City of Aztec, New Mexico

Animas River Diversion

Conceptual Design Analysis and Engineering Report

June 2012
Revised
November 2013

Prepared By:

LARKIN GROUP N.M. INC

8500 Menaul Boulevard NE, Suite A-440
Albuquerque, New Mexico 87112

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 ACKNOWLEDGEMENT

Larkin Group NM, Inc. would like to express its gratitude to the following for their contributions to this Animas River Diversion, Conceptual Design Analysis and Engineering Report:

Mr. Michael Huber, P.E. – Public Works Director, City of Aztec

Mr. Andrew Galloway – Water Treatment Plant Supervisor, City of Aztec

John Shomaker & Associates, Inc.

Animas Environmental Services, LLC

Terracon Consultants, Inc.

2.0 EXECUTIVE SUMMARY

Of the City of Aztec's current drinking water diversions only one provides year-round service. The other two are valuable because they supply water during the summer high-demand season, but during the winter months the City must rely on the Animas River diversion north of the City. The Animas River is not controlled by upstream dams and experiences periods of high and low flow depending on weather conditions in the watershed. Periods of lowest flow usually occur in late summer and fall during drought conditions and in winter during very cold weather when snow melt in the mountains is minimal. To divert flow during these low flow conditions, the City has constructed a temporary berm across the river to divert flow into the diversion channel. This berm is constructed and maintained annually, but the authorization of this activity will no longer be permitted after the fall of 2011, which could result in insufficient water supply for the City.

The purpose of this study is to determine the most effective way to develop a permanent diversion of flow from the Animas River to the existing pump station. This diversion will be required to be capable of delivering a flow of 2,600 gallons per minute at river flows as low as 100 cubic feet per second, and it must not interfere with the normal river morphology. In addition, any permanent construction must comply with the requirements of the Federal Emergency Management Agency, City of Aztec and San Juan County regarding flood levels on the Animas River.

Five alternatives including the "no-action alternative" were considered. These alternatives included conventional wells with infiltration galleries, horizontal wells, a re-aligned diversion channel, a permanent diversion weir, and no action. The no-action alternative was not recommended because it would not meet the prime need of the study – to develop a reliable all-weather water source for the City of Aztec. The two well alternatives were carefully studied, but were not recommended because the water quality from a sub-surface source at this location is likely to be of much lower quality than surface water and may cause treatment concerns at the City water treatment plant. This was based on substantial testing at a nearby site on the Animas River. Of the final two alternatives, the re-aligned diversion channel and the permanent diversion weir, the re-aligned diversion channel was selected as the preferred alternative because it had less potential to adversely affect the river morphology, interfered less with aquatic life, and posed less interference with river activities (such as rafting). We were advised by the regulatory authorities that the re-aligned diversion channel would be considerably easier to permit than the diversion weir. For these reasons, the re-aligned diversion channel was selected as the preferred alternative.

3.0 INTRODUCTION AND HISTORY

The City of Aztec owns a diversion structure on the Animas River that must function continuously to divert river water to a pump station and from there to the City water treatment plant. Ultimately, this diverted water is made potable and is distributed throughout the City. In the past, the diversion has not functioned during periods of low flows in the river. If this continues, the risk of not being able to meet the demand increases. To counter this circumstance, the City has modified the diversion by adding an earthen berm adjacent to and in front of the diversion head gate. Although this appears to facilitate the flow of water into the diversion structure during periods of low flow, it is a cumbersome task due to the yearly efforts required to maintain the berm and due to the agency coordination required to allow this activity.

Each year the City applies to the U.S. Army Corps of Engineers (USACE) for a 404 permit to reconstruct the berm, and each year the USACE has issued a permit subject to a Nationwide Permit. However, in 2011 the Surface Water Quality Bureau (SWQB) of the New Mexico

Environment Department (NMED) took exception to the USACE permit believing that the berm is impeding sediment transport and allowing deposition in places where it would not occur naturally. This may be true, as it appears sediment deposits just upstream and in front of the diversion channel reducing its capacity during low flows.

Furthermore, the NMED-SWQB believes the use of this berm over the years has caused or contributed to the formation of a mid-stream bar, and that this bar may be causing bank erosion. They recommend the City design a more permanent structure at this location that will not interfere with sediment transport and normal river morphology.

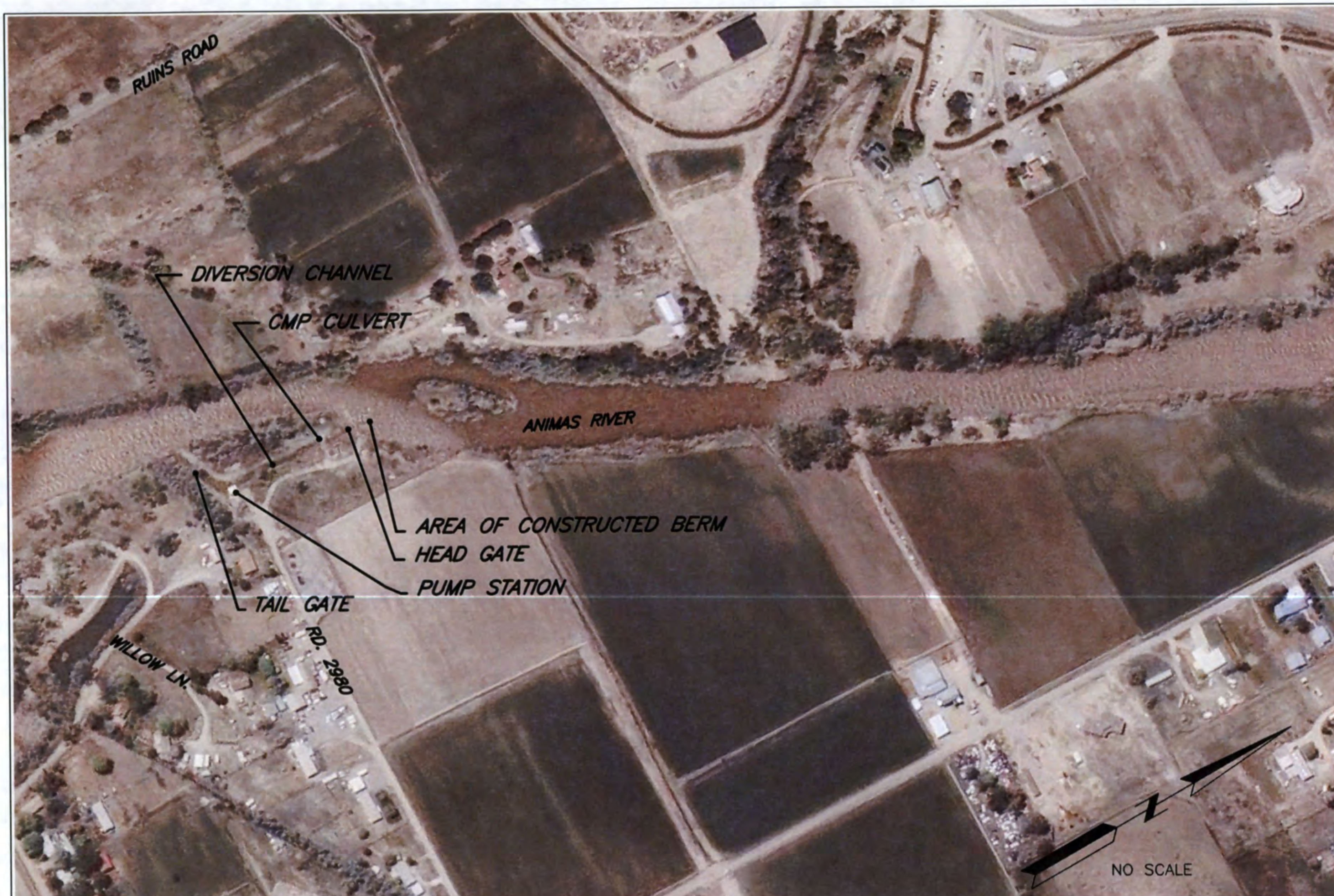
This Conceptual Design Analysis and Engineering Report is not intended to provide design parameters or construction details for any recommended option, but rather its goal is to evaluate the expected performance of five river diversion options while considering seasonal river flows, river morphology and needs of the City.

4.0 EXISTING CONDITIONS

Upstream and downstream of the diversion structure, the Animas River appears to have a uniform width of approximately 160 feet. However, as the river passes the diversion structure, the width narrows to about 95 feet. Furthermore, a small island is observed about 200 feet upstream of the diversion head gate. The east and west banks of the river as well as the diversion banks are heavily vegetated.

The existing river diversion structure is located on the east bank of the Animas River and is approximately 0.70 miles west of the intersection of Aztec Boulevard (US 550) and Navajo Dam Road (NM 173). See Figure 1 for a project location map. The diversion structure consists of an earthen berm, a head gate, an unlined channel, a culvert, a pump station and a tail gate. See Figure 2 for an aerial of the existing site.

Figure 1: Project Location Map



LARKIN GROUP NM, INC.

CONSULTING ENGINEERS AND SURVEYORS
8500 MENAUL BLVD. NE, SUITE A-440
ALBUQUERQUE, NEW MEXICO 87112
505-275-7500, FAX 505-275-0748
www.larkinnm.com

CITY OF AZTEC, NEW MEXICO
ANIMAS RIVER DIVERSION
FIGURE 2
AERIAL OF EXISTING SITE

4.1 Constructed Earthen Berm

The earthen berm is constructed of riverbed material consisting of sand, some silt and rocks ranging in size from ½ inch to 12 inches in diameter. The berm varies in size as it is constructed each year, but on average it is approximately 80 feet long and about 30 feet wide. The height of the berm also varies and is currently built to about three feet high. Figures 3 and 4 are aerial photographs showing the berm as constructed and showing what it looks like as it erodes.

Figure 3: River Diversion with Berm

Figure 4: River Diversion without Berm (Eroded)

4.2 Head Gate

The head gate consists of a steel sluice gate operated by a cast iron hand wheel and lifting stem. The hand wheel has been removed to prevent unauthorized operation. Reinforced concrete walls on each side support the gate and the lifting assembly. The head gate appears to be deteriorating, and it is known that the gate does not fully close. Figure 5 shows the head gate along with the support walls.

Figure 5: Head Gate

4.3 Unlined Channel

The diversion channel is approximately 570 linear feet long, varies from 20 to 30 feet wide and is about 5 feet deep. Currently, there is heavy vegetation on the top of the banks, and in some areas riprap has been added to the toe of the banks to mitigate erosion. It appears the existing channel's alignment was intended to skew from the natural river at approximately 20 degrees. However, due to the construction of the berm and river morphology over time, the skew is now at about 80 degrees. Figure 6 shows a portion of the diversion channel. Also Figures 3 and 4 show an aerial view of the diversion channel in its entirety, as well as the berm and the channel skew from the river.

Figure 6: Diversion Channel

4.4 Culvert

A corrugated metal pipe (CMP) is located within the channel, approximately 90 feet downstream of the head gate. The pipe serves as a culvert, allowing the passage of river water and provides a bridge to get to the constructed berm. Figure 7 shows the top of the CMP. The bridge is simply native fill material over the culvert.

Figure 7: CMP Culvert

4.5 Pump Station

The pump station is capable of pumping approximately 2,600 gallons per minute (gpm) to the water treatment plant. The pumps and controls are shielded from the outside elements by a small metal enclosure. The sump area is approximately 12 feet deep and the pump extends to that depth. Figure 8 shows the pump enclosure.

Figure 8: Pump Station (House)

4.6 Tail Gate

The tail gate, similar to the head gate, also consists of a steel sluice gate operated by a cast iron hand wheel and lifting stem. Again, the hand wheel has been removed to prevent unauthorized operation. Reinforced concrete walls on each side support the gate and the lifting assembly. The tail gate is located approximately 110 feet upstream from the outlet and appears to be in fair condition. Figure 9 shows the tail gate fully open.

Figure 9: Tail Gate

5.0 PROPOSED DIVERSION OPTIONS

Below is a discussion of four possible options designed to maintain an adequate water supply within the diversion channel during river flows as low as 100 cubic feet per second (cfs). Another option presented in this section is "no action," which discusses the disadvantages of the current structure and the detrimental effects to the City water supply if the current structure is to remain in place. Exploring these options in detail facilitates the determination of construction feasibility, environmental effects, construction costs, costs of operation and maintenance, agency requirements and functionality during simulated river flow rates of 100 cfs (typical of yearly lows), 13,000 cfs (100-year flood flow) and 21,500 cfs (highest recorded flow according to the Federal Emergency Management Agency [FEMA] Flood Study Number 35045CV000A).

5.1 Conventional Wells with Infiltration Galleries

Conventional wells coupled with infiltration galleries can provide a significant amount of river water. The concept of this option is to direct river water towards the conventional wells by utilizing infiltration trenches below the fine-grained material and backfill with coarser-grained material. The trenches would run essentially parallel to the river, and on both sides of the proposed conventional wells. A proposed completion diagram is shown in Figure 6b of Appendix A. The trenches would allow river water to enter upstream and flow past the wells, similar to the concept of a French drain. The proximity of the infiltration trenches would offset the effects of drawdown in the conventional well, and particularly the drawdown effects of wells on each other if multiple wells were used. Theoretically, the infiltration trenches should be capable of offsetting the total diversion rate from the conventional wells if these wells are not producing enough water alone. John Shomaker & Associates has explored the feasibility of this option, and their subsequent report is attached in Appendix A.

5.1.1 Construction Feasibility and Costs

The yield of domestic wells in the Animas River Valley is limited by drilling methods, well construction, development and casing diameter. It is noted that most domestic wells in the area yield 10 to 20 gpm, and that the yield can be increased tenfold with improved construction and development (see Appendix A for reference). Installing large-diameter shallow conventional wells at the City of Aztec Animas River diversion site could be challenging since geotechnical investigation determined that cobbles, boulders and caving conditions are likely to be encountered. Optimum well completion would involve stainless steel high open area screen from the water table to total depth of the alluvium, and a 15- to 20-ft pump chamber installed below the base of the alluvium. Excavation depths for the trenches are estimated to be less than five feet and approximately eight feet in width. A proposed completion diagram is shown as Figure 6a of Appendix A.

Table 1 shows a preliminary cost estimate for construction of this option. Costs may reduce if all six wells are completed at the same time.

Preliminary Construction Cost Estimate					
Bid #	**Description**	**Quantity**	**Unit**	**Unit Price**	**Amount**
1	Mobilization / Demobilization	1	LS	$10,000.00	$10,000.00
2	Drill Borehole	35	FT	$125.00	$4,375.00
3	Supply and Install Blank Stainless Steel Casing	20	FT	$400.00	$8,000.00
4	Supply and Install Continuous Wrap Stainless Steel Screen	15	FT	$300.00	$4,500.00
5	Supply and Install Filter Gravel	15	FT	$200.00	$3,000.00
6	Supply and Install Annular Seals	20	FT	$175.00	$3,500.00
7	Well Development	8	HR	$300.00	$2,400.00
8	Disinfection	1	LS	$1,500.00	$1,500.00
9	Infiltration Trenches (assume 12)	1	LS	$30,000.00	$30,000.00
10	Supply, Install and Remove Test Pump	1	LS	$7,500.00	$7,500.00
11	Development and Test Pumping	30	HR	$300.00	$9,000.00
12	Water Quality	1	LS	$3,000.00	$3,000.00
	Clean up and Restore Site	incidental	--	--	--
Sub-total					$86,775.00
NMGRT	7.7500%				$6,725.06
				Total Construction Cost Estimate per Well	**$93,500.06**
				Extended Cost for 6 Wells	**$561,000.38**

Table 1: Preliminary Cost Estimate for Conventional Wells with Infiltration Galleries

5.1.2 Operation and Maintenance

Primary operation and maintenance issues are related to pumps, flow meters and well performance. Pumping and non-pumping water levels should be collected at least quarterly and include the date, depth to water from a consistent measuring point and the instantaneous pumping rate if the wells are pumping. Non-pumping water levels should be collected after the wells have not been pumped for at least several hours, but preferably 12 hours. Water level data should be evaluated at least annually with the objective being to assess potential changes that may indicate whether pump performance has changed or well efficiency has decreased. If the data indicate that the pump or well performance has decreased, pump replacement/repair or well maintenance should be performed. Well maintenance may consist of brushing the well, or if significant mineral precipitation is documented by a video survey to be on the well screen, more aggressive maintenance may include the use of acid products approved for use in water supply wells.

5.1.3 Advantages and Disadvantages

One advantage of conventional wells with infiltration galleries is that this system is not entirely dependent on river flows. Also, this option requires less disturbance to the environment and is the least invasive to the river. This option can be configured so that the wells and pumping system are entirely on City-owned property alleviating the need for land acquisition. However, these advantages are eclipsed when considering water quality.

The major disadvantage of this option is the water quality of the sub-surface river water. Based on extensive testing at a nearby site on the Animas River, it is believed that this option will produce much harder water with high Total Dissolved Solids (TDS) than what the diversion currently produces, which can adversely impact the water treatment plant.

5.1.4 Agency Coordination and Permitting

The completion of new wells will require a permit application to be submitted with the New Mexico Office of the State Engineer (OSE) to change the point of diversion. This type of application is subject to advertisement, public protest and review by the OSE. If the application is protested or the OSE acts unfavorably on the application, it is likely that an OSE administrative hearing would be held. The OSE hearing decision can be appealed to District Court should the applicant or protestant be aggrieved by the decision. The City should involve its legal counsel and hydrogeologic consultant in the application process.

During well development and test pumping, produced water will need to be discharged to an appropriate location. It is unlikely that the water can be discharged to the Animas River without a National Pollutant Discharge Elimination System (NPDES) permit. The likelihood that a NPDES permit can be obtained for this type of discharge may be relatively small and take a significant amount of time. If the water is not discharged to the river, discharge permits may not be required.

5.2 Horizontal Wells

Inflows to horizontal screens in shallow alluvial aquifers can range between 0.5 to 2 gpm per foot of horizontal screen. Yield can be increased by installing designed backfill above the screen that allows better hydraulic connection with river water (see Figure 6c of Appendix A).

Ideally, the horizontal wells would be installed near the base of the shallow aquifer, which is about 25 feet below ground surface. John Shomaker & Associates investigated the feasibility of horizontal wells, and their subsequent report is attached in Appendix A.

5.2.1 Construction Feasibility and Costs

The horizontal wells would be located parallel or diagonal to the Animas River, and a pump chamber would be required at the down-gradient end of the wells. Horizontal wells are installed by excavating into the aquifer and backfilling with select gravel materials. From field investigation done by Terracon, it is known that large cobbles exist at the site and just under the existing ground. Rock encounter can hamper excavation and make it difficult to install such wells. Also, rock excavation can become expensive and can potentially delay the construction schedule.

Below is a cost estimate for construction of this option. Costs may reduce if all seven wells are completed at the same time.

Preliminary Construction Cost Estimate					
Bid #	**Description**	**Quantity**	**Unit**	**Unit Price**	**Amount**
1	Mobilization / Demobilization	1	LS	$20,000.00	$20,000.00
2	Drill Borehole	25	FT	$125.00	$3,125.00
3	Supply and Install Blank Stainless Steel Casing	25	FT	$400.00	$10,000.00
4	Excavate Trench (assume trench boxes must be used) and Dewater Is Required	1	LS	$12,000.00	$12,000.00
5	Supply and Install Perforated Casing	100	FT	$350.00	$35,000.00
6	Supply and Install Filter Gravel	1	LS	$7,000.00	$7,000.00
7	Well Development	10	HR	$300.00	$3,000.00
8	Disinfection	1	LS	$1,500.00	$1,500.00
9	Supply, Install and Remove Test Pump	1	LS	$7,500.00	$7,500.00
10	Development and Test Pumping	30	HR	$300.00	$9,000.00
11	Water Quality	1	LS	$3,000.00	$3,000.00
	Clean up and Restore Site	incidental	--	--	--
Sub-total					$111,125.00
NMGRT	7.7500%				$8,612.19
Total Construction Cost Estimate per Well					**$119,737.19**
Extended Cost for 7 Wells					**$838,160.31**

Table 2: Preliminary Cost Estimate for Horizontal Wells

5.2.2 Operation and Maintenance

Primary operation and maintenance issues are related to pumps, flow meters and well performance. Pumping and non-pumping water levels should be collected at least quarterly and include the date, depth to water from a consistent measuring point, and the instantaneous pumping rate if the wells are pumping. Non-pumping water levels should be collected after the wells have not been pumped for at least several hours, but preferably 12 hours. Water level data should be evaluated at least annually with the objective being to assess potential changes that may indicate whether pump performance has changed or well efficiency has decreased. If the data indicate that the pump or well performance has decreased, pump replacement/repair or well maintenance should be performed. Well maintenance may consist of brushing the well, or if significant mineral precipitation is documented by a video survey to be on the well screen, more aggressive maintenance may include the use of acid products approved for use in water supply wells.

5.2.3 Advantages and Disadvantages

The major advantage of horizontal collection is that it would remove all structures from the riverbed. Also, this option can be configured so that the wells and pumping system are entirely on City owned property alleviating the need for land acquisition. Furthermore, horizontal wells are less invasive to the surrounding environment and the river. However, the major disadvantage of poor water quality overshadows these advantages.

Again, the major disadvantage of horizontal wells is the water quality of the sub-surface river water. It is believed that this option will produce water with higher TDS than what has currently been seen at the water treatment plant. High TDS is a good indicator of water hardness, and hard water causes scaling in pipes and equipment.

5.2.4 Agency Coordination and Permitting

The completion of new wells will require a permit application to be submitted with the OSE to change the point of diversion. This type of application is subject to advertisement, public protest and review by the OSE. If the application is protested or the OSE acts unfavorably on the application, it is likely that an OSE administrative hearing would be held. The OSE hearing decision can be appealed to District Court should the applicant or protestant be aggrieved by the decision. The City should involve its legal counsel and hydrogeologic consultant in the application process.

Dewatering will be required during the installation of the horizontal screen sections, and additional water will be produced during well development and test pumping. The water generated during these activities will need to be discharged to an appropriate location. It is unlikely that the water can be discharged to the Animas River without an NPDES permit. The likelihood that a NPDES permit can be obtained for this type of discharge may be relatively small and take a significant amount of time. If the water is not discharged to the river, discharge permits may not be required.

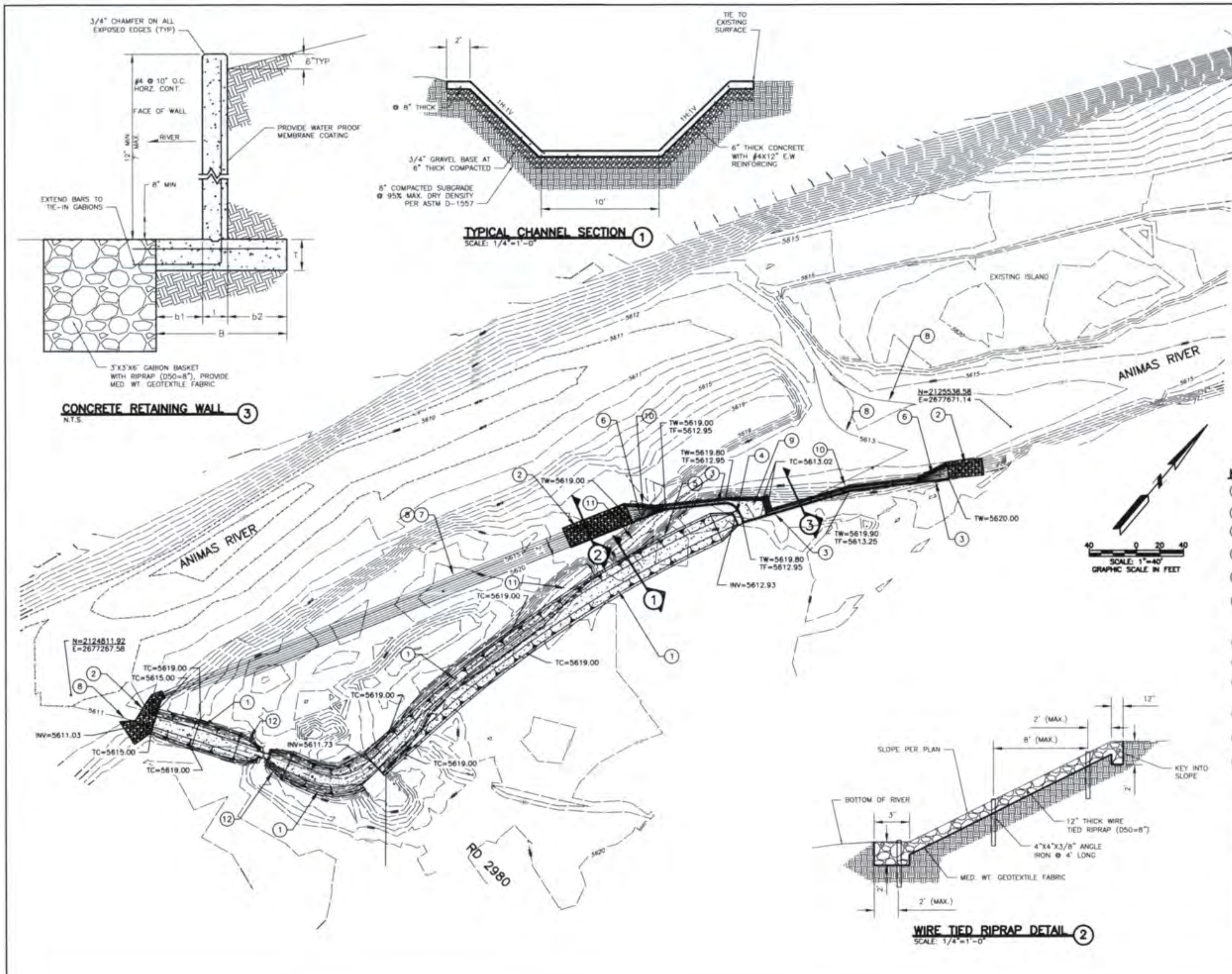
5.3 Re-Aligned Diversion Channel

This option involves a realignment and deepening of a portion of the existing diversion channel, construction of a new head gate and concrete bank wall, modifications to the upstream island and the installation of stream barbs along the opposite bank just upstream of the diversion channel head gate (see Figure 10).

The aim of this design is to facilitate flows into the diversion channel by constructing a channel that is more in-line with the natural river flow. The stream barbs and island modifications (shown in Figure 10) are intended to decrease the river velocity along the opposite bank to discourage erosion and, therefore, increase the velocity along the adjacent bank just upstream of the head gate. The head gate is integrated into a concrete wall along the upstream adjacent riverbank and parallel with the river (see Figure 10). This wall serves to change the roughness factor ("n" value) of the adjacent bank, hence increasing the river velocity along this bank, which should ultimately alleviate sediment accumulation and encourage river water to flow into the realigned diversion channel during low flow periods. Deepening the diversion channel should also help with diverting low flows from the river into the diversion channel.

Executing a simulated computer model of this option, as it is described above, aids in predicting overall performance during low, average and flood flows in the river. See Section 6.0 of this report for analysis procedure, assumptions, results and discussion of a simulated computer model for this option.

The results of this modeling indicate approximately 0.1 ft. effects on the water surface elevations for the 100-yr flow event at the upstream and downstream limits of the project. See Appendix C for detailed analysis.



LEGEND

	5' EXISTING CONTOURS
XXX5	1' EXISTING CONTOURS
	5' NEW CONTOURS
XXX5	1' NEW CONTOURS
	EDGE OF EXISTING CONCRETE
	NEW RIPRAP
	EXISTING BUILDING
	NEW WALL
	EXISTING WATER LINE W/ VALVE
OHE	EXISTING OVERHEAD ELECTRIC LINE
	LOT LINE
	CENTERLINE
	EASEMENT LINE
	CHAIN-LINK FENCE
	BARBED WIRE FENCE
•	FOUND PROPERTY CORNER
Δ	SURVEY CONTROL POINT
TW	TOP OF WALL ELEVATION
TF	TOP OF FOOTER ELEVATION
INV	INVERT ELEVATION
TC	TOP OF CONCRETE ELEVATION

KEYED CONSTRUCTION NOTES

1. CONSTRUCT NEW 10' WIDE DIVERSION CHANNEL WITH 1H:1V (MAX.) SIDE SLOPES. CHANNEL SLOPE TO BE 0.33% (MIN.) CONTINUOUS.
2. INSTALL WIRE TIED RIPRAP BLANKET.
3. CONSTRUCT NEW CONCRETE DIVERSION RETAINING WALL AS SHOW ON PLANS.
4. CONSTRUCT NEW CONCRETE DIVERSION STRUCTURE WITH INTEGRATED GATE. TIE-IN CONCRETE DIVERSION RETAINING WALL.
5. RELOCATE EXISTING POWER POLE AND GUY WIRES. COORDINATE WITH UTILITY OWNER.
6. PROVIDE CONCRETE TRANSITION FROM VERTICAL WALL TO SLOPE OF BANK. WITH #4X12" E.W. PROVIDE 3/4" GRAVEL BASE @ 6" THICK OVER 8" PREPARED SUBGRADE COMPACTED TO 95% MAX. DRY DENSITY PER ASTM D-1557.
7. GRADE EAST BANK AS SHOWN, PROVIDE 2H:1V (MAX.) SIDE SLOPES. REVEGETATE.
8. GRADE AREA AS SHOWN ON PLAN.
9. PROVIDE CONCRETE APRON @ 8" THICK WITH #4X12" E.W. PROVIDE 3/4" GRAVEL BASE @ 6" THICK OVER 8" PREPARED SUBGRADE COMPACTED TO 95% MAX. DRY DENSITY PER ASTM D-1557
10. INSTALL 3X3X6 GABIONS ADJACENT TO FOOTER. TOP OF GABION TO BE AT SAME ELEVATION OF TOP OF FOOTER.
11. FILL IN EXISTING DIVERSION CHANNEL WITH NATIVE MATERIAL. PROVIDE COMPACTION TO MATCH SURROUNDING GROUND.
12. TRANSITION NEW DIVERSION CHANNEL FROM 1H:1V SLOPE TO VERTICAL WALL AND TIE INTO EXISTING GATE STRUCTURE.

REVISION	DATE	DESCRIPTION	BY
1.			
2.			
3.			

REVISIONS (OR CHANGE NOTICES)

CITY OF AZTEC
SAN JUAN COUNTY, NEW MEXICO

ANIMAS RIVER DIVERSION
RE-ALIGNED DIVERSION CHANNEL
SITE PLAN

LARKIN GROUP NM, INC
CONSULTING ENGINEERS AND SURVEYORS
8500 MENAUL BLVD. NE, SUITE A-440
ALBUQUERQUE, NEW MEXICO 87112
505-275-7500, FAX 505-275-0748
www.larkinnm.com

PROJECT NO.	DRAWN	CHECKED	DATE	FIGURE
2011-0015	CAI	JC	JUNE 2013	10

5.3.1 Construction Feasibility and Costs

This option offers the advantage of a phased construction. If this were the selected option, a suggested construction phasing would be in three phases. Each phase can be executed during low flows so that river encroachment and disturbance are minimized.

- Phase 1 would be the diversion channel itself and should include concrete lining of the channel banks as well as deepening the channel.
- Phase 2 should include the construction of the head gate, tail gate (as applicable), concrete wall and riprap installation along the upstream adjacent bank.
- Phase 3 would be the modification to the upstream island and the installation of stream barbs in that area.

Shown in the table below are estimated construction and operation and maintenance costs.

Preliminary Construction Cost Estimate					
Bid #	**Description**	**Quantity**	**Unit**	**Unit Price**	**Amount**
1	Mobilization / Demobilization	1	LS	$ 7,500.00	$ 7,500.00
2	Construction Staking	1	LS	$ 5,000.00	$ 5,000.00
3	Removal and Disposal of Existing Structures	2	LS	$ 3,500.00	$ 7,000.00
4	Unclassified Excavation (not including rock)	6,395	CY	$ 10.00	$ 63,950.00
5	Fill and Compact	639	CY	$ 4.00	$ 2,556.00
6	Import / Export Material	4,285	CY	$ 8.00	$ 34,280.00
7	Final Channel Grading and Shaping	405	LF	$ 10.00	$ 4,050.00
8	Wire Tied Riprap	205	CY	$ 105.00	$ 21,525.00
10	Reinforced Concrete Channel Lining	340	CY	$ 400.00	$ 136,000.00
11	Reinforced Concrete Headwall with Sluice Gate	9	CY	$ 500.00	$ 4,500.00
12	Irrigation Head Gate	2	EA	$ 2,500.00	$ 5,000.00
13	Reinforced Concrete Retaining Wall and Footer	170	CY	$ 500.00	$ 85,000.00
14	Temporary Construction Dam and Dewatering	1	LS	$ 7,500.00	$ 7,500.00
15	Agency Coordination and Permitting	1	LS	$ 4,800.00	$ 4,800.00
Sub-total					$388,661.00
NMGRT	7.7500%				$30,121.23
				Total Construction Cost Estimate	**$418,782.23**

Preliminary Operation and Maintenance Cost Estimate				
	Maintenance Items	**Duration**	**Cost**	
	Removal of Debris, Sediment and Rocks	Bi-Annually	$0.50/SF	
	Concrete Crack Sealing and Patching	As Needed	$10/LF	
	Concrete Repair	As Needed	$200/CF	
	Repair of Wire Tied Riprap	As Needed	$105/CY	
	Vegetation Control	Bi-Annually	$1,500/AC	
	Operation Items	**Duration**	**Cost**	
	Head Gate Valve	Bi-Annually	NA	

Table 3: Preliminary Cost Estimate for Re-Aligned Diversion Channel

5.3.2 Operation and Maintenance

This option should be mainly self-sustaining since operation will be dependent on river flows. However, it is anticipated that minimal maintenance will be required to ensure the diversion functions as intended. The major maintenance item will be removing any sediment and rocks that may have accumulated at the head gate or in the diversion channel. This can be done by shovel or small equipment such as a Bobcat. Over time, the concrete may become damaged and need patching, repair or full replacement. In addition, the diversion gates (head and tail) should be operated at least twice a year. It is recommended that a full operation and maintenance manual be drafted for this option.

5.3.3 Advantages and Disadvantages

The major advantage of this option, and perhaps the most critical, is the current receptiveness from regulatory agencies such as the NMED-SWQB, OSE, San Juan County Flood Commission, City of Aztec and the USACE. Another advantage is that the increased velocity just upstream of the head gate should allow sediment to be transported past the diversion and sediment should not accumulate as it currently does. Also, modifying the island upstream of the diversion provides uniformity to the river by alleviating fabricated bottlenecks and bends, hence bringing the river morphology into a more natural state.

One disadvantage of this option is the unknown performance for flows below 100 cfs. The simulated computer model predicted performance for flows at 100 cfs; however, flows in the river are known to be much less at times. According to data provided from the USGS Gauge Station 09364010 (see Figure 11) flows were well below 100 cfs during the late summer months of 2009 and 2010. Another disadvantage that may hamper the implementation of this option is the required land acquisition from the bordering landowner. As can be seen in Figure 10, the head gate and the new point of diversion are located on private property. Land negotiations may take some time, which ultimately delays the construction schedule.

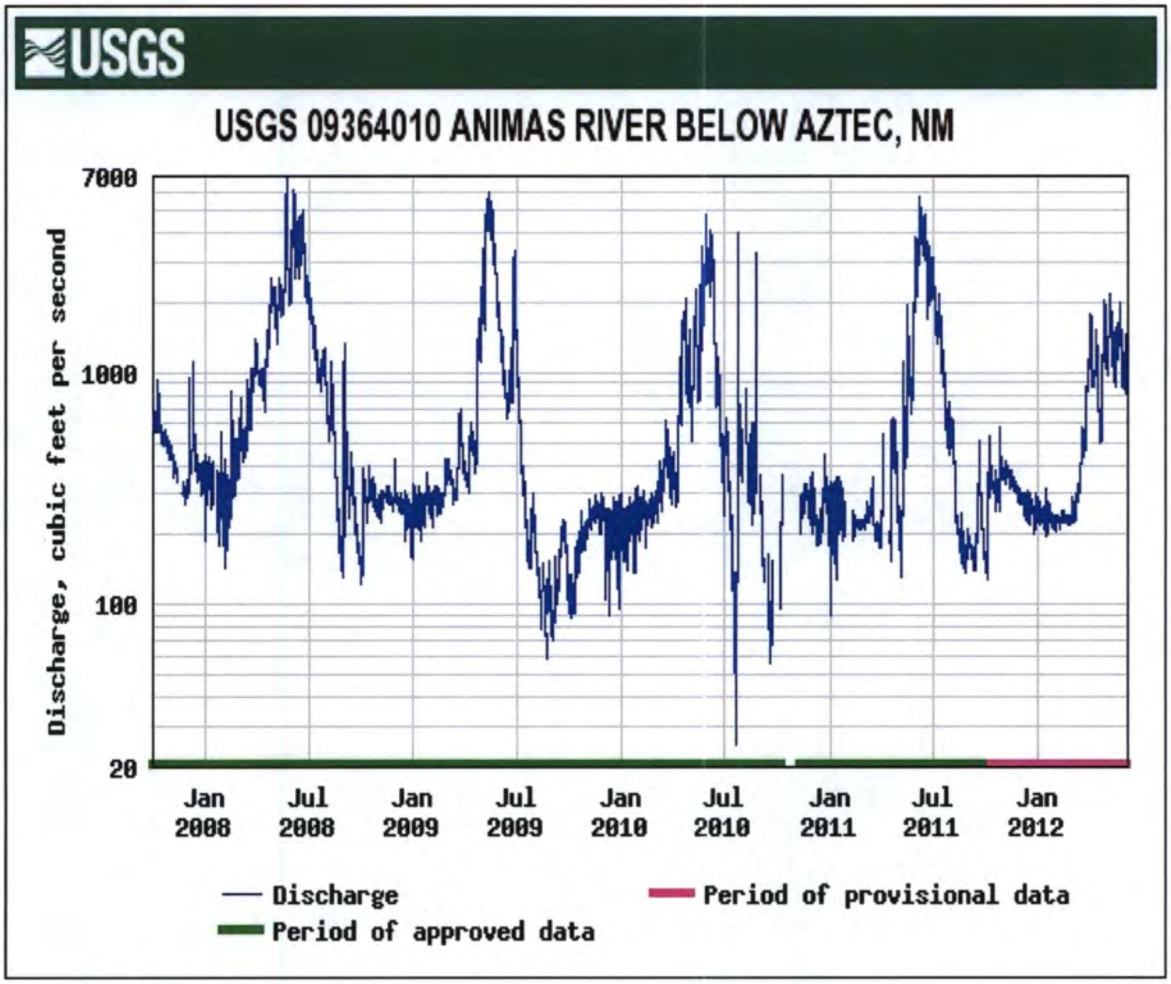


Figure 11: Animas River Flow Data from Station 09364010

5.3.4 Agency Coordination and Permitting

Preliminary plans as shown in Figure 10 have been sent to Mr. Chris Wrbas of the USACE. According to Mr. Wrbas, this option will require a formal submittal to and approval from the USACE, but will not be as extensive to permit as a diversion weir. In fact, Mr. Wrbas had very few comments on the preliminary plans. In addition, phasing this option may allow it, or portions of it, to fit under a Nationwide Permit 7 and/or 13.

This option was also discussed in detail with Mr. Neal Schaeffer of the NMED-SWQB, who indicated that this is the preferred option because it is less invasive to the river than the diversion weir option. It also provides uniformity to the river, which brings it back to its natural state and halts the formation of islands such as the current one just upstream of the existing head gate.

Furthermore, this option was sent to Mr. Shawn Williams of the OSE in Aztec. Mr. Williams indicated that a new file map showing the new point of diversion will need to be submitted to the OSE. Also, Mr. Williams indicated that a permit will not be needed for construction. However, the City will be required to formally submit to the OSE so that a correspondence letter on OSE letterhead can be delivered to the City formally indicating no permit required and formally requesting the point of diversion file map.

In order to obtain a permit from San Juan County, and in the City of Aztec, conditions given in Ordinance Number 58, which is titled "Flood Damage Prevention Ordinance," need to be met. Two major conditions that need to be submitted with the permit application, among others, are "a description of the extent to which the river will be altered as a result of the proposed development," and "the expected heights, velocity, duration, rate of rise and sediment transport of flood waters to be expected at the site." The preliminary plans along with the short descriptions as presented in this report could serve to meet these conditions.

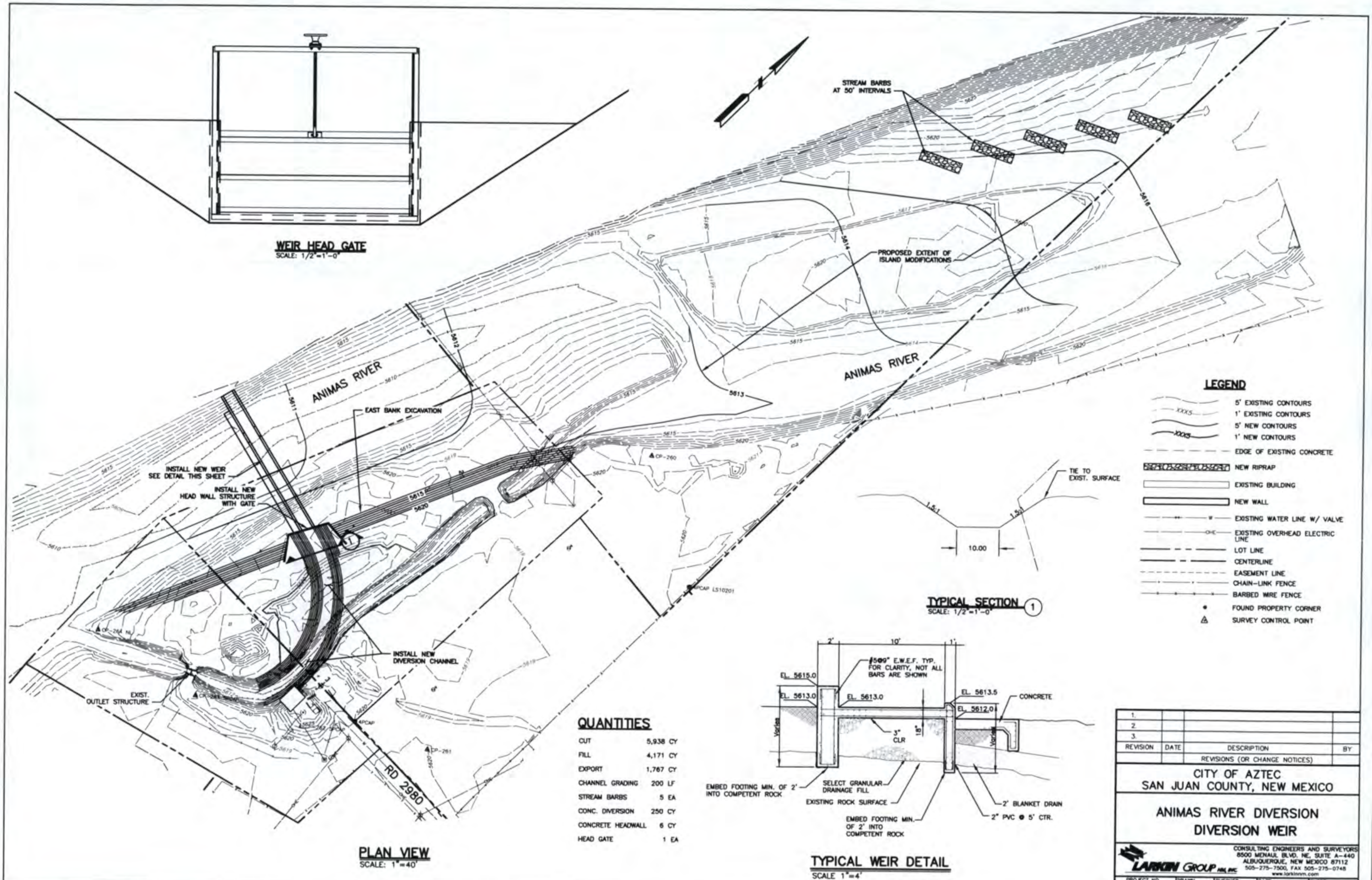
5.4 Diversion Weir

This option involves constructing a new concrete diversion weir at approximately eighteen inches higher than the riverbed. Behind the weir will be a ten-foot wide trough with a six-inch extruded curb opposite of the weir, all made of concrete (see Typical Weir Detail on Figure 12). The concrete trough will be integrated into a new head gate in order to allow isolation of the diversion channel for maintenance. The weir, trough and extruded curb will be constructed as one piece that will span the river width, and they will be located west and just north of the existing pump station (see Figure 12). This option also involves modifications to the upstream island and the installation of stream barbs along the west bank and adjacent to the upstream island (see Figure 12).

The intent of this design is to pool river water in the trough and direct it towards a new diversion channel that will connect to a portion of the existing channel (see Figure 12). The weir and extruded curb will have notches that allow water into the trough area during times when water surface elevation becomes lower than the weir elevation. Also, the notches will allow aquatic life to pass through the structure. The stream barbs will serve to alleviate erosion to the west bank, and the island modifications are proposed in order to guide the river morphology back to a more natural state.

The current riverbed at the proposed weir site varies by about three feet as it gradually becomes deeper near the west bank. These conditions are representative of non-uniform flow and uneven sediment transportation probably due to the existing fabricated diversion berm, which creates a bottleneck and hence increases river velocity along the west bank (see Figure 12). It is believed that this increased velocity along the west riverbank is responsible for transporting sediment out of this area and ultimately creating the three-foot-deep hole in the riverbed. It is important for the river flow to be as uniform as possible in order for the weir to function properly. To do this, three things must happen; the upstream island modifications (previously discussed), removal of the existing fabricated berm and widening the river to better match the upstream and downstream river width.

Executing a simulated computer model of this option, as it is described above, aids in predicting overall performance during low, average and flood flows in the river. See Section 6.0 of this report for analysis procedure, assumptions, results and discussion of a simulated computer model for this option.



QUANTITIES

CUT	5,938 CY
FILL	4,171 CY
EXPORT	1,767 CY
CHANNEL GRADING	200 LF
STREAM BARBS	5 EA
CONC. DIVERSION	250 CY
CONCRETE HEADWALL	6 CY
HEAD GATE	1 EA

REVISION	DATE	DESCRIPTION	BY
1.			
2.			
3.			

REVISIONS (OR CHANGE NOTICES)

CITY OF AZTEC
SAN JUAN COUNTY, NEW MEXICO

ANIMAS RIVER DIVERSION
DIVERSION WEIR

LARKIN GROUP NM, INC
CONSULTING ENGINEERS AND SURVEYORS
8500 MENAUL BLVD. NE, SUITE A-440
ALBUQUERQUE, NEW MEXICO 87112
505-275-7500, FAX 505-275-0748
www.larkinnm.com

PROJECT NO.	DRAWN	CHECKED	DATE	SHEET
2011-0015	CAI	JC	JUNE 2013	12

5.4.1 *Construction Feasibility and Costs*

One of the challenging aspects of this option is construction of the weir structure in the riverbed. The weir structure, as can be seen in Figure 12, will require a footing that will extend into the riverbed. Recent attempts to observe the soil characteristics within the riverbed allowed excavation to the depth of only about three feet before refusal was encountered. Assuming what was encountered during these efforts is representative of the riverbed in the area of the proposed weir, bulkheads and bracing or other means may be necessary to get through the cobbles and boulders. This type of excavation typically adds substantial costs to the project and can hinder the project schedule. Shown in the table below is an estimated construction cost for this option along with estimated operation and maintenance costs.

Preliminary Construction Cost Estimate					
Bid #	**Description**	**Quantity**	**Unit**	**Unit Price**	**Amount**
1	Mobilization / Demobilization	1	LS	$ 7,500.00	$ 7,500.00
2	Construction Staking	1	LS	$ 5,000.00	$ 5,000.00
3	Removal and Disposal of Existing Structures	1	LS	$ 3,500.00	$ 3,500.00
4	Unclassified Excavation (not including rock)	5,938	CY	$ 15.00	$ 89,070.00
5	Fill and Compact	4,171	CY	$ 4.00	$ 16,684.00
6	Import / Export Material	1,767	CY	$ 8.00	$ 14,136.00
7	Final Channel Grading and Shaping	200	LF	$ 10.00	$ 2,000.00
8	Stream Barbs	5	EA	$ 3,500.00	$ 17,500.00
9	Reinforced Concrete Diversion Structure	250	CY	$ 500.00	$ 125,000.00
10	Reinforced Concrete Headwall for Irrigation Gate	6	CY	$ 500.00	$ 3,000.00
11	Irrigation Head Gate	1	EA	$ 2,500.00	$ 2,500.00
12	Temporary Construction Dam and Dewatering	1	LS	$ 7,500.00	$ 7,500.00
13	Agency Coordination and Permitting	1	LS	$ 7,200.00	$ 7,200.00
Sub-total					$300,590.00
NMGRT	7.7500%				$23,295.73
				Total Construction Cost Estimate	**$323,885.73**
Preliminary Maintenance Cost Estimate					
	Maintenance Items	**Duration**		**Cost**	
	Removal of Debris, Sediment and Rocks	Bi-Annually		$0.50/SF	
	Concrete Crack Sealing and Patching	As Needed		$10/LF	
	Concrete Repair	As Needed		$200/CF	
	Repair of Wire Tied Riprap	As Needed		$105/CY	
	Vegetation Control	Bi-Annually		$1,500/AC	
	Operation Items	**Duration**		**Cost**	
	Head Gate Valve	Bi-Annually		NA	

Table 4: Preliminary Cost Estimate for Diversion Weir

5.4.2 Operation and Maintenance

No direct operation is required for a weir diversion as this option is solely dependent on river flows and should be self-sustaining. Maintenance required to keep the weir and diversion channel functioning as intended would be limited to the removal of any sediment and rocks that may have accumulated in the trough, at the head gate and/or in the diversion channel. Also, sediment accumulation along the upstream side of the weir should be monitored and removed as needed in order to restore the existing bed elevation. Sediment and rock removal should be performed by shovel or small equipment. Since this option is more susceptible to damage by rolling boulders in the river, it is recommended to monitor and repair the concrete to ensure the diversion weir is maintained at design elevation. Furthermore, it is recommended that a full operation and maintenance manual be drafted for this option.

5.4.3 Advantages and Disadvantages

This option offers two advantages; the river morphology is returned to its natural state by modifying the island upstream of the diversion and removing the current diversion berm, and the notches in the weir and extruded curb allow the diversion to function during low river flows. Although this option is advantageous because the design provides a means for river water to enter the diversion channel during river flows under 100 cfs, it has several disadvantages.

The major disadvantage is the permanent obstruction to the river. The diversion weir can potentially hinder sediment transport and cause island formation upstream. Also, large boulders and debris moving along the riverbed during high flows can get caught on the weir. The biggest disadvantage, brought up by the OSE, involves rafters who may not be aware of this structure when it is fully submerged. In fact, the OSE pointed to a case at the City of Farmington diversion weir that involved rafters getting trapped on the structure. Although the Farmington diversion weir is much bigger than what is proposed here, the risk is still present. Another disadvantage of this option is the required land acquisition from the bordering landowner. As can be seen in Figure 12, a portion of the weir and trough are located on private property. Land negotiations may take some time, which ultimately delays the construction schedule.

5.4.4 *Agency Coordination and Permitting*

Preliminary plans, as shown in Figure 12, have been sent to Mr. Wrbas of the USACE. According to him, this option will also require a formal submittal to and approval from the USACE. Mr. Wrbas feels the review and approval of this option will be extensive since it affects the entire width of the river. It is believed that this option will not fit under any nationwide permitting.

This option was also discussed in detail with Mr. Schaeffer of the NMED-SWQB, who indicated that this option would have to be reviewed carefully to ensure no adverse effects to the river quality and aquatic life. Mr. Schaeffer appeared to be concerned with the effects of this option to the morphology and pointed out that he believed the current "obstruction" or berm has already changed the natural morphology. Although Mr. Schaeffer did indicate that permitting this option would not be impossible, he believed that due to the river invasiveness, the re-aligned diversion channel was the better option for this situation. Mr. Schaeffer stressed that the selected option should be judicious to the river and should be aimed at alleviating the formation of islands such as the current one just upstream of the existing head gate.

Furthermore, this option was sent to Mr. Williams of the OSE in Aztec. He indicated that a new file map showing the new point of diversion will need to be submitted to the OSE. Mr. Williams indicated that a permit will not be needed for construction of this option, but the City will need to formally submit so that a correspondence letter can be delivered to the City formally requesting the point of diversion file map and indicating no permit will be required from the OSE.

Again, conditions given in San Juan County's Ordinance Number 58 need to be met in order to obtain a permit for construction. The same two condition as described in the re-aligned diversion channel option are important to the weir option as well. The preliminary plans along with the short descriptions as presented in this section could serve to meet these conditions.

5.5 No Action

In very dry years the river stage sometimes falls so low that water will not flow naturally into the existing diversion channel. This is because the elevation of the existing head gate does not allow the diversion channel to be deepened to allow it to receive water at very low river stages. Therefore, the City has constructed a diversion berm to divert low flows into the channel. This berm typically erodes during the spring and summer months and by the next fall is not effective. Therefore, the City rebuilds the berm each fall to provide diversion during the winter months when their other diversions are not available. The NMED-SWQB believes the berm has changed the river morphology causing sediment deposition upstream resulting in a small island just upstream of the berm location. The City has been notified that the USACE will no longer issue a 404 permit for berm reconstruction, so the City cannot continue its current operation of the diversion. Therefore, if the No Action alternative is selected, water may not be available from the river during periods of very low flow. Most of these periods have historically occurred when the City's other diversions were not available. Hence, the No Action alternative has a fatal flaw in that it will endanger the reliability of water supply to the City's population and, therefore, cannot be considered further.

6.0 ANALYSIS AND DISCUSSION

6.1 Existing Diversion

Computer modeling was created and executed to simulate current hydraulic conditions in the river and the existing diversion channel for flow rates of 100 cfs (typical of yearly lows), 13,000 cfs (100-year flood flow) and 21,500 cfs (the highest recorded flow according to the FEMA).

6.1.1 Analysis Parameters

A survey of the river channel upstream and downstream of the diversion was executed in order to accurately model existing conditions. The survey included full topography of the existing site and adjacent island, river cross section at approximately 50-foot intervals upstream and downstream of the existing diversion and topography of the existing diversion channel and structures. From the survey, it is observed that the riverbed on average is three feet lower than the bottom of the diversion channel. This is shown by comparing elevations along a cross section taken through the existing diversion channel culvert (INV. EL. = 5612.47) and the riverbed (approx. EL. = 5610). See Figure 13 for existing topography of the river and the diversion channel with cross section.

From survey data, a three-dimensional model was created utilizing AutoCAD Civil 3D 2012. This model represents the ground surface at the site and within the river and is imported into the USACE's Hydrologic Engineering Centers River Analysis System Version 4.0 (HEC-RAS).

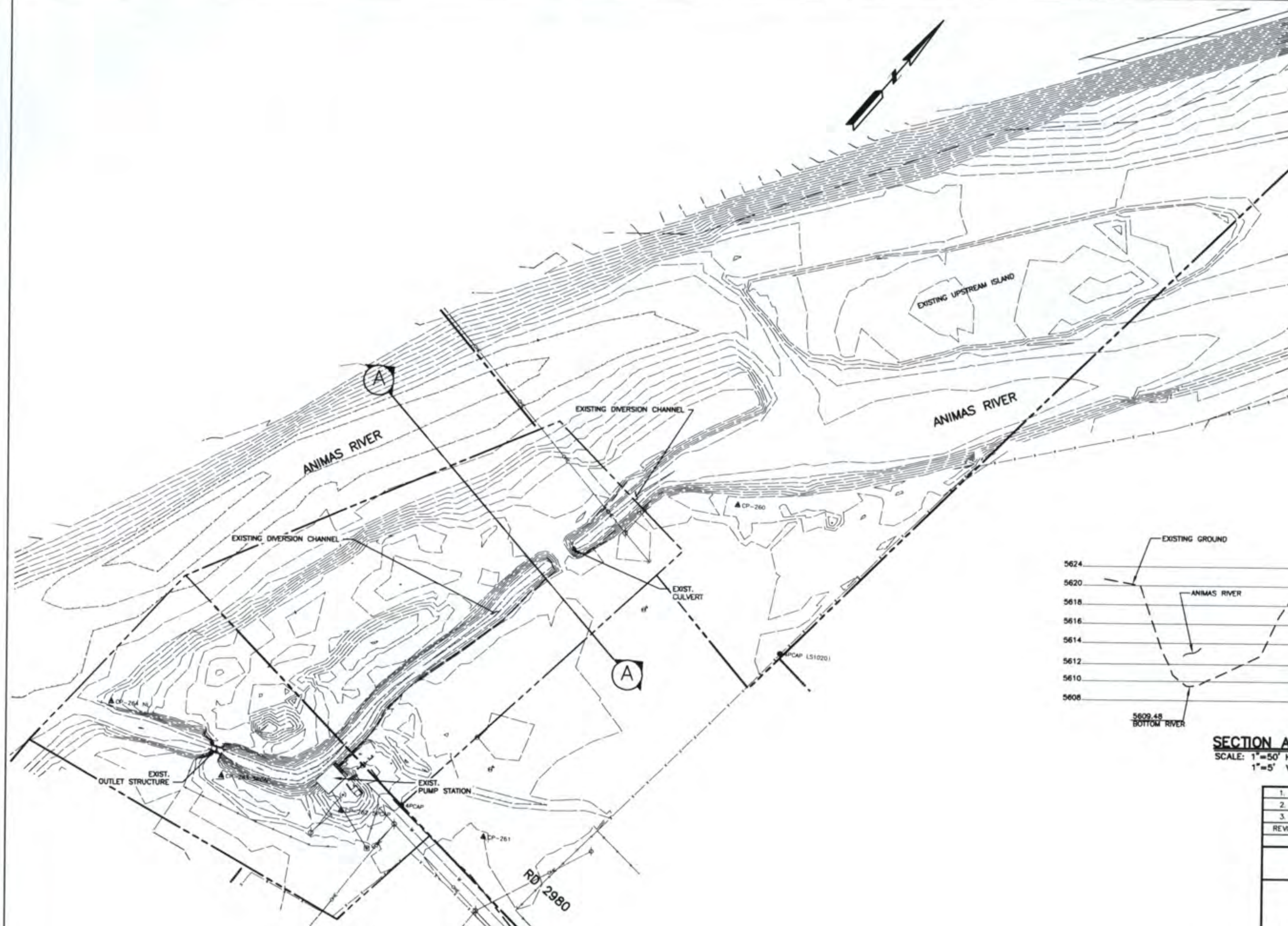
6.1.2 Model Assumptions

During the first simulation for the 100-year river flow, it was noticed that the east riverbank is not at a sufficient elevation to contain the flow. Therefore, the ground elevation in HEC-RAS was extended approximately 600 feet east using inferred elevations in order to contain the river and alleviate model errors. Other assumptions in the model are as follows:

- The diversion channel is free of obstructions and plant growth,
- The control gates on the diversion channel are fully open,
- The culvert pipe in the diversion channel is clear of debris and obstructions,
- Mannings n values are 0.025 for the riverbed and 0.045 for the overbank areas with vegetation and
- No ice cover is present.

6.1.3 Model Results

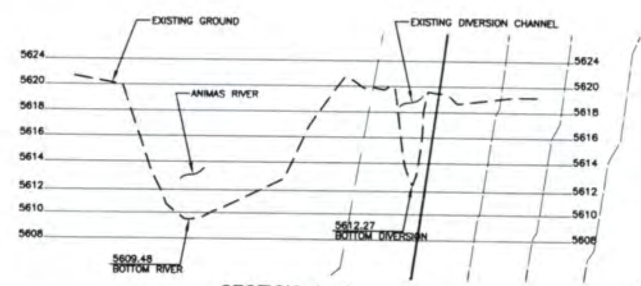
Once the parameters were coordinated and the assumptions known, HEC-RAS was executed to determine the current hydraulic conditions that exist at the site under the three flow conditions previously mentioned. HEC-RAS is consistent with the requirements of *NMSHTD Drainage Manual Volume II, Hydraulics, Sedimentation and Erosion*. Analysis results are attached in Appendix B. These results will serve as a baseline to compare results from proposed hydraulics of similar HEC-RAS models for the applicable proposed options.



PLAN VIEW
SCALE: 1"=40'

LEGEND

- 5' EXISTING CONTOURS
- 1' EXISTING CONTOURS
- 5' NEW CONTOURS
- 1' NEW CONTOURS
- EDGE OF EXISTING CONCRETE
- NEW RIPRAP
- EXISTING BUILDING
- NEW WALL
- EXISTING WATER LINE W/ VALVE
- EXISTING OVERHEAD ELECTRIC LINE
- EXISTING RIPRAP
- LOT LINE
- CENTERLINE
- EASEMENT LINE
- CHAIN-LINK FENCE
- BARBED WIRE FENCE
- EXISTING WALL
- DRAINAGE AREA BOUNDARY
- DIRECTION OF FLOW – EXISTING OR DEVELOPED
- DRAINAGE FLOW ARROW
- FOUND PROPERTY CORNER
- SURVEY CONTROL POINT



SECTION A–A
SCALE: 1"=50' HORIZ.
1"=5' VERT.

REVISION	DATE	DESCRIPTION	BY
1.			
2.			
3.			

REVISIONS (OR CHANGE NOTICES)

CITY OF AZTEC
SAN JUAN COUNTY, NEW MEXICO

ANIMAS RIVER DIVERSION
EXISTING DIVERSION

LARKIN GROUP NM, INC
CONSULTING ENGINEERS AND SURVEYORS
8500 MENAUL BLVD. NE, SUITE A-440
ALBUQUERQUE, NEW MEXICO 87112
505-275-7500, FAX 505-275-0748
www.larkinnm.com

PROJECT NO.	DRAWN	CHECKED	DATE	SHEET
2011-0015	CAI	JC	JUNE 2013	13

6.2 Conventional Wells with Infiltration Galleries

A groundwater-flow model was constructed using MODFLOW in order to evaluate well production, effects of hydraulic conductivity, aquifer dewatering and well spacing on yield. The site-specific grid is the same as the regional model, but telescoped in on a smaller area with a more detailed grid.

6.2.1 Analysis Parameters

The model includes approximately one square mile of the Animas River Valley north of the City of Aztec (see Figure 7 of Appendix A). Also, the model contains three layers. The upper two layers are representative of the Animas Valley alluvium and their thickness is set at 5 feet and 15 feet respectively, while the lower layer is representative of the San Jose and Nacimiento Formations and has no set thickness. The two layers of the Animas Valley alluvial aquifer are required to better represent boundary conditions related to the Animas River and to evaluate vertical differences in hydraulic conductivity of the alluvium. To represent lateral and upward groundwater in-flow from the Nacimiento and San Jose Formations, constant-head cells were assigned to the model perimeter.

6.2.2 Model Assumptions

Since there are no available time-series water-levels and pumping data for model calibration, a range of hydraulic values for the alluvium was used for evaluating model results for the feasibility analysis. The observed sand and clay layer representative of the upper 5 feet of the alluvial aquifer was given a value of 10 ft/day, and the hydraulic conductivity for the lower 15 feet of coarse-grained alluvium was varied between 100 and 200 ft/day. The thickness of the two layers representative of the Animas Valley alluvial aquifer is also assumed. The model layers were allowed to have varying transmissivity and storage properties so the effects of aquifer dewatering on well yield could be evaluated.

6.2.3 Model Results

The specific capacity result from the groundwater flow model analysis indicates the yield from conventional wells alone would range between 100 and 200 gpm. The actual yield depends on the diameter of the wells, saturated thickness of the alluvial aquifer, hydraulic conductivity of the alluvium adjacent to the well screen and well spacing. The well spacing at the City of Aztec Animas River diversion facility property is limited by the property dimensions. The subject property is approximately 400 feet in length (parallel to the river) and 250 feet in width. Model results indicate the minimum well spacing is 75 feet, as well spacing less than 75 feet causes significant drawdown from well interference. Model simulated drawdown is shown on Figure 8 of Appendix A. Using the high-end hydraulic conductivity (200 ft/day), a 200-gpm well would have a sustained yield of 160 gpm. Using the low-end hydraulic conductivity (100 ft/day), a 100-gpm well would have a sustained yield of 65 gpm. Well production is increased by installing adjacent infiltration trenches hydraulically connected to the river, but the imposed boundary condition is not expected to increase the yield above 200 gpm. Even with an adjacent infiltration trench, the initial pumping is at the expense of groundwater storage causing drawdown that limits yield. The maximum model-simulated sustained yield from 6 vertical wells with adjacent infiltration trenches is 1,200 gpm. It may be possible to configure two lines of equally spaced wells on the parcel of land between the Animas River and the diversion canal for a maximum of ten vertical wells. The maximum model-simulated yield from 10 vertical wells with adjacent infiltration trench ranges between 1,000 and 2,000 gpm. See Appendix A for a complete analysis and results for this option.

6.3 Horizontal Wells

Again using MODFLOW, a groundwater-flow model was constructed and executed. The results are used in order to evaluate well production, effects of hydraulic conductivity, aquifer dewatering and well spacing on yield.

6.3.1 Analysis Parameters

The analysis parameters for this option are the same as described for the conventional wells with infiltration galleries. See Section 6.1.1 for analysis parameters.

6.3.2 Model Assumptions

The model assumptions for this option are the same as described for the conventional wells with infiltration galleries. See Section 6.1.2 for assumptions.

6.3.3 Model Results

There are a number of ways horizontal wells could be configured at the site. When considering the parcel of land west of the diversion canal, the best possible configuration of horizontal wells consists of seven 100-foot laterals trending northwest to southeast (see Figure 9 of Appendix A). The canal side of the laterals would have a pump chamber (Figures 6c and 9 of Appendix A), and the trench containing the laterals would consist of engineered backfill to maximize hydraulic connection with the Animas River. A series of model runs were used to evaluate the combined yield from the seven horizontal wells by varying the hydraulic connection to the Animas River and hydraulic conductivity of the alluvium. The model-simulated range in combined yield from the seven horizontal wells is 1,400 to 2,800 gpm. For a complete analysis of this option with model results, see Appendix A.

6.4 Re-Aligned Diversion Channel

An analysis of the proposed hydraulics was performed using HEC-RAS in order to determine the effects to the river by modifying the diversion alignment. Results such as water surface elevations along different cross sections of the re-aligned diversion model are compared to the existing model to verify compliance with the FEMA, City of Aztec and the San Juan County Flood Commission ordinance. The resulting velocity and Froude's number are also compared to the existing model.

6.4.1 Analysis Parameters

Utilizing AutoCAD Civil 3D 2012, the channel was realigned and a ground surface was created. The new ground surface depicts the proposed horizontal and vertical alignment of the channel integrated into existing conditions. Furthermore, the new surface takes into account the removal of the constructed berm, removal of a portion of the upstream island, removal of a portion of the island between the diversion channel and the river and re-alignment of the diversion channel inlet (see Figure 10). Data from this surface was exported into HEC-RAS, and a proposed model was executed to determine the hydraulic effects.

6.4.2 Model Assumptions

The model assumptions specific to this option are as follows:

- Bank slopes along cut islands and the diversion channel are 2H:1V maximum,
- A portion of the former diversion channel has been filled to match the surrounding ground elevation,
- The realigned diversion channel alignment has a smooth transition to the existing diversion channel at the pump station,
- The diversion channel bottom has been excavated to an elevation of 5612 at the inlet with a uniform slope to the pump station and outlet to the river,
- A new control head gate has been placed at the inlet to the diversion channel and
- An "n" value = 0.015 has been placed on the concrete wall just upstream of the diversion channel head gate.

6.4.3 Model Results

The model results indicate that the water surface elevation during a 100-year event increases by 0.1 feet (maximum). This is under the one-foot threshold of the FEMA, City of Aztec and San Juan County. Also, the average velocity is decreased in the area of the current diversion and increased upstream of the current diversion. It also important to point out that even with the changes in river velocity, the subcritical flow regime is unaffected. Full analysis results are attached in Appendix C.

6.5 Diversion Weir

An analysis of the proposed hydraulics was performed using HEC-RAS in order to determine the effects to the river by adding a diversion weir across the river. Again, results such as water surface elevation, velocity and Froude's number are compared to determine compliance with the regulatory agencies.

6.5.1 Analysis Parameters

Utilizing AutoCAD Civil 3D 2012, a new ground surface was created depicting the removal of the berm and proposed horizontal and vertical alignment of the channel integrated into the proposed diversion weir. A concrete weir structure has been placed across the river channel just upstream of the pump station. This weir has a constant top elevation of 5612.5 with a 5-foot wide notch at a bottom elevation of 5611.7. This data was imported into HEC-RAS, and a proposed model was executed. Figure 12 shows a graphical representation of the data used for the model.

6.5.2 Model Assumptions

The assumptions used in the HEC-RAS for this option include:

- The river channel bottom elevation at the weir location is unchanged from the 5608.5 elevation,
- A new diversion channel has been excavated from the riverbank at the upstream side of the weir to the pump station,
- The former diversion channel has been filled as necessary to the surrounding ground elevation,
- The realigned diversion channel alignment has a smooth transition to the existing diversion channel at the pump station,
- The diversion channel bottom has been excavated to an elevation of 5611.7 at the weir with a uniform slope to the pump station and outlet to the river channel downstream and
- A new control head gate has been placed at the inlet to the diversion channel for maintenance purposes.

6.5.3 Model Results

The proposed river weir model results show an increase in water surface elevation above the weir that appears to be over one foot higher than existing conditions. This, according to San Juan

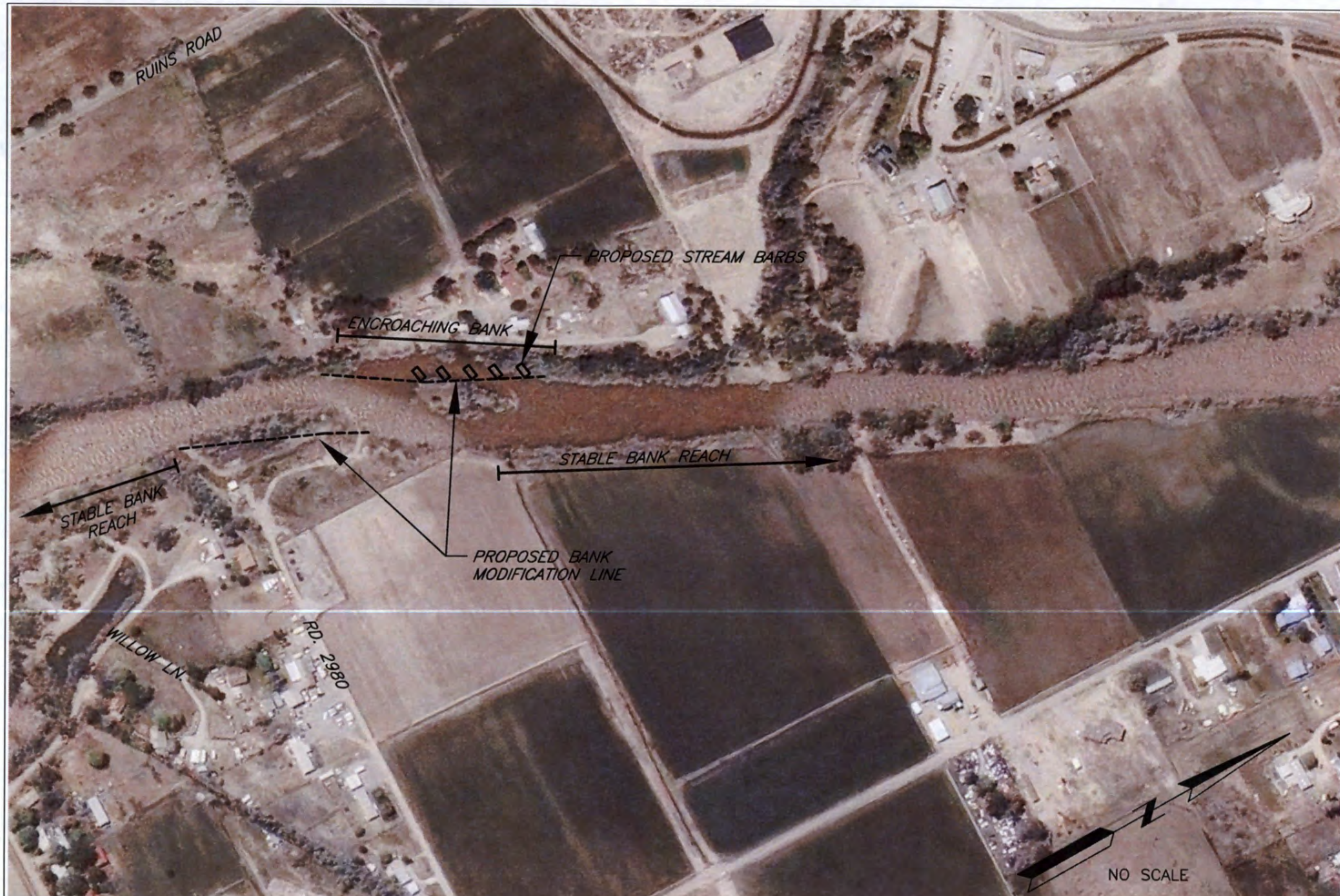
County's Flood Ordinance, would constitute a Conditional Letter of Map Revision (CLOMR). Also, during higher flows the weir appears to cause a transition to supercritical flow in an area that currently is subject to subcritical flow. This is more than likely due to the disruption in velocity and energy caused by the weir. Results are attached in Appendix D.

6.6 River Morphology and Sediment Transport

As shown in Figure 14, there are stable bank reaches both above and below the current diversion point. Currently, the reach where the diversion is located shows signs of deposition both in the river (the upstream island) and in the area of the diversion (sediment at the inlet). Also, the riverbed across from the diversion pump station has been narrowed and deepened as a result of the constriction at the diversion inlet. Means to mitigate these conditions and bring the river back to a state of more natural morphology have been integrated into the re-aligned channel and the diversion weir option as discussed above.

6.7 Environmental and Archeological Evaluation

See Appendix E for a preliminary evaluation and memo discussing the anticipated environmental and archeological aspects that may be encountered on this project.



LARKIN GROUP NM, INC.

CONSULTING ENGINEERS AND SURVEYORS
8500 MENAUL BLVD. NE, SUITE A-440
ALBUQUERQUE, NEW MEXICO 87112
505-275-7500, FAX 505-275-0748
www.larkinnm.com

CITY OF AZTEC, NEW MEXICO
ANIMAS RIVER DIVERSION
FIGURE 14 – CONCEPTUAL MORPHOLOGY IMPROVEMENTS

7.0 CONCLUSIONS AND RECOMMENDATIONS

Water quality issues are a major disadvantage to utilizing wells to divert river water, because the water chemistry would be different from what is currently being pumped from this diversion. Effects on the water treatment plant integrity must be considered. One aspect to consider when introducing different water to an existing plant is the hardness and the potential to foul membranes and/or other ancillary treatment units. Hardness is known for sub-surface and surface waters at a location approximately four miles downstream of the diversion. These values are assumed at the diversion and are determined to be 650 mg/L for sub-surface water and 120 mg/L for surface water. We believe that an over 400% increase in hardness will significantly change the operation of the treatment plant. This coupled with testing costs and time constraints required to further investigate an infiltration gallery or a horizontal well renders these options unfeasible. It would be beneficial to the City to consider an option that utilizes surface water.

Although a diversion weir offers the advantage of ensuring surface water is diverted into the channel and pump station at flows under 100 cfs, the liability associated with obstructing the river overshadows this advantage. Furthermore, this option comes with the added expense of re-determining FEMA flood maps since the water surface elevation at the weir increases more than one foot. Lastly, river morphology is very sensitive to this option and can potentially create sediment deposits at locations different from what has been seen historically. These concerns are alleviated in the re-aligned diversion option. Therefore, it is recommended that the existing diversion channel be re-aligned and improved as described in Section 5.3.

Pending a detailed analysis and design, with respect to hydrology, hydraulics and river morphology, realigning the diversion channel will:

- Provide a year-round water supply for the City of Aztec.
- Eliminate the need for the annual berm construction.
- Begin the stabilization of the indicated reach.
- Provide 6 cfs in the diversion at 100-cfs river flow.

Some of the key design features of the re-aligned diversion channel are shown below. These suggested improvements are included in the re-aligned diversion option hydraulic analysis and are shown in Figure 10. They are:

- Install smooth concrete headwall and concrete wall at and just upstream of the diversion entrance to enhance sediment movement away from the inlet.
- Provide concrete lining of a portion of the diversion channel (if not all) to further enhance sediment movement. Lining will also provide a base elevation during maintenance.
- Lower the bed elevation of the diversion channel to better match the river channel.
- Replace the culvert and head gate to match the new lowered elevation.
- Use lower inlets to the pump station or modify the pump station to work with a lower water surface elevation in the diversion channel.
- Install erosion control devices (such as stream barbs) on the west riverbank to favor sediment accumulation there and facilitate sediment transport at the east riverbank and diversion inlet.
- Remove a portion of the island upstream of the diversion to promote natural morphology.
- Remove portions of the east riverbank between the diversion inlet and outlet to alleviate bottleneck and reduce the riverbed scour.

8.0 LIST OF APPENDICES

Appendix A – Hydrogeologic Evaluation of Developing a Groundwater Supply from the Animas River Valley Alluvium

Appendix B – Existing Hydraulic Data

Appendix C – Proposed Hydraulic Data for Re-Aligned Diversion Channel

Appendix D – Proposed Hydraulic Data for Diversion Weir

Appendix E – Environmental and Archeological Preliminary Evaluation

9.0 REFERENCES

1. Federal Emergency Management Agency, *Flood Insurance Study Number 35045CV000A*, August 5, 2010.
2. New Mexico State Highway and Transportation Department, *Drainage Manual, Volume I, Hydrology*, 1995.
3. New Mexico State Highway and Transportation Department, *Drainage Manual, Volume II, Hydraulics, Sedimentation and Erosion*, 1998.
4. U.S. Army Corps of Engineers, *HEC-RAS, River Analysis System, Users Manual, Version 3.0*, Hydrologic Engineering Center, 2001.

Appendix A

Hydrogeologic Evaluation of Developing a Groundwater Supply from the Animas River Valley Alluvium

DRAFT

HYDROGEOLOGIC EVALUATION OF DEVELOPING A GROUNDWATER SUPPLY FROM THE ANIMAS RIVER VALLEY ALLUVIUM, CITY OF AZTEC, NEW MEXICO

prepared by

Steven T. Finch, Jr., CPG

Roger Peery, CPG

JOHN SHOMAKER & ASSOCIATES, INC.

Water-Resource and Environmental Consultants

2611 Broadbent Parkway NE

Albuquerque, New Mexico 87107

505-345-3407

www.shomaker.com

prepared for

Larkin Group NM, Inc.

Albuquerque, New Mexico

February 2012

DRAFT

HYDROGEOLOGIC EVALUATION OF DEVELOPING A GROUNDWATER SUPPLY FROM THE ANIMAS RIVER VALLEY ALLUVIUM, CITY OF AZTEC, NEW MEXICO

prepared by

Steven T. Finch, Jr., CPG

Roger Peery, CPG

JOHN SHOMAKER & ASSOCIATES, INC.
Water-Resource and Environmental Consultants
2611 Broadbent Parkway NE
Albuquerque, New Mexico 87107
505-345-3407
www.shomaker.com

prepared for

Larkin Group NM, Inc.
Albuquerque, New Mexico

February 2012

CONTENTS

page

TABLES

page

ILLUSTRATIONS

(follow text)

HYDROGEOLOGIC EVALUATION OF DEVELOPING A GROUNDWATER SUPPLY FROM THE ANIMAS RIVER VALLEY ALLUVIUM, CITY OF AZTEC, NEW MEXICO

1.0 INTRODUCTION

John Shomaker & Associates, Inc. (JSAI) was contracted by Larkin Group, Inc. to evaluate the feasibility of developing a groundwater supply from the Animas River Valley alluvium for the City of Aztec (City), New Mexico. Currently, the City obtains its water supply from a surface-water diversion facility on the Animas River (Fig. 1). Due to issues with the surface-water diversion structure and subsequent river bed sedimentation, the City of Aztec would like to explore the option of developing groundwater at the same location along the Animas River.

1.1 Previous Work

JSAI (2003) performed an initial evaluation of the shallow groundwater system. The previous work included drilling and testing of an exploratory well, and preliminary yield analysis using a pro-forma groundwater-flow model. A pumping test performed on the exploratory well indicated the alluvial aquifer has a high hydraulic conductivity (>75 ft/day). The groundwater-flow modeling and yield analysis were based on the conservative assumption that the river was dry and the only source of water was from groundwater storage in the shallow alluvium. Under extreme drought conditions it was estimated that a 1,000-ft horizontal L-shaped well would yield approximately 260 gallons per minute (gpm). It was also stated that it may be possible to produce larger quantities of water from a shallow or horizontal well when considering recharge from the river.

In 2011, Terracon performed a geotechnical evaluation of sediments excavated from test pits dug into the shallow alluvial aquifer around the City of Aztec surface-water diversion facility. The test pits primarily contained poorly sorted gravel with sand and cobbles; similar to the shallow aquifer characteristics observed at the nearby exploratory well (JSAI, 2003).

1.2 Project Objective

The objectives of this project are to review all available data, update the JSAI (2003) groundwater-flow model, evaluate yield from the shallow aquifer, and recommend alternatives for developing a groundwater diversion system.

1.3 Diversion Requirements

The City of Aztec has three points of diversion approved by the New Mexico Office of the State Engineer (NMOSE): 1) Animas River, 2) Lower Animas Ditch, and 3) Aztec Ditch (see Fig. 1). The City has an instantaneous diversion limit of 2,500 gpm from the Animas River point of diversion, and a calendar year limit of 1,422 acre-feet (ac-ft). The City diverted approximately 1,390 ac-ft in 2011 from the Animas River surface-water facility (Fig. 2). In 2011, monthly diversions ranged between 50 and 200 ac-ft, and estimated peak-day demand was near 3 million gallons per day (MGD) or 2,000 gpm.

2.0 HYDROGEOLOGIC SETTING

The Animas River Valley directly north of the City of Aztec contains a shallow aquifer composed of alluvium, underlain by the Nacimiento Formation. Groundwater-flow direction follows the land surface, and the Animas River is gaining from groundwater inflow originating from deep regional flow paths in the San Juan Basin (GRI, 1991).

Most water-supply wells in the Animas River Valley are completed in the alluvial aquifer. Numerous oil and gas wells in the area target deeper sandstone and coal bed formations of the San Juan Basin. Irrigation ditches run parallel to the Animas River on both sides of the valley (Fig. 1).

2.1 Animas River

The U.S. Geological Survey (USGS) maintains stream measurement data from a gage (USGS Station 09364010) on the Animas River located south of the City of Aztec (Fig. 1). A statistical summary of the stream-measurement data can be referenced from Table 1, and a graph of average daily streamflow is presented as Figure 3. The Animas River stage can vary approximately 6 ft between low flow and spring runoff.

The base streamflow ranges between 100 and 200 cubic feet per second (cfs), which likely represents baseflow from the upper watershed in Colorado plus groundwater inflow along the New Mexico section of the river. Groundwater inflow to the New Mexico section of the Animas River has been estimated at 47 cfs (USBR, 2002). The stretch of Animas River near the City of Aztec is not expected to go dry during drought conditions. Low flow conditions in the Animas River may be amplified during the irrigation season by diversions to Farmers Ditch, Lower Animas Ditch, and the Aztec Ditch; see streamflow events below 100 cfs on Figure 3.

Table 1. Statistical summary of measured Animas River streamflow data at USGS station 09364010, below the City of Aztec, New Mexico

statistic	gage height (ft)	discharge (cfs)	channel width (ft)	channel area (ft^2)	channel velocity (ft/sec)
average	7.63	924	104	207	3.99
median	7.52	382	107	158	2.64
minimum	5.15	88	63	4	0.88
maximum	11.43	5,520	188	666	62.90

cfs - cubic feet per second ft/sec - feet per second

2.2 Alluvial Aquifer

The extent of the Animas River Valley alluvial aquifer is shown on Figure 4. The alluvium varies in grain size from boulders to clay, but mostly consists of sand and gravel. The average thickness is reported to be approximately 60 ft, which generally occurs in the center of the valley (Brown and Stone, 1979). JSAI reviewed 47 well records from NMOSE permitted wells in the Animas River Valley area (see Fig. 4). A summary of the well record data is listed in Table 2. It appears that a good percentage of the wells in the Animas River Valley are not drilled to the total depth of the alluvial aquifer; however, from the well logs, the average saturated thickness of the alluvium is 22 ft. The maximum reported alluvial saturated thickness was 50 ft (NMOSE, 2010).

As observed from the test pits investigation performed by Terracon (2011) and reported in several well records, the upper 5 to 10 ft of alluvium can locally contain finer-grained sediments than the underlying sand, gravel, cobbles, and boulders. The lateral extent of the fine grained sediments is unknown, and may be localized to fluvial overbank depositional environments. The coarse-grained lower unit of the alluvium is mostly outwash from Pleistocene-age glaciers in the San Juan Mountains (Bandoian, 1968).

Table 2. Summary of reported alluvial aquifer characteristics from New Mexico Office of the State Engineer well records

characteristic	unit	value
average well depth	ft bgl	48
average depth to water	ft bgl	23
average yield	gpm	17
average saturated thickness	ft	22

ft bgl - feet below ground level gpm - gallons per minute

A schematic west to east hydrogeologic cross-section through the Animas River Valley is presented as Figure 5. The alluvial thickness appears to increase between the Animas River and the eastern side of the valley. Shown on Figure 5 is the estimated distribution of the upper finer-grained unit and the lower coarser-grained unit in the alluvium. The localities with thicker alluvium likely represent paleo-channels filled with outwash. The alluvial thickness at the City of Aztec Animas River diversion facility is about 22 ft. The saturated thickness of the alluvium likely varies several feet with respect to river stage.

The hydraulic conductivity of the Animas River Valley alluvium is not well known. Analysis of the pumping test JSAI (2003) performed on the exploratory well at the City of Aztec Animas River diversion facility suggests a hydraulic conductivity in the range of 75 to 100 ft/day. Hydraulic conductivity values less than 100 ft/day for coarse-grained alluvium appear low, and it is possible that sand accumulation in the exploratory well during the test may have resulted in a lower estimate of hydraulic conductivity. Hydraulic conductivity values from other pumping tests in the Animas River Valley range from 27 to 400 ft/day (NMOSE, 2010; Stone et al., 1983).

When considering the coarse-grained stream alluvium, reasonable estimates of hydraulic conductivity would range between 100 and 300 ft/day. Some examples of hydraulic conductivity values for stream alluvium in other parts of New Mexico are summarized in Table 3.

Table 3. Summary of hydraulic conductivity values derived from pumping tests performed on stream alluvium in New Mexico

location	hydraulic conductivity (ft/day)	source
Rio Grande alluvium in White Rock Canyon	267 to 347	JSAI (2011)
Whitewater Creek alluvium, Hurley, New Mexico	175 to 250	JSAI (2001)
Santa Cruz River alluvium, Chimayo, New Mexico	84 to 285	JSAI (2005)

JSAI - John Shomaker & Associates, Inc.

3.0 WATER DEVELOPMENT ALTERNATIVES

There are several alternatives for developing groundwater from the shallow aquifer at the City of Aztec Animas River diversion, which include the following:

1. large diameter conventional wells
2. large diameter conventional wells with infiltration beds
3. horizontal well(s) installed by excavating trench(es)

Other types of shallow wells with horizontal completions including Collector Wells (Ranney Well) and conventionally drilled horizontal wells are not considered feasible because of the presence of cobbles and boulders that would impede advancement of the drill bit or driven lateral screen sections.

3.1 Conventional Wells

The yield of domestic wells in the Animas River Valley is limited by drilling methods, well construction, development, and casing diameter. Brown and Stone (1979) noted that most domestic wells in the area yield 10 to 20 gpm, and that the yield can be increased tenfold with improved construction and development. Large diameter shallow conventional wells could easily be installed at the City of Aztec Animas River diversion location. Optimum well completion would involve stainless-steel high open area screen from the water table to total depth of the alluvium, and a 15- to 20-ft pump chamber installed below the base of the alluvium. A proposed completion diagram is shown as Figure 6a.

There is an optimum well diameter for maximizing specific capacity and well yield. As shown in Table 4, well yield can be increased by more than 30 percent by a threefold increase in the casing diameter.

At the City of Aztec Animas River diversion facility, the yield from individual conventional wells could range between 100 and 200 gpm, but sustained yields depend on capture efficiency of surface water and its influence on drawdown and specific capacity.

Table 4. Estimated specific capacity and well yield for different casing diameters

well diameter (inches)	specific capacity (gpm/ft)*	potential yield (gpm)**
12	15.0	150
18	16.5	165
24	17.0	170
30	18.5	185
36	20.0	200

* based on hydraulic conductivity of 150 ft/d and saturated thickness of 20 ft
** based on 10 ft of available drawdown and no surface water boundary conditions
gpm/ft - gallons per minute per foot of drawdown
gpm - gallons per minute

3.2 Conventional Wells With Infiltration Trenches

As previously discussed, the sustained well yield could be significantly increased by creating infiltration trenches that bring the river water closer to the well. The concept is to excavate infiltration trenches below the fine-grained unit and backfill with coarser-grained material. Excavation depths are estimated to be less than 5 ft, and approximately 8 ft in width. The trenches would run essentially parallel to the river, and on both sides of the proposed conventional wells. A proposed completion diagram is shown as Figure 6b. The trenches would allow river water to enter upstream and flow past the wells: similar to the concept of a French drain.

The proximity of the infiltration trenches would offset the effects of drawdown in the conventional well, particularly the drawdown effects of wells on each other. Theoretically, the infiltration trenches should be capable of offsetting the total diversion rate from the conventional wells.

3.3 Horizontal Well(s)

Due to the large cobbles and boulders found in the alluvium, horizontal wells would have to be installed using trench and trench box construction. Trenching is typically limited to a maximum depth of 20-ft. The horizontal well screen would have a gravel envelope, so the maximum depth of the screen in a 20 ft trench would be 18 to 19 ft. A proposed completion diagram is shown as Figure 6c.

Inflows to horizontal screens in shallow alluvial aquifers can range between 0.5 to 2 gpm per foot of horizontal screen (CWI, 2001). Ideally, the horizontal well would be installed parallel or diagonal to the Animas River, and a pump chamber would be required at the downgradient end of the well. Yield may be increased by creating an infiltration bed above the horizontal well that would be connected to the river. The horizontal well capacity could be increased by installing designed backfill above the screen that allows better hydraulic connection with river water (Fig. 6c).

4.0 GROUNDWATER-FLOW MODEL ANALYSIS

A groundwater-flow model was constructed using MODFLOW. The model includes approximately 1 square mile of the Animas River Valley north of the City of Aztec (Fig. 7). Two different grid spacings were used: 1) model cell dimensions of 100 by 100 ft, and 2) site-specific grid spacing with model cell dimensions of 20 by 20 ft surrounding the City of Aztec Animas River diversion facility. The site-specific grid is the same as the regional model, but telescoped in on a smaller area with a more detailed model grid.

The model contains three layers: 1) upper two layers representative of the Animas Valley alluvium, and 2) lower layer representative of the San Jose and Nacimiento Formations. The alluvial aquifer was divided into two layers: 1) upper 5 ft, and 2) lower 15 ft to better represent boundary conditions related to the Animas River and to evaluate vertical differences in hydraulic conductivity of the alluvium. Model-assigned hydraulic properties are summarized in Table 5.

The MODFLOW RIV package was used to simulate boundary conditions established by the Animas River, and constant-head cells were assigned to the model perimeter to represent lateral and upward groundwater inflow from the Nacimiento and San Jose Formations.

Table 5. Summary of model assigned hydraulic properties

aquifer unit	hydraulic conductivity (ft/day)	specific yield	specific storage (1/ft)
alluvium	10 to 200	0.15	$1x10^{-6}$
San Jose/Nacimiento Formations	1	0.10	$1x10^{-6}$

There are no available time-series water-level and pumping data for model calibration. In place of model calibration, a range of hydraulic values for the alluvium were used for evaluating model results for the feasibility analysis. The observed sand and clay layer representative of the upper 5 ft of the alluvial aquifer was given a value of 10 ft/day, and the hydraulic conductivity for the lower 15 ft of coarse-grained alluvium was varied between 100 and 200 ft/day. The model layers were allowed to have varying transmissivity and storage properties (MODFLOW layer type 3) so the effects of aquifer dewatering on well yield could be evaluated.

4.1 Evaluation of Conventional Wells

The specific capacity analysis presented in Table 4 and results from the groundwater-flow model analysis indicate the yield from a conventional well would range between 100 and 200 gpm. The actual yield depends on diameter of well, saturated thickness of alluvial aquifer, hydraulic conductivity of alluvium adjacent to the well screen, and well spacing. The groundwater-flow model analysis was used to evaluate effects of hydraulic conductivity, aquifer dewatering, and well spacing on yield. The aquifer thickness was assumed to be 20 ft, but additional drilling and time-series water-level data are needed to further evaluate variations in alluvial aquifer thickness at the diversion site.

The well spacing at the City of Aztec Animas River diversion facility property is limited by the property dimensions. The subject property is approximately 400 ft in length (parallel to the river) and 250 ft in width. Model results indicate the minimum well spacing is 75 ft; well spacing less than 75 ft causes significant drawdown from well interference. Model-simulated drawdown is shown on Figure 8. A maximum of six wells parallel to the river could be configured at the City of Aztec Animas River diversion facility.

Model-assigned hydraulic conductivity and subsequent transmissivity of the alluvium influence the degree of drawdown and aquifer dewatering around the well. Transmissivity and well yield decrease as the aquifer dewaters. Using the high-end hydraulic conductivity (200 ft/day), a 200 gpm well would have a sustained yield of 160 gpm. Using the low-end hydraulic conductivity (100 ft/day), a 100 gpm well would have a sustained yield of 65 gpm.

The maximum model-simulated sustained yield from six conventional wells at the diversion site is 960 gpm when considering a hydraulic conductivity of 200 ft^2/day for the lower 15 ft of alluvial aquifer, and 400 gpm when considering a hydraulic conductivity of 100 ft/day for the lower 15 ft of alluvial aquifer.

It may be possible to increase the yield of a conventional well by installing adjacent infiltration trenches hydraulically connected to the river, but the imposed boundary condition is not expected to increase the yield above 200 gpm. Even with an adjacent infiltration trench, the initial pumping is at the expense of groundwater storage causing drawdown that limits yield. The maximum model-simulated sustained yield from six vertical wells with adjacent infiltration trenches is 1,200 gpm. It may be possible to configure two lines of equally spaced wells on the parcel of land between the Animas River and the diversion canal for a maximum of ten vertical wells. The maximum model-simulated yield from ten vertical wells with adjacent infiltration trench ranges between 1,000 and 2,000 gpm.

4.3 Evaluation of Horizontal Wells

There are a number of ways horizontal well(s) could be configured at the City of Aztec Animas River diversion facility. When considering the parcel of land west of the diversion canal, the best possible configuration of horizontal wells consists of seven 100-ft laterals trending northwest to southeast (see Fig. 9). The canal side of the laterals would have a pump chamber (Figs. 6c and 9), and the trench containing the later would consist of engineered backfill to maximize hydraulic connection with the Animas River. A series of model runs were used to evaluate the combined yield from the seven horizontal wells by varying the hydraulic connection to the Animas River and hydraulic conductivity of the alluvium. The model-simulated range in combined yield from the seven horizontal wells is 1,400 to 2,800 gpm.

4.4 Simulated Regional Drawdown

The model was used to evaluate drawdown at the nearest water-supply wells of other ownership resulting from shallow groundwater diversions at the City of Aztec Animas River diversion facility. The maximum model-simulated drawdown is shown on Figure 8. No significant drawdown effects occur from the proposed groundwater diversions because most of the pumped water will be at the expense of captured river water, and the alluvial aquifer is not thick enough to allow significant removal from groundwater storage and drawdown to propagate. Drawdown stabilized after 2 years of pumping.

5.0 FINDINGS

The work performed by JSAI (2003) recommended an L-shaped horizontal well 800 ft long with a 200-ft leg. The estimated yield was approximately 240 gpm, assuming a hydraulic conductivity of 100 ft/day, specific yield of 0.2, and the Animas River was dry, and all water came from groundwater storage. These assumptions were considered very conservative and minimized potential yield. Furthermore, it is suspected that the hydraulic conductivity of the alluvium is greater than the results (75 to 93 ft/day) obtained from the exploratory well pumping test performed by JSAI (2003), and a representative range in hydraulic conductivity values would be between 100 and 300 ft/day. The groundwater-flow model was used to evaluate the effects of hydraulic conductivity on well yield.

Streamflow statistics and calculations of groundwater inflow suggest the Animas River will not go dry and water will always be in the river to offset the effects of pumping from the alluvial aquifer. The river stage can vary by 6 ft, with low flow 2 ft below average stage and high flow 4 ft above average stage (Table 1). There are no available time-series water-level data to determine how river stage affects the saturated thickness of the alluvium at the City of Aztec Animas River diversion facility. Average flow conditions for the Animas River were considered for the groundwater-flow model analysis.

As determined from available well logs, the average reported alluvial saturated thickness is 22 ft, with a maximum reported saturated thickness of 50 ft. It is possible that the saturated thickness of the alluvium varies across the City of Aztec Animas River diversion facility site, but there are limited data to determine these local variations. To keep the analysis conservative, saturated thickness of the alluvium was assumed to equal 20 ft in the groundwater-flow model. Variations in alluvium grain-size were considered in the groundwater-flow model analysis by adjusting the vertical distribution of hydraulic conductivity. A lower hydraulic conductivity for the alluvium results in greater drawdown, lower specific capacity, and longer time needed to intercept river water.

Design considerations included vertical and horizontal wells (Fig. 6). Vertical wells may be able to yield 15 to 20 gpm per foot of drawdown (Table 4), where horizontal wells may be able to yield 1 to 4 gpm per foot of horizontal screen. The limiting effect of drawdown on yield can be mitigated by enhancing the hydraulic connection between the river and the well. Otherwise, the yield from a well is limited by available drawdown and saturated thickness of the alluvium. Vertical wells would have to be installed using casing-advance drilling methods. Due to the presence of cobbles and boulders in the alluvium, horizontal wells would have to be installed using trench and trench box methods.

Horizontal wells are favored over vertical wells due to the limited alluvial saturated thickness and availability of land at the City of Aztec Animas River diversion facility. The most efficient configuration of horizontal wells is shown on Figure 9, and consists of seven horizontal wells, diagonal to the river, with engineered backfill to enhance hydraulic connection to the river. Model-simulated yield from the seven horizontal wells ranges between 1,400 and 2,800 gpm.

Ideally the proposed groundwater diversion system would yield as much as the existing surface-water diversion system; therefore, drawdown would be the primary hydraulic effect created. Due to the hydraulic connection to the river, model-simulated drawdown is minimized and is less than 2 ft at the nearest well of other ownership.

6.0 RECOMMENDATIONS

There are viable options for groundwater diversions at the City of Aztec Animas River diversion facility. JSAI recommends pursuing these options by installing a test well that would further evaluate the feasibility of conventional and horizontal wells. One test well, constructed and tested in stages, could evaluate both options. The recommended test well program is outlined as follows:

1. Select test well location on land between river and existing diversion channel.
2. Install vertical well with a minimum 16-inch diameter to 35 ft using auger-casing advance methods. The well would also have an adaptor for attaching horizontal screen.
3. Perform pumping test on vertical well.
4. Install 60-ft horizontal 12-inch diameter well screen in trench and attach to conventional well.
5. Perform pumping test to assess addition of horizontal well screen.

If deemed successful, the test well could become part of the new groundwater diversion facility, and the testing results could be used to design remaining infrastructure. Dewatering would be required to attach the horizontal well screen to the vertical well. An application would need to be made to the NMOSE to change the point of diversion.

ILLUSTRATIONS

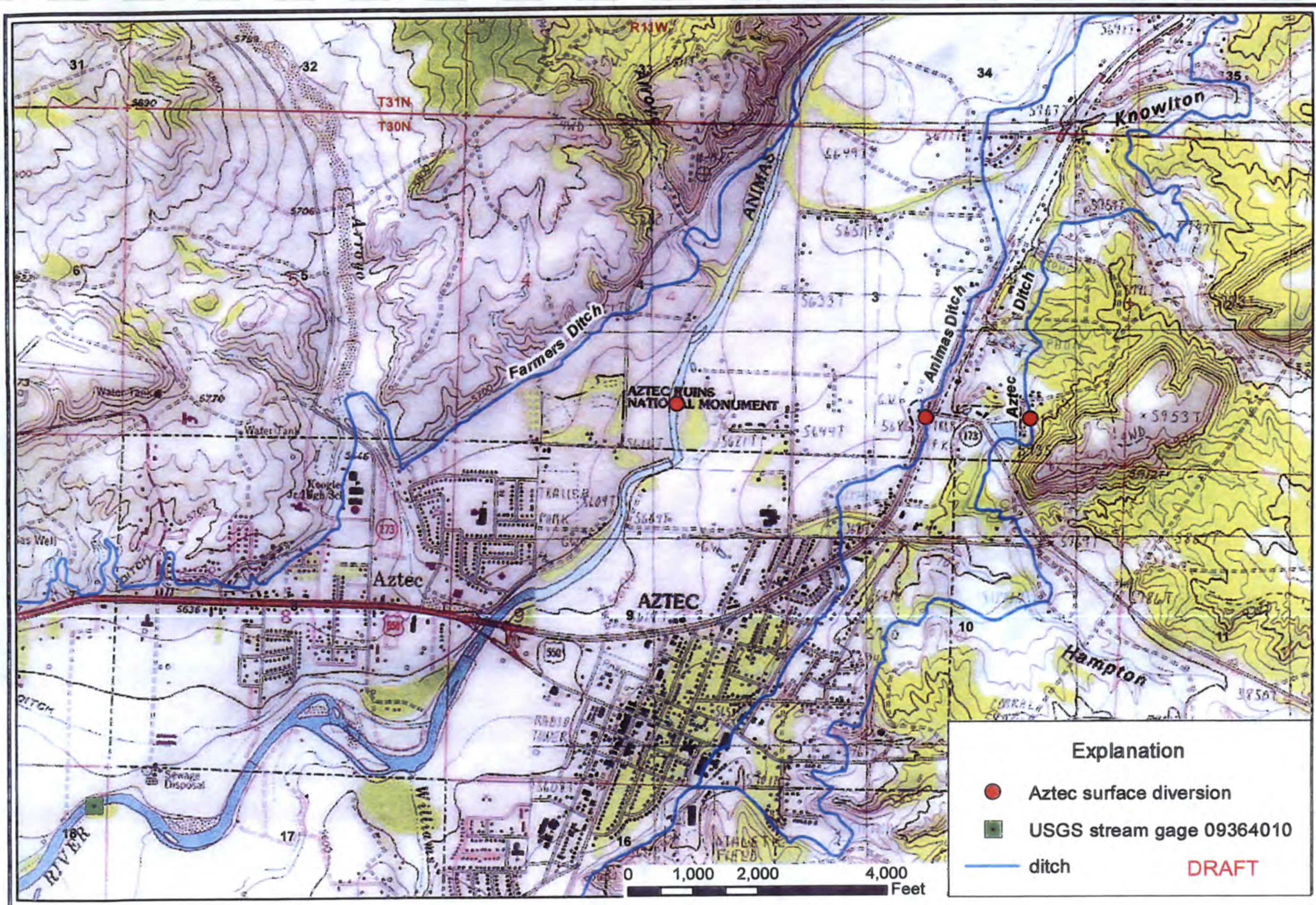


Figure 1. Topographic map showing locations of USGS stream gage 09364010, irrigation ditches, and City of Aztec surface-water diversion points in the Animas River Valley.

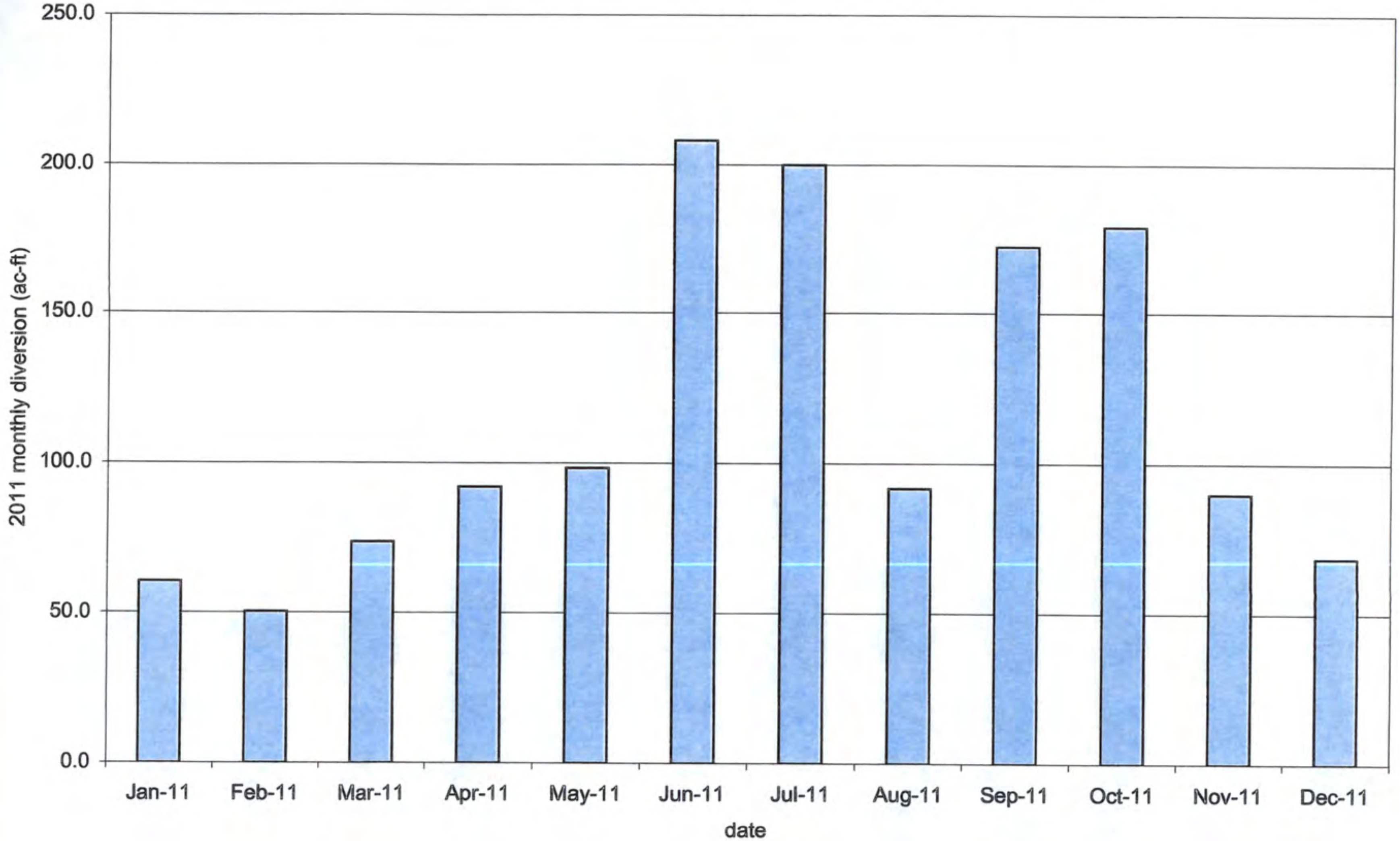


Figure 2. Bar graph of 2011 monthly diversions from the Animas River for City of Aztec, New Mexico.

DRAFT

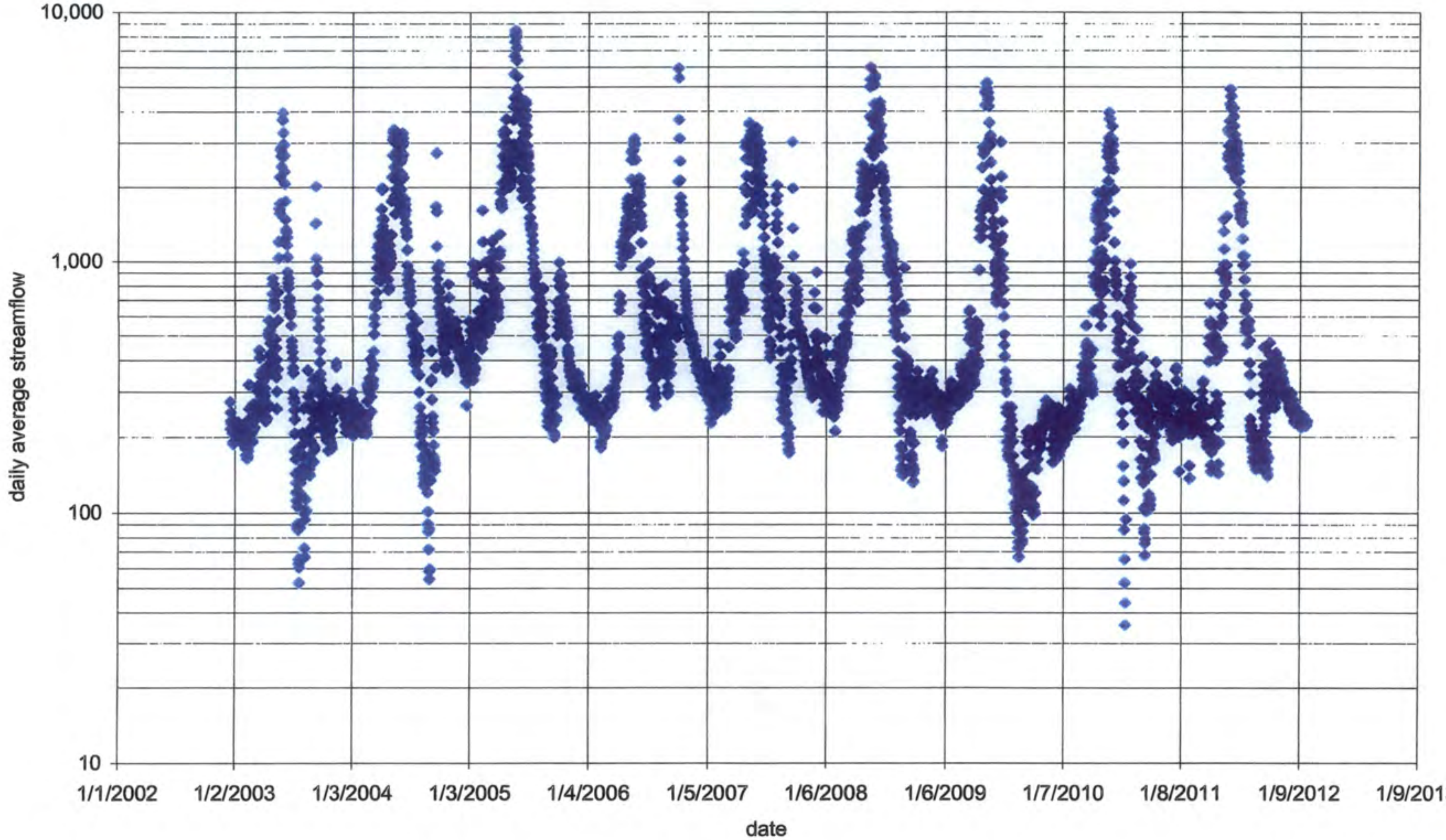


Figure 3. Graph of average daily streamflow at the USGS gage 09364010 for the Animas River near City of Aztec, New Mexico.

DRAFT

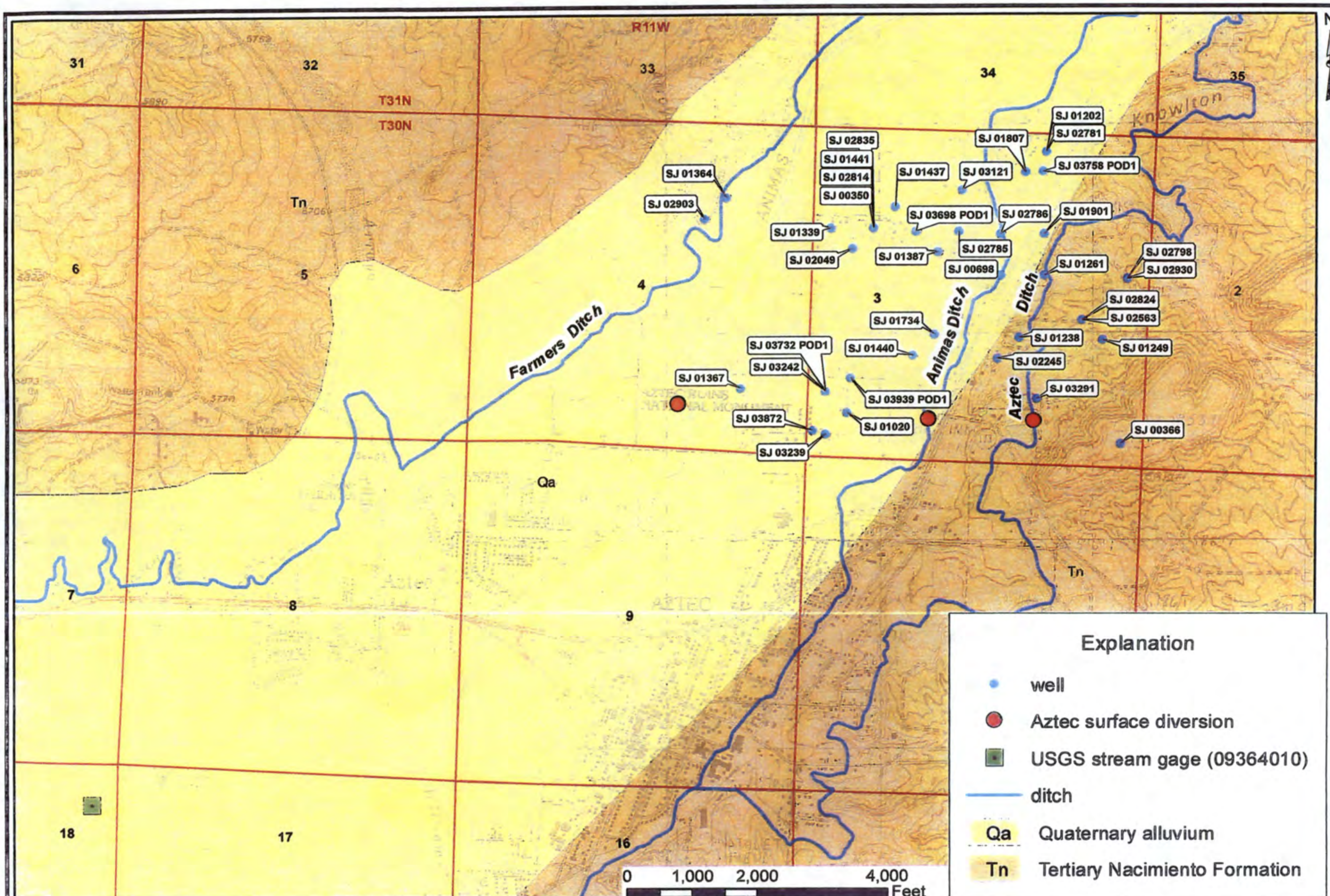


Figure 4. Geologic map of the Animas River Valley near City of Aztec, New Mexico and locations of selected wells. DRAFT

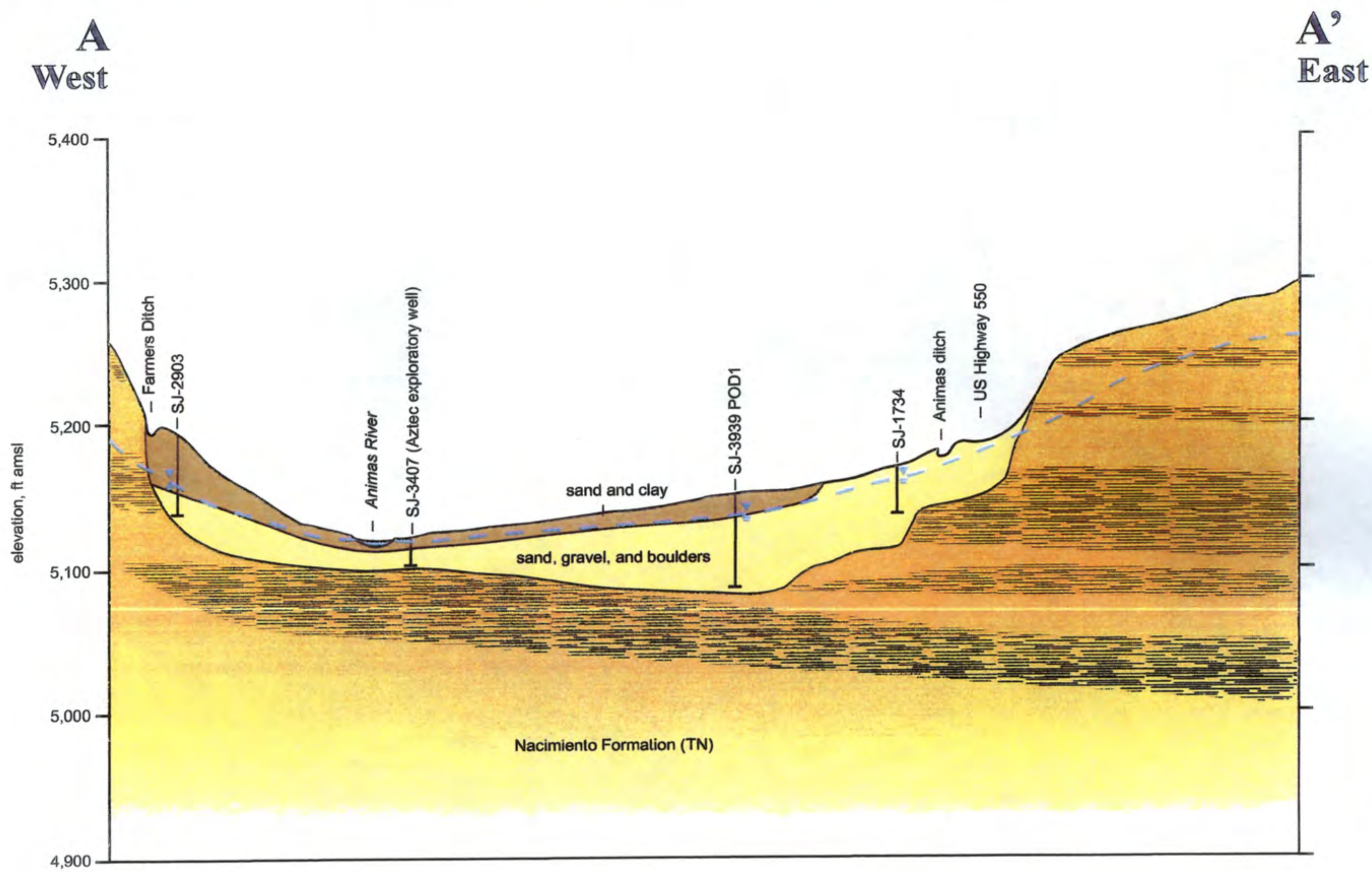


Figure 5. Schematic west to east hydrogeologic cross-section through Animas River Valley near City of Aztec, New Mexico.

DRAFT

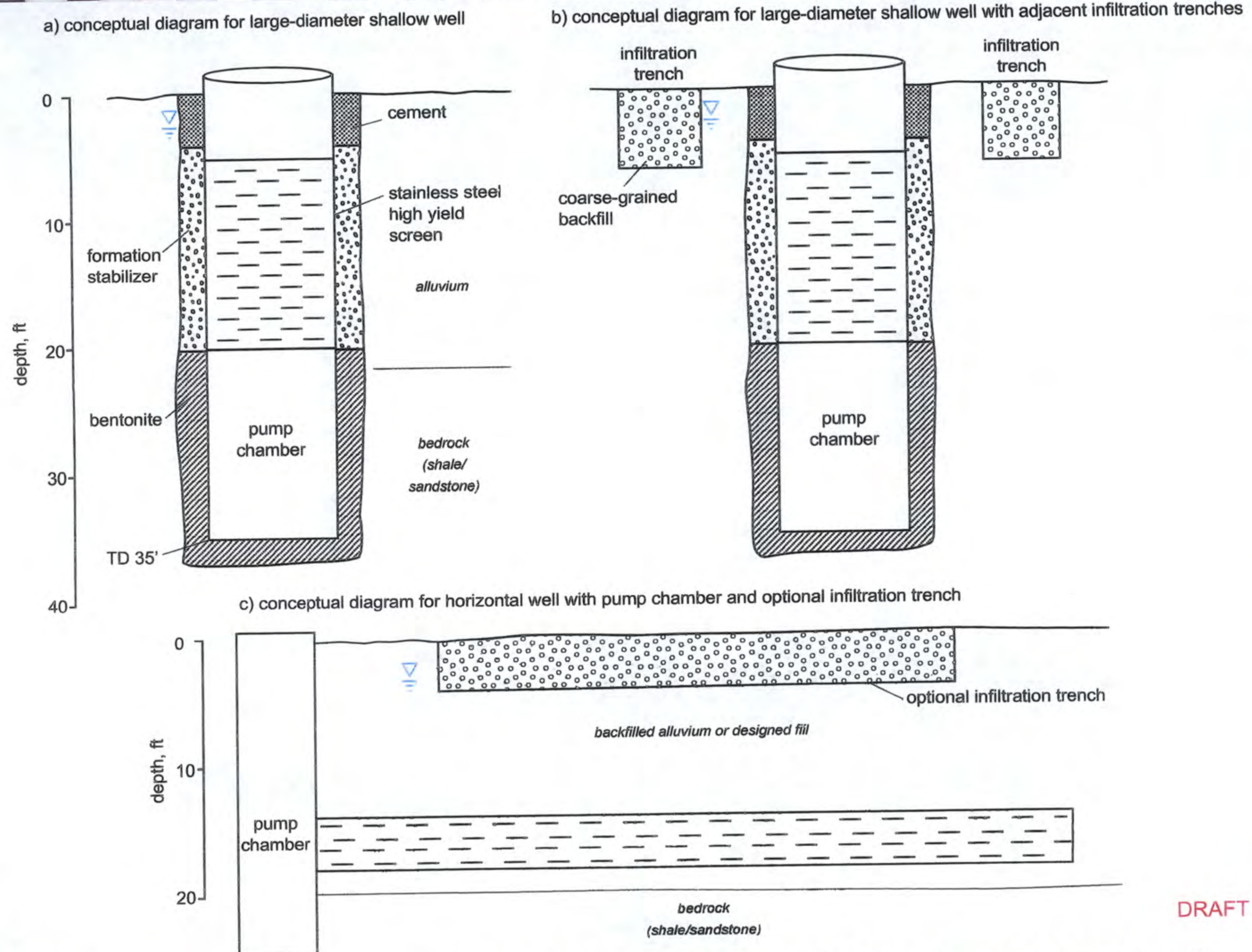


Figure 6. Proposed well completion diagrams: a) conventional well, b) conventional well with infiltration trenches, and c) horizontal well.

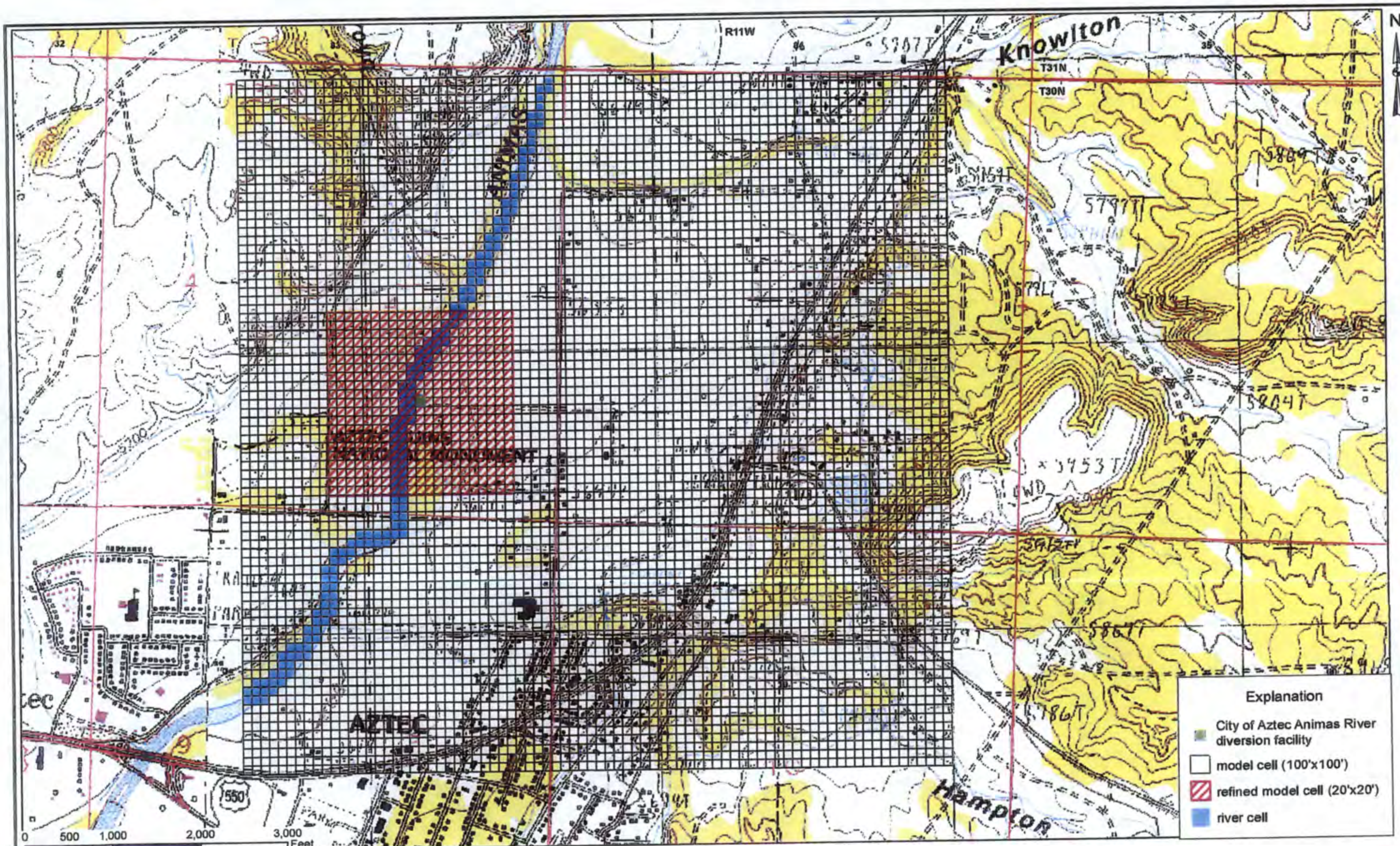


Figure 7. Map showing groundwater-flow model grid and river boundary, Animas River Valley near City of Aztec, New Mexico.

DRAFT

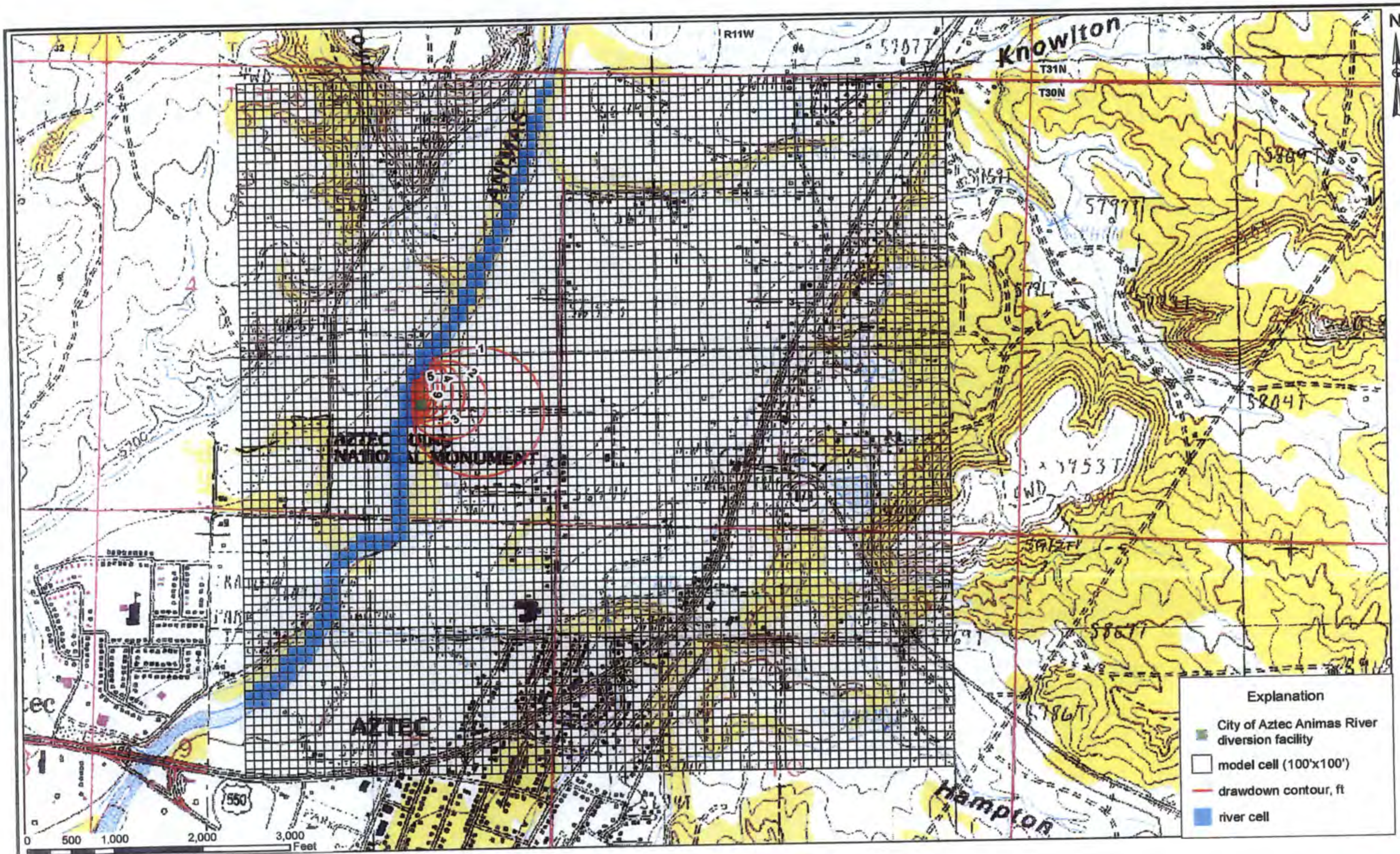


Figure 8. Map showing maximum model-simulated drawdown from proposed groundwater diversions at the City of Aztec Animas River diversion facility.

DRAFT

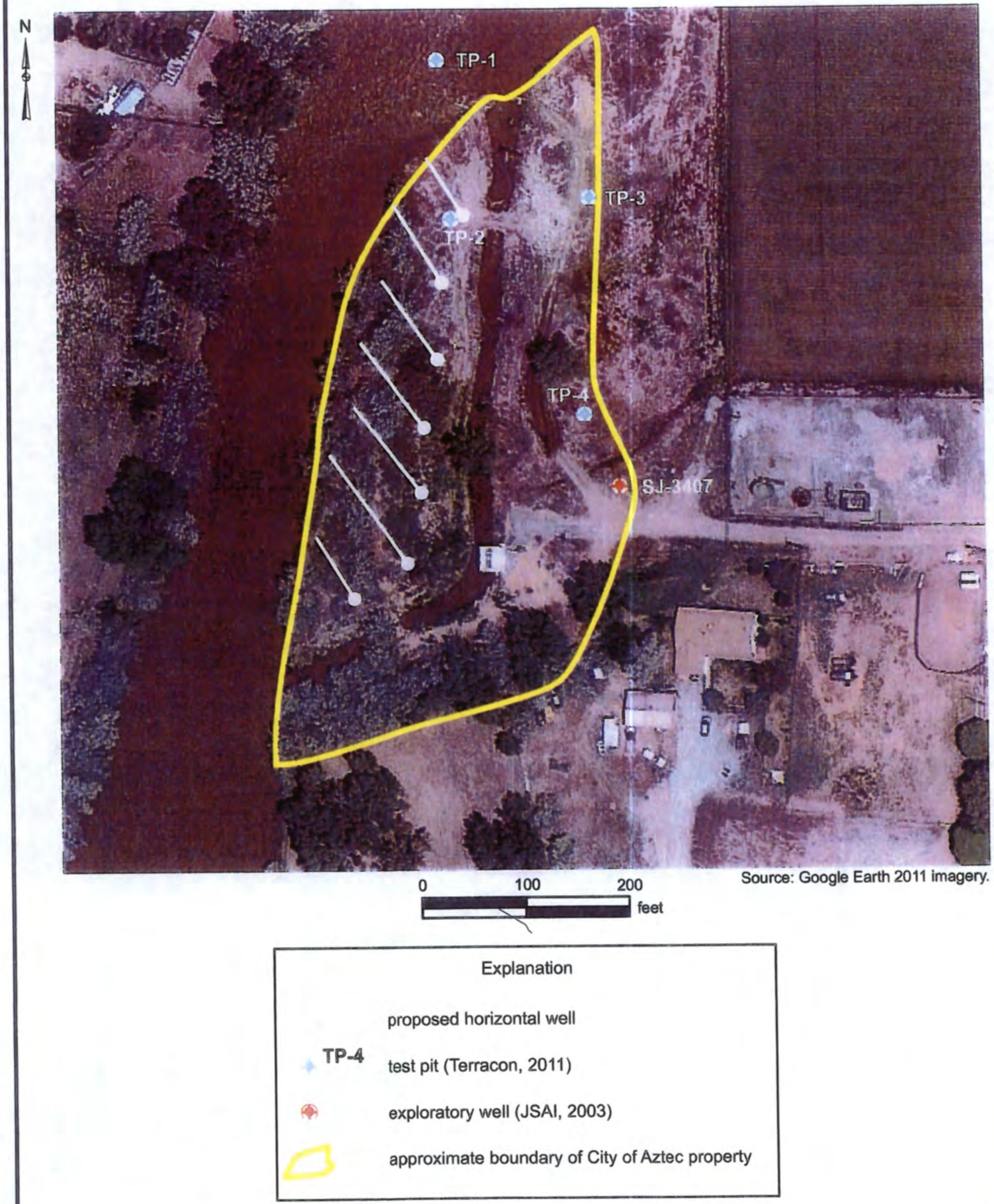
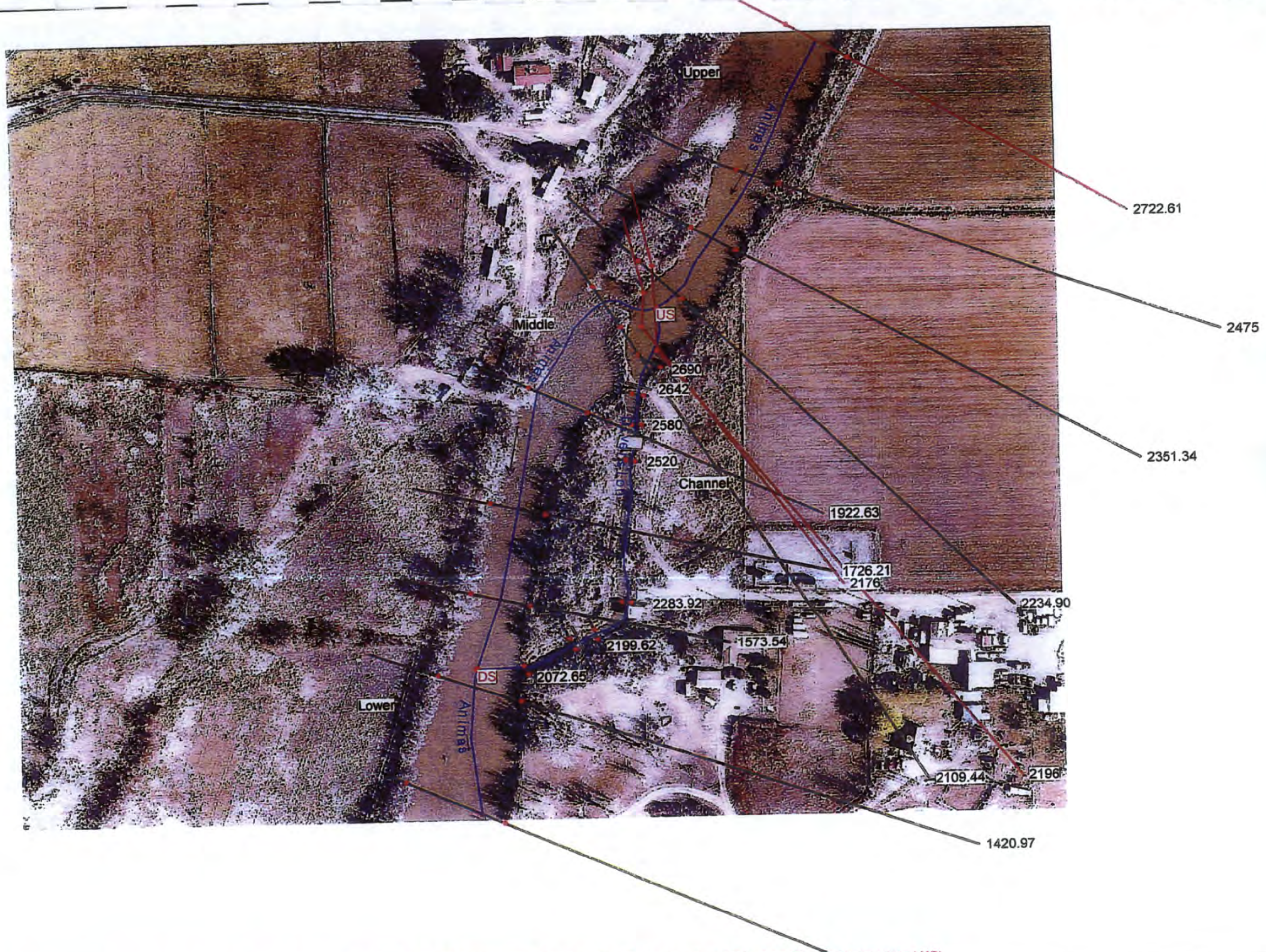


Figure 9. Aerial photograph of City of Aztec Animas River diversion facility showing locations of test pits, exploratory well, and proposed horizontal wells.

DRAFT

Appendix B

Existing Hydraulic Data



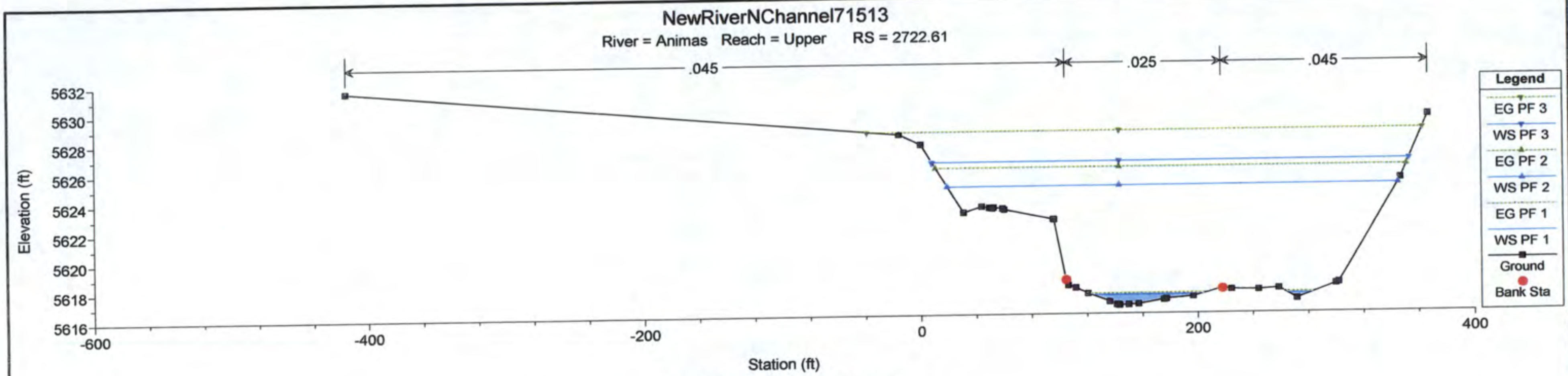
3 of the 20 XS's are not Geo-Referenced (- Geo-Ref user entered XS - Geo-Ref interpolated XS - Non Geo-Ref user entered XS - Non Geo-Ref interpolated XS)

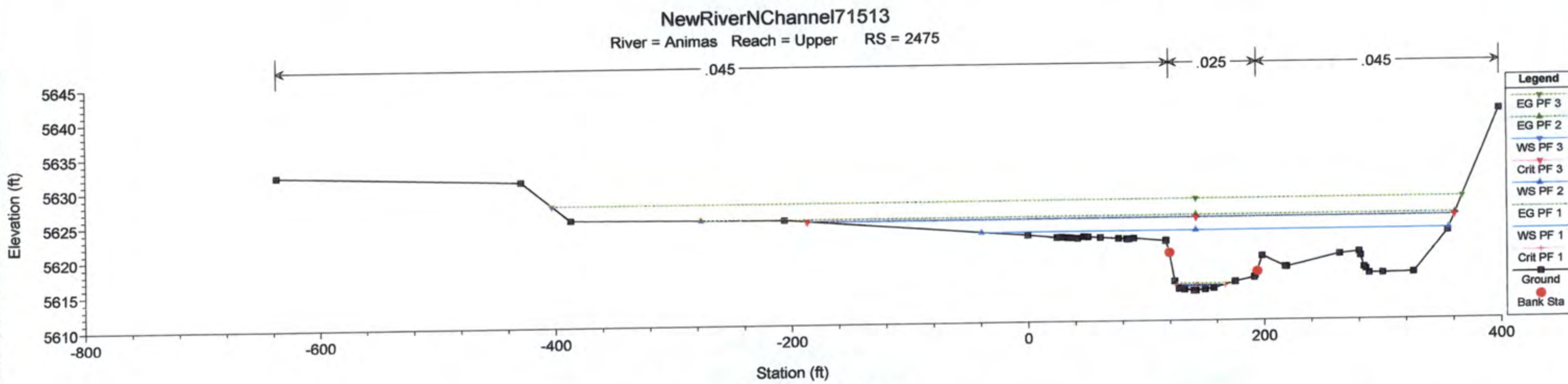
HEC-RAS Plan: Plan 04

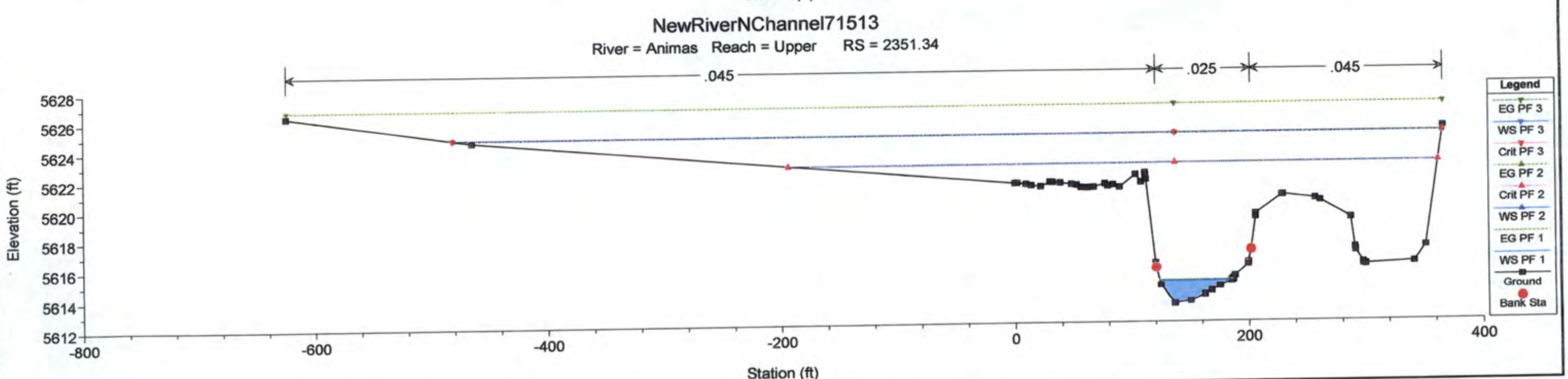
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Diversion	Channel	2690	PF 1	6.00	5613.17	5614.57	5613.59	5614.57	0.000018	0.22	27.80	35.10	0.04
Diversion	Channel	2690	PF 2	300.00	5613.17	5622.07	5615.09	5622.08	0.000014	0.86	388.11	57.99	0.05
Diversion	Channel	2690	PF 3	500.00	5613.17	5623.23	5615.62	5623.25	0.000024	1.23	455.67	57.99	0.07
Diversion	Channel	2642		Inl Struct									
Diversion	Channel	2630	PF 1	6.00	5612.80	5613.87		5613.89	0.001056	1.25	4.80	8.96	0.30
Diversion	Channel	2630	PF 2	300.00	5612.80	5621.97		5622.01	0.000068	1.79	220.30	40.58	0.11
Diversion	Channel	2630	PF 3	500.00	5612.80	5623.11		5623.19	0.000112	2.53	266.62	40.58	0.15
Diversion	Channel	2580	PF 1	6.00	5612.47	5613.86	5613.10	5613.87	0.000189	0.69	8.69	10.70	0.14
Diversion	Channel	2580	PF 2	300.00	5612.47	5621.95	5615.87	5622.01	0.000076	1.95	197.13	36.05	0.12
Diversion	Channel	2580	PF 3	500.00	5612.47	5623.08	5616.78	5623.18	0.000130	2.78	237.72	36.05	0.16
Diversion	Channel	2550		Culvert									
Diversion	Channel	2520	PF 1	6.00	5612.27	5613.85		5613.85	0.000143	0.63	9.49	10.77	0.12
Diversion	Channel	2520	PF 2	300.00	5612.27	5621.86		5621.91	0.000075	1.96	208.79	44.60	0.12
Diversion	Channel	2520	PF 3	500.00	5612.27	5623.01		5623.11	0.000123	2.73	260.23	44.60	0.16
Diversion	Channel	2283.92	PF 1	6.00	5611.75	5613.83		5613.84	0.000035	0.39	15.26	11.97	0.06
Diversion	Channel	2283.92	PF 2	300.00	5611.75	5621.84		5621.89	0.000074	1.94	211.64	43.79	0.12
Diversion	Channel	2283.92	PF 3	500.00	5611.75	5622.98		5623.08	0.000124	2.72	262.53	45.34	0.15
Diversion	Channel	2199.62	PF 1	6.00	5612.37	5613.82	5613.19	5613.83	0.000250	0.75	7.98	10.30	0.15
Diversion	Channel	2199.62	PF 2	300.00	5612.37	5621.83	5615.92	5621.88	0.000087	2.00	195.72	46.87	0.13
Diversion	Channel	2199.62	PF 3	500.00	5612.37	5622.96	5616.86	5623.07	0.000139	2.76	248.96	46.87	0.16
Diversion	Channel	2168		Inl Struct									
Diversion	Channel	2159.06	PF 1	6.00	5611.21	5612.46	5612.07	5612.50	0.002344	1.76	3.41	6.48	0.43
Diversion	Channel	2159.06	PF 2	300.00	5611.21	5621.03		5621.06	0.000052	1.63	232.20	46.53	0.10
Diversion	Channel	2159.06	PF 3	500.00	5611.21	5622.85		5622.91	0.000067	2.11	317.13	46.53	0.12
Diversion	Channel	2072.65	PF 1	6.00	5611.66	5611.99	5611.99	5612.08	0.015717	2.52	2.38	12.01	1.00
Diversion	Channel	2072.65	PF 2	300.00	5611.66	5621.02		5621.06	0.000045	1.72	234.70	27.68	0.10
Diversion	Channel	2072.65	PF 3	500.00	5611.66	5622.83		5622.90	0.000069	2.40	284.71	27.68	0.13
Animas	Upper	2722.61	PF 1	100.00	5616.57	5617.32		5617.44	0.006682	2.75	38.88	101.17	0.74
Animas	Upper	2722.61	PF 2	13000.00	5616.57	5625.05		5626.19	0.001736	9.87	1888.36	330.33	0.62
Animas	Upper	2722.61	PF 3	21500.00	5616.57	5626.31		5628.42	0.002736	13.66	2310.46	344.49	0.79
Animas	Upper	2475	PF 1	100.00	5614.20	5615.06	5615.06	5615.34	0.010961	4.27	23.40	41.03	1.00
Animas	Upper	2475	PF 2	13000.00	5614.20	5624.69		5625.76	0.001568	10.41	2277.67	533.85	0.59
Animas	Upper	2475	PF 3	21500.00	5614.20	5625.77		5627.70	0.002594	14.39	2980.65	752.50	0.78
Animas	Upper	2351.34	PF 1	100.00	5613.22	5614.84		5614.88	0.000846	1.67	59.99	63.20	0.30
Animas	Upper	2351.34	PF 2	13000.00	5613.22	5624.79		5625.51	0.000922	8.64	3172.81	851.59	0.47
Animas	Upper	2351.34	PF 3	21500.00	5613.22	5626.22		5627.21	0.001214	10.79	4482.90	980.73	0.55
Animas	Upper	2234.90	PF 1	100.00	5613.66	5614.65		5614.73	0.002270	2.19	45.58	66.71	0.47
Animas	Upper	2234.90	PF 2	13000.00	5613.66	5624.86		5625.35	0.000648	7.21	3791.65	978.37	0.39
Animas	Upper	2234.90	PF 3	21500.00	5613.66	5626.35		5626.99	0.000814	8.83	5270.79	996.67	0.45
Animas	Middle	2196	PF 1	94.00	5613.66	5614.65		5614.71	0.002052	2.07	45.47	67.52	0.44
Animas	Middle	2196	PF 2	12700.00	5613.66	5624.92		5625.32	0.000630	6.28	4013.99	1209.28	0.37
Animas	Middle	2196	PF 3	21000.00	5613.66	5626.46		5626.93	0.000685	7.30	5883.70	1209.47	0.40
Animas	Middle	2176	PF 1	94.00	5613.00	5614.26	5614.26	5614.61	0.010553	4.74	19.84	28.92	1.01
Animas	Middle	2176	PF 2	12700.00	5613.00	5623.80	5623.80	5625.20	0.002510	12.70	2313.02	712.36	0.74
Animas	Middle	2176	PF 3	21000.00	5613.00	5625.41		5626.81	0.002424	13.92	3461.98	715.46	0.75
Animas	Middle	2109.44	PF 1	94.00	5611.52	5612.41	5612.41	5612.74	0.011090	4.56	20.61	33.03	1.02
Animas	Middle	2109.44	PF 2	12700.00	5611.52	5622.43		5623.57	0.001727	10.64	2650.90	1053.31	0.62
Animas	Middle	2109.44	PF 3	21000.00	5611.52	5626.07		5626.45	0.000536	7.43	6506.57	1061.43	0.37
Animas	Middle	1922.63	PF 1	94.00	5609.75	5611.82		5611.83	0.000238	1.08	87.17	67.97	0.17
Animas	Middle	1922.63	PF 2	12700.00	5609.75	5622.22	5619.17	5623.32	0.001006	9.25	2278.03	559.15	0.49
Animas	Middle	1922.63	PF 3	21000.00	5609.75	5625.34		5626.28	0.000747	9.42	4134.76	613.76	0.44
Animas	Middle	1726.21	PF 1	94.00	5609.21	5611.78		5611.79	0.000186	0.91	103.36	86.75	0.15
Animas	Middle	1726.21	PF 2	12700.00	5609.21	5618.94	5618.94	5622.70	0.004332	15.93	884.51	124.38	0.98
Animas	Middle	1726.21	PF 3	21000.00	5609.21	5624.38	5623.68	5626.02	0.001262	12.04	3425.63	700.00	0.57
Animas	Middle	1573.54	PF 1	94.00	5608.18	5611.77		5611.78	0.000047	0.63	148.44	76.29	0.08
Animas	Middle	1573.54	PF 2	12700.00	5608.18	5618.26	5618.26	5621.80	0.004391	15.52	940.18	153.29	0.97
Animas	Middle	1573.54	PF 3	21000.00	5608.18	5621.53	5621.53	5625.50	0.003300	16.95	1712.09	310.97	0.89
Animas	Lower	1420.97	PF 1	95.00	5610.68	5611.74		5611.76	0.000514	1.09	87.09	119.38	0.23
Animas	Lower	1420.97	PF 2	12995.00	5610.68	5618.68	5618.68	5620.58	0.002561	11.44	1588.70	677.84	0.74
Animas	Lower	1420.97	PF 3	21495.00	5610.68	5620.48	5620.48	5622.43	0.002342	12.64	3054.72	889.10	0.73
Animas	Lower	1200	PF 1	95.00	5610.45	5611.42	5611.29	5611.50	0.005000	2.22	42.72	110.93	0.63

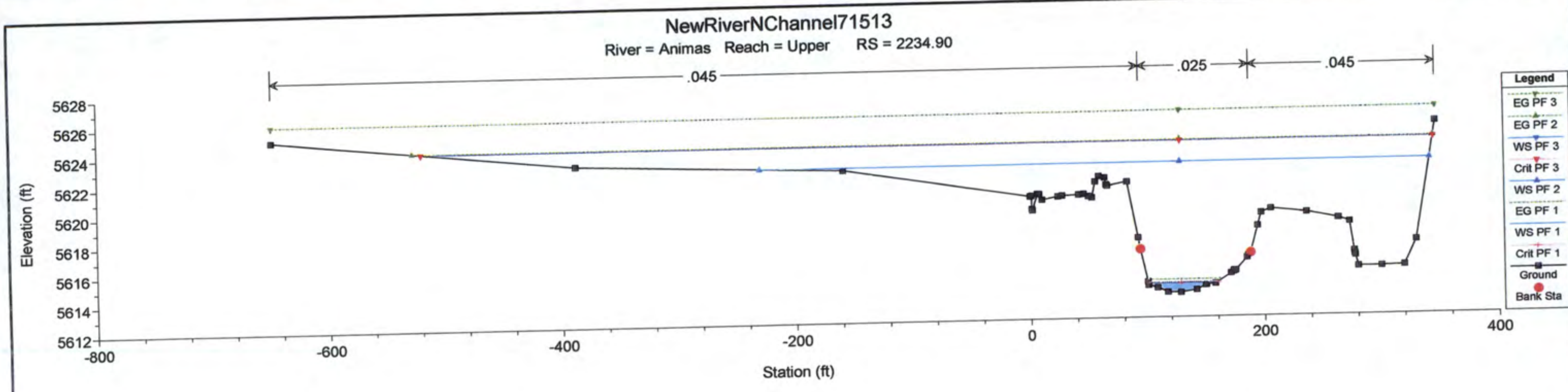
HEC-RAS Plan: Plan 04 (Continued)

River	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)	
Animas	Lower	1200	PF 2	12995.00	5610.45	5616.65	5616.42	5618.93	0.005000	12.74	1437.86	657.08	0.98
Animas	Lower	1200	PF 3	21495.00	5610.45	5618.54	5618.54	5620.46	0.003323	12.73	2736.90	717.57	0.84

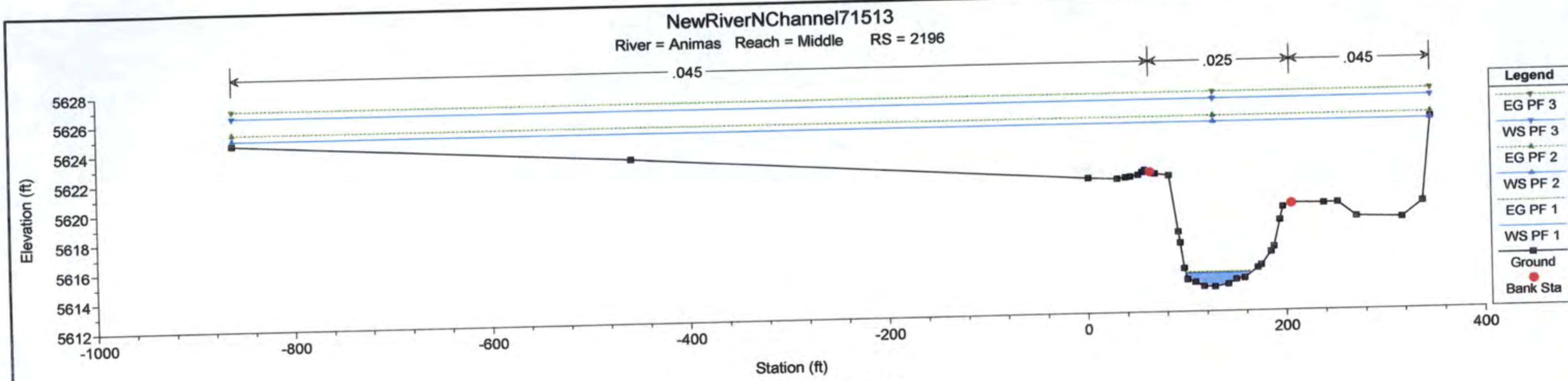

NewRiverNChannel71513
River = Animas Reach = Upper RS = 2722.61
.045
.025
.045
Elevation (ft)
Station (ft)
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

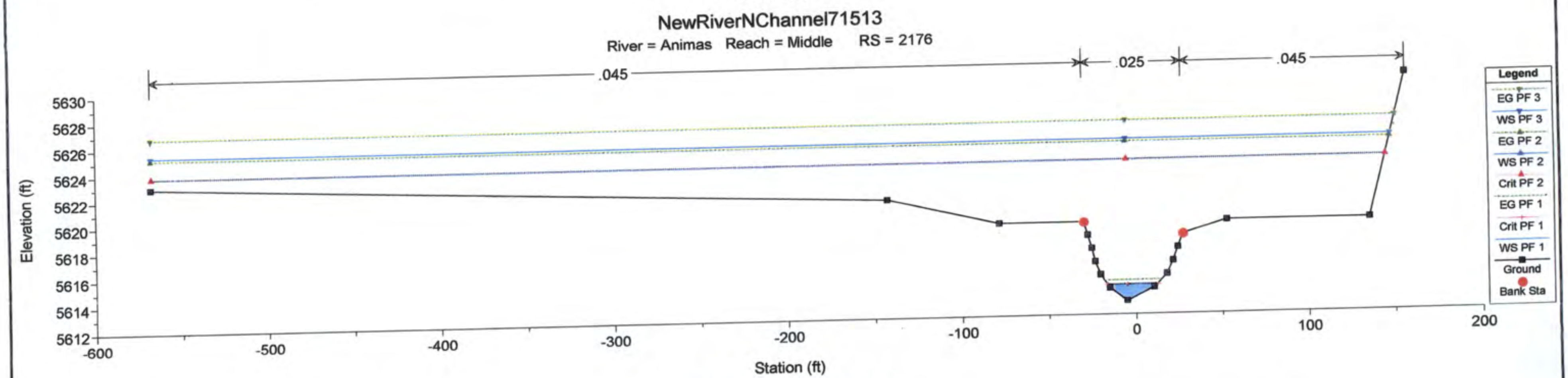

NewRiverNChannel71513
River = Animas Reach = Upper RS = 2475
.045
.025
.045
Elevation (ft)
Station (ft)
Legend
EG PF 3
EG PF 2
WS PF 3
Crit PF 3
WS PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta

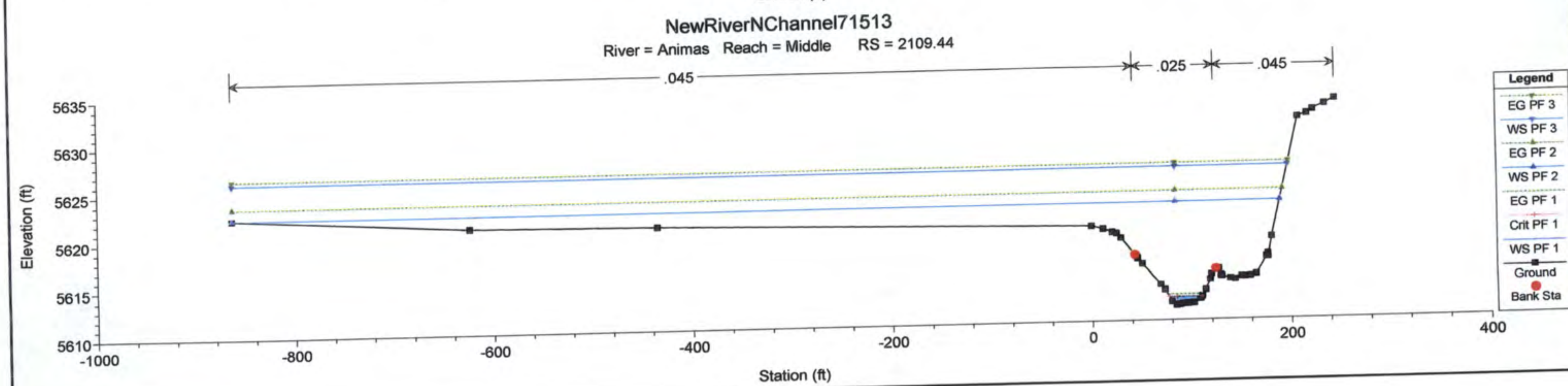

NewRiverNChannel71513
River = Animas Reach = Upper RS = 2351.34
.045
.025
.045
Elevation (ft)
Station (ft)
Legend
EG PF 3
WS PF 3
Crit PF 3
EG PF 2
Crit PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta



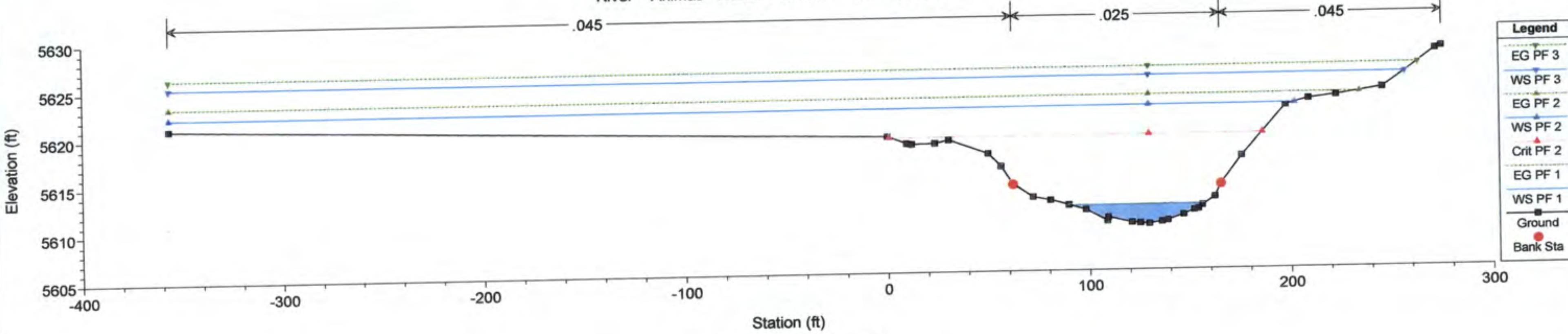
NewRiverNChannel71513
River = Animas Reach = Upper RS = 2234.90
.045
.025
.045
Legend
EG PF 3
EG PF 2
WS PF 3
Crit PF 3
WS PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
5628
5626
5624
5622
5620
5618
5616
5614
5612
-800
-600
-400
-200
0
200
400
Station (ft)


NewRiverNChannel71513
River = Animas Reach = Middle RS = 2196
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

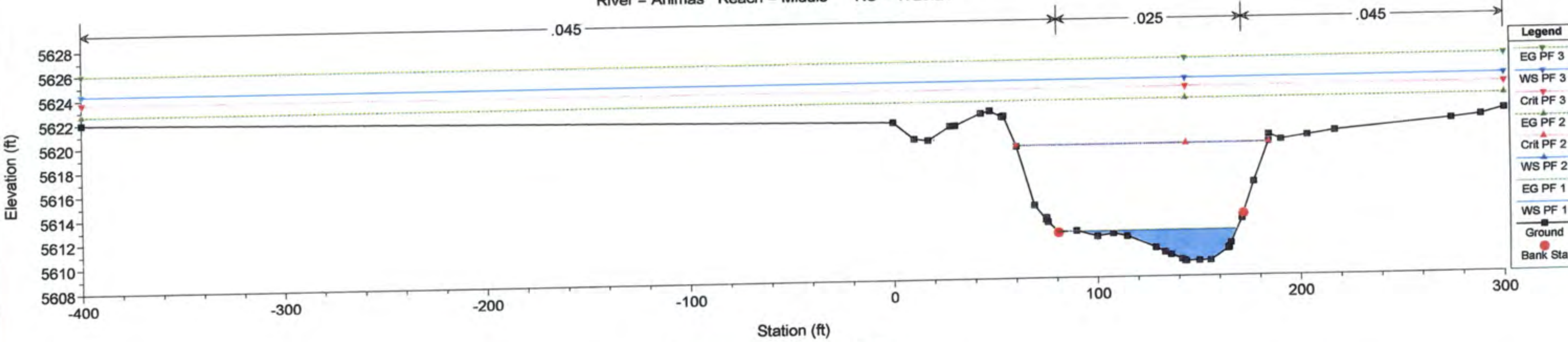

NewRiverNChannel71513
River = Animas Reach = Middle RS = 2176
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Crit PF 2
EG PF 1
Crit PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


NewRiverNChannel71513
River = Animas Reach = Middle RS = 2109.44
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
Crit PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

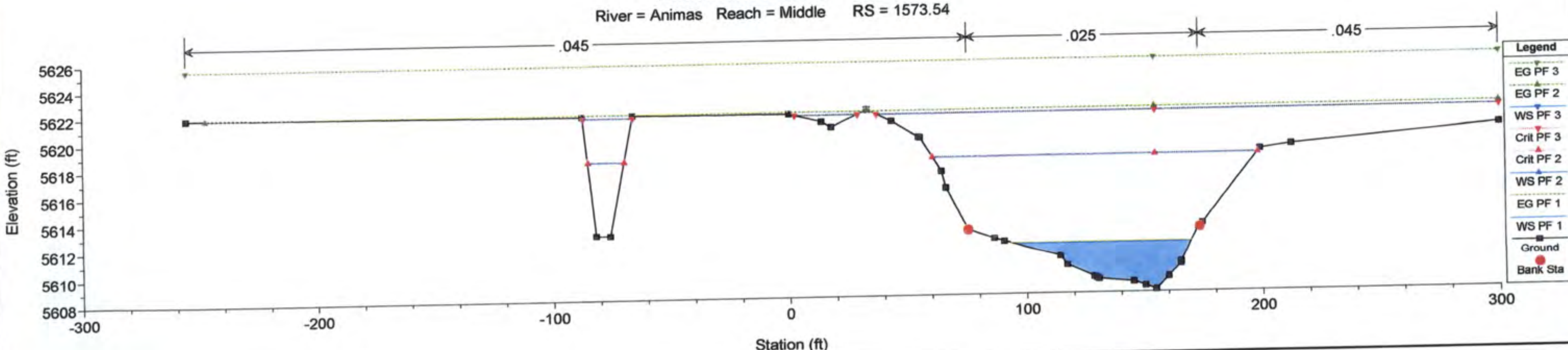
NewRiverNChannel71513
River = Animas Reach = Middle RS = 1922.63

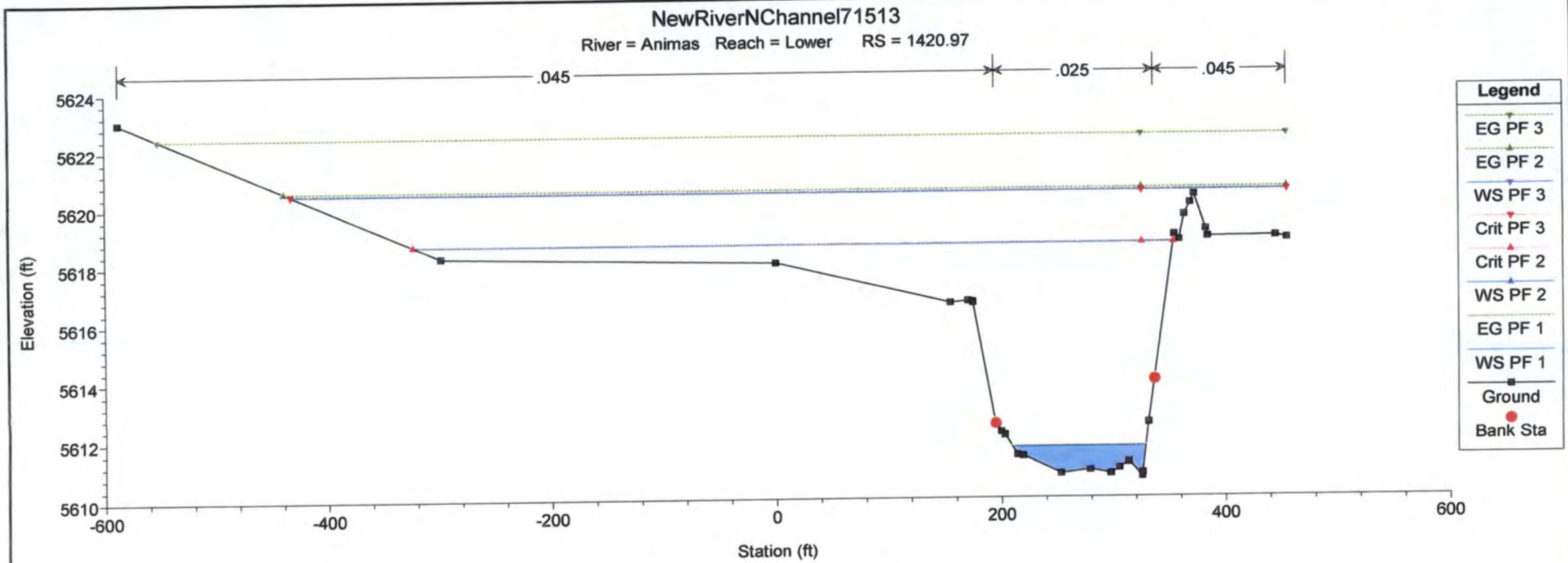


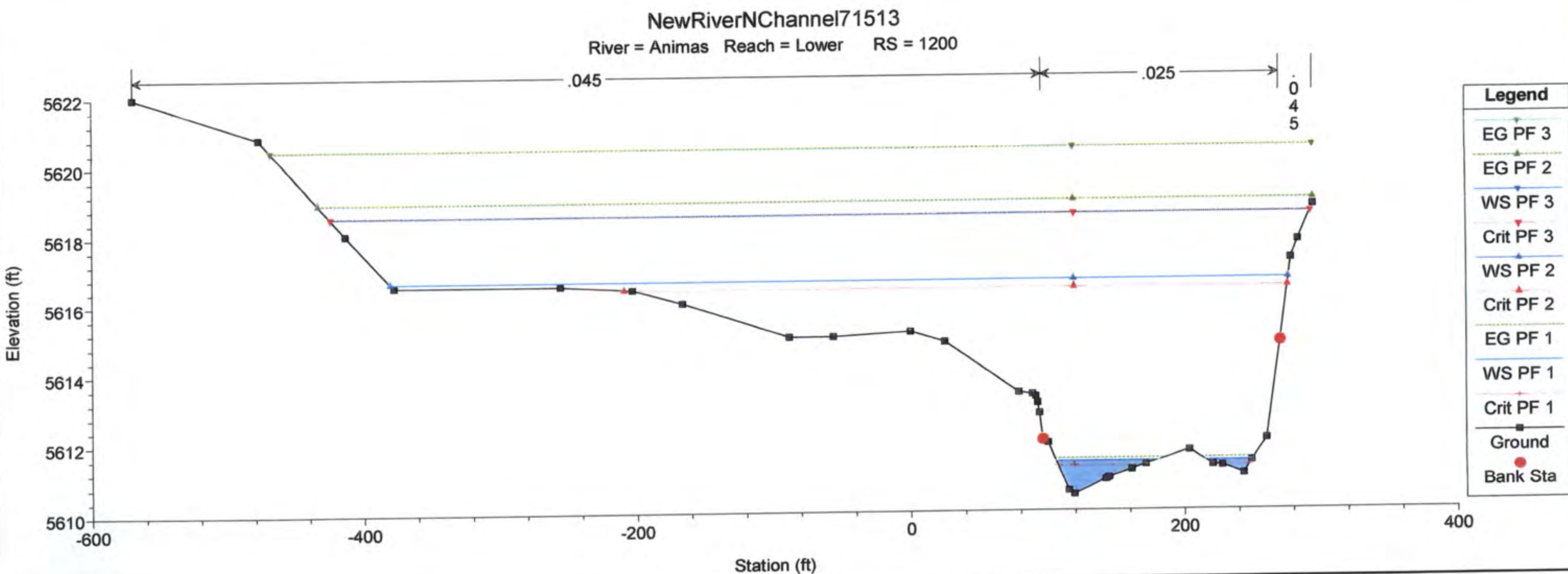
NewRiverNChannel71513
River = Animas Reach = Middle RS = 1726.21



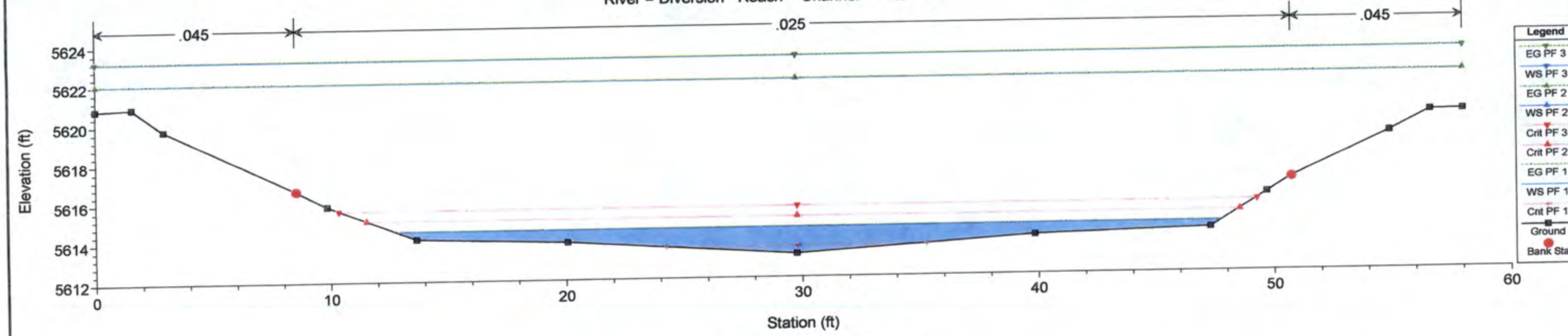
NewRiverNChannel71513
River = Animas Reach = Middle RS = 1573.54



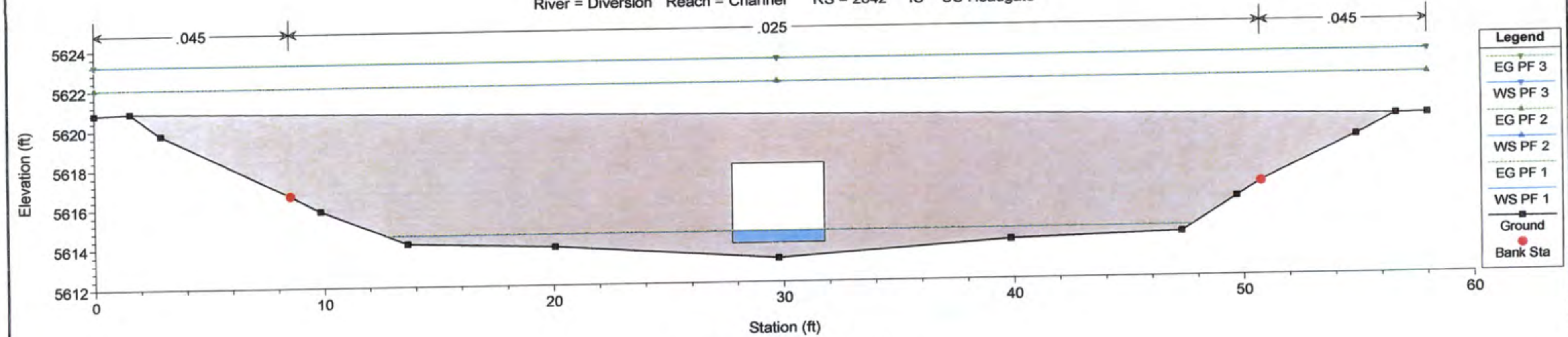

NewRiverNChannel71513
River = Animas Reach = Lower RS = 1420.97
.045
.025
.045
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
5610
-600
-400
-200
0
200
400
600
Station (ft)
Legend
EG PF 3
EG PF 2
WS PF 3
Crit PF 3
Crit PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta


NewRiverNChannel71513
River = Animas Reach = Lower RS = 1200
.045
.025
.045
Elevation (ft)
5622
5620
5618
5616
5614
5612
5610
-600
-400
-200
0
200
400
Station (ft)
Legend
EG PF 3
EG PF 2
WS PF 3
Crit PF 3
WS PF 2
Crit PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta

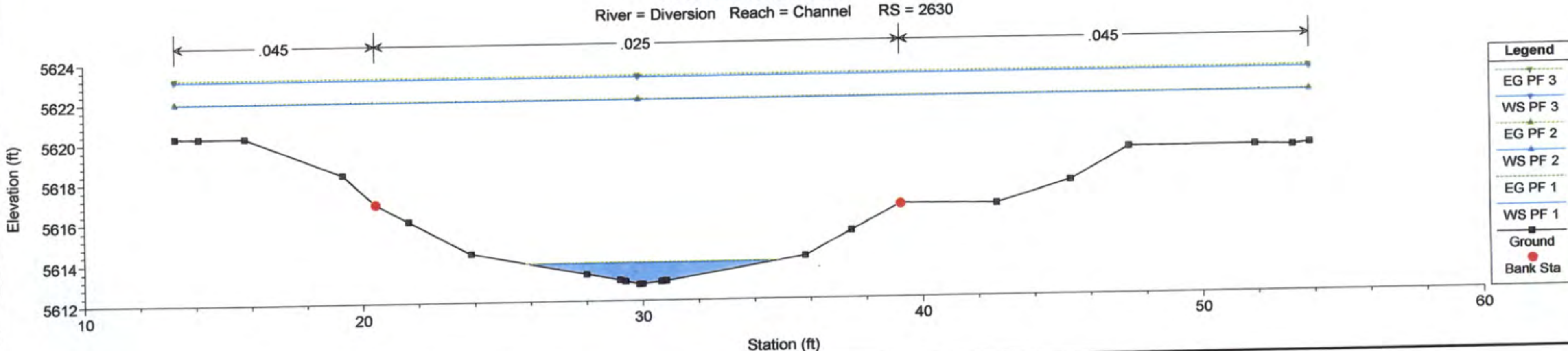
NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2690



NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2642 IS US Headgate

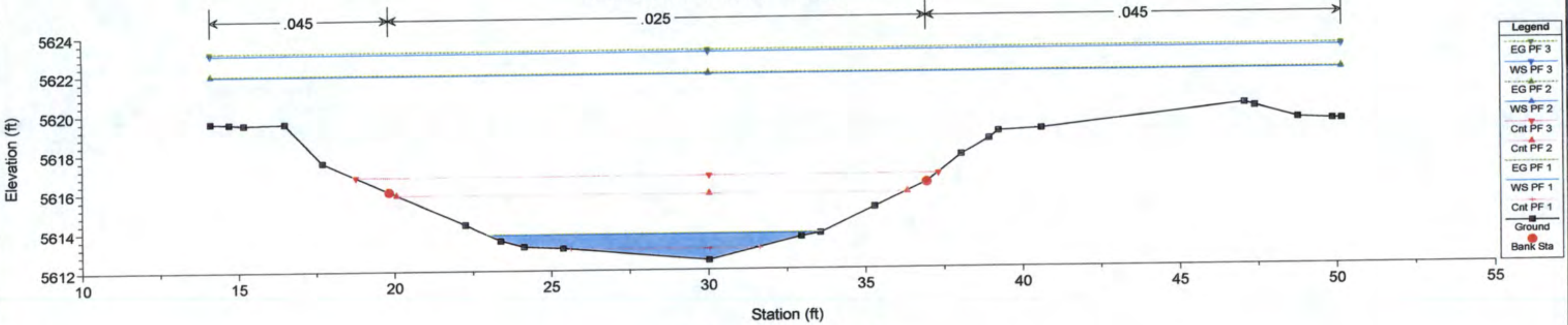


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2630



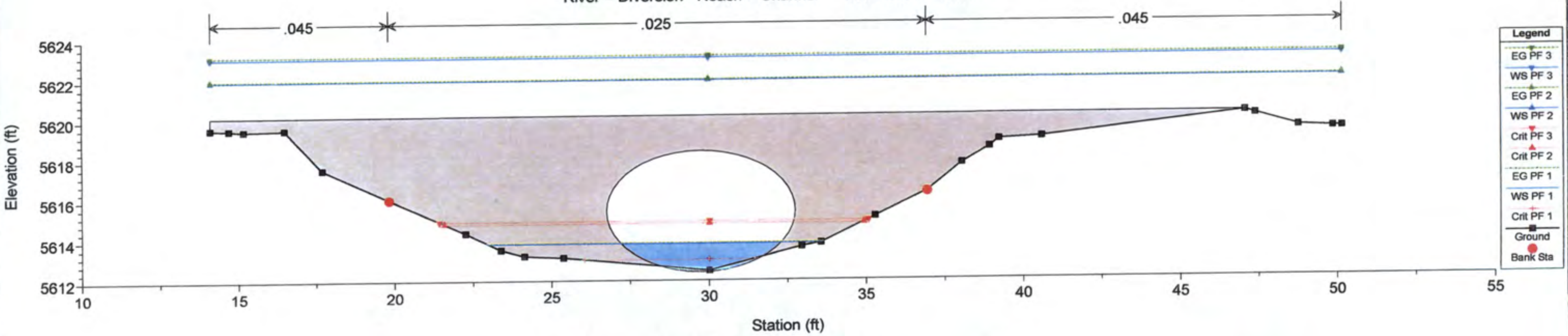
NewRiverNChannel71513

River = Diversion Reach = Channel RS = 2580



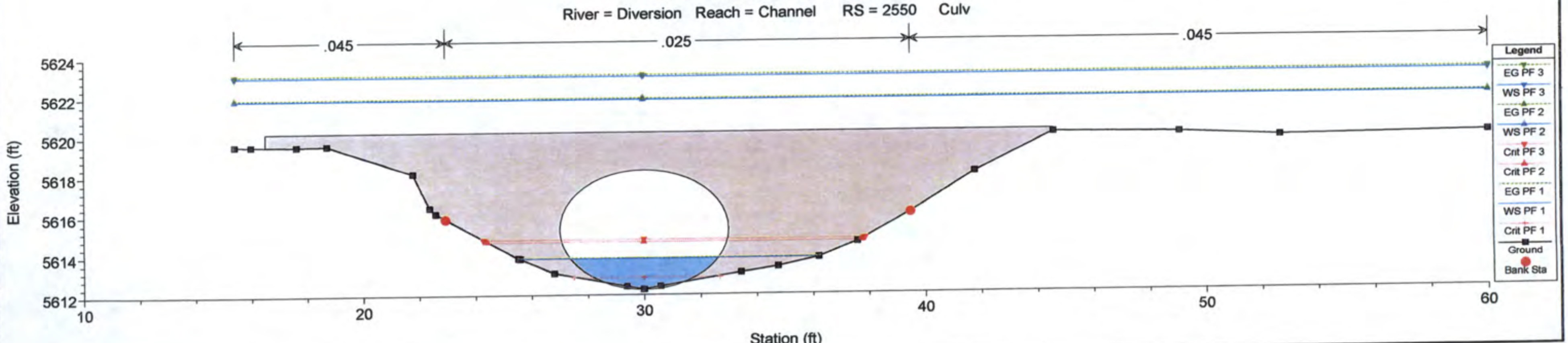
NewRiverNChannel71513

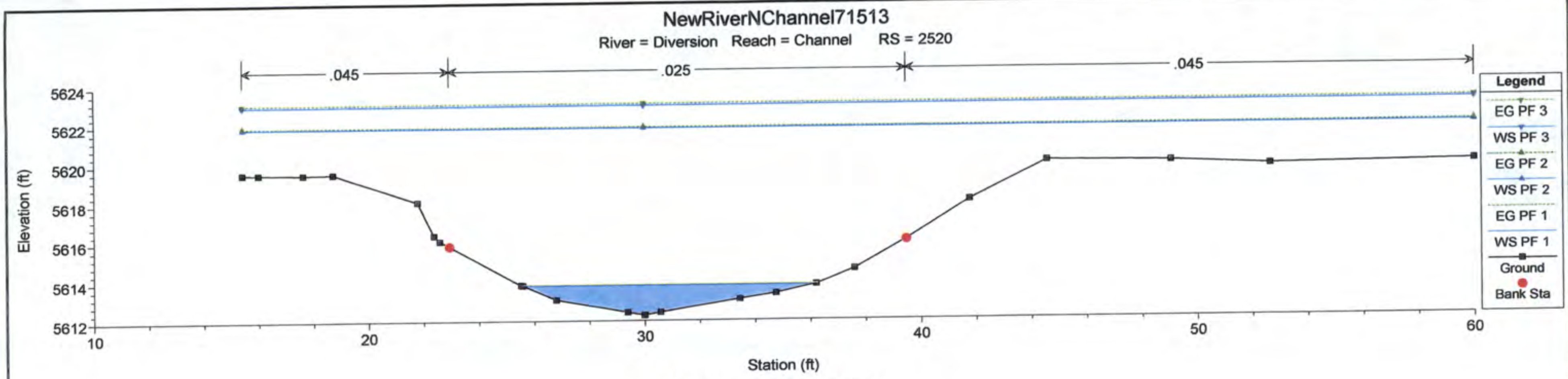
River = Diversion Reach = Channel RS = 2550 Culv

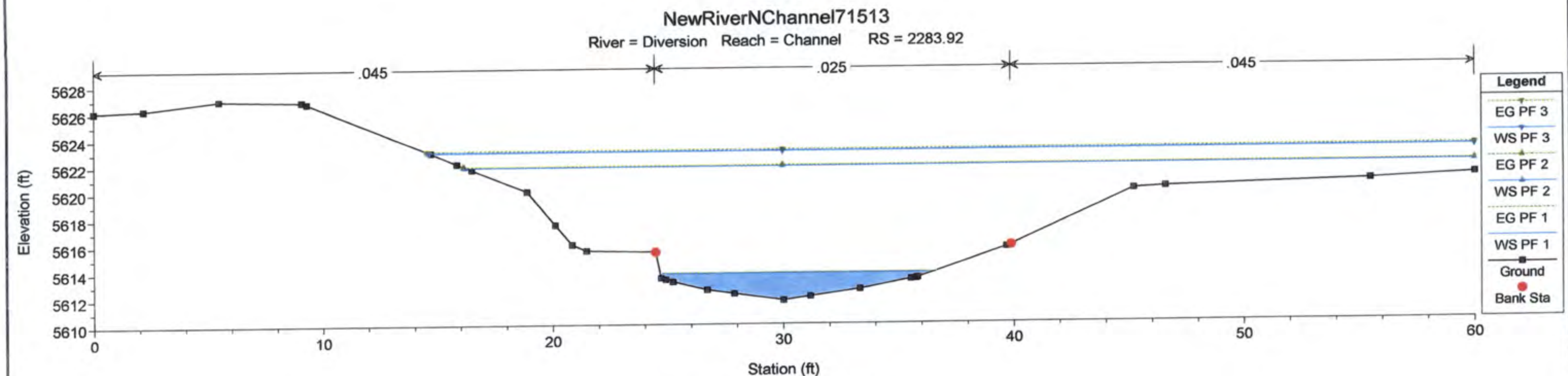


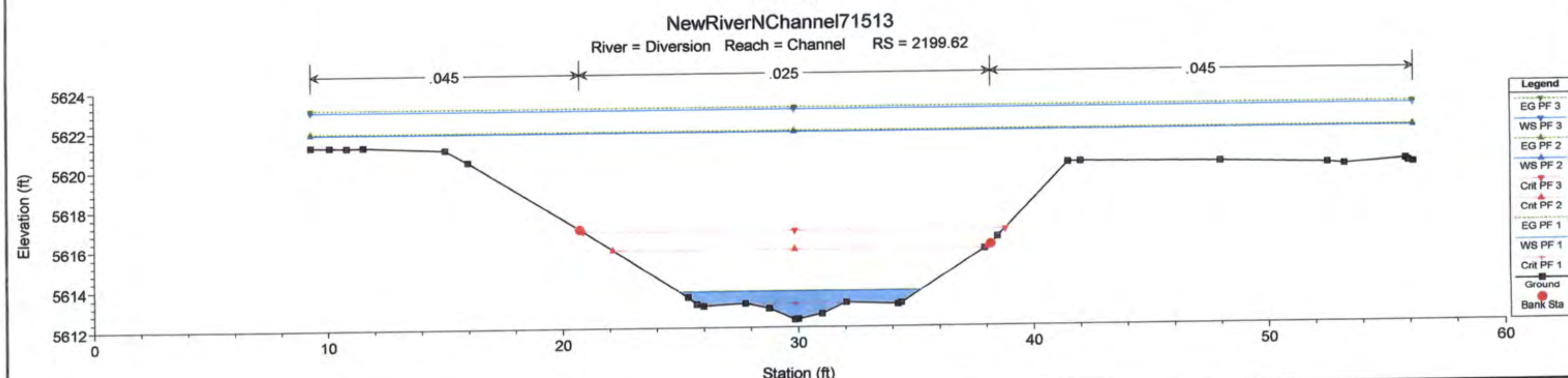
NewRiverNChannel71513

River = Diversion Reach = Channel RS = 2550 Culv



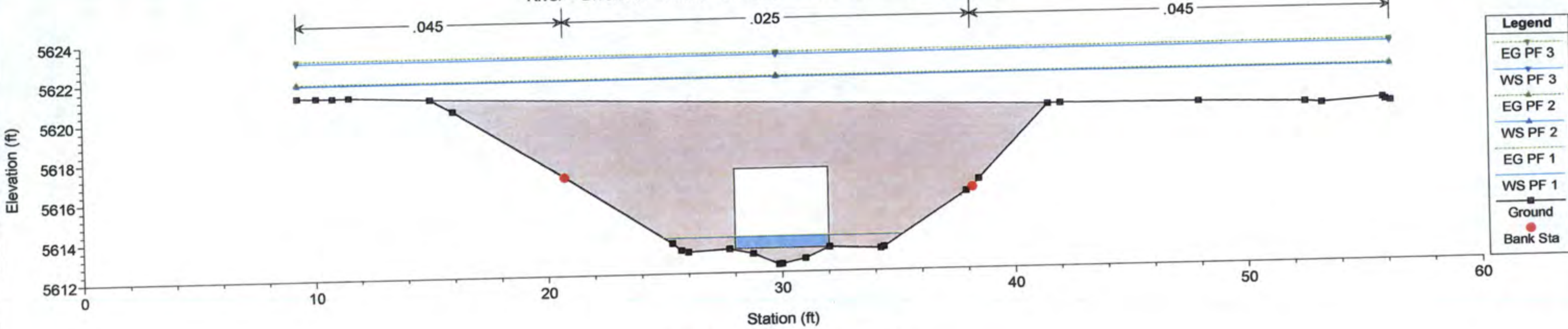

NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2520
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
10
20
30
40
50
60
Station (ft)


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2283.92
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
5628
5626
5624
5622
5620
5618
5616
5614
5612
5610
0
10
20
30
40
50
60
Station (ft)


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2199.62
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Crit PF 3
Crit PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
0
10
20
30
40
50
60
Station (ft)

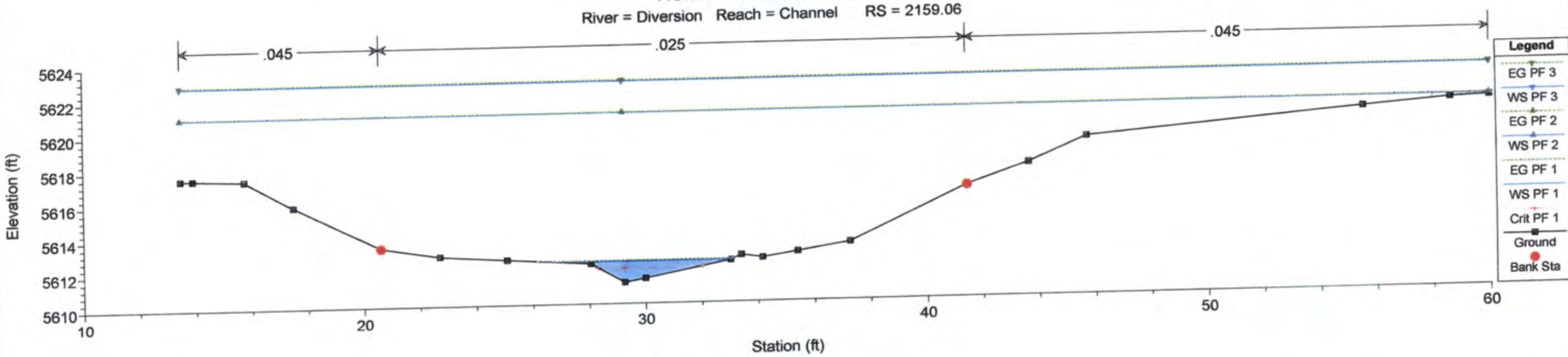
NewRiverNChannel71513

River = Diversion Reach = Channel RS = 2168 IS DS Headgate



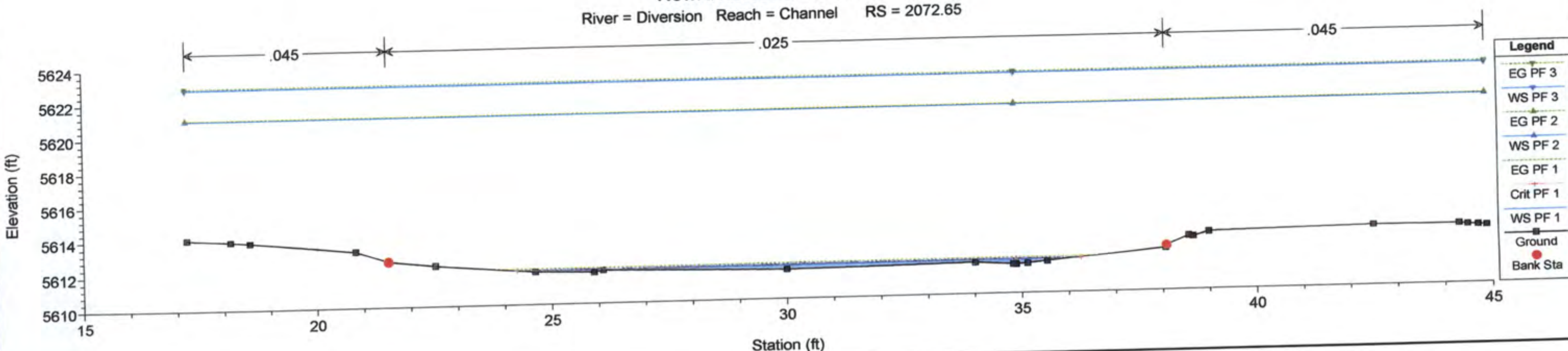
NewRiverNChannel71513

River = Diversion Reach = Channel RS = 2159.06



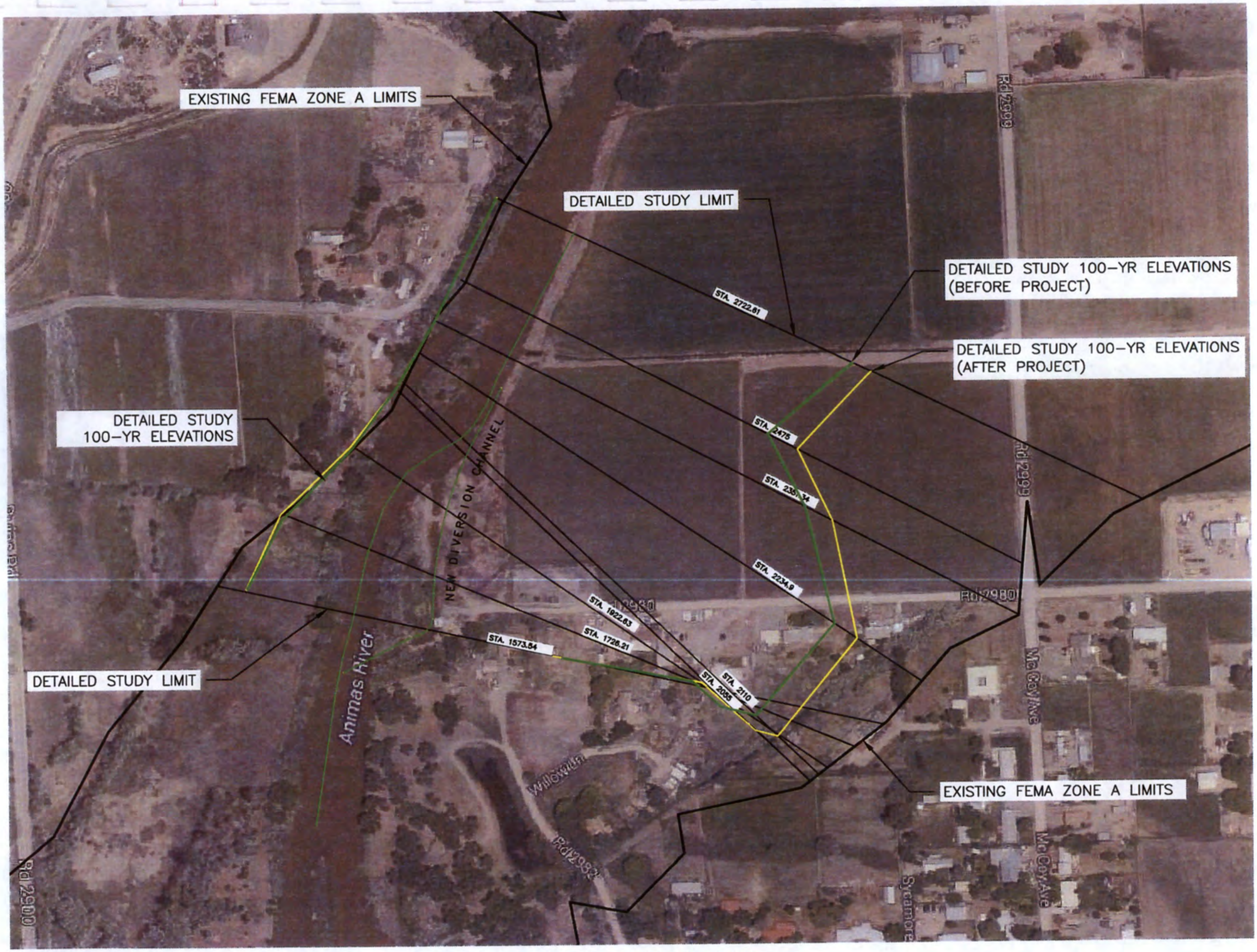
NewRiverNChannel71513

River = Diversion Reach = Channel RS = 2072.65



Appendix C

Proposed Hydraulic Data for Re-Aligned Diversion Channel



100 YEAR FLOW ELEVATIONS

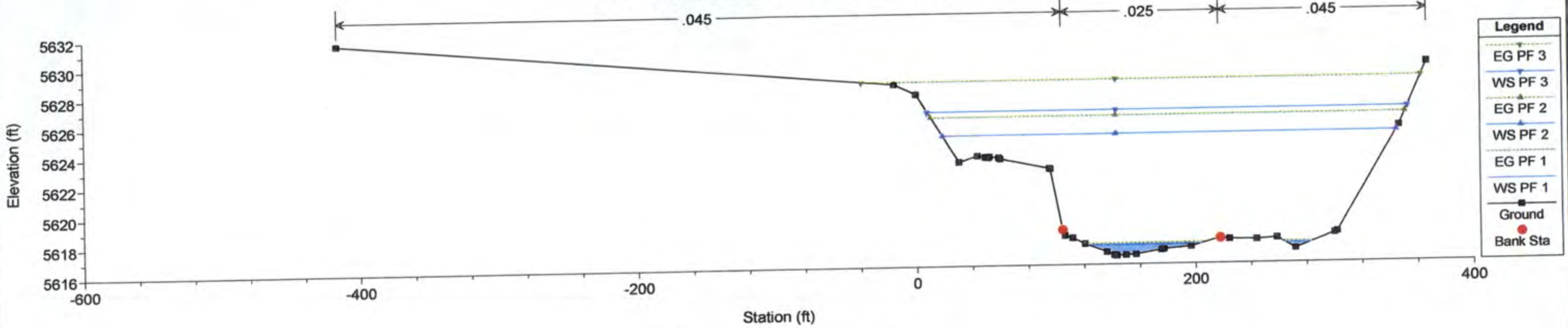
2722.61
2475
2351.34
2234.90
2110
2055
1922.63
1726.21
1420.97
Upper
US
2670
Middle
2600
2500
hannel
2400
2284
1573.54
2199.62
2072.65
DS
Lower
An imas

HEC-RAS Plan:

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Diversion	Channel	2670	PF 1	6.00	5611.85	5612.33	5612.07	5612.34	0.000400	0.97	6.20	15.28	0.27
Diversion	Channel	2670	PF 2	300.00	5611.85	5621.34	5614.13	5621.36	0.000025	1.23	251.19	34.88	0.08
Diversion	Channel	2670	PF 3	500.00	5611.85	5624.04	5614.94	5624.07	0.000025	1.51	345.33	34.88	0.08
Diversion	Channel	2664		Inl Struct									
Diversion	Channel	2600	PF 1	6.00	5611.72	5612.06		5612.10	0.001961	1.70	3.52	13.20	0.58
Diversion	Channel	2600	PF 2	300.00	5611.72	5621.19		5621.21	0.000025	1.24	248.93	34.94	0.08
Diversion	Channel	2600	PF 3	500.00	5611.72	5623.98		5624.01	0.000025	1.51	346.50	34.94	0.08
Diversion	Channel	2500	PF 1	6.00	5611.54	5611.88		5611.91	0.001747	1.56	3.84	14.46	0.54
Diversion	Channel	2500	PF 2	300.00	5611.54	5621.19		5621.21	0.000022	1.19	259.61	34.94	0.07
Diversion	Channel	2500	PF 3	500.00	5611.54	5623.98		5624.01	0.000022	1.46	357.18	34.94	0.08
Diversion	Channel	2400	PF 1	6.00	5611.35	5611.79		5611.81	0.000607	1.07	5.59	16.02	0.32
Diversion	Channel	2400	PF 2	300.00	5611.35	5621.18		5621.20	0.000021	1.16	265.24	34.88	0.07
Diversion	Channel	2400	PF 3	500.00	5611.35	5623.98		5624.01	0.000021	1.44	362.64	34.88	0.08
Diversion	Channel	2284	PF 1	1.00	5611.14	5611.79		5611.79	0.000005	0.14	7.15	12.16	0.03
Diversion	Channel	2284	PF 2	295.00	5611.14	5621.16		5621.20	0.000038	1.62	196.43	28.02	0.10
Diversion	Channel	2284	PF 3	495.00	5611.14	5623.94		5624.00	0.000040	2.01	279.87	31.95	0.10
Diversion	Channel	2199.62	PF 1	1.00	5610.98	5611.79	5611.08	5611.79	0.000002	0.11	9.04	12.07	0.02
Diversion	Channel	2199.62	PF 2	295.00	5610.98	5621.15	5613.66	5621.20	0.000046	1.77	215.15	60.00	0.10
Diversion	Channel	2199.62	PF 3	495.00	5610.98	5623.94	5614.69	5624.00	0.000041	2.00	382.84	60.00	0.10
Diversion	Channel	2168		Inl Struct									
Diversion	Channel	2159.06	PF 1	1.00	5610.91	5611.79		5611.79	0.000002	0.11	9.28	12.50	0.02
Diversion	Channel	2159.06	PF 2	295.00	5610.91	5621.00		5621.02	0.000023	1.39	300.66	60.00	0.08
Diversion	Channel	2159.06	PF 3	495.00	5610.91	5623.94		5623.97	0.000021	1.61	477.02	60.00	0.08
Diversion	Channel	2072.65	PF 1	1.00	5610.75	5611.79		5611.79	0.000001	0.08	13.32	14.17	0.01
Diversion	Channel	2072.65	PF 2	295.00	5610.75	5621.00		5621.02	0.000012	1.19	447.41	57.95	0.07
Diversion	Channel	2072.65	PF 3	495.00	5610.75	5623.94		5623.97	0.000013	1.49	617.66	57.95	0.07
Animas	Upper	2722.61	PF 1	100.00	5616.57	5617.33		5617.44	0.006637	2.74	38.98	101.28	0.74
Animas	Upper	2722.61	PF 2	13000.00	5616.57	5624.75		5626.00	0.002012	10.35	1786.88	326.31	0.66
Animas	Upper	2722.61	PF 3	21500.00	5616.57	5626.39		5628.45	0.002647	13.51	2338.42	345.41	0.78
Animas	Upper	2475	PF 1	100.00	5614.20	5615.05	5615.05	5615.34	0.011099	4.29	23.30	40.98	1.00
Animas	Upper	2475	PF 2	13000.00	5614.20	5622.97		5625.22	0.003893	14.38	1481.17	395.36	0.91
Animas	Upper	2475	PF 3	21500.00	5614.20	5624.86	5624.86	5627.58	0.003938	16.70	2371.42	547.86	0.94
Animas	Upper	2351.34	PF 1	100.00	5613.22	5614.81		5614.85	0.000928	1.72	58.12	62.60	0.31
Animas	Upper	2351.34	PF 2	13000.00	5613.22	5622.73	5622.73	5624.74	0.002909	13.27	1707.53	556.47	0.80
Animas	Upper	2351.34	PF 3	21500.00	5613.22	5624.75	5624.75	5626.74	0.002574	14.40	3140.03	848.04	0.78
Animas	Upper	2234.90	PF 1	100.00	5613.66	5614.34	5614.34	5614.57	0.012538	3.83	26.14	59.92	1.02
Animas	Upper	2234.90	PF 2	13000.00	5613.66	5622.57		5624.07	0.002300	11.52	1918.25	572.62	0.71
Animas	Upper	2234.90	PF 3	21500.00	5613.66	5624.01	5624.01	5626.03	0.002800	14.17	3007.74	865.91	0.81
Animas	Upper	2110	PF 1	100.00	5612.15	5612.56	5612.56	5612.71	0.014263	3.07	32.61	114.84	1.01
Animas	Upper	2110	PF 2	13000.00	5612.15	5623.25		5623.64	0.000362	5.41	3358.09	791.79	0.29
Animas	Upper	2110	PF 3	21500.00	5612.15	5623.19		5624.29	0.001015	9.03	3309.88	787.95	0.49
Animas	Middle	2055	PF 1	94.00	5610.82	5611.85		5611.92	0.002316	2.02	46.59	78.62	0.46
Animas	Middle	2055	PF 2	12700.00	5610.82	5622.91		5623.59	0.000766	6.65	2047.15	320.16	0.40
Animas	Middle	2055	PF 3	2100.00	5610.82	5623.93		5623.94	0.000014	0.97	2381.73	339.02	0.06
Animas	Middle	1922.63	PF 1	94.00	5610.00	5611.78		5611.81	0.000353	1.26	74.65	62.24	0.20
Animas	Middle	1922.63	PF 2	12700.00	5610.00	5619.80	5619.68	5623.11	0.004756	14.62	868.60	126.01	0.98
Animas	Middle	1922.63	PF 3	2100.00	5610.00	5623.91		5623.94	0.000027	1.38	1940.01	604.55	0.08
Animas	Middle	1726.21	PF 1	94.00	5609.25	5611.77		5611.78	0.000057	0.65	144.86	83.51	0.09
Animas	Middle	1726.21	PF 2	12700.00	5609.25	5619.70		5621.98	0.003715	12.10	1049.58	169.14	0.86
Animas	Middle	1726.21	PF 3	2100.00	5609.25	5623.92		5623.93	0.000015	0.92	3021.10	700.00	0.06
Animas	Middle	1573.54	PF 1	94.00	5608.54	5611.77		5611.77	0.000032	0.56	167.30	77.60	0.07
Animas	Middle	1573.54	PF 2	12700.00	5608.54	5618.32	5618.05	5621.29	0.004471	13.83	918.08	138.35	0.95
Animas	Middle	1573.54	PF 3	2100.00	5608.54	5623.91		5623.93	0.000013	1.11	2334.21	300.00	0.06
Animas	Lower	1420.97	PF 1	95.00	5610.68	5611.74		5611.76	0.000513	1.09	87.15	119.39	0.22
Animas	Lower	1420.97	PF 2	12995.00	5610.68	5617.76	5617.76	5620.58	0.004341	13.65	1058.44	235.11	0.94
Animas	Lower	1420.97	PF 3	21495.00	5610.68	5620.66	5620.66	5623.55	0.002959	14.39	2088.91	674.30	0.83
Animas	Lower	1200	PF 1	95.00	5610.45	5611.42	5611.29	5611.50	0.005000	2.22	42.72	110.93	0.63
Animas	Lower	1200	PF 2	12995.00	5610.45	5616.93	5616.93	5618.73	0.003826	11.54	1527.91	456.19	0.86
Animas	Lower	1200	PF 3	21495.00	5610.45	5618.65	5618.65	5620.86	0.003541	13.28	2465.87	613.02	0.87

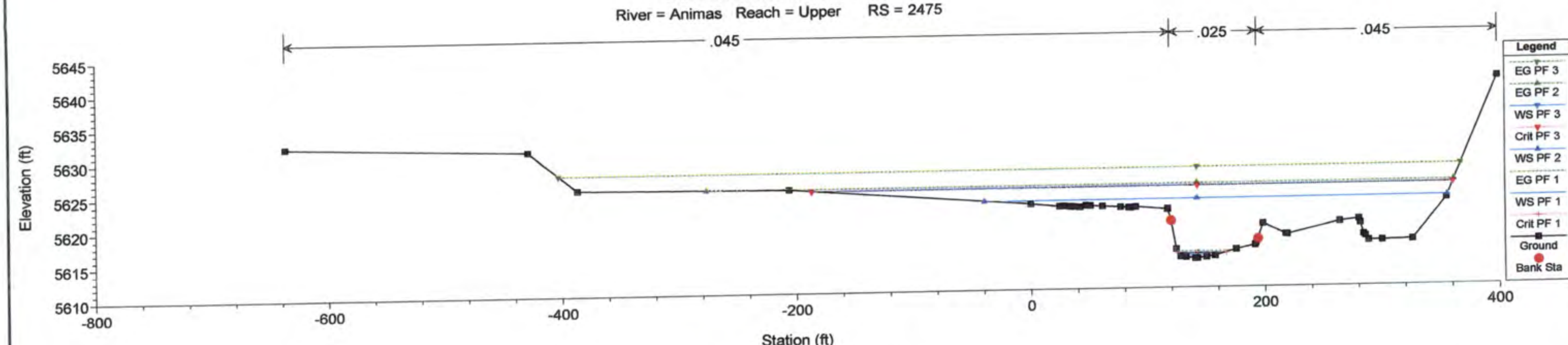
NewRiverNChannel71513

River = Animas   Reach = Upper   RS = 2722.61



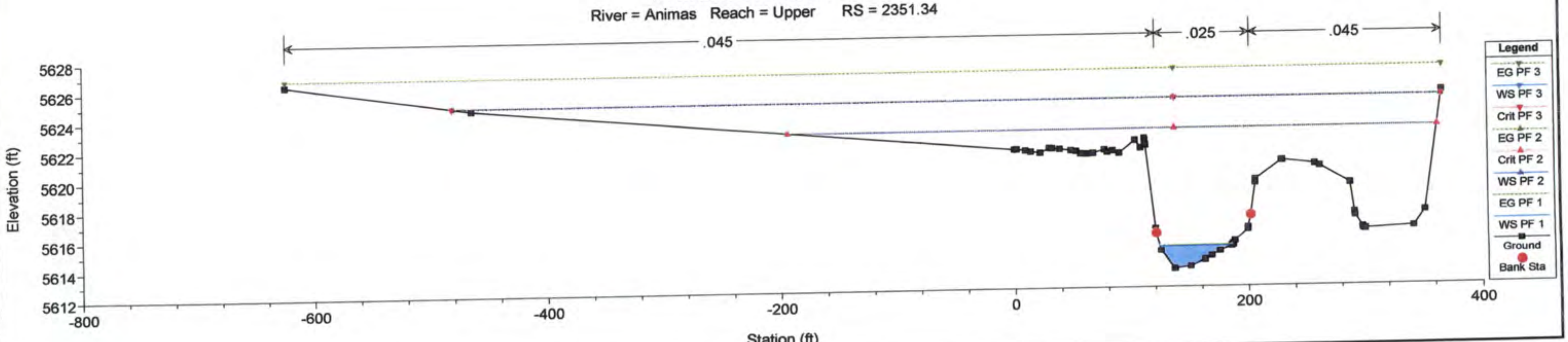
NewRiverNChannel71513

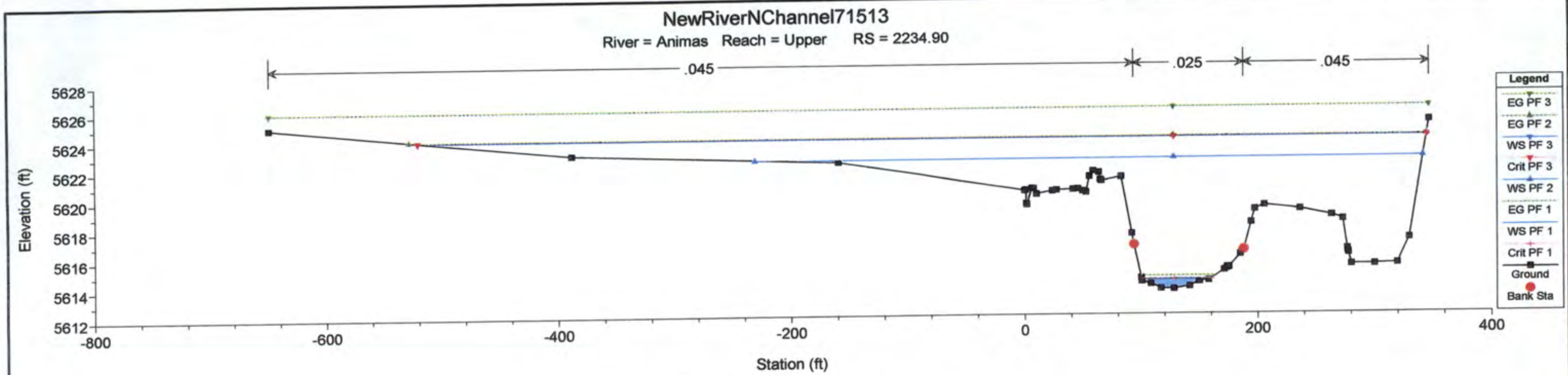
River = Animas   Reach = Upper   RS = 2475

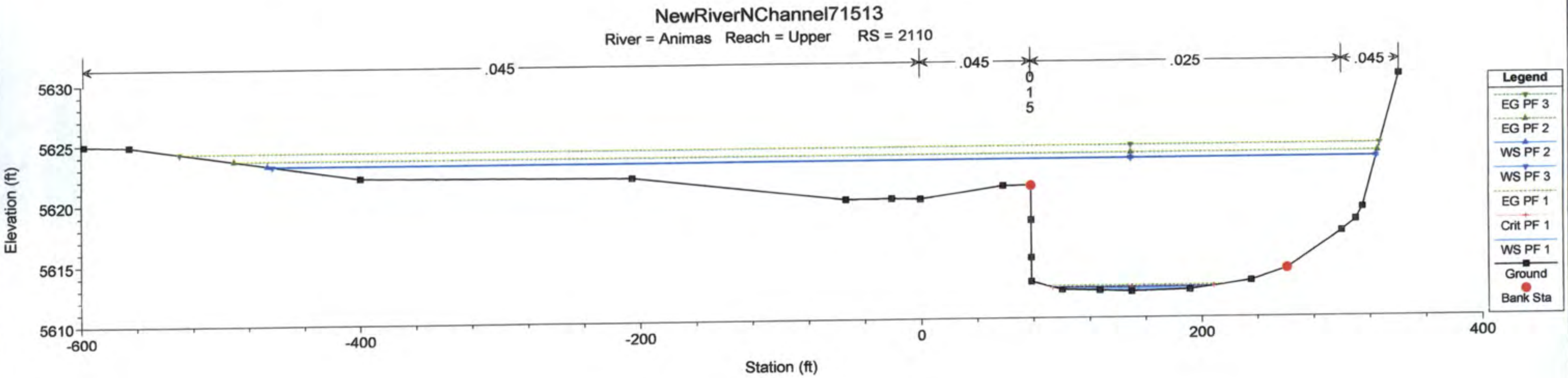


NewRiverNChannel71513

River = Animas   Reach = Upper   RS = 2351.34

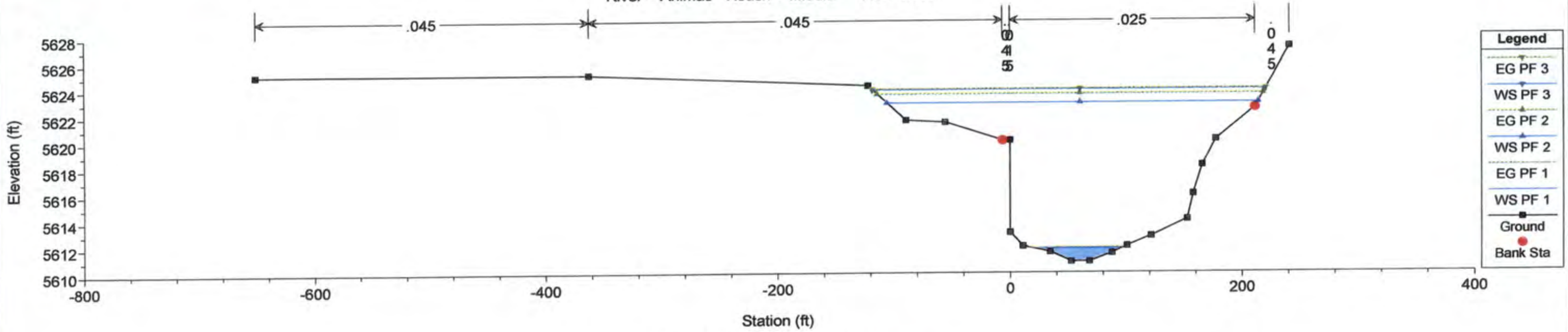



NewRiverNChannel71513
River = Animas Reach = Upper RS = 2234.90
.045
.025
.045
Elevation (ft)
Station (ft)
Legend
EG PF 3
EG PF 2
WS PF 3
Crit PF 3
WS PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta


NewRiverNChannel71513
River = Animas Reach = Upper RS = 2110
.045
.045
.025
.045
Elevation (ft)
Station (ft)
Legend
EG PF 3
EG PF 2
WS PF 2
WS PF 3
EG PF 1
Crit PF 1
WS PF 1
Ground
Bank Sta

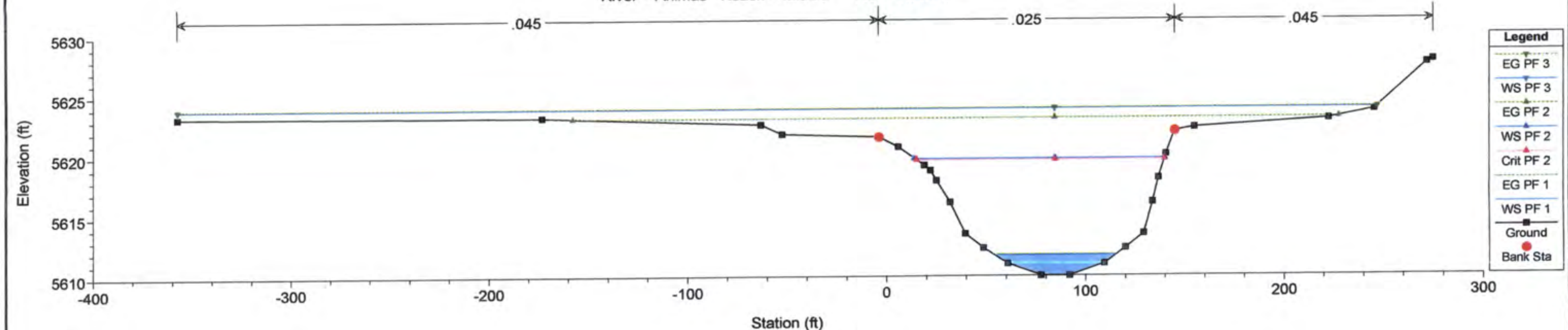
NewRiverNChannel71513

River = Animas Reach = Middle RS = 2055



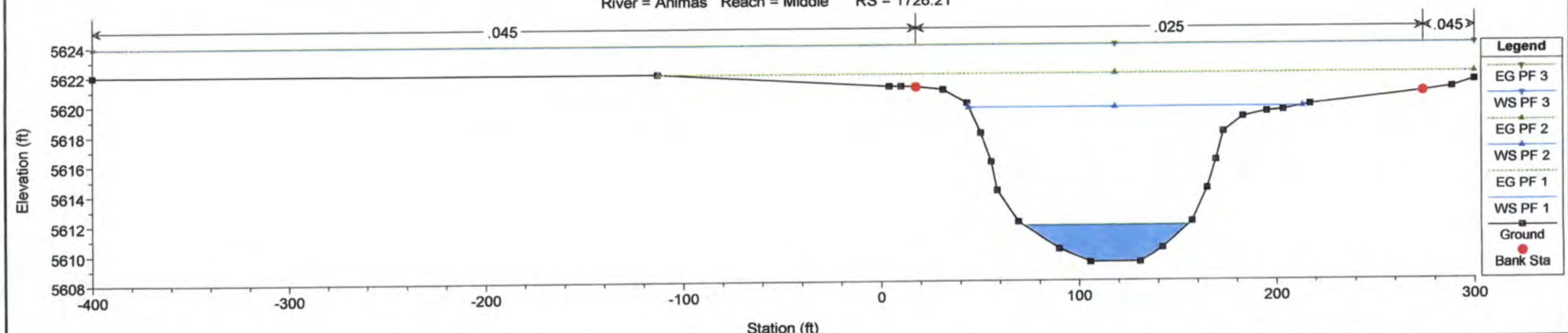
NewRiverNChannel71513

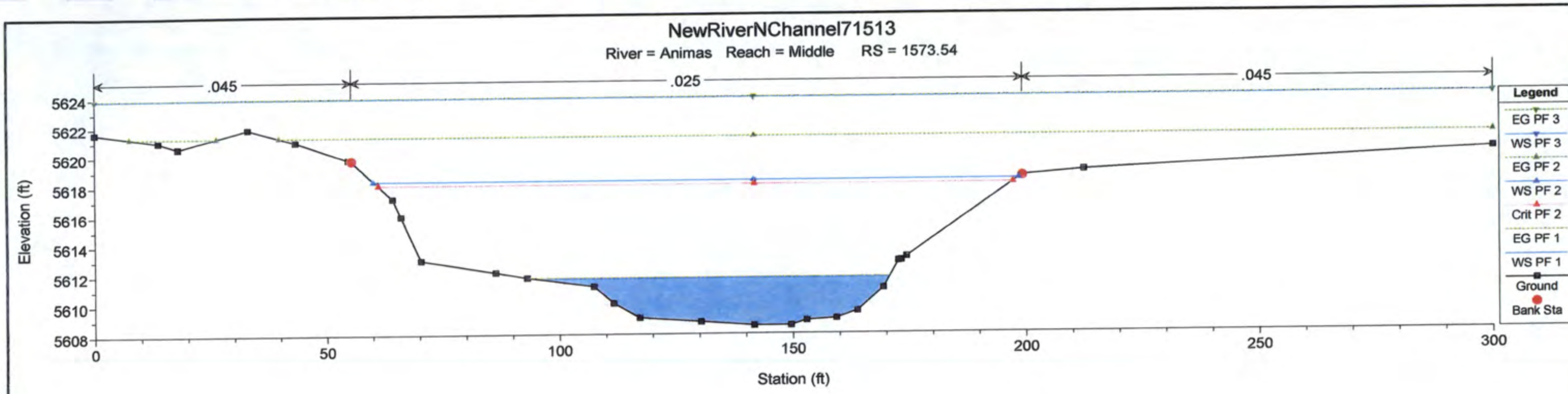
River = Animas Reach = Middle RS = 1922.63



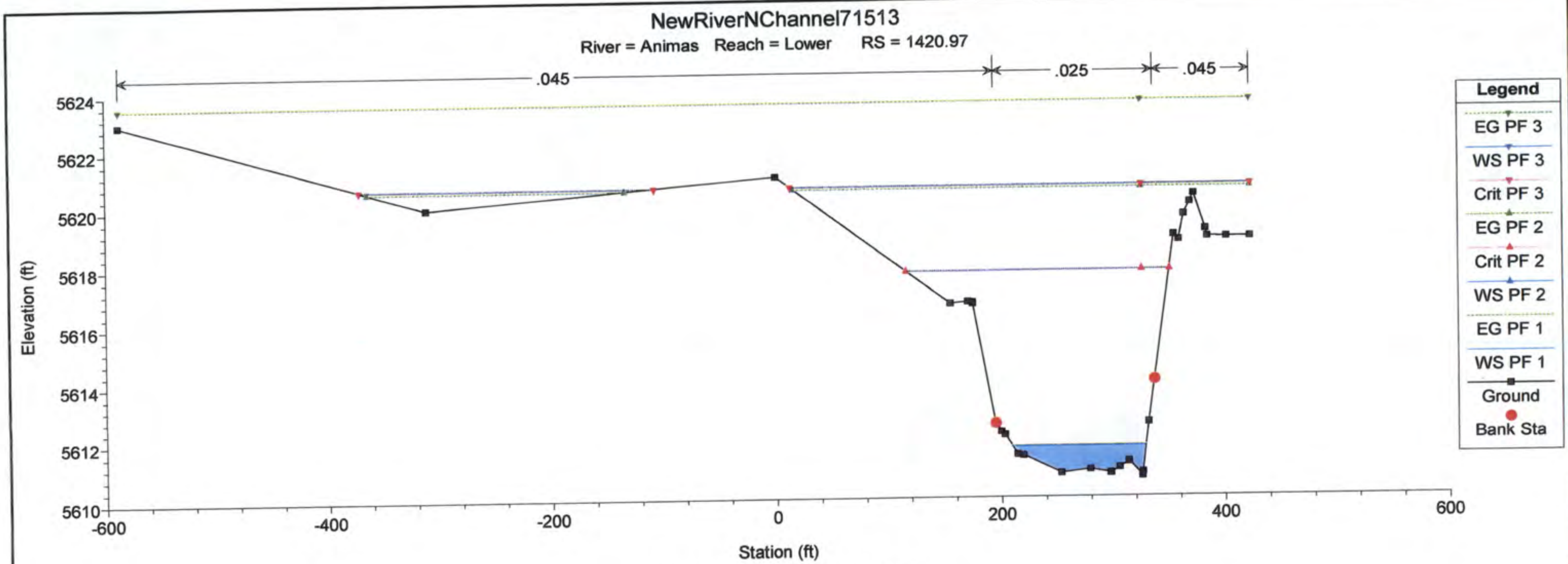
NewRiverNChannel71513

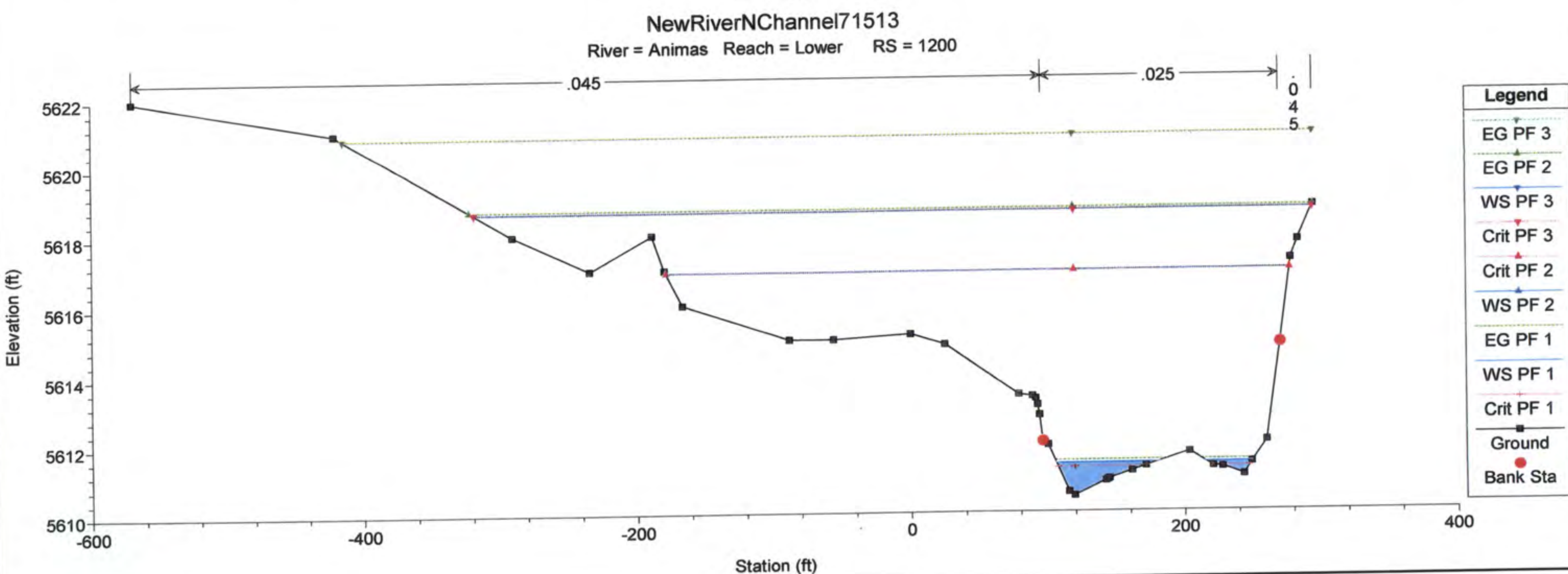
River = Animas Reach = Middle RS = 1726.21

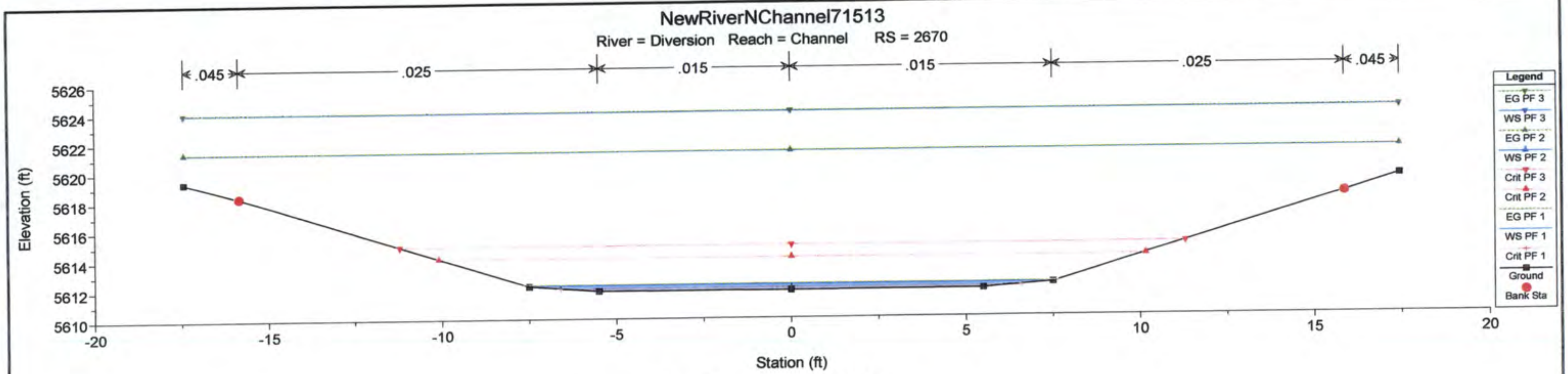




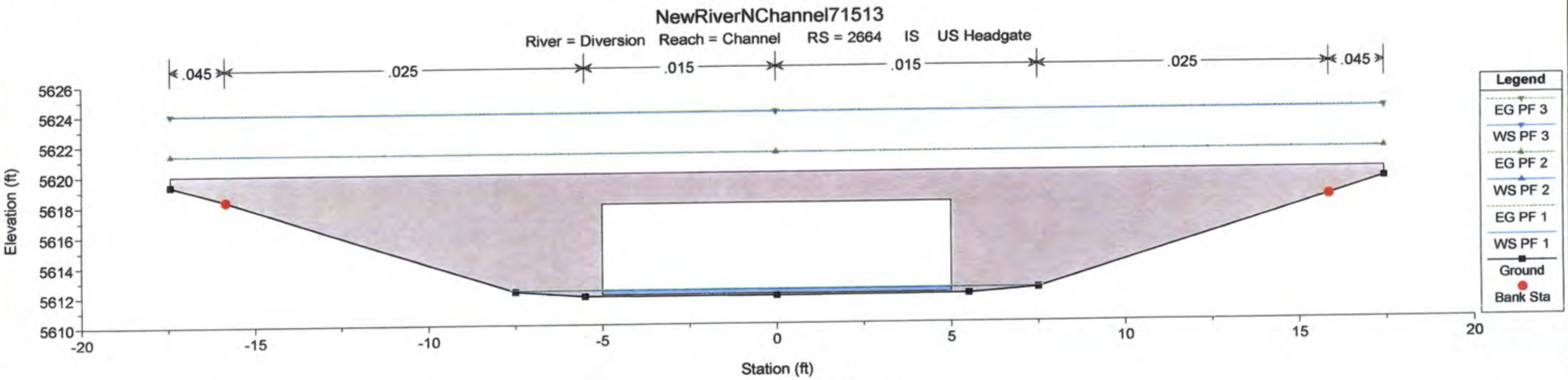
NewRiverNChannel71513
River = Animas Reach = Middle RS = 1573.54
.045
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Crit PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
5610
5608
0
50
100
150
200
250
300
Station (ft)


NewRiverNChannel71513
River = Animas Reach = Lower RS = 1420.97
.045
.025
.045
Legend
EG PF 3
WS PF 3
Crit PF 3
EG PF 2
Crit PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
5624
5622
5620
5618
5616
5614
5612
5610
-600
-400
-200
0
200
400
600

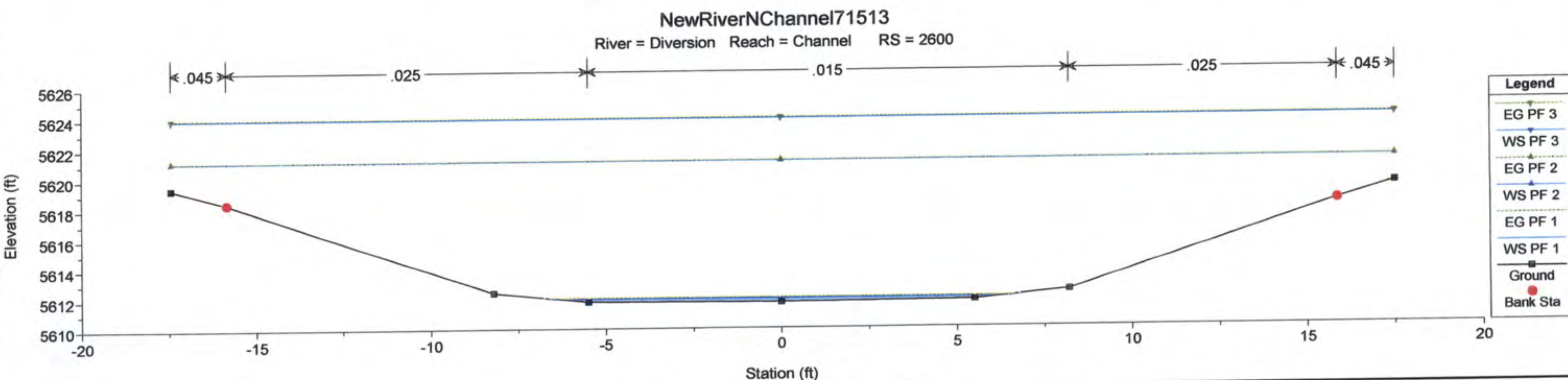

NewRiverNChannel71513
River = Animas Reach = Lower RS = 1200
.045
.025
.045
Legend
EG PF 3
EG PF 2
WS PF 3
Crit PF 3
Crit PF 2
WS PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
5622
5620
5618
5616
5614
5612
5610
-600
-400
-200
0
200
400



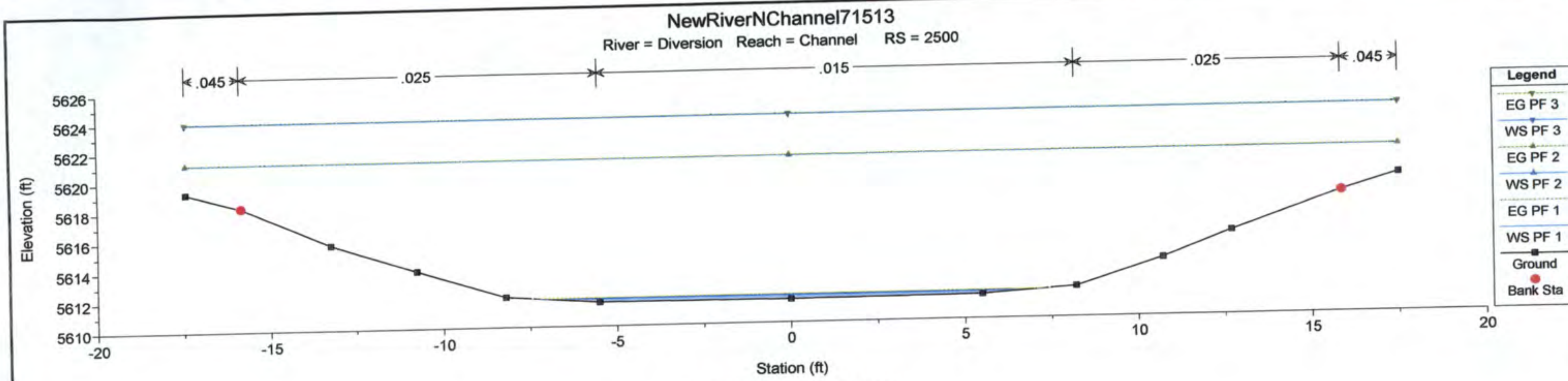
NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2670
.045
.025
.015
.015
.025
.045
Elevation (ft)
5610
5612
5614
5616
5618
5620
5622
5624
5626
Station (ft)
-20
-15
-10
-5
0
5
10
15
20
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Crit PF 3
Crit PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta



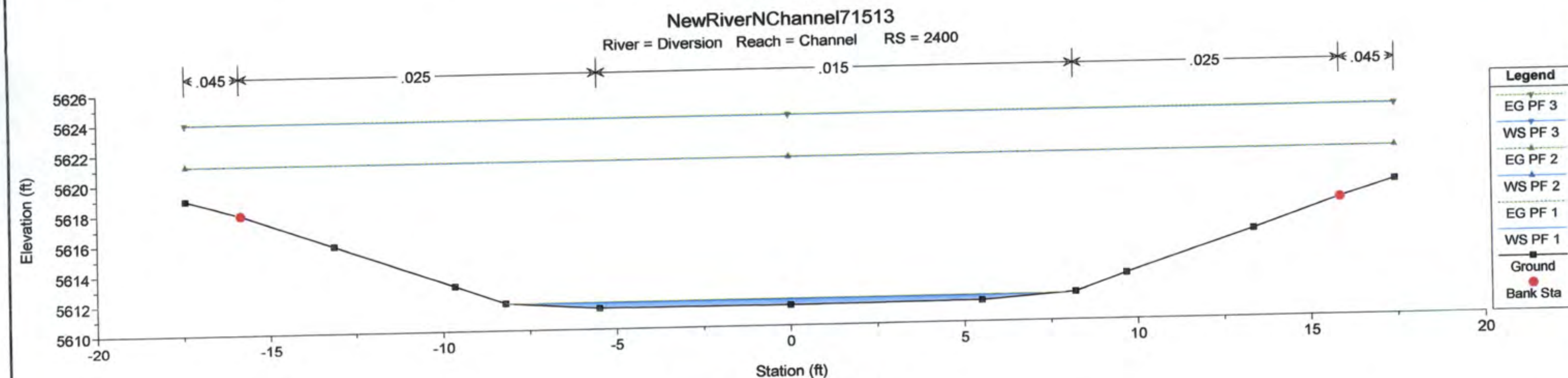
NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2664 IS US Headgate
.045
.025
.015
.015
.025
.045
Elevation (ft)
5610
5612
5614
5616
5618
5620
5622
5624
5626
Station (ft)
-20
-15
-10
-5
0
5
10
15
20
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta



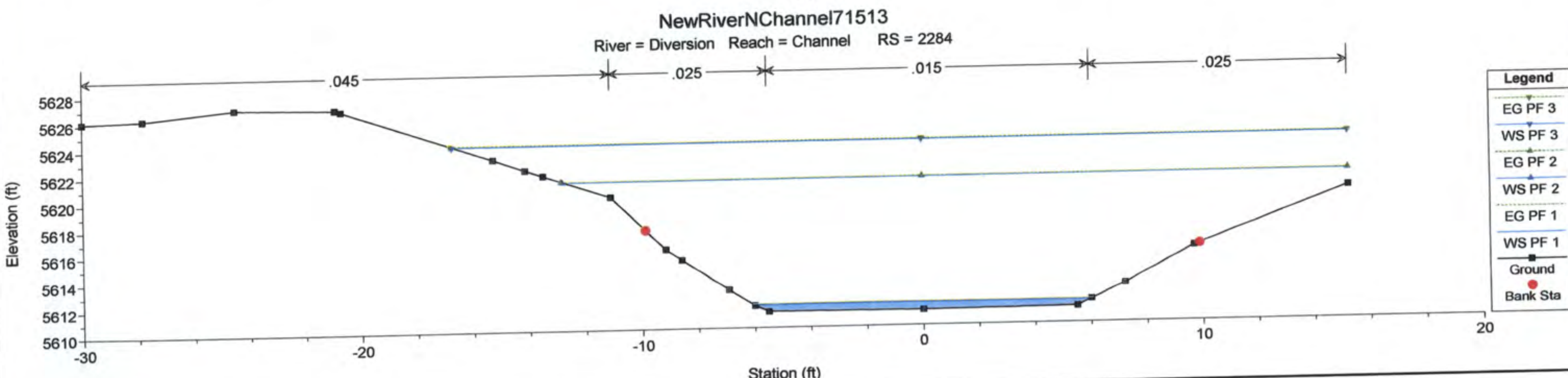
NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2600
.045
.025
.015
.025
.045
Elevation (ft)
5610
5612
5614
5616
5618
5620
5622
5624
5626
Station (ft)
-20
-15
-10
-5
0
5
10
15
20
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta



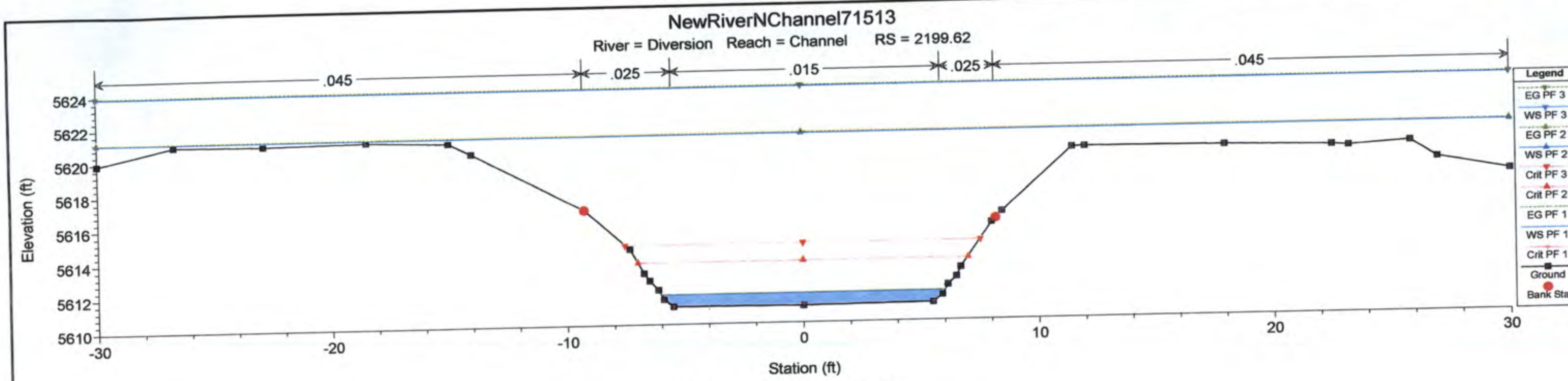
NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2500
.045
.025
.015
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

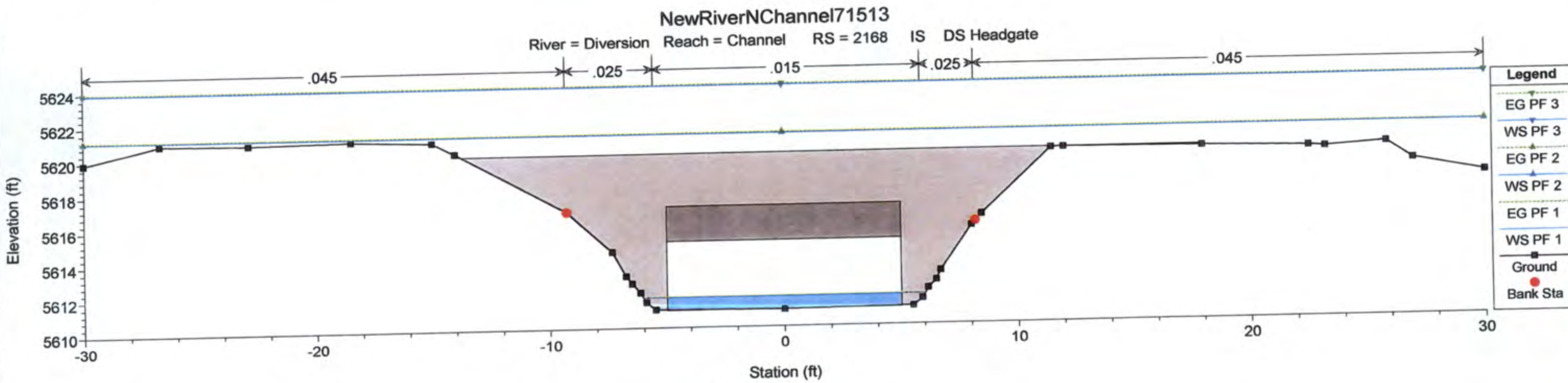


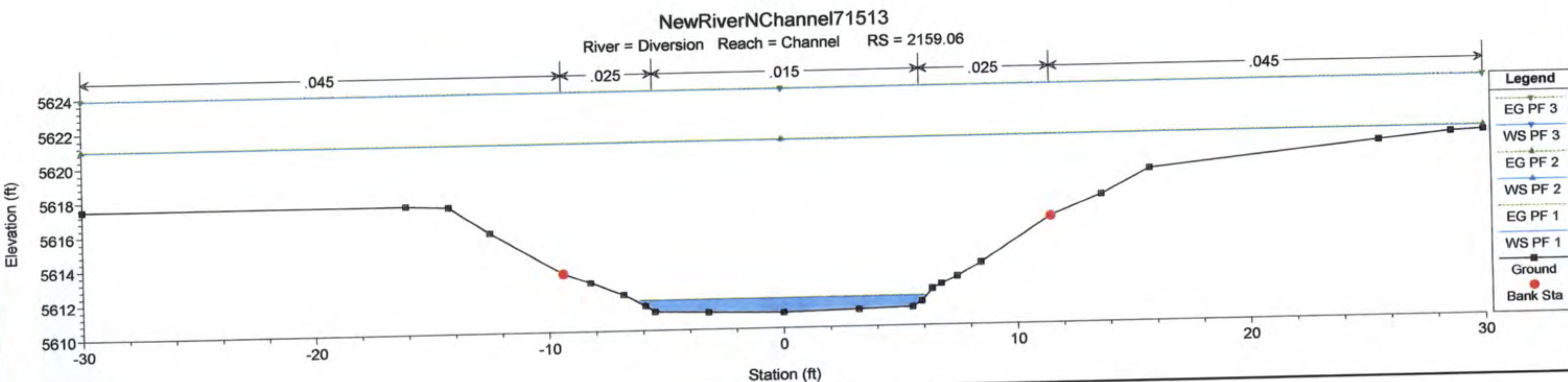
NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2400
.045
.025
.015
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

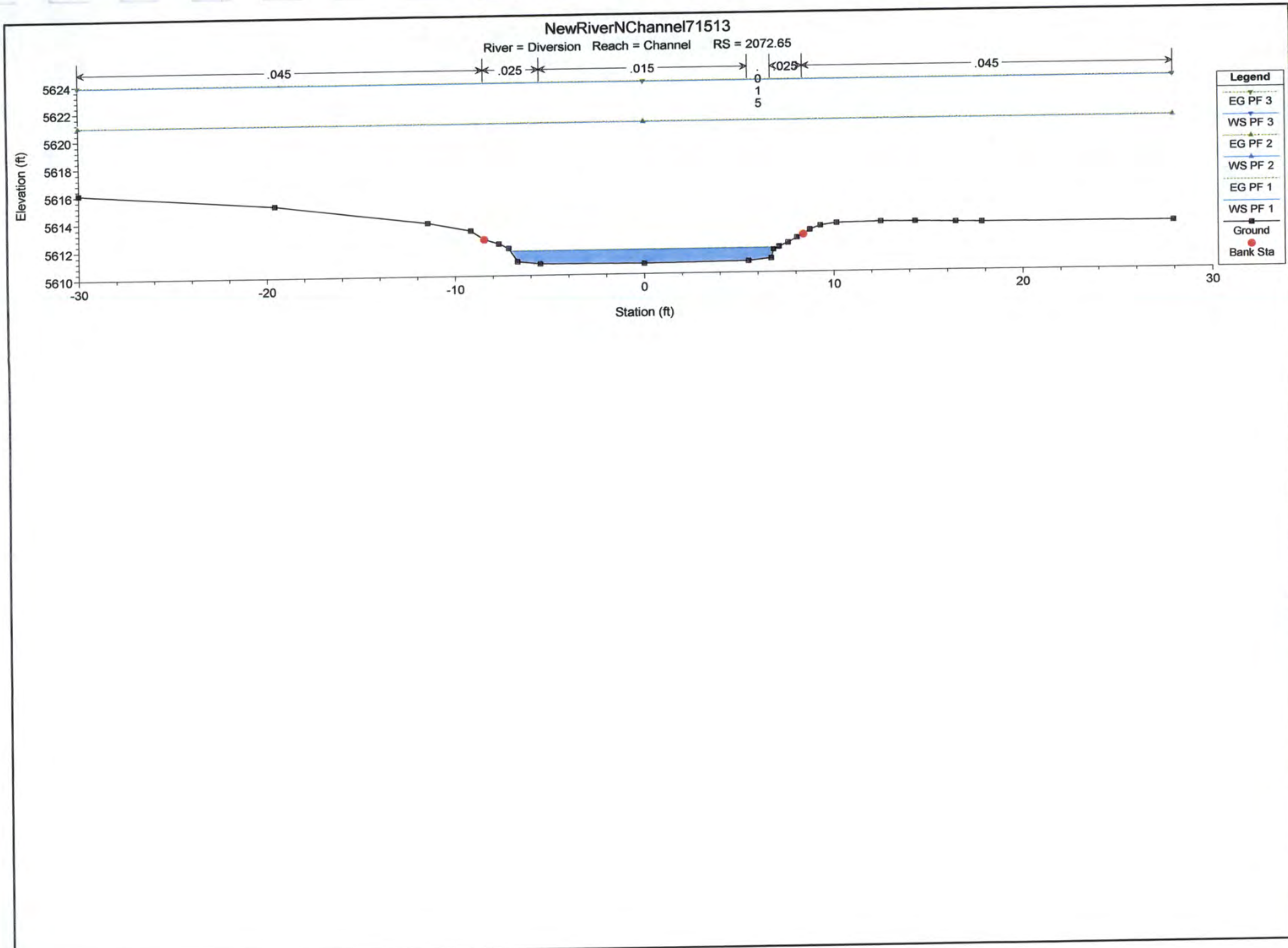


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2284
.045
.025
.015
.025
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2199.62
.045
.025
.015
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Crit PF 3
Crit PF 2
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
5610
-30
-20
-10
0
10
20
30
Station (ft)


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2168 IS DS Headgate
.045
.025
.015
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
5610
-30
-20
-10
0
10
20
30
Station (ft)


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2159.06
.045
.025
.015
.025
.045
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
5624
5622
5620
5618
5616
5614
5612
5610
-30
-20
-10
0
10
20
30
Station (ft)


NewRiverNChannel71513
River = Diversion Reach = Channel RS = 2072.65
.045
.025
.015
.025
.045
Elevation (ft)
Station (ft)
Legend
EG PF 3
WS PF 3
EG PF 2
WS PF 2
EG PF 1
WS PF 1
Ground
Bank Sta

Appendix D

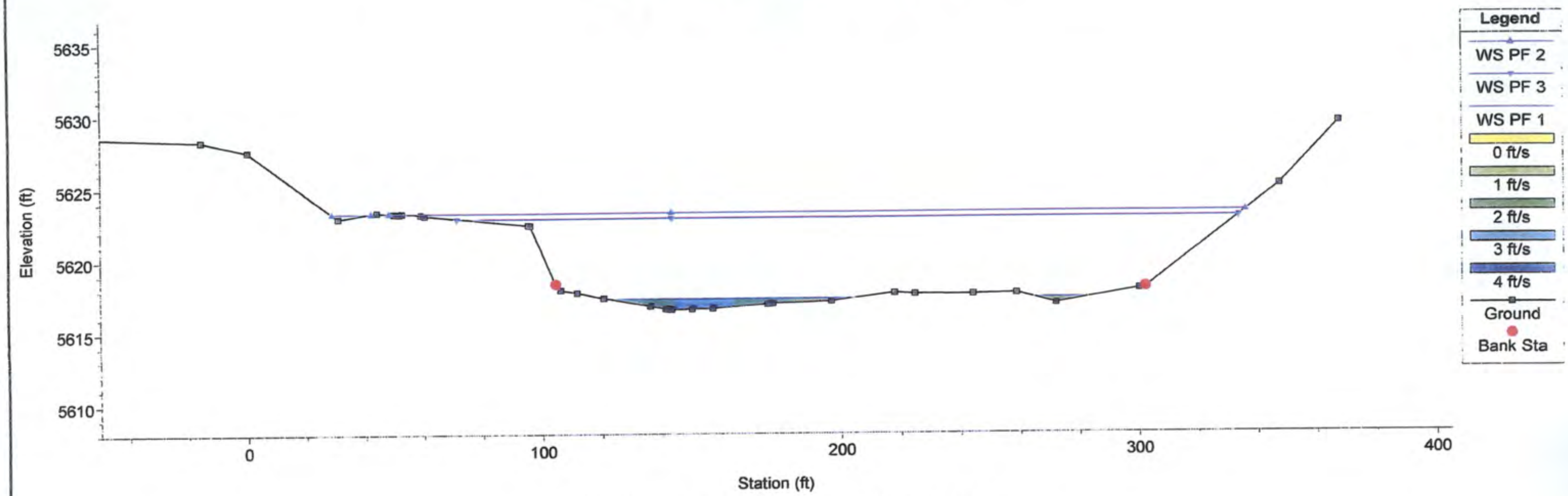
Proposed Hydraulic Data for Diversion Weir


2722.61
2475
2351.34
2234.90
2109.44
1420.97
Upper
Animas
0
Above Weir
Channel
1922.63
2400
1690
1625
Middle
2284
1573.54
2199.62
2072.65
DS
Lower

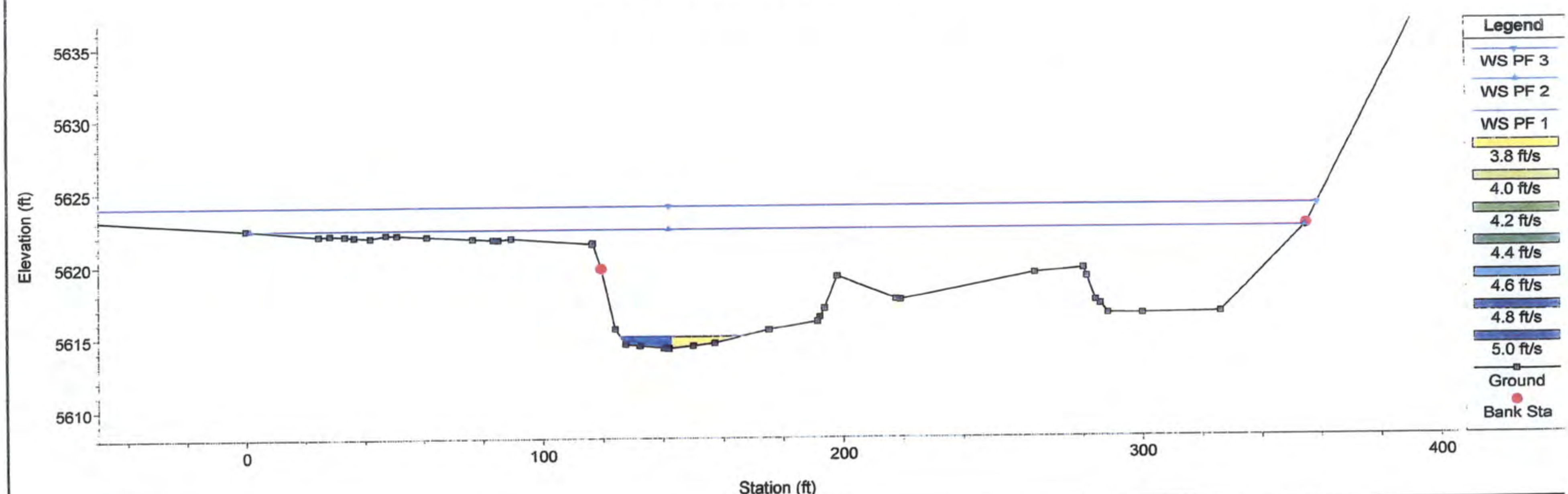
WEIR AT 1675

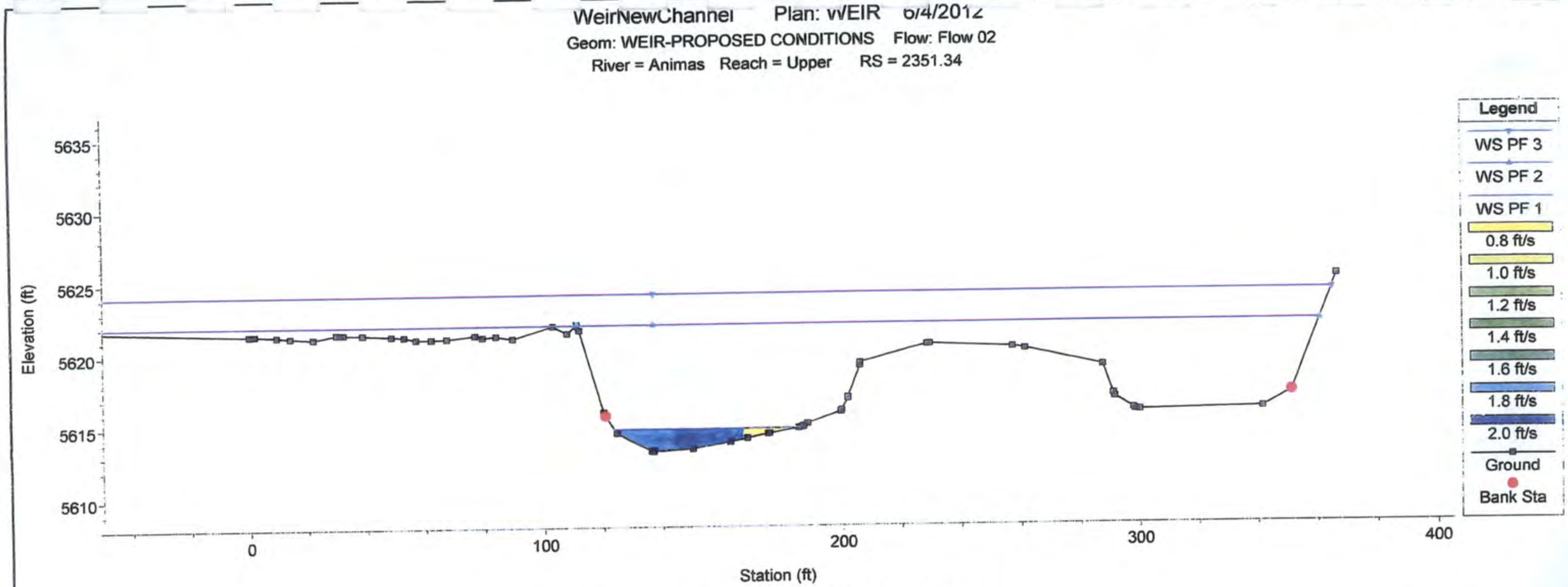
River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Diversion	Channel	2610	PF 1	6	5612	5612.4		5612.5	0.015622	2.54	2.37	11.83	1
Diversion	Channel	2610	PF 2	300	5612	5621.67	5614.5	5621.7	0.000033	1.23	251.86	34.94	0.08
Diversion	Channel	2610	PF 3	500	5612	5622.34	5615.32	5622.4	0.000069	1.88	275.23	34.94	0.11
Diversion	Channel	2605	Inl Struct										
Diversion	Channel	2500	PF 1	6	5611.68	5612.33	5612.12	5612.35	0.001774	1.22	4.91	14.34	0.37
Diversion	Channel	2500	PF 2	300	5611.68	5621.27		5621.3	0.000035	1.25	246.89	35.44	0.08
Diversion	Channel	2500	PF 3	500	5611.68	5621.27		5621.34	0.000098	2.09	246.89	35.44	0.13
Diversion	Channel	2400	PF 1	6	5611.53	5612.23		5612.24	0.000723	0.92	6.53	14.84	0.24
Diversion	Channel	2400	PF 2	300	5611.53	5621.27		5621.29	0.000032	1.22	254.12	34.94	0.08
Diversion	Channel	2400	PF 3	500	5611.53	5621.27		5621.33	0.000088	2.03	253.98	34.94	0.13
Diversion	Channel	2284	PF 1	6	5611.35	5611.89	5611.87	5612.01	0.012693	2.84	2.11	7.58	0.95
Diversion	Channel	2284	PF 2	300	5611.35	5621.23		5621.29	0.000084	1.89	187.42	42.71	0.12
Diversion	Channel	2284	PF 3	500	5611.35	5621.15		5621.31	0.000242	3.19	184.07	42.6	0.2
Diversion	Channel	2199.62	PF 1	1	5611.23	5611.77	5611.44	5611.77	0.000126	0.31	3.25	10.2	0.1
Diversion	Channel	2199.62	PF 2	295	5611.23	5621.23	5614.28	5621.28	0.000077	1.86	200.2	60	0.11
Diversion	Channel	2199.62	PF 3	495	5611.23	5621.14	5615.33	5621.28	0.000225	3.15	195.15	52.73	0.19
Diversion	Channel	2168	Inl Struct										
Diversion	Channel	2159.06	PF 1	1	5611.17	5611.76		5611.77	0.000045	0.22	4.46	10.19	0.06
Diversion	Channel	2159.06	PF 2	295	5611.17	5620.74		5620.77	0.000043	1.47	273.23	57.79	0.09
Diversion	Channel	2159.06	PF 3	495	5611.17	5614.96	5614.96	5616.33	0.00741	9.41	53.76	20.79	1
Diversion	Channel	2072.65	PF 1	1	5611.04	5611.76		5611.76	0.000013	0.14	6.99	12.26	0.03
Diversion	Channel	2072.65	PF 2	295	5611.04	5620.75		5620.77	0.00002	1.13	433.26	57.95	0.07
Diversion	Channel	2072.65	PF 3	495	5611.04	5613.91	5614.35	5615.54	0.01051	10.8	59.88	39.84	1.21
Animas	Upper	2722.61	PF 1	100	5616.57	5617.33	5617.24	5617.43	0.006611	2.56	39.08	101.39	0.73
Animas	Upper	2722.61	PF 2	13000	5616.57	5623.27	5622.32	5624.99	0.002945	10.65	1319.79	300.86	0.77
Animas	Upper	2722.61	PF 3	21500	5616.57	5622.9	5624.49	5628.28	0.010006	18.83	1217.5	262.01	1.4
Animas	Upper	2475	PF 1	100	5614.2	5615.06	5615.06	5615.34	0.010989	4.28	23.38	41.02	1
Animas	Upper	2475	PF 2	13000	5614.2	5622.45	5621.78	5624.18	0.003611	10.59	1263.58	352.9	0.82
Animas	Upper	2475	PF 3	21500	5614.2	5624.02	5623.89	5626.52	0.003806	12.96	1938.86	479.85	0.88
Animas	Upper	2351.34	PF 1	100	5613.22	5614.81	5614.15	5614.85	0.000934	1.72	58	62.56	0.32
Animas	Upper	2351.34	PF 2	13000	5613.22	5621.99	5621.53	5623.72	0.00367	10.68	1339.17	446.32	0.83
Animas	Upper	2351.34	PF 3	21500	5613.22	5624.13		5625.93	0.002628	11.39	2631.83	765.44	0.74
Animas	Upper	2234.9	PF 1	100	5613.66	5614.34	5614.34	5614.57	0.012538	3.83	26.14	59.92	1.02
Animas	Upper	2234.9	PF 2	13000	5613.66	5622.01		5623.24	0.002349	9.05	1635.09	470.41	0.67
Animas	Upper	2234.9	PF 3	21500	5613.66	5624.25		5625.52	0.001716	9.67	3212.57	896.65	0.61
Animas	Upper	2109.44	PF 1	100	5611.52	5612.96	5612.45	5613.06	0.00166	2.47	40.45	39.02	0.43
Animas	Upper	2109.44	PF 2	13000	5611.52	5621.73		5622.91	0.00265	9.14	1985.42	933.68	0.71
Animas	Upper	2109.44	PF 3	21500	5611.52	5624.57		5625.14	0.000934	7.25	4942.05	1058.07	0.45
Animas	Upper	1922.63	PF 1	100	5609.75	5613.02		5613.02	0.000017	0.35	282.42	159.35	0.05
Animas	Upper	1922.63	PF 2	13000	5609.75	5621.92		5622.55	0.000562	6.58	2565.63	554.33	0.36
Animas	Upper	1922.63	PF 3	21500	5609.75	5624.08		5624.97	0.000673	8.18	3819.49	605.21	0.41
Animas	Upper	1726.21	PF 1	100	5609.21	5613.02		5613.02	0.000021	0.41	246.09	135.11	0.05
Animas	Upper	1726.21	PF 2	13000	5609.21	5621.38		5622.37	0.000972	8.18	2048.67	589.16	0.47
Animas	Upper	1726.21	PF 3	21500	5609.21	5623.64		5624.79	0.000968	9.42	3597.03	700	0.49
Animas	Middle	1690	PF 1	94	5608.95	5612.96	5610.06	5612.96	0.000019	0.42	222.82	105.75	0.05
Animas	Middle	1690	PF 2	12700	5608.95	5620.93	5617.88	5622.1	0.001269	8.78	1575.29	284.05	0.53
Animas	Middle	1690	PF 3	21000	5608.95	5623.54	5620.5	5624.97	0.00118	10.1	2990.13	768	0.53
Animas	Middle	1675	Inl Struct										
Animas	Middle	1625	PF 1	94	5608.47	5611.78		5611.78	0.000071	0.71	131.63	77.06	0.1
Animas	Middle	1625	PF 2	12700	5608.47	5619.48		5621.45	0.002438	11.3	1180.01	205.51	0.72
Animas	Middle	1625	PF 3	21000	5608.47	5623.05	5621	5624.82	0.001499	11.32	2754.42	758	0.6
Animas	Middle	1573.54	PF 1	94	5608.18	5611.77		5611.78	0.000047	0.63	148.73	76.38	0.08
Animas	Middle	1573.54	PF 2	12700	5608.18	5618.66		5621.24	0.003504	13.16	1068.4	175.39	0.86
Animas	Middle	1573.54	PF 3	21000	5608.18	5621.31	5621.31	5624.56	0.003343	15.08	1735.86	303.35	0.87
Animas	Lower	1420.97	PF 1	95	5610.68	5611.74		5611.76	0.000505	1.09	87.55	119.46	0.22
Animas	Lower	1420.97	PF 2	12995	5610.68	5618.68	5618.68	5620.58	0.002567	11.45	1586.05	677.59	0.74
Animas	Lower	1420.97	PF 3	21495	5610.68	5618.78	5620.49	5623.7	0.006682	18.51	1656.23	685.5	1.19
Animas	Lower	1200	PF 1	95	5610.45	5611.34	5611.29	5611.46	0.008995	2.77	34.26	99.22	0.83
Animas	Lower	1200	PF 2	12995	5610.45	5615.79	5617.21	5619.42	0.009682	15.77	1021.91	423.99	1.32
Animas	Lower	1200	PF 3	21495	5610.45	5616.98	5618.54	5621.91	0.010288	19.04	1661.42	666.15	1.41

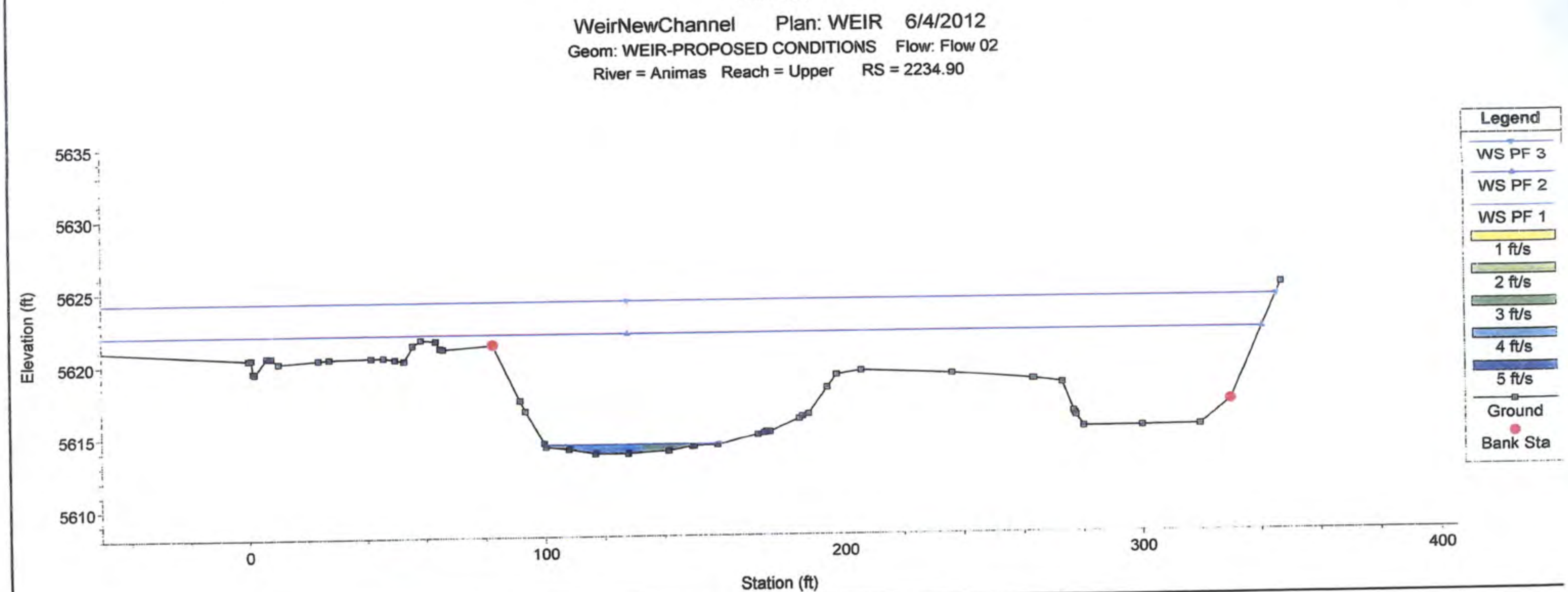
WeirNewChannel   Plan: WEIR   6/4/2012
Geom: WEIR-PROPOSED CONDITIONS   Flow: Flow 02
River = Animas   Reach = Upper   RS = 2722.61



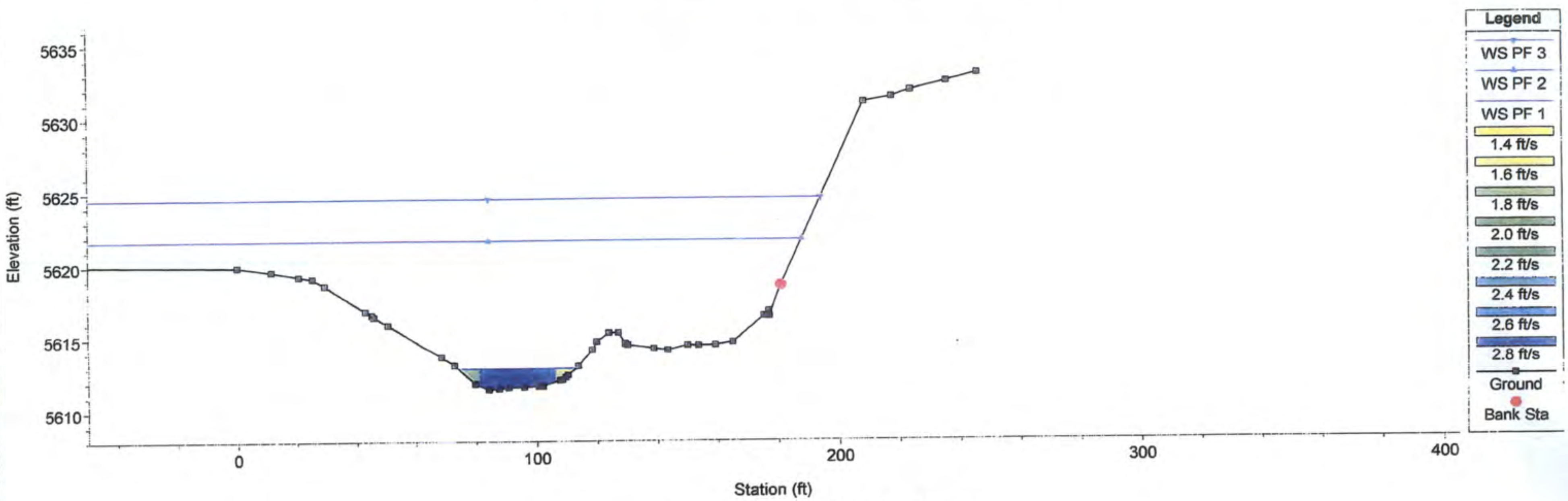
WeirNewChannel   Plan: WEIR   6/4/2012
Geom: WEIR-PROPOSED CONDITIONS   Flow: Flow 02
River = Animas   Reach = Upper   RS = 2475



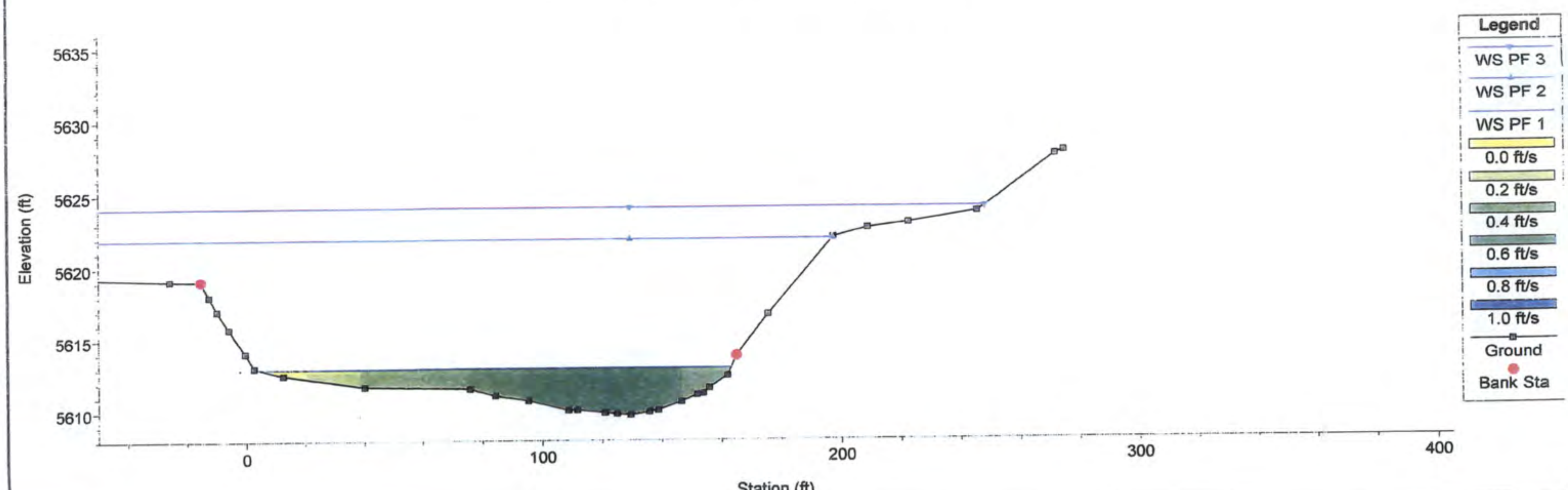

WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Upper RS = 2351.34
Legend
WS PF 3
WS PF 2
WS PF 1
0.8 ft/s
1.0 ft/s
1.2 ft/s
1.4 ft/s
1.6 ft/s
1.8 ft/s
2.0 ft/s
Ground
Bank Sta
Elevation (ft)
5635
5630
5625
5620
5615
5610
0
100
200
300
400
Station (ft)

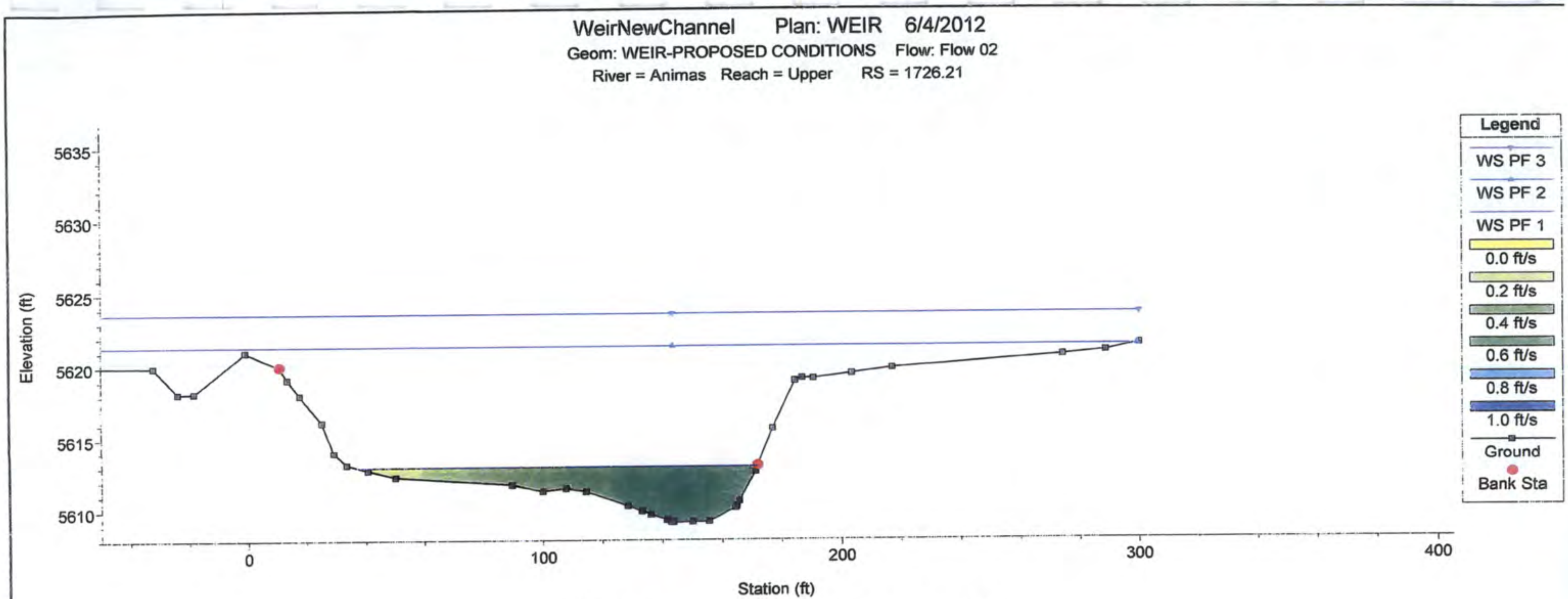

WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Upper RS = 2234.90
Legend
WS PF 3
WS PF 2
WS PF 1
1 ft/s
2 ft/s
3 ft/s
4 ft/s
5 ft/s
Ground
Bank Sta
Elevation (ft)
5635
5630
5625
5620
5615
5610
0
100
200
300
400
Station (ft)

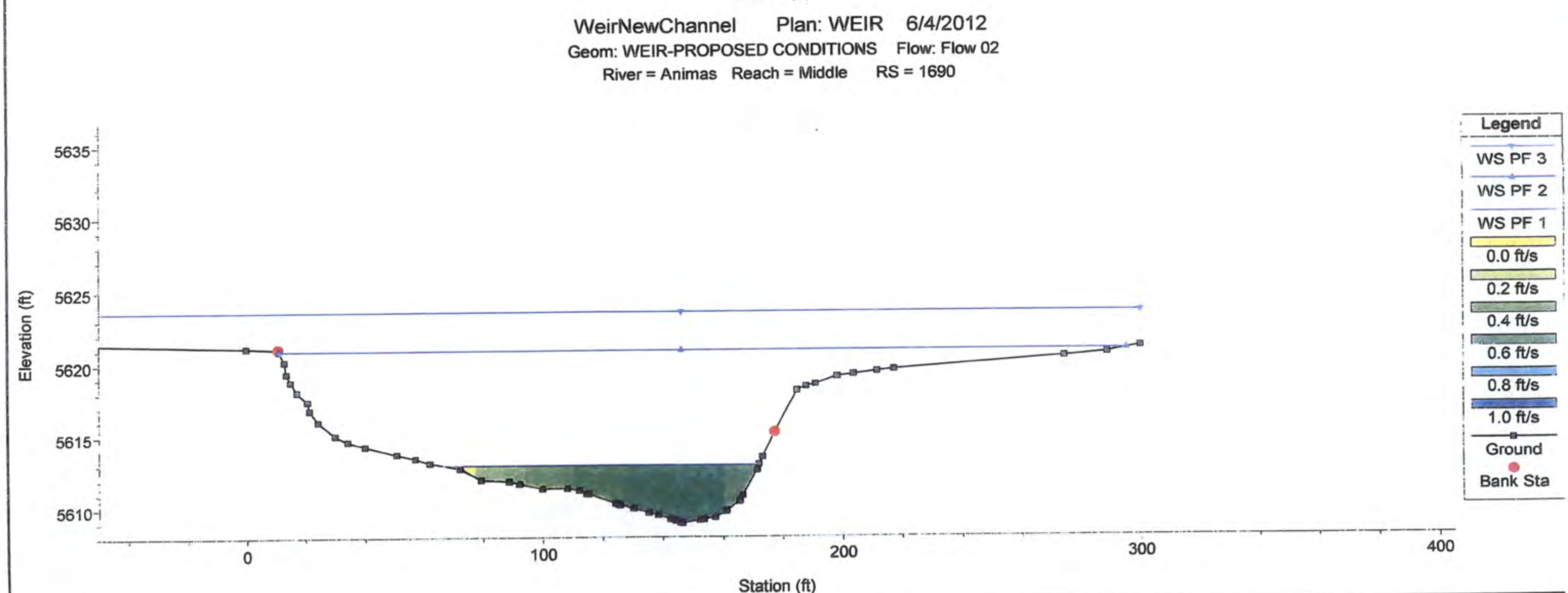
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Upper RS = 2109.44 2109 Island



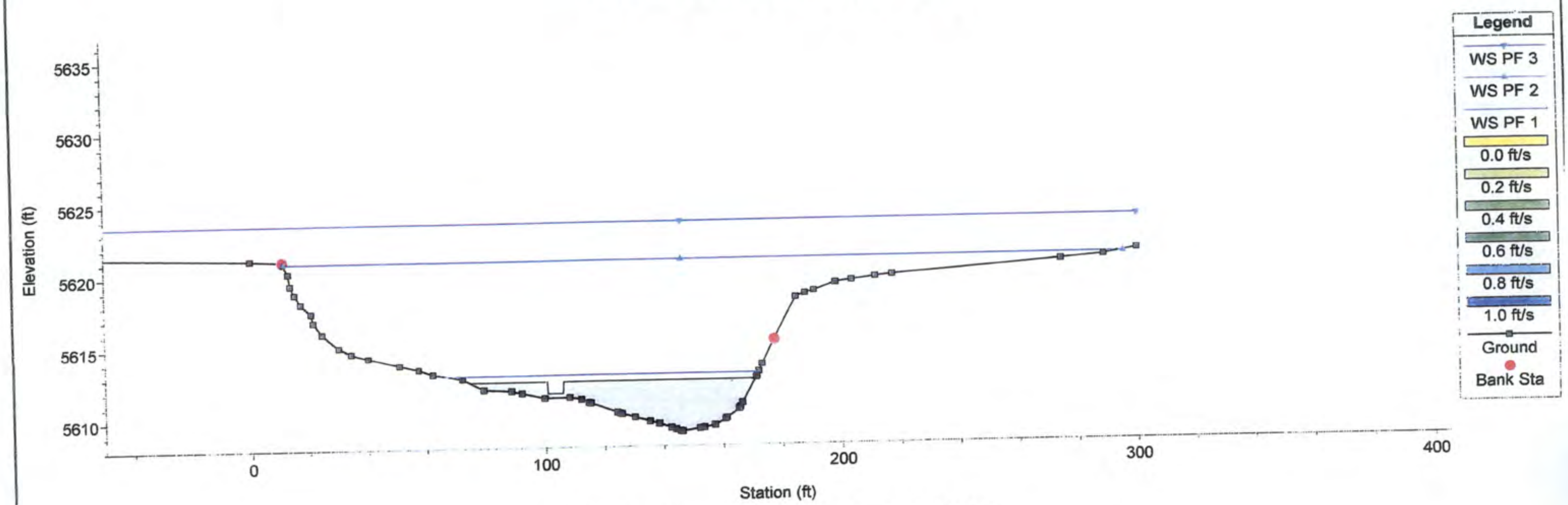
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Upper RS = 1922.63



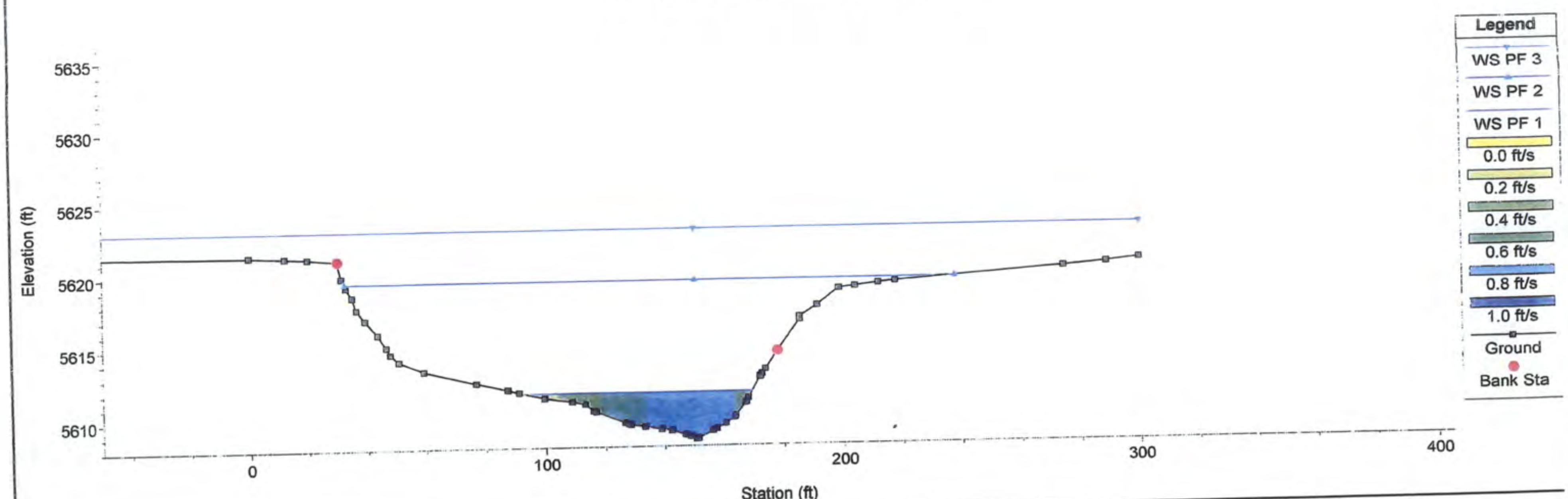

WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Upper RS = 1726.21
Legend
WS PF 3
WS PF 2
WS PF 1
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Bank Sta
Elevation (ft)
5635
5630
5625
5620
5615
5610
0
100
200
300
400
Station (ft)


WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Middle RS = 1690
Legend
WS PF 3
WS PF 2
WS PF 1
0.0 ft/s
0.2 ft/s
0.4 ft/s
0.6 ft/s
0.8 ft/s
1.0 ft/s
Ground
Bank Sta
Elevation (ft)
5635
5630
5625
5620
5615
5610
0
100
200
300
400
Station (ft)

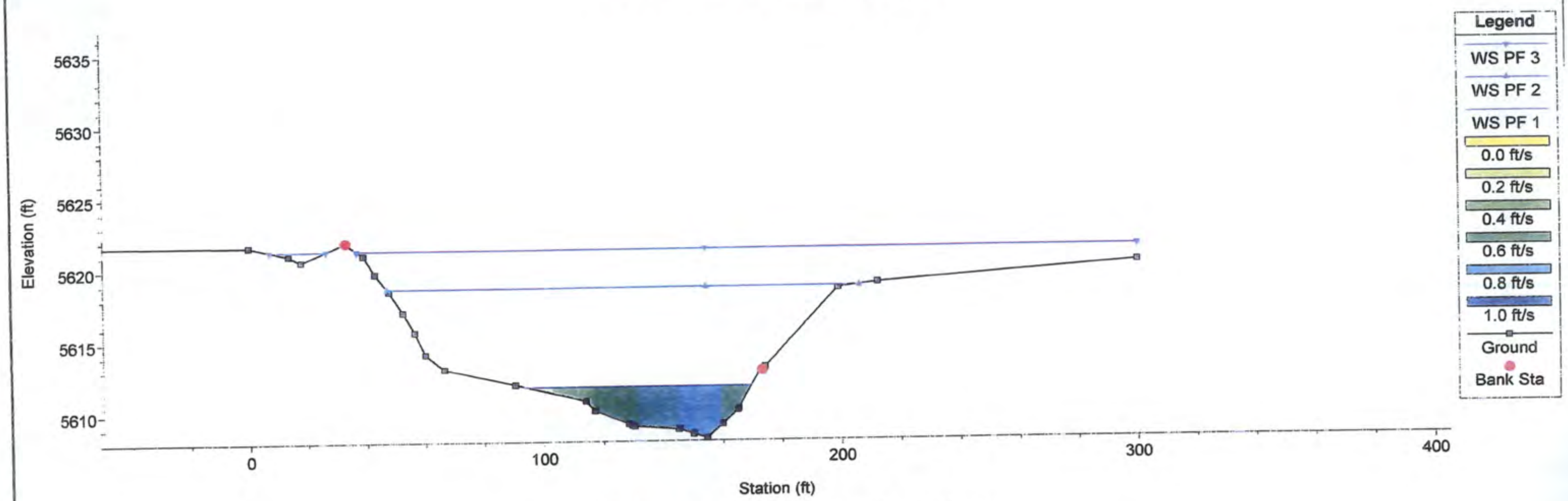
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Middle RS = 1675 IS



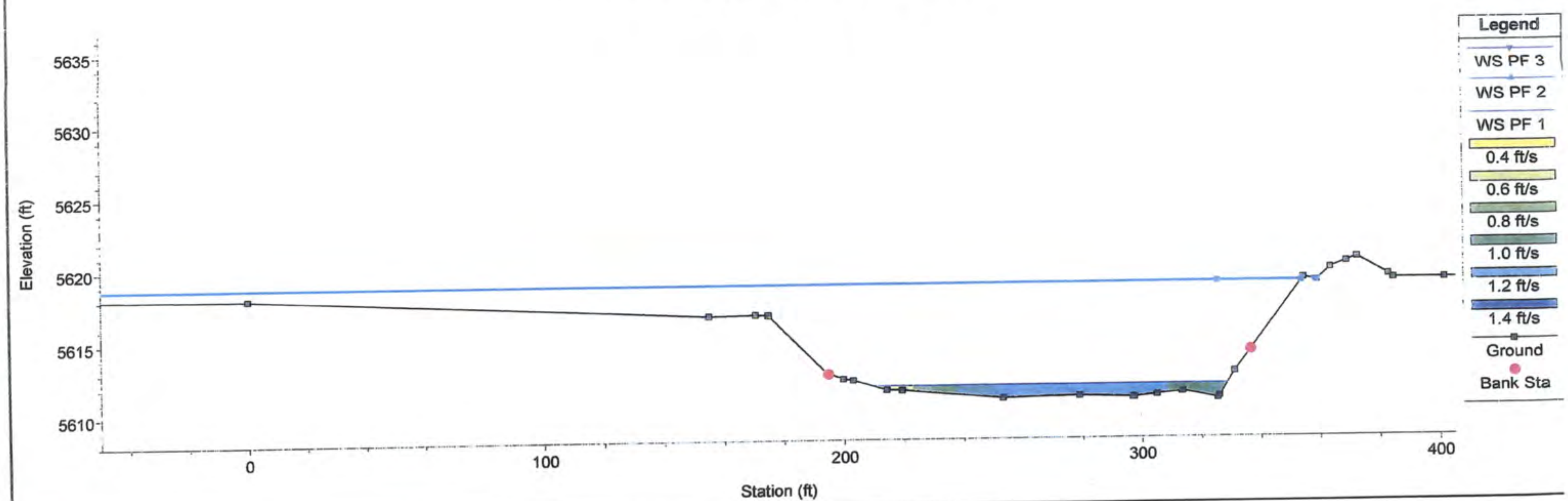
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Middle RS = 1625



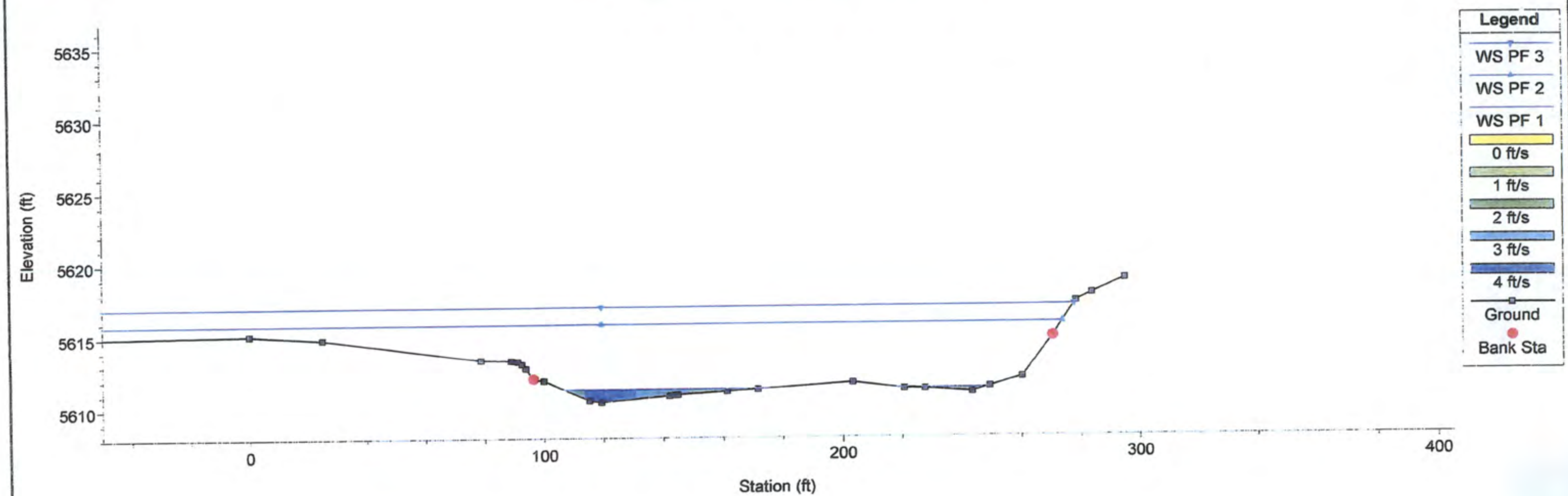
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Middle RS = 1573.54



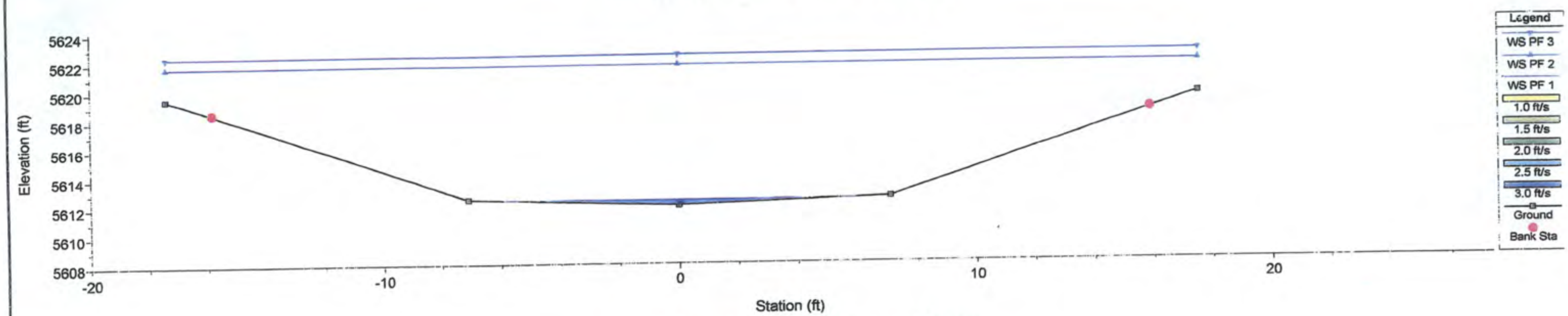
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Lower RS = 1420.97



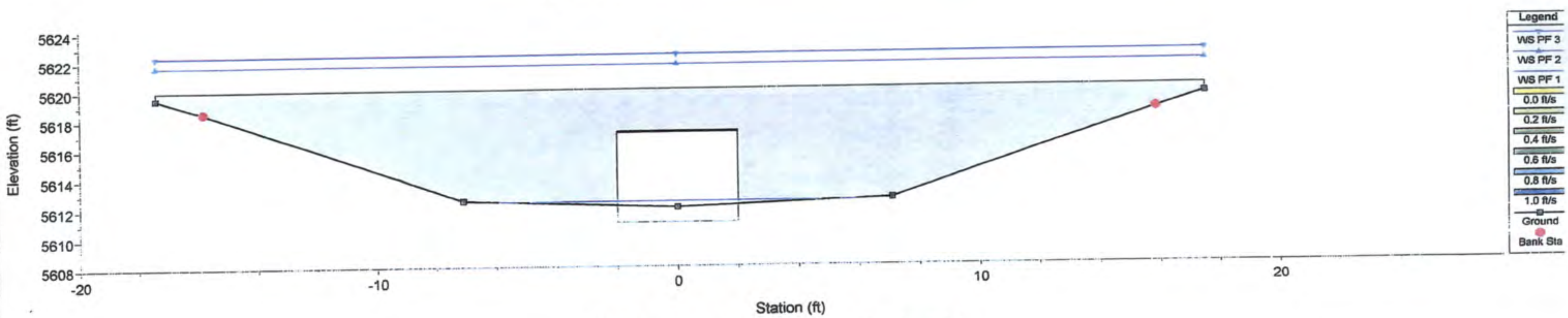
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Animas Reach = Lower RS = 1200



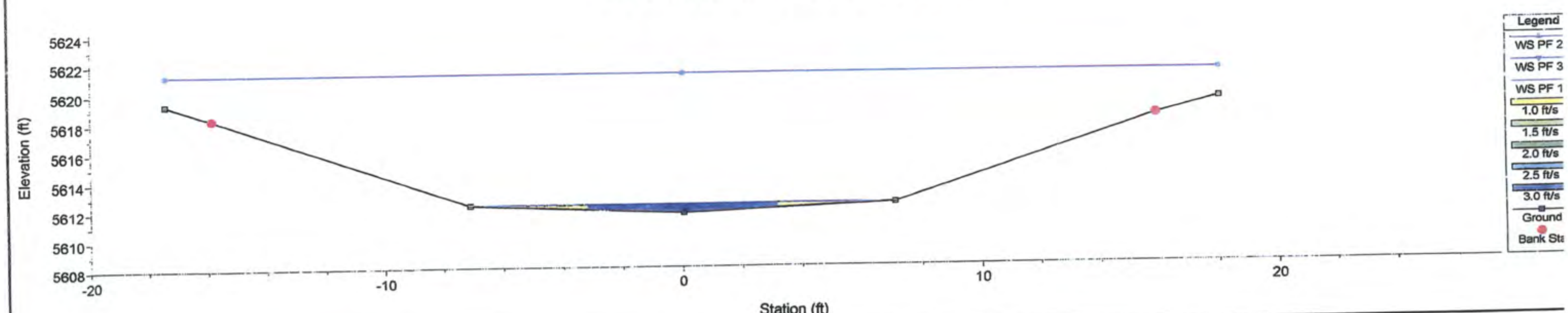
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2610



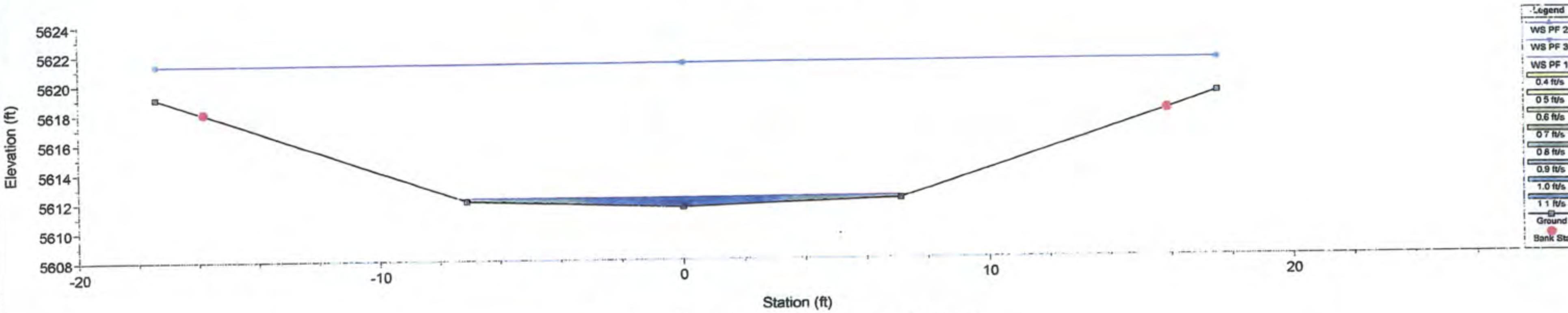
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2605 IS US Headgate



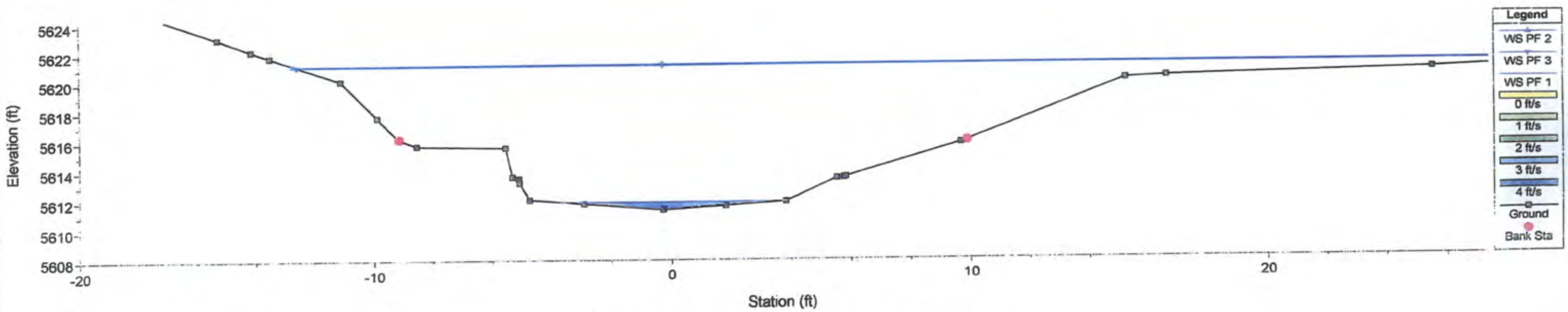
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2500



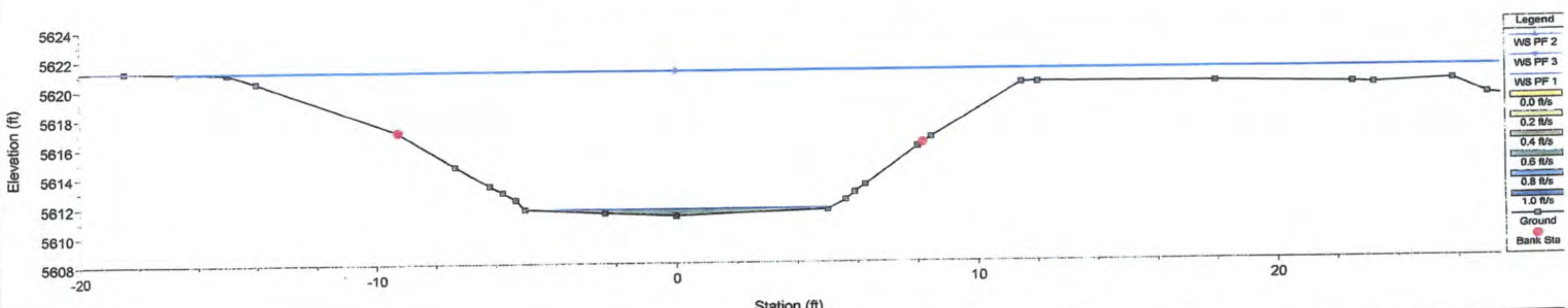
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2400



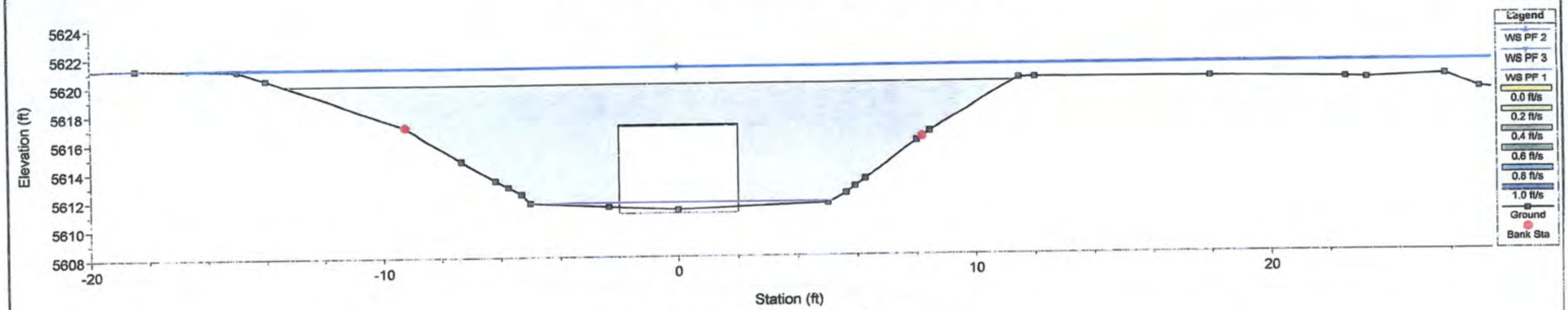
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2284



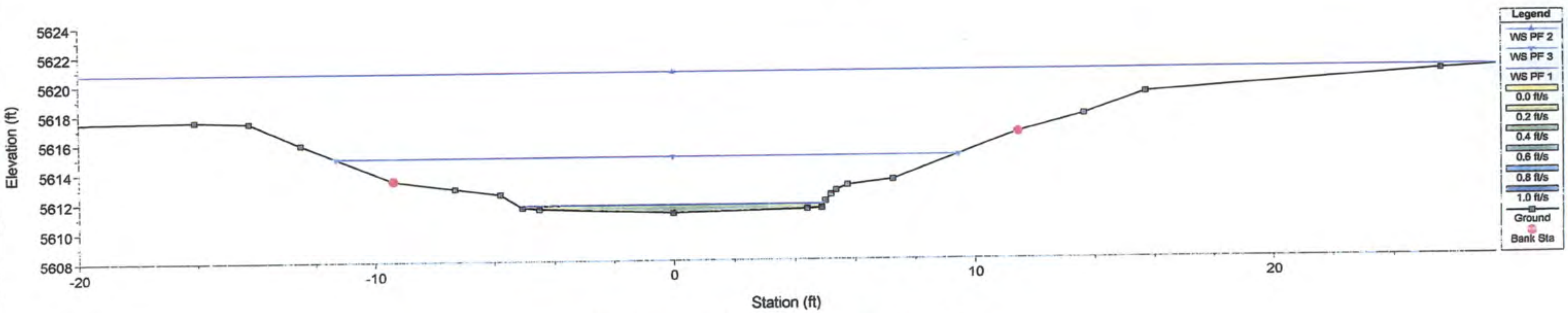
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2199.62



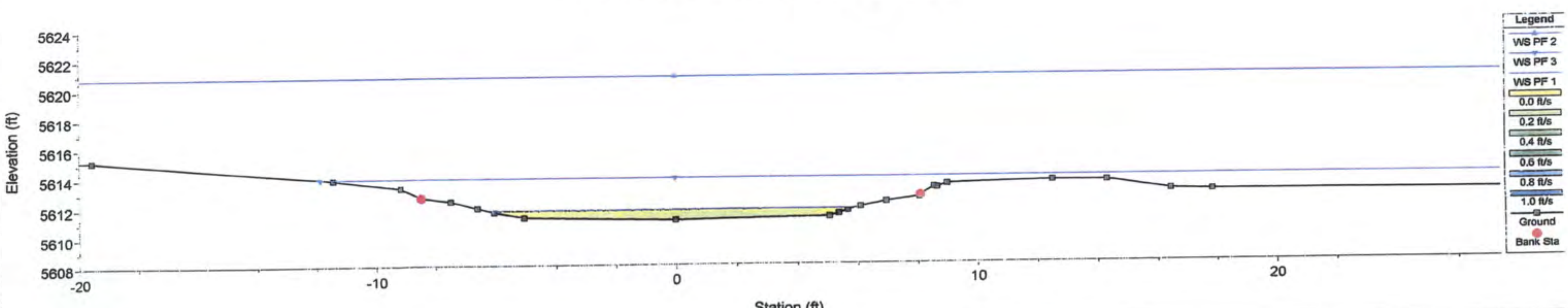
WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2168 IS DS Headgate



WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2159.06



WeirNewChannel Plan: WEIR 6/4/2012
Geom: WEIR-PROPOSED CONDITIONS Flow: Flow 02
River = Diversion Reach = Channel RS = 2072.65



Appendix E

Environmental and Archeological Preliminary Evaluation

Animas Environmental Services, LLC
www.animasenvironmental.com
624 E. Comanche
Farmington, NM 87401
505-564-2281
Durango, Colorado
970-403-3274

March 29, 2012

Joseph Casares, P.E.
Larkin Group NM, Inc.
8500 Menaul Blvd NE
Suite A-440
Albuquerque, New Mexico 87112

**RE: City of Aztec Water Diversion Project,
Aztec, San Juan County, New Mexico**

Dear Mr. Casares:

Animas Environmental Services, LLC (AES) was retained by Larkin Group in December 2011 to assist in coordinating environmental issues associated with the City of Aztec water diversion project, which included evaluating shallow groundwater flows and potential diversion channel repair alternatives. The project area is located in the northern portion of Aztec, on the east side of the Animas River near the City of Aztec's current intake diversion channel.

As part of obtaining environmental clearances for the study project, the San Juan County Museum's Division of Contract Archaeology (DCA) conducted a Class III cultural resources inventory of approximately 3.41 acres prior to beginning the study. The project area is surrounded by private property on the north, east, and south sides, and the Animas River borders the project area to the west. No new cultural resources were inventoried, and a recommendation of *No Historic Properties Affected* was made by DCA in a report entitled "*The Cultural Resources Inventory of a 3.41 Acre Block Area for the City of Aztec's Proposed Diversion Channel Repair Work, San Juan County, New Mexico*" (DCA Technical Report 11DCA083). The New Mexico State Historic Preservation Office (SHPO) concurred with the recommendation on February 21, 2012, as an annotation to correspondence from City of Aztec dated January 23, 2012. A copy of the DCA report and the correspondence from City of Aztec to SHPO are attached.

Depending on the final project recommendations and the next phase of project work, AES anticipates that the following environmental issues will need to be addressed:

- U.S. Army Corps of Engineers (USACE) Clean Water Act 404/401 Permitting with Certification from the New Mexico Environment Department (NMED) Surface Water Quality Bureau (SWQB). Permitting will require completion of a biological survey (Federal and State species), wetland delineation survey, and determination of the ordinary high water mark (OHWM).

- Consultation with either the Aztec Flood Plain Manager or the San Juan County Flood Plain Manager to confirm that proposed work will be consistent with existing floodplain management plans.

- Based on AES' current understanding of the project, no further cultural resources clearances are anticipated. However, if the project scope changes, additional work may be needed.

Depending on the funding source for the next phase of work, the funding agency may require a formal Environmental Assessment or Environmental Information Document which will need to follow the specific agency document preparation requirements, including formal agency consultation efforts. Please also note that depending upon the construction of future work, the project may require coverage under the recently re-issued USEPA National Pollutant Discharge Elimination System (NPDES) Stormwater Construction General Permit (CGP), which has more stringent requirements and a longer waiting period than the previous CGP.

Please do not hesitate to contact me at (505) 564-2281 if you have any questions about environmental issues for the project.

Sincerely,

Elizabeth C. McNally

Elizabeth McNally, P.E.

Attachment: DCA Technical Report 11-DCA-083

Files:S:\Animas 2000\2012 Projects\City of Aztec\Water Diversion Project\gc\gc Larkin Group 032912.docx

Mayor
Sally Burbridge

Mayor Pro-Tem
Jim Crowley

Commissioners

Eugene L. Current
Diana C. Mesch
Sherri A. Sipe

A desirable place to live, work and play; rich in history and small town values!

PUBLIC WORKS/ENGINEERING DEPARTMENT

93792

January 23, 2012

MME

Michelle M. Ensey, Archaeologist
Department of Cultural Affairs
Historic Preservation Division
407 Galisteo Street, Suite 236
Santa Fe, NM 87501
NMCRIS No. 122863

RE: The archaeological inventory of a block area for the City of Aztec's proposed diversion channel repair work and groundwater monitoring.

Dear Ms. Ensey:

Enclosed please find two copies of DCA Technical Report 11-DCA-083, *The Cultural Resources Inventory of a 3.41-Acre Block Area for the City of Aztec's Proposed Diversion Channel Repair Work, San Juan County, New Mexico.* This report details the Class III inventory of a 3.41 acre irregularly shaped block area in which the City of Aztec is proposing to repair a diversion channel and conduct ground water monitoring. The project is located on private land. The project area is fenced and surrounded on the north, east and south sides by private land. The Animas River borders the project area to the west. No new cultural resources were identified during the inventory. A recommendation of *No Historic Properties Affected* is made. It is recommended that the City of Aztec's proposed work within the 3.41-acre land parcel be allowed to proceed. If you have questions or comments please feel free to contact me.

Sincerely,

Mike Huber, P.E.
Public Works Director/City Engineer
City of Aztec

No Historic Properties Affected. 2/21/12
Michelle Ensey
for NM State Historic Preservation Officer

cc: Project File

201 West Chaco ✦ Aztec, New Mexico 87410 ✦ (505) 334-7600 ✦ Fax: (505) 334-7609
www.aztecnm.gov ✦ ✦ ✦ Winner All American City Award ✦ ✦ ✦ www.aztecnm.com

SAN JUAN COUNTY MUSEUM ASSOCIATION

Salmon Ruins Museum
Research Library
Division of Conservation Archaeology
Heritage Park

January 19, 2012

Elizabeth McNally, P.E.
Animas Environmental Services, LLC
624 E. Comanche
Farmington, NM 87401

RE: The archaeological inventory of a block area for proposed diversion channel repair work and ground water monitoring.

Dear Beth:

Enclosed please find a copy of DCA Technical Report 11-DCA-083, *The Cultural Resources Inventory of a 3.41-Acre Block Area for the City of Aztec's Proposed Diversion Channel Repair Work, San Juan County, New Mexico.* This report details the Class III inventory of a 3.41 acre irregularly shaped block area in which the City of Aztec is proposing to repair a diversion channel and conduct ground water monitoring. The project is located on private land. The project area is fenced and surrounded on the north, east and south sides by private land. The Animas River borders the project area to the west. No new cultural resources were identified during the inventory. A recommendation of *No Historic Properties Affected* is made. It is recommended that the City of Aztec's proposed work within the 3.41-acre land parcel be allowed to proceed. If you have questions or comments please feel free to contact me.

Sincerely,

Erik Simpson
Staff Archaeologist

cc: Mike Huber, City of Aztec Public Works (1)

Post Office Box 125 • Bloomfield, New Mexico 87413 • Museum Phone (505) 632-2013
Museum Fax (505) 632-8633 • DCA Phone (505) 632-2733 or (505) 632-2779 • DCA Fax (505) 632-1707

NMCRIS No.: To Be Assigned

NMCRIS INVESTIGATION ABSTRACT FORM (NIAF)

1. NMCRIS Activity No.:	2a. Lead (Sponsoring) Agency: City of Aztec	2b. Other Permitting Agency(ies):	3. Lead Agency Report No.:

4. Title of Report: *The Cultural Resources Inventory of a 3.41-Acre Block Area for the City of Aztec's Proposed Diversion Channel Repair Work, San Juan County, New Mexico.*

Author(s): Simpson, Erik

5. Type of Report
☒ Negative
☐ Positive

6. Investigation Type
☐ Research Design ☒ **Survey/Inventory** ☐ Test Excavation ☐ Excavation ☐ Collections/Non-Field Study
☐ Overview/Lit Review ☐ Monitoring ☐ Ethnographic study ☐ Site specific visit ☐ Other: Reconnaissance

7. Description of Undertaking: This report details the Class III inventory of a 3.41 acre irregularly shaped block area in which the City of Aztec is proposing to repair a diversion channel and conduct ground water monitoring. The project is located on private land. The project area is fenced and surrounded on the north, east and south sides by private land. The Animas River borders the project area to the west. No new cultural resources were identified during the inventory.

8. Dates of Investigation: December 14, 2011

9. Report Date: January 19, 2012

10. Performing Agency/Consultant: SJ County Museum Association, Division of Conservation Archaeology
Principal Investigator: Larry L. Baker
Field Supervisor: Erik Simpson
Field Personnel Names: Leonard Yazzie

11. Performing Agency/Consultant Report No.: 11-DCA-083

12. Applicable Cultural Resource Permit No(s): NM-10-011-S

13. Client: Animas Environmental Services
Contact: Beth McNally
Address: 624 E. Comanche, Farmington, NM 87401
Phone: 505-564-2281

14. Client/Customer Project No.:

15. Land Ownership Status ***(Must be indicated on project map):***

Land Owner	Acres Surveyed	Acres in APE
Private	3.41	3.41
TOTALS	3.41	3.41

16 Records Search(es):

Date(s) of ARMS File Review 12-12-2011	Name of Reviewer(s) L. Wharton	
Date(s) of Other Agency File Review 12-12-11	Name of Reviewer(s) T. Myers	Agency BLM-FFO

The Docket 229 (Navajo) Plaintiff's Exhibit No. 687 map (Van Valkenburgh 1974) was consulted prior to the commencement of this project. The closest sacred place to the project is *Kin niteel* (Wide House) – Aztec Ruin which is about .2 mile (.3 km) to the southwest. There are no known sacred places within 500 feet of the project area.

17. Survey Data:

a. Source Graphics ☒ **NAD 83**
☒ **USGS 7.5' (1:24,000) topo map** ☐ **Other topo map, Scale:**
☒ **GPS Unit** **Accuracy** ☐ **<1.0m** ☒ **1-10m** ☐ **10-100m** ☐ **>100m**

b.

USGS 7.5' Topographic Map Name	USGS Quad Code
Aztec, NM	36107-G8

c. County(ies): San Juan

17. Survey Data (continued):

d. Nearest City or Town: Aztec, NM

e. Legal Description:

Township (N/S)	Range (E/W)	Section	¼	¼	¼
30N	11W	4	SE	NW	SE

Projected legal description? Yes [X] , No [ ] **Unplatted [ ]**

f. Other Description (e.g. well pad footages, mile markers, plats, land grant name, etc.): See attached survey plat

18. Survey Field Methods:
Intensity: ☒ **100% coverage** ☐ <100% coverage (see below)

Configuration: ☒ **block survey units** ☐ linear survey units (l x w): ☐ other survey units (specify):

Scope: ☒ **non-selective (all sites recorded)** ☐ selective/thematic (selected sites recorded)

Coverage Method: ☒ **systematic pedestrian coverage** ☐ other method (describe)

Survey Interval (m): 10 m **Crew Size:** 2 **Fieldwork Dates:** December 20, 2011

Survey Person Hours: **Recording Person Hours:** **Total Hours:**

Additional Narrative: The project area is fenced and surrounded on the north, east and south sides by private land. The Animas River borders the project area to the west. Due to the presence of the private land and the river, no cultural buffer was inventoried.

19. Environmental Setting (NRCS soil designation; vegetative community; elevation; etc.): The project area is located adjacent to and east of the Animas River in a densely vegetated area, which has been previously disturbed. The estimated amount of disturbance is 95 percent of the survey area. The western edge of the survey area along the river is covered in thick overstory vegetation and ground visibility was limited throughout the project area due to dense grasses. River cobbles are strewn about the project area, some apparently having been brought in to stabilize the river bank and the island created by the existing diversion channel. Vegetation includes cottonwood, Russian olive, willow, a variety of grasses, serviceberry, and rabbitbrush.

20.
a. Percent Ground Visibility: 70% due to dense grasses
b. Condition of Survey Area: Extensive mechanical disturbance was noted over an estimated 95 percent of the project area. Sources of disturbance include an existing structure and diversion channel, a power line, subsurface pipes, and numerous push piles.

21. CULTURAL RESOURCE FINDINGS ☐ Yes, See Page 3 ☒ **No**

22. Required Attachments (check all appropriate boxes):
☒ **USGS 7.5 Topographic Map with sites, isolates, and survey area clearly drawn**
☒ **Copy of NMCRIS Mapserver Map Check**
☐ LA Site Forms - new sites (*with sketch map & topographic map*)
☐ LA Site Forms (update) - previously recorded & un-relocated sites (*first 2 pages minimum*)
☐ Historic Cultural Property Inventory Forms
☐ List and Description of isolates, if applicable
☐ List and Description of Collections, if applicable

23. Other Attachments:
☐ Photographs and Log ☒ **Other Attachments:** General Project Area Map, Survey Plat, Vicinity Map

24. I certify the information provided above is correct and accurate and meets all applicable agency standards.

Principal Investigator/Responsible Archaeologist: **Erik Simpson by Lyn Wharton**

Signature ______________ **Date:** **January 19, 2012** **Title: DCA Projects Manager**

25. Reviewing Agency: **Reviewer's Name/Date** **Accepted ( ) Rejected ( )**	**26. SHPO** **Reviewer's Name/Date:** **HPD Log #:**

Tribal Consultation (if applicable): ☐ Yes ☐No	SHPO File Location: Date sent to ARMS:

SURVEY RESULTS:

Sites discovered and registered: 0
Sites discovered and NOT registered: 0
Previously recorded sites revisited *(site update form required)*: **0**
Previously recorded sites not relocated *(site update form required)*: 0
TOTAL SITES VISITED: 0
Total isolates recorded: 0 **Non-selective isolate recording?** ☐
Total structures recorded *(new and previously recorded, including acequias)*:

MANAGEMENT SUMMARY: No new cultural resources were identified during the inventory. A recommendation of *No Historic Properties Affected* is made. It is recommended that the City of Aztec's proposed work within the 3.41-acre land parcel be allowed to proceed.

IF REPORT IS NEGATIVE YOU ARE DONE AT THIS POINT.

SURVEY LA NUMBER LOG

Sites Discovered:

LA No.	Field/Agency No.	Eligible? (Y/N, applicable criteria)

Previously recorded revisited sites:

LA No.	Field/Agency No.	Eligible? (Y/N, applicable criteria)

MONITORING LA NUMBER LOG *(site form required)*

Sites Discovered *(site form required)* :

LA No.	Field/Agency No.

Previously recorded sites *(Site update form required)*:

LA No.	Field/Agency No.

Areas outside known nearby site boundaries monitored? Yes ☐, No ☐ If no explain why:

TESTING & EXCAVATION LA NUMBER LOG *(site form required)*

Tested LA number(s)	Excavated LA number(s)

SUPPLEMENTAL DATA ATTACHMENT

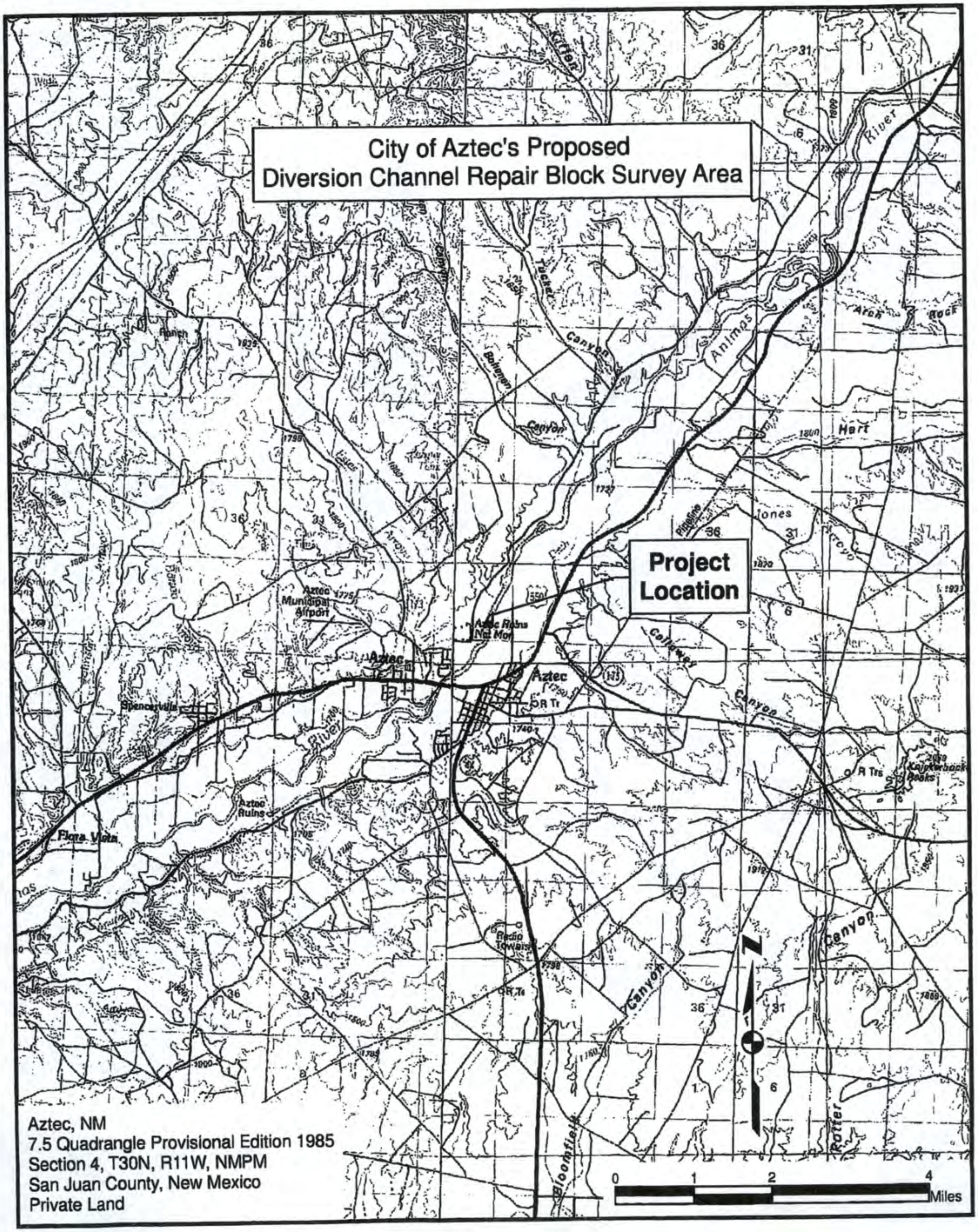
Area of Effect and Area Surveyed:
Block Survey Area: 3.41 acres (determined using GIS software).

References Cited:

Van Valkenburg, Richard P.
1974 Navajo Sacred Places, edited by Clyde Kluckhohn. In *Navajo Indians III*, pp. 9-199. Garland Publishers, New York.

For Official Use Only
Disclosure of Site Locations is Prohibited (36 CFR 296.18)

GENERAL LOCATION MAP

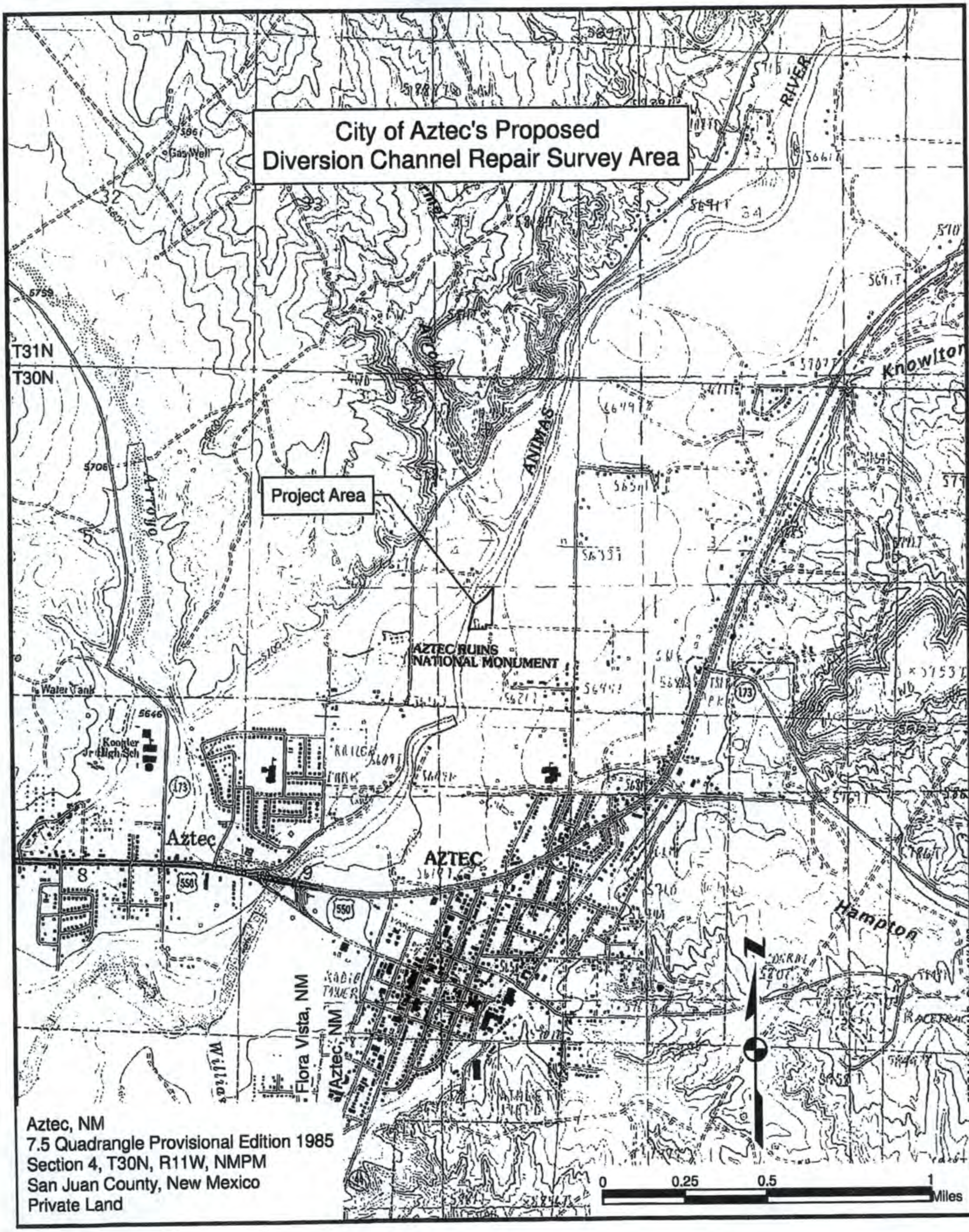


Report No. 11-DCA-083

Figure 1. General Project Location Map

For Official Use Only
Disclosure of Site Locations is Prohibited (36 CFR 296.18)

VICINITY MAP



Report No. 11-DCA-083

Figure 2. Vicinity map showing the project location.