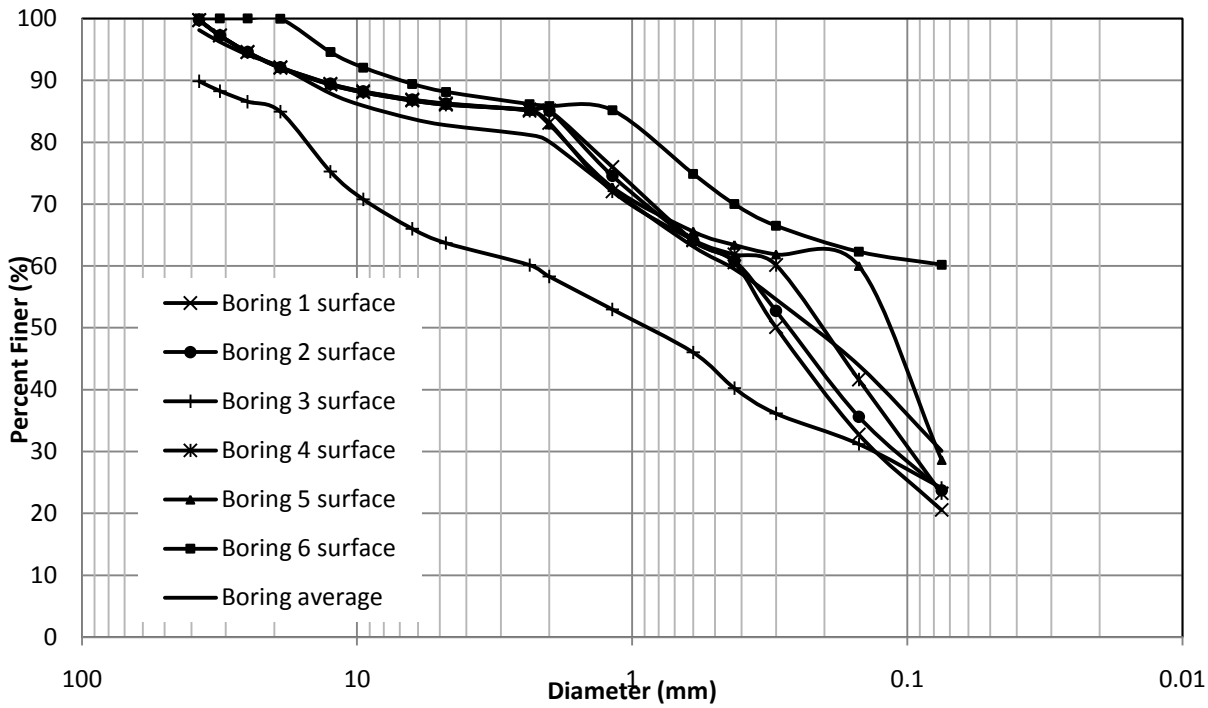


Fig. 4. 3 Soil Size distributions at boring holes and averaged size distribution

Equilibrium sediment load was the boundary conditions at both the upstream and downstream cross section. The maximum erodible depth was set as 50 ft. HEC-RAS sediment transport analysis also requires the user to select sediment transport formulas, sediment sorting method, and fall velocity method.

4.2 Sediment Transport Equation

Seven different sediment transport functions are available in HEC-RAS (Brunner, 2010). They are:

- Ackers and White (1973)
- Engelund and Hansen (1972)
- Copeland's form of Laursen (1990)
- Meyer-Peter and Muller (1948)
- Toffaleti
- Yang
- Wilcock

The Laursen (Copeland) and Yang equations were selected as the transport functions most suitable to the sandy Santa Cruz River. The Laursen equation is a total sediment load

predictor, derived from a combination of qualitative analysis, original experiments, and supplementary data. The contributions extend to the gravel sized sediment and the applicability ranges from 0.011 to 29 mm, median particle diameter. The general transport equation for the Laursen (Copeland) function for a single grain size is represented by:

$$C_m = 0.01\gamma\left(\frac{d_s}{D}\right)^{7/6}\left(\frac{\tau_0^{'}}{\tau_c}-1\right)f\left(\frac{u_*}{\omega}\right) \qquad (4.1)$$

Where: C_m = Sediment discharge concentration, in weight/volume

d_s = Mean particle diameter

D = Effective depth of flow

$\tau_0^{'}$ = Bed shear stress due to grain resistance

τ_c = Critical bed shear stress

$f\left(\frac{u_*}{\omega}\right)$ = Function of the ratio of shear velocity to fall velocity

Yang's method (1973) was developed under the premise that unit stream power is the dominant factor in the determination of total sediment concentration. Yang (1984) expanded the applicability of his function to include the gravel-sized sediments. The general transport equation for sand and gravel using the Yang function for a single grain size is represented by:

$$\log C_t = 5.435 - 0.286\log\frac{\omega d_m}{\nu} - 0.457\log\frac{u_*}{\omega} + \left(1.799 - 0.409\log\frac{\omega d_m}{\nu} - 0.314\log\frac{u_*}{\omega}\right)\log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \quad \text{for sand } d_m < 2mm \qquad (4.2)$$

$$\log C_t = 6.681 - 0.633\log\frac{\omega d_m}{\nu} - 4.816\log\frac{u_*}{\omega} + \left(2.784 - 0.305\log\frac{\omega d_m}{\nu} - 0.282\log\frac{u_*}{\omega}\right)\log\left(\frac{VS}{\omega} - \frac{V_{cr}S}{\omega}\right) \quad \text{for gravel } d_m \geq 2mm \qquad (4.3)$$

where: C_t = Total sediment concentration

ω = Particle fall velocity

d_m = Median particle diameter

ν = Kinematic viscosity

u_* = Shear velocity

V = Average channel velocity

S = Energy gradient

Two sorting methods are available in HEC-RAS 4.1: the Exner 5 method and the active layer method. Exner 5 is a three-layer active bed model that allows the formation of a coarse surface layer that will limit erosion of deeper material. This enable the model to simulate bed armoring. The Exner 5 method was used in this study because the amount of gravels in the bed material may form an armoring layer that prevents fine material from transport. The Exner equation for calculating bed elevation change is given as:

$$B\left(1-p_0\right)\frac{\partial z_b}{\partial t}+\frac{\partial Q_t}{\partial x}=0 \qquad (4.4)$$

Where: p_0 = Porosity

z_b = Bed elevation

Q_t = Volumetric sediment transport rate

x = Longitudinal distance

In HEC-RAS 4.1, four methods are available for computing the fall velocity. The four methods are Toffaleti (1968), Van Rijn (1993), Ruby (1933) and Report 12. Report 12 is recommended by the American Society of Civil Engineers (ASCE) and was used in this study.

4.3 Simulation Results

The Laursen (Copeland) and Yang equations were used as the sediment transport functions. Both 100-year and 500-year design floods were simulated for the interim and ultimate geometric conditions. In total, eight scenarios were simulated with the combinations of flow, geometry, and sediment transport equations. The eight scenarios were numbered from 1 to 8 depending on the simulation conditions. Table 4.2 is the descriptions of eight scenarios.

Table 4.2 Descriptions of Scenarios

Sediment Transport Function	Flow Condition (Year)	Geometric Data	Sediment Data	Scenario Number
Laursen	100 Year Design	Interim	Using sediment sampling data and boring data	1
		Ultimate		2
	500 Year Design	Interim		3
		Ultimate		4
Yang	100 Year Design	Interim		5
		Ultimate		6
	500 Year Design	Interim		7
		Ultimate		8

4.3.1 Results Using Laursen's Sediment Equation

The results by using Laursen's sediment equation are shown on Figure 4.4 and 4.5. Figure 4.4 compares the bed elevations changes at thalweg for 100-year and 500-year flows for interim and ultimate geometry. Figure 4.5 shows the zoom-in view of the thalweg elevation changes at the neighborhood of the proposed Sunset Bridge site.

Table 4.3 is the summary of the bed elevation change at the thalweg at each cross section near the Sunset Bridge for two design flows and two geometries using the Laursen's equation. 100-year flood will cause 5.98 ft and 6.14 ft erosion, immediately downstream from the bridge for intermediate and ultimate geometry condition respectively. The maximum scour depth is about 17.12 feet, and will occur at about 1000 ft from the bridge for the intermediate geometry. However, 500-year event will scour about 15.3 ft and 11 ft for the interim and ultimate design geometry immediately downstream from the bridge. The maximum scour depth 22.39 ft will occur at 1000 ft from the bridge. Those scour depth indicated moderate risk of downstream scour from the bridge site.

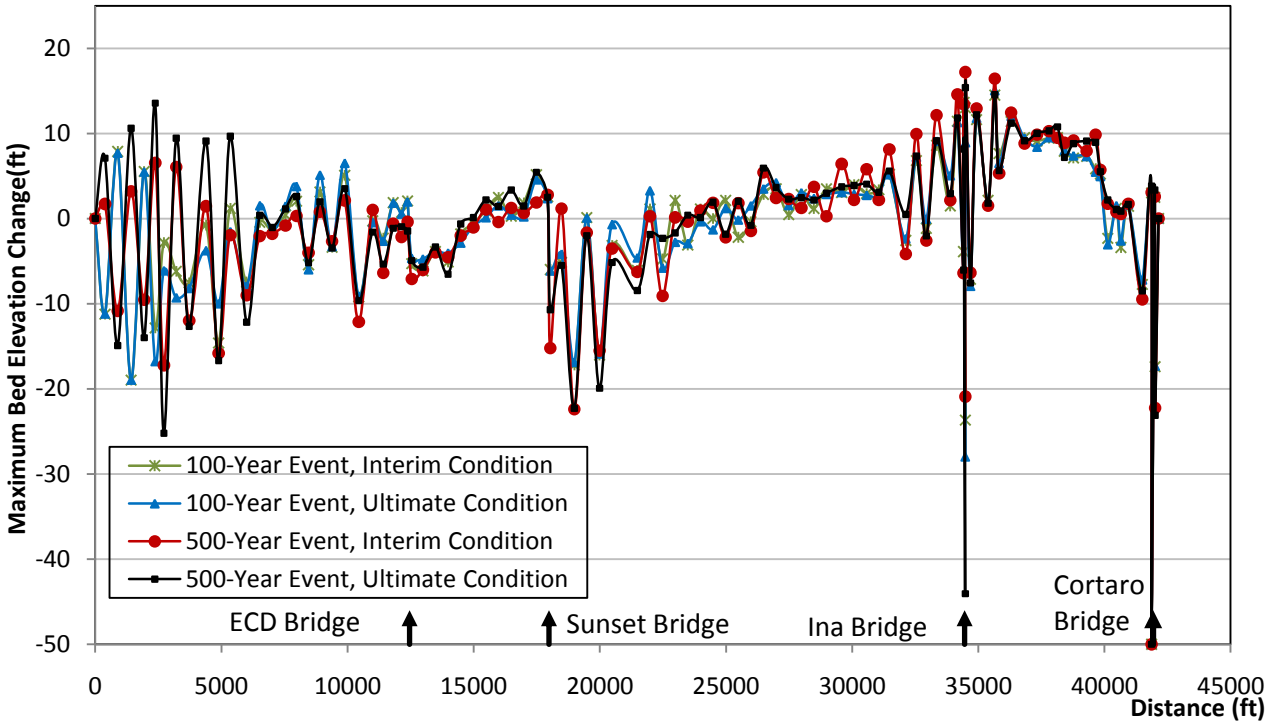


Fig. 4.4 Thalweg comparison using Laursen's sediment equation

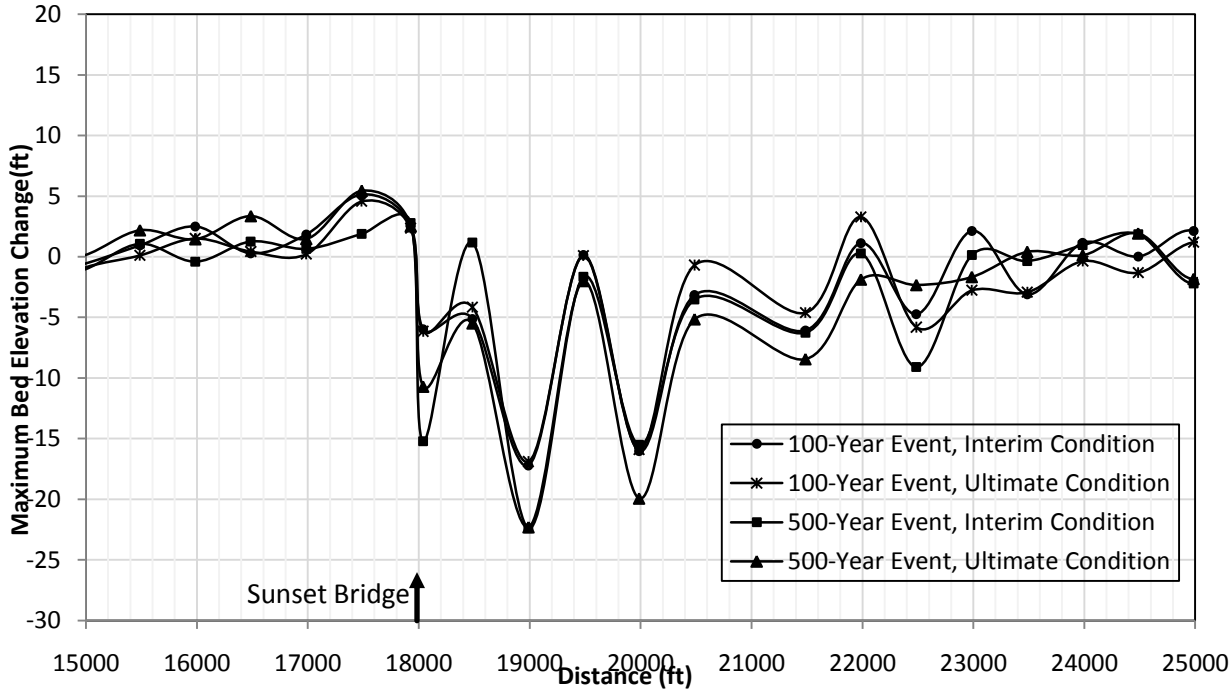


Fig. 4.5 Zoom-in thalweg view at the neighborhood of the proposed Sunset bridge using Laursen's sediment equation

Table 4.3 Invent Change of Cross Sections near the Proposed Sunset Bridge using Laursen's Sediment Equation

Sediment Equation		Laursen-sediment equation			
Flow Condition		100 Year Flow		500 Year Flow	
Bridge Condition		Intermediate Design	Ultimate Design	Intermediate Design	Ultimate Design
Scenario Number		1	2	3	4
HEC-RAS RS Number	Distance to Sunset Bridge	Invent Change (ft)			
52999	1999	2.49	1.51	-0.40	1.44
52499	1499	0.28	0.43	1.26	3.35
51999	999	1.84	0.22	0.65	1.47
51499	499	5.14	4.57	1.88	5.44
51057	57	2.56	2.36	2.79	2.51
51000	Bridge Location				
50945	-55	-5.98	-6.14	-15.22	-10.71
50500	-500	-5.13	-4.16	1.16	-5.49
49996	-1004	-17.21	-16.89	-22.39	-22.30
49501	-1499	0.13	0.09	-1.64	-2.00
48999	-2001	-16.03	-15.89	-15.52	-19.93
48499	-2501	-3.16	-0.69	-3.52	-5.16

4.3.2 Results Using Yang's Sediment Equation

The results by using the Yang's sediment equation are shown in Figure 4.6 and 4.7. Figure 4.6 are the results of bed elevation changes at the thalweg for 100-year and 500-year flows using the interim and ultimate geometries. Figure 4.7 is the zoom-in view of bed elevation changes in the vicinity of the proposed Sunset Bridge. Table 4.4 is the summary of bed elevation changes at the thalweg for 100-year and 500-year floods. 500-year event will cause minor erosion for the ultimate geometry. For other cases, deposition will occur at the downstream from the bridge. Therefore, there is nearly no erosion that will occur downstream from the bridge.

Although Laursen's equation predicted moderate erosion, while Yang's equation predicted minor erosion and some deposition downstream from the bridge. It's likely the realistic results are between light deposition and about 20 ft erosion. So, there will be no significant scour downstream from the bridge.

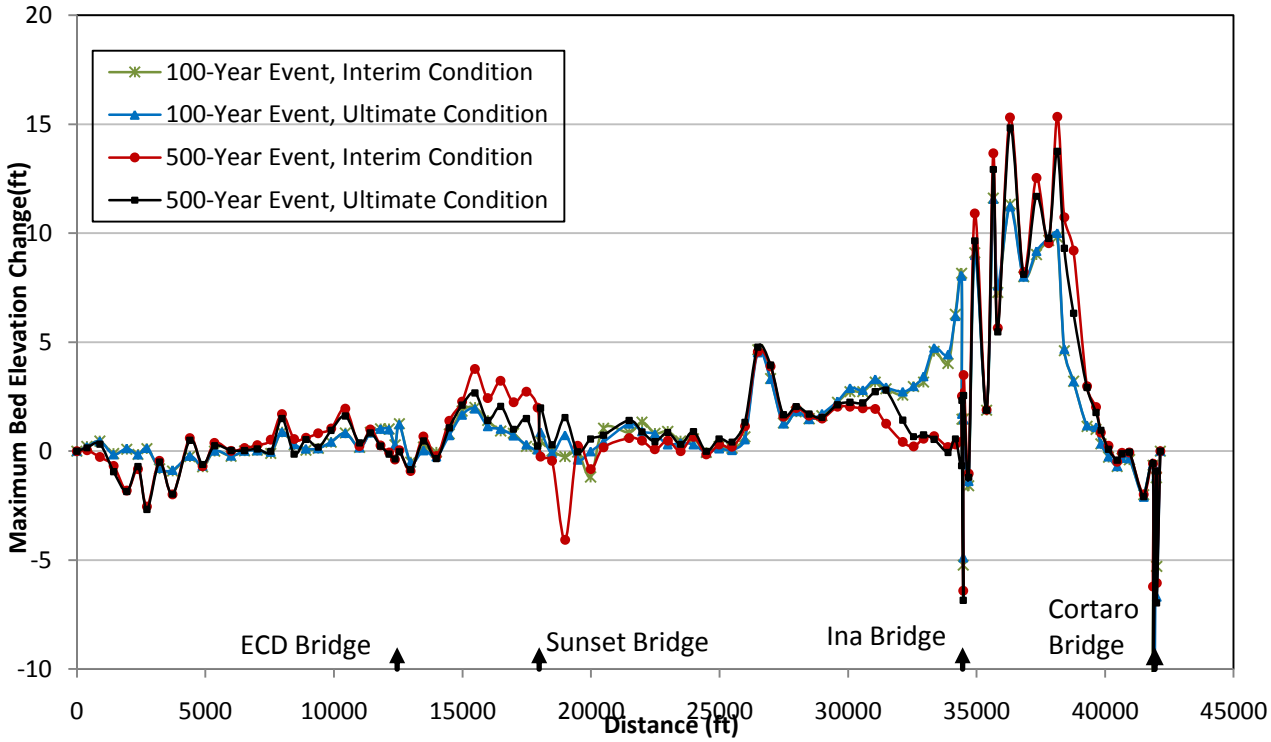


Fig. 4.6 Thalweg comparison using Yang's sediment equation

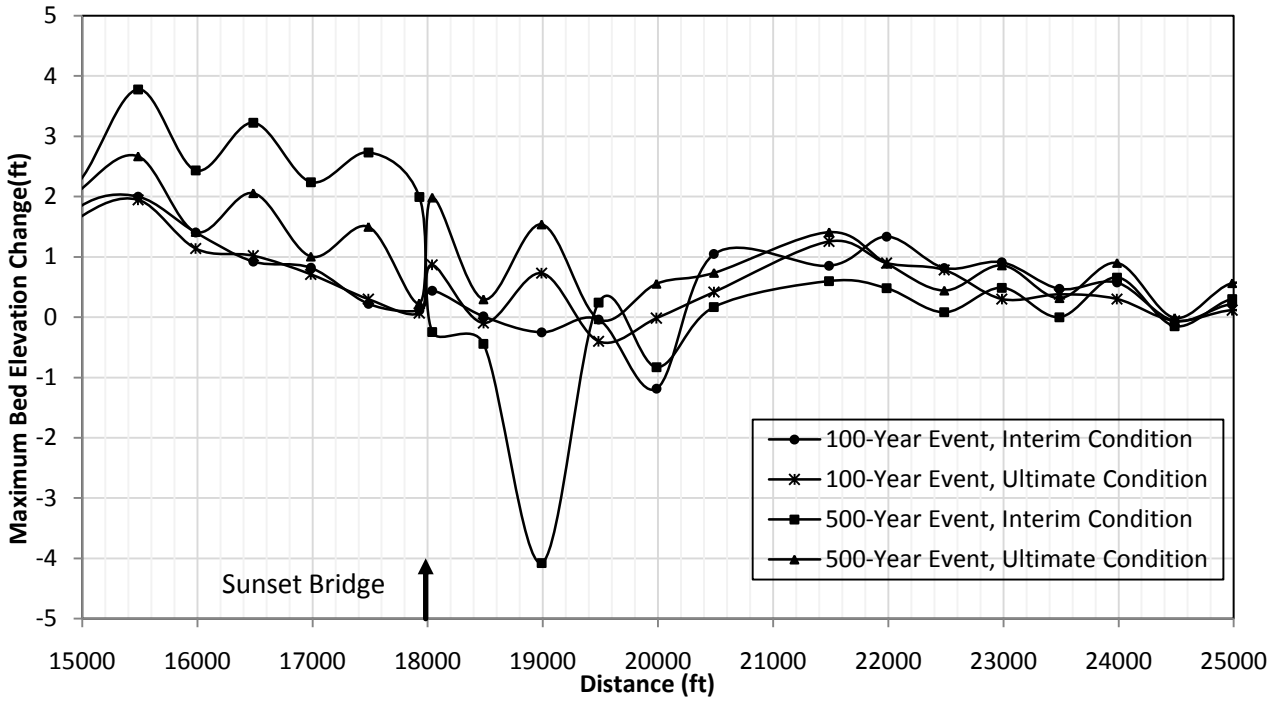


Fig. 4.7 Zoom-in thalweg views at the neighborhood of the proposed Sunset bridge using Yang's sediment equation

Table 4.4 Invent Change of Cross Sections near the Proposed Sunset Bridge using Yang's Sediment Equation

Sediment Equation		Yang-sediment equation			
Flow Condition		100 Year Flow		500 Year Flow	
Bridge Condition		Intermediate Design	Ultimate Design	Intermediate Design	Ultimate Design
Scenario Number		5	6	7	8
HEC-RAS RS Number	Distance to Sunset Bridge	Invent Change (ft)			
52999	1999	1.40	1.14	2.43	1.41
52499	1499	0.92	1.02	3.22	2.05
51999	999	0.82	0.71	2.24	1.00
51499	499	0.22	0.30	2.73	1.50
51057	57	0.11	0.07	1.99	0.23
51000	Bridge Location				
50945	-55	0.44	0.87	-0.25	1.98
50500	-500	0.01	-0.10	-0.44	0.29
49996	-1004	-0.25	0.73	-4.07	1.54
49501	-1499	-0.04	-0.40	0.24	-0.03
48999	-2001	-1.18	-0.02	-0.83	0.55
48499	-2501	1.05	0.42	0.17	0.73

5 Recommended Counter-Scour Measurements

5.1 Pier Protection

Pier scour depth was estimated by using the CSU equation in HEC-18. The scoured bed elevation is determined by subtracting the total scour depth from the thalweg or the toe elevation of the lowest pier. The bridge structural design will base on the scoured bed elevation that assumes bed surface will be lowered the total scour depth. Therefore, no pier protection is needed.

5.2 Grade Control Structure

After the bridge is constructed, the maximum scour depth (about 21 ft) in 100-year event will occur approximately 1000 ft downstream from the bridge if using Laursen's sediment transport equation. Yang's equation predicted deposition immediately downstream from the bridge for 100-year flow, and less than 1 ft erosion for 500-year event. Although Laursen's

sediment transport equation predicted 8.5 ft erosion immediately downstream from the bridge, this is unlikely occur if considering the prediction from using the Yang's equation. Therefore, sediment modeling results indicate that the proposed bridge will not result in a significant scour downstream from the bridge. Therefore, grade control structure is not immediately necessary for the proposed bridge. However, other factors, such as headcut from the gravel pits, the storm drainage immediately at the neighborhood of the bridge may cause excessive scour in the vicinity of the bridge. In particular, the lack of a grade control structure from the Sunset to the Ina Road may expose this reach to long-term degradation if there will be a considerable reduction in sediment supply. Those scour together with local scour may threaten the safety of bridge. A grade control structure will be necessary if either local scour, channel incision, or head cut start to occur in the neighborhood of bridge.

5.3 Abutment Protection – Soil Cement

The scour depth at the West Abutment is approximately 40 ft. The proposed abutment is spill through sloped abutment. NCHRP Report 587 (Barkdoll et. al., 2007) recommends extending the riprap around the abutment and down to the expected scour depth. An alternative is to lay an equivalent blanket of riprap, a launching apron, on the existing bed. Specific guidelines for the riprap layout for a launching apron should satisfy two criteria: 1) the apron at the toe of the abutment slope should extend along the entire length of the abutment toe, around the curved portions of abutment to the point of tangency with the plane of the embankment slopes (Richardson and Richardson, 1993); 2) the apron should extend from the toe of the abutment into the bridge waterway a distance equal to twice the flow depth in the overbank area near the embankment, but need not exceed 7.6m (Lagasse et al., 1997). The placement of riprap around abutment is shown in Fig.5.1 (Fig.5-20 in NCHRP Report 587).

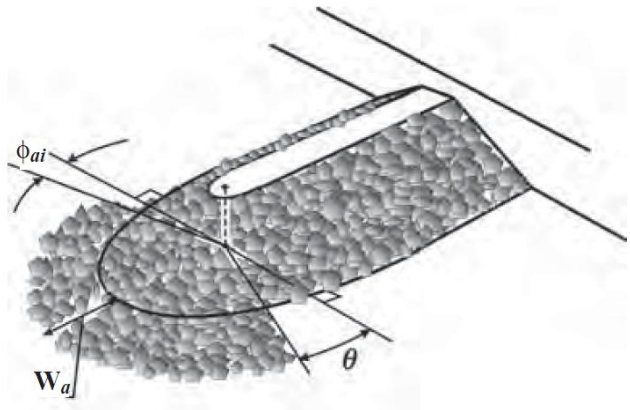


Fig.5.1 Definition diagram for placement of a riprap launching apron at a spill-though abutment

However, riprap is not the most cost-effective counter scour measurements in Arizona. Soil cement is an alternative to construct drop structures and armor embankments, dikes, levees, channels in Southwest United States (Lagasse et al. 2011). Soil cement serves the same function as the riprap blanket. Pima County Department of Transportation has guidelines on the applications and use of soil cement for Flood Control Projects (Shields at al. 1998). According to PDOT's guideline, the soil cement can be placed using the stair step method or the plating method. The plating method requires the soil cement to extend to the scour depth and tie to a non-erodible sections or abutment. The stair-step method requires to place the soil cement at 1V:3H slope in a working width of 2.4m, with individual layers of 6 inch. This results in a 24 in thick (vertical to slope surface) soil cement layer. The thickness of soil cement is calculated by Eq. 7.1. in HEC-23 (vol. 2). For a slope of 2(H):1(V), the soil cement thickness is calculated by Eq. 5.1 (Eq.7.1 in HEC23):

$$W = t_n\sqrt{S^2+1} + vS \tag{5.1}$$

where W is the horizontal layer width; S is the slope of facing; v is the thickness of compacted horizontal layer; and t_n is the minimum facing thickness measured normal to the slope.

According to HEC-23, bank stabilization along major rivers in Pima County is constructed by using 6 in. thick, 8 ft width of soil cement. For a working side slope of 1V: 2H, the resulting minimum thickness of facing would be t_n =3.13 ft.

For the West Abutment and the East Abutment, the layouts of soil cement are shown in Fig.5.2, Fig. 5.3. The calculation of soil cement volumes are in Table 5.1 and Table 5.2. The total volume for the West abutment is 15140 ft^3, for the east abutment is 7157 ft^3.

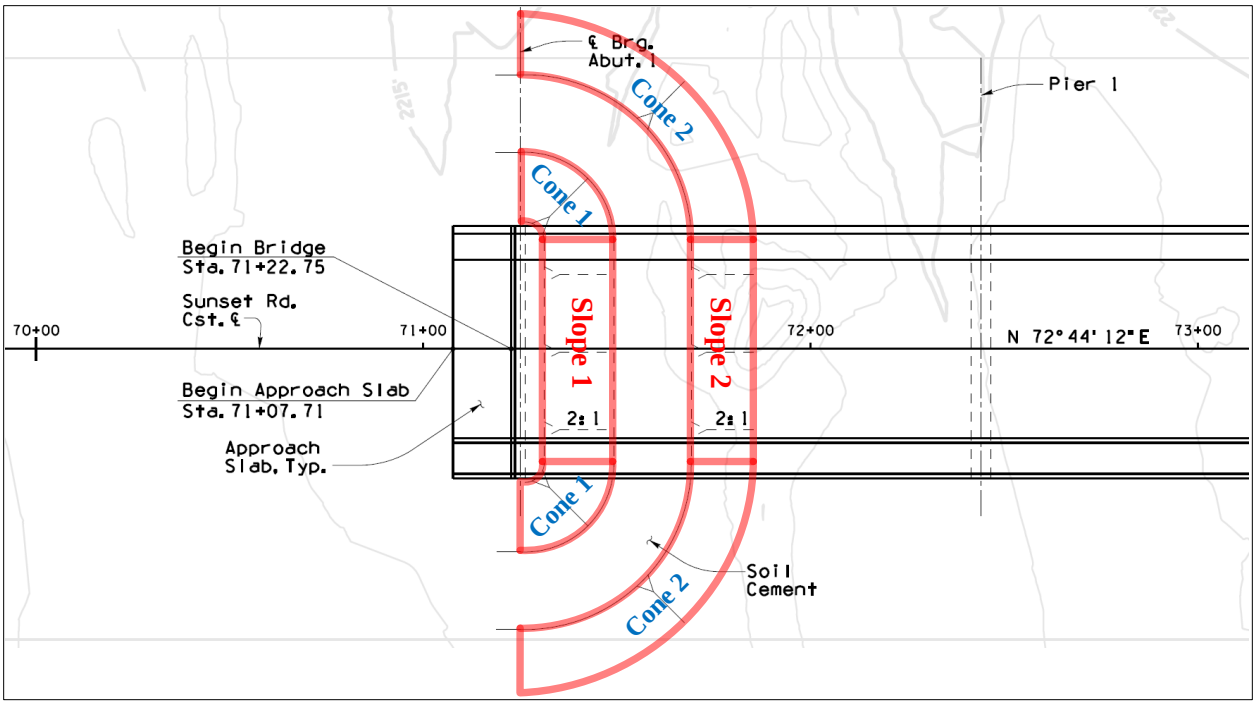


Fig.5.2 Soil cement coverage area for the West Abutment

Table 5.1 Calculation of the West Abutment

	Width (ft)	Length (ft)	Area (ft^2)	Volume (ft^3)
Slope 1	19.85	56.94	1130.49	3538.99
Slope 2	17.80	56.94	1013.54	3172.89
	Inner Radius (ft)	Outer Radius (ft)	Area (ft^2)	Volume (ft^3)
Cone 1	4.90	22.66	859.24	2689.86
Cone 2	58.17	48.37	1833.05	5738.36
Total				15140.10

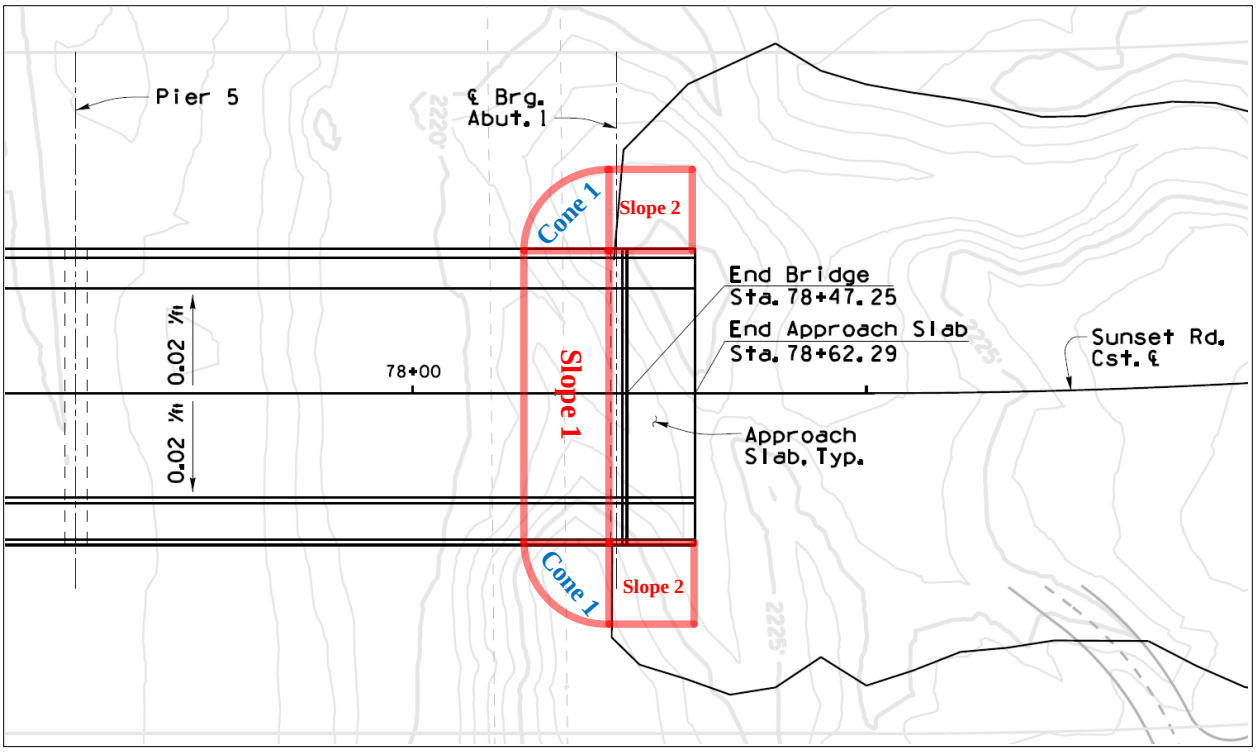


Fig.5.3 Soil cement coverage area for the East Abutment

Table 5.2 Calculation of the East Abutment

	Width (ft)	Length (ft)	Area (ft^2)	Volume (ft^3)
Slope 1	18.34	64.29	1179.14	3691.29
Slope 2	18.34	28.16	516.57	1617.14
	Radius (ft)	Outer Radius (ft)	Area (ft^2)	Volume (ft^3)
Cone 1	0.00	18.34	590.74	1849.30
Total				**7157.72**

Reference

Barkdoll, B.D., Ettema, R., Melville, B.W. 2007. Countermeasures to Protect Bridge Abutments from Scour, NCHRP Report 587, National Cooperative Highway Research Program, Transportation Research Board, Washington, DC.

Brunner, G.W., 2010. HEC-RAS, River Analysis System, Hydraulic Reference Manual. Version 4.1. US Army Corps of Engineers, Hydrologic Engineering Center, CPD-69

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Richardson, J.R., and Richardson, E.V. (1993). Discussion of local scour at bridge abutments, by B. W. Melville, *J. of Hydraul. Engr.*, Vol. 119, No.9, American Society of Civil Engineering.

Shields, S.J., Maucher, L.E., Taji-Farouki, A.A., Osmolski, A., and Amutzer, D.A., 1988, Soil Cement Applications and Use in Pima County for Flood Control Projects, prepared for the Board of Supervisors/Board of Directors.

Simons, Li & Associates, Inc. 1998, Standards Manual for Drainage Design and Floodplain Management in Tucson, Arizona, published by City of Tucson, Department of Transportation, Engineering Division.

APPENDECIES

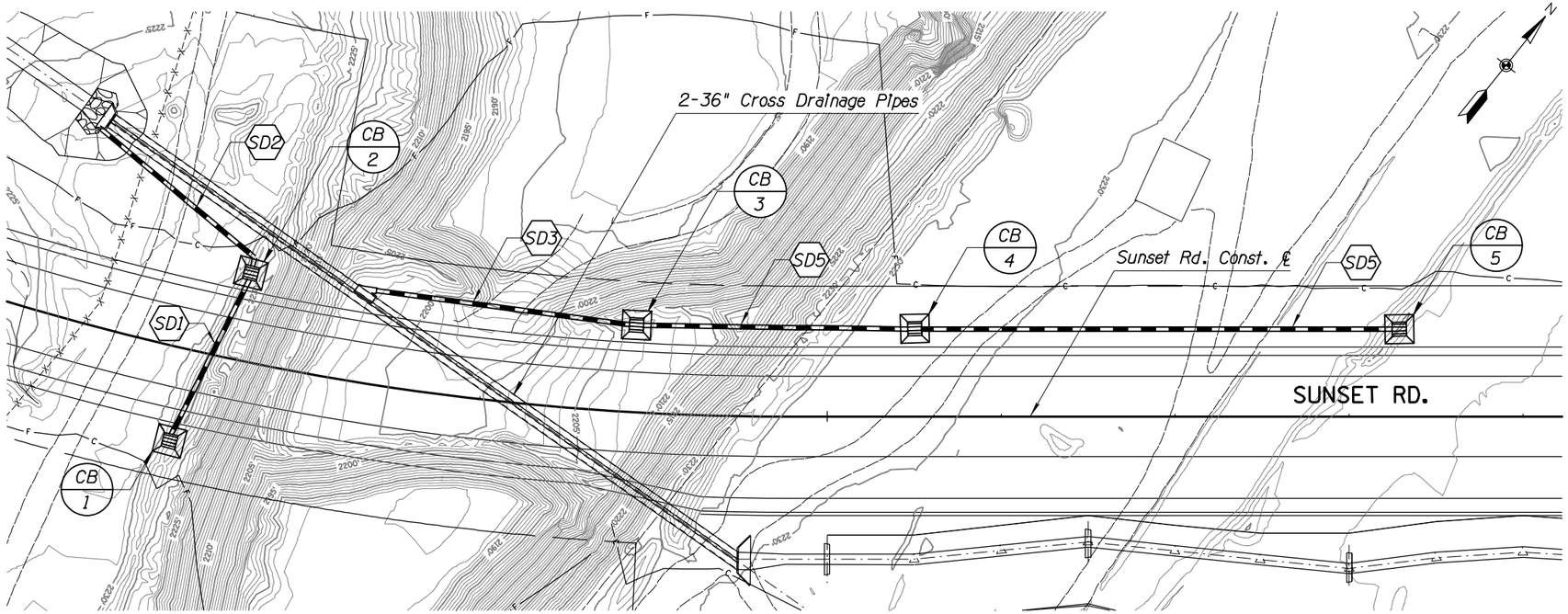
APPENDIX A PROJECT MAPPING AND SURVEY CONTROL

APPENDIX B ONSITE DRAINAGE

APPENDIX C OFFSITE DRAINAGE

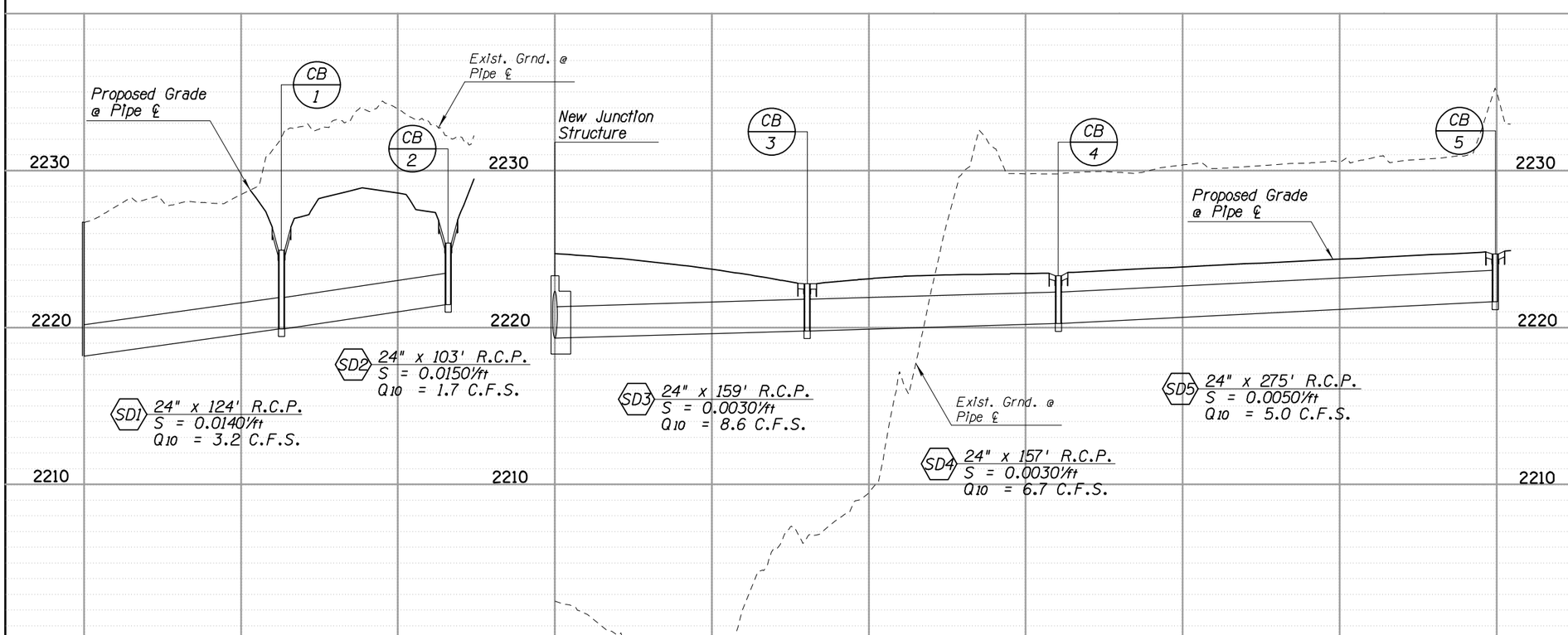
APPENDIX D SANTA CRUZ HYDRAULICS

APPENDIX E DCR LEVEL CONSTRUCTION PLANS



Notes:

1. For Horizontal Alignment Control See Sheet HC01
2. For Geometric Curb Data See Sheet GD01
3. For Roadway Plan See Sheets PL01 To PL07
4. For Roadway Profiles See Sheets PR01 To PR04
5. For Pavement Marking Plans See Sheets PM01 To PM05



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SCALE: 1" = 40'

Scale: 1" = 40' Horiz. 1" = 4' Vert.

Sheet SD01 of SD01

Page 19 of 36

Pima County Department of Transportation

Priscilla S. Cornelio, P.E., Director

	Date
Designed	09/14
Drawn	09/14
Checked	09/14
Proj. Engr.	09/14

No.	Revision Description	Engineer	Date

PRELIMINARY NOT FOR CONSTRUCTION STAGE 1

AECOM

TRANSPORTATION
AECOM USA, Inc.
5151 E. Broadway, Suite 1600
Tucson, Arizona 85711-3723
T 520.294.5757 F 520.294.8777
www.aecom.com

Arizona Blue Stake
1-800-STAKE-IT
1-800-782-5348

STORM DRAIN PLAN & PROFILE SHEET
SUNSET ROAD - SEGMENT I
SILVERBELL RD. TO I-10
STA. 76+00 TO STA. 84+00
PROJECT NO. 4RTSUN

SUNSET ROAD – SILVERBELL ROAD TO I-10 – PROJECT NO. 4RTSUN

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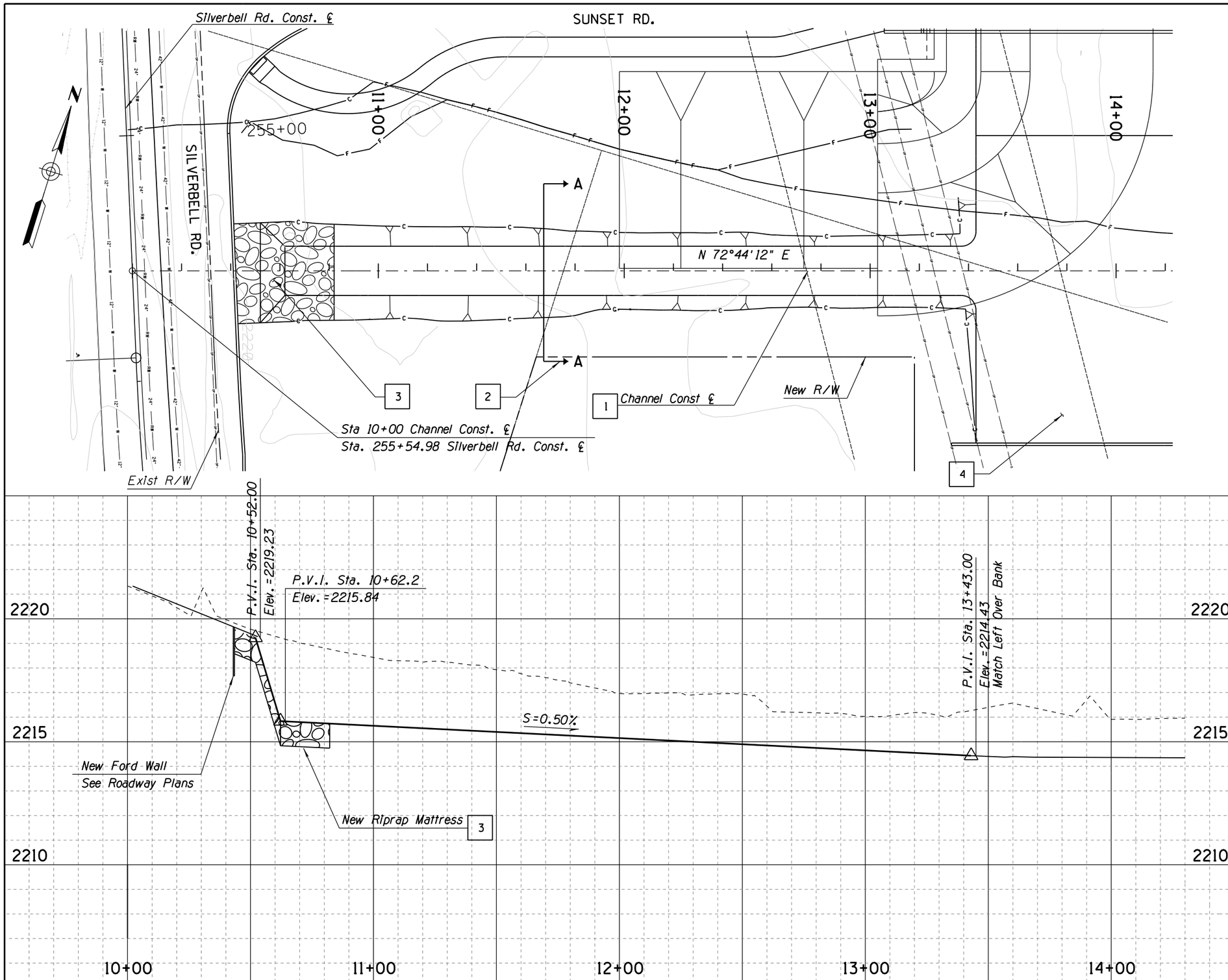
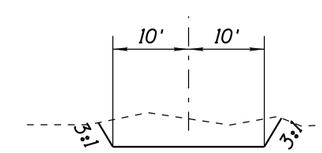


Notes:

1. Channel Const. ℄
   505 C.Y. Drainage Excavation
2. Channel Typical Section
   See Section A-A
3. 65 CY New Riprap Mattress
   See Detail D
4. Left Overbank Grading
   See Sheets CD02 & CD03



SECTION A-A

20' 0 20' 40'
SCALE: 1"=20'

Priscilla S. Cornelio, P.E., Director

Designed	GB	09/14
Drawn	CPG	09/14
Checked	JJK	09/14
Proj. Engr.	GB	09/14

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PRELIMINARY NOT FOR CONSTRUCTION STAGE 1

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177 N. CHURCH AVE., STE. 610
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Arizona Blue Stake
1-800-STAKE-IT
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Pima County Department of Transportation

WEST ROADSIDE CHANNEL
SUNSET ROAD - SEGMENT I
SILVERBELL RD. TO I-10
PROJECT NO. 4RTSUN

SUNSET ROAD - SILVERBELL ROAD TO I-10 - PROJECT NO. 4RTSUN

Scale: 1"=20' Horiz. | Sheet CD01 of CD06 | Page 20 of 36

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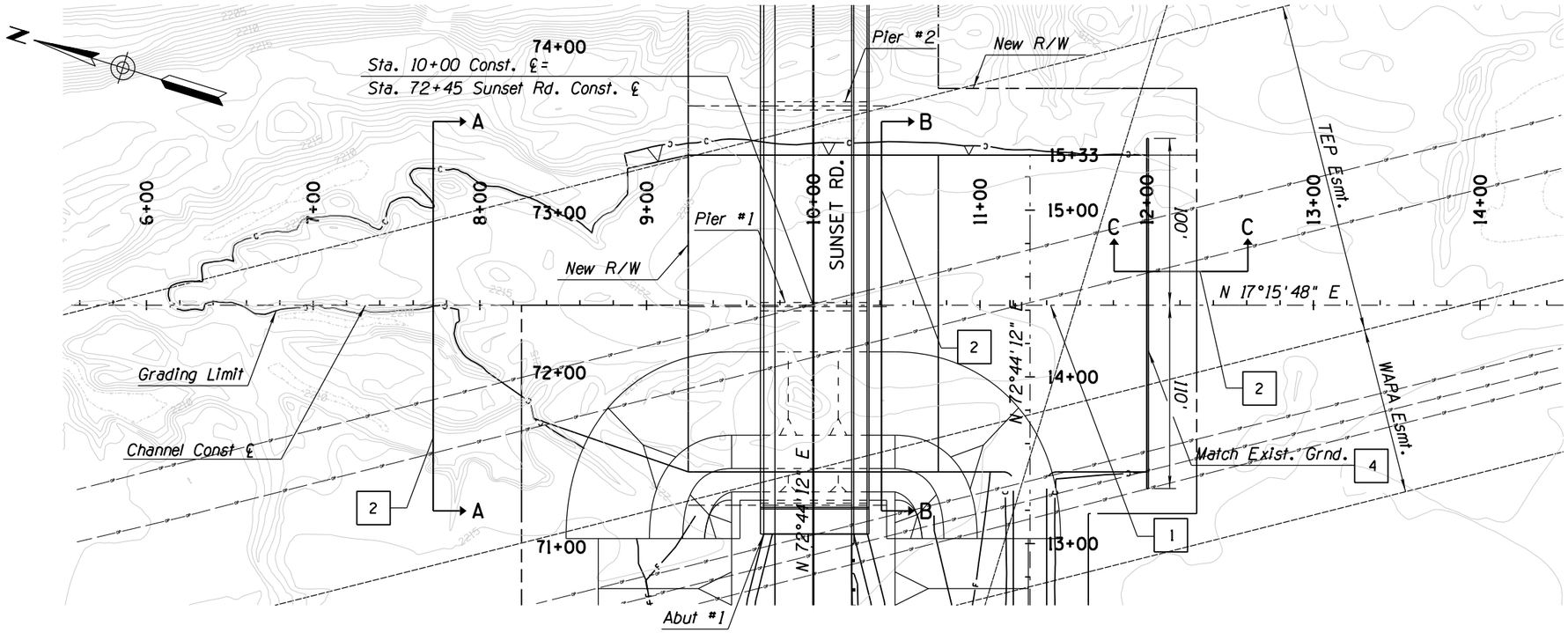

Notes:

1. Channel Const ℄
   7645 C.Y. Drainage Excavation
2. Channel Typical Sections See
   Left Overbank Grading
   Sheet CD03
3. Not Used
4. 210 L.F. New Conc. Ford Wall
   ADOT Std. Dwg. C-19.10

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

Scale:	1"=40' Horiz.	Sheet CD02 of CD06	Page 21 of 36

Priscilla S. Cornelio, P.E., Director

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Arizona Blue Stake
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1-800-782-5348

Pima County Department of Transportation

LEFT OVERBANK GRADING
SUNSET ROAD - SEGMENT I
SILVERBELL RD. TO I-10

PROJECT NO. 4RTSUN

SUNSET ROAD - SILVERBELL ROAD TO I-10 - PROJECT NO. 4RTSUN

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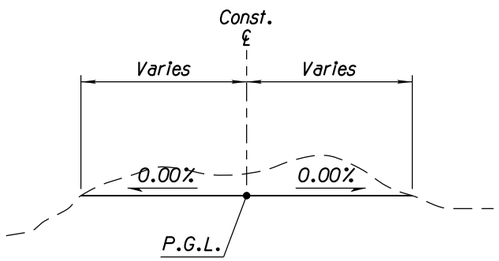
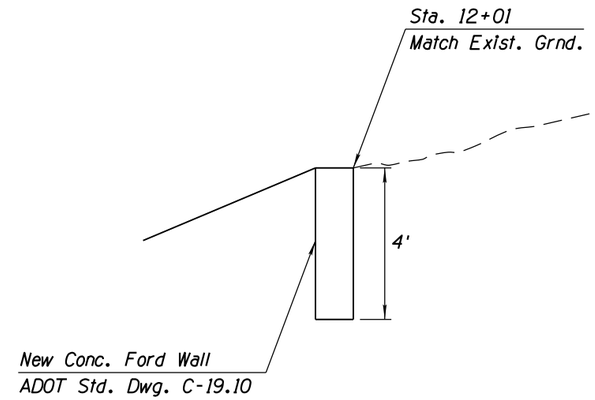


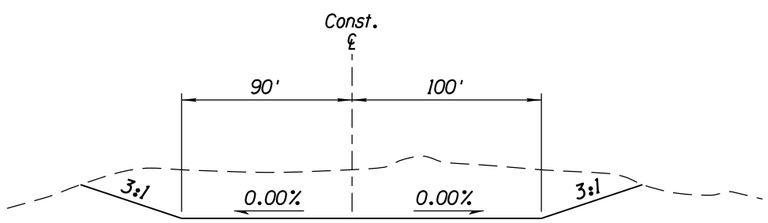
SECTION A-A

Sta. 7+00 to Sta. 8+30



SECTION C-C

Ford Wall



SECTION B-B

Sta. 8+90 to Sta. 12+00

Priscilla S. Cornelio, P.E., Director

No.	Revision Description	Engineer	Date

		Date
Designed	GB	09/14
Drawn	CPG	09/14
Checked	JJK	09/14
Proj. Engr.	GB	09/14

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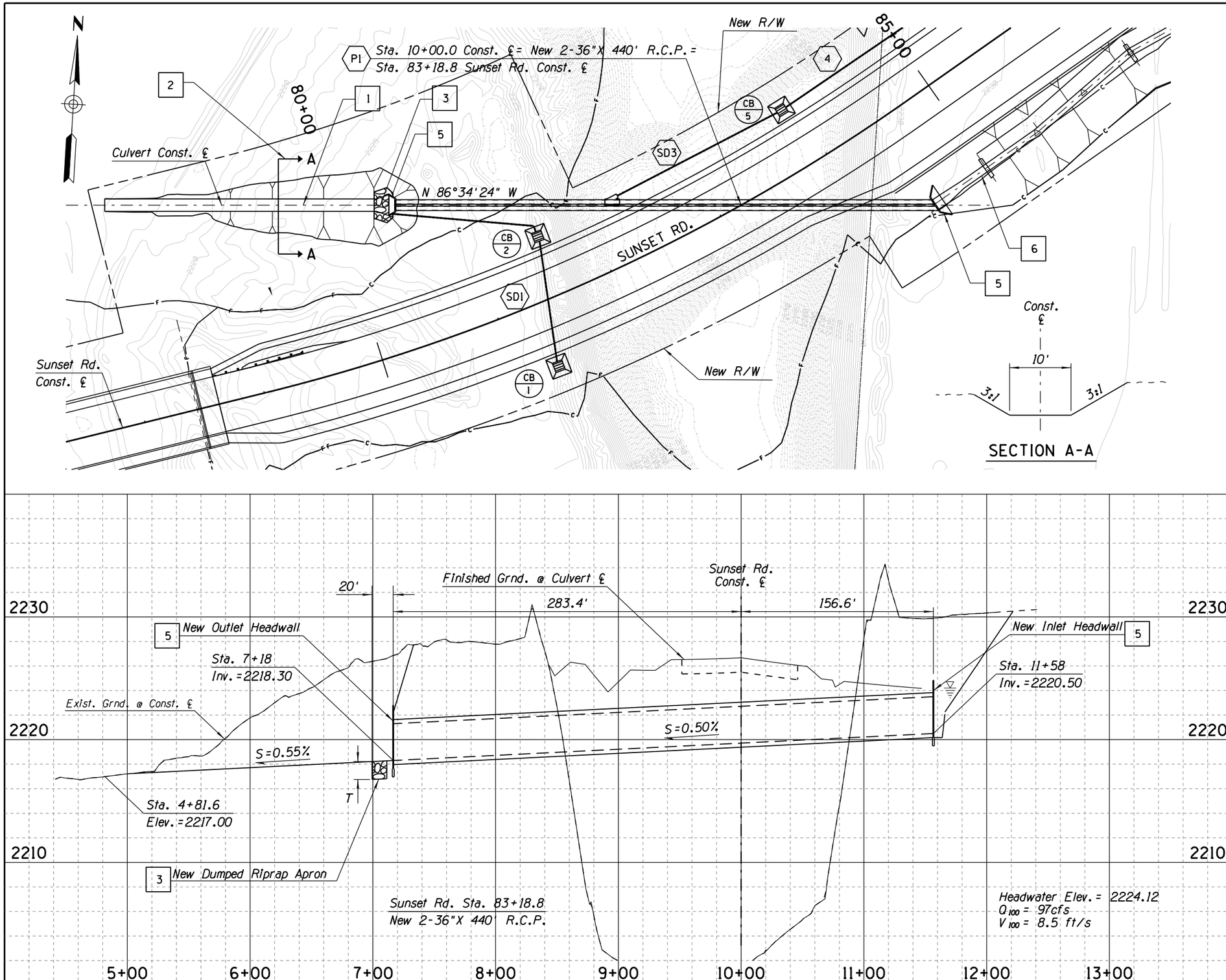
Pima County Department of Transportation

LEFT OVERBANK GRADING
SUNSET ROAD - SEGMENT 1
SILVERBELL RD. TO I-10

PROJECT NO. 4RTSUN

SUNSET ROAD - SILVERBELL ROAD TO I-10 - PROJECT NO. 4RTSUN

Scale:	N.T.S	Sheet CD03 of CD06	Page 22 of 36



Notes:

1. Culvert and Channel const. ℄ 1010 C.Y. Drainage Excavation
2. Channel Typical Section See Section A-A
3. 20 C.Y. Dumped Riprap Apron, w/ Filter Fabric T=18", D^{50}=6" Gradation:

% Passing	Size

4. Not Used
5. New Headwall, ADOT Std. Dwg. B-11.12, Mod See Detail D_
6. New Roadside Channel w/ Check Dams, See Sheets CD05 & CD06

P1 New Pipe Culvert I.D.

SD New Storm Drain Pipe I.D. See Storm Drain Plans

CB New Storm Drain Catch Basin I.D. See Storm Drain Plans

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

Pima County Department of Transportation

Priscilla S. Cornelio, P.E., Director

No.	Revision Description	Engineer	Date

		Date
Designed	GB	09/14
Drawn	CPG	09/14
Checked	JJK	09/14
Proj. Engr.	GB	09/14

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TUCSON, AZ. 85701
(520) 882-4824

Arizona Blue Stake
1-800-STAKE-IT
1-800-782-5348

CULVERT PLAN & PROFILE
SUNSET ROAD - SEGMENT I
SILVERBELL RD. TO I-10
PROJECT NO. 4RTSUN

SUNSET ROAD - SILVERBELL ROAD TO I-10 - PROJECT NO. 4RTSUN

Scale: 1"=40' Horiz. | Sheet CD04 of CD06 | Page 23 of 36

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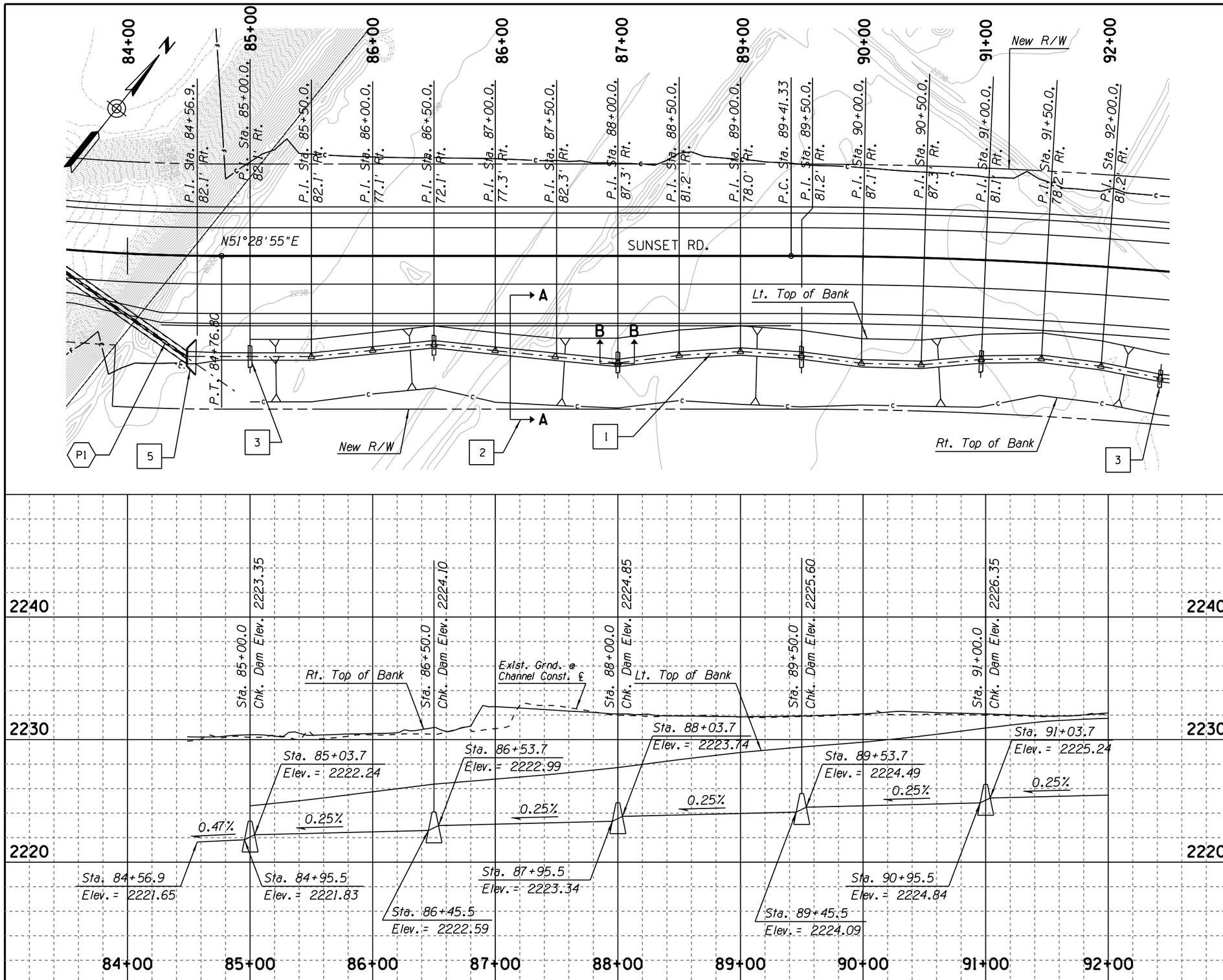

Notes:

1. Channel Const. ℄ Excavation Included w/ Roadway Excavation
2. Channel Typical Section See Section A-A, Sheet CD06
3. Dumped Riprap or Gabion Check Dam (TBD) 9Typ) See Section B-B, Sheet CD06
4. Not Used
5. New Headwall, See Sheet CD04
6. Not Used

P1 New Culvert I.D.

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

Priscilla S. Cornelio, P.E., Director

	Designed	GB	09/14
	Drawn	CPG	09/14
	Checked	JJK	09/14
	Proj. Engr.	GB	09/14

No.	Revision Description	Engineer	Date

PRELIMINARY NOT FOR CONSTRUCTION STAGE I

PARSONS BRINCKERHOFF
177 N. CHURCH AVE., STE. 610
TUCSON, AZ. 85701
(520) 882-6424

Arizona Blue Stake
1-800-STAKE-IT
1-800-782-5348

Pima County Department of Transportation

ROADSIDE CHANNEL
Sta 84+50 to Sta 92+00
SUNSET ROAD - SEGMENT I
SILVERBELL RD. TO I-10

PROJECT NO. 4RTSUN

SUNSET ROAD - SILVERBELL ROAD TO I-10 - PROJECT NO. 4RTSUN

Scale: 1"=40' Horiz. | Sheet CD05 of CD06 | Page 24 of 36

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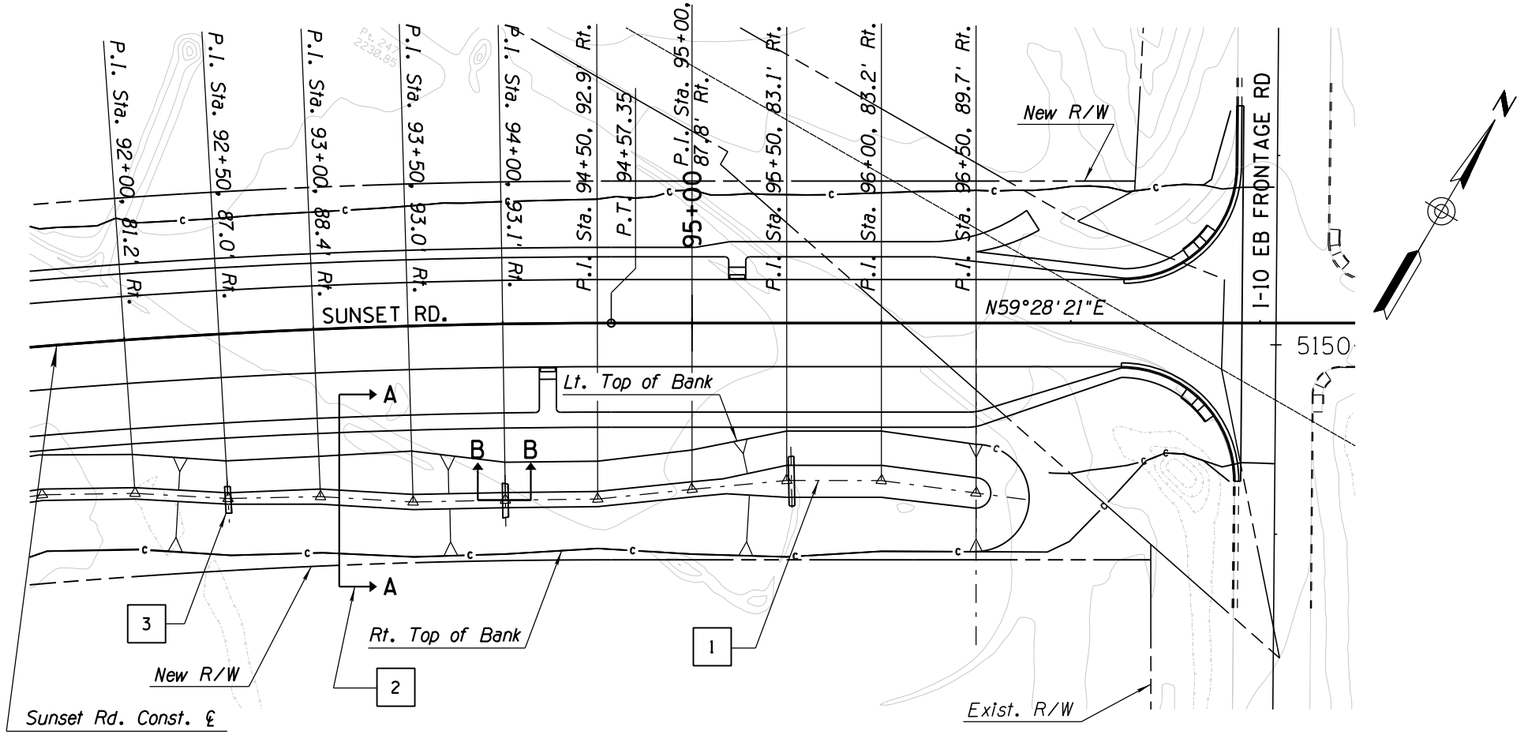
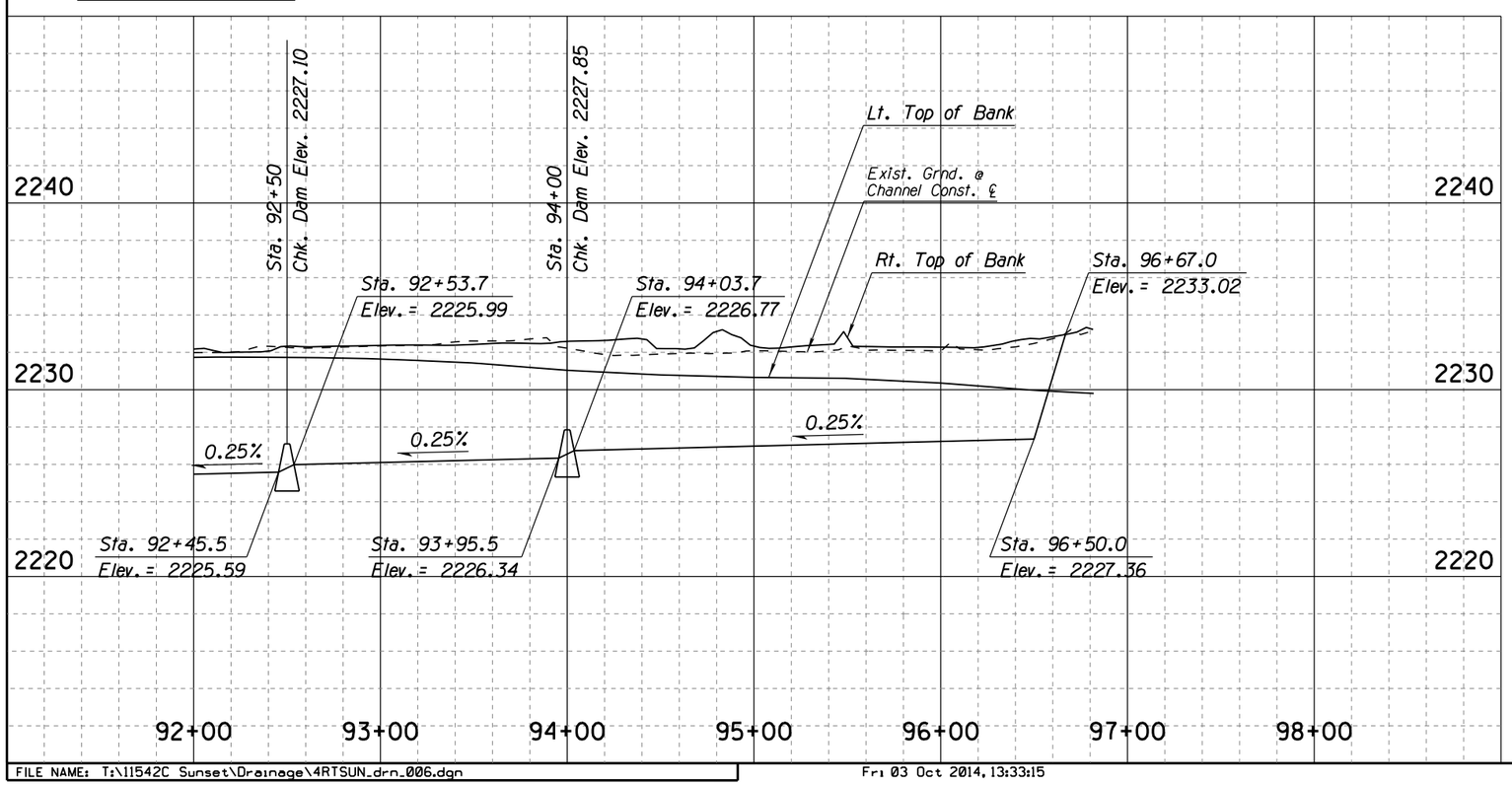
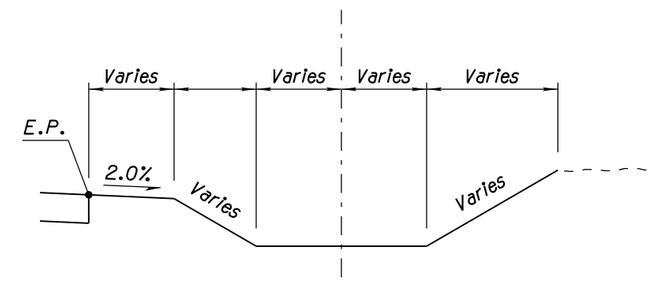


Notes:

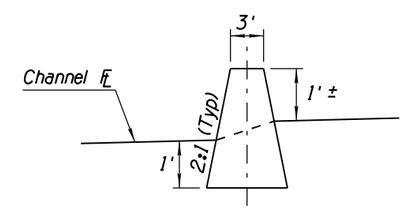
1. Channel const. ℄ Excavation Included w/ Roadway Excavation
2. Channel Typical Section See Section A-A, Sheet CD06
3. Dumped Riprap or Gabion Check Dam (TBD) 9Typ) See Section B-B, Sheet CD06
4. Not Used
5. New Headwall, See Sheet CD04
6. Not Used





SECTION A-A

* See Staking Plan, Detail _



SECTION B-B

Riprap Check Dam or Gabion Check Dam

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

Scale:	1"=40' Horiz.	Sheet CD06 of CD06	Page 25 of 36

Priscilla S. Cornelio, P.E., Director

Designed	GB	09/14
Drawn	CPG	09/14
Checked	JJK	09/14
Proj. Engr.	GB	09/14

No.	Revision Description	Engineer	Date

PRELIMINARY NOT FOR CONSTRUCTION STAGE 1

PARSONS BRINCKERHOFF
177 N. CHURCH AVE., STE. 610
TUCSON, AZ. 85701
(520) 882-6824

Arizona Blue Stake
1-800-STAKE-IT
1-800-782-5348

Pima County Department of Transportation

ROADSIDE CHANNEL
Sta 92+00 to Sta 100+00
SUNSET ROAD - SEGMENT I
SILVERBELL RD. TO I-10

PROJECT NO. 4RTSUN

SUNSET ROAD - SILVERBELL ROAD TO I-10 - PROJECT NO. 4RTSUN

FILE NAME: T:\11542C Sunset\Drainage\4RTSUN_drn_006.dgn

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