

**MARICOPA WATER DISTRICT
BEARDSLEY CANAL
AND ASSOCIATED DELIVERY SYSTEM
HYDRAULIC CAPACITY ANALYSIS
AN EVALUATION AND ASSESSMENT REPORT**

PHASE 1



PREPARED FOR
USBR / WESTCAPS



BY
**BOOKMAN-EDMONSTON
ENGINEERING, INC.**

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BOOKMAN-EDMONSTON
ENGINEERING, INC.

Specialists in Water Resources

May 17, 1999

Mr. Tom Wotring
U.S. Bureau of Reclamation
2222 West Dunlap Avenue
Suite 100
Phoenix, AZ 85021

Attention: PXAO-7700, Marvin Murray

Subject: Phase 1 Report

Dear Tom:

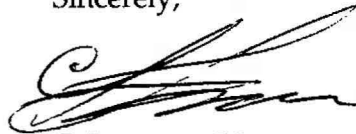
This letter transmits the final report for the West Salt River Valley Water Management Study, Beardsley Canal Capacity Study. The report is entitled *Maricopa Water District Beardsley Canal and Associated Delivery System Hydraulic Capacity Analysis - An Evaluation and Assessment Report*.

Also enclosed is a CD containing the HEC-RAS model, the available canal capacity model (in Lotus 4.1 format), selected photographs of the Beardsley Canal in bmp format, and indices to the photographs.

The transmittal of this report and models completes Contract No. 6-CA-20-0341C.

It has been a pleasure working with Marvin Murray, Warren Greenwell, and other USBR staff, as well as Harold Thomas and the WESTCAPS group. We would like to express a special thank you to the USBR, who provided the color copies for the final report. We look forward to Phase 2 of the Beardsley Canal work.

Sincerely,



C. Laurence Linser
Senior Vice President

cc: Harold Thomas, WESTCAPS
Jim Sweeney, Maricopa Water District

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AND ASSOCIATED DELIVERY SYSTEM
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Executive Summary

EXECUTIVE SUMMARY

The Beardsley Canal, owned and operated by Maricopa County Municipal Water Conservation District No. 1 (Maricopa Water District or MWD), is one of several options that WESTCAPS is considering for conveying CAP water to its members. The Beardsley Canal is approximately 33 miles long and has an initial reach capacity of approximately 300 cfs. The canal was constructed in the early 1930s and is primarily a shotcrete-lined, trapezoidal-shaped canal with varying cross-section dimensions. No as-built drawings are available for the canal, and actual flow capacity by reach is unknown due to the age of the canal and structures, and the modifications that have been made over the years.

Bookman-Edmonston Engineering, Inc. (B-E) contracted to study the Beardsley Canal. The goals of this study were to:

- Determine the capacity of the Beardsley Canal.
- Determine how much of the capacity is currently used by MWD.
- Determine the unused capacity difference (i.e., how much could be available for transporting CAP and other water for WESTCAPS' members without impacting MWD operations.)

B-E first undertook a survey of the Beardsley Canal and used the data collected to construct a hydraulic analysis using the HEC-RAS software. The model was calibrated using known flows and water surface elevations. Following calibration, the flows were increased in the model on a reach-by-reach basis to determine the estimated maximum capacity. Table ES-1 shows the results of this analysis.

Figure ES-1 is a map of the Beardsley Canal showing the reach-by-reach capacities and identifying the restrictive flow structures.

In order to estimate how much of the Beardsley Canal capacity may be available for WESTCAPS members, B-E collected MWD water use information for five representative years (1988, 1993, 1994, 1995, and 1996). Figure ES-2 shows the water use patterns for the five-year study period.

Based on water use information for the five representative years, unused or available canal capacity was estimated for each identified reach. Losses due to evaporation and seepage were estimated and incorporated in the analysis. It was assumed that there were no deliveries during December and January, the canal dry-up period. Figure ES-3 depicts the estimated available capacity in the Beardsley Canal based on a high MWD demand year. Table ES-2 shows the estimated available capacity on a reach-by-reach basis for the five-year study period.

Table ES-1
Beardsley Canal Capacity Study - Phase 1
Summary of Estimated Maximum Reach Capacities

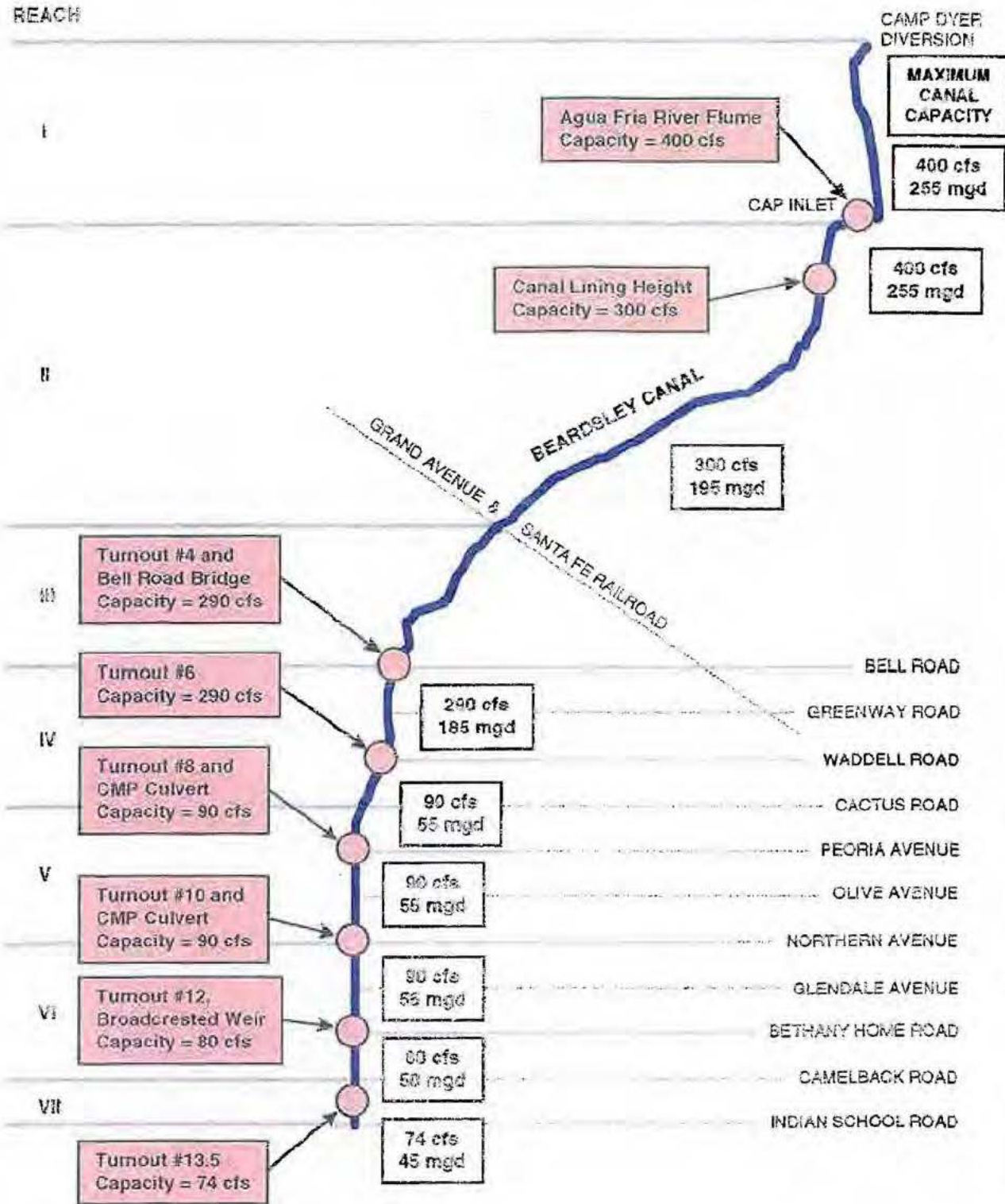
Reach No.	Reach Description	1993 MWD High Flow ⁽¹⁾ (cfs)	Estimated Maximum Capacity ⁽²⁾ (cfs)	Estimated Maximum Capacity ⁽²⁾ (mgd)
I	Lake Pleasant to CAP Inlet	230	400	255
II	CAP Inlet to Grand Avenue	230	300	195
III	Grand Avenue to Bell Road	230	300	195
IV	Bell Road to Greenway Road	200	290	185
	Greenway Road to Waddell Road	179	290	185
	Waddell Road to Cactus Road	144	290	185
V	Cactus Road to Peoria Avenue	119	90	55
	Peoria Avenue to Olive Avenue	99	90	55
	Olive Avenue to Northern Avenue	82	90	55
VI	Northern Avenue to Glendale Avenue	67	90	55
	Glendale Avenue to Camelback Road	39	80	50
VII	Camelback Road to Indian School Road	25	74	45

Notes:

1. Flows measured by MWD in 1993 as maximum capacities constrained by existing demands. MWD has since made improvements to the Beardsley Canal. In some instances, MWD exceeded canal freeboard constraints used for computing the estimated maximum capacity.

2. Based on six inches of freeboard.

REACH



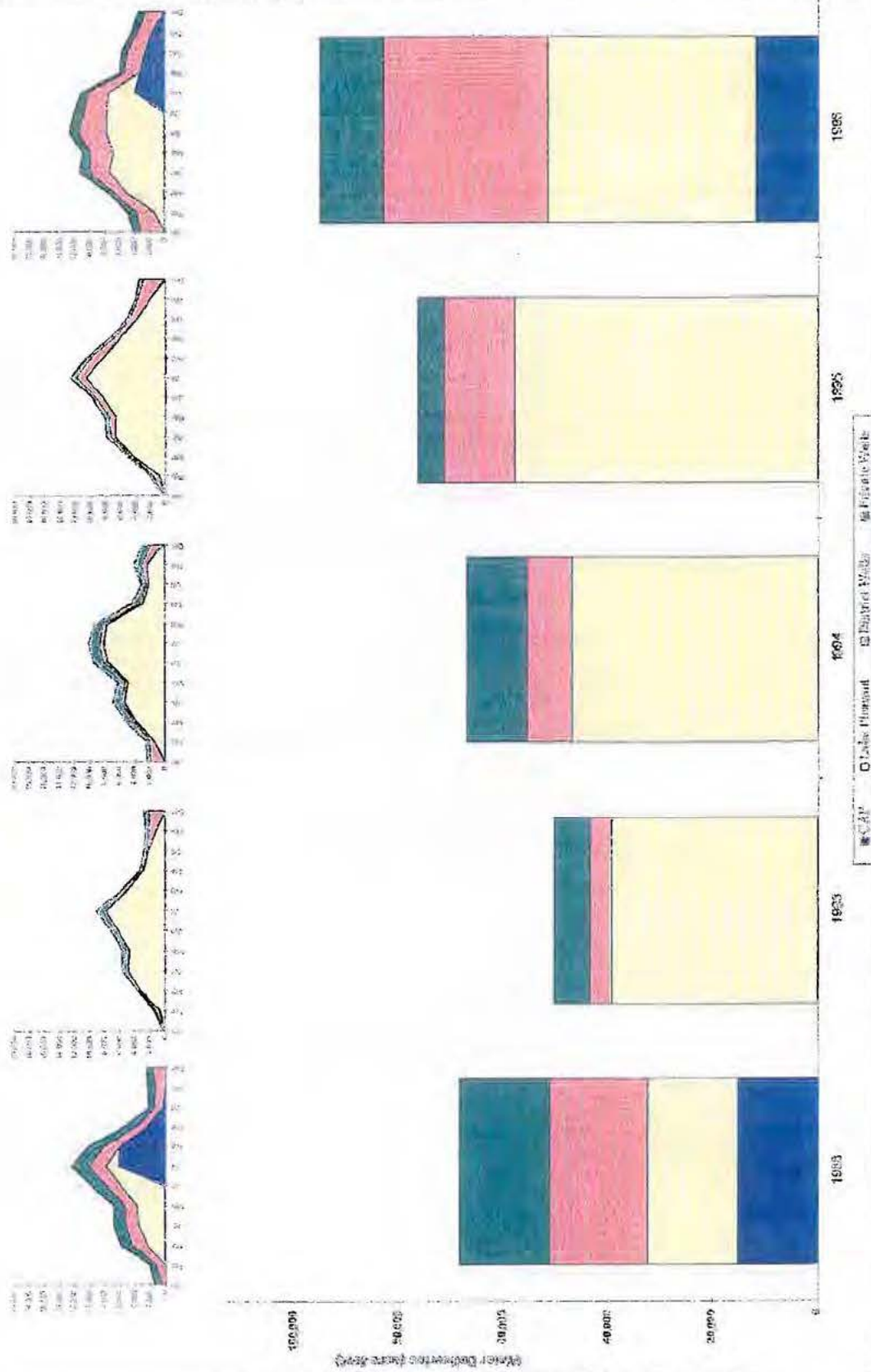
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May 14, 1999

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USBR/WESTCAPS

Beardsley Canal Capacity Study - Phase I
Restrictive Structures and
Their Existing Capacities

Figure ES-1

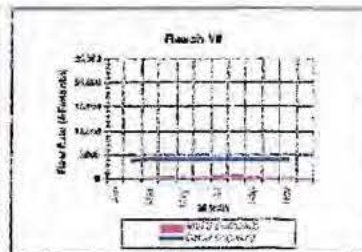
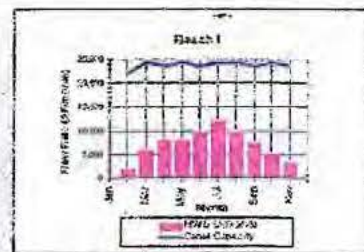
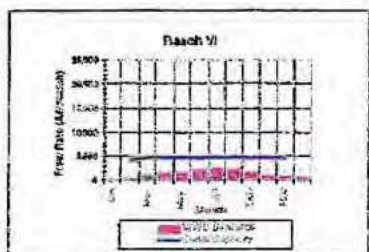
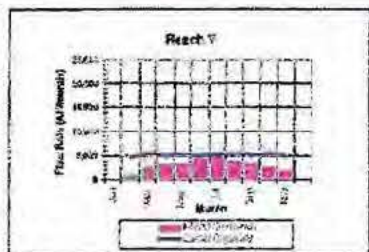
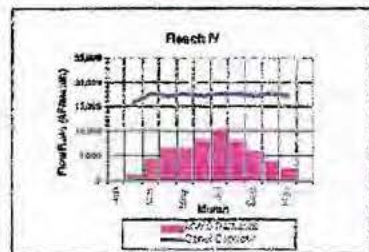
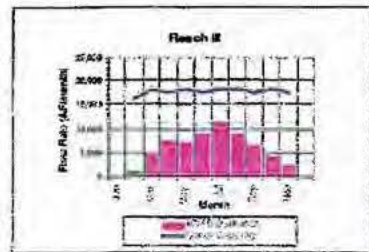
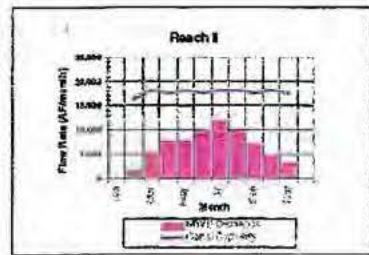
Figure ES-2
 Beardsley Canal Capacity Study
 Maricopa Water District - Water Usage by Year and Month



Prepared by	BOOKMAN-EDMONSTON ENGINEERING, INC.
Date	November, 1986, Revised April 16, 1989



REACH



II

III

IV

V

VI

VII

GRAND AVENUE &
SANTA FE RAILROAD

BEARDSLEY CANAL

CAP INLET

CAMP DYER
DIVERSION

UNUSED
CAPACITY
DURING MWD
PEAK USE

195 cfs
125 mgd

100 cfs
65 mgd

100 cfs
65 mgd

120 cfs
75 mgd

0 cfs
0 mgd

30 cfs
20 mgd

BELL ROAD

GREENWAY ROAD

WADDELL ROAD

CACTUS ROAD

PEORIA AVENUE

OLIVE AVENUE

NORTHERN AVENUE

GLENDALE AVENUE

BETHANY HOME ROAD

CAMELBACK ROAD

INDIAN SCHOOL ROAD

Prepared by
Bookman-Edmonston
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May 14, 1999

Prepared for
USBH/WESTCAPS
WESTCAPS

Beardsley Canal Capacity Study - Phase 1
Monthly Reach-by-Reach Delivery to MWD
and Estimated Maximum Canal Capacity
(for High MWD Canal Demand Year (1995))

Figure ES-3

Table ES-2
Beardsley Canal Capacity Study - Phase 1
Estimated Available Capacity Remaining in the Beardsley Canal
For the Five-Year Study Period
(Acre-Feet)

Reach No.	Reach Description	1988	1993	1994	1995	1996
I	Lake Pleasant to CAP Inlet	193,700	185,900	178,500	166,900	174,200
II	CAP Inlet to Grand Avenue	136,300	128,700	121,300	109,700	116,800
III	Grand Avenue to Bell Road	142,000 ⁽¹⁾	134,400 ⁽¹⁾	127,000 ⁽¹⁾	115,400 ⁽¹⁾	122,500 ⁽¹⁾
IV	Bell Road to Cactus Road	137,400 ⁽¹⁾	132,900 ⁽¹⁾	126,300 ⁽¹⁾	115,200 ⁽¹⁾	119,300 ⁽¹⁾
V	Cactus Road to Northern Avenue	33,200	31,900	27,700	20,900	20,900
VI	Northern Avenue to Camelback Road	36,000 ⁽¹⁾	36,200 ⁽¹⁾	33,500 ⁽¹⁾	30,500 ⁽¹⁾	30,100 ⁽¹⁾
VII	Camelback Road to Indian School Road	41,000 ⁽¹⁾	40,600 ⁽¹⁾	39,600 ⁽¹⁾	39,000 ⁽¹⁾	39,300 ⁽¹⁾

Note:

1. Reach capacity currently unattainable because upstream reach unable to deliver total quantity.

Section 1

BOOKMAN-EDMONSTON
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Study Need and Background

A coalition of West Valley CAP Subcontractors (WESTCAPS) is investigating potential ways for its members to put Central Arizona Project (CAP) water supplies to use. WESTCAPS and the U.S. Bureau of Reclamation (USBR) are working cooperatively under an in-kind cost-share agreement to evaluate regional water resources and facilities to efficiently use CAP water.

The Beardsley Canal, owned and operated by Maricopa County Municipal Water Conservation District No. 1 (Maricopa Water District or MWD), is one of several options that WESTCAPS is considering for conveying CAP water to its members. The Beardsley Canal is approximately 33 miles long and has an initial reach capacity of approximately 300 cfs. The canal was constructed in the early 1930s and is primarily a shotcrete-lined, trapezoidal-shaped canal with varying cross-section dimensions. No as-built drawings are available for the canal, and actual flow capacity by reach is unknown due to the age of the canal and structures, and the modifications that have been made over the years.

Prior to this study, there was insufficient information available to adequately evaluate the amount and timing of unused canal capacity available to transport CAP water. A study of the canal was needed to determine where flow limiting constrictions are located, modifications that would be needed to expand the capacity of the canal, and the associated costs.

Scope of Work

The scope of this Phase I study is to evaluate the capability of using the Beardsley Canal to convey CAP water to WESTCAPS members, while still meeting the needs of MWD. Alternative methods for conveying CAP water that do not include the Beardsley Canal are beyond the scope of this study.

Phase I of the Beardsley Canal Capacity Study seeks to meet three goals:

- An evaluation of the existing canal capacity based upon field survey measurements and engineering hydraulics;
- An evaluation of the existing canal capacity utilized by MWD as established from canal operations data; and
- A summary of available unused capacity of the Beardsley Canal as it currently exists and under current water delivery obligations to serve MWD lands.

These goals were met through seven tasks:

- Task 1 - Existing data collection
- Task 2 - Field measurement of canal structures and water flow

- Task 3 - Field survey of canal
- Task 4 - Hydraulic analysis
- Task 5 - Available canal capacity model development
- Task 6 - Coordination meetings
- Task 7 - Phase I Report.

Deliverables

The deliverables for Tasks 1 and 2 were presented at the WESTCAPS Technical Committee meeting on November 13, 1998. The Task 3 deliverables were presented in draft form at the WESTCAPS Technical Committee meeting on January 8, 1999 and in final form at the WESTCAPS General Committee meeting on January 29, 1999. The deliverables for Tasks 4 and 5 were presented in the draft report at the WESTCAPS Technical Committee meeting on April 16, 1999. Task 6, meeting minutes, are published by WESTCAPS. This report comprises the deliverable for Task 7 and was presented to the WESTCAPS Technical Committee meeting in final form on May 14, 1999.

WESTCAPS Mission Statement

WESTCAPS is a coalition of CAP subcontractors most of whom serve drinking water to communities in the west Salt River Valley. It is WESTCAPS' mission to develop workable alternatives for its members to provide their customers with a cost effective, sustainable, reliable, and high quality water supply through partnerships and cooperative efforts in regional water resource planning and management, emphasizing CAP utilization.

WESTCAPS Members

WESTCAPS members are the following: Arizona State Land Department, Arizona Water Company, Town of Buckeye, Citizens Utilities Company, City of Glendale, City of Goodyear, Litchfield Park Water Service Company, City of Peoria, City of Phoenix, Sunrise and West End Water Companies, City of Surprise, and West Maricopa Combine. Figure 1-1 shows the WESTCAPS members' water planning areas.

Contracting Arrangements

Bookman-Edmonston Engineering, Inc. (B-E) was issued Delivery Order No. 98-PE-32-0341C-D008 Entitled West Salt River Valley Water Mangement Study and Beardsley Canal Capacity Study - Contract No. 6-CA-20-0341C Entitled Architectural-Engineering Services for the Bureau of Reclamation, Mid-Pacific Region on September 22, 1998 by the Bureau of Reclamation.

Acknowledgments

B-E acknowledges the assistance of the MWD staff, who generously gave of their time and expertise.

West Salt River Valley CAP Subcontractors (WESTCAPS)

- Boundary Canal
- CAP Canal
- Canals
- Roads
- West Salt River Valley Sub-basin
- WESTCAPS
- Ac. Water Co. White Tanks CC&N
- Buckeye WPA
- Calumet Water Resources CC&N
- Glendale WPA
- Goodyear WPA
- LPS&O CC&N
- Peoria WPA
- Phoenix WPA
- Surprise CC&N
- Surprise WPA
- West End CC&N
- West Maricopa Combine CC&N

1-3



4 0 4 8 Miles

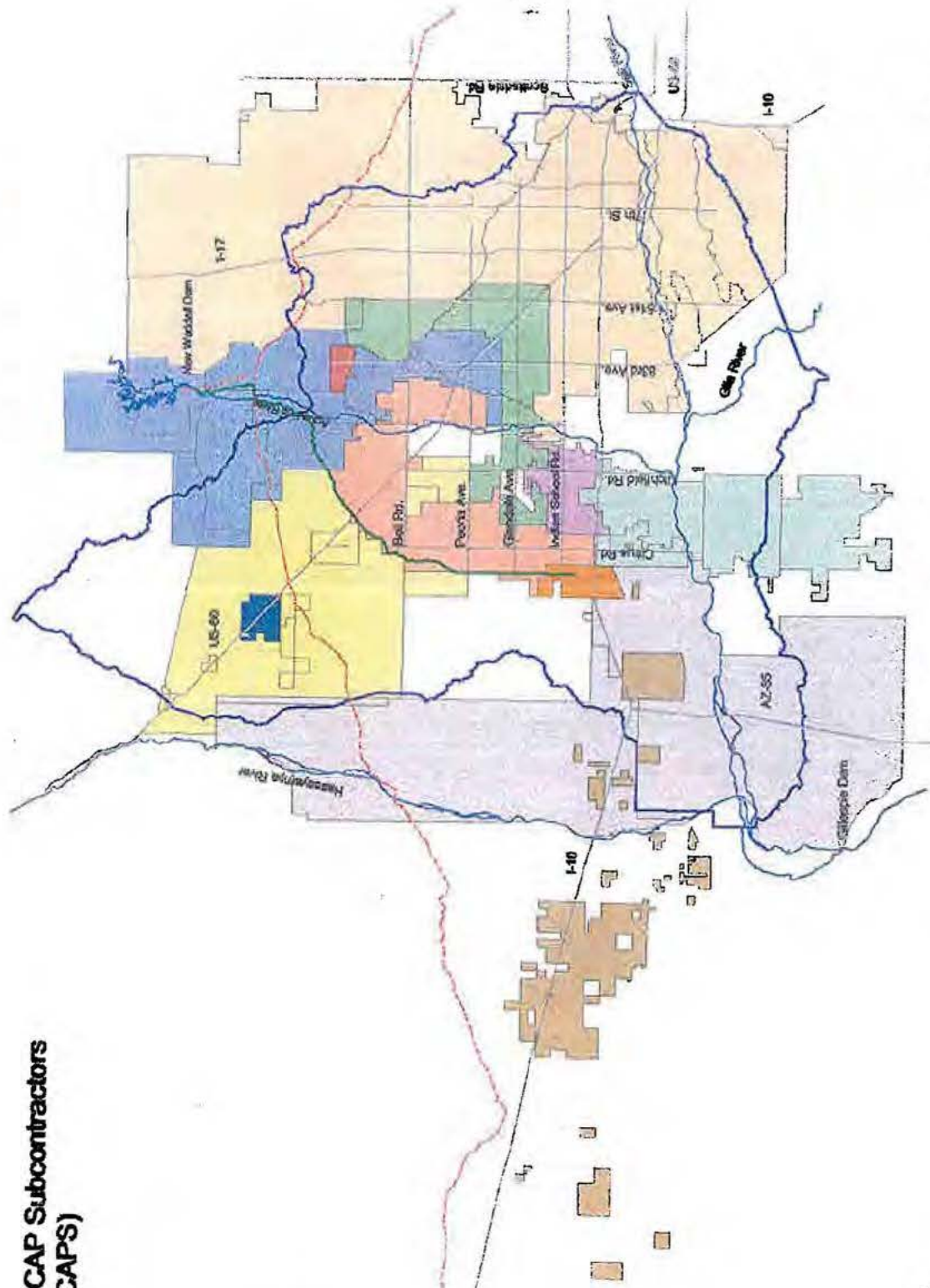


Figure 1-1

Figure courtesy of U.S. Bureau of Reclamation

Section 2

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SECTION 2

MARICOPA WATER DISTRICT OVERVIEW

Brief Description

The Maricopa Water District provides water and power to district landowners for approximately 40,000 acres in the west Salt River Valley. Its predecessor was organized in the mid-1880s as the Agua Fria Water and Land Company and filed for rights to appropriation of flow and subflow of the Agua Fria River and its tributaries in 1888. The Agua Fria Water and Land Company assigned a contract to build a dam across the Agua Fria River to William Beardsley in 1892. The Waddell Dam on the Agua Fria River was completed in 1927 and impounded approximately 158,000 acre-feet of storage as Lake Pleasant. With the completion of the Beardsley Canal in the 1930s, the newly named Maricopa Water Conservation District No. 1 (informally called the Maricopa Water District or MWD) began delivering water.

In 1994, completion of the New Waddell Dam by the CAP submerged the original dam. The storage potential of Lake Pleasant was increased to 1.3 million acre-feet, with the original storage space being held by MWD and the remainder used by CAP.

Land Uses

The primary land use within MWD is agricultural. Crops include cotton, alfalfa, wheat, lettuce, melons, onions, grapes, and roses. Figure 2-1 shows current land uses within the District.

Parts of MWD have become urbanized, notably Sun City West, Sun City Grand, and Clearwater Estates. The urbanization in the northern part of the District has brought water demands for residential irrigation, golf courses and community parks. MWD continues to serve irrigation water to the golf course at Sun City Grand and the lots of the Clearwater Estates. Potable water is provided by Citizens Utilities to Sun City West and Sun City Grand. It is likely that urbanization will continue to take agricultural land out of production.

Luke Air Force Base is adjacent to MWD's southeastern boundary. It is possible that an agricultural preserve will be established buffering Luke Air Force Base in order to help keep the Base active.

Physical System

MWD owns and operates the Hank Raymond Lake, the Beardsley Canal, approximately 100 miles of laterals and sublaterals, and approximately 50 groundwater wells. Figure 2-2 shows the MWD water conveyance infrastructure.

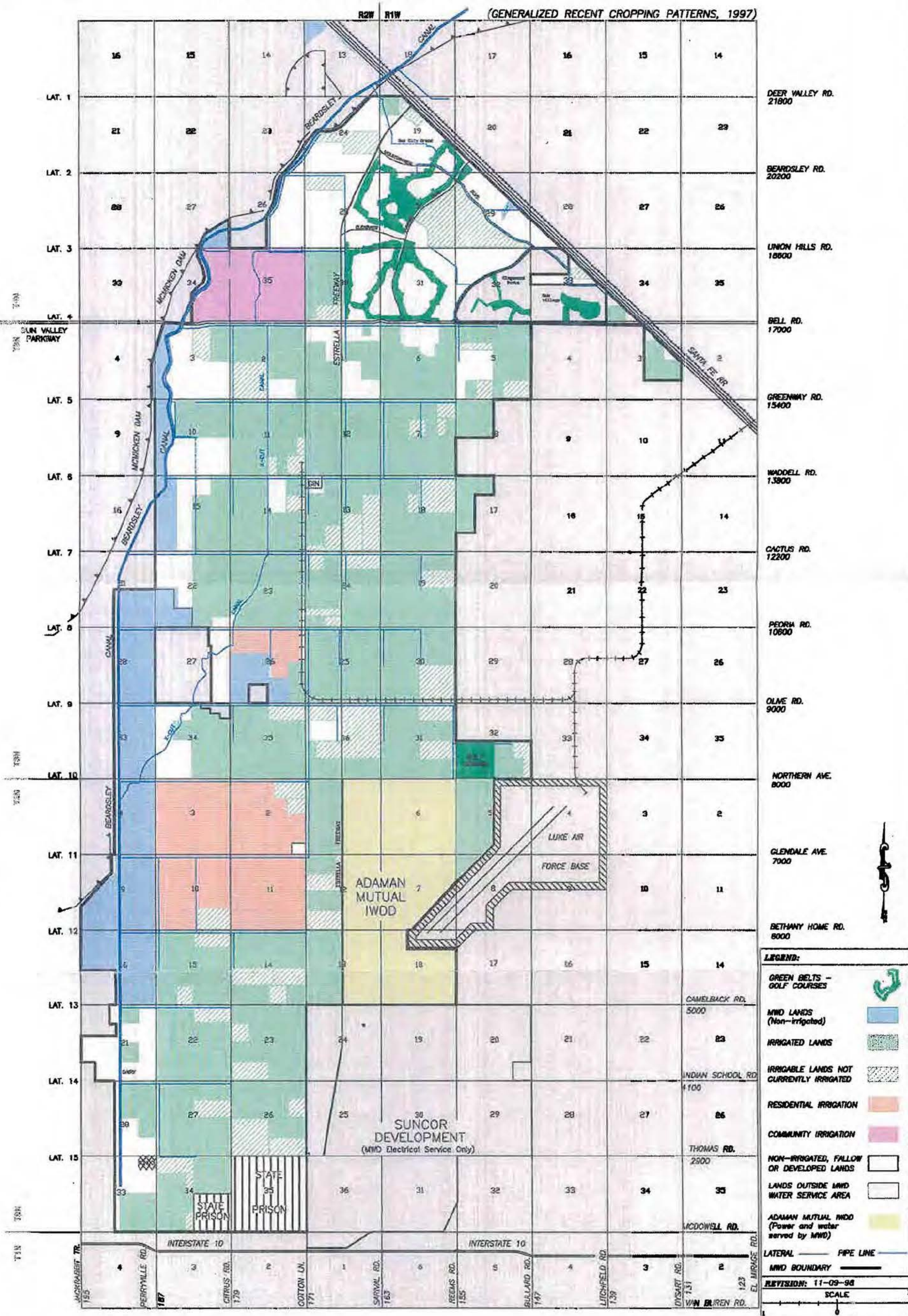
The main conveyance in the MWD, the Beardsley Canal, transports water from Lake Pleasant about 17 miles to the beginning of the MWD distribution system just below Grand Avenue. The remaining 15 miles of the Beardsley Canal, from Grand Avenue to Indian School Road, contain lateral canal turnouts at about one-mile intervals. In

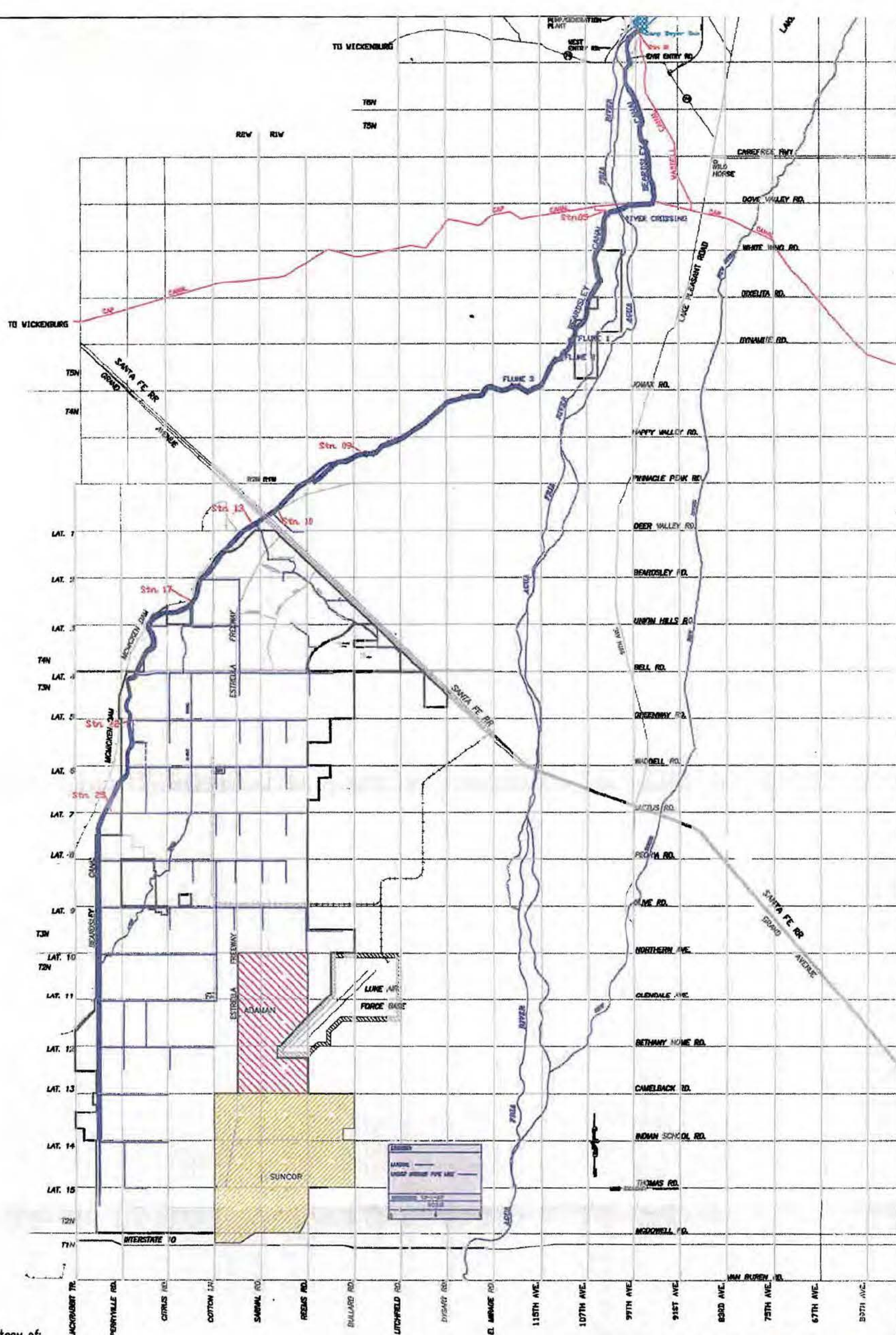


Figure 2-1

LAND USES WITHIN MARICOPA WATER DISTRICT

Prepared by: COOKMAN-EDMISTON ENGINEERING, INC.
Date: November, 1998





Base Map Courtesy of:

 MARICOPA WATER DISTRICT



BOOKMAN-EDMONSTON
 ENGINEERING, INC.
 May 14, 1999

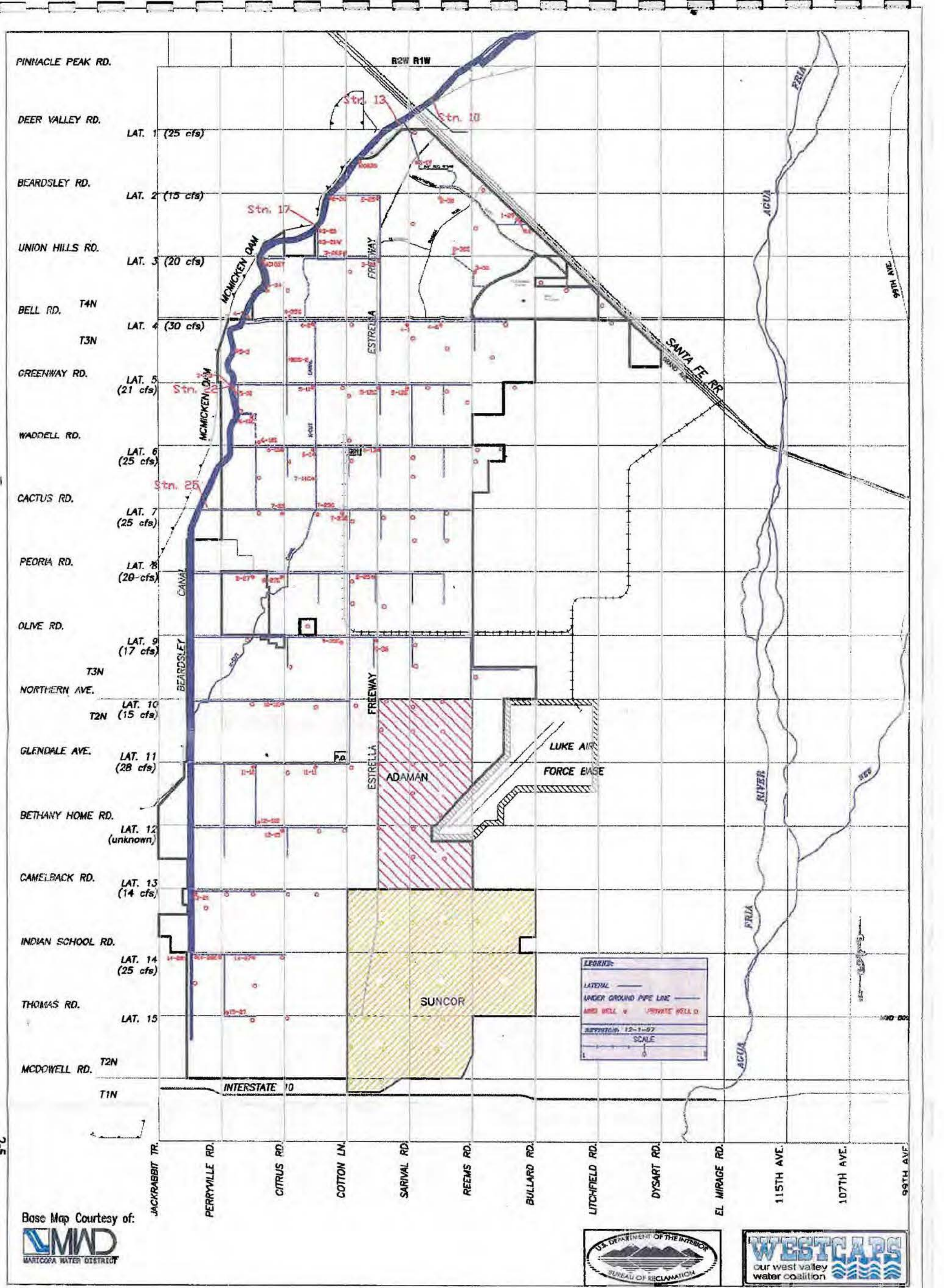
Beardsley Canal Capacity Study
 MWD Conveyance and Distribution System

FIGURE 2-2

addition to water delivered through the canal, MWD owns and operates 50 groundwater wells which supplement the surface water supplies. Table 2-1 lists the MWD wells and capacities; Figure 2-3 displays their locations. Approximately 53 private irrigation wells are also located within the District.

Table 2-1 Beardsley Canal Capacity Study - Phase 1 MWD Wells and Pumping Capacity					
MWD Well ID	DWR Well ID	Capacity (gpm)	MWD Well ID	DWR Well ID	Capacity (gpm)
BD DOM	55-612951	71	5-12E	55-612987	1,071
BOSCO2	55-613017	543	6-10C	55-612988	1,022
MC1057	55-612957	668	6-10S	55-612989	685
MC938	55-612956	663	6-13	55-612990	1,212
1-19	55-612965	1,005	6-14	55-612991	620
1-20	55-612966	-	6-15	55-612992	995
1-29	55-612967	1,478	7-14C	55-612993	712
2-25	55-612968	647	7-22	55-612997	940
2-26	55-612969	1,011	7-23C	55-612996	870
2-30	55-612970	1,038	7-23E	55-612995	842
2-30S	55-612971	1,141	8-25	55-612998	804
3-26	55-612972	609	8-27	55-613000	946
3-26S	55-612973	1,082	8-27E	55-613001	978
3-26W	55-612974	696	9-35E	55-613002	826
3-36	55-612975	940	9-36	55-613004	1,245
4-1	55-612976	1,370	10-3E	55-613005	1,027
4-2	55-516893	516	11-10	55-613007	505
4-3	55-612978	783	11-11	55-613008	1,011
4-6	55-612979	1,120	12-10S	55-613009	-
4-34	55-612980	603	12-15	55-613010	951
4-35S	55-612981	1,033	13-21	55-613011	755
5-3	55-612983	761	14-27	55-613013	1,071
5-10	55-612984	1,196	14-28E	55-613014	-
5-11	55-612985	658	14-28W	55-613015	451
5-12C	55-612986	973	15-27	55-613016	1,163

The MWD internal distribution system is integrated. Many laterals are joined together with a system of interconnecting canals. The most significant of these, known as the Cross Cut Canal, joins eight laterals within the system and reconnects to the lower portion of the Beardsley Canal, effectively joining four additional laterals. The Cross Cut Canal is primarily used to convey well water during the Beardsley Canal dry-up



BOOKMAN-EDMONSTON ENGINEERING, INC. May 14, 1999	Beardsley Canal Capacity Study MWD Well Locations and Lateral Capacities	FIGURE 2-3
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period. The majority of the MWD-owned wells pump into the interconnected canals and laterals. Figure 2-3 shows the locations and conveyance capacities of these canals.

Water Sources

The surface water supply originally provided by the Agua Fria River and impounded by Waddell Dam now comes primarily through an exchange with the Central Arizona Water Conservation District (CAWCD) at the CAP inlet to the Beardsley Canal.

When available, MWD can also purchase excess Colorado River water and is a Groundwater Savings Facility eligible to receive CAP water in lieu of pumping groundwater. Both of these supplies are delivered through the CAP system.

No appreciable storm water enters the Beardsley Canal.

The Lake Pleasant and CAP supplies are conveyed through the Beardsley Canal to the MWD lands. Wells located throughout the MWD service area also serve as significant sources of water. Most wells pump into lateral canals or are private wells located on individual farms. Only four wells are capable of pumping directly into the Beardsley Canal. The quantities of water diverted and delivered from all of these sources for each month of the study period are shown in Table 2-2.

Water Use Patterns

The ability to convey water independent from the Beardsley Canal allows farming operations to continue during the winter months while the Beardsley Canal is closed for maintenance. This dry-up period usually runs throughout the months of December and January, and often longer, depending upon demands for water. Figure 2-4 summarizes the average monthly water use in MWD for a five-year study period (1988, 1993-1996). The study period was selected to represent a range of water demands reflecting current farming practices within the MWD service area. This range includes low, medium and high system water demand years (1993, 1994, and 1996, respectively), and low and high canal demand years (1988 and 1995, respectively). Each year of the study period is broken into supply source and monthly use in Figure 2-5.

To initiate this study, a preliminary evaluation of the Beardsley Canal capacity was made from the information displayed in Figure 2-5, where it can be seen from the study period data that the maximum delivery of surface water occurred in July 1995. For the preliminary assessment, it was assumed that this quantity represents the maximum capacity of the Beardsley Canal. This assumed maximum capacity was then compared to actual canal deliveries (Lake Pleasant and CAP deliveries) as shown on Figure 2-6. The difference between MWD monthly surface water deliveries and the assumed maximum capacity represents the minimum remaining or unused capacity in the Beardsley Canal. Since the surface water deliveries are system totals, this value can only be representative of canal capacity up to the first turnout near Grand Avenue.

Further study involved constructing a hydraulic model which determined if the Beardsley Canal could carry more than the July 1995 flow to Grand Avenue. In addition, a distribution system model addressed the flow capacity once the Beardsley Canal entered the distribution portion of the MWD system below Grand Avenue. These analyses are presented in Sections 4 and 5.

Table 2-2

MWD - Historic Water Use for 5 Year Study Period⁽¹⁾

1988 Total Water Usage (AF)

	Lake Pleasant (SW)		CAP		MWD Wells		Private Wells ⁽²⁾		TOTAL		Lost & Unacct. For	
	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	AF	%
Jan	0	0	0	0	536	471	902	902	1,438	1,373	65	5%
Feb	0	0	0	0	1,197	1,247	743	743	1,939	1,990	-51	-3%
Mar	3,508	2,411	0	0	2,008	2,041	1,522	1,522	7,038	5,974	1,064	15%
Apr	4,760	3,577	0	0	2,546	1,687	1,660	1,660	8,966	6,925	2,041	23%
May	5,057	3,809	0	0	1,628	1,578	1,480	1,480	8,165	6,867	1,298	16%
Jun	7,760	5,888	0	0	1,988	1,904	1,992	1,992	11,740	9,784	1,956	17%
Jul	2,077	1,588	7,649	6,356	2,336	2,261	2,291	2,291	14,353	12,496	1,857	13%
Aug	0	0	6,961	6,189	2,222	2,059	2,060	2,060	11,244	10,309	935	8%
Sep	0	0	3,222	2,459	1,968	1,460	1,629	1,629	6,820	5,548	1,271	19%
Oct	0	0	418	414	949	1,026	793	793	2,160	2,233	-73	-3%
Nov	0	0	0	0	1,664	1,256	1,201	1,201	2,865	2,457	408	14%
Dec	0	0	0	0	2,123	1,636	964	964	3,087	2,600	487	16%
TOTAL	23,161	17,274	18,250	15,418	21,165	18,627	17,237	17,237	79,813	68,556	11,257	14%

1993 Total Water Usage

	Lake Pleasant (SW) ⁽³⁾		CAP		MWD Wells		Private Wells ⁽²⁾		TOTAL		Lost & Unacct. For	
	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	AF	%
Jan	0	0	0	0	55	52	95	95	149	146	3	2%
Feb	1,090	723	0	0	623	568	137	137	1,850	1,428	422	23%
Mar	4,065	3,368	0	0	9	7	337	337	4,410	3,712	698	16%
Apr	5,989	4,891	0	0	33	23	727	727	6,749	5,641	1,108	16%
May	5,766	4,684	0	0	103	87	821	821	6,689	5,592	1,097	16%
Jun	7,443	6,289	0	0	69	41	875	875	8,387	7,205	1,182	14%
Jul	9,628	7,948	0	0	74	71	1,087	1,087	10,789	9,106	1,683	16%
Aug	6,074	5,101	0	0	41	35	690	690	6,804	5,826	978	14%
Sep	4,097	3,060	0	0	42	38	305	305	4,444	3,403	1,040	23%
Oct	2,861	2,213	0	0	269	263	382	382	3,512	2,857	655	19%
Nov	1,398	1,189	0	0	1,013	928	468	468	2,879	2,585	294	10%
Dec	0	0	0	0	2,212	2,064	847	847	3,059	2,911	148	5%
TOTAL	48,410	39,468	0	0	4,541	4,177	6,770	6,770	59,722	50,415	9,307	16%

⁽¹⁾ Data source is MWD, except as noted.⁽²⁾ Total Private Well Pumpage from DWR annual reports, monthly usage computed from power service records.⁽³⁾ 1993 Lake Pleasant water supply includes water spilled and diverted during the months of February and March.

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Table 2-2 (cont)
MWD - Historic Water Use for 5 Year Study Period⁽¹⁾

1994 Total Water Usage

	Lake Pleasant (SW)		CAP		MWD Wells		Private Wells ⁽²⁾		TOTAL		Lost & Unacct. For	
	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	AF	%
Jan	12	0	0	0	1,897	1,789	591	591	2,501	2,381	120	5%
Feb	2,191	1,451	0	0	701	615	561	561	3,453	2,627	826	24%
Mar	4,983	3,976	0	0	422	354	923	923	6,327	5,253	1,074	17%
Apr	6,739	5,392	0	0	477	424	1,129	1,129	8,345	6,944	1,401	17%
May	6,106	4,873	0	0	377	360	1,081	1,081	7,564	6,314	1,250	17%
Jun	9,247	7,625	0	0	627	588	1,295	1,295	11,169	9,508	1,661	15%
Jul	9,877	8,094	0	0	673	637	1,456	1,456	12,006	10,186	1,820	15%
Aug	9,374	7,782	0	0	469	450	1,124	1,124	10,966	9,356	1,611	15%
Sep	3,805	3,088	0	0	452	424	907	907	5,164	4,419	746	14%
Oct	2,847	2,141	0	0	470	428	570	570	3,887	3,139	748	19%
Nov	2,925	2,363	0	0	1,043	926	772	772	4,741	4,061	679	14%
Dec	205	325	0	0	1,688	1,520	1,161	1,161	3,054	3,007	48	2%
TOTAL	58,312	47,109	0	0	9,296	8,517	11,570	11,570	79,178	67,195	11,982	15%

1995 Total Water Usage

	Lake Pleasant (SW)		CAP		MWD Wells		Private Wells ⁽²⁾		TOTAL		Lost & Unacct. For	
	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	AF	%
Jan	0	0	0	0	266	228	148	148	414	376	38	9%
Feb	1,251	873	0	0	1,026	903	256	256	2,533	2,032	502	20%
Mar	5,633	4,405	0	0	456	407	275	275	6,364	5,086	1,278	20%
Apr	8,072	6,762	0	0	664	626	464	464	9,200	7,852	1,348	15%
May	8,077	6,671	0	0	1,020	897	485	485	9,582	8,053	1,529	16%
Jun	9,854	8,341	0	0	1,033	948	523	523	11,410	9,812	1,599	14%
Jul	12,789	10,659	0	0	1,333	1,227	683	683	14,805	12,569	2,236	15%
Aug	10,228	8,386	0	0	1,669	1,617	565	565	12,462	10,569	1,894	15%
Sep	6,762	6,058	0	0	1,001	894	426	426	8,189	7,378	811	10%
Oct	4,311	3,784	0	0	993	918	311	311	5,614	5,012	602	11%
Nov	1,899	2,020	0	0	1,872	1,704	276	276	4,047	4,001	47	1%
Dec	0	0	0	0	3,271	3,008	504	504	3,776	3,513	263	7%
TOTAL	68,876	57,959	0	0	14,605	13,376	4,917	4,917	88,398	76,252	12,146	14%

⁽¹⁾ Data source is MWD, except as noted.

⁽²⁾ Total Private Well Pumpage from DWR annual reports, monthly usage computed from power service records.

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Table 2-2 (cont)
MWD - Historic Water Use for 5 Year Study Period⁽¹⁾

1996 Total Water Usage

	Lake Pleasant (SW)		CAP		MWD Wells		Private Wells ⁽²⁾		TOTAL		Lost & Unacct. For	
	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	Diverted	Delivered	AF	%
Jan	0	0	0	0	3,601	3,286	864	864	4,465	4,150	315	7%
Feb	2,043	1,331	0	0	2,626	2,490	1,169	1,169	5,838	4,990	848	15%
Mar	6,094	5,171	0	0	1,778	1,670	763	763	8,635	7,605	1,031	12%
Apr	8,620	7,405	0	0	2,728	2,572	1,451	1,451	12,798	11,427	1,371	11%
May	8,224	6,882	0	0	3,252	3,034	1,036	1,036	12,512	10,952	1,560	12%
Jun	9,076	7,788	0	0	3,885	3,718	1,208	1,208	14,170	12,715	1,455	10%
Jul	8,596	7,726	0	0	3,198	3,019	1,363	1,363	13,157	12,107	1,050	8%
Aug	4,107	3,463	4,540	4,008	2,880	2,742	980	980	12,507	11,192	1,315	11%
Sep	0	0	4,073	3,364	2,085	1,978	741	741	6,899	6,082	817	12%
Oct	0	0	3,450	2,766	2,458	2,279	700	700	6,608	5,744	864	13%
Nov	0	0	1,808	1,692	2,233	2,040	702	702	4,744	4,434	309	7%
Dec	0	0	0	0	2,797	2,562	971	971	3,768	3,533	236	6%
TOTAL	46,760	39,765	13,871	11,829	33,522	31,390	11,948	11,948	106,100	94,931	11,169	11%

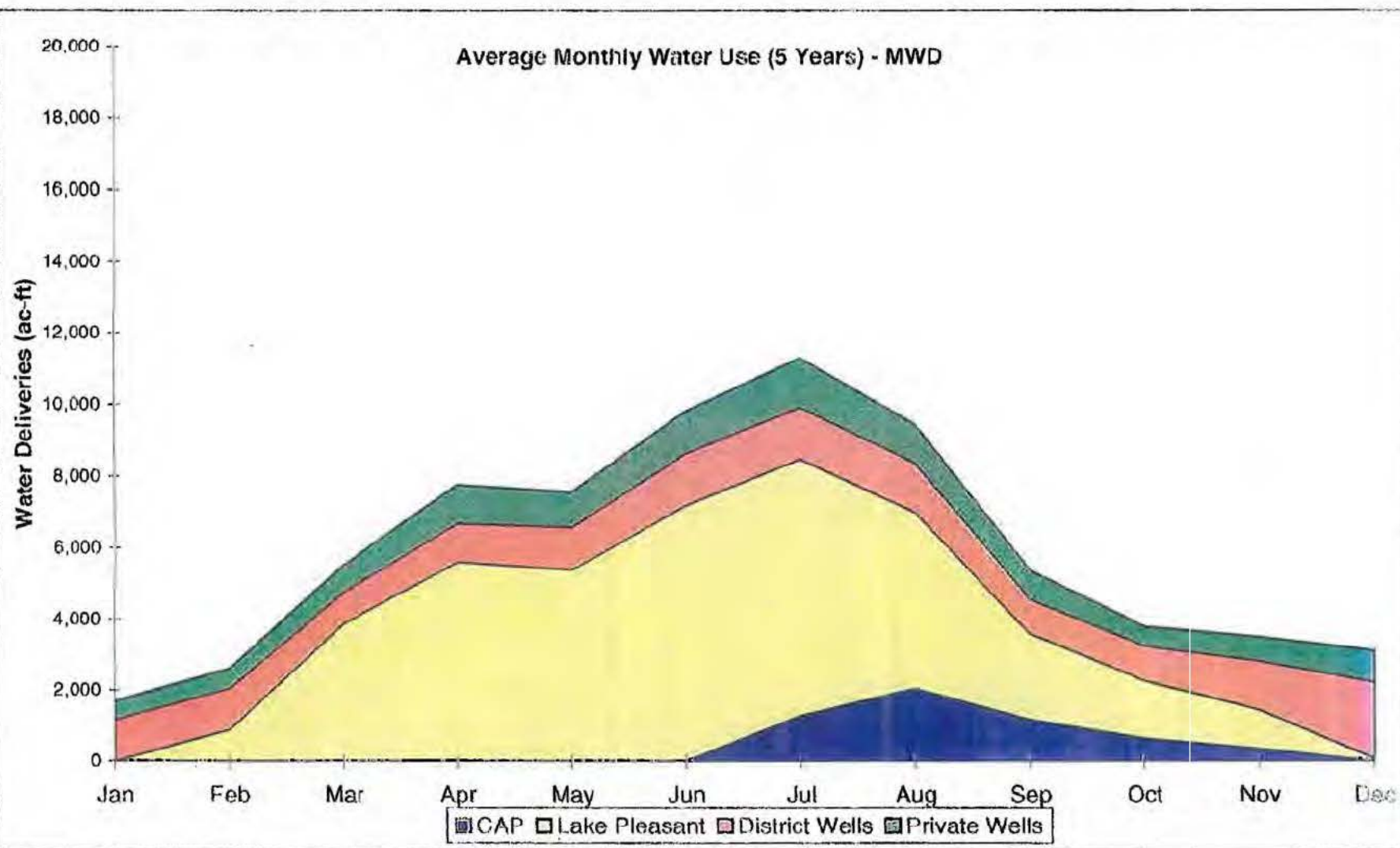
⁽¹⁾ Data source is MWD, except as noted.

⁽²⁾ Total Private Well Pumpage from DWR annual reports, monthly usage computed from power service records.

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Figure 2-4
Beardsley Canal Capacity Study

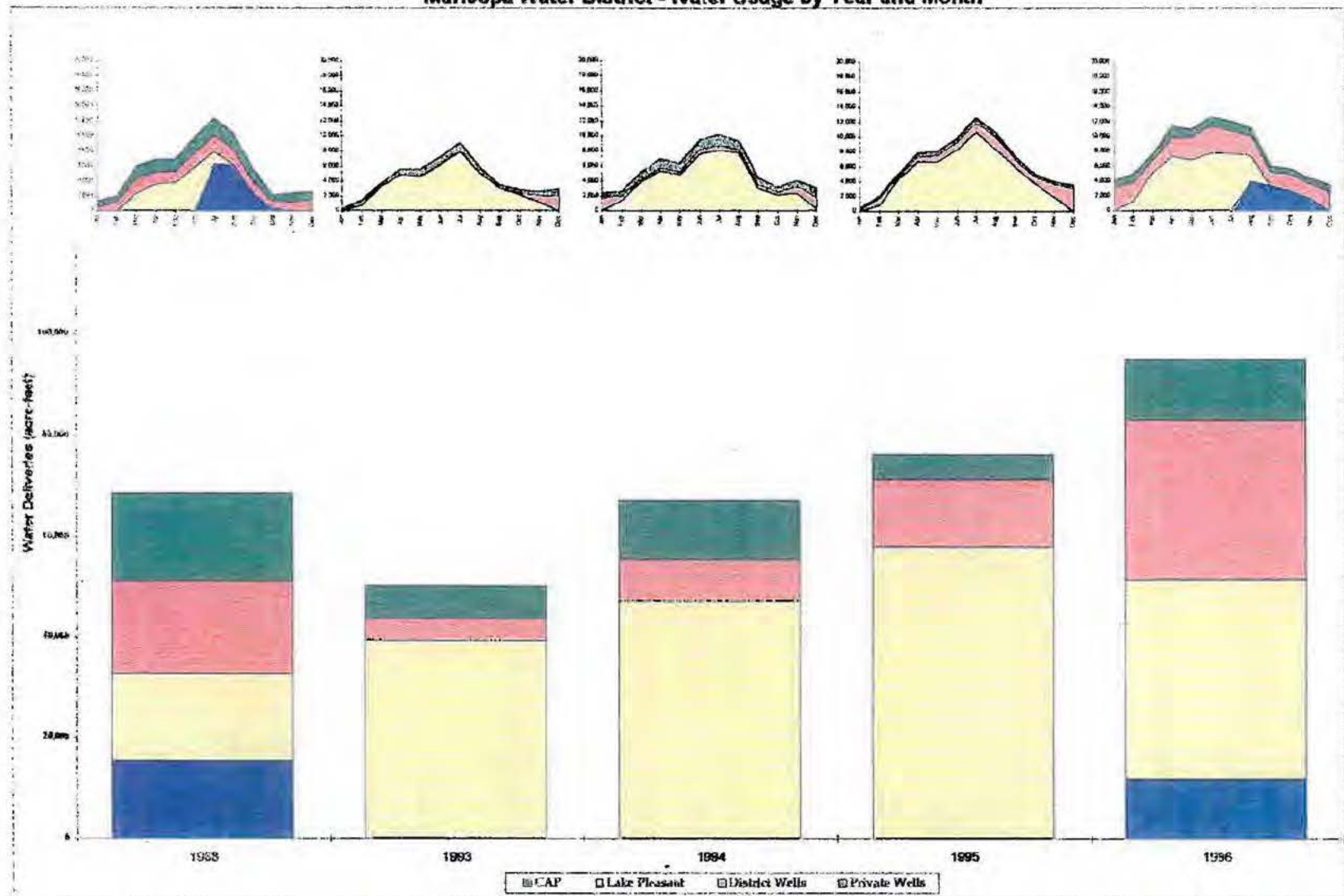


2-10

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Figure 2-5
Beardsley Canal Capacity Study
Maricopa Water District - Water Usage by Year and Month

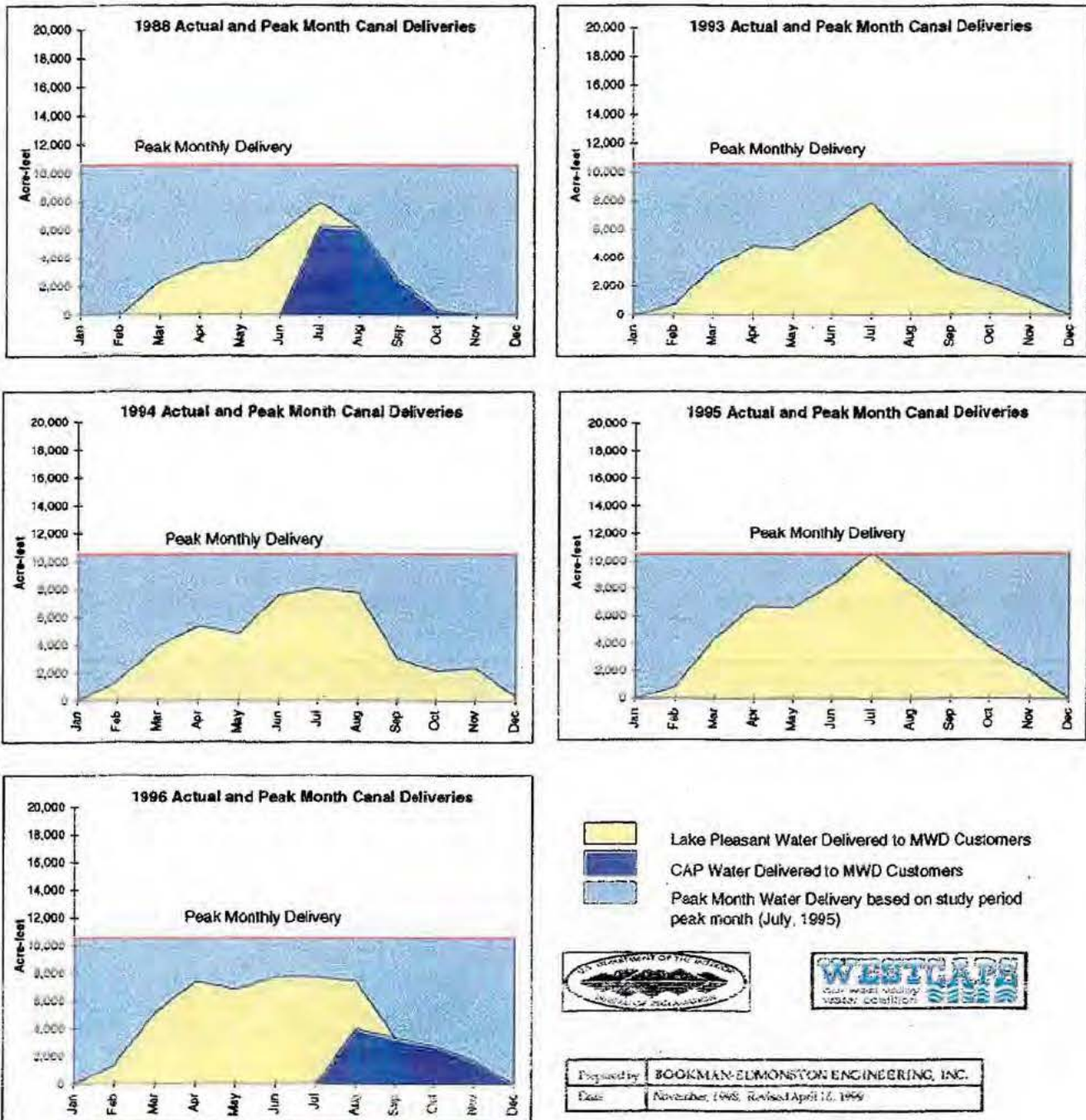


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Figure 2-6

Beardsley Canal Capacity Study
Historic Monthly Deliveries through the Beardsley Canal
Compared to Peak Monthly Delivery (July, 1995)
 (Values represent delivery volume to head of distribution system near Grand Ave.)



Section 3

SECTION 3

BEARDSLEY CANAL PHYSICAL DESCRIPTION

Introduction

The Beardsley Canal was constructed in the early 1930s and is primarily a concrete-lined, trapezoidal-shaped canal with varying cross-section dimensions. No as-built drawings were available for the canal, and actual flow capacity by reach was previously unknown due to the age of the canal and structures, and the modifications that have been made over the years. Therefore, B-E undertook a comprehensive survey of the Beardsley Canal in December 1998.

Survey Work Performed

B-E established vertical control monuments adjacent to and on the Beardsley Canal and surveyed canal cross sections and structure elevations. The field work was completed in two parts, with the vertical control monuments established first and the cross sections and structures surveyed based on the control monuments.

To establish the control monuments quickly and accurately, B-E employed Global Positioning System (GPS) survey methods rather than a level circuit. The GPS method used satellite data collected from base stations at known coordinates in the western portion of the Salt River Valley to constrain satellite data gathered at monuments located near the canal. These canal monuments were then used as base stations to constrain satellite data for the remaining control monuments. The degree of error for the vertical control is less than one centimeter (± 0.03 feet).

The vertical control monuments were typically established near canal structures or where cross sections would be required. Additional monuments were established to provide a back sight where necessary. Canal cross sections and structure elevations were surveyed using a Topcon GTS 3 total station instrument and a Hewlett-Packard TDS-48 data logger. The locations and coordinates of the vertical control monuments are shown on Figure 3-1.

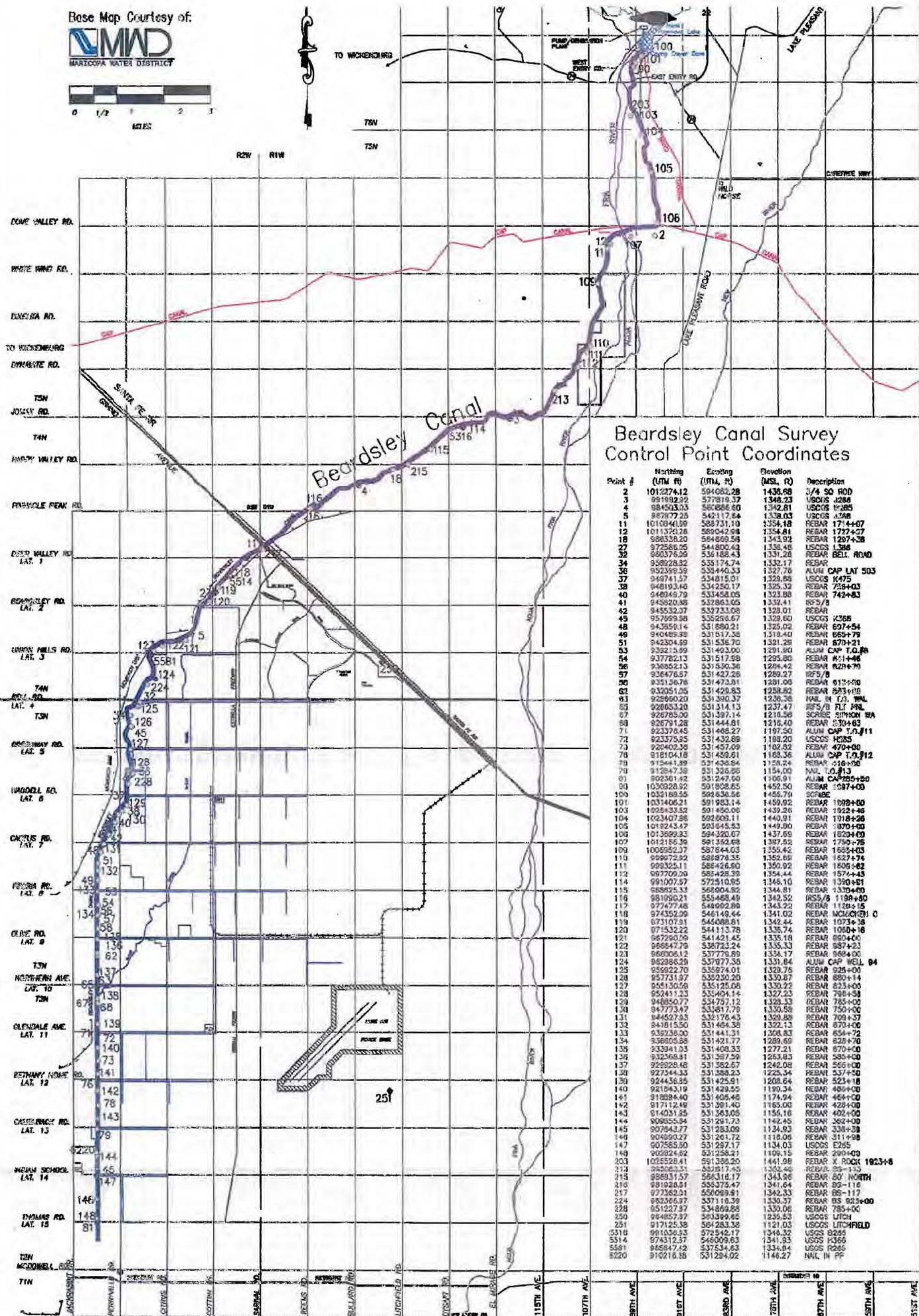
Physical Description

Canal

The Beardsley Canal may be divided into several reaches, as follows:

- Reach I: Camp Dyer Diversion to the CAP Inlet;
- Reach II: CAP Inlet to Grand Avenue;
- Reach III: Grand Avenue to Bell Road;
- Reach IV: Bell Road to Cactus Road;
- Reach V: Cactus Road to Northern Avenue;
- Reach VI: Northern Avenue to Camelback Road; and
- Reach VII: Camelback Road to the end of the canal.

Base Map Courtesy of:



Beardsley Canal Survey Control Point Coordinates

Point #	Northing (UTM #)	Eastings (UTM #)	Elevation (MSL, ft)	Description
2	1012274.12	594082.28	1436.88	3/4 SQ ROD
3	991982.92	577819.37	1348.23	USCOS J288
4	984503.03	580886.60	1342.81	USCOS J285
5	987977.25	542117.84	1338.03	USCOS J288
11	1010840.59	588731.19	1354.18	REBAR 1714+07
12	1011370.28	589042.98	1354.81	REBAR 1727+27
18	988338.20	584869.58	1343.92	REBAR 1287+38
27	972586.05	544800.42	1336.48	USCOS L388
32	980376.09	536188.43	1331.28	REBAR BELL ROAD
34	958228.82	533174.74	1332.17	REBAR
36	952359.59	538440.33	1327.76	ALUM CAP LAT 503
37	949741.57	534815.01	1329.88	USCOS K475
38	948193.48	534250.17	1325.32	REBAR 718+03
40	948949.79	533458.05	1323.88	REBAR 742+83
41	945620.88	532863.05	1332.41	RF 5/8
42	945532.07	532733.08	1329.01	REBAR
45	957999.58	538258.67	1329.80	USCOS J286
48	943599.14	531880.21	1325.02	REBAR 697+54
49	940489.39	531517.38	1319.40	REBAR 685+79
51	942304.59	531536.70	1331.28	REBAR 670+21
53	939215.99	531493.00	1291.80	ALUM CAP T.O. 88
54	937782.13	531517.88	1295.80	REBAR K11+46
56	938852.13	531530.36	1288.42	REBAR 628+70
57	936476.57	531427.26	1289.27	RF 5/8
60	935136.78	531473.81	1281.06	REBAR 613+80
61	932051.05	531428.83	1258.82	REBAR 823+00
63	928860.20	531380.37	1236.36	NAIL IN T.O. NAL
65	928653.20	531314.13	1237.47	RF 5/8 FLT NAL
67	926785.00	531387.14	1216.58	SCREE SIMON WA
68	926791.28	531444.81	1216.40	REBAR 630+83
71	923376.45	531488.27	1197.50	ALUM CAP T.O. 11
72	923375.85	531432.89	1188.20	USCOS H385
73	920402.36	531457.09	1182.82	REBAR 470+00
78	918104.18	531489.61	1168.36	ALUM CAP T.O. 112
79	915441.89	531438.84	1158.24	REBAR 618+00
79	912847.38	531328.86	1154.00	NAIL T.O. 113
81	902501.42	531247.00	1108.91	ALUM CAP 285+00
83	1030928.92	591908.65	1452.50	REBAR 1997+00
100	1008180.55	590630.56	1465.79	REBAR 1998+00
101	1031406.21	591983.14	1459.92	REBAR 1998+00
103	1028433.52	591450.00	1439.26	REBAR 1922+45
104	1023407.88	592605.11	1440.91	REBAR 1918+26
105	1018243.47	591645.53	1449.80	REBAR 1870+00
106	1013889.33	594320.67	1437.69	REBAR 1820+00
107	1012185.39	591352.68	1387.52	REBAR 1750+75
109	1008952.07	587844.03	1355.42	REBAR 1685+03
110	999972.92	588878.35	1352.69	REBAR 1627+74
111	999325.11	588426.60	1350.92	REBAR 1605+82
112	997709.00	588428.39	1354.44	REBAR 1574+43
114	991007.57	577510.85	1348.10	REBAR 1390+01
115	988825.33	568804.82	1344.81	REBAR 1330+00
116	981990.21	555488.48	1342.52	RF 5/8 1198+80
117	977477.48	548992.88	1343.22	REBAR 1128+15
118	974352.99	546149.44	1341.02	REBAR MICHIGAN 0
119	973107.81	544088.81	1342.44	REBAR 1073+38
120	971532.22	544113.78	1338.74	REBAR 1080+16
121	967260.59	541421.45	1335.18	REBAR 980+00
122	968647.79	538723.24	1335.33	REBAR 987+23
123	968006.12	537776.89	1334.17	REBAR 988+00
124	962388.29	537977.38	1331.84	ALUM CAP WELL 84
125	959922.70	538744.01	1329.75	REBAR 925+00
126	957731.97	538230.20	1330.87	REBAR 880+14
127	955130.58	535125.08	1330.22	REBAR 823+00
128	952411.23	535404.14	1327.23	REBAR 798+58
129	948850.77	534757.12	1328.33	REBAR 785+00
130	947773.47	533617.79	1330.58	REBAR 750+00
131	944527.93	533176.43	1329.88	REBAR 709+37
132	941815.50	531484.38	1322.12	REBAR 670+00
133	939238.00	531441.31	1308.83	REBAR 654+72
134	936605.88	531421.77	1289.69	REBAR 628+70
135	933941.03	531408.33	1277.21	REBAR 670+00
136	932568.81	531387.52	1263.83	REBAR 585+00
137	929282.48	531382.67	1245.08	REBAR 556+00
138	927344.33	531388.23	1228.34	REBAR 537+50
139	924436.85	531425.91	1208.64	REBAR 523+18
140	921843.19	531429.55	1190.34	REBAR 486+00
141	918894.40	531405.48	1174.94	REBAR 464+00
142	917112.48	531381.40	1165.00	REBAR 428+00
143	914031.85	531363.05	1156.18	REBAR 402+00
144	909855.84	531291.73	1142.45	REBAR 362+00
145	907843.77	531283.09	1134.93	REBAR 338+38
146	904990.27	531261.72	1118.06	REBAR 311+98
147	907585.50	531287.17	1134.03	USCOS E265
148	902824.82	531258.21	1109.15	REBAR 290+00
203	1025528.41	591386.20	1441.98	REBAR X ROCK 1923+8
213	980623.31	582917.43	1362.46	REBAR 85-113
215	988931.57	588116.17	1343.96	REBAR 80' NORTH
216	981928.81	588375.47	1341.64	REBAR 82-116
217	977362.01	588069.91	1342.33	REBAR 85-117
224	982366.97	537118.39	1330.37	REBAR 85 823+00
228	951227.97	534869.88	1330.06	REBAR 785+00
250	984857.97	583399.65	1235.53	USCOS LITCH
251	917125.38	584283.38	1121.03	USCOS LITCHFIELD
5316	981036.83	572542.17	1348.32	USCOS 8285
5514	974312.37	548009.83	1341.33	USCOS 1366
5581	985847.42	537534.63	1334.84	USCOS R285
8220	910218.28	531284.02	1146.27	NAIL IN PP



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January 29, 1999

Beardsley Canal Capacity Study Vertical Control Monument Locations

FIGURE 3-1

Figure 2-2 is a map of the Beardsley Canal, and a profile is shown on Figure 3-2. Table 3-1 is a line list detailing all the structures on the Beardsley Canal.

Reach I: Camp Dyer Diversion to CAP Inlet



Figure 3-4 Chute and basin upstream of the Agua Fria River Flume.

This uppermost reach of the Beardsley Canal is characterized by shotcrete lining and rugged terrain. In general, the canal has a 15-foot bottom width, an 8-foot depth, and a slope of 0.0022. A typical cross section is shown in Figure 3-3. Upstream of the CAP inlet, however, the canal experiences a substantial vertical drop prior to entering the Agua Fria River Flume.



Figure 3-5 Agua Fria River Flume.

Starting at station 178126, the Beardsley Canal enters a chute which abruptly drops 45 feet. The flow goes supercritical and the canal is only 2.5 feet deep along the chute. The chute ends in a basin structure, then immediately enters another chute for an additional 33-foot drop. The second chute also ends in a basin, which overflows into the Agua Fria River Flume.

Subsequent to the construction of the CAP inlet, this reach of canal is typically dry. There are no turnouts on this reach of canal.

Reach II: CAP Inlet to Grand Avenue

Downstream of the 600 cfs (388 mgd) CAP inlet, the Beardsley Canal typically has a bottom-width of 25 feet, a depth of 8 feet, and a gentle slope of 0.00016. The upper

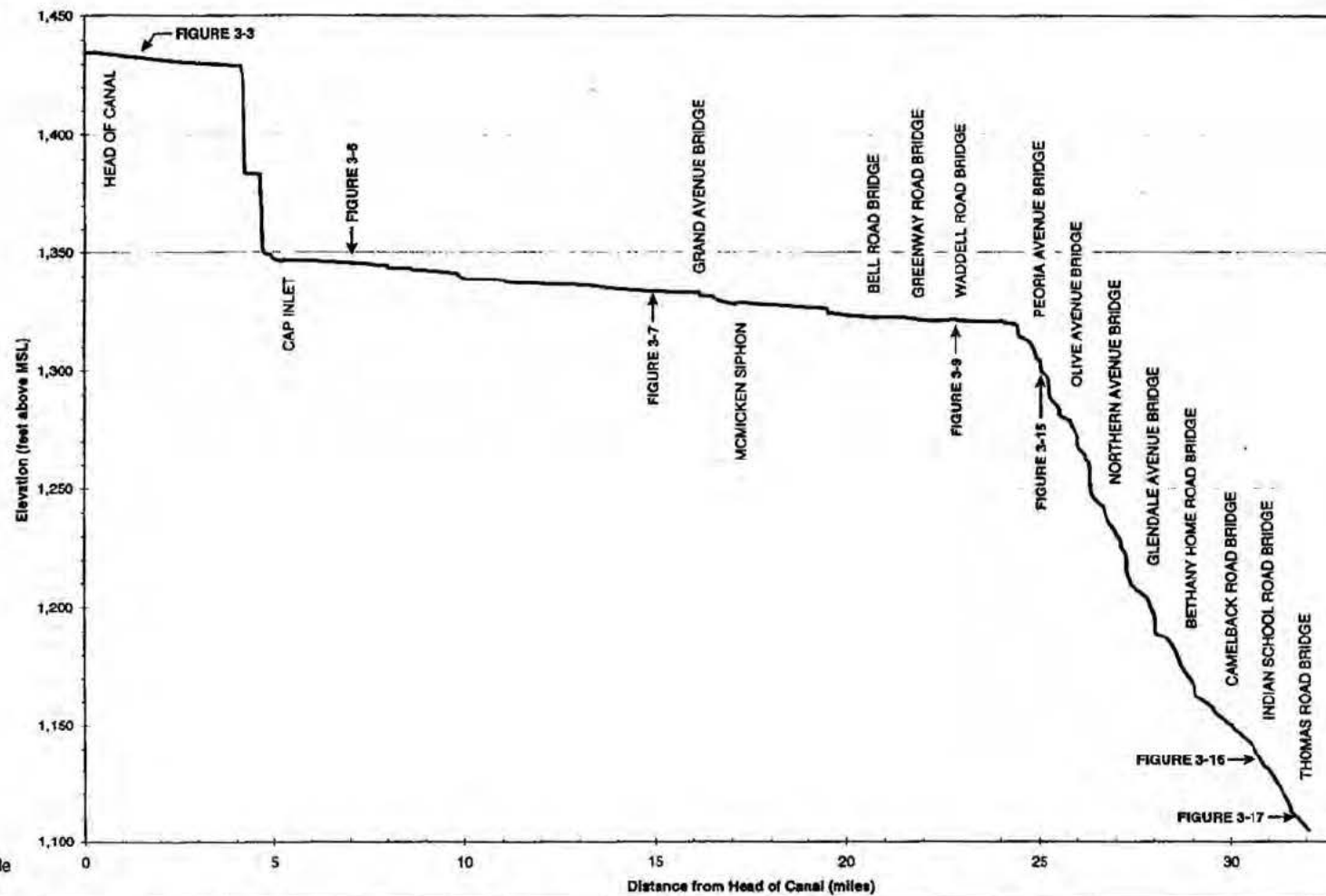


Figure 3-8 Flume crossing of a local wash.

segment was constructed using shotcrete, while the lower segment closer to Grand Avenue was constructed of concrete using the slip-form method. Figure 3-6 shows a picture and cross section just downstream of the CAP inlet, while Figure 3-7 shows comparable information for a stretch just above Grand Avenue. In order to cross three steep canyons formed by local washes, the Beardsley Canal uses ten-foot diameter pipe flumes. Figure 3-8 depicts the flume beginning at station 153639. The Bard Citrus Ranch turnout is the only turnout on

this reach of canal.

**FIGURE 3-2
BEARDSLEY CANAL CAPACITY STUDY
PROFILE OF BEARDSLEY CANAL INVERT**



Note, does not include detail at structures.



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Table 3-1
Beardsley Canal Capacity Study
Line List - Beardsley Canal Structures and Cross Sections

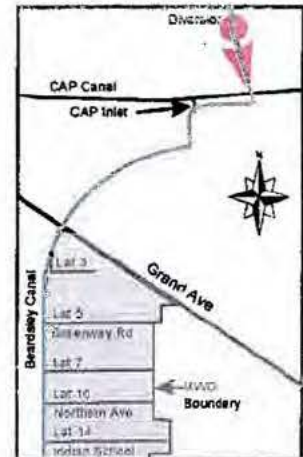
	Canal Station (feet)	Canal Mile	Structure/Reach Description	Structure Dimensions		Road Alignment
				Cross Section	Length (ft)	
REACH I	200,000	-	Diversion headworks, start of canal			
	197,651	0.4	Weir & recording gauge, MWD Station 1	9' h x 16' w		
	197,473	0.5	Bridge on road to Beardsley Canal diversion			
	185,558	2.7	Canal cross section			
	185,472	2.8	Bridge for road to Cowtown			Carefree
	178,126	4.1	Weir and checkdrop, unused	3 @ 8' h x 5.25' w		
	177,923	4.2	1st Chute			
	175,486	4.6	2nd Chute			
	175,096	4.7	Flume #1 - Agua Fria River Flume	13' Dia Semi-circular	1,150	
REACH II	172,787	5.2	CAP inlet to Beardsley Canal			
	172,153	5.3	Rec. weir & MWD Station 5 gauge	7' h x 20' w		
	168,203	6.0	Turnout for Bard Citrus Ranch			
	158,990	7.8	Canal cross section			
	157,469	8.1	Flume #2 (pipe)	10' I.D.	440	Dynamite
	154,080	8.7	Flume #3 (pipe)	10' I.D.	440	
	147,581	9.9	Flume #4 (pipe)	10' I.D.	380	Jomax
	141,387	11.1	Inverted siphon	10' x 10'	51	
	132,048	12.9	Inverted siphon	10' x 10'	51	
	127,855	13.7	Inverted siphon	10' x 10'	100	
	127,453	13.7	Radial gate	2 @ 8' h x 10' w		
	115,009	16.1	Radial gate, unused turnout	2 @ 8' h x 10' w		
	114,520	16.2	163rd Ave. bridge			
	114,443	16.2	CMP double culvert under Santa Fe railroad	2 @ 8' Dia	54	
	114,282	16.2	Box culvert at Grand Ave.	8.4' h x 18' w	46	Grand
REACH III	112,797	16.5	Turnout #1. Rec. weir provides grade control.			
	112,430	16.6	Inverted siphon and MWD Station 13 gauge	10 x 10 ft	50	
	112,350	16.6	Rectangular weir checkdrop	6' h x 10' w		
	109,365	17.2	Inverted siphon at McMicken Dam chute	12' x 12'	36	Beardsley
	104,988	18.0	Turnout #2, no grade control			
	101,801	18.6	Turnout #3, rec. sluice gate, MWD Station 17 gauge	5 @ 8' h x 5.8' w		
	96,647	19.6	Inverted siphon	8' x 8'	100	Union Hills
	93,836	20.1	Turnout for golf course, no grade control			
REACH IV	90,639	20.7	Turnout #4, rectangular checkboard	4 @ 10' h x 5.8' w		
	90,563	20.7	Bell Road bridge			Bell
	84,479	21.9	Greenway Road bridge			Greenway
	84,411	21.9	Turnout #5, radial gate, MWD Station 22 gauge	2 @ 8' h x 8' w		
	81,772	22.4	Turnout #5.03, no grade control			
	79,013	22.9	Turnout #6, rectangular checkboard	4 @ 9.5' h x 5.8' w		Waddell
REACH V	73,059	24.0	Turnout #7, rec. sluice gate, MWD Station 25 gauge	2 @ 8.8' h x 5.8' w		Cactus
	72,160	24.2	Weir, checkdrop - last station gauge	6.7' h x 12' w		
	70,740	24.5	Inverted siphon	5' x 5'	117	
	67,670	25.1	CMP culvert at Turnout #8	5' Dia	55	Paoria
	67,647	25.1	Turnout #8, rec. checkboards	5' x 5'		
	65,027	25.6	Inverted siphon	6' x 6'	118	
	62,413	26.1	CMP culvert under Olive Ave	7' x 4.8' ellipse	40	Olive
	62,366	26.1	Turnout #9, rectangular checkdrop	6.3' h x 7.8' w		
	61,000	26.3	Canal cross section			
	57,117	27.1	CMP culvert at Northern Ave	6' x 3.6' ellipse	20	Northern
REACH VI	57,083	27.1	Turnout #10, rectangular checkdrop	3.9' h x 7.5' w		
	55,206	27.4	Inverted siphon	5.2' x 5.2'	98	
	52,860	27.9	Rectangular weir & checkdrop - unused	4' h x 5' w		
	51,802	28.1	Turnout #11, rec. weir checkdrop	4.1' h x 7' w		Glendale
	46,554	29.1	Turnout #12, broadcrested weir	1.5' in channel		Bethany Home
	46,475	29.1	Inverted siphon	4.4' x 4.4'	103	Camelback
REACH VII	41,274	30.1	Turnout #13, rectangular weir checkboard	4.8' h x 6' w		
	38,658	30.6	Turnout 13.5, rectangular checkboard	3.2' h x 5.2' w		
	36,051	31.1	Box culvert at Indian School Rd.	5.5' h x 8' w	32	Indian School
	36,011	31.1	Turnout #14, rec. weir checkdrop	4.1' h x 6.2' w		
	35,977	31.1	End of canal			
	33,370	31.1	Checkboards at Osborn Rd. on lateral ditch			Osborn
	30,700	32.1	End of lateral ditch at Thomas Rd.			Thomas

Beardsley Canal Capacity Study

Figure 3-3

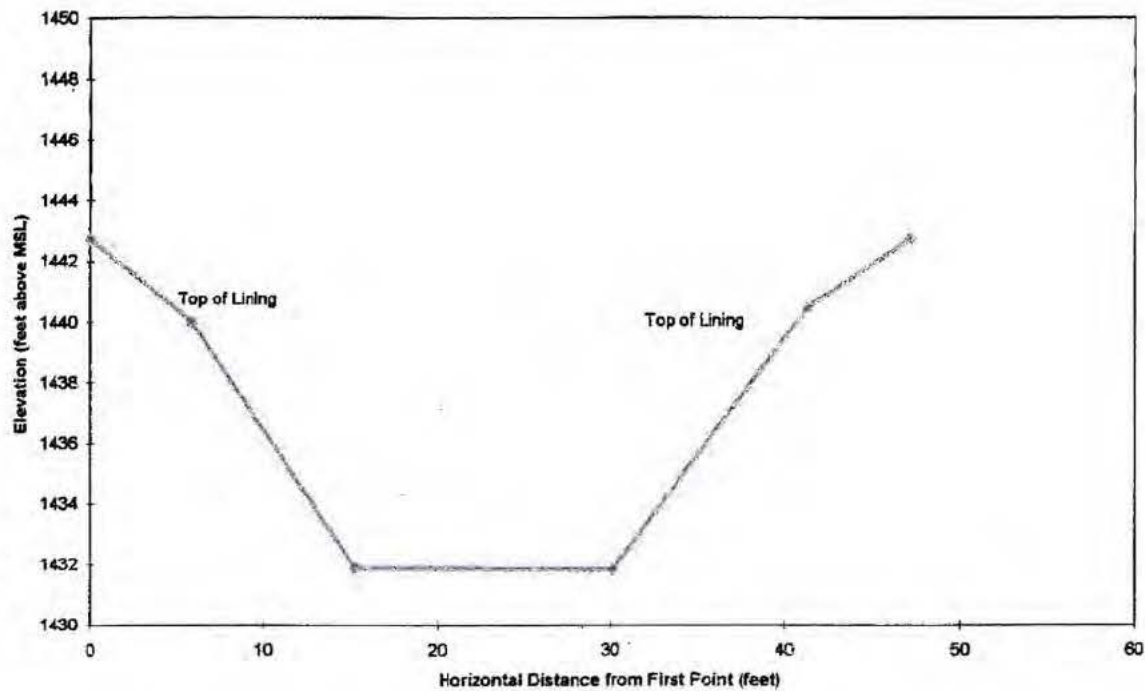


Beardsley Canal south of the Camp Dyer Diversion.



Canal Mile: 1.5
 Pictured Flow Rate: NA
 Design Flow Rate: ~700 cfs
 Initial Structure Assessment:
 Good Design/Good Condition

Photo #L-10



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Date	January 29, 1999

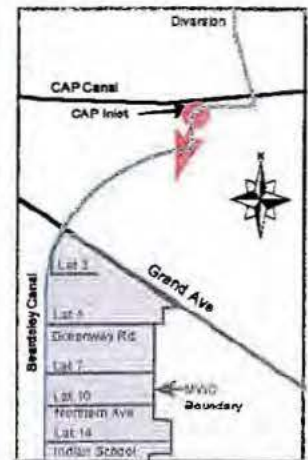


Beardsley Canal Capacity Study

Figure 3-6

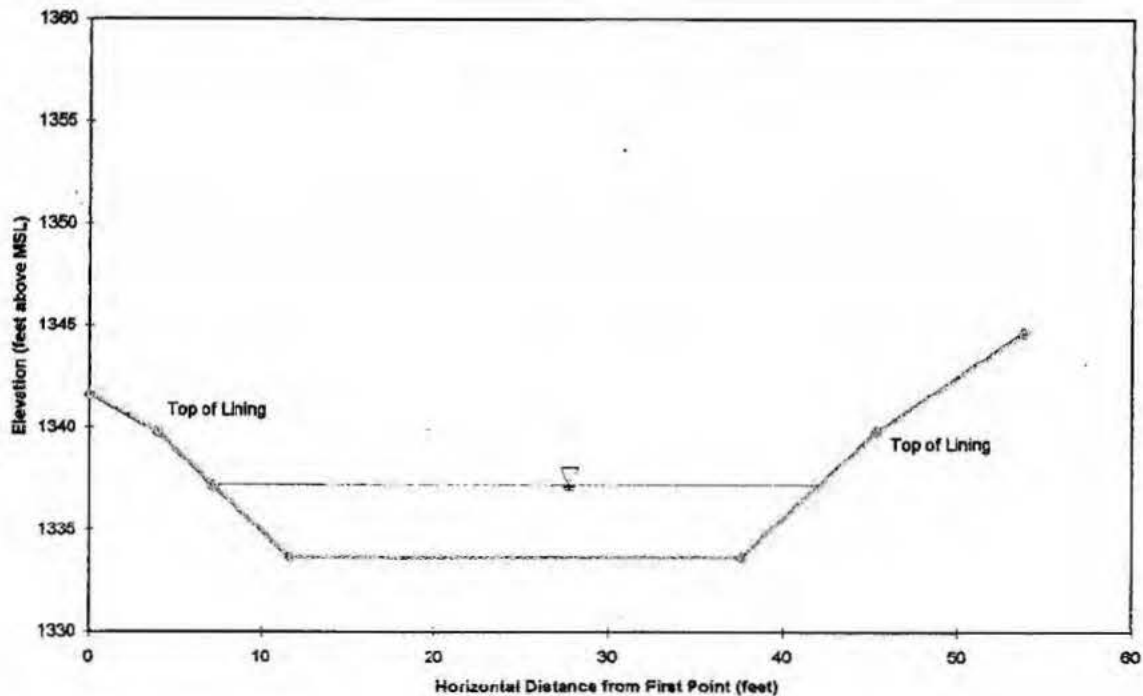


Typical Beardsley Canal cross section above Canal Mile 11. Shotcrete construction, maintenance ramp pictured at left.



Canal Mile: 5.7
 Pictured Flow Rate: 155 cfs
 Design Flow Rate: ~700 cfs
 Initial Structure Assessment:
 Newer shotcrete section
 pictured, some portions
 require substantial
 maintenance/ reworking.

Photo #H-18



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Date	January 29, 1999

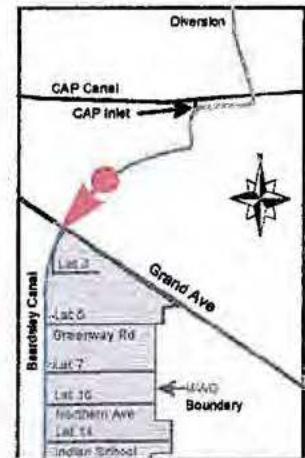


Beardsley Canal Capacity Study

Figure 3-7

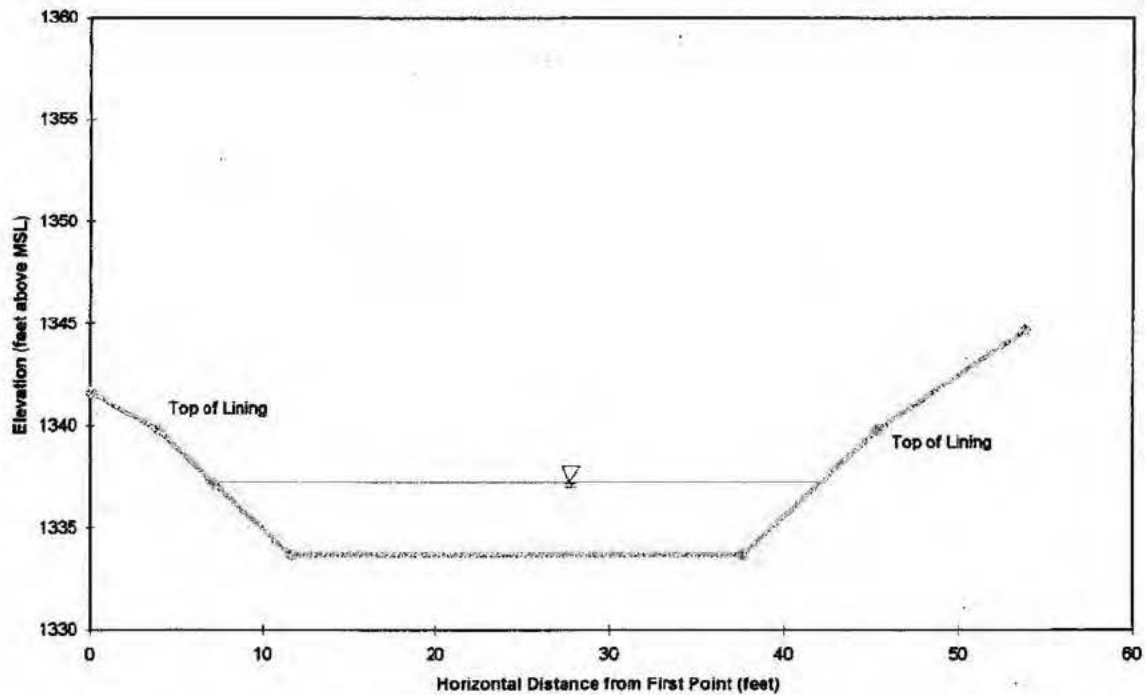


Typical Beardsley Canal cross section above Grand Avenue. Form placed concrete with uniform cross sections. Caved portion at photo right.



Canal Mile: 13.3
 Pictured Flow Rate: 155 cfs
 Design Flow Rate: ~625 cfs
 Initial Structure Assessment:
 Form placed concrete
 typically in good condition
 with some minor repairs
 required.

Photo #1-19



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Reaches III and IV: Grand Avenue to Cactus Road

Figure 3-10 Entrance to concrete box inverted siphon under the McMicken Dam chute.

Between Grand Avenue and Cactus Road, the Beardsley Canal typically has a bottom width of 20 feet, a depth of 5 feet, and is constructed of slip-formed concrete. From Grand Avenue to Bell Road, the canal has a gentle slope of 0.00006 and from Bell Road to Cactus Road it has a slope of 0.00007. Figure 3-9 depicts a typical picture and cross section of these reaches of canal. Turnouts #1 through 7 are included in these reaches, as is the concrete box inverted siphon transporting flow under the McMicken Dam Chute (Figure 3-10). Figure 3-11 shows Turnout #4 and the Bell Road bridge.

Considerable new home construction is adjacent to the Beardsley Canal in these reaches, as shown in Figure 3-12.



Figure 3-11 Turnout structure for Lateral 4 and the Bell Road bridge.



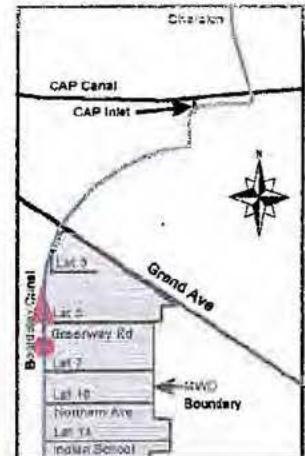
Figure 3-12 New home construction north of Bell Road.

Beardsley Canal Capacity Study

Figure 3-9

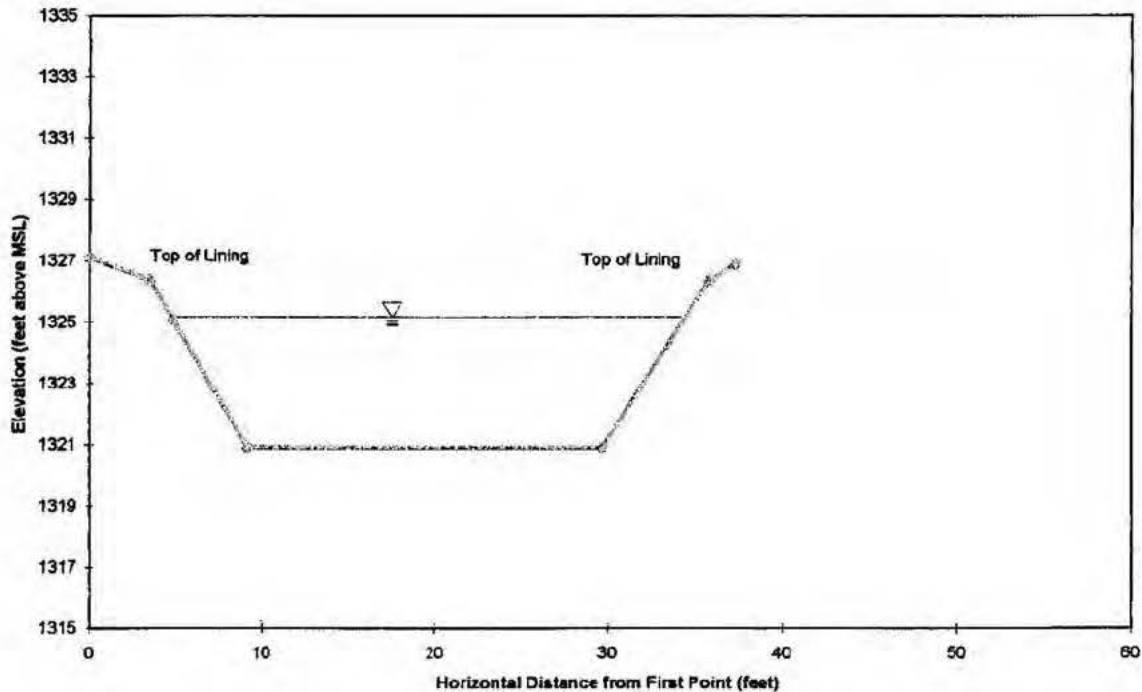


Typical canal reach near Lateral #6. Note the small amount of remaining freeboard although flow rate in canal is approximately 1/3 of design rate.



Canal Mile: 23.3
 Pictured Flow Rate: 110 cfs
 Design Flow Rate: ~370 cfs
 Initial Structure Assessment:
 Good Condition - Possible
 constriction, low slope or
 checked as part of
 operational requirements.

Photo #E-15



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Reaches V and VI: Cactus Road to Camelback Road

Downstream of Cactus Road, the Beardsley Canal changes character from a gentle-sloping canal to a canal with a relatively steep descending gradient. It typically has a bottom width of 5 feet, is 5 feet deep, has a slope of 0.025, and is shotcrete-lined. Flow is typically turbulent. The canal also experiences six drops at check structures, including the check structure for Turnout #9 at Olive Avenue (Figure 3-13). Turnouts # 8 through 13 are on these reaches and Figure 3-14 shows the CMP culvert in which resides the checkboard structure which turns out flow for Lateral #8. Figure 3-15 depicts a typical picture and cross section from this reach of the Beardsley Canal.



Figure 3-13 Drop at Turnout #9 check structure, Olive Avenue.



Figure 3-14 CMP culvert for Turnout #8.

Reach VII: Camelback Road to End of Canal

Downstream of Camelback Road, the dimensions of the Beardsley Canal become smaller as MWD conveyance needs are correspondingly decreased. In this final reach, the canal typically has a bottom width of 2 feet, a depth of 3 feet, a slope of 0.006, and is constructed of shotcrete or slip-formed concrete. Figure 3-16 shows a typical picture and cross section from this reach of canal. Turnouts # 13.5 and 14 are on this reach and the canal ends with a turnout to a farm field at Thomas Road. Figure 3-17 shows the end of the Beardsley Canal.

Structures

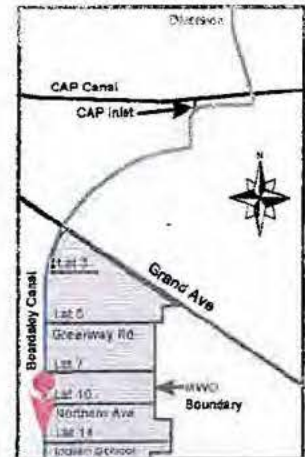
There are a number of structures on the Beardsley Canal including bridges, check structures, measuring weirs, culverts, inverted siphons, flumes, and turnouts. Check structures include radial gates, sluice gates, and check gates and may or may not have associated canal drops. Representative structures are pictured throughout this section and Table 3-1 lists all the structures, with references to the photographs in Appendix A. Appendix B contains a detailed description of the Beardsley Canal HEC-RAS model, which includes detailed information on all the structures.

Beardsley Canal Capacity Study

Figure 3-15

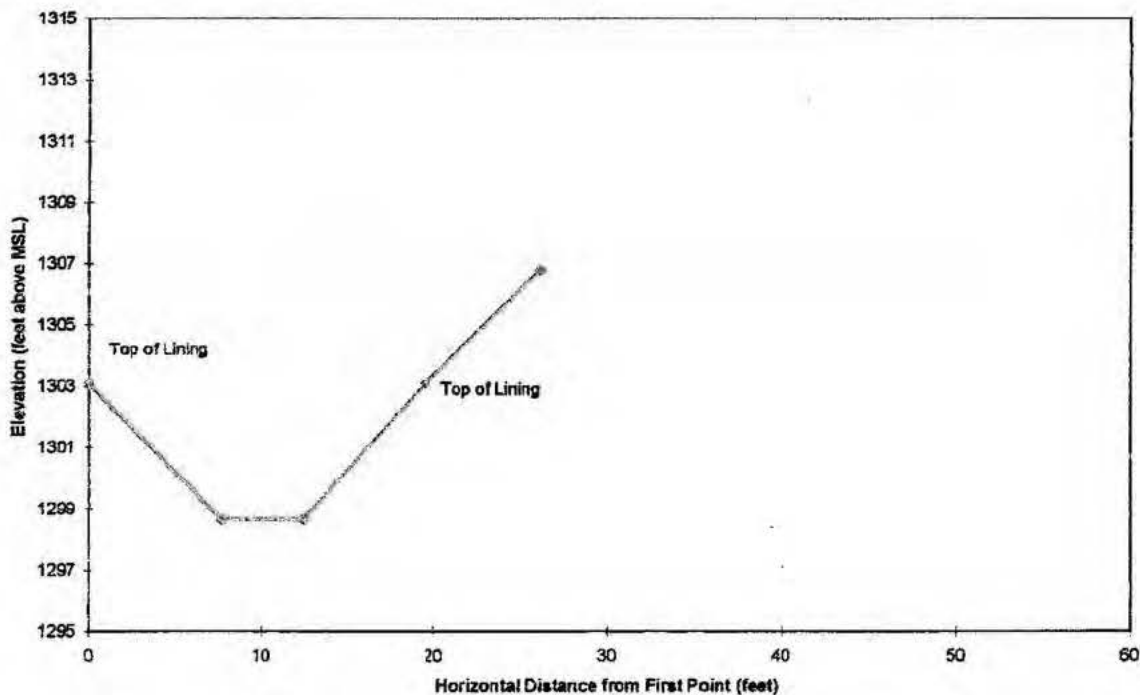


Canal cross section below Lateral 8. Segments with steep slopes or drop structures are common below this point. Much of the canal is lined with shotcrete.



Canal Mile: 25.5
 Pictured Flow Rate: 66 cfs
 Design Flow Rate: ~360 cfs
 Initial Structure Assessment:
 Steep slopes, shotcrete
 construction, some segments
 require maintenance

Photo #D-4



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Date	January 29, 1999

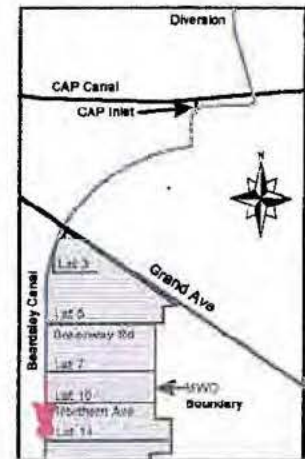


Beardsley Canal Capacity Study

Figure 3-16

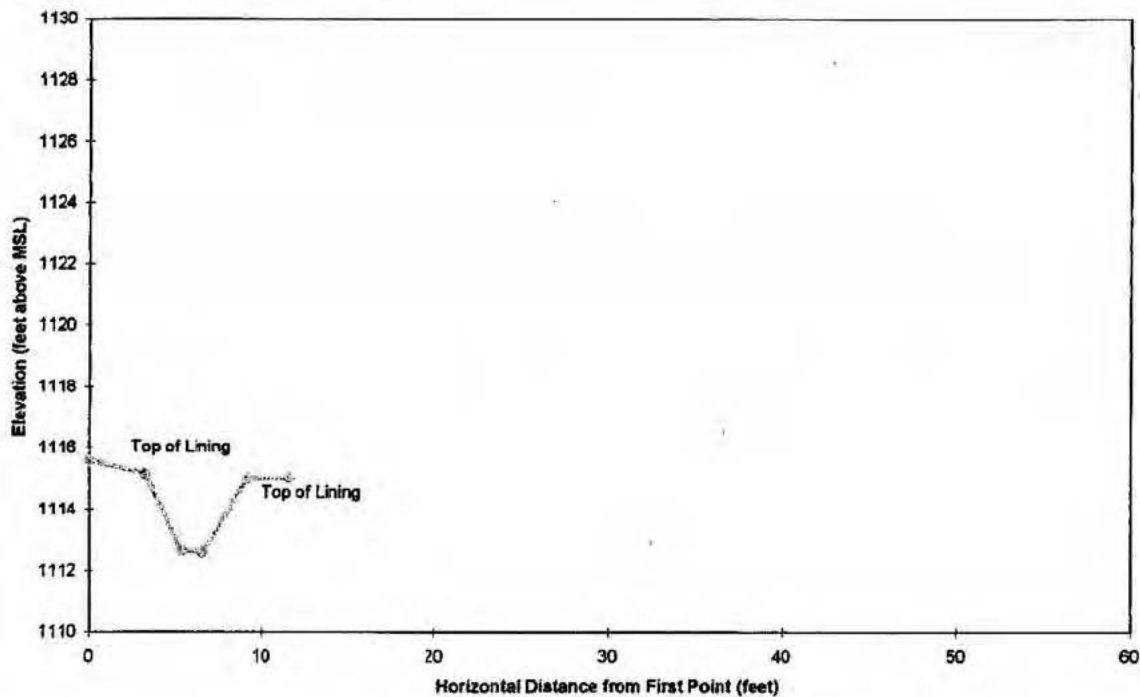


Beardsley Canal and turnout to Lateral 13.5.



Canal Mile: 31.0
 Pictured Flow Rate: unknown
 Design Flow Rate: ~150 cfs
 Initial Structure Assessment:
 Broken lining, does not
 appear to be capable of
 meeting design Q

Photo #L-15



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Date	January 29, 1999

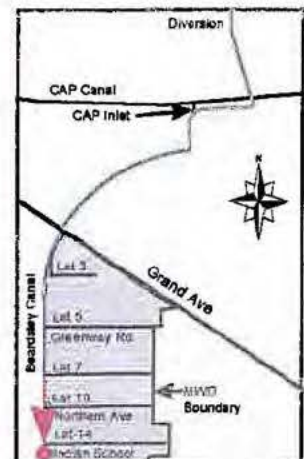


Beardsley Canal Capacity Study

Figure 3-17

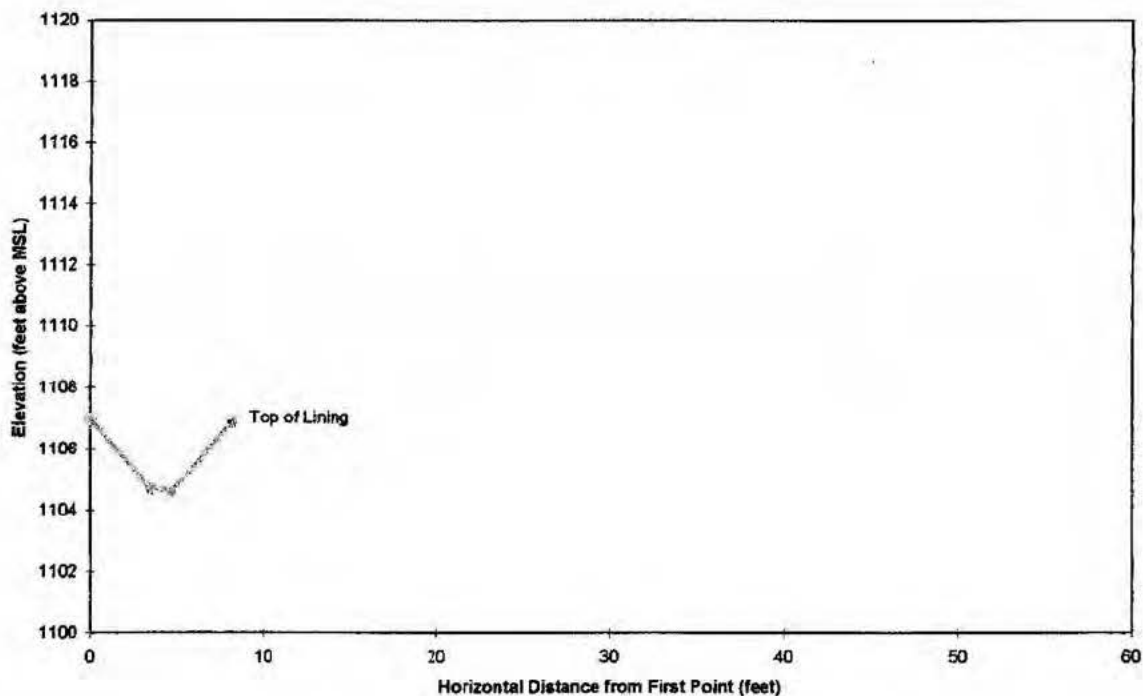


End of Beardsley Canal near Thomas Road.



Canal Mile: 32.5
 Pictured Flow Rate: 0 cfs
 Design Flow Rate: ~52 cfs
 Initial Structure Assessment:
 Form place concrete, does
 not appear to be capable of
 meeting design Q

Photo #C-18



Prepared By	Bookman-Edmonston ENGINEERING, INC.
Date	January 29, 1999



Section 4

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HEC-RAS Model Description

A hydraulic analysis of the Beardsley Canal was undertaken using data collected in the field and HEC-RAS (Hydrologic Engineering Center River Analysis System) version 2.2. The basic input data requirements for HEC-RAS include canal geometry (represented by a series of cross sections); energy loss coefficients for hydraulic resistance and the expansion or contraction of flow; the rate of discharge; and conditions for the flow boundaries of the canal (i.e., top of lining). A detailed description of the hydraulic model is included as Appendix B.

Within HEC-RAS, canal geometry is defined by a series of cross sections, each comprised of points with coordinates in three dimensions sufficient to define the area available for the conveyance of flow. For this project, canal geometry was developed from survey data collected in the field by B-E in December 1998. Ninety-seven points were set for vertical control and sufficient data were collected to generate over 250 cross sections. Section 3 provides more detail on the Beardsley Canal survey.

Figure 4-1 is a typical cross section showing the left and right canal banks the inverts, top of lining, and top of bank points. Additionally, selected cross sections have a water mark for the calibration flow regime (see below). Cross sections were typically surveyed every half-mile with more cross sections being taken in the vicinity of structures. Cross sections were also surveyed at points to aid in model calibration such as the extent of obvious backwater effects and changes in canal geometry, slope, or roughness. Additional cross sections were generated using judgment to aid in the model calibration process. Appendix B contains all the Beardsley Canal cross sections.



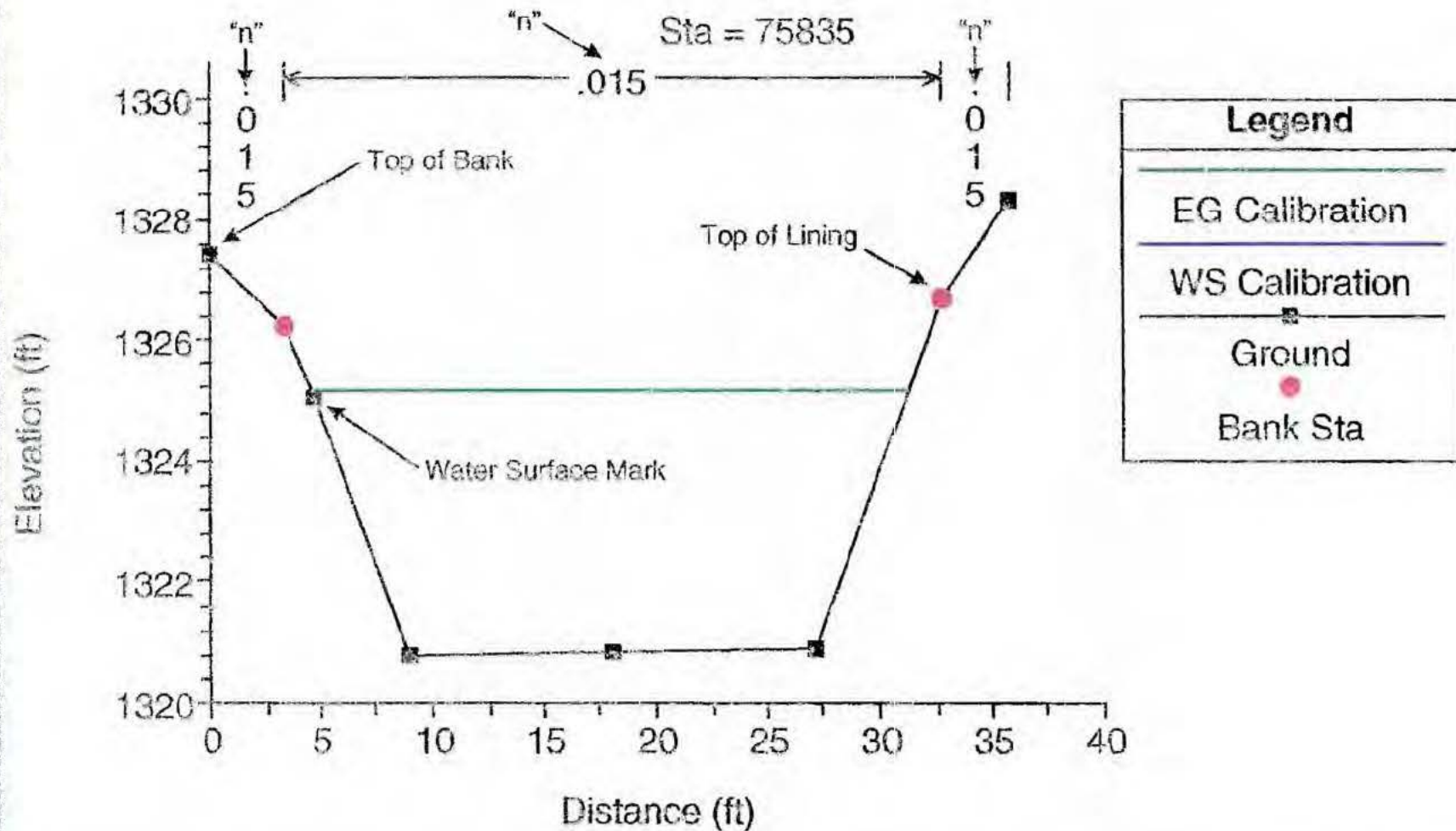
Figure 4-2 Blue paint water surface mark and label.

The water surface for a known flow regime was marked on the canal lining by B-E staff on August 4 and 5, 1998, high flow days for MWD. Blue paint was used to apply the marks at selected intervals (Figure 4-2). The coordinates of the water surface marks were surveyed and used to calibrate the HEC-RAS model. Using the known flow and water surface elevation, B-E was able to determine the hydraulic parameters of the Beardsley Canal.

HEC-RAS Model Results

After calibrating the model, flow was incrementally increased on a reach-by-reach basis until the modeled water surface was within six inches of the top of the canal lining. As HEC-RAS linearly interpolates between cross sections (except at structures), it is possible that the water surface will be closer than six inches to the top of the canal lining in areas where the top of canal lining is uneven.

FIGURE 4-1
Beardsley Canal Capacity Study - Phase 1
TYPICAL HEC-RAS CROSS SECTION



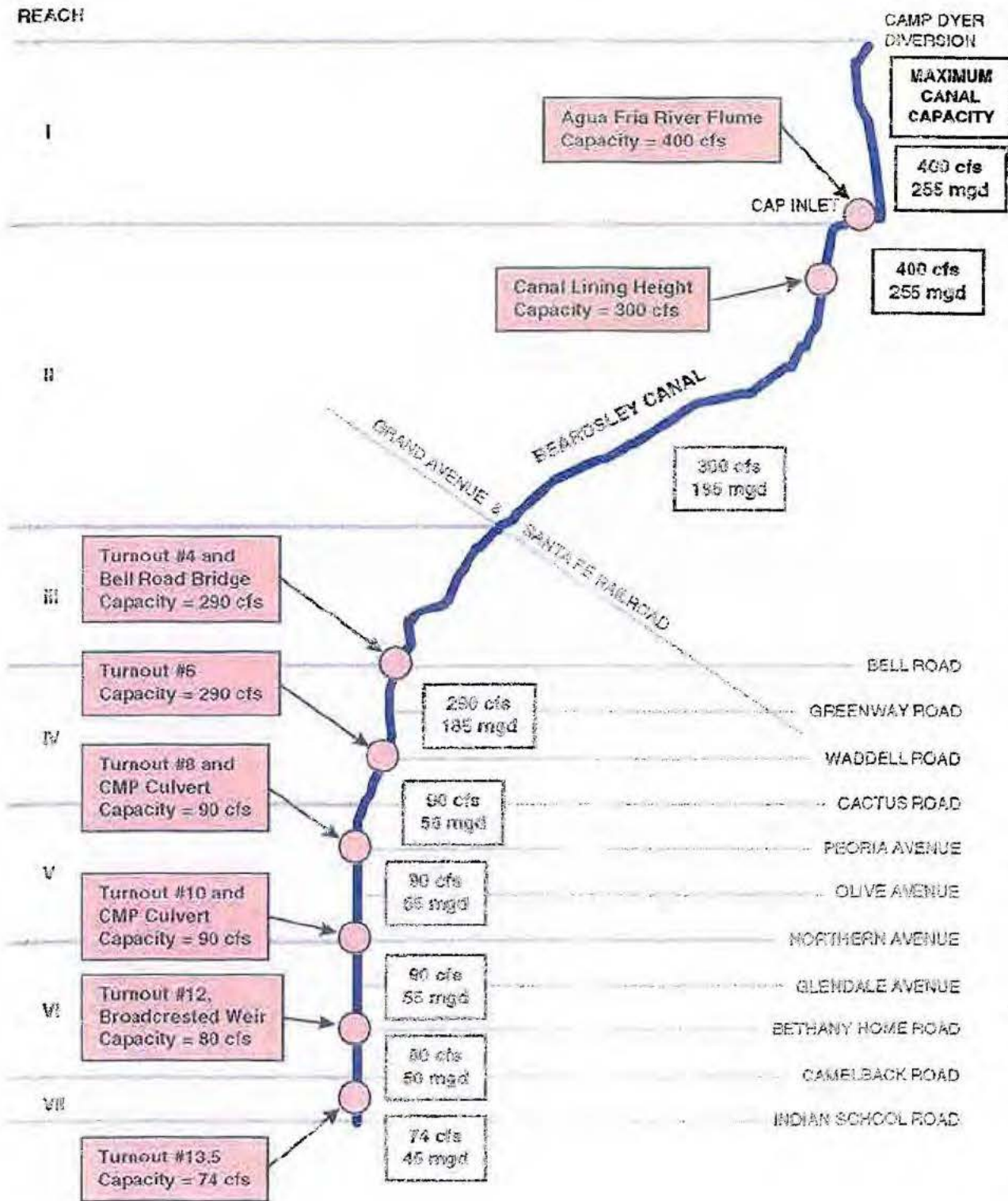
Typically, the check gates were modeled as fully open to achieve the higher flows. In all cases, the modeled water surface is high enough to allow MWD turnout deliveries. Table 4-1 summarizes the reach-by-reach estimated maximum capacities.

Table 4-1 Beardsley Canal Capacity Study - Phase 1 Summary of Estimated Maximum Reach Capacities				
Reach No.	Reach Description	1993 MWD High Flow ⁽¹⁾ (cfs)	Estimated Maximum Capacity ⁽²⁾ (cfs)	Estimated Maximum Capacity ⁽²⁾ (mgd)
I	Lake Pleasant to CAP Inlet	230	400	255
II	CAP Inlet to Grand Avenue	230	300	195
III	Grand Avenue to Bell Road	230	300	195
IV	Bell Road to Greenway Road	200	290	185
	Greenway Road to Waddell Road	179	290	185
	Waddell Road to Cactus Road	144	290	185
V	Cactus Road to Peoria Avenue	119	90	55
	Peoria Avenue to Olive Avenue	99	90	55
	Olive Road to Northern Avenue	82	90	55
VI	Northern Avenue to Glendale Avenue	67	90	55
	Glendale Avenue to Camelback Road	39	80	50
VII	Camelback Road to Indian School Road	25	74	45
Notes: 1. Flows measured by MWD in 1993 as maximum capacities constrained by existing demands. MWD has since made improvements to the Beardsley Canal. In some instances, MWD exceeded canal freeboard constraints used for computing the estimated maximum capacity. 2. Based on six inches of freeboard.				

The MWD 1993 flows were developed by MWD several years ago during a Lake Pleasant spill event, and are based on high flows to satisfy MWD demands. It should be noted that MWD has made improvements to the Beardsley Canal in subsequent dry-up periods, including raising the canal lining in selected areas. The estimated maximum capacity is significantly greater than the MWD 1993 flow in the upper reaches (Lake Pleasant to Cactus Road) for two reasons: MWD demands were not greater than the MWD 1993 flow, and improvements have been made to the Beardsley Canal in the interim. Between Cactus Road and Olive Avenue, the estimated maximum capacity is lower than the MWD 1993 flow because MWD was able to operate the water surface above the six inches of freeboard required in the modeling effort. In the lower reaches (Olive Avenue to Indian School Road), existing demands kept the MWD 1993 flows less than the estimated maximum capacity.

Figure 4-3 shows the reach-by-reach maximum estimated capacities and the locations of the structures which limit flow. Table 4-2 summarizes the restrictive structures and/or

REACH



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Prepared for
USBR/WESTCAPS



Beardsley Canal Capacity Study - Phase 1
Restrictive Structures and
Their Existing Capacities

Figure 4-3

canal segments while Figures 4-4 through 4-11 provide detail. The circle in the profile section on Figures 4-4 through 4-11 shows the location where the maximum flow water surface comes within six inches of the top of canal lining.

Table 4-2
Beardsley Canal Capacity Study - Phase 1
Summary of Beardsley Canal Features Which Restrict Conveyance Capacity

Canal Station	Structure	Description	Estimated Maximum Capacity (cfs)	Estimated Maximum Capacity (mgd)
175096	Flume	Agua Fria River Crossing	400	255
158990	Canal Lining	Below CAP Inlet	300	195
90639	Bridge	Bell Rd.	290	185
90563	Check Gate	Turnout #4	290	185
81772	Canal Lining	Between Turnouts # 5 and 6	290	185
79013	Sluice Gate	Turnout #6	290	185
67670	Check Gate in CMP Culvert	Turnout #8	90	55
57083	Check Gate	Culvert at Northern Ave. and Turnout #10	90	55
46554	Broadcrested Weir	Turnout #12	80	50
38658	Check Gate	Turnout #13.5	74	45

Figures 4-4 through 4-11 illustrate the model results for a variety of structures. Although not restrictive at the maximum modeled flow regime, Figures 4-12 through 4-14 provide detail on two additional structures of interest.

Sensitivity Analysis

A variety of parameters are incorporated into the HEC-RAS model including energy loss coefficients for hydraulic resistance and the expansion or contraction of flow; and weir and other structure-specific coefficients. The reliability of the modeling results depends on the ability to accurately estimate these parameters. All of the parameters selected were within accepted ranges for the conditions being modeled. For example, the Manning's "n" value (a measure of the roughness of the canal lining) chosen for the slip-form placed concrete sections was 0.015, while the range of Manning's "n" recommended for comparable material in the *HEC-RAS Hydraulic Reference Manual, Version 2.2* (U.S. Army Corps of Engineers, Hydrologic Engineering Center, August 1998) is 0.013 to 0.016, with 0.015 identified as "normal." Appendix B includes a comprehensive listing of model parameters.

While HEC-RAS is widely used to model open channel flow, it is worthwhile to note that it is based on empirical equations which reasonably predict hydraulics.

The model parameters were chosen systematically to reflect the canal lining and structures observed in the field and also to replicate the water surfaces measured for a known flow regime. In effect, the calibration process itself could be considered as a sensitivity analysis. A formal sensitivity analysis was performed, however, to determine the impact of varying the Manning's "n" value within the range of values for a given material. Increasing the hydraulic resistance of the canal lining (by increasing the Manning's "n" value from 0.015 to 0.016 and 0.020 to 0.023-- the "maximum" values) results in a decrease in the estimated maximum capacity of 12 percent in Reach I and approximately five percent in the remaining reaches. To replicate the water surface elevations predicted by the model for the maximum estimated flow regime using increased Manning's "n" values, a flow regime of 12 percent less flow in Reach I and approximately five percent less flow in the other reaches was required. The greater impact in Reach I is likely due to the absence of regulating structures in that reach.

FLOW RESTRICTION - AGUA FRIA RIVER FLUME

PHOTOGRAPHS



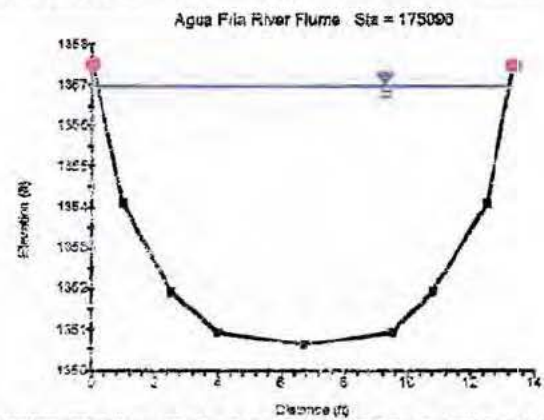
Agua Fria River Flume.



Photograph of inside of Agua Fria River Flume.

CROSS SECTIONS

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Water Surface for Maximum Calculated Flow



Canal Prism/Ground



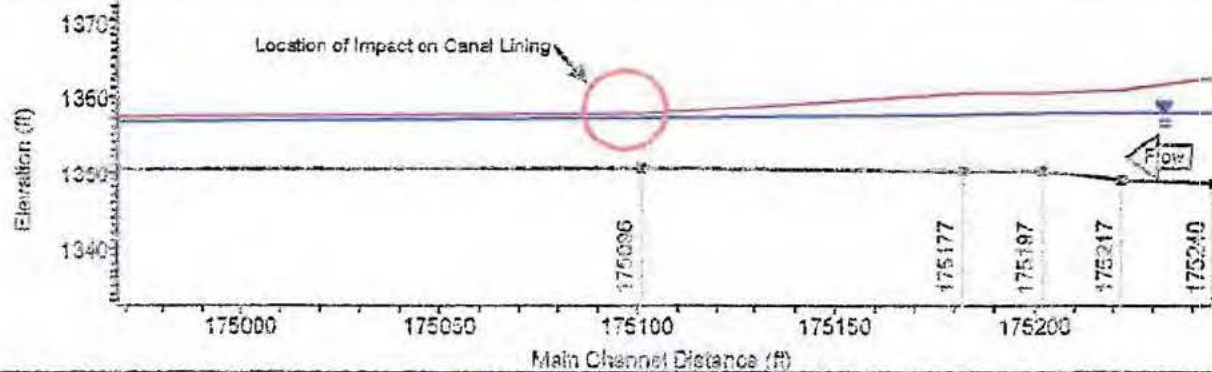
Top of Canal Lining



DESCRIPTION

Flow restrictions in this area are caused by a small flume flow area compared to upstream cross sections. Cross sections and profile depict maximum flow (400 cfs or 255 mgd).

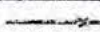
PROFILE



Water Surface for Maximum Calculated Flow



Canal Invert



Top of Canal Lining



Prepared by
Reckman-Elliott
ENGINEERING, INC.
May 14, 1999



Prepared for



Beardsley Canal Capacity Study - Phase I
Hydraulic Model Output for Restrictive Flow Area

Figure 4-4

FLOW RESTRICTION - LOW CANAL LINING BETWEEN FLUMES

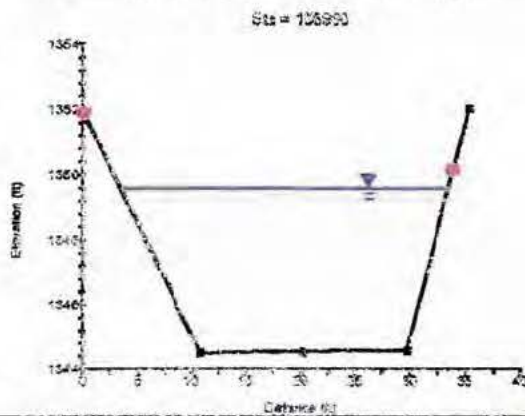
PHOTOGRAPHS



Low canal lining on left shown in cross section below as on the right bank.

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CROSS SECTIONS



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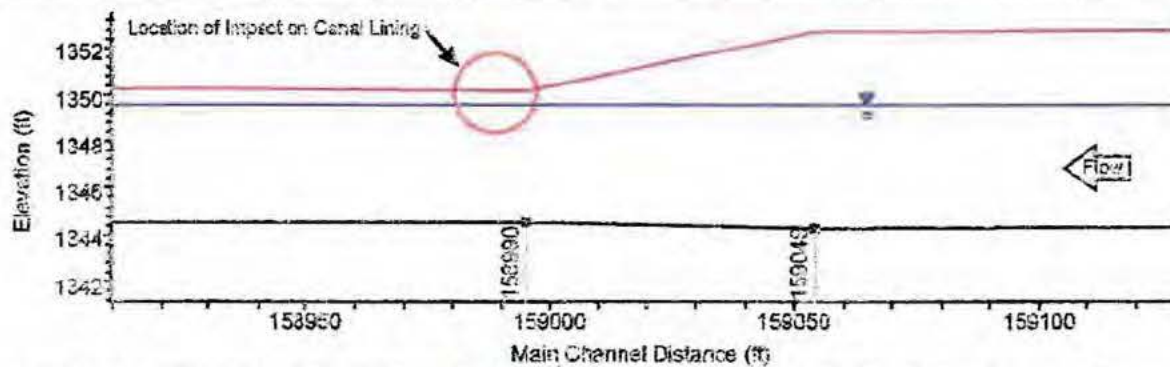
Water Surface for Maximum Calculated Flow Canal Prism/Ground Top of Canal Lining

DESCRIPTION

Flow restrictions in this area caused by low lining on right bank.

Note: calibration flow (145 cfs or 90 mgd) is pictured while cross sections and profile depict maximum flow (300 cfs or 195 mgd).

PROFILE



Water Surface for Maximum Calculated Flow Canal Invert Top of Canal Lining

Prepared by
Bookman-Edmondson
ENGINEERING, INC.
May 14, 1988



Seardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Restrictive Flow Area

Figure 4-5

FLOW RESTRICTION - BELL ROAD BRIDGE AREA

PHOTOGRAPHS

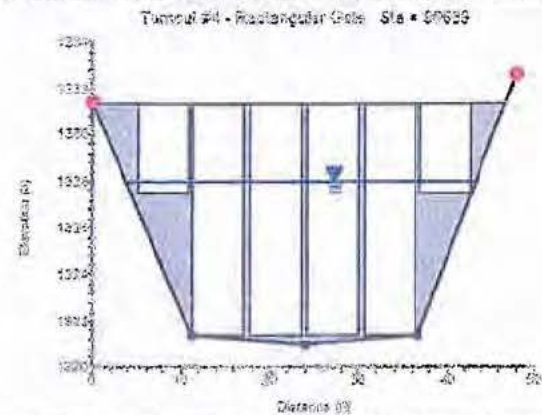
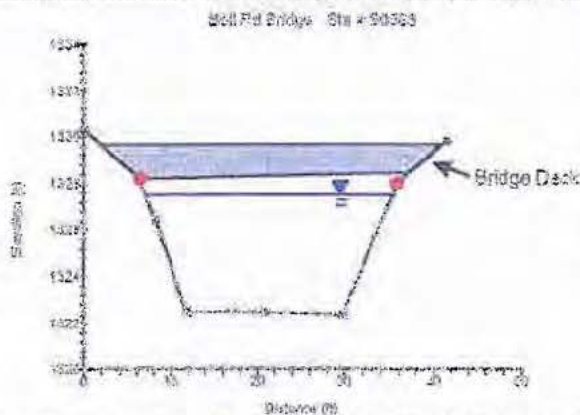


Bell Road Bridge, looking downstream.



Checkboard structure for Turnout #4, looking upstream.

CROSS SECTIONS

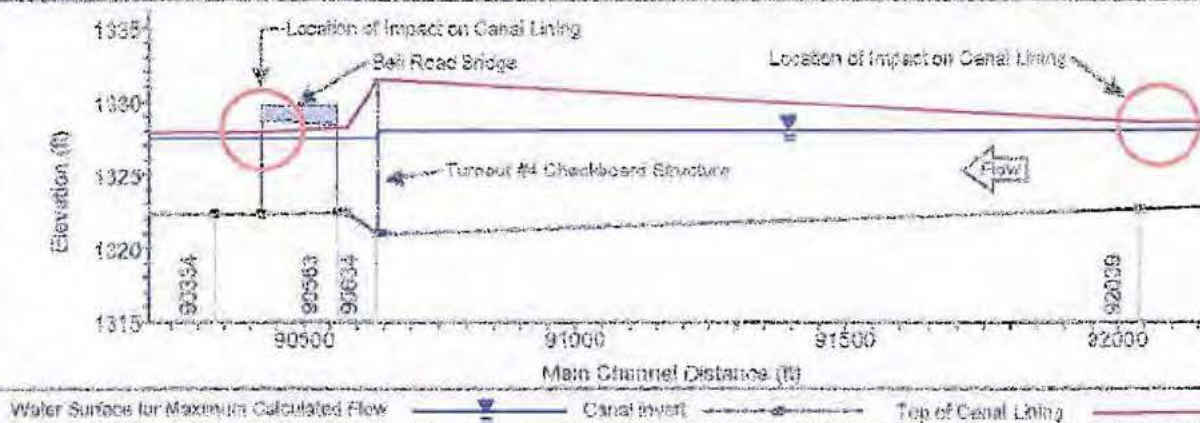


Water Surface for Maximum Calculated Flow Canal Prism/Ground Top of Canal Lining

DESCRIPTION

Flow restrictions in this area caused by either the checkboard structure, the bridge or the reduction in the canal size appear to raise the water surface to maximum allowable height upstream, as shown on the profile. Note: calibration flow (110 cfs or 70 mgd) is pictured while cross sections and profile depict maximum flow (290 cfs or 185 mgd).

PROFILE



Prepared by
Bookman-Edmondson
ENGINEERING, INC.
May 14, 1993



Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Restrictive Flow Area

Figure 4-6

FLOW RESTRICTION - UPSTREAM OF TURNOUT #6

PHOTOGRAPHS

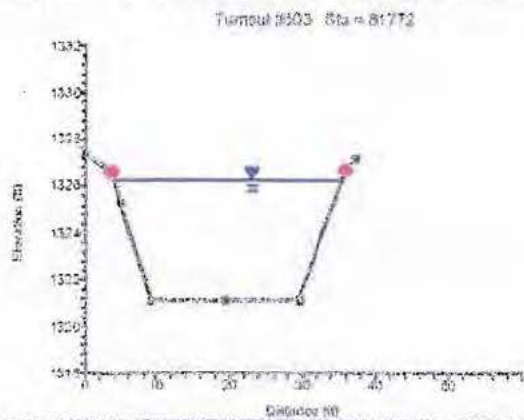


Turnout #5.03, midway between Turnouts #5 and 6

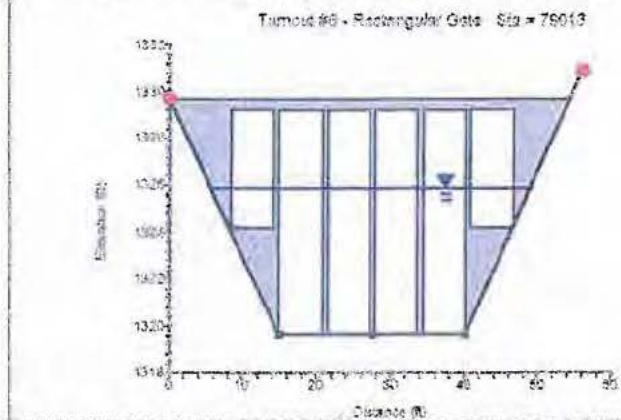


Turnout #6 checkboard structure.

CROSS SECTIONS



Water Surface for Maximum Calculated Flow



Canal Prism/Ground

Canal Prism/Ground

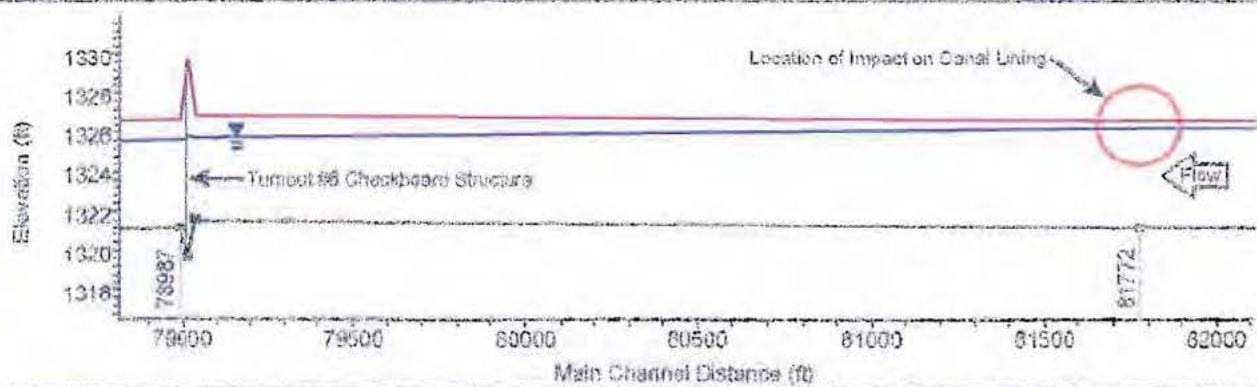
Top of Canal Lining

DESCRIPTION

Flow restrictions in this area caused by the flat slope. The slope is slightly negative in this area.

Note: calibration flow (94 cfs or 60 mgd) is pictured while cross sections and profile depict maximum flow (290 cfs or 185 mgd).

PROFILE



Water Surface for Maximum Calculated Flow

Canal Invert

Top of Canal Lining

Prepared by
Bookman-Edmonston
ENGINEERING, INC.
May 14, 1999



Boardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Restrictive Flow Area

Figure 4-7

FLOW RESTRICTION - CMP CULVERT FOR TURNOUT #8

PHOTOGRAPHS

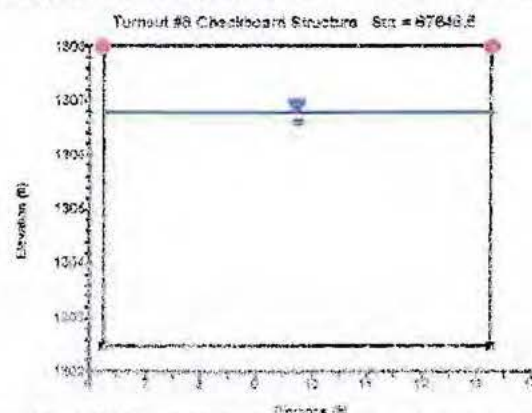
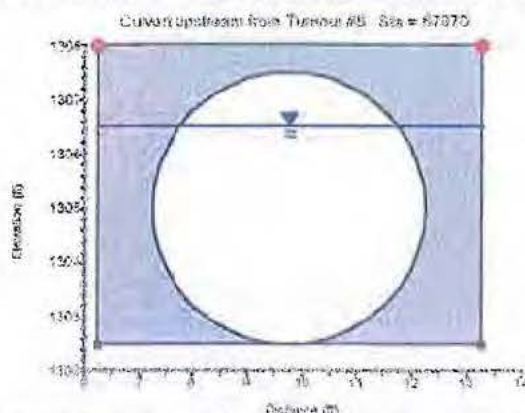


CMP culvert, Turnout #8 checkboard structure inside.



Interior of CMP culvert showing checkboards for Turnout #8. Note, checkboards are removed for high flow shown in cross section.

CROSS SECTIONS



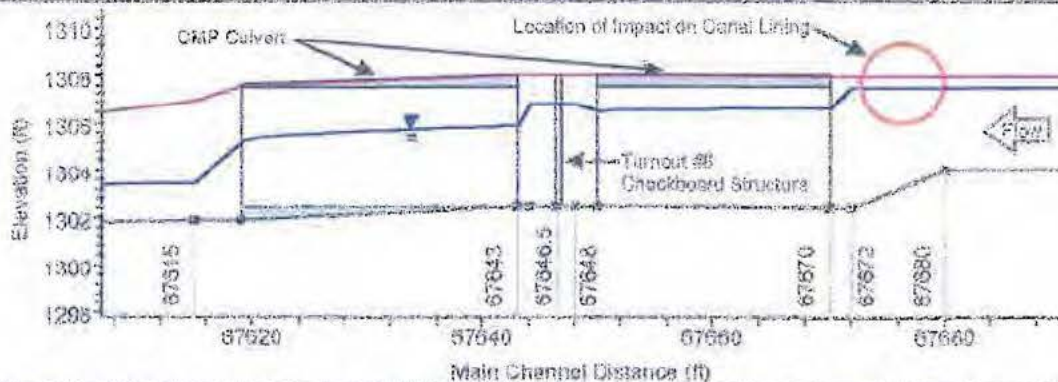
Water Surface for Maximum Calculated Flow Canal Firm/Ground Top of Canal Lining

DESCRIPTION

Flow restrictions in this area caused by the Turnout #8 checkboard structure and the CMP culvert.

Note: calibration flow (63 cfs or 40 mgd) is pictured while cross sections and profile depict maximum flow (90 cfs or 55 mgd).

PROFILE



Water Surface for Maximum Calculated Flow Canal Invert Top of Canal Lining

Prepared by
Bookman-Edmonson
ENGINEERING, INC.
May 14, 1999



Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Restrictive Flow Area

Figure 4-8

FLOW RESTRICTION - CULVERT UNDER NORTHERN AVENUE AND TURNOUT #10

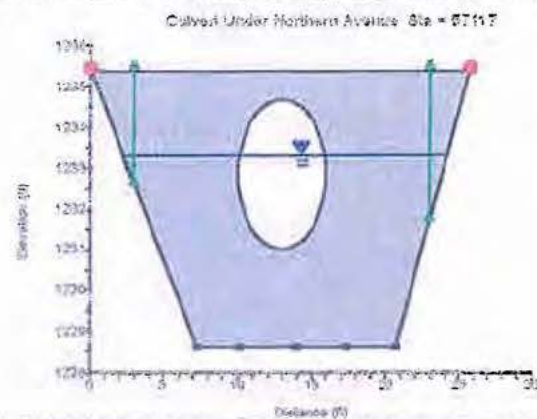
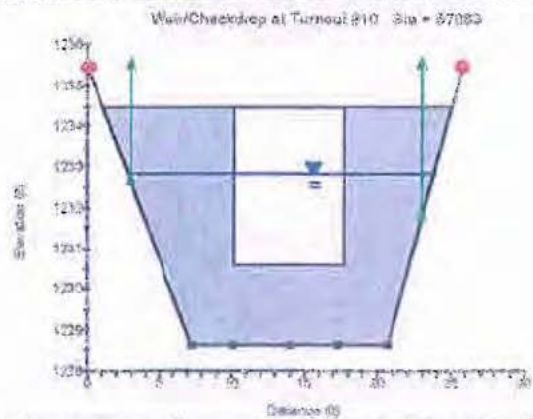
PHOTOGRAPHS



Turnout #10 and CMP culvert under Northern Avenue just upstream of turnout structure

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CROSS SECTIONS



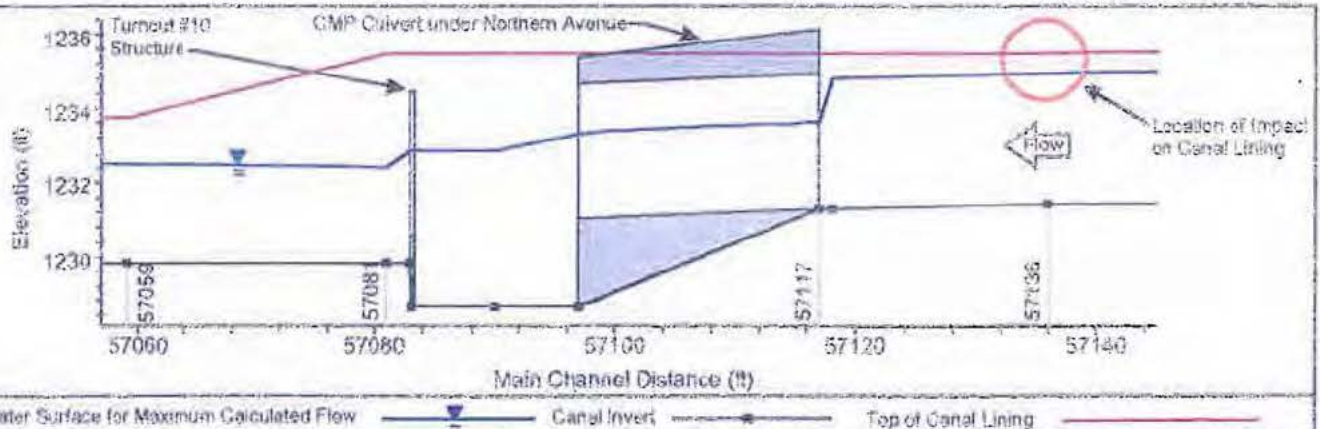
Water Surface for Maximum Calculated Flow: Canal Bottom/Ground: Top of Canal Lining:

DESCRIPTION

Flow restrictions in this area caused by the CMP culvert under Northern Avenue and the Turnout #10 structure.

Note: calibration flow (40 cfs or 25 mgd) is pictured while cross sections and profile depict maximum flow (90 cfs or 55 mgd).

PROFILE



Water Surface for Maximum Calculated Flow: Canal Invert: Top of Canal Lining:

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Bookman-Edmonston
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May 14, 1999

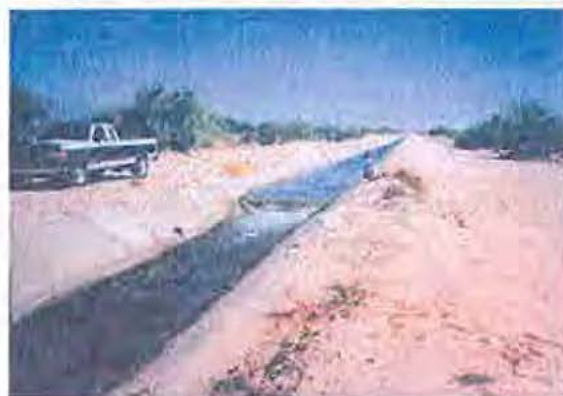


Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Restrictive Flow Area

Figure 4-9

FLOW RESTRICTION - TURNOUT #12 BROADCRESTED WEIR

PHOTOGRAPHS

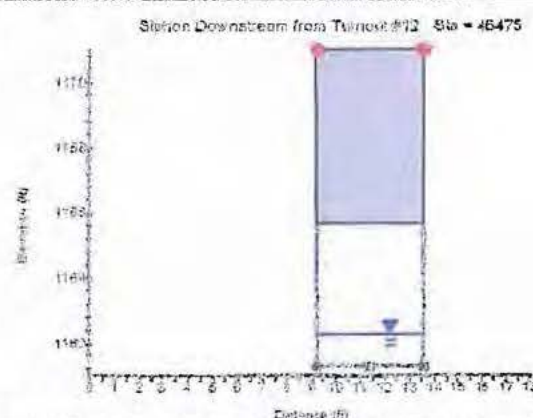
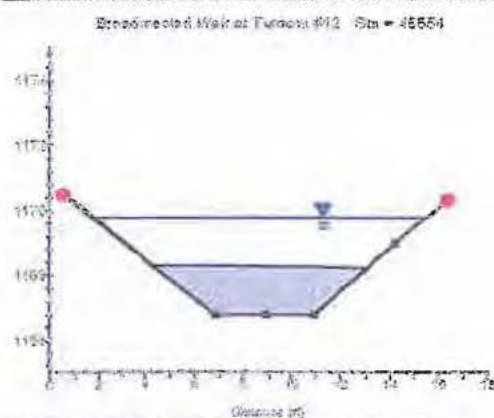


Turnout #12 broadcrested weir, looking upstream.



Turnout #12 broadcrested weir, looking downstream and flowing into inverted siphon.

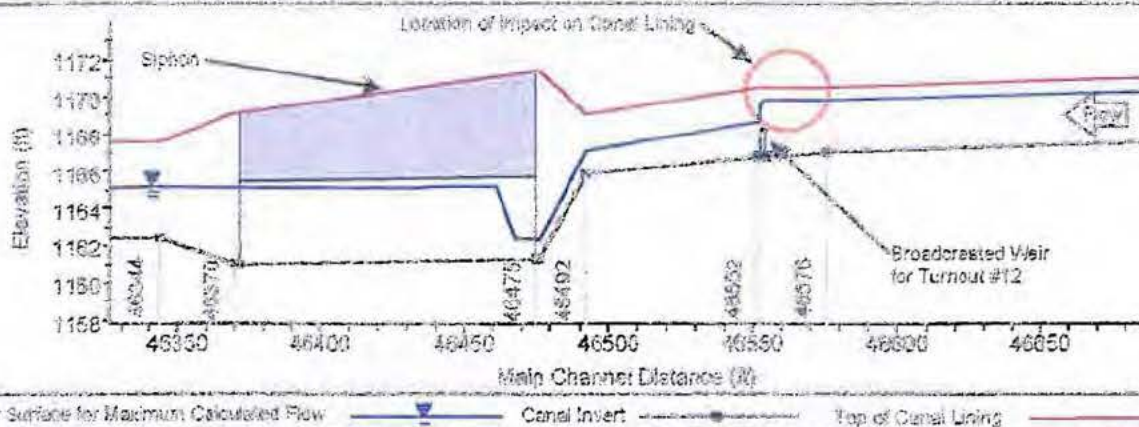
CROSS SECTIONS



Flow restrictions in this area caused by the Turnout #12 broadcrested weir.

Note: calibration flow (20 cfs or 13 mgd) is pictured while cross sections and profile depict maximum flow (80 cfs or 50 mgd).

PROFILE



Prepared by
Bookman-Edmonson
ENGINEERING, INC.
May 14, 1999



Prepared for



Beardsley Canal Capacity Study - Phase I
Hydraulic Model Output for Restrictive Flow Area

Figure 4-10

FLOW RESTRICTION - TURNOUT #13.5

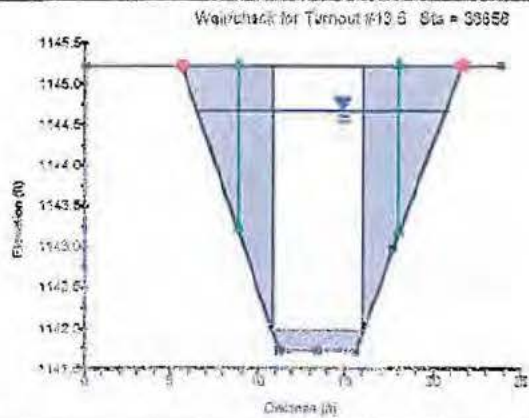
PHOTOGRAPHS



Turnout #13.5 checkboard structure.

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CROSS SECTIONS



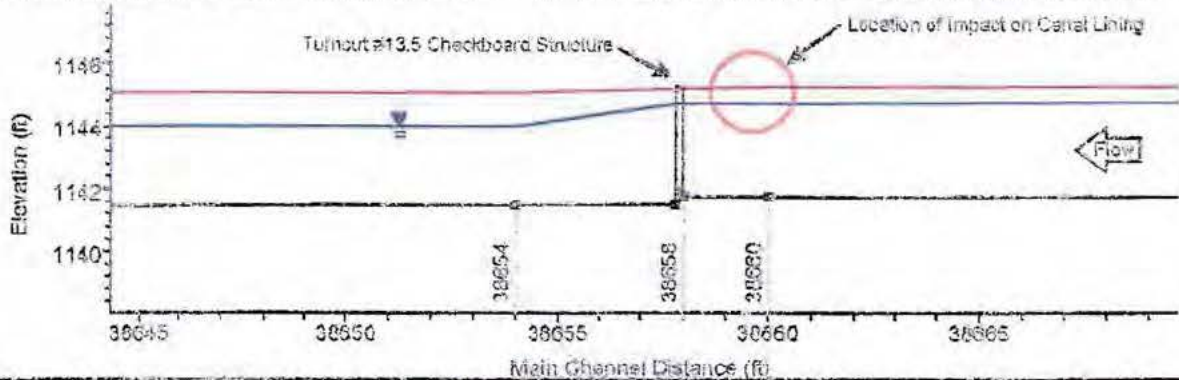
This space intentionally left blank.

DESCRIPTION

Flow restrictions in this area caused by the Turnout #13.5 structure.

Note: calibration flow (5 cfs or 3 mgd) is pictured while cross sections and profile depict maximum flow (74 cfs or 45 mgd).

PROFILE



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Bookman-Edmonson
ENGINEERING, INC.
May 14, 1999



Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Restrictive Flow Area

Figure 4-11

REPRESENTATIVE STRUCTURES - CHUTES ABOVE AGUA FRIA RIVER FLUME

PHOTOGRAPHS



First drop of chute, drops 45 vertical feet. Note canal is 2.5 feet deep.



Second drop of chute, drops 33 vertical feet. Note canal is 2.5 feet deep.

PHOTOGRAPHS

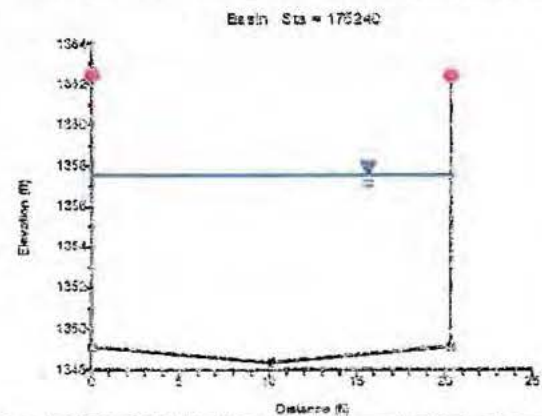
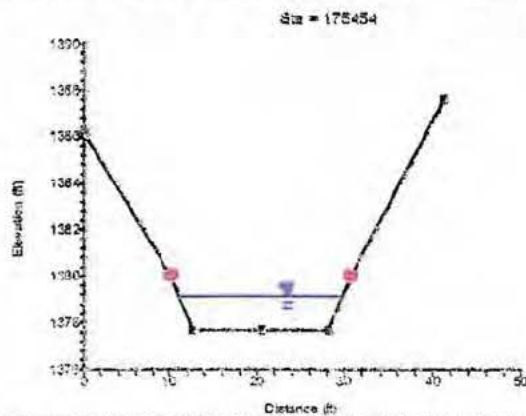


Final drop of chute (33 vertical feet), basin at bottom.



Oblique view of final drop of chute and basin. Start of Agua Fria River Flume at upper right.

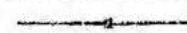
CROSS SECTIONS



Water Surface for Maximum Calculated Flow



Canal Prism/Ground



Top of Canal Lining



Prepared by
Bookman-Edmonston
ENGINEERING, INC.
May 14, 1999



Prepared for

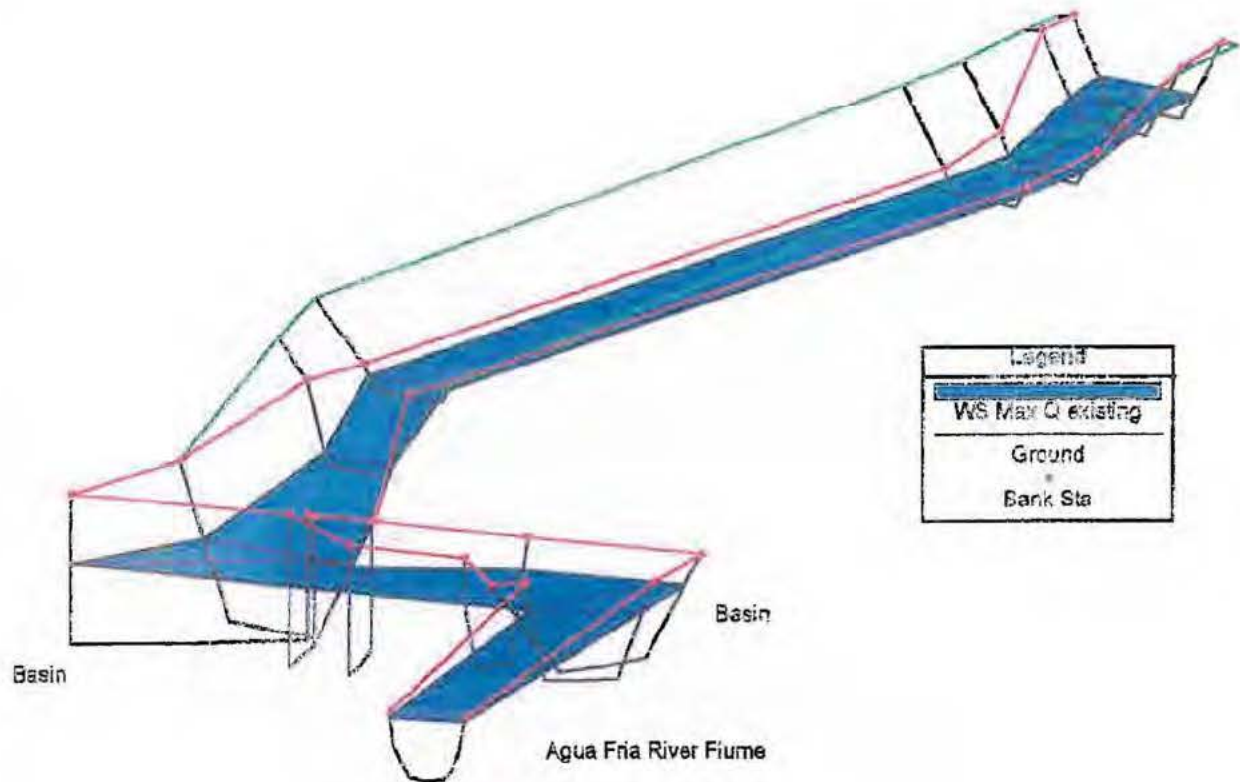


Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Representative Area

Figure 4-12a

REPRESENTATIVE STRUCTURES - CHUTES ABOVE AGUA FRIA RIVER FLUME

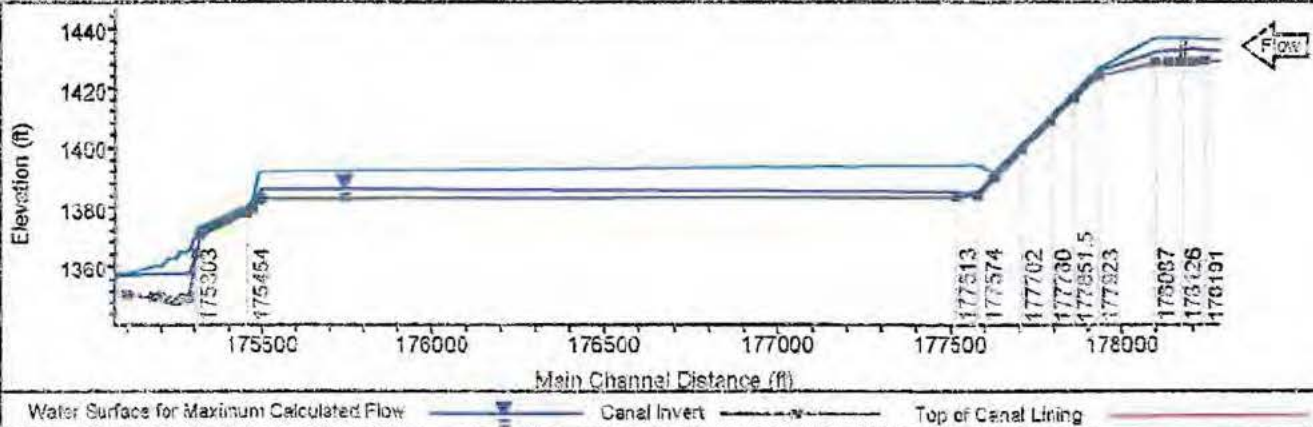
3-DIMENSIONAL VIEW



DESCRIPTION

Cross sections and profile depict maximum flow (400 cfs or 255 mgd).

PROFILE



Prepared by
Bookman-Edmonson
ENGINEERING, INC.
May 14, 1999

Prepared for
WESTCAP
Water Conservation
Agency

Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Representative Area

Figure 4-12b

REPRESENTATIVE STRUCTURES - INVERTED SIPHON AT McMICKEN DAM CHUTE

PHOTOGRAPHS

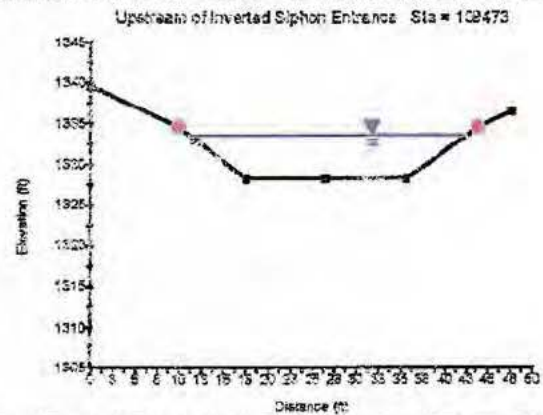
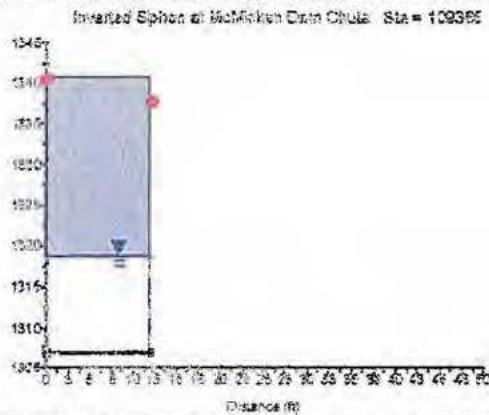


Entrance of inverted siphon at McMicken Dam Chute, McMicken Dam on right.



Inverted siphon exit, McMicken Dam on left.

CROSS SECTIONS



Water Surface for Maximum Calculated Flow



Canal Prism/Ground



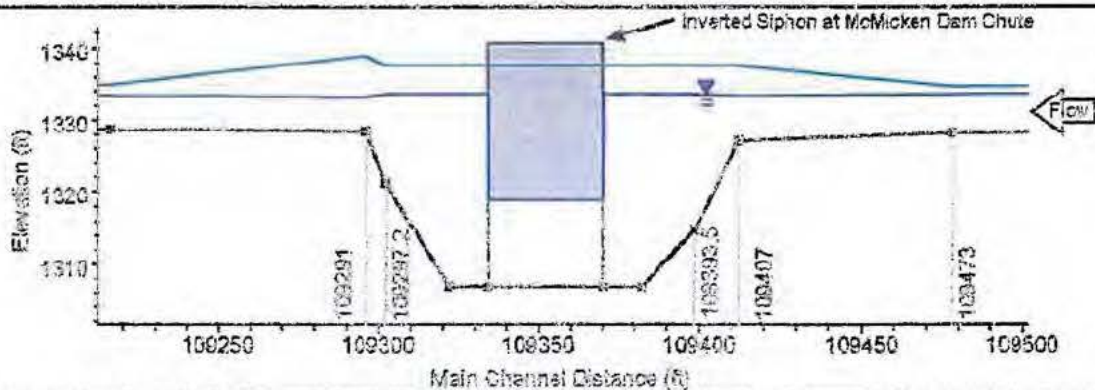
Top of Canal Lining



DESCRIPTION

Calibration flow (130 cfs or 85 mgd) is pictured while cross sections and profile depict maximum flow (300 cfs or 195 mgd) for Reach III.

PROFILE



Water Surface for Maximum Calculated Flow



Canal Invert



Top of Canal Lining



Prepared by
Beckman-Edwards
ENGINEERING, INC.
May 14, 1999



Prepared for



Beardsley Canal Capacity Study - Phase 1
Hydraulic Model Output for Representative Area

Figure 4-13

Section 5

Introduction

In the previous section, the full hydraulic capacity of the Beardsley Canal was computed through use of a HEC-RAS model. This section discusses the determination, on a reach-by-reach basis, of the excess capacity in the canal to transport water for WESTCAPS members.

Since MWD does not maintain flow records of the Beardsley Canal, the excess capacity in the canal could not be computed by simply subtracting the study period flows from the hydraulic capacity. Instead, a basic distribution system model to calculate the system demands on the Beardsley Canal was constructed.

Delineating canal reaches and subsequent demands by reach was accomplished through understanding both the Beardsley Canal hydraulic characteristics and the MWD delivery system operations.

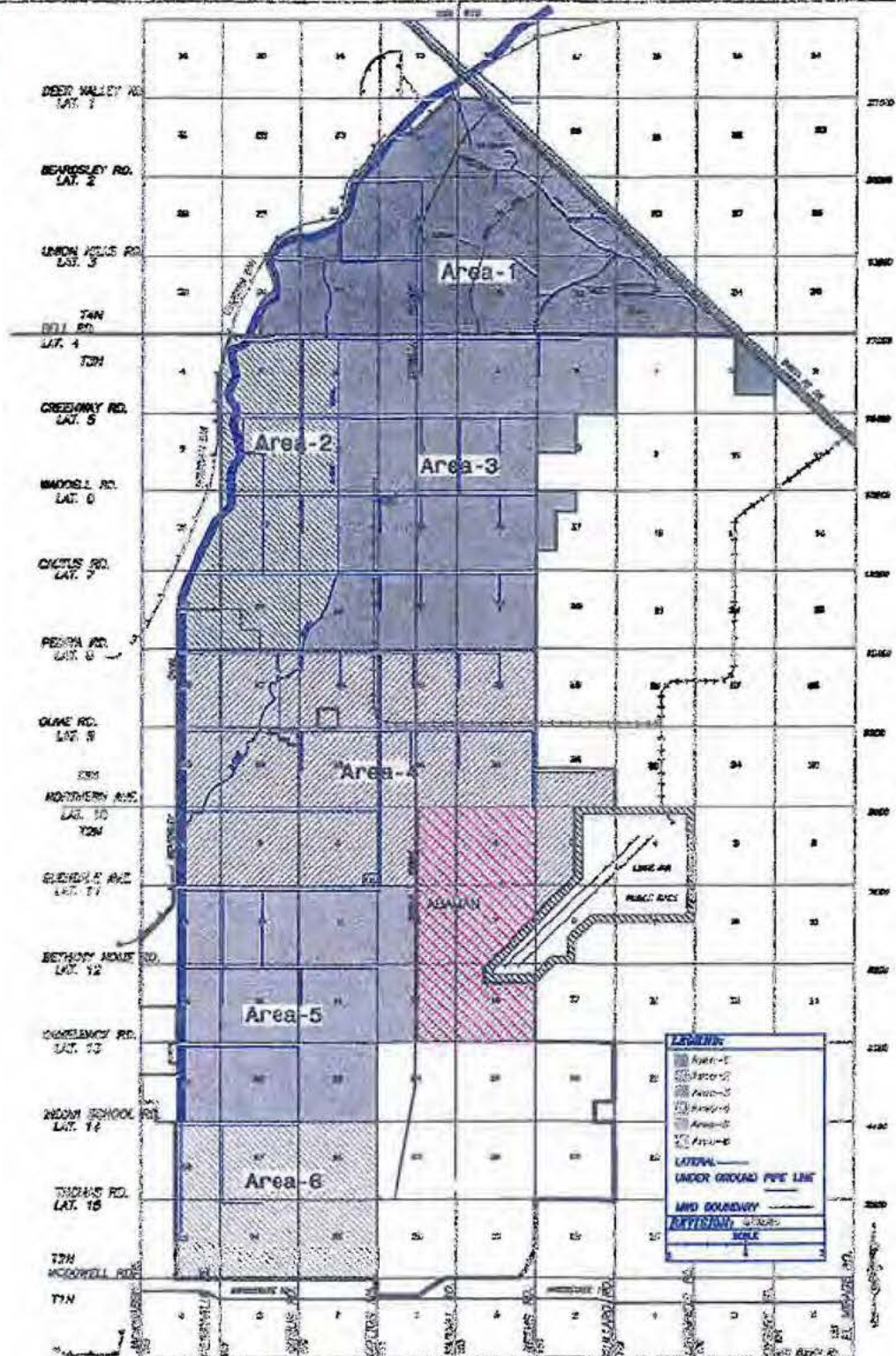
MWD Operations



Figure 5-1 Cross-Cut Canal.

The MWD delivery system is typified by farm laterals served by the Beardsley Canal at about one mile intervals, as shown in Figure 2-3. These laterals are supplied additional water from MWD wells, and are capable of delivering water to other laterals through interconnecting ditches such as the Cross-Cut Canal (25 cfs) or others. As such, the MWD delivery system is well integrated.

Calculating water demands for each reach of the Beardsley Canal required that Water Demand Areas be delineated within the MWD service area. The delineation was based upon factors such as the hydraulic capacity of the Beardsley Canal to deliver water to a lateral ditch or the existence of interconnecting canals. A total of six separate Water Demand Areas were delineated as shown in Figure 5-2. MWD staff has reviewed the delineated areas and agrees that this provides an adequate model of normal operations. Table 5-1 is a short description of these areas and operations.



Bookman-Edmonston
 Engineering, Inc.
 May 14, 1999

Beardsley Canal Capacity Study Water Demand Areas

FIGURE 5-2

Table 5-1 Beardsley Canal Capacity Study - Phase 1 Characteristics of Water Demand Areas		
Water Demand Area	Defining Characteristics	General Operational Characteristics
1	Located north of Bell Road. Service area includes golf courses. Interconnects allow water conveyance to all other areas	Wells can supply all other Areas.
2	Located south of Bell Road and West of the Cross-Cut Canal. Service area includes mix of farm and residential customers. Interconnects allow water conveyance to Areas 3, 4, 5, and 6	Wells can supply Areas 3, 4, 5 and 6
3	Located south of Bell Road and East of the Cross-Cut Canal. Service area includes farm customers. No interconnect to other Areas.	Wells can only supply demand within Area 3
4	Located south of Peoria Avenue. Beardsley Canal capacity is significantly reduced. Interconnects allow some conveyance to Areas 5 and 6	Some wells can supply demands within Areas 5 and 6
5	Located below inlet of Cross Cut to the Beardsley Canal. The Beardsley Canal must carry all water supplied internally from other Areas to Area 5.	Some wells can supply demands in Area 6, but must be conveyed in Beardsley Canal.
6	Located at southern end of District. Area 6 has no ability to connect with the rest of the district.	Wells can only supply Area 6 demands.

The Beardsley Canal was divided into seven different reaches based upon either the hydraulic characteristics of the canal or the canal's relationship to the Water Demand Areas.

Table 5-2 Beardsley Canal Capacity Study - Phase 1 Description of Canal Reaches and Water Demand Areas Served by Each			
Canal Reach	Reach Description	Area Demands	Conveyance Losses
I	Lake Pleasant to the CAP inlet	Areas 1-6	Reaches I - VII
II	CAP inlet to Turnout #1 (below Grand Avenue)	Areas 1-6	Reaches II - VII
III	Turnout #1 to Turnout #4 (Bell Road)	Areas 1-6	Reaches III-VII
IV	Turnout #4 to Turnout #7 (Cactus Road)	Areas 2-6	Reaches IV-VII
V	Turnout #7 to Turnout # 10 (Northern Avenue)	Areas 4-6	Reaches V-VII
VI	Turnout #10 to Turnout 13 (Camelback Road)	Areas 5 and 6	Reaches VI and VII
VII	Turnout #13 to Turnout #14 (Indian School Road)	Area 6	Reach VII

MWD System Demands

Farm account deliveries make up the primary demand within the MWD distribution system. These demands can be met from Beardsley Canal deliveries and well pumping. The demands within each Water Demand Area were calculated from individual monthly farm account deliveries for 1995. This Water Demand Area delivery pattern, represented by a percentage of total monthly deliveries, is used to calculate the Water Demand Area deliveries for the remaining study period years. Table 5-3 shows the 1995 deliveries to each Area represented as a percentage of the monthly total deliveries.

Table 5-3
Beardsley Canal Capacity Study - Phase 1
Percentage of Total 1995 Deliveries
by Water Demand Area

Month	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Total
January	0.0	0.0	17.0	9.9	58.5	14.6	100
February	3.6	4.3	24.9	29.3	21.9	16.0	100
March	9.3	6.6	28.5	27.0	20.5	8.1	100
April	8.4	10.0	34.5	22.4	15.8	8.9	100
May	7.0	10.3	33.9	24.0	18.6	6.2	100
June	8.7	9.5	32.4	22.6	21.4	5.4	100
July	9.9	10.0	34.3	20.1	17.9	7.8	100
August	11.6	13.3	31.3	17.7	14.5	11.6	100
September	7.4	10.9	27.2	25.3	18.9	10.3	100
October	8.3	5.1	27.2	26.4	19.8	13.2	100
November	10.6	2.7	24.7	28.0	17.8	16.2	100
December	5.9	3.2	25.4	23.1	25.5	16.9	100

The account deliveries are satisfied from District well pumping and from water conveyed in the Beardsley Canal. Private well pumping is not included in the account deliveries. To determine only the demand placed on Beardsley Canal conveyance, the volume of District well pumping is subtracted from the account deliveries. MWD records showing monthly well pumping for each well for the study period were summarized as total volume pumped within each Water Demand Area. This volume was then subtracted from the account deliveries to each water budget area.

Table 5-4 shows the total account deliveries within the MWD service area for 1995 broken into water budget areas. Table 5-5 shows the total volume of pumping from wells located within each water budget area. Table 5-6 is the result of subtracting the well pumping from the account deliveries.

Table 5-4
Beardsley Canal Capacity Study - Phase 1
1995 MWD Account Deliveries by Water Demand Area
(Acre-Feet)

Month	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Jan	0.0	0.0	38.7	22.6	133.2	33.4
Feb	64.7	76.2	441.8	521.0	387.9	283.7
Mar	447.6	316.0	1370.7	1300.1	987.6	389.7
Apr	618.2	739.9	2556.0	1651.5	1167.6	654.7
May	528.9	782.1	2563.2	1816.6	1408.5	468.5
Jun	803.8	885.2	3017.8	2097.1	1983.8	500.9
Jul	1170.9	1189.4	4086.6	2383.7	2132.7	922.6
Aug	1164.1	1334.0	3123.6	1771.5	1448.1	1161.9
Sep	514.8	755.8	1889.6	1757.3	1315.3	719.2
Oct	389.7	240.0	1282.3	1241.0	930.2	618.3
Nov	393.3	99.7	922.2	1043.4	664.2	602.0
Dec	178.6	96.2	765.7	693.7	766.2	508.0

Table 5-5
Beardsley Canal Capacity Study - Phase 1
1995 MWD Well Pumping by Water Demand Area
(Acre-Feet)

Month	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Jan	0.0	22.5	27.1	38.7	131.3	8.3
Feb	83.2	329.2	107.0	170.2	95.7	117.4
Mar	68.8	56.3	123.0	19.3	105.9	33.3
Apr	138.2	124.1	165.7	97.4	95.5	5.3
May	74.6	131.9	457.3	117.4	94.5	20.9
Jun	126.1	177.4	373.7	67.0	109.4	94.5
Jul	125.5	165.3	491.7	122.4	152.1	169.6
Aug	295.6	444.4	371.4	182.8	158.2	164.4
Sep	64.3	213.6	298.5	84.6	111.4	121.8
Oct	91.2	121.0	316.3	57.2	24.1	307.8
Nov	250.5	541.6	346.4	198.5	54.7	312.8
Dec	445.6	990.6	609.0	426.7	241.2	295.1

Table 5-6
Beardsley Canal Capacity Study - Phase 1
Result of Subtracting Well Pumping from Account Deliveries
Table 5-4 minus Table 5-5
(Excess supply from pumping is represented by negative (-) values)
(Acre-Feet)

Month	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Jan	0.0	-22.5	11.6	-16.1	1.9	25.1
Feb	-18.6	-253.0	334.8	350.7	292.2	166.3
Mar	378.8	259.7	1247.7	1280.8	881.7	356.4
Apr	480.0	615.8	2390.3	1554.1	1072.1	649.4
May	454.3	650.2	2105.9	1699.2	1314.0	447.6
Jun	677.7	707.9	2644.1	2030.1	1874.4	406.5
Jul	1045.4	1024.1	3595.0	2261.3	1980.6	753.0
Aug	868.5	889.5	2752.2	1588.7	1289.9	997.5
Sep	450.6	542.2	1591.1	1672.7	1203.8	597.4
Oct	298.5	119.0	966.0	1183.9	906.1	310.5
Nov	142.8	-441.9	575.8	844.9	609.6	289.2
Dec	-267.1	-894.5	156.7	266.9	525.0	212.9

In many instances, well water in excess of account deliveries is pumped within a single water budget area. The MWD internal distribution system allows pumped water to be conveyed to many portions of the system. For the purpose of modeling this distribution system, the excess pumping in one area is distributed to demands remaining in other areas according to the conveyance rules established in Table 5-2 above. An example of these calculations for 1995 are shown in Table 5-7.

Table 5-7 Beardsley Canal Capacity Study - Phase 1 1995 Demands on Beardsley Canal after Considering Well Water Deliveries to Other Water Demand Areas (Acre-Feet)						
Month	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Jan	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	63.3	350.7	292.2	166.3
Mar	378.8	259.7	1247.7	1280.8	881.7	356.4
Apr	480.0	615.8	2390.3	1554.1	1072.1	649.4
May	454.3	650.2	2105.9	1699.2	1314.0	447.6
Jun	677.7	707.9	2644.1	2030.1	1874.4	406.5
Jul	1045.4	1024.1	3595.0	2261.3	1980.6	753.0
Aug	868.5	889.5	2752.2	1588.7	1289.9	997.5
Sep	450.6	542.2	1591.1	1672.7	1203.8	597.4
Oct	298.5	119.0	966.0	1183.9	906.1	310.5
Nov	142.8	0.0	276.7	844.9	609.6	289.2
Dec	0.0	0.0	0.0	0.0	0.0	0.0

As seen in Table 5-7 above, well pumping is capable of supplying all account demands for the months of January and December, the dry-up period for the Beardsley Canal. The remaining volumes of water represent the demands at the farm which would be placed on the Beardsley Canal for conveyance. Additional conveyance volumes such as losses and other conveyance requirements must also be considered.

Conveyance Losses

Distribution System Losses

Conveyance losses within the Beardsley Canal and the MWD distribution system include seepage and evaporation. MWD staff has stated that overall losses for water delivered through the Beardsley Canal are from 15 to 20 percent of the total water conveyed. Of this quantity, approximately three percent is lost in the MWD distribution system. To account for losses within the MWD distribution system, three percent was added to the Canal Demands listed in Table 5-7.

Canal Conveyance Losses

Estimated conveyance losses for each reach of the Beardsley Canal were based on the canal length, water surface width and wetted perimeter of each reach. The water surface width and wetted perimeter are variable based upon the flow rate in the canal at any given time. These variables were compared for normal deliveries (150 cfs) and maximum flows (300 cfs). The resulting difference between the two flow rates for wetted perimeter and water surface width was approximately 10 percent. Since the

water level must be checked to make turnouts into laterals possible, the difference in area caused by different flow rates is small. The wetted perimeter and water surface widths were used for the maximum flow rate.

Evaporation Losses

Evaporation losses are calculated from the water surface area in the Beardsley Canal multiplied by the net evaporation rate from an open water surface. The net evaporation from an open water surface was calculated as the 10-year average reference crop evaporation at the AZMET agricultural weather station located at Waddell, Arizona times a coefficient of 1.15 (*Food and Agriculture Organization Report No. 24*, J. Doorenbos and W.O. Pruitt, 1977). Total monthly evaporation losses for each reach were calculated by multiplying the net evaporation by the water surface width and canal length and are shown in Table 5-8.

Table 5-8 Beardsley Canal Capacity Study - Phase 1 Evaporative Losses by Reach Maximum Flow Profile (Acre-Feet)								
Month	Net Evaporation (Inch/Month)	Reach I	Reach II	Reach III	Reach IV	Reach V	Reach VI	Reach VII
Jan	1.09	2	5	1	2	<1	<1	<1
Feb	2.56	4	11	2	4	1	1	1
Mar	4.95	8	21	3	8	2	1	1
Apr	8.11	13	34	5	13	3	2	2
May	10.40	17	43	7	16	4	2	2
Jun	11.51	19	48	7	18	5	3	2
Jul	9.42	15	39	6	15	4	2	2
Aug	7.10	12	29	5	11	3	2	1
Sep	6.17	10	26	4	10	3	1	1
Oct	4.98	8	21	3	8	2	1	1
Nov	2.89	5	12	2	5	1	1	1
Dec	1.15	2	5	1	2	1	<1	<1

Seepage Losses

Seepage losses from the Beardsley Canal occur at joints and cracks in the lining, from leaking gates, from portions of the canal with missing bottom lining, and to a lesser degree, from the lining itself. Due to the age and construction of the Beardsley Canal, the seepage losses are considered to be high for a lined canal. Using the approximate amount of conveyance losses observed during field visits and confirmed by MWD staff, and subtracting the calculated evaporation losses, a system-wide seepage loss factor was calculated for the Beardsley Canal. The derived seepage factor of $0.39 \text{ ft}^3/\text{ft}^2/\text{day}$ was multiplied by the reach length and average wetted perimeter to calculate daily seepage losses. While this analysis treated seepage as a function of wetted perimeter and reach length, it is likely that seepage losses are greater in the upper reaches of the Beardsley Canal as the canal traverses fractured hard rock and seepage through canal lining cracks would not tend to self-seal under those conditions. The seepage losses by reach and month for the Beardsley Canal are summarized in Table 5-9 and total conveyance losses are summarized in Table 5-10.

Table 5-9
Beardsley Canal Capacity Study - Phase 1
Seepage Losses by Reach
Maximum Flow Profile
(Acre-Feet)

Month	Reach I	Reach II	Reach III	Reach IV	Reach V	Reach VI	Reach VII
Jan	285	554	104	259	64	36	31
Feb	260	505	95	236	59	33	28
Mar	285	554	104	259	64	36	31
Apr	276	536	101	251	62	35	30
May	285	554	104	259	64	36	31
Jun	276	536	101	251	62	35	30
Jul	285	554	104	259	64	36	31
Aug	285	554	104	259	64	36	31
Sep	276	536	101	251	62	35	30
Oct	285	554	104	259	64	36	31
Nov	276	536	101	251	62	35	30
Dec	285	554	104	259	64	36	31

Table 5-10
Beardsley Canal Capacity Study - Phase 1
Total Conveyance Losses by Reach
Maximum Flow Profile
(Acre-Feet)

Month	Reach I	Reach II	Reach III	Reach IV	Reach V	Reach VI	Reach VII
Jan	287	558	105	261	65	36	31
Feb	264	515	97	240	60	34	28
Mar	293	574	107	267	66	37	32
Apr	289	569	106	264	66	37	31
May	302	597	111	276	69	39	33
Jun	294	583	108	269	67	38	32
Jul	300	593	110	274	68	38	32
Aug	297	583	109	271	67	38	32
Sep	286	561	105	261	65	36	31
Oct	293	574	107	267	66	37	32
Nov	281	548	103	256	63	36	30
Dec	287	558	105	261	65	36	31

Note, these values include evaporation and seepage losses. Rounding may cause numbers in this table to differ slightly from the addition of numbers from Tables 5-8 and 5-9.

Other Conveyance Considerations

Canal Dry-Up Period

A significant factor in the available capacity consideration is the canal maintenance schedule. MWD typically ceases canal water deliveries during the months of December and January. During these months, crop demands are met by pumping wells and conveying the water through the internal distribution system. No canal capacity is considered to be available for conveying water during the months of December and January. It may be possible to shorten the dry-up period, which could significantly increase the canal capacity available to convey CAP and other water to WESTCAPS members.

Well Water Conveyed in the Beardsley Canal

In addition to water from outside sources (CAP, Lake Pleasant) which must be conveyed in the Beardsley Canal to meet demands of MWD customers, the Beardsley Canal is also used to convey well water during normal operations. Four MWD wells have the capability to pump into the Beardsley Canal or a lateral canal. To account for the capacity requirements to convey this water, estimates were made of the quantity of water pumped from these wells into the Beardsley Canal versus what is pumped into the laterals.

Total Conveyance Requirements of the Beardsley Canal

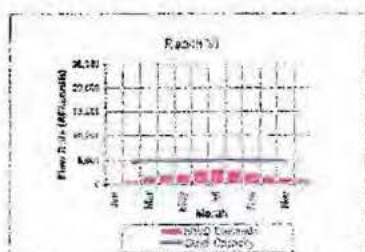
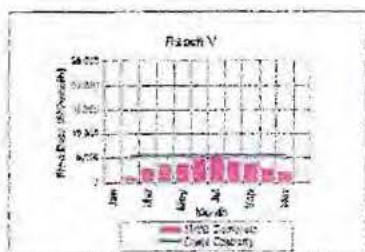
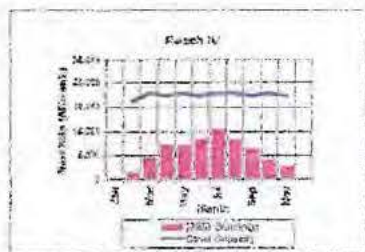
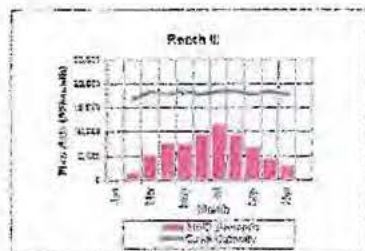
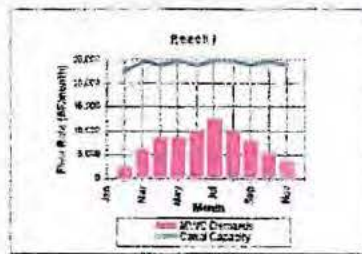
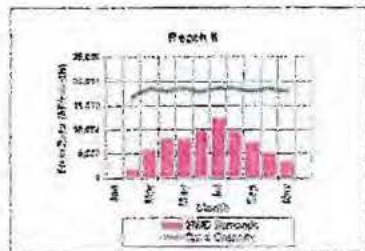
The conveyance requirements of the Beardsley Canal were calculated in an additive fashion. The upstream reaches must carry the entire volume of water to meet MWD demands and offset conveyance losses. The demands and losses which are carried in each reach are listed in Table 5-11 below. For instance, Reach I of the Beardsley Canal will need to carry enough water to offset all demands and conveyance losses. Reach VI, since it is near the end of the canal, will only need to carry the volume of water to offset demand in Areas 5 and 6, and conveyance losses in Reaches VI and VII.

Table 5-11 Beardsley Canal Capacity Study - Phase 1 Summary of District Demands and Conveyance Losses Which Require Capacity in the Beardsley Canal		
Capacity in Reach Below	Water Budget Areas	Reach Conveyance Losses
Reach I	All Areas 1-6	All Reaches I-VII
Reach II	All Areas 1-6	Reaches II-VII
Reach III	All Areas 1-6	Reaches III-VII
Reach IV	Areas 2-6	Reaches IV-VII
Reach V	Areas 4-6	Reaches V-VII
Reach VI	Areas 5-6	Reaches VI-VII
Reach VII	Area 6	Reach VII

The total capacity of the Beardsley Canal required by MWD to maintain deliveries for its customers is presented in Table 5-12 by reach for the full study period. Figure 5-3 shows the monthly reach-by-reach MWD demands and Beardsley Canal capacity for a high MWD demand year (1995).

Full utilization of the capacity remaining in the Beardsley Canal would allow the volumes of water shown in Table 5-13 to be conveyed to the end of the reach listed without impacting MWD operations. Table 5-14 summarizes the reach-by-reach estimated available capacity for the five-year study period.

REACH



GRAND AVENUE &

BEARDSLEY CANAL

SANTA FE RAILROAD

CAMP DYER DIVERSION

UNUSED CAPACITY DURING MWD PEAK USE

195 cfs
125 mgd

CAP INLET

100 cfs
65 mgd

100 cfs
65 mgd

120 cfs
75 mgd

0 cfs
0 mgd

30 cfs
20 mgd

BELL ROAD

GREENWAY ROAD

WADDELL ROAD

CACTUS ROAD

PEORIA AVENUE

OLIVE AVENUE

NORTHERN AVENUE

GLENDAL AVENUE

BETHANY HOME ROAD

CAMELBACK ROAD

INDIAN SCHOOL ROAD

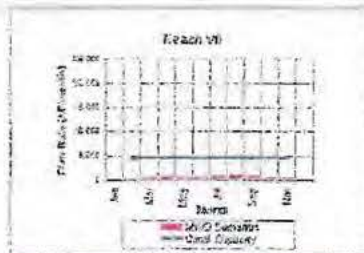


Figure 5-3

Prepared by
Bookman-Edmonston
ENGINEERING, INC.
May 14, 1999

Prepared for
USBR/WESTCAPS
WESTCAPS

Beardsley Canal Capacity Study - Phase 1
Monthly Reach-by-Reach Delivery to MWD
and Estimated Maximum Canal Capacity
(for High MWD Canal Demand Year (1998))

Table 5-12
Beardsley Canal Capacity Study - Phase 1
Total MWD Demand on Beardsley Canal (Acre-Feet/Month)

Year	Month	Reach I - Lake Pleasant to CAP Inlet	Reach II CAP Inlet to Grand Ave	Reach III Grand Ave. to Bell Rd.	Reach IV Bell Rd. to Cactus Rd.	Reach V Cactus Rd. to Northern Ave	Reach VI Northern to Camelback ⁽⁴⁾	Reach VII Camelback to Indian School ⁽⁴⁾
1988 ⁽¹⁾	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	367	96
1988	Feb	1251	988	472	490	122	473	221
1988	Mar	3880	3587	3013	3052	2076	1187	272
1988	Apr	5076	4787	4218	4087	2378	1283	441
1988	May	5386	5084	4487	4358	2542	1287	247
1988	Jun	7465	7170	6587	6478	3594	1911	267
1988	Jul	9609	9308	8716	8290	4384	2362	611
1988	Aug	7762	7465	6882	6323	3233	1906	809
1988	Sep	3915	3629	3068	2925	2070	1077	409
1988	Oct	1836	1543	969	959	563	418	184
1988	Nov	1356	1076	528	481	131	287	159
1988	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	586	271
1993	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	102	39
1993	Feb	1982	1718	1203	1141	815	432	163
1993	Mar	4846	4553	3979	3549	2064	1061	312
1993	Apr	6404	6115	5546	5015	2502	1303	477
1993	May	6249	5948	5351	4896	2514	1282	334
1993	Jun	7876	7581	6998	6329	3342	1810	378
1993	Jul	9611	9310	8718	7810	3916	2188	673
1993	Aug	6644	6348	5765	5068	2454	1450	646
1993	Sep	4496	4211	3849	3311	1855	991	352
1993	Oct	3659	3366	2792	2608	1590	862	341
1993	Nov	2694	2414	1866	1648	1091	519	212
1993	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	573	190
1994	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	1144	232
1994	Feb	2741	2477	1962	1908	1340	764	296
1994	Mar	5472	5179	4605	4111	2539	1322	390
1994	Apr	6921	6632	6062	5499	2830	1439	564
1994	May	6443	6141	5545	5122	2641	1338	362
1994	Jun	9253	8959	8375	7608	4045	2299	475
1994	Jul	9761	9461	8868	7945	3909	2321	729
1994	Aug	9402	9106	8523	7493	3685	2266	1016
1994	Sep	4525	4239	3678	3388	1996	1098	399
1994	Oct	3585	3292	2718	2427	1560	859	310
1994	Nov	3753	3472	2924	2531	1810	871	302
1994	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	521	145
1995 ⁽²⁾	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	94	56
1995	Feb	2143	1880	1365	1297	956	535	200
1995	Mar	5914	5621	5047	4550	2728	1343	399
1995	Apr	8334	8045	7475	6872	3513	1844	703
1995	May	8296	7994	7397	6818	3704	1885	494
1995	Jun	9992	9697	9114	8303	4584	2423	451
1995	Jul	12407	12107	11514	10322	5289	2886	813
1995	Aug	10023	9727	9144	8144	4129	2427	1058
1995	Sep	7584	7298	6737	6168	3707	1918	643
1995	Oct	5279	4986	4412	3997	2611	1325	354
1995	Nov	3549	3269	2721	2624	1925	992	330
1995	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	780	244
1996 ⁽³⁾	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	1917	286
1996	Feb	2643	2379	1864	1987	1492	1170	483
1996	Mar	6703	6410	5836	5326	3376	1676	434
1996	Apr	8998	8709	8140	7450	3942	2026	663
1996	May	8534	8232	7636	7503	4242	2063	417
1996	Jun	9529	9235	8651	8332	4775	2584	359
1996	Jul	9384	9084	8491	7865	4305	2452	662
1996	Aug	9080	8783	8200	7265	3963	2424	1060
1996	Sep	4823	4537	3976	4005	2688	1413	429
1996	Oct	4234	3941	3367	3484	2745	1401	492
1996	Nov	3110	2830	2282	2354	1876	936	333
1996	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	764	210

Notes: ⁽¹⁾ For the study period, 1988 is the low demand year

⁽²⁾ For the study period, 1995 is the high demand year

⁽³⁾ For the study period, 1996 is the high groundwater pumping year.

⁽⁴⁾ January and December Beardsley Canal capacity requirement shown is well water pumped by MWD and supplied conveyance through Reaches VI and VII by the Cross Cut Canal



Table 5-13
Beardsley Canal Capacity Study - Phase 1
Volumetric Capacity Remaining to Convey Water Through the Beardsley Canal
Assumes MWD Operations are Not Impacted (Acre-Foot/Month)

Year	Month	Reach I - Lake Pleasant to CAP Inlet	Reach II CAP Inlet to Grand Ave	Reach III Grand Ave. to Bell Rd.	Reach IV Bell Rd. to Cactus Rd.	Reach V Cactus Rd. to Northern Ave	Reach VI Northern to Camelback	Reach VII Camelback to Indian School
1988 ⁽¹⁾	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1988	Feb	21,757	16,269	16,269	16,191	5,055	4,128	4,035
1988	Mar	20,715	14,859	14,859	14,780	3,458	3,458	3,458
1988	Apr	18,726	13,064	13,064	13,064	2,977	2,977	2,977
1988	May	19,210	13,363	13,363	13,363	2,992	2,992	2,992
1988	Jun	16,337	10,681	10,681	10,681	1,762	1,762	1,762
1988	Jul	14,987	9,138	9,138	9,138	1,150	1,150	1,150
1988	Aug	16,834	10,981	10,981	10,981	2,301	2,301	2,301
1988	Sep	19,887	14,222	14,222	14,222	3,285	3,285	3,285
1988	Oct	22,759	16,904	16,904	16,872	4,971	4,501	4,367
1988	Nov	22,446	16,776	16,776	16,775	5,225	4,473	4,244
1988	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1993	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1993	Feb	20,233	14,943	14,943	14,943	4,183	4,011	3,947
1993	Mar	19,750	13,894	13,894	13,894	3,470	3,470	3,470
1993	Apr	17,398	11,737	11,737	11,737	2,853	2,853	2,853
1993	May	18,346	12,499	12,499	12,499	3,020	3,020	3,020
1993	Jun	15,926	10,270	10,270	10,270	2,013	2,013	2,013
1993	Jul	14,985	9,136	9,136	9,136	1,618	1,618	1,618
1993	Aug	17,951	12,099	12,099	12,099	3,080	3,080	3,080
1993	Sep	19,306	13,641	13,641	13,641	3,500	3,500	3,500
1993	Oct	20,936	15,081	15,081	15,081	3,944	3,944	3,944
1993	Nov	21,108	15,438	15,438	15,438	4,265	4,241	4,191
1993	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1994	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1994	Feb	19,474	14,184	14,184	14,184	3,658	3,658	3,658
1994	Mar	19,123	13,268	13,268	13,268	2,995	2,995	2,995
1994	Apr	16,881	11,220	11,220	11,220	2,525	2,525	2,525
1994	May	18,152	12,305	12,305	12,305	2,893	2,893	2,893
1994	Jun	14,549	8,893	8,893	8,893	1,311	1,311	1,311
1994	Jul	14,834	8,986	8,986	8,986	1,625	1,625	1,625
1994	Aug	15,193	9,341	9,341	9,341	1,849	1,849	1,849
1994	Sep	19,277	13,612	13,612	13,612	3,360	3,360	3,360
1994	Oct	21,010	15,154	15,154	15,154	3,974	3,974	3,974
1994	Nov	20,049	14,379	14,379	14,379	3,546	3,546	3,546
1994	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1995 ⁽²⁾	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1995	Feb	20,072	14,782	14,782	14,782	4,043	3,908	3,908
1995	Mar	18,681	12,826	12,826	12,826	2,806	2,806	2,806
1995	Apr	15,468	9,807	9,807	9,807	1,842	1,842	1,842
1995	May	16,300	10,453	10,453	10,453	1,830	1,830	1,830
1995	Jun	13,810	8,154	8,154	8,154	772	772	772
1995	Jul	12,188	6,340	6,340	6,340	245	245	245
1995	Aug	14,572	8,720	8,720	8,720	1,405	1,405	1,405
1995	Sep	16,218	10,553	10,553	10,553	1,648	1,648	1,648
1995	Oct	19,316	13,460	13,460	13,460	2,923	2,923	2,923
1995	Nov	20,253	14,583	14,583	14,583	3,430	3,430	3,430
1995	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1996 ⁽³⁾	Jan	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up
1996	Feb	20,366	14,878	14,878	14,695	3,685	3,432	3,432
1996	Mar	17,892	12,037	12,037	12,037	2,158	2,158	2,158
1996	Apr	14,804	9,142	9,142	9,142	1,414	1,414	1,414
1996	May	16,061	10,214	10,214	10,214	1,291	1,291	1,291
1996	Jun	14,273	8,617	8,617	8,617	581	581	581
1996	Jul	15,211	9,362	9,362	9,362	1,229	1,229	1,229
1996	Aug	15,516	9,664	9,664	9,664	1,571	1,571	1,571
1996	Sep	18,979	13,315	13,315	13,251	2,668	2,668	2,668
1996	Oct	20,361	14,505	14,505	14,348	2,789	2,789	2,789
1996	Nov	20,692	15,022	15,022	14,903	3,480	3,480	3,480
1996	Dec	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up	Dry Up

Notes: ⁽¹⁾ For the study period, 1988 is the low demand year

⁽²⁾ For the study period, 1995 is the high demand year

⁽³⁾ For the study period, 1996 is the high groundwater pumping year.



Table 5-14
Beardsley Canal Capacity Study - Phase 1
Estimated Available Capacity Remaining in the Beardsley Canal
For the Five-Year Study Period
(Acre-Feet)

Reach No.	Reach Description	1988	1993	1994	1995	1996
I	Lake Pleasant to CAP Inlet	193,700	185,900	178,500	166,900	174,200
II	CAP Inlet to Grand Avenue	136,300	128,700	121,300	109,700	116,800
III	Grand Avenue to Bell Road	142,000 ⁽¹⁾	134,400 ⁽¹⁾	127,000 ⁽¹⁾	115,400 ⁽¹⁾	122,500 ⁽¹⁾
IV	Bell Road to Cactus Road	137,400 ⁽¹⁾	132,900 ⁽¹⁾	126,300 ⁽¹⁾	115,200 ⁽¹⁾	119,300 ⁽¹⁾
V	Cactus Road to Northern Avenue	33,200	31,900	27,700	20,900	20,900
VI	Northern Avenue to Camelback Road	36,000 ⁽¹⁾	36,200 ⁽¹⁾	33,500 ⁽¹⁾	30,500 ⁽¹⁾	30,100 ⁽¹⁾
VII	Camelback Road to Indian School Road	41,000 ⁽¹⁾	40,600 ⁽¹⁾	39,600 ⁽¹⁾	39,000 ⁽¹⁾	39,300 ⁽¹⁾
Note: 1. Reach capacity currently unattainable because upstream reach unable to deliver total quantity.						

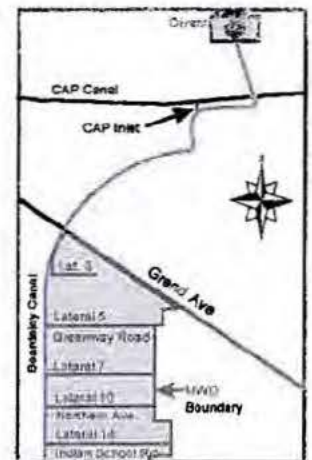
Appendix A

Table A-1
Beardsley Canal Capacity Study
Line List - Beardsley Canal Structures and Cross Sections

	Canal Station (feet)	Canal Mile	Canal Structures Structure/Reach Description	Road Alignment	Photo Page Number	Restrictive Reach or Structure
REACH I	200,000	-	Diversion headworks, start of canal	Carefree	A-1	Restrictive
	197,651	0.4	Weir & recording gauge, MWD Station 1		A-1	
	197,473	0.5	Bridge on road to Beardsley Canal diversion		A-1	
	185,558	2.7	Canal cross section		A-1	
	185,472	2.8	Bridge for road to Cowtown		A-1	
	178,126	4.1	Weir and checkdrop, unused		A-1	
	177,923	4.2	1st Chute		A-2	
	175,486	4.6	2nd Chute		A-2	
	175,096	4.7	Flume #1 - Agua Fria River Flume		A-2	
	172,787	5.2	CAP inlet to Beardsley Canal		A-2	
REACH II	172,153	5.3	Rec. weir & MWD Station 5 gauge	Dynamite Jomax Grand	A-2	Restrictive
	168,203	6.0	Turnout for Bard Citrus Ranch		A-3	
	158,990	7.8	Canal cross section		A-3	
	157,469	8.1	Flume #2 (pipe)		A-3	
	154,080	8.7	Flume #3 (pipe)		A-3	
	147,581	9.9	Flume #4 (pipe)		A-3	
	141,387	11.1	Inverted siphon		A-4	
	132,048	12.9	Inverted siphon		A-4	
	127,855	13.7	Inverted siphon		A-4	
	127,453	13.7	Radial gate		A-4	
	115,009	16.1	Radial gate, unused turnout		A-4	
	114,520	16.2	163rd Ave. bridge		A-5	
	114,443	16.2	CMP double culvert under Santa Fe railroad		A-5	
	114,282	16.2	Box culvert at Grand Ave.		A-5	
	112,797	16.5	Turnout #1. Rec. weir provides grade control.		A-5	
REACH III	112,430	16.6	Inverted siphon and MWD Station 13 gauge	Beardsley Union Hills	A-5	Restrictive
	112,350	16.6	Rectangular weir checkdrop		A-5	
	109,365	17.2	Inverted siphon at McMicken Dam chute		A-6	
	104,988	18.0	Turnout #2, no grade control		A-6	
	101,801	18.6	Turnout #3, rec. sluice gate, MWD Station 17 gauge		A-6	
	96,647	19.6	Inverted siphon		A-6	
	93,836	20.1	Turnout for golf course, no grade control		A-6	
	90,639	20.7	Turnout #4, rectangular checkboard		A-7	
REACH IV	90,563	20.7	Bell Road bridge	Bell Greenway Waddell Cactus	A-7	Restrictive
	84,479	21.9	Greenway Road bridge		A-7	
	84,411	21.9	Turnout #5, radial gate, MWD Station 22 gauge		A-7	
	81,772	22.4	Turnout #5.03, no grade control		A-7	
	79,013	22.9	Turnout #6, rectangular checkboard		A-7	
	73,059	24.0	Turnout #7, rec. sluice gate, MWD Station 25 gauge		A-7	
REACH V	72,160	24.2	Weir, checkdrop - last station gauge	Peoria Olive Northern	A-8	Restrictive
	70,740	24.5	Inverted siphon		A-8	
	67,670	25.1	CMP culvert at Turnout #8		A-8	
	67,647	25.1	Turnout #8, rec. checkboards		A-8	
	65,027	25.6	Inverted siphon		A-8	
	62,413	26.1	CMP culvert under Olive Ave		A-9	
	62,366	26.1	Turnout #9, rectangular checkdrop		A-9	
	61,000	26.3	Canal cross section		A-9	
	57,117	27.1	CMP culvert at Northern Ave		A-9	
	57,083	27.1	Turnout #10, rectangular checkdrop		A-9	
REACH VI	55,206	27.4	Inverted siphon	Glendale Bethany Home Camelback	A-9	Restrictive
	52,860	27.9	Rectangular weir & checkdrop - unused		A-9	
	51,802	28.1	Turnout #11, rec. weir checkdrop		A-9	
	46,554	29.1	Turnout #12, broadcrested weir		A-10	
	46,475	29.1	Inverted siphon		A-10	
	41,274	30.1	Turnout #13, rectangular weir checkboard		A-10	
REACH VII	38,658	30.6	Turnout 13.5, rectangular checkboard	Indian School Osborn Thomas	A-10	Restrictive
	36,051	31.1	Box culvert at Indian School Rd.		A-10	
	36,011	31.1	Turnout #14, rec. weir checkdrop		A-10	
	35,977	31.1	End of canal		A-10	
	33,370	31.1	Checkboards at Osborn Rd. on lateral ditch		A-11	
	30,700	32.1	End of lateral ditch at Thomas Rd.		A-11	

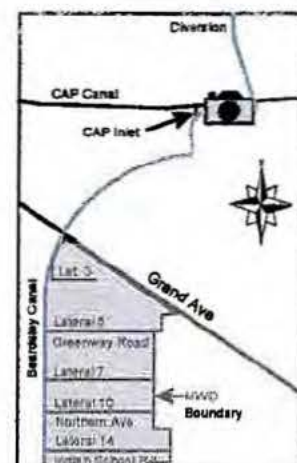
Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	Above Canal	Hank Raymond Lake, Beardsley Canal diversion headworks to right
	200,000	Beardsley Canal diversion headworks
No photograph	197,651	Weir and recording gauge, MWD Station 1
No photograph	197,473	Bridge for road to Beardsley Canal diversion headworks
	185,558	Canal during dry-up period
No photograph	185,472	Bridge for road to Cowtown
	178,126	Weir and checkdrop structure, unused



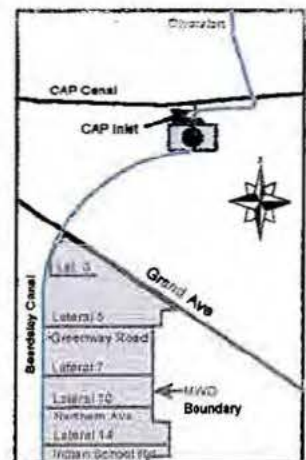
Beardsley Canal Capacity Study - Phase 1 **BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST**

Picture	Station	Description
	177,923	Start of first chute
	175,486	Start of second chute
	175,096	Agua Fria River Flume (Flume #1)
	172,787	CAP inlet to the Beardsley Canal
	172,153	Weir and recording gauge, MWD Station 5



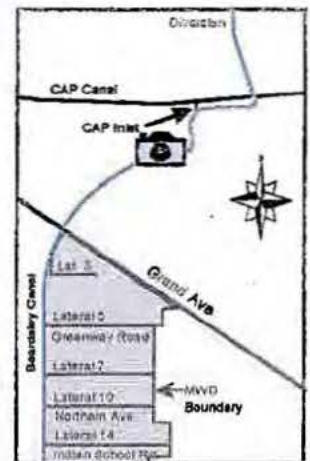
Beardsley Canal Capacity Study - Phase 1 **BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST**

Picture	Station	Description
	168,203	Turnout for Bard Citrus Ranch, no check structure
	158,990	Beardsley Canal, cross-section. Note low top of canal lining on left.
	157,469	Flume #2
	154,080	Flume #3
	147,581	Flume #4



Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	141,387	Inverted siphon
	132,048	Inverted siphon
	127,855	Inverted siphon
	127,453	Radial gate, shown during canal dry-up period
	115,009	Radial gate and unused turnout



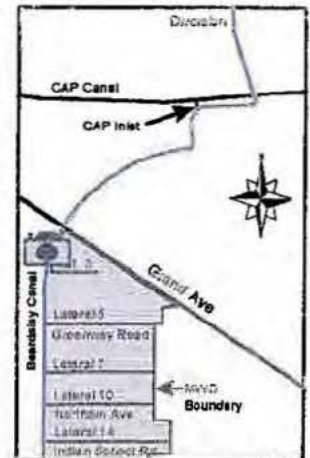
Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	114,520	163rd Avenue bridge
	114,443	CMP double-barreled culvert under the Santa Fe Railroad
	114,282	Box culvert at Grand Avenue. Photo taken from Santa Fe Railroad tracks.
No photograph	112,797	Turnout #1. Rectangular weir provides grade control.
	112,430	Inverted siphon, MWD Station 13
	112,350	Rectangular weir checkboard structure



Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	109,365	Inverted siphon under McMicken Dam chute
	104,988	Turnout #2, no grade control
	101,801	Turnout #3 - rectangular sluice gate and MWD Station 17
	96,647	Inverted siphon
	93,836	Turnout for golf course, no grade control



Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	90,639	Turnout #4 - rectangular checkboard structure
	90,563	Bell Road bridge
No photograph	84,479	Greenway Road bridge
	84,411	Turnout #5 - radial gate structure and MWD Station 22. Greenway Road bridge to left.
	81,772	Turnout #5.03, no grade control
	79,013	Turnout #6 - rectangular checkboard structure
	73,059	Turnout #7 - rectangular sluice gate and MWD Station 25

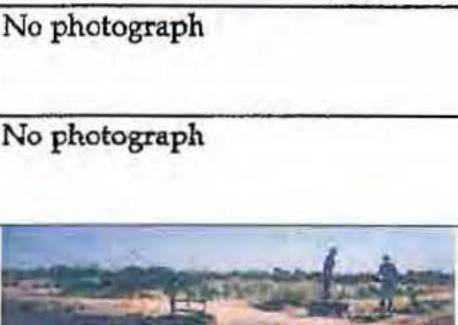


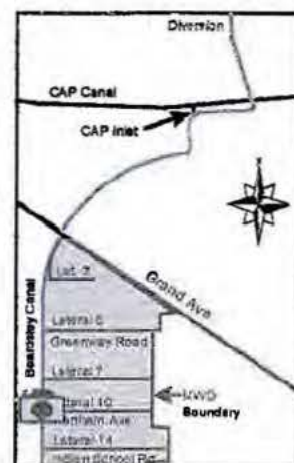
Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	72,160	Weir checkdrop structure and last MWD Station
	70,740	Inverted siphon
	67,670	CMP culvert, Turnout #8 checkboards inside.
	67,647	Turnout #8 checkboards inside of CMP culvert.
	65,027	Inverted siphon



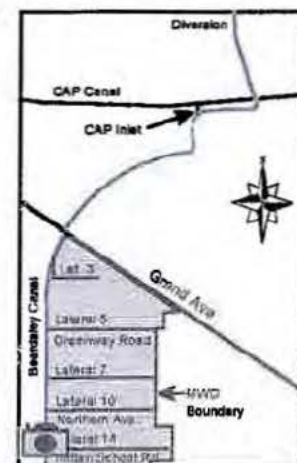
Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	62,413	CMP culvert under Olive Avenue (in background).
	62,366	Turnout #9 - rectangular checkdrop structure (in foreground).
	61,000	Beardsley Canal cross-section looking downstream south of Turnout #9.
	57,117	CMP culvert under Northern Avenue (in background).
	57,083	Turnout #10 - rectangular checkdrop structure (in foreground).
No photograph	55,206	Inverted siphon
No photograph	52,860	Rectangular weir and drop structure, unused.
	51,802	Turnout #11 - rectangular weir and checkdrop structure, Glendale Avenue alignment.



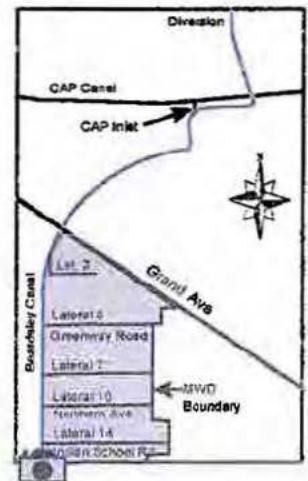
Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	46,554	Turnout #12 - broadcrested weir
	46,475	Inverted siphon, looking downstream from the Turnout #12 broadcrested weir.
	41,274	Turnout #13 - rectangular weir checkboard structure
	38,658	Turnout #13.5 - rectangular checkboard structure
	36,051	Box culvert under Indian School Road (to left).
	36,011	Turnout #14 - weir checkdrop structure (to right).
		End of Beardsley Canal, ditch continues south.



Beardsley Canal Capacity Study - Phase 1
BEARDSLEY CANAL PHOTOGRAPHIC LINE LIST

Picture	Station	Description
	33,400	Check structure to turn out flow near Osborn Road
	30,700	Looking north from Thomas Road



Appendix B

Introduction

A hydraulic analysis of the Beardsley Canal was undertaken using data collected in the field and HEC-RAS version 2.2. HEC-RAS is the Hydrologic Engineering Center River Analysis System software developed by the U.S. Army Corps of Engineers. It is in the public domain and it, along with its manuals, may be downloaded from the Hydraulic Engineering Center's website: <http://www.hec.usace.army.mil/> HEC-RAS is compatible with and supersedes HEC-2.

Model Formulation

Objectives

The objectives of the HEC-RAS modelling were to adequately reflect the hydraulic characteristics of the Beardsley Canal under current flow conditions and to develop a tool to predict the hydraulic characteristics of the Beardsley Canal under increased flow conditions.

Model Description

HEC-RAS is based on the solution of the one-dimensional energy equation and uses an iterative procedure to achieve an energy balance between consecutive cross sections. It employs a form of the empirical Manning's equation to provide the relationship between the rate of discharge, hydraulic resistance, channel geometry, and rate of friction loss. For changes in canal prism, energy losses are evaluated using contraction/expansion coefficients multiplied by the change in velocity head. When the water surface profile is rapidly varied (i.e., across structures), the momentum equation is utilized. A full discussion of HEC-RAS' theoretical basis may be found in *HEC-RAS Hydraulic Reference Manual, Version 2.2* (U.S. Army Corps of Engineers, Hydrologic Engineering Center, August 1998). Basic assumptions of the model include:

- Flow is steady;
- Flow is gradually varied (except at structures);
- Flow is one dimensional; and
- Channel slope less than 0.1.

The Beardsley Canal reasonably satisfies the model basic assumptions.

Model Input Requirements

The basic input data requirements for HEC-RAS include canal geometry (represented by a series of cross sections); energy loss coefficients for hydraulic resistance and the expansion or contraction of flow; the rate of discharge; and conditions for the flow boundaries of the canal (i.e., top of lining).

The canal geometry is defined by a series of cross sections of the canal perpendicular to flow, each comprised of points with coordinates in three dimensions sufficient to define the geometry of the given cross section. The hydraulic resistance is reflected in the selection of Manning's "n" values for each cross section. More than one "n" value may be assigned to each cross section.

Model Output

HEC-RAS model output consists of the water surface elevation and is available in the form of tables, cross sections, profiles, or three-dimensional diagrams.

Canal Geometry

Within HEC-RAS, canal geometry is defined by a series of cross sections, each comprised of points with coordinates in three dimensions sufficient to define the area available for the conveyance of flow. For this project, canal geometry was developed from survey data collected in the field by B-E in December 1998. Ninety-seven points were set for vertical control, and sufficient data were collected to generate over 250 cross sections. Section 3 provides more detail on the Beardsley Canal survey.

Figure B-1 is a typical cross section showing for the left and right canal banks the inverts, top of lining, and top of bank points. Additionally, selected cross sections have a water mark for the calibration flow regime (see below). Cross sections were typically surveyed every half mile with more cross sections being taken in the vicinity of structures. Cross sections were also surveyed at points to aid in model calibration such as the extent of obvious backwater effects and changes in canal geometry, slope, or roughness. Additional cross sections were generated using judgment to aid in the model calibration process. A complete set of all the Beardsley Canal cross sections follows the text of this Appendix.

Model Calibration

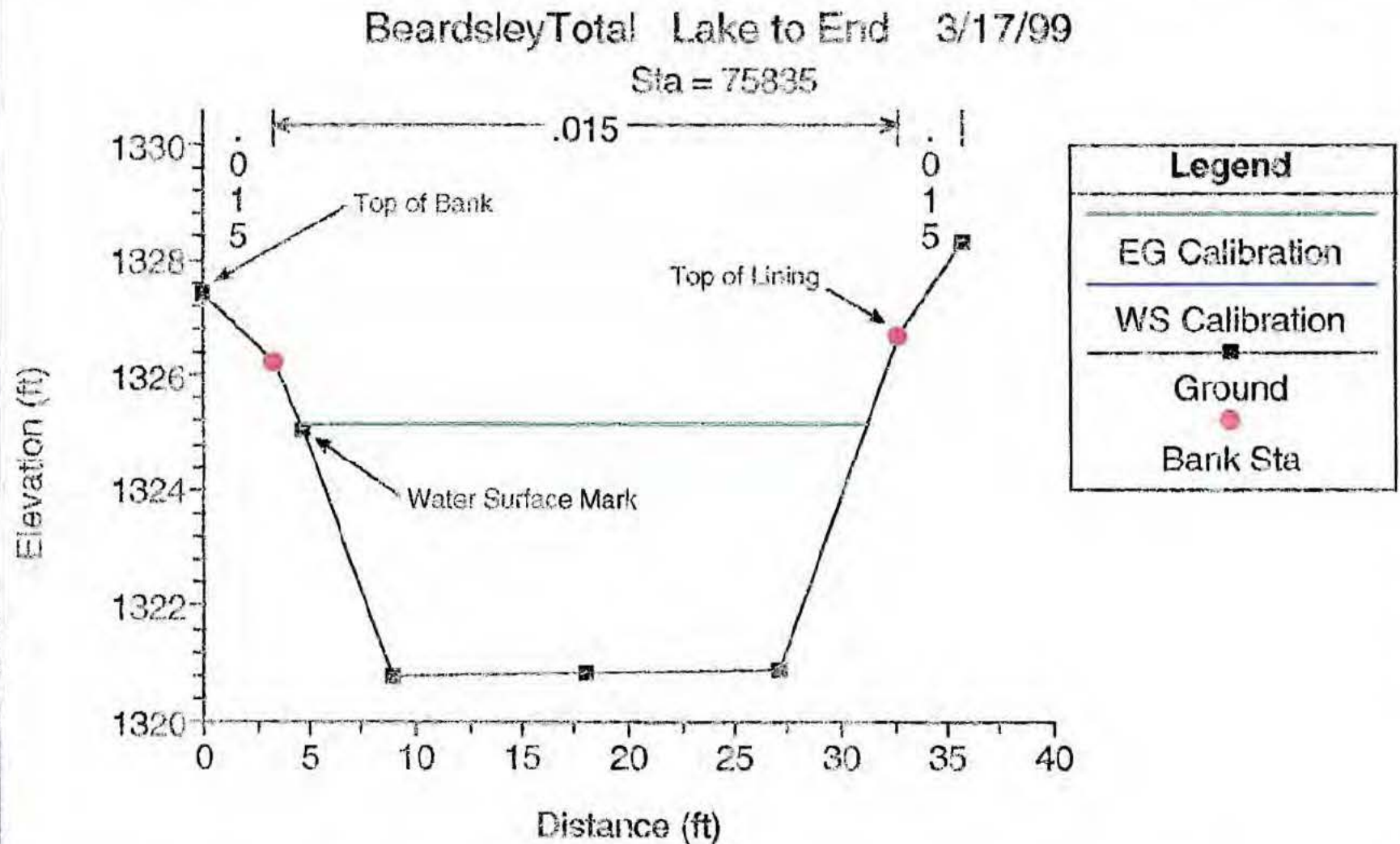
The water surface for a known flow regime was marked on the canal lining by B-E staff on August 4 and 5, 1998, high flow days for MWD. Blue paint was used to apply the marks at selected intervals as follows:

Table B-1 Beardsley Canal Capacity Study - Phase 1 Frequency of Water Surface Marks	
Reach	Frequency
Camp Dyer Diversion to CAP Turnout	No marks (no flow)
CAP Turnout to Grand Avenue	Every half mile
Grand Avenue to Thomas Road	Every quarter mile
All Reaches - Around Structures	As required to define hydraulic characteristics

Pictures were also taken of key canal structures and conditions.

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FIGURE B-1
Beardsley Canal Capacity Study - Phase 1
TYPICAL HEC-RAS CROSS SECTION



The water surface marks were used to calibrate the HEC-RAS model. Using the known flow and water surface elevation, the hydraulic parameters of the Beardsley Canal were estimated.

Canal Lining

Hydraulic Resistance

Hydraulic resistance reflects the friction provided by the canal wall materials and other conditions which impede flow. This parameter is represented in the model by a coefficient of roughness, referred to as the Manning's "n" value. The Beardsley Canal's concrete lining has been constructed using two distinct techniques: slip-form and shotcrete. All sections of the Beardsley Canal are concrete lined. A Manning's "n" value of 0.015 was assigned to the slip-form sections while a Manning's "n" value of 0.020 was assigned to the shotcrete sections, as shown in Figures B-2 and B-3.



Figure B-2 Example of Beardsley Canal Reach Constructed Using Slip-Formed Concrete.
Manning's "n" = 0.015



Figure B-3 Example of Beardsley Canal Reach Constructed Using Shotcrete.
Manning's "n" = 0.020

The above-cited Manning's "n" values were selected on the basis of field inspection and a search of the literature, which included the *Hydraulic Reference Manual*, prior studies, and general references. The general references included *Applied Hydraulics in Engineering* (Morris, H.M. and Wiggert, J.M., 1972) and *Engineering Handbook - Hydraulics* (USDA Soil Conservation Service).

It should be noted that the integrity of the canal lining varies, with some sections in good repair while other sections have breaks in the lining and some sections have canal lining bottoms that are broken and strewn with rubble. As MWD has an ongoing canal maintenance program whereby sections are cleaned, repaired, and/or replaced, the Manning's "n" value was not adjusted to reflect the integrity of the lining. The model calibration process verified the appropriateness of assigning only two Manning's "n" values to describe the roughness of the Beardsley Canal based on the type of construction.

The algae and debris in the Beardsley Canal could also influence the choice of Manning's "n" value. Again, as MWD's maintenance program clears the canal of algae and debris, the Manning's "n" value in the model was not varied to reflect the algae and

debris field conditions at the calibration flow. This decision was verified during the model calibration process.

The banks above the concrete lining are comprised of compacted earth and could be modeled with an appropriate Manning's "n" value. Since the model objective was to determine the hydraulic capacity of the Beardsley Canal without exceeding the concrete lining, a separate Manning's "n" value was not assigned for the bank portion of the cross sections.

Expansion and Contraction Coefficients

Expansion and contraction coefficients account for energy losses associated with changes in the shape and area of the effective flow area. The contraction coefficient modeled for this project was 0.1 and the expansion coefficient was 0.3. These values are consistent with those recommended in *Hydraulic Reference Manual* (U.S. Army Corps of Engineers, Hydrologic Engineering Center, August 1998).

Canal Structures

Inverted Siphons

The Beardsley Canal has a number of inverted siphons and culverts, which route flow under floodways and other canal crossings. There are ten inverted siphons. A typical inverted siphon is constructed of concrete with a smooth finish and has a rectangular cross section with rounded entrance and exit edges. Figures B-4 and B-5 are two views of the inverted siphon at station 65027.



These inverted box siphons were modeled using the HEC-RAS culvert subroutine by inserting additional cross sections with the siphon geometry immediately upstream and downstream of the siphon. The entrance and exit loss coefficients are summarized in Table B-2.

Table B-2
Beardsley Canal Capacity Study - Phase 1
Inverted Concrete Siphon Characteristics

Note	Beg. Station	Shape	Dimensions (feet)	Length (feet)	Manning's "n" Value	Entrance, Exit Loss Coefficients	Chart No. ¹	Scale No. ¹
Siphon #1	141387	Box	10x10	51	0.014	0.2, 0.3	8	1
Siphon #2	132048	Box	10x10	51	0.014	0.2, 0.3	8	1
Siphon #3	127855	Box	10x10	100	0.014	0.2, 0.2	8	1
Near TO #1	112430	Box	10x10	50	0.014	0.2, 0.3	9	2
McMicken Dam Chute	109365	Box	12x12	36	0.014	0.2, 0.3	8	2
Downstream of TO #3	96647	Box	8x8	100	0.014	0.2, 0.3	9	2
Between TOs #7 and 8	70740	Box	5x5	117	0.014	0.5, 0.3	9	2
Between TOs #8 and 9	65027	Box	6x6	118	0.014	0.2, 0.3	9	2
Between TOs #10 and 11	55206	Box	5.2x5.2	98	0.014	0.2, 0.3	13	3
Downstream of TO #12	46475	Box	4.4x4.4	103	0.014	0.2, 0.3	9	2

Notes:

1. Chart and scale numbers refer to Table B-12.

The Manning's "n" value, entrance loss coefficient, and exit loss coefficient were varied during model calibration to arrive at the measured calibration water surfaces upstream and downstream of each inverted siphon. It is likely that debris in the bottom of the inverted siphons contributes to the variation in hydraulic parameters. Unlike debris in the canal, debris in the inverted siphons is not removed during canal dry-up, as the inverted siphons are not de-watered.

Culverts

There are four corrugated metal pipe (CMP) and two concrete box culverts on the Beardsley Canal. Figures B-6 and B-7 show a CMP and concrete box culvert, respectively. Tables B-3 and B-4 summarize culvert modeling characteristics. The turnout for Lateral 8 also incorporates a CMP culvert, which is discussed on page B-8.



Figure B-6 Santa Fe Railroad crossing - CMP double-barrel culvert.



Figure B-7 Grand Avenue crossing - concrete box culvert. Picture taken from Santa Fe Railroad crossing, looking downstream.

Table B-3
Beardsley Canal Capacity Study - Phase 1
CMP Culvert Characteristics

Note	Beg. Station	Shape	Dimensions (feet)	Length (feet)	Manning's "n" Value	Entrance, Exit Loss Coeffs.	Chart No. ¹	Scale No. ¹
Santa Fe RR	114443	Circular, 2 barrels	8	54	0.021	0.7, 0.3	1	1
Olive Ave.	62413	Ellipse	7x4.8	40	0.021	0.5, 0.3	29	1
Northern Ave.	57117	Ellipse	6x3.7	20	0.026	0.5, 0.3	29	1

Notes:

1. Chart and scale numbers refer to Table B-12.

Table B-4 Beardsley Canal Capacity Study - Phase 1 Concrete Box Culvert Characteristics								
Note	Beg. Station	Shape	Dimensions (feet)	Length (feet)	Manning's "n" Value	Entrance, Exit Loss Coefficients	Chart No. ¹	Scale No. ¹
Grand Ave.	114282	Box	8.4x18	46	0.014	0.3, 0.3	8	1
Indian School Road	36051	Box	8x5.5	32	0.014	0.3, 0.3	8	1
<u>Notes:</u> 1. Chart and scale numbers refer to Table B-12.								

Flumes



Figure B-8 Flume beginning at station 154080.

There are three flumes on the Beardsley Canal which convey water over local washes. Figure B-8 shows a typical flume. These flumes are constructed of 10-foot diameter steel pipe and were modeled using the HEC-RAS culvert subroutine, with relevant parameters shown in Table B-5.

Table B-5 Beardsley Canal Capacity Study - Phase 1 Flume Characteristics								
Note	Beg. Station	Shape	Diameter (feet)	Length (feet)	Manning's "n" Value	Entrance, Exit Loss Coefficients	Chart No. ¹	Scale No. ¹
Flume #2	157469	Circular	10	440	0.012	0.1, 0.2	55	1
Flume #3	154080	Circular	10	440	0.012	0.1, 0.2	55	1
Flume #4	147581	Circular	10	380	0.012	0.1, 0.2	55	1
<u>Notes:</u> 1. Chart and scale numbers refer to Table B-12.								



Figure B-9 Flume crossing the Agua Fria River.

Additionally, the Beardsley Canal crosses the Agua Fria River in a flume constructed of semi-circular 12-foot diameter concrete-lined steel pipe. The Agua Fria River Flume was modeled using semi-circular cross sections and may be found beginning at Station 175096. It is shown in Figure B-9.

Turnout #8



Figure B-10 Entrance to CMP Culvert with Turnout #8.

Turnout #8 consists of checkboards and an outlet inside a five-foot diameter CMP. This arrangement was modeled as a sharp rise in the canal invert between two culverts. Figure B-10 shows the entrance to the CMP. Table B-6 lists the parameters used to model this structure.

Table B-6
Beardsley Canal Capacity Study - Phase 1
Lateral #8 Turnout CMP Culvert Characteristics

Note	Beg. Station	Shape	Dia-meter (feet)	Length (feet)	Manning's "n" Value	Entrance, Exit, Loss Coefficients	Chart No. ¹	Scale No. ¹
Inlet culvert	67670	Circular	5	20	0.026	0.9, 0.2	2	3
Outlet culvert	67643	Circular	5	24	0.026	0.5, 0.5	2	3

Notes:

1. Chart and scale numbers refer to Table B-12.

Check Structures

The Beardsley Canal has 21 check structures which are used to regulate flow, gauge flow, and/or route flow from the Beardsley Canal into the lateral canals for eventual delivery to farm fields or golf courses. There are several types of check structures. In the case of checks used for turnouts, the turnouts were modeled as a branching flow immediately upstream of the check structure.

Radial Gates



Figure B-11 Radial gate structure upstream of Grand Avenue.

Figure B-11 shows the radial gates for flow regulation upstream of Grand Avenue. The radial gate structures were modeled using the HEC-RAS weir and radial gate subroutine. The entrance and exit loss coefficients are summarized in Table B-7.

Table B-7 Beardsley Canal Capacity Study - Phase 1 Radial Gate Characteristics			
	Radial Gate #1	Radial Gate #2	Radial Gate #3
Note	Below Siphon #3	Below Siphon #3	Turnout #5
Beginning Station	127453	115009	84411
Number of Openings	2	2	2
Height (feet)	8	8	8
Width (feet)	10	10	8
Discharge Coefficient	0.6	0.6	0.7
Trunnion Exponent	0.16	0.16	0.16
Opening Exponent	0.72	0.72	0.72
Head Exponent	0.62	0.62	0.62
Trunnion Height	4	4	4
Orifice Coefficient	0.8	0.8	0.8
Weir Coefficient	3	3	3

Sluice Gates



Figure B-12 Sluice Gates for Turnout #3, looking upstream.

Figure B-12 shows the sluice gates for the Lateral 3 turnout structure. The sluice gate structures were modeled using the HEC-RAS weir and sluice gate subroutine. The entrance and exit loss coefficients are summarized in Table B-8.

Table B-8
Beardsley Canal Capacity Study - Phase 1
Non-Radial Gate Check Structure Characteristics

Note	Beg. Station	Function	No. of Openings	Height (feet)	Width (feet)	Discharge Coeff.	Opening Exponent	Head Exponent	Orifice Coeff.	Weir Coeff.
Gauging Station	197651	Measuring Weir	1	8.9	15.9	0.5	1	0.5	0.8	3
Old Gate	178126	Unused	3	8	5.3	3	1	0.5	0.8	3.1
Past CAP Inlet	172153	Measuring Weir	1	7	20	0.5	1	0.5	0.8	3
Past Turnout #1 Siphon	112350	Check Board	1	6	10	0.5	1	0.5	0.8	3.9
Turnout #3	101801	Sluice	5	8	5.8	0.8	1	0.5	0.8	3.9
Turnout #4	90639	Check Board	4	10	5.8	0.6	1	0.5	0.8	3.8
Turnout #6	79013	Sluice	4	9.5	5.8	0.5	1	0.5	0.8	3.9
Turnout #7	73059	Sluice	2	8.8	5.8	0.5	1	0.5	0.8	3.9
Last Gauge Below TO #7	72160	Measuring Weir	1	6.7	12	0.6	1	0.5	0.8	3.65
Turnout #8	67646.5	Check Board	1	5.5	7	0.6	1	0.5	0.8	3.9
Turnout #9	62366	Check Board	1	6.3	7.8	0.5	1	0.5	0.8	2.5
Turnout #10	57083	Check Board	1	3.9	7.5	0.5	1	0.5	0.8	3.5
Between TOs #10 and 11	52860	Check Board, Unused	1	4	5	0.7	1	0.5	0.8	3.9
Turnout #11	51802	Check Board	1	4.1	7	0.5	1	0.5	0.8	3
Turnout #13	41274	Check Board	1	4.8	6	0.5	1	0.5	0.8	3
Turnout #13.5	38658	Check Board	1	3.2	5.2	0.5	1	0.5	0.8	3
Turnout #14	36011	Check Board	1	4.1	6.2	0.5	1	0.5	0.8	3.9

Checkboards



Figure B-13 Checkboard structure for Turnout #4, shown during canal dry-up.

Figure B-13 shows the checkboard structure for Turnout #4. The checkboard structures were modeled using the HEC-RAS weir and sluice gate subroutine. For the maximum flow, the gates are wide open. The entrance and exit loss coefficients are summarized in Table B-8.

Broadcrested Weir



Figure B-14 Broadcrested weir for Turnout #12.

Figure B-14 shows the broadcrested weir that is the Turnout #12 structure. The broadcrested weir was modeled using the HEC-RAS broadcrested weir subroutine. The entrance and exit loss coefficients are summarized in Table B-9.

Table B-9 Beardsley Canal Capacity Study - Phase 1 Broadcrested Weir Characteristics	
Note	Turnout #12
Beginning Station	46554
Opening Exponent	1
Head Exponent	0.5
Orifice Coefficient	0.8
Weir Coefficient	3

Bridges



Figure B-15 Bell Road bridge crossing of the Beardsley Canal.

There are five bridged crossings of the Beardsley Canal. They were modeled using the HEC-RAS bridge subroutine, and the bridge parameters used are detailed in Table B-10. Most bridges are single-span with no piers. Figure B-15 shows a typical bridge crossing at Bell Road.

Table B-10 Beardsley Canal Capacity Study - Phase 1 Bridge Characteristics						
Note	Beginning Station	Width (feet)	Weir Coefficient	Maximum Submergence	No. of Piers	Pier Width (feet)
To Diversion	197473	35	2.6	0.95	2	1
To Cowtown	185472	36	2.6	0.95	2	0.7
163 rd Avenue	114520	30	2.6	0.95	0	-
Bell Road	90563	142	2.6	0.95	0	-
Greenway Road	84479	50	2.6	0.95	0	-

Chute

Starting at station 178126, the Beardsley Canal abruptly drops 45 feet vertically in a chute. The flow goes supercritical, and the Beardsley Canal is only 2.5 feet deep along the chute. The chute ends in a pool structure, then immediately enters another chute for a 33-foot vertical drop. The second chute also ends in a pool which overflows into the Agua Fria Flume. These chute structures were modeled using enough cross sections to adequately portray the geometry and supercritical flow. The expansion and contraction coefficients used for the chute are 0.1 and 0.3, respectively. Figures B-16 and B-17 depict the chute.



Figure B-16 Chute on Beardsley Canal.



Figure B-17 Chute on Beardsley Canal just upstream of Agua Fria River Flume.

Sensitivity Analysis

A variety of parameters are incorporated into the HEC-RAS model including energy loss coefficients for hydraulic resistance and the expansion or contraction of flow; and weir and other structure-specific coefficients. The reliability of the modeling results depends on the ability to accurately estimate these parameters. All of the parameters selected were within accepted ranges for the conditions being modeled. For example, the Manning's "n" value (a measure of the roughness of the canal lining) chosen for the slip-form placed concrete sections was 0.015, while the range of Manning's "n" recommended for comparable material in the *HEC-RAS Hydraulic Reference Manual, Version 2.2* (U.S. Army Corps of Engineers, Hydrologic Engineering Center, August 1998) is 0.013 to 0.016, with 0.015 identified as "normal."

The model parameters were chosen systematically to reflect the canal lining and structures observed in the field and also to replicate the water surfaces measured for a known flow regime. In effect, the calibration process itself could be considered as a sensitivity analysis. A formal sensitivity analysis was performed, however, to determine the impact of varying the Manning's "n" value within the range of values for a given material. To replicate the water surface elevations predicted by the model for the maximum estimated flow regime using increased Manning's "n" values, a flow regime of 12 percent less flow in Reach I and approximately 5 percent less flow in the other reaches was required. The greater impact of the Manning's "n" value in Reach I is likely due to the absence of regulating structures in that reach. The following table summarizes the impact of raising the Manning's "n" values.

Table B-11
Beardsley Canal Capacity Study - Phase 1
Impact of Raising Manning's "n" Values
To Highest Value in Range for Given Material

Reach No.	Reach Description	1993 Estimated Capacity (cfs)	Estimated Maximum Capacity (cfs)	Estimated Maximum Capacity with Increased Manning's "n" Value (cfs)
I	Lake Pleasant to CAP Inlet	230	400	355
II	CAP Inlet to Grand Avenue	230	300	290
III	Grand Avenue to Bell Road	230	300	290
IV	Bell Road to Greenway Road	200	290	283
IV	Greenway Road to Waddell Road	179	290	283
IV	Waddell Road to Cactus Road	144	290	283
V	Cactus Road to Peoria Avenue	119	90	87
V	Peoria Avenue to Olive Avenue	99	90	87
V	Olive Avenue to Northern Avenue	82	90	87
VI	Northern Avenue to Glendale Avenue	67	80	79
VI	Glendale Avenue to Camelback Road	39	80	79
VII	Camelback Road to Indian School Road	25	74	73

Note: Manning's "n" value for slip-form placed concrete raised from 0.015 to 0.016 and for shotcrete from 0.020 to 0.023.

Table B-12

FHWA Chart and Scale Numbers for Culverts

Chart Number	Scale Number	Description
1		Concrete Pipe Culvert
	1	Square edge entrance with headwall (See Figure 6.10)
	2	Groove end entrance with headwall (See Figure 6.10)
2	3	Groove end entrance, pipe projecting from fill (See Figure 6.12)
		Corrugated Metal Pipe Culvert
	1	Headwall (See Figure 6.10)
3	2	Mitered to conform to slope (See Figure 6.11)
	3	Pipe projecting from fill (See Figure 6.12)
8		Concrete Pipe Culvert; Beveled Ring Entrance (See Figure 6.13)
	1(A)	Small bevel: $b/D = 0.042$; $a/D = 0.063$; $c/D = 0.042$; $d/D = 0.083$
	2(B)	Large bevel: $b/D = 0.083$; $a/D = 0.125$; $c/D = 0.042$; $d/D = 0.125$
9		Box Culvert with Flared Wingwalls (See Figure 6.14)
	1	Wingwalls flared 30 to 75 degrees
	2	Wingwalls flared 90 or 15 degrees
10	3	Wingwalls flared 0 degrees (sides extended straight)
		Box Culvert with Flared Wingwalls and Inlet Top Edge Bevel (See Figure 6.15)
	1	Wingwall flared 45 degrees; inlet top edge bevel = $0.43D$
11	2	Wingwall flared 18 to 33.7 degrees; inlet top edge bevel = $0.083D$
		Box Culvert; 90-degree Headwall; Chamfered or Beveled Inlet Edges (See Figure 6.16)
	1	Inlet edges chamfered 3/4-inch
12	2	Inlet edges beveled 1/2-in/ft at 45 degrees (1:1)
	3	Inlet edges beveled 1-in/ft at 33.7 degrees (1:1.5)
13		Box Culvert; Skewed Headwall; Chamfered or Beveled Inlet Edges (See Figure 6.17)
	1	Headwall skewed 45 degrees; inlet edges chamfered 3/4-inch
	2	Headwall skewed 30 degrees; inlet edges chamfered 3/4-inch
16-19	3	Headwall skewed 15 degrees; inlet edges chamfered 3/4-inch
	4	Headwall skewed 10 to 45 degrees; inlet edges beveled
		Box Culvert; Non-Offset Flared Wingwalls; 3/4-inch Chamfer at Top of Inlet (See Figure 6.18)
29	1	Wingwalls flared 45 degrees (1:1); inlet not skewed
	2	Wingwalls flared 18.4 degrees (3:1); inlet not skewed
	3	Wingwalls flared 18.4 degrees (3:1); inlet skewed 30 degrees
30		Box Culvert; Offset Flared Wingwalls; Beveled Edge at Top of Inlet (See Figure 6.19)
	1	Wingwalls flared 45 degrees (1:1); inlet top edge bevel = $0.042D$
	2	Wingwalls flared 33.7 degrees (1.5:1); inlet top edge bevel = $0.083D$
34	3	Wingwalls flared 18.4 degrees (3:1); inlet top edge bevel = $0.083D$
		Corrugated Metal Box Culvert
	1	90 degree headwall
29	2	Thick wall Projecting
	3	Thin wall projecting
30		Horizontal Ellipse; Concrete
	1	Square edge with headwall
	2	Grooved end with headwall
34	3	Grooved end projecting
		Vertical Ellipse; Concrete
	1	Square edge with headwall
34	2	Grooved end with headwall
	3	Grooved end projecting
34		Pipe Arch; 16" Corner Radius; Corrugated Metal
	1	90 Degree headwall
	2	Mitered to slope
34	3	Projecting

From HEC-RAS Hydraulic Reference Manual, Version 2.2 (U.S. Army Corps of Engineers, Hydrologic Engineering Center, August 1998).

Table B-12, Continued

FHWA Chart and Scale Numbers for Culverts

Chart Number	Scale Number	Description
35	1	Projecting
	2	No bevels
	3	33.7 degree bevels
36	1	Projecting
	2	No bevels
	3	33.7 degree bevels
41-43	1	Arch; low-profile arch; high-profile arch; semi circle; Corrugated Metal
	2	90 degree headwall
	3	Mitered to slope
55	1	Thin wall projecting
	2	
	3	
56	1	Smooth tapered inlet throat
	2	Rough tapered inlet throat
	3	
57	1	Tapered inlet; Beveled edges
	2	Tapered inlet; Square edges
	3	Tapered inlet; Thin edge projecting
58	1	Tapered inlet throat
	2	
	3	
59	1	Side tapered; Less favorable edges
	2	Side tapered; More favorable edges
	3	

From *HEC-RAS Hydraulic Reference Manual, Version 2.2* (U.S. Army Corps of Engineers, Hydrologic Engineering Center, August 1998).

SUMMARY TABLE
OF
HEC-RAS BEARDSLEY CANAL MODEL OUTPUT

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Grade Line Elevation (ft)	Energy Grade Line Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
200000	155	1434.6	1446.28	1446.18	1437.96	1435.82	1438.04	0.000269	2.26	68.51	20.4
200000	400	1434.6	1446.28	1446.18	1439.87	1436.88	1440.09	0.000476	3.72	107.5	20.4
198519	155	1434.67	1442.99	1441.25	1437.37		1437.49	0.000532	2.78	55.71	25.39
198519	400	1434.67	1442.99	1441.25	1439.06		1439.29	0.000603	3.88	103.01	30.63
197730	155	1434.19	1442.11	1442.39	1435.91		1436.5	0.004787	6.14	25.23	18.26
197730	400	1434.19	1442.11	1442.39	1438		1438.52	0.001664	5.78	69.18	23.82
197665	155	1434.05	1442.97	1442.97	1435.85		1436.21	0.002476	4.85	31.99	19.99
197665	400	1434.05	1442.97	1442.97	1438.01		1438.39	0.001086	4.96	80.62	25.01
197652	155	1434.05	1442.97	1442.97	1435.7	1435.44	1436.16	0.003088	5.48	28.28	19.64
197652	400	1434.05	1442.97	1442.97	1437.78	1436.61	1438.36	0.001258	6.12	65.4	24.46
197651	Inline Weir Weir & recording gauge, MWD Station 1										
197650	155	1434.05	1442.97	1442.97	1435.69	1435.44	1436.16	0.00314	5.51	28.14	19.62
197650	400	1434.05	1442.97	1442.97	1437.77	1436.6	1438.35	0.001267	6.13	65.26	24.44
197635	155	1434.05	1442.97	1442.97	1435.46	1435.46	1436.09	0.005747	6.39	24.27	19.07
197635	400	1434.05	1442.97	1442.97	1437.87		1438.28	0.001239	5.2	76.96	24.67
197504	155	1426.51	1441.79	1442.18	1435.45	1427.96	1435.46	0.000011	0.76	204.39	30.65
197504	400	1426.51	1441.79	1442.18	1438.13		1438.15	0.000029	1.37	292.5	35.3
197474	155	1426.51	1441.79	1442.18	1435.45	1427.96	1435.46	0.000011	0.76	204.38	30.65
197474	400	1426.51	1441.79	1442.18	1438.12	1429.16	1438.15	0.000029	1.37	292.47	35.3
197473	Bridge Bridge on road to Beardsley Canal diversion										
197438	155	1426.51	1441.79	1442.18	1435.45		1435.46	0.000011	0.76	204.32	30.65
197438	400	1426.51	1441.79	1442.18	1438.12		1438.15	0.000029	1.37	292.28	35.29
197378	155	1426.51	1441.79	1442.18	1435.45		1435.46	0.000011	0.76	204.3	30.65
197378	400	1426.51	1441.79	1442.18	1438.12		1438.15	0.000029	1.37	292.21	35.29
190088	155	1431.83	1440.01	1440.48	1435.11		1435.21	0.000353	2.53	61.25	22.81
190088	400	1431.83	1440.01	1440.48	1437.46		1437.63	0.000338	3.29	121.68	28.6
185558	155	1430.36	1438.37	1438.02	1434.31		1434.35	0.000115	1.59	97.3	32.42
185558	400	1430.36	1438.37	1438.02	1436.62		1436.7	0.000132	2.2	182.02	40.79
185475	155	1429.77	1438.18	1438.18	1434.3	1431.17	1434.34	0.000097	1.59	97.24	26.88
185475	400	1429.77	1438.18	1438.18	1436.59	1432.3	1436.69	0.000147	2.43	164.93	32.14
185472	Bridge Bridge for road to Cowtown - Carefree Rd.										
185436	155	1429.77	1438.18	1438.18	1434.28		1434.32	0.000098	1.6	96.83	26.84
185436	400	1429.77	1438.18	1438.18	1436.57		1436.66	0.000149	2.44	164.05	32.08
185377	155	1430.54	1439.06	1438.75	1434.24		1434.31	0.00023	2.18	71.09	23.67
185377	400	1430.54	1439.06	1438.75	1436.5		1436.64	0.000276	3.06	130.55	29.02
179629	155	1429.34	1436.65	1436.97	1432.6		1432.7	0.000351	2.49	62.25	24.01
179629	400	1429.34	1436.65	1436.97	1434.41		1434.62	0.000461	3.62	110.52	29.19
178191	155	1429.15	1436.44	1436.49	1430.7	1430.7	1431.35	0.005674	6.46	24	18.47
178191	400	1429.15	1436.44	1436.49	1431.87	1431.87	1432.96	0.005024	8.4	47.61	22.05
178157	155	1428.59	1437.23	1437.06	1430.58	1429.92	1430.83	0.001468	3.98	38.91	22.12
178157	400	1428.59	1437.23	1437.06	1432.28	1431.01	1432.67	0.001164	4.98	80.25	26.57
178127	155	1428.5	1437.06	1437.14	1430.43	1429.87	1430.77	0.001668	4.7	32.96	18.63
178127	400	1428.5	1437.06	1437.14	1431.81	1431.07	1432.58	0.001848	7.09	56.45	19.59
178126	Inline Weir Weir and checkdrop, unused										
178120	155	1428.5	1437.06	1437.14	1430.42	1430.02	1430.84	0.002711	5.2	29.81	16.84
178120	400	1428.5	1437.06	1437.14	1431.77	1431.24	1432.66	0.002785	7.57	52.82	18.15

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Grade Line Elevation (ft)	Energy Grade Line Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
178087	155	1428.5	1437.06	1437.14	1430.02	1430.02	1430.72	0.003342	6.71	23.11	16.45
178087	400	1428.5	1437.06	1437.14	1431.26	1431.26	1432.53	0.003083	9.04	44.24	17.65
177923	155	1424.05	1426.94	1426.87	1424.65	1425.47	1428.86	0.062211	16.47	9.41	16.84
177923	400	1424.05	1426.94	1426.87	1425.32	1426.64	1430.89	0.03234	18.95	21.11	18.27
177851.5	155	1416.36	1418.39	1418.23	1416.87	1417.78	1422.89	0.111035	19.7	7.87	16.7
177851.5	400	1416.36	1418.39	1418.23	1417.33	1418.95	1427.17	0.078958	25.17	15.89	17.76
177780	155	1408.66	1410.69	1410.53	1409.17	1410.08	1415.03	0.106152	19.43	7.98	16.71
177780	400	1408.66	1410.69	1410.53	1409.58	1411.25	1420.8	0.097057	26.88	14.88	17.63
177702	155	1399.23	1401.26	1401.1	1399.72	1400.65	1406.18	0.124089	20.39	7.6	16.66
177702	400	1399.23	1401.26	1401.1	1400.11	1401.82	1412.31	0.110741	28.03	14.27	17.55
177624	155	1389.8	1391.92	1391.99	1390.3	1391.22	1396.61	0.120616	20.17	7.68	16.71
177624	400	1389.8	1391.92	1391.99	1390.67	1392.38	1403.32	0.117219	28.55	14.01	17.42
177574	155	1383.7	1394.39	1394.36	1384.28	1385.21	1390.63	0.119695	20.22	7.88	16.51
177574	400	1383.7	1394.39	1394.36	1384.65	1386.38	1397.52	0.118975	28.8	13.89	17.26
177513	155	1383.55	1394.29	1394.21	1386.47	1385.04	1386.61	0.000313	2.98	52.02	21.19
177513	400	1383.55	1394.29	1394.21	1384.77	1386.21	1391.61	0.042988	20.99	19.06	17.53
175494	155	1383.02	1391.79	1391.75	1384.43	1384.43	1385.09	0.003267	6.48	23.91	18.37
175494	400	1383.02	1391.79	1391.75	1385.59	1385.59	1386.74	0.002933	8.61	46.44	20.76
175486	155	1382.33	1390.14	1390.99	1383.33	1383.82	1384.93	0.013467	10.15	15.27	17.68
175486	400	1382.33	1390.14	1390.99	1384.28	1384.98	1386.58	0.008397	12.17	32.88	19.7
175469	155	1378.6	1382.46	1382.4	1379.19	1380.05	1384.2	0.083953	17.97	8.62	16.99
175469	400	1378.6	1382.46	1382.4	1379.84	1381.2	1385.92	0.0378	19.79	20.21	18.5
175454	155	1377.69	1380.04	1380.03	1378.25	1379.08	1382.97	0.074658	17.43	8.89	16.77
175454	400	1377.69	1380.04	1380.03	1378.86	1380.26	1385.3	0.040385	20.35	19.66	18.1
175316	155	1370.67	1373.15	1373.17	1371.38	1372.14	1374.79	0.044361	14.81	10.46	16.96
175316	400	1370.67	1373.15	1373.17	1371.84	1373.32	1379.05	0.048122	21.54	18.57	17.89
175303	155	1364.15	1372.96	1372.46	1364.65	1365.7	1373.31	0.180522	23.62	6.58	15.09
175303	400	1364.15	1372.96	1372.46	1365.14	1366.95	1377.62	0.102766	28.35	14.11	15.62
175282	155	1349.41	1362.37	1365.14	1354.88	1350.71	1354.91	0.000025	1.21	127.99	28.05
175282	400	1349.41	1362.37	1365.14	1357.83	1351.76	1357.68	0.00004	1.9	211.03	32.52
175268	155	1349.36	1362.37	1364.88	1354.89		1354.9	0.000009	0.79	195.15	35.59
175268	400	1349.36	1362.37	1364.88	1357.84		1357.67	0.000019	1.36	293.08	35.59
175250	155	1349.06	1362.37	1364.89	1354.86		1354.9	0.000046	1.54	100.79	17.59
175250	400	1349.06	1362.37	1364.89	1357.55		1357.66	0.000106	2.7	148.08	17.59
175240	155	1348.38	1362.37	1362.38	1354.87		1354.89	0.000026	1.24	124.76	20.29
175240	400	1348.38	1362.37	1362.38	1357.57		1357.65	0.000062	2.23	179.63	20.29
175217	155	1348.95	1360.84	1362.43	1354.87		1354.89	0.000019	1.08	142.95	31.78
175217	400	1348.95	1360.84	1362.43	1357.6		1357.64	0.000031	1.7	235.7	36.06
175197	155	1350.23	1360.46	1360.33	1354.86		1354.89	0.000048	1.5	103.23	28.62
175197	400	1350.23	1360.46	1360.33	1357.57		1357.64	0.000057	2.1	190.26	35.5
175177	155	1350.23	1360.46	1360.33	1354.83		1354.89	0.000076	1.85	83.6	21.16
175177	400	1350.23	1360.46	1360.33	1357.51		1357.63	0.000108	2.77	144.28	24.16
175096	155	1350.64	1357.53	1357.47	1354.52		1354.84	0.001289	4.56	34.02	11.74
175096	400	1350.64	1357.53	1357.47	1356.96		1357.56	0.001517	6.24	64.14	13
173945	155	1348.45	1355.34	1355.28	1351.03	1351.03	1352.01	0.006026	7.92	19.58	10.2
173945	400	1348.45	1355.34	1355.28	1352.75	1352.75	1354.39	0.005882	10.27	38.95	11.95
173920	155	1347.95	1356.35	1356.14	1349.62	1350.26	1351.67	0.020254	11.49	13.49	10.77

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy GradeLine Elevation (ft)	Energy GradeLine Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
173920	400	1347.95	1356.35	1356.14	1353.15	1351.82	1353.73	0.001635	6.12	65.38	18.69
173895	155	1347.7	1356.97	1355.99	1350.92	1349.18	1351.01	0.000335	2.42	64.18	25.19
173895	400	1347.7	1356.97	1355.99	1353.45		1353.58	0.00026	2.92	137.02	32.59
173041	155	1346.58	1354.66	1355.72	1350.83		1350.86	0.000092	1.49	103.69	31.74
173041	400	1346.58	1354.66	1355.72	1353.36		1353.42	0.000105	2.06	194.43	39.98
172787	155	1346.52	1355.44	1356.99	1350.81		1350.84	0.000076	1.4	110.44	32.08
172787	400	1346.52	1355.44	1356.99	1353.34		1353.4	0.000094	1.99	201.32	39.87
172172	155	1346.49	1354.07	1357.25	1350.75		1350.79	0.000094	1.54	100.94	29.87
172172	400	1346.49	1354.07	1357.25	1353.26		1353.33	0.000115	2.16	184.93	37.1
172154	155	1346.49	1354.07	1357.25	1350.74	1347.79	1350.79	0.000087	1.72	89.92	29.82
172154	400	1346.49	1354.07	1357.25	1353.21	1348.82	1353.33	0.00012	2.77	144.19	36.93
172153	Inline Weir	Rec. weir & MWD Station 5 gauge									
172152	155	1346.49	1354.07	1357.25	1350.73	1347.79	1350.78	0.000087	1.73	89.8	29.95
172152	400	1346.49	1354.07	1357.25	1353.2	1348.82	1353.32	0.00012	2.78	144.12	36.95
172140	155	1346.69	1354.29	1357.8	1350.74		1350.77	0.000105	1.57	98.62	30.8
172140	400	1346.69	1354.29	1357.8	1353.23		1353.3	0.000118	2.16	185	38.41
168203	146.53	1346.41	1354.69	1354.45	1350.16		1350.22	0.000197	1.99	73.52	25.68
168203	400	1346.41	1354.69	1354.45	1352.55		1352.67	0.000227	2.81	142.58	32.21
160334	146.53	1345.2	1354.03	1353.84	1347.99		1348.08	0.000399	2.52	58.21	23.79
160334	400	1345.2	1354.03	1353.84	1349.89		1350.11	0.000501	3.73	107.23	27.57
159049	146.53	1344.27	1351.92	1352.65	1347.74		1347.78	0.000143	1.7	86.43	30.65
159049	400	1344.27	1351.92	1352.65	1349.54		1349.66	0.000232	2.73	146.48	35.82
158990	144.75	1344.5	1351.88	1350.16	1347.7		1347.77	0.000224	2.04	70.8	25.9
158990	300	1344.5	1351.88	1350.16	1349.55		1349.64	0.000198	2.45	122.28	29.99
157606	144.75	1344.39	1352.68	1352.38	1347.28		1347.37	0.000376	2.46	58.8	24.45
157606	300	1344.39	1352.68	1352.38	1349.21		1349.33	0.000259	2.7	111.13	29.59
157495	144.75	1344.15	1353.06	1353.11	1347.01		1347.28	0.001269	4.19	34.57	14.92
157495	300	1344.15	1353.06	1353.11	1348.95		1349.26	0.000859	4.48	66.9	18.5
157477	144.75	1343.29	1353.16	1353.18	1347.03		1347.25	0.000886	3.75	38.62	10.7
157477	300	1343.29	1353.16	1353.18	1348.81		1349.23	0.001255	5.17	58.03	11.04
157470	144.75	1342.94	1353.16	1353.18	1347.04	1344.97	1347.23	0.000758	3.57	40.51	10.7
157470	300	1342.94	1353.16	1353.18	1348.82	1346.12	1349.21	0.00113	5	59.95	11.04
157469	Culvert	Flume #2 (pipe) - Dynamite Rd.									
157029	144.75	1342.17	1352.42	1352.42	1346.82		1346.95	0.000476	2.99	48.41	10.84
157029	300	1342.17	1352.42	1352.42	1348.47		1348.79	0.000872	4.5	66.62	11.14
157005	144.75	1343.25	1352.12	1351.94	1346.78		1346.94	0.000586	3.19	45.36	15.95
157005	300	1343.25	1352.12	1351.94	1348.5		1348.75	0.000614	3.98	75.38	18.92
156966	144.75	1343.39	1351.63	1351.63	1346.84		1346.9	0.000194	1.91	75.7	27.99
156966	300	1343.39	1351.63	1351.63	1348.6		1348.69	0.000178	2.32	129.53	33.02
154345	144.75	1343.23	1350.2	1350.83	1346.17		1346.26	0.000313	2.3	63	25.06
154345	300	1343.23	1350.2	1350.83	1348.04		1348.14	0.000243	2.65	113.35	29.07
154179	144.75	1342.74	1350.91	1351.02	1346.06		1346.19	0.000466	2.85	50.75	16.01
154179	300	1342.74	1350.91	1351.02	1347.86		1348.08	0.000539	3.74	80.14	16.75
154113	144.75	1341.55	1350.91	1351.02	1345.99		1346.15	0.000592	3.22	44.92	10.24
154113	300	1341.55	1350.91	1351.02	1347.65		1348.01	0.001081	4.84	61.96	10.32
154081	144.75	1341.55	1350.91	1351.02	1345.97	1343.41	1346.13	0.0006	3.24	44.72	10.23
154081	300	1341.55	1350.91	1351.02	1347.61	1344.57	1347.98	0.0011	4.87	61.54	10.32

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradeline Elevation (ft)	Energy Gradeline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
154080	Culvert	Flume #3 (pipe)									
153639	144.75	1341.3	1350.66	1350.77	1345.71		1345.87	0.000604	3.25	44.6	10.23
153639	300	1341.3	1350.66	1350.77	1347.13		1347.53	0.001219	5.07	59.18	10.31
153623	144.75	1341.23	1350.74	1350.9	1345.73		1345.85	0.000367	2.73	52.94	15.94
153623	300	1341.23	1350.74	1350.9	1347.24		1347.46	0.000533	3.8	78.97	18.7
153458	143.25	1342.39	1350.26	1350.26	1345.74		1345.79	0.000173	1.87	76.79	26.21
153458	300	1342.39	1350.26	1350.26	1347.27		1347.37	0.000209	2.51	119.29	29.14
147960	143.25	1341.34	1348.66	1349.13	1343.29		1343.57	0.00172	4.18	34.24	20.29
147960	300	1341.34	1348.66	1349.13	1345.23		1345.45	0.000676	3.82	78.45	25.47
147777	143.25	1340.51	1348.72	1348.79	1343.05		1343.3	0.001184	3.98	35.95	15.36
147777	300	1340.51	1348.72	1348.79	1345		1345.31	0.00085	4.48	67.02	16.63
147615	143.25	1339.14	1349.18	1349.18	1342.92		1343.13	0.00081	3.7	38.71	11.27
147615	300	1339.14	1349.18	1349.18	1344.76		1345.15	0.001071	4.99	60.17	12.06
147583	143.25	1339.14	1349.18	1349.18	1342.89	1341.09	1343.11	0.000831	3.73	38.37	11.26
147583	300	1339.14	1349.18	1349.18	1344.72	1342.26	1345.11	0.001095	5.03	59.67	12.04
147581	Culvert	Flume #4 (pipe) - Jomax Rd.									
147199	143.25	1338.43	1348.5	1348.5	1341.61		1341.92	0.000856	4.52	31.71	10.16
147199	300	1338.43	1348.5	1348.5	1342.45		1343.31	0.00192	7.44	40.34	10.2
147176	143.25	1339.23	1348.21	1348.12	1341.35		1341.87	0.001876	5.83	24.55	13.59
147176	300	1339.23	1348.21	1348.12	1342.32		1343.26	0.002242	7.78	38.57	15.28
147036	142	1338.85	1345.89	1345.46	1341.58		1341.67	0.000224	2.43	58.5	26.27
147036	300	1338.85	1345.89	1345.46	1342.77		1342.94	0.000269	3.26	91.99	30
141608	142	1338.23	1344.36	1344.49	1340.21		1340.29	0.000287	2.38	59.59	33.97
141608	300	1338.23	1344.36	1344.49	1341.38		1341.52	0.000252	2.96	101.3	37.19
141422	142	1323.25	1346.26	1346.26	1340.25		1340.27	0.000012	0.83	170.17	10.01
141422	300	1323.25	1346.26	1346.26	1341.43		1341.47	0.000045	1.65	181.93	10.02
141389	142	1323.25	1346.26	1346.26	1340.25	1325.09	1340.26	0.000012	0.83	170.16	10.01
141389	300	1323.25	1346.26	1346.26	1341.43	1326.28	1341.47	0.000045	1.65	181.91	10.02
141387	Culvert	Inverted siphon									
141336	142	1326.5	1346.31	1346.31	1340.23		1340.25	0.000019	1.03	137.44	10.01
141336	300	1326.5	1346.31	1346.31	1341.34		1341.41	0.000072	2.02	148.54	10.01
141220	141.7	1337.29	1344.53	1344.65	1340.2		1340.24	0.000097	1.7	83.21	34.28
141220	300	1337.29	1344.53	1344.65	1341.3		1341.39	0.000136	2.45	122.42	37.03
132151	141.7	1336.4	1342.01	1342.36	1339.52		1339.56	0.00006	1.45	98.01	35.97
132151	300	1336.4	1342.01	1342.36	1339.71		1339.84	0.000221	2.86	104.82	36.48
132050	141.7	1330	1346.49	1346.49	1339.52	1331.83	1339.55	0.000046	1.49	95.22	10.01
132050	300	1330	1346.49	1346.49	1339.67	1333.02	1339.82	0.0002	3.1	96.72	10.01
132048	Culvert	Inverted siphon									
131995	141.7	1330	1346.66	1346.66	1339.51		1339.54	0.000046	1.49	95.13	10.01
131995	300	1330	1346.66	1346.66	1339.63		1339.78	0.000202	3.11	96.32	10.01
131903	139.9	1336.36	1342.76	1342.22	1339.5		1339.54	0.000062	1.46	95.53	35.28
131903	300	1336.36	1342.76	1342.22	1339.61		1339.75	0.000255	3.02	99.4	35.57
128028	139.9	1335.5	1341.13	1341.68	1339.39		1339.41	0.000019	0.95	147.46	43.15
128028	300	1335.5	1341.13	1341.68	1338.96		1339.04	0.000133	2.33	128.92	42.01
127896	139.9	1335.5	1341.13	1341.68	1339.39		1339.4	0.000019	0.95	147.73	43.34
127896	300	1335.5	1341.13	1341.68	1338.94		1339.02	0.000135	2.34	128.46	42.13

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

**Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles**

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Grade Line Elevation (ft)	Energy Grade Line Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
127857	139.9	1328.83	1342.83	1342.83	1339.37	1330.65	1339.4	0.000035	1.33	105.53	10.02
127857	300	1328.83	1342.83	1342.83	1338.87	1331.86	1339.01	0.000182	2.98	100.52	10.01
127855	Culvert	Inverted siphon									
127753	139.9	1327.76	1342.76	1342.76	1339.37		1339.39	0.000028	1.2	116.16	10.02
127753	300	1327.76	1342.76	1342.76	1338.84		1338.96	0.000143	2.7	110.91	10.01
127574	139.9	1335.06	1341.42	1341.53	1339.37		1339.38	0.000022	1.02	136.8	39.03
127574	300	1335.06	1341.42	1341.53	1338.82		1338.93	0.000162	2.59	116.02	37.38
127460	139.9	1335.04	1342.04	1342.04	1339.36	1335.98	1339.38	0.000018	1	139.7	39.1
127460	300	1335.04	1342.04	1342.04	1338.81	1336.57	1338.91	0.000139	2.51	119.71	37.46
127453	Inline Weir	Radial gate									
127436	139.9	1334.91	1340.87	1340.98	1337.84	1335.95	1337.88	0.000079	1.58	88.34	37.55
127436	300	1334.91	1340.87	1340.98	1338.78	1336.54	1338.87	0.000131	2.46	121.97	41.81
127385	137.3	1334.91	1340.87	1340.98	1337.84		1337.88	0.000081	1.55	88.72	37.37
127385	300	1334.91	1340.87	1340.98	1338.78		1338.86	0.000141	2.39	125.67	41.68
121544	134.7	1333.76	1339.9	1339.91	1337.58		1337.6	0.00003	1.15	117.42	35.57
121544	300	1333.76	1339.9	1339.91	1338.12		1338.19	0.000095	2.19	136.82	36.9
115117	134.7	1332.9	1339.06	1338.97	1337.45		1337.47	0.000015	0.89	151.62	39.72
115117	300	1332.9	1339.06	1338.97	1337.63		1337.69	0.000065	1.89	158.65	40.21
115010	134.7	1333	1341.03	1341.01	1337.44	1333.99	1337.46	0.000022	1.26	106.52	39.28
115010	300	1333	1341.03	1341.01	1337.55	1334.69	1337.67	0.000102	2.75	109.29	39.54
115009	Inline Weir	Radial gate, unused turnout									
114992	134.7	1332.83	1338.67	1338.68	1336.49	1333.8	1336.51	0.000034	1.18	113.96	37.13
114992	300	1332.83	1338.67	1338.68	1337.55	1334.43	1337.61	0.000069	1.93	155.07	40.4
114940	134.7	1332.83	1338.67	1338.68	1336.49		1336.51	0.000035	1.19	113.32	36.83
114940	300	1332.83	1338.67	1338.68	1337.54		1337.6	0.00007	1.95	154.09	40.23
114558	134.7	1332.88	1340.06	1339.72	1336.47		1336.49	0.000041	1.21	110.91	39.99
114558	300	1332.88	1340.06	1339.72	1337.52		1337.57	0.000077	1.94	154.86	44.03
114521	134.7	1332.88	1340.06	1339.72	1336.47	1334.06	1336.49	0.000041	1.22	110.85	39.98
114521	300	1332.88	1340.06	1339.72	1337.51	1334.67	1337.57	0.000077	1.94	154.74	44.02
114520	Bridge	163rd Ave. bridge									
114462	134.7	1332.88	1340.06	1339.72	1336.47		1336.49	0.000041	1.22	110.76	39.98
114462	300	1332.88	1340.06	1339.72	1337.51		1337.57	0.000077	1.94	154.53	44
114445	134.7	1332.16	1340.06	1339.72	1336.47	1333.11	1336.49	0.000021	1.16	115.98	41.5
114445	300	1332.16	1340.06	1339.72	1337.5	1333.78	1337.57	0.00005	2.08	144.31	45
114443	Culvert	CMP double culvert under Santa Fe railroad									
114306	134.7	1331.48	1338.79	1338.2	1336.34		1336.37	0.000034	1.28	105.11	28.78
114306	300	1331.48	1338.79	1338.2	1337.06		1337.15	0.000101	2.37	126.67	30.93
114284	134.7	1331.49	1338.79	1338.2	1336.34	1332.66	1336.37	0.000024	1.31	103.07	29.21
114284	300	1331.49	1338.79	1338.2	1337.05	1333.44	1337.15	0.000075	2.53	118.67	31.15
114282	Culvert	Box culvert at Grand Ave.									
114234	134.7	1331.09	1338.9	1337.68	1336.33	1332.12	1336.35	0.000013	1.01	133.54	34.28
114234	300	1331.09	1338.9	1337.68	1337.02	1332.82	1337.08	0.000041	1.98	151.48	35.88
114221	134.7	1331.09	1338.9	1337.68	1336.33		1336.35	0.00002	1.04	129.36	33.57
114221	300	1331.09	1338.9	1337.68	1337.02		1337.08	0.000063	1.96	153.1	35.42
112797	134	1331.58	1337.88	1340.18	1336.31		1336.32	0.000018	0.97	137.89	35.45

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Beardsley Canal Capacity Study
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River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Grade/Elevation (ft)	Energy Grade/Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
112797	300	1331.58	1337.88	1340.18	1336.94		1336.99	0.000057	1.87	160.85	37.12
112465	134	1331.58	1337.88	1340.18	1336.3		1336.32	0.000018	0.97	137.6	35.4
112465	300	1331.58	1337.88	1340.18	1336.92		1336.97	0.000058	1.87	160.02	37.04
112431	130.9	1323.2	1337.7	1337.64	1336.3	1324.94	1336.31	0.000018	1	130.95	10
112431	300	1323.2	1337.7	1337.64	1336.9	1326.24	1336.97	0.000087	2.19	136.91	10.01
112430	Culvert	Inverted siphon and MWD Station 13 gauge									
112380	130.9	1323.7	1339	1338.95	1336.29	1325.45	1336.3	0.00002	1.04	125.85	10.01
112380	300	1323.7	1339	1338.95	1336.83	1326.73	1336.91	0.000096	2.28	131.3	10.01
112350	Inline Weir	Rectangular weir checkdrop									
112349	130.9	1329.98	1336.13	1336.55	1332.95	1331.65	1333.18	0.000368	3.82	34.25	28.91
112349	300	1329.98	1336.13	1336.55	1333.67	1332.79	1334.43	0.000917	7.01	42.82	30.75
112150	130.9	1329.98	1336.13	1336.55	1333.04		1333.09	0.000097	1.74	75.02	29.35
112150	300	1329.98	1336.13	1336.55	1334.04		1334.17	0.000186	2.84	105.51	31.86
112000	130.9	1329.98	1336.13	1336.55	1333.03		1333.08	0.000099	1.76	74.24	29.1
112000	300	1329.98	1336.13	1336.55	1334.01		1334.14	0.000193	2.88	103.99	31.63
110736	130.9	1329.98	1336.13	1336.55	1332.89		1332.94	0.000118	1.87	70.11	28.73
110736	300	1329.98	1336.13	1336.55	1333.7		1333.85	0.000258	3.18	94.26	30.82
109473	130.9	1328.18	1334.58	1334.66	1332.84		1332.87	0.000028	1.19	110.38	29.44
109473	300	1328.18	1334.58	1334.66	1333.57		1333.65	0.000089	2.26	132.48	31.18
109407	130.9	1327.09	1340.61	1337.58	1332.8		1332.86	0.000089	1.91	68.51	12
109407	300	1327.09	1340.61	1337.58	1333.38		1333.63	0.000361	3.98	75.43	12
109393.5	130.9	1314.84	1340.61	1337.58	1332.84		1332.84	0.000005	0.61	215.93	12
109393.5	300	1314.84	1340.61	1337.58	1333.53		1333.56	0.000024	1.34	224.25	12.01
109377.1	130.9	1306.78	1340.61	1337.58	1332.84		1332.84	0.000002	0.42	312.67	12.01
109377.1	300	1306.78	1340.61	1337.58	1333.54		1333.55	0.000011	0.93	321.09	12.01
109377	130.9	1306.78	1340.61	1337.58	1332.84		1332.84	0.000002	0.42	312.67	12.01
109377	300	1306.78	1340.61	1337.58	1333.54		1333.55	0.000011	0.93	321.09	12.01
109365.1	130.9	1306.78	1340.61	1337.58	1332.84	1308.32	1332.84	0.000002	0.42	312.67	12.01
109365.1	300	1306.78	1340.61	1337.58	1333.54	1309.46	1333.55	0.000011	0.93	321.09	12.01
109365	Culvert	Inverted siphon at McMicken Dam chute									
109328.9	130.9	1306.78	1340.61	1337.58	1332.83		1332.84	0.000002	0.42	312.59	12.01
109328.9	300	1306.78	1340.61	1337.58	1333.51		1333.52	0.000011	0.94	320.69	12.01
109317	130.9	1306.78	1340.61	1337.58	1332.83		1332.84	0.000002	0.42	312.59	12.01
109317	300	1306.78	1340.61	1337.58	1333.51		1333.52	0.000011	0.94	320.69	12.01
109316.9	130.9	1306.78	1340.61	1337.58	1332.83		1332.84	0.000002	0.42	312.59	12.01
109316.9	300	1306.78	1340.61	1337.58	1333.51		1333.52	0.000011	0.94	320.69	12.01
109297.2	130.9	1321.1	1340.61	1337.58	1332.82		1332.84	0.000014	0.93	140.62	12
109297.2	300	1321.1	1340.61	1337.58	1333.45		1333.52	0.000065	2.02	148.19	12
109291	130.9	1328.37	1341.87	1338.82	1332.73		1332.83	0.000186	2.51	52.22	12
109291	300	1328.37	1341.87	1338.82	1333.03		1333.48	0.000814	5.38	55.81	12
109211	130.9	1328.73	1335.25	1334.8	1332.77		1332.8	0.000055	1.5	87.47	27.46
109211	300	1328.73	1335.25	1334.8	1333.22		1333.36	0.000197	3	100.11	28.6
107818	130.9	1328.68	1334.98	1334.79	1332.69		1332.73	0.000052	1.46	89.53	27.72
107818	300	1328.68	1334.98	1334.79	1332.91		1333.06	0.000225	3.14	95.6	28.29
106457	130.9	1328.3	1334.37	1334.33	1332.64		1332.67	0.000034	1.26	103.87	29.54
106457	300	1328.3	1334.37	1334.33	1332.65		1332.78	0.000179	2.88	104.24	29.57

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradeline Elevation (ft)	Energy Gradeline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
104988	130.2	1328.06	1334.04	1334.1	1332.6		1332.62	0.000023	1.08	120.7	32.42
104988	300	1328.06	1334.04	1334.1	1332.44		1332.54	0.000141	2.6	115.34	31.99
101941	130.2	1327.46	1333.55	1333.45	1332.55		1332.57	0.000015	0.92	142.2	34.67
101941	300	1327.46	1333.55	1333.45	1332.07		1332.16	0.000112	2.39	125.76	33.43
101825	130.2	1327.53	1334.52	1335.98	1332.55		1332.56	0.000002	1.04	124.93	32.05
101825	300	1327.53	1334.52	1335.98	1332.02		1332.14	0.000162	2.77	108.48	30.59
101818	130.2	1327.11	1337.29	1337.56	1332.55		1332.56	0.000018	1.02	127.14	30.25
101818	300	1327.11	1337.29	1337.56	1332.02		1332.14	0.000141	2.69	111.69	28.96
101806	119.7	1327.11	1337.3	1337.3	1332.55	1327.84	1332.56	0.000005	0.58	207.43	42.64
101806	300	1327.11	1337.3	1337.3	1332.07	1328.45	1332.11	0.000041	1.6	187.16	41.84
101801	Inline Weir Turnout #3, rec. sluice gate, MWD Station 17 gauge										
101796	119.7	1327.11	1337.3	1337.3	1329.81		1329.84	0.000049	1.24	96.8	38.07
101796	300	1327.11	1337.3	1337.3	1331.3		1331.35	0.000072	1.93	155.12	40.54
101657	119.7	1327.43	1333.4	1333.49	1329.74		1329.82	0.000216	2.25	53.19	26.13
101657	300	1327.43	1333.4	1333.49	1331.17		1331.33	0.000259	3.22	93.07	29.8
98127	119.7	1326.69	1332.84	1332.93	1328.73		1328.84	0.000372	2.62	45.72	27.45
98127	300	1326.69	1332.84	1332.93	1330.04		1330.23	0.000376	3.55	84.4	31.72
96851	119.7	1326.31	1332.41	1332.3	1328.15		1328.29	0.000503	2.95	40.58	25.34
96851	300	1326.31	1332.41	1332.3	1329.44		1329.68	0.000491	3.99	75.28	28.71
96662	119.7	1324.99	1334.51	1334.5	1327.95		1328.17	0.000623	3.8	31.47	10.86
96662	300	1324.99	1334.51	1334.5	1327.92	1327.92	1329.36	0.004036	9.64	31.13	10.86
96658	119.7	1324.99	1334.51	1334.5	1327.95		1328.17	0.000609	3.78	31.68	11.01
96658	300	1324.99	1334.51	1334.5	1327.85	1327.9	1329.34	0.00421	9.79	30.64	10.99
96648	119.7	1321.2	1334.7	1334.75	1328.05	1323.11	1328.12	0.000142	2.19	54.75	8
96648	300	1321.2	1334.7	1334.75	1328.58	1324.72	1328.98	0.000738	5.08	59.04	8
96647	Culvert Inverted siphon										
96547	119.7	1322.15	1334.97	1334.92	1327.99		1328.09	0.000212	2.56	46.69	8
96547	300	1322.15	1334.97	1334.92	1328.23		1328.82	0.0012	6.17	48.6	8
96536	119.7	1323.91	1334.89	1334.84	1328.03		1328.07	0.000066	1.61	74.42	18.21
96536	300	1323.91	1334.89	1334.84	1328.49		1328.7	0.000302	3.62	82.84	18.23
96480	119.7	1324.2	1329.65	1329.98	1328.04		1328.07	0.000051	1.42	84.03	26.45
96480	300	1324.2	1329.65	1329.98	1328.52		1328.67	0.00021	3.09	97.09	27.5
93836	119	1323.2	1329.17	1329.05	1327.96		1327.98	0.000022	1.06	112.66	28.92
93836	300	1323.2	1329.17	1329.05	1328.14		1328.24	0.000122	2.55	117.82	29.32
92039	119	1322.72	1328.55	1328.73	1327.93		1327.94	0.000017	0.97	122.64	29.27
92039	300	1322.72	1328.55	1328.73	1327.94		1328.03	0.000107	2.44	122.95	29.29
90647	119	1321.03	1331.41	1332.87	1327.92		1327.93	0.000008	0.76	155.89	30.22
90647	300	1321.03	1331.41	1332.87	1327.86		1327.92	0.000054	1.95	154.18	30.1
90644	111.4	1320.98	1331.43	1332.59	1327.92	1322.02	1327.92	0.000003	0.51	216.41	39.27
90644	290	1320.98	1331.43	1332.59	1327.88	1322.75	1327.91	0.000023	1.35	214.88	39.19
90639	Inline Weir Turnout #4, rectangular checkboard										
90634	111.4	1320.98	1331.43	1332.59	1326.29		1326.29	0.000009	0.74	149.54	35.07
90634	290	1320.98	1331.43	1332.59	1327.48		1327.51	0.000031	1.5	192.91	37.77
90579	111.4	1322.4	1328.25	1328.02	1326.26	1323.5	1326.29	0.000045	1.34	82.96	25.64
90579	290	1322.4	1328.25	1328.02	1327.4	1324.39	1327.5	0.000124	2.56	113.46	28.03
90563	Bridge Bell Road bridge										

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Grade Line Elevation (ft)	Energy Grade Line Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
90334	111.4	1322.31	1327.9	1328.25	1326.25		1326.28	0.000053	1.46	76.46	23.16
90334	290	1322.31	1327.9	1328.25	1327.34		1327.46	0.000153	2.82	102.81	24.87
87170	111.4	1322.27	1327.78	1328.01	1326.07		1326.1	0.000058	1.47	75.74	24.72
87170	290	1322.27	1327.78	1328.01	1326.73		1326.89	0.000219	3.13	92.64	26.14
84505	111.4	1321.74	1328.84	1329.23	1325.98		1326	0.000026	1.09	102.44	29.2
84505	290	1321.74	1328.84	1329.23	1326.32		1326.42	0.000134	2.58	112.42	29.99
84480	111.4	1321.74	1328.84	1329.23	1325.98	1322.75	1326	0.000026	1.09	102.24	29.11
84480	290	1321.74	1328.84	1329.23	1326.31	1323.6	1326.42	0.000135	2.59	112.1	29.92
84479	Bridge	Greenway Road bridge									
84414	97.2	1321.22	1329.22	1329.22	1325.98	1322.09	1325.99	0.000012	0.89	108.88	28.47
84414	290	1321.22	1329.22	1329.22	1326.31	1323.01	1326.41	0.000082	2.48	116.71	29.04
84411	Inline Weir	Turnout #5, radial gate, MWD Station 22 gauge									
84403	97.2	1321.29	1326.9	1327.71	1325.36	1322.35	1325.38	0.000025	1.22	79.37	29.4
84403	290	1321.29	1326.9	1327.71	1326.31	1323.29	1326.44	0.000107	2.94	98.62	31.61
84381	97.2	1321.29	1326.9	1327.71	1325.36		1325.38	0.000023	1	97.21	29.41
84381	290	1321.29	1326.9	1327.71	1326.34		1326.42	0.000096	2.28	127.07	31.69
81772	94	1321.13	1326.61	1326.62	1325.31		1325.33	0.000018	0.9	104.42	29.51
81772	290	1321.13	1326.61	1326.62	1326.1		1326.17	0.000093	2.26	128.17	31.21
79040	94	1321.61	1326.83	1327.06	1325.24		1325.26	0.000032	1.11	84.74	27.96
79040	290	1321.61	1326.83	1327.06	1325.66		1325.8	0.000208	3	96.78	29.04
79018	83.7	1319.66	1329.71	1330.87	1325.25	1320.35	1325.26	0.000003	0.45	186.12	41.41
79018	290	1319.66	1329.71	1330.87	1325.74	1321.21	1325.77	0.000028	1.4	206.6	42.82
79013	Inline Weir	Turnout #6, rectangular checkboard									
79010	83.7	1319.66	1329.71	1330.87	1325.22		1325.22	0.000004	0.53	159.14	34.06
79010	290	1319.66	1329.71	1330.87	1325.58		1325.63	0.000041	1.69	171.77	34.77
78987	83.7	1321.14	1326.66	1326.31	1325.21		1325.22	0.000015	0.81	102.75	30.44
78987	290	1321.14	1326.66	1326.31	1325.52		1325.62	0.000014	2.58	112.2	31.23
77326	83.7	1320.97	1326.62	1326.73	1325.18		1325.19	0.000016	0.85	99.03	27.61
77326	290	1320.97	1326.62	1326.73	1325.22		1325.35	0.000181	2.9	100.13	27.68
75835	83.7	1320.76	1326.26	1326.68	1325.16		1325.17	0.000016	0.86	96.86	26.69
75835	290	1320.76	1326.26	1326.68	1324.87		1325.04	0.000245	3.25	89.34	26.11
74374	83.7	1320.61	1326.5	1326.25	1325.14		1325.15	0.000015	0.84	99.38	26.67
74374	290	1320.61	1326.5	1326.25	1324.43		1324.62	0.000324	3.58	80.91	25.25
73082	83.7	1320.57	1326.57	1326.57	1325.11		1325.13	0.000017	0.89	94.12	26.33
73082	290	1320.57	1326.57	1326.57	1322.74	1322.7	1323.63	0.002798	7.56	38.38	20.63
73063	62.8	1320.43	1328.75	1328.75	1325.12	1320.98	1325.12	0.000004	0.53	118.47	35.71
73063	90	1320.43	1328.75	1328.75	1323.34	1321.16	1323.36	0.000037	1.23	73.43	31.69
73059	Inline Weir	Turnout #7, rec. sluice gate, MWD Station 25 gauge - Cactus Rd Alignment									
73055	62.8	1320.43	1328.75	1328.75	1322.72	1321.03	1322.74	0.000076	1.1	57.08	28.92
73055	90	1320.43	1328.75	1328.75	1323.11	1321.27	1323.14	0.000092	1.34	66.94	29.89
72978	62.8	1321.02	1326.04	1326.04	1322.65		1322.72	0.0000561	2.18	28.87	19.95
72978	90	1321.02	1326.04	1326.04	1323.03		1323.12	0.0000567	2.46	36.55	20.93
72180	62.8	1319.83	1325.36	1325.28	1322.38		1322.43	0.000252	1.75	35.96	18.64
72180	90	1319.83	1325.36	1325.28	1322.7		1322.77	0.000033	2.13	42.16	19.67
72161	62.8	1319.83	1325.36	1325.28	1322.36	1320.87	1322.42	0.000236	1.93	32.5	18.03
72161	90	1319.83	1325.36	1325.28	1322.67	1321.13	1322.77	0.000319	2.44	36.84	19.06

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradieline Elevation (ft)	Energy Gradieline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
72160	Inline Weir	Weir, checkdrop - last station gauge									
72159	62.8	1319.9	1325.95	1325.45	1321.86	1320.83	1321.95	0.000461	2.38	26.36	17.68
72159	90	1319.9	1325.95	1325.45	1322.24	1321.06	1322.37	0.000508	2.83	31.77	18.85
72104	62.8	1319.9	1325.95	1325.45	1321.84		1321.92	0.000497	2.17	28.95	18.23
72104	90	1319.9	1325.95	1325.45	1322.24		1322.33	0.000523	2.47	36.37	19.37
70785	62.8	1319.1	1323.41	1323.77	1320.54		1320.74	0.002009	3.59	17.51	14.89
70785	90	1319.1	1323.41	1323.77	1320.84		1321.09	0.002082	4.07	22.1	15.82
70745	62.8	1319.1	1323.41	1323.77	1320.14	1320.14	1320.58	0.006409	5.32	11.8	13.37
70745	90	1319.1	1323.41	1323.77	1320.4	1320.4	1320.93	0.006055	5.88	15.3	14.19
70741	62.8	1315.96	1323.41	1323.41	1316.81	1317.66	1320.22	0.073024	14.81	4.24	4.99
70741	90	1315.96	1323.41	1323.41	1317.18	1318.11	1320.56	0.051219	14.74	6.1	4.99
70740	Culvert	Inverted siphon									
70622	62.8	1314.63	1320.45	1320.45	1317.35		1317.68	0.002719	4.62	13.59	5
70622	90	1314.63	1320.45	1320.45	1317.66		1318.21	0.004193	5.94	15.16	5
70552	62.8	1315.25	1320.02	1320.45	1317.36	1316.59	1317.51	0.001144	3.15	19.92	12.99
70552	90	1315.25	1320.02	1320.45	1317.77	1316.89	1317.96	0.001177	3.51	25.62	14.43
68918	62.8	1311.53	1315.82	1315.77	1313.14	1313.14	1313.73	0.00641	6.15	10.22	8.71
68918	90	1311.53	1315.82	1315.77	1313.5	1313.5	1314.19	0.006145	6.68	13.48	9.74
68125	62.8	1305.34	1309.66	1309.66	1306.47	1306.66	1307.24	0.010794	7.03	8.93	9.6
68125	90	1305.34	1309.66	1309.66	1307.44	1306.97	1307.77	0.00237	4.58	19.64	12.51
68093	62.8	1305.03	1309.44	1309.44	1306.77	1306.37	1307.04	0.00241	4.14	15.17	11.58
68093	90	1305.03	1309.44	1309.44	1307.45		1307.68	0.001413	3.77	23.84	13.81
67714	62.8	1304.02	1307.91	1308.13	1306.46		1306.56	0.000641	2.53	24.78	14.57
67714	90	1304.02	1307.91	1308.13	1307.29		1307.37	0.000409	2.38	37.84	17.29
67680	62.8	1304.02	1307.91	1308.13	1306.44		1306.54	0.000684	2.61	24.11	14.26
67680	90	1304.02	1307.91	1308.13	1307.27		1307.36	0.000431	2.42	37.14	17.14
67672	62.8	1302.42	1307.91	1308	1306.47	1303.8	1306.52	0.000114	1.83	34.34	16.04
67672	90	1302.42	1307.91	1308	1307.28	1304.1	1307.35	0.000124	2.16	41.59	18.05
67670	Culvert	CMP culvert at Turnout #8 - Peoria Rd.									
67648	62.8	1302.5	1308	1308	1306.06	1303.85	1306.16	0.000539	2.52	24.92	7.01
67648	90	1302.5	1308	1308	1306.64	1304.22	1306.79	0.000741	3.1	29.02	7.02
67646.5	Inline Weir	Turnout #8, rec. checkboards									
67644	54.2	1302.5	1308	1308	1305.61	1303.72	1305.71	0.000574	2.48	21.82	7.01
67644	90	1302.5	1308	1308	1306.63	1304.22	1306.78	0.000745	3.11	28.96	7.02
67643	Culvert										
67615	54.2	1301.89	1306.88	1307.6	1303.06	1303.06	1303.5	0.006664	5.3	10.23	12.07
67615	90	1301.89	1306.88	1307.6	1303.43	1303.43	1304	0.005847	6.05	14.89	13.47
67590	54.2	1301.65	1305.42	1305.03	1302.71	1302.8	1303.29	0.010117	6.12	8.85	11.53
67590	90	1301.65	1305.42	1305.03	1303.04	1303.2	1303.79	0.009174	6.93	12.99	12.95
67474	54.2	1300.28	1304.53	1303.93	1301.4	1301.53	1302.08	0.010525	6.64	8.16	9.47
67474	90	1300.28	1304.53	1303.93	1301.76	1301.98	1302.66	0.010122	7.6	11.84	10.79
67445	54.2	1299.35	1303.8	1303.8	1300.3	1300.71	1301.58	0.023677	9.08	5.97	7.9
67445	90	1299.35	1303.8	1303.8	1300.67	1301.16	1302.19	0.019751	9.9	9.09	9.12
66485	54.2	1296.61	1301.57	1301.24	1298.31	1297.96	1298.59	0.002762	4.27	12.68	10.06
66485	90	1296.61	1301.57	1301.24	1298.79	1298.41	1299.19	0.002943	5.02	17.92	11.59
66460	54.2	1296.61	1301.57	1301.24	1297.94	1297.94	1298.47	0.006627	5.81	9.32	9.13

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradeline Elevation (ft)	Energy Gradeline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
66460	90	1296.61	1301.57	1301.24	1298.39	1298.39	1299.06	0.00617	6.54	13.75	10.55
66180	54.2	1288.74	1292.43	1292.18	1289.31	1290.04	1293.23	0.128609	15.89	3.41	7.08
66180	90	1288.74	1292.43	1292.18	1289.54	1290.47	1294.32	0.105279	17.55	5.13	7.8
65070	54.2	1284.2	1288.11	1288.4	1285.57	1285.57	1286.07	0.006449	5.7	9.5	9.45
65070	90	1284.2	1288.11	1288.4	1286	1286	1286.65	0.006096	6.46	13.94	10.91
65042	54.2	1283.96	1288.48	1288.42	1284.96	1285.16	1285.78	0.01273	7.27	7.45	8.22
65042	90	1283.96	1288.48	1288.42	1285.4	1285.62	1286.39	0.01031	7.99	11.26	8.89
65028	54.2	1277.09	1288.48	1288.42	1283.35	1278.46	1283.38	0.000147	1.44	37.53	6
65028	90	1277.09	1288.48	1288.42	1283.98	1279	1284.06	0.000322	2.18	41.31	6
65027	Culvert	Inverted siphon									
64908	54.2	1277.02	1289.19	1289.19	1283.33		1283.36	0.000144	1.43	37.84	6
64908	90	1277.02	1289.19	1289.19	1283.92		1283.99	0.000321	2.18	41.36	6
64875	54.2	1281.17	1286.01	1286.11	1283.19		1283.34	0.0012	3.11	17.41	11.96
64875	90	1281.17	1286.01	1286.11	1283.75		1283.96	0.001266	3.66	24.62	13.68
63607	54.2	1279.04	1283.79	1283.62	1280.57		1280.89	0.003597	4.56	11.89	10.74
63607	90	1279.04	1283.79	1283.62	1281.04		1281.46	0.003418	5.18	17.36	12.28
63544	54.2	1278.72	1283.65	1283.65	1280.07	1280.07	1280.57	0.006467	5.7	9.5	9.43
63544	90	1278.72	1283.65	1283.65	1280.5	1280.5	1281.15	0.006071	6.46	13.92	10.78
63511	54.2	1278.4	1283.1	1282.84	1279.56	1279.73	1280.27	0.010702	6.8	7.97	8.95
63511	90	1278.4	1283.1	1282.84	1279.94	1280.17	1280.87	0.010111	7.73	11.65	10.23
62488	54.2	1272.13	1277.53	1276.86	1274.91	1273.51	1274.98	0.000414	2.12	25.53	13.78
62488	90	1272.13	1277.53	1276.86	1274.19	1273.96	1274.66	0.003773	5.47	16.46	11.41
62430	54.2	1271.93	1277.36	1275.94	1274.9		1274.96	0.000292	1.84	29.44	15.32
62430	90	1271.93	1277.36	1275.94	1274		1274.43	0.003524	5.26	17.1	12.05
62425	54.2	1271.93	1277.36	1275.94	1274.9		1274.95	0.000292	1.84	29.42	15.32
62425	90	1271.93	1277.36	1275.94	1273.96		1274.42	0.003814	5.42	16.61	11.9
62414	54.2	1270.52	1275	1275.94	1274.91	1271.94	1274.95	0.000078	1.52	35.74	15.88
62414	90	1270.52	1275	1275.94	1274.16	1272.4	1274.31	0.000431	3.1	29.01	13.95
62413	Culvert	CMP culvert under Olive Ave									
62370	45.1	1270.52	1277.49	1277.49	1274.87	1271.22	1274.87	0.000016	0.71	63.73	18.29
62370	90	1270.52	1277.49	1277.49	1273.91	1271.67	1273.96	0.000159	1.86	48.46	17.33
62366	Inline Weir	Turnout #9, rectangular checkdrop									
62364	45.1	1267.59	1277.49	1277.49	1269.52		1269.66	0.00115	2.99	15.09	7.82
62364	90	1267.59	1277.49	1277.49	1270.2		1270.5	0.001948	4.42	20.37	7.83
62307	45.1	1267.59	1272.99	1272.82	1269.31		1269.56	0.002468	3.96	11.4	9.22
62307	90	1267.59	1272.99	1272.82	1269.98		1270.36	0.002701	4.94	18.24	11.14
61428	45.1	1264.63	1269.06	1269.33	1265.75	1265.75	1266.19	0.006623	5.35	8.43	9.54
61428	90	1264.63	1269.06	1269.33	1266.29	1266.29	1266.92	0.006064	6.36	14.15	11.38
61283	45.1	1262.47	1267.17	1267.17	1263.41	1263.77	1264.56	0.022485	8.59	5.25	7.24
61283	90	1262.47	1267.17	1267.17	1263.9	1264.37	1265.41	0.018928	9.87	9.12	8.82
60795	45.1	1260.14	1264.46	1264.53	1261.71	1261.45	1262	0.003272	4.31	10.47	9.41
60795	90	1260.14	1264.46	1264.53	1262.37	1262.04	1262.78	0.003222	5.18	17.37	11.53
60785	45.1	1260.14	1264.46	1264.53	1261.45	1261.45	1261.93	0.00666	5.58	8.08	8.43
60785	90	1260.14	1264.46	1264.53	1262.05	1262.05	1262.72	0.00612	6.56	13.72	10.38
60492	45.1	1248.37	1251.67	1251.91	1248.76	1249.54	1255.18	0.322312	20.34	2.22	6.42
60492	90	1248.37	1251.67	1251.91	1249.02	1250.11	1256.77	0.214303	22.33	4.03	7.36

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradeline Elevation (ft)	Energy Gradeline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
59446	45.1	1243.74	1248.41	1248.7	1245.57	1245.05	1245.75	0.001731	3.4	13.28	10.61
59446	90	1243.74	1248.41	1248.7	1246.27	1245.62	1246.54	0.001815	4.17	21.56	12.92
58863	45.1	1242.17	1246.76	1246.69	1243.46	1243.46	1243.95	0.006669	5.58	8.08	8.44
58863	90	1242.17	1246.76	1246.69	1244.06	1244.06	1244.73	0.00617	6.58	13.68	10.38
58390	45.1	1238.01	1241.71	1241.75	1239.16	1239.3	1239.86	0.011259	6.75	6.68	7.8
58390	90	1238.01	1241.71	1241.75	1239.63	1239.91	1240.72	0.012025	8.39	10.72	9.36
58352	45.1	1237.4	1241.56	1241.14	1238.56	1238.78	1239.38	0.014234	7.28	6.19	7.72
58352	90	1237.4	1241.56	1241.14	1239.04	1239.38	1240.24	0.013749	8.8	10.23	9.2
58303	45.1	1236.99	1240.85	1240.75	1238.34	1238.42	1238.92	0.008473	6.12	7.37	7.99
58303	90	1236.99	1240.85	1240.75	1238.96	1239.02	1239.71	0.006972	6.92	13	9.95
58227	45.1	1236.11	1240.32	1239.89	1237.19	1237.45	1238.06	0.015249	7.52	6	7.53
58227	90	1236.11	1240.32	1239.89	1237.67	1238.04	1238.92	0.014295	8.97	10.04	9.05
57136	45.1	1231.39	1235.48	1235.57	1233.73	1232.58	1233.79	0.000484	2.11	21.41	13.44
57136	90	1231.39	1235.48	1235.57	1234.94	1233.14	1235.02	0.000341	2.23	40.35	17.62
57118	45.1	1231.28	1235.48	1235.57	1233.68	1232.52	1233.78	0.000483	2.62	17.21	13.03
57118	90	1231.28	1235.48	1235.57	1234.82	1233.1	1235	0.000463	3.41	26.38	17.1
57117	Culvert	CMP culvert at Northern Ave									
57090	40.2	1228.64	1235.46	1235.46	1231.92	1229.27	1231.93	0.000031	0.75	53.75	19.34
57090	90	1228.64	1235.46	1235.46	1232.84	1229.73	1232.86	0.000063	1.25	71.81	21
57083	Inline Weir	Turnout #10, rectangular checkdrop - Northern Ave									
57081	40.2	1229.82	1235.46	1235.46	1231.61		1231.75	0.001254	2.99	13.43	7.5
57081	90	1229.82	1235.46	1235.46	1232.31		1232.67	0.002464	4.82	18.66	7.5
57059	40.2	1229.82	1233.73	1234.41	1231.62		1231.72	0.000839	2.46	16.37	12.54
57059	90	1229.82	1233.73	1234.41	1232.41		1232.58	0.001002	3.28	27.44	15.37
57040	40.2	1229.82	1233.73	1234.41	1231.6		1231.7	0.000927	2.57	15.64	11.98
57040	90	1229.82	1233.73	1234.41	1232.37		1232.56	0.001145	3.46	25.98	14.72
56900	40.2	1229.82	1233.73	1234.41	1231.39		1231.53	0.001474	3.03	13.25	11.25
56900	90	1229.82	1233.73	1234.41	1232.09		1232.35	0.001808	4.09	21.99	13.73
56814	40.2	1229.87	1233.52	1233.58	1230.9	1230.88	1231.28	0.006289	4.94	8.13	10.13
56814	90	1229.87	1233.52	1233.58	1231.48	1231.48	1232.06	0.005929	6.12	14.71	12.59
56444	40.2	1227.15	1230.38	1231.02	1228.42	1228.42	1228.86	0.006753	5.36	7.5	8.52
56444	90	1227.15	1230.38	1231.02	1229.03	1229.08	1229.73	0.006746	6.68	13.47	10.84
56359	40.2	1224.86	1228.12	1228.68	1225.51	1226.02	1227.44	0.057037	11.16	3.6	6.91
56359	90	1224.86	1228.12	1228.68	1225.96	1226.66	1228.4	0.039786	12.53	7.18	8.72
55689	40.2	1214.71	1219.95	1220.97	1215.8	1215.81	1216.26	0.007558	5.41	7.42	9.13
55689	90	1214.71	1219.95	1220.97	1216.3	1216.46	1217.12	0.0088	7.26	12.4	10.85
55226	40.2	1210.47	1214.21	1215.67	1211.98	1211.72	1212.25	0.003166	4.11	9.79	9.31
55226	90	1210.47	1214.21	1215.67	1212.73	1212.4	1213.13	0.003089	5.1	17.65	11.7
55216	40.2	1210.47	1214.21	1215.67	1211.73	1211.73	1212.18	0.006633	5.38	7.47	8.27
55216	90	1210.47	1214.21	1215.67	1212.4	1212.4	1213.07	0.006125	6.57	13.71	10.41
55207	40.2	1206.77	1216.64	1216.64	1210.45	1208	1210.52	0.000457	2.1	19.11	5.2
55207	90	1206.77	1216.64	1216.64	1211.26	1208.88	1211.49	0.001391	3.86	23.31	5.2
55206	Culvert	Inverted siphon									
55107	40.2	1206.8	1216.7	1216.7	1210.41		1210.48	0.00048	2.14	18.76	5.2
55107	90	1206.8	1216.7	1216.7	1211.13		1211.38	0.00152	4	22.49	5.2
55076	40.2	1208.93	1213.2	1212.78	1209.98	1209.98	1210.41	0.006731	5.24	7.67	9.03
55076	90	1208.93	1213.2	1212.78	1210.61	1210.61	1211.26	0.006097	6.42	14.01	11.08

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradeline Elevation (ft)	Energy Gradeline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
52886	40.2	1203.74	1207.91	1207.88	1205.75	1204.94	1205.85	0.000888	2.58	15.57	11.3
52886	90	1203.74	1207.91	1207.88	1206.88	1205.59	1207.02	0.000708	2.95	30.54	15.08
52861	40.2	1203.74	1207.91	1207.88	1205.85	1204.93	1205.82	0.001026	3.32	12.11	10.95
52861	90	1203.74	1207.91	1207.88	1206.62	1205.64	1206.97	0.001164	4.76	18.92	14.2
52860	Inline Weir Rectangular weir & checkdrop - unused										
52858	40.2	1203.56	1208.05	1207.92	1205.01	1204.69	1205.24	0.002492	3.88	10.36	9.6
52858	90	1203.56	1208.05	1207.92	1205.62	1205.3	1206.12	0.003054	5.69	15.81	11.42
52835	40.2	1203.56	1208.05	1207.92	1204.7	1204.7	1205.14	0.006705	5.31	7.57	8.66
52835	90	1203.56	1208.05	1207.92	1205.35	1205.35	1206	0.006086	6.51	13.83	10.61
51835	40.2	1194.51	1198.04	1197.76	1196.91	1195.52	1196.95	0.000295	1.7	23.6	14.02
51835	90	1194.51	1198.04	1197.76	1195.85	1196.18	1196.95	0.013315	8.39	10.73	10.37
51803	30.8	1193.88	1198.33	1198.33	1196.93	1194.8	1196.94	0.000059	0.88	35.17	16.85
51803	90	1193.88	1198.33	1198.33	1196.57	1195.45	1196.72	0.000822	3.06	29.4	15.62
51802	Inline Weir Turnout #11, rec. weir checkdrop - Glendale Ave										
51801	30.8	1193.88	1198.33	1198.33	1194.8	1194.8	1195.09	0.005287	4.32	7.13	9.49
51801	90	1193.88	1198.33	1198.33	1195.48	1195.48	1196.09	0.005975	6.25	14.41	11.85
51799	30.8	1192.23	1196.73	1196.52	1192.66	1193.11	1194.85	0.100674	11.89	2.59	7.01
51799	90	1192.23	1196.73	1196.52	1193.2	1193.93	1195.86	0.046502	13.09	6.88	8.77
51797	30.8	1190.59	1195.12	1194.7	1190.98	1191.56	1194.45	0.181241	14.94	2.06	6.12
51797	90	1190.59	1195.12	1194.7	1191.48	1192.4	1195.61	0.081389	16.3	5.52	7.66
51795	30.8	1188.94	1193.52	1192.89	1189.32	1189.99	1194.06	0.255826	17.47	1.76	5.33
51795	90	1188.94	1193.52	1192.89	1189.82	1190.88	1195.38	0.11475	18.92	4.76	6.75
51758	30.8	1188.94	1193.52	1192.89	1190.66	1189.99	1190.77	0.001135	2.69	11.43	9.16
51758	90	1188.94	1193.52	1192.89	1191.86	1190.87	1192.07	0.001205	3.67	24.52	12.62
50260	30.8	1186.7	1191.09	1190.63	1188.03		1188.23	0.002813	3.65	8.45	8.84
50260	90	1186.7	1191.09	1190.63	1188.93		1189.32	0.003063	5.05	17.82	11.96
49239	30.8	1182.51	1186.22	1186.01	1183.6	1183.6	1183.99	0.00679	5.01	6.15	7.77
49239	90	1182.51	1186.22	1186.01	1184.44	1184.44	1185.09	0.005971	6.44	13.97	10.77
48847	30.8	1179.71	1183.46	1183.59	1180.91	1180.91	1181.32	0.006835	5.13	6.01	7.31
48847	90	1179.71	1183.46	1183.59	1181.69	1181.79	1182.48	0.007327	7.11	12.65	9.65
48015	30.8	1173.29	1177.32	1177.03	1174.36	1174.43	1174.84	0.009083	5.57	5.53	7.45
48015	90	1173.29	1177.32	1177.03	1175.13	1175.29	1175.96	0.008382	7.29	12.35	10.28
46576	30.8	1167.09	1170.52	1170.32	1169	1168.02	1169.06	0.000486	1.91	16.13	11.81
46576	90	1167.09	1170.52	1170.32	1169.9	1168.82	1170.05	0.000907	3.2	28.12	14.96
46555	19.9	1166.83	1170.52	1170.32	1169.02	1167.64	1169.04	0.000174	1.19	16.66	11.15
46555	80	1166.83	1170.52	1170.32	1169.9	1168.62	1170.03	0.000707	2.88	27.8	14.08
46554	Inline Weir Turnout #12, broadcrested weir - Bethany Home Rd.										
46552	19.9	1166.83	1170.52	1170.32	1167.64	1167.64	1167.96	0.007338	4.56	4.36	6.72
46552	80	1166.83	1170.52	1170.32	1168.61	1168.61	1169.25	0.006217	6.41	12.49	9.91
46492	19.9	1165.86	1169	1169.77	1166.42	1166.61	1167.1	0.027492	6.64	3	7.37
46492	80	1165.86	1169	1169.77	1167.04	1167.5	1168.54	0.022195	9.84	8.13	9.11
46476	19.9	1161.26	1171.41	1171.41	1163.92	1162.12	1163.97	0.000406	1.7	11.73	4.41
46476	80	1161.26	1171.41	1171.41	1162.25	1163.43	1167.47	0.1012	18.34	4.36	4.4
46475	Culvert Inverted siphon										
46370	19.9	1161.02	1169.12	1169.12	1163.9		1163.94	0.000331	1.57	12.7	4.41
46370	80	1161.02	1169.12	1169.12	1165.08		1165.39	0.002255	4.47	17.88	4.41

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Grade Line Elevation (ft)	Energy Grade Line Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
46344	19.9	1162.41	1167.54	1166.08	1163.88		1163.93	0.000551	1.78	11.15	9.93
46344	80	1162.41	1167.54	1166.08	1165.16	1164.03	1165.31	0.000812	3.02	26.51	13.99
46000	19.9	1162.41	1167.54	1166.08	1163.11	1163.11	1163.42	0.00781	4.47	4.45	7.51
46000	80	1162.41	1167.54	1166.08	1164.01	1164.01	1164.65	0.006473	6.4	12.5	10.36
45286	19.9	1159.93	1164.41	1164.32	1161.17	1160.68	1161.25	0.001127	2.31	8.62	8.99
45286	80	1159.93	1164.41	1164.32	1162.44	1161.6	1162.63	0.001257	3.55	22.54	12.98
44095	19.9	1157.37	1161.32	1161.46	1158.16	1158.16	1158.46	0.007364	4.4	4.52	7.53
44095	80	1157.37	1161.32	1161.46	1159.05	1159.05	1159.69	0.006534	6.44	12.42	10.31
43812	19.9	1155.45	1159.11	1159.05	1156.03	1156.23	1156.71	0.025379	6.62	3	6.92
43812	80	1155.45	1159.11	1159.05	1157.46	1157.13	1157.82	0.003089	4.84	16.53	12.02
42772	19.9	1152.67	1156.69	1156.58	1154.11	1153.62	1154.2	0.001268	2.43	8.17	8.66
42772	80	1152.67	1156.69	1156.58	1155.29		1155.52	0.001614	3.87	20.66	12.64
42290	19.9	1151.78	1155.75	1156.08	1152.59	1152.59	1152.93	0.008435	4.67	4.26	7.11
42290	80	1151.78	1155.75	1156.08	1153.61	1153.55	1154.18	0.005525	6.08	13.16	10.4
41779	19.9	1150.48	1154.57	1154.02	1151.78	1151.2	1151.84	0.00081	1.9	10.46	11.74
41779	80	1150.48	1154.57	1154.02	1152.84		1152.99	0.001076	3.13	25.58	16.61
41290	19.9	1149.64	1153.5	1153.97	1151.64		1151.66	0.000181	1.2	16.61	11.44
41290	80	1149.64	1153.5	1153.97	1151.29	1151.29	1151.9	0.00621	6.27	12.75	10.49
41275	9.8	1149	1153.8	1153.8	1151.65	1149.46	1151.66	0.000013	0.47	20.69	12.35
41275	74	1149	1153.8	1153.8	1151.31	1150.45	1151.57	0.001151	4.13	17.92	11.58
41274	Inline Weir	Turnout #13, rectangular weir checkboard - Camelback Rd.									
41272	9.8	1148.52	1152.23	1152.39	1149.44	1149.03	1149.5	0.001204	1.94	5.05	7.27
41272	74	1148.52	1152.23	1152.39	1150.94	1150.21	1151.23	0.001404	4.38	16.9	12.83
41244	9.8	1148.52	1152.23	1152.39	1149.39		1149.46	0.001563	2.15	4.56	6.82
41244	74	1148.52	1152.23	1152.39	1150.95		1151.17	0.00158	3.73	19.85	12.76
39573	9.8	1144.23	1147.17	1147.07	1144.78	1144.78	1144.94	0.005725	3.25	3.01	6.57
39573	74	1144.23	1147.17	1147.07	1145.83	1145.83	1146.42	0.006386	6.17	11.99	10.52
38670	9.8	1141.73	1145.21	1145.21	1143.05	1142.2	1143.07	0.000258	1.12	8.73	8.82
38670	74	1141.73	1145.21	1145.21	1144.69	1143.39	1144.8	0.000615	2.67	27.77	14.32
38660	5	1141.73	1145.21	1145.21	1143.06	1142.08	1143.06	0.000067	0.57	8.73	8.75
38660	74	1141.73	1145.21	1145.21	1144.64	1143.38	1144.79	0.000599	3.19	23.23	14.1
38658	Inline Weir	Turnout 13.5, rectangular checkboard									
38654	5	1141.46	1145.15	1145.19	1142.16		1142.2	0.001088	1.56	3.21	5.95
38654	74	1141.46	1145.15	1145.19	1143.97		1144.21	0.001688	3.91	18.91	11.45
38615	5	1141.41	1145.09	1145.13	1142.13		1142.16	0.001	1.51	3.3	5.98
38615	74	1141.41	1145.09	1145.13	1143.9		1144.14	0.001718	3.95	18.71	11.4
38389	5	1141.09	1144.56	1144.51	1141.49	1141.49	1141.64	0.009067	3.15	1.59	5.17
38389	74	1141.09	1144.56	1144.51	1142.85	1142.85	1143.44	0.006139	6.18	11.98	10.06
38161	5	1139.47	1142.69	1142.87	1140.07	1139.9	1140.15	0.003214	2.26	2.21	5.36
38161	74	1139.47	1142.69	1142.87	1141.28	1141.34	1141.94	0.006993	6.51	11.37	9.71
36755	5	1131.81	1135.01	1135.25	1132.24	1132.24	1132.43	0.011642	3.52	1.42	4.67
36755	74	1131.81	1135.01	1135.25	1134.37	1133.68	1134.6	0.001652	3.85	19.23	12.01
36063	5	1130.15	1133.78	1135.06	1131.77	1130.51	1131.78	0.000043	0.5	10.06	8.82
36063	74	1130.15	1133.78	1135.06	1131.94	1131.94	1132.57	0.006325	6.37	11.62	9.37
36052	5	1130.13	1135.88	1135.88	1131.77	1130.4	1131.78	0.000021	0.38	13.15	8.01
36052	74	1130.13	1135.88	1135.88	1132.06	1131.52	1132.41	0.002941	4.8	15.41	8.01

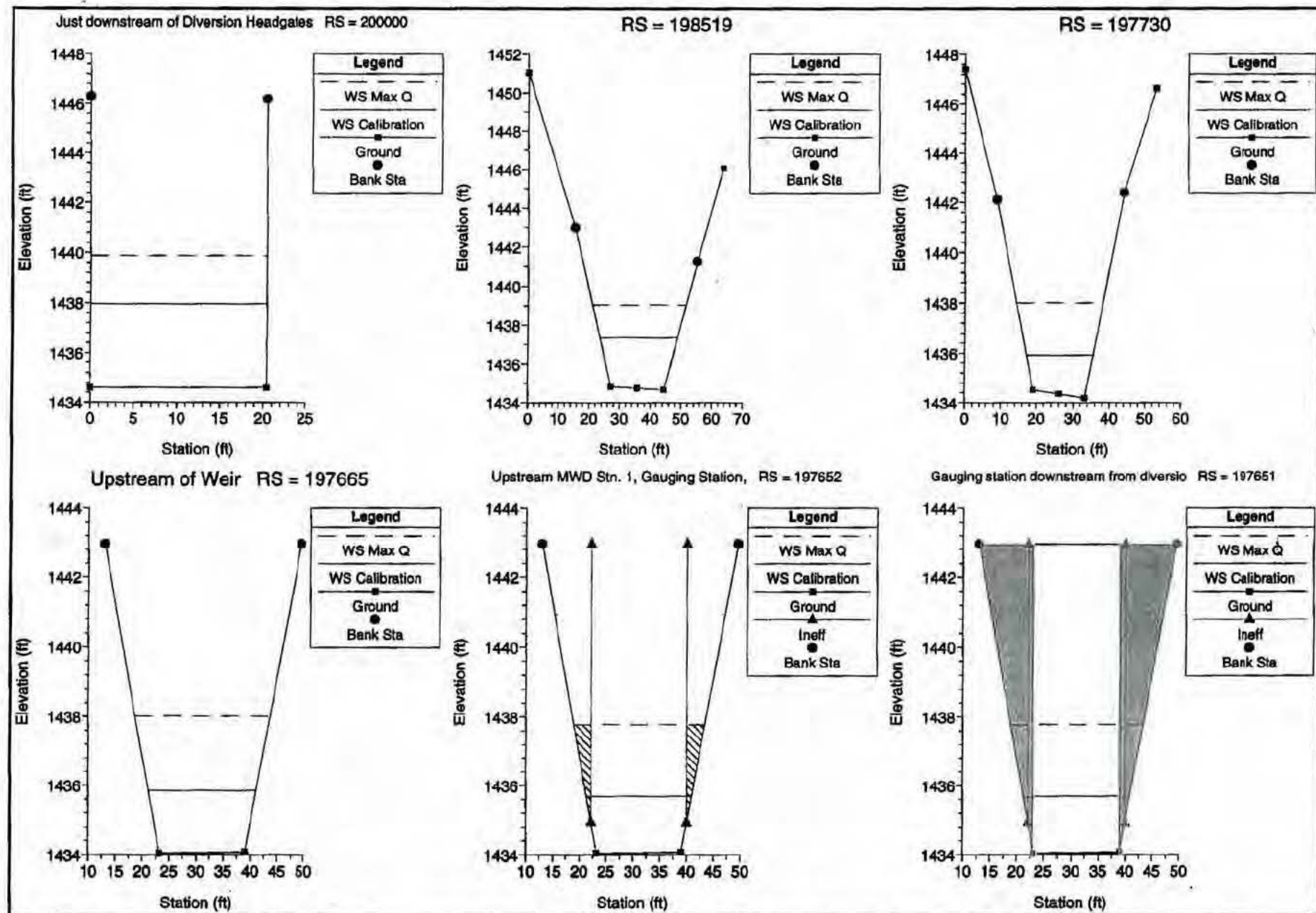
(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

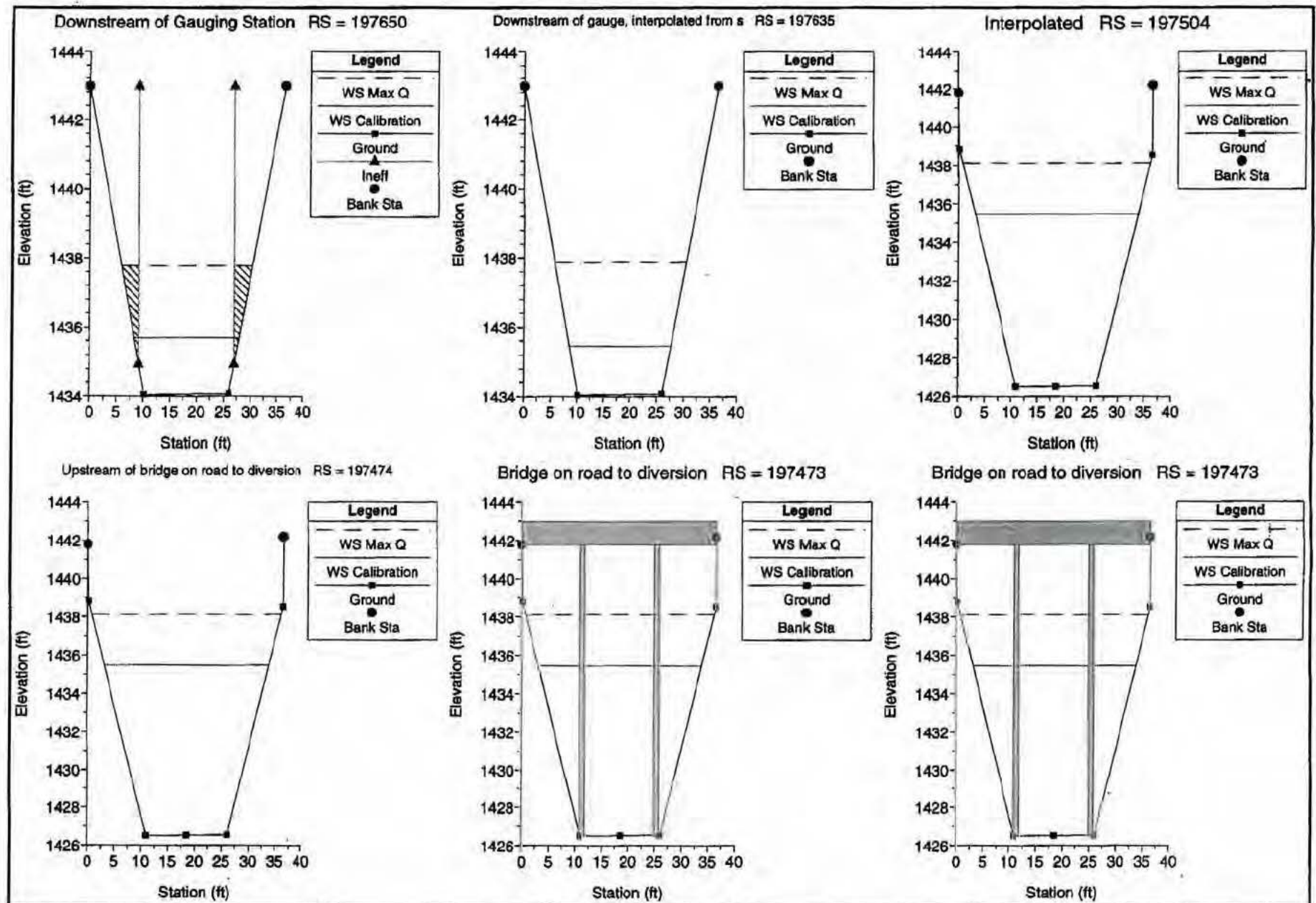
Beardsley Canal Capacity Study
Summary Table - HEC-RAS Model Output
at Calibration and Maximum Flow Rate Profiles

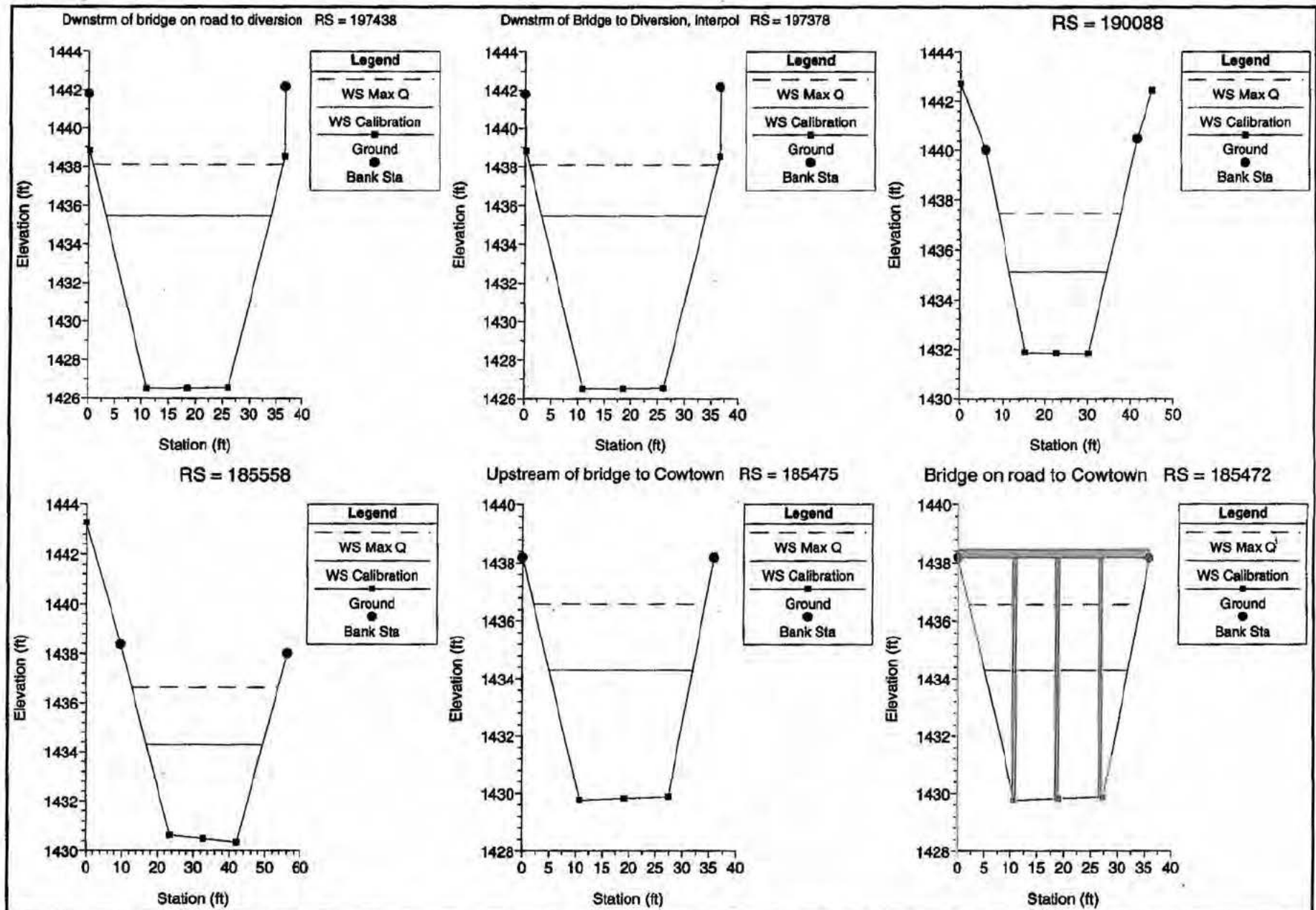
River Station	Flow Rate ⁽¹⁾ (cfs)	Channel Invert Elevation (ft)	Left Overbank Elevation (ft)	Right Overbank Elevation (ft)	Computed Water Surface Elevation (ft)	Critical Water Surface Elevation (ft)	Energy Gradeline Elevation (ft)	Energy Gradeline Slope (ft/ft)	Velocity in Channel (ft/s)	Flow Area (sq ft)	Top Width (ft)
36051	Culvert	Box culvert at Indian School Rd.									
36015	1	1128.27	1134.23	1134.23	1131.77	1128.35	1131.77	0	0.02	47.87	14.94
36015	10	1128.27	1134.23	1134.23	1130.55	1128.57	1130.55	0.000009	0.33	30.73	14.18
36011	Inline Weir	Turnout #14, rec. weir checkdrop									
36009	1	1125.81	1127.83	1127.82	1126.31		1126.34	0.001572	1.35	0.74	1.99
36009	10	1125.81	1127.83	1127.82	1127.23		1127.37	0.002607	2.94	3.4	3.77
35977	1	1125.81	1127.83	1127.82	1126.08	1126.08	1126.22	0.013835	2.92	0.34	1.55
35977	10	1125.81	1127.83	1127.82	1126.85	1126.85	1127.2	0.009276	4.74	2.11	3.04

(1) 1st value = calibration flow rate, 2nd value = maximum flow rate

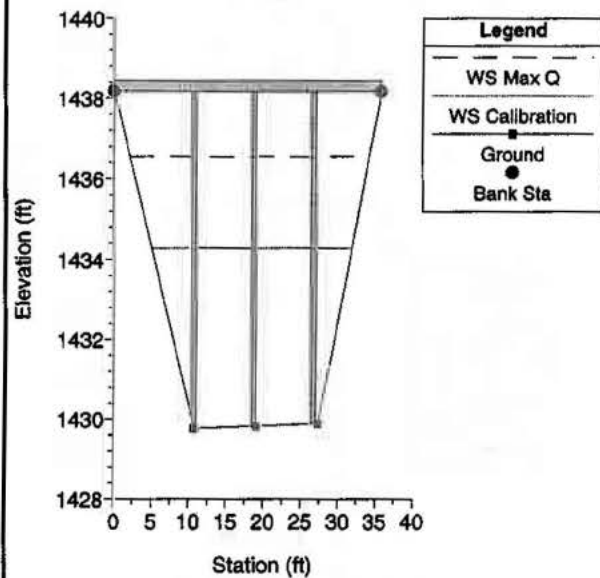
**COMPLETE SET OF
CROSS-SECTIONS FOR THE
HEC-RAS BEARDSLEY CANAL MODEL**



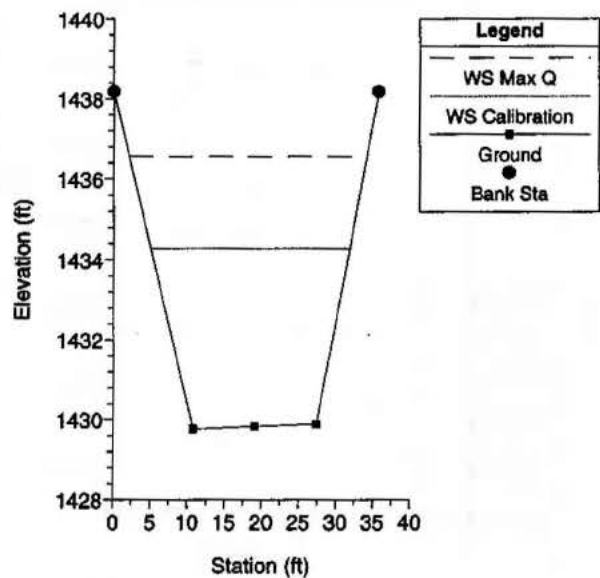




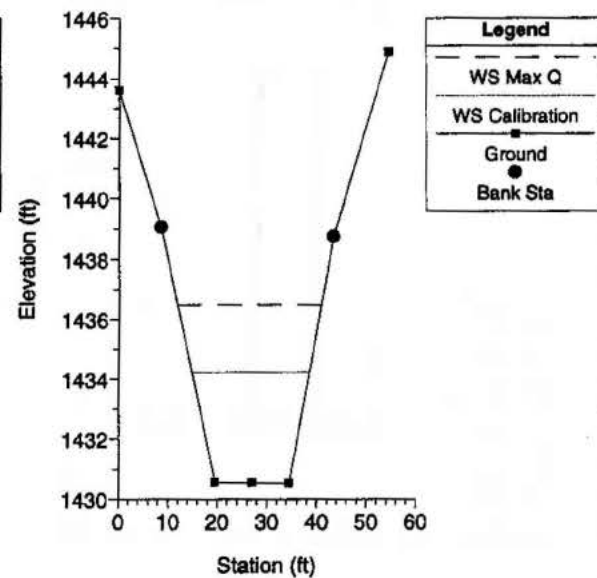
Bridge on road to Cowtown RS = 185472



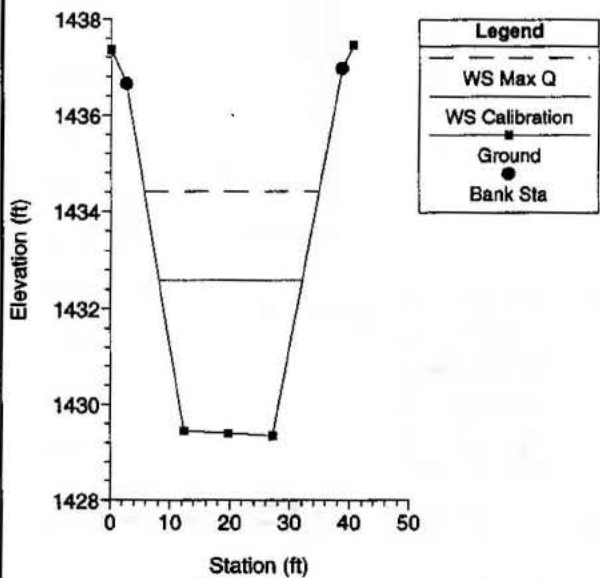
Downstream of Bridge to Cowtown RS = 185436



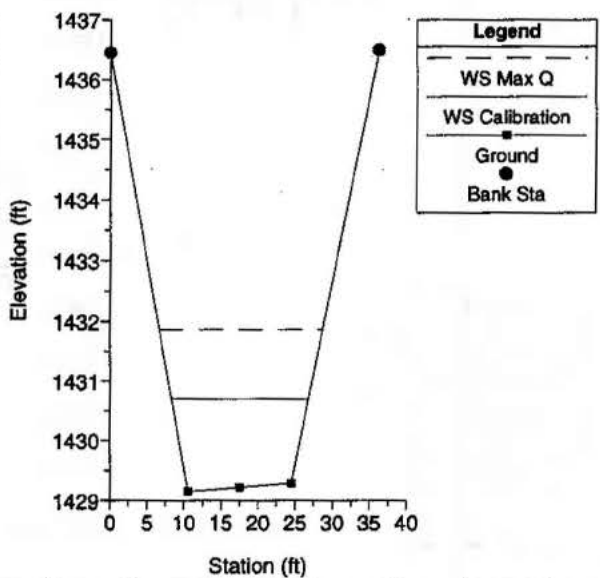
RS = 185377



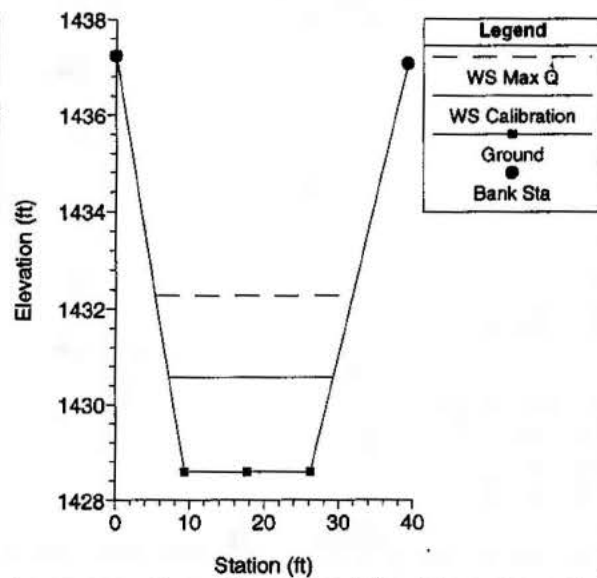
RS = 179629

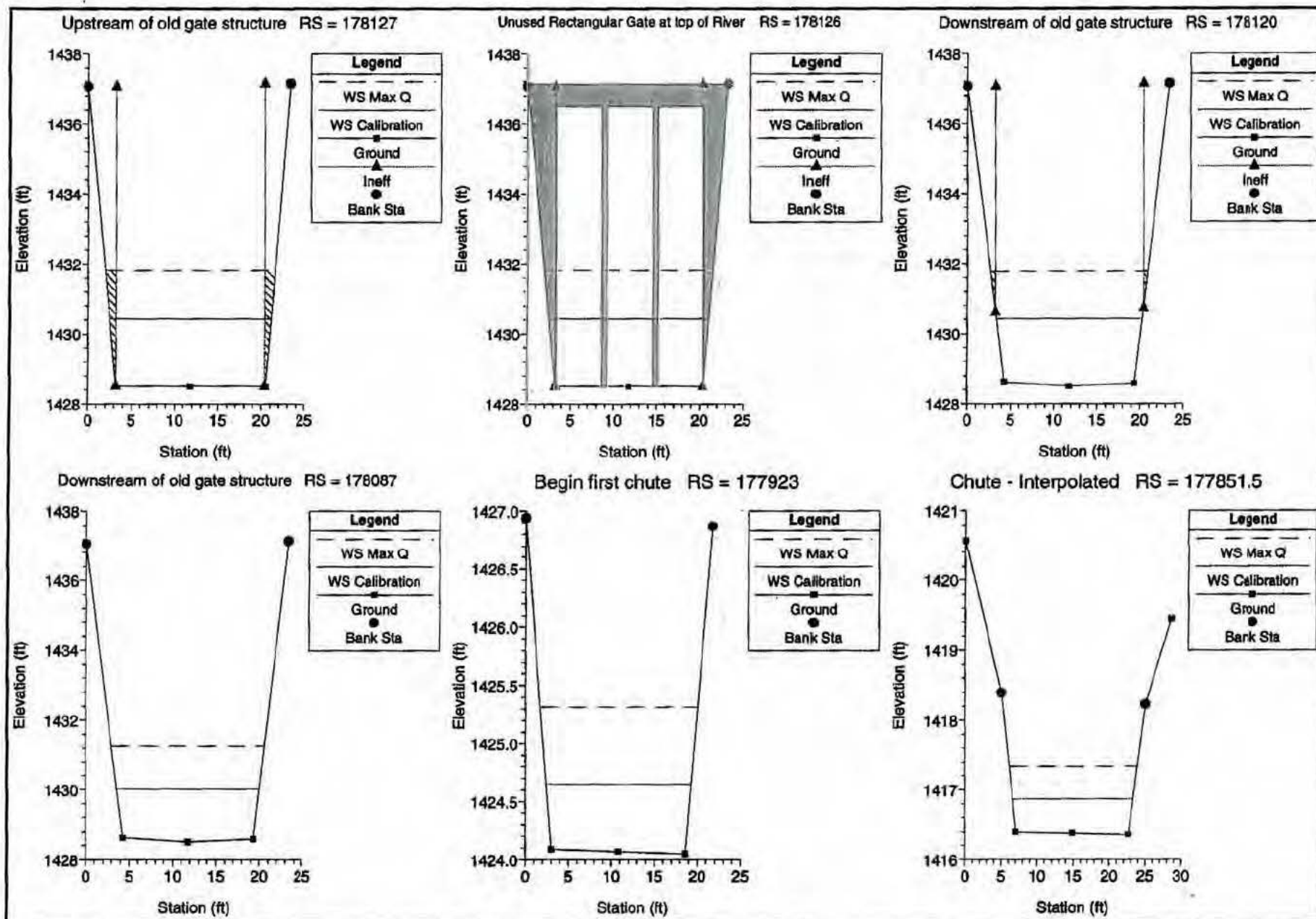


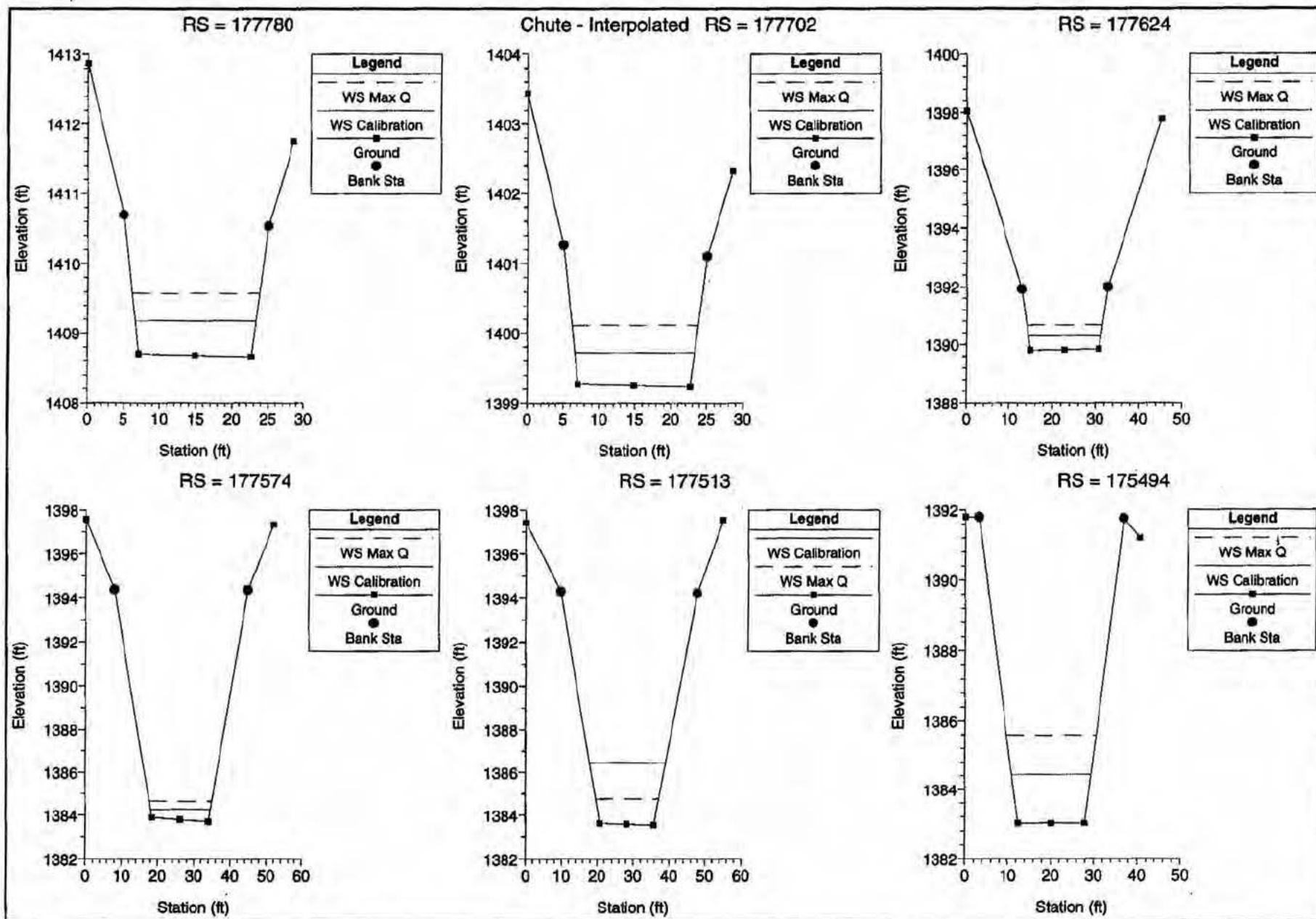
RS = 178191

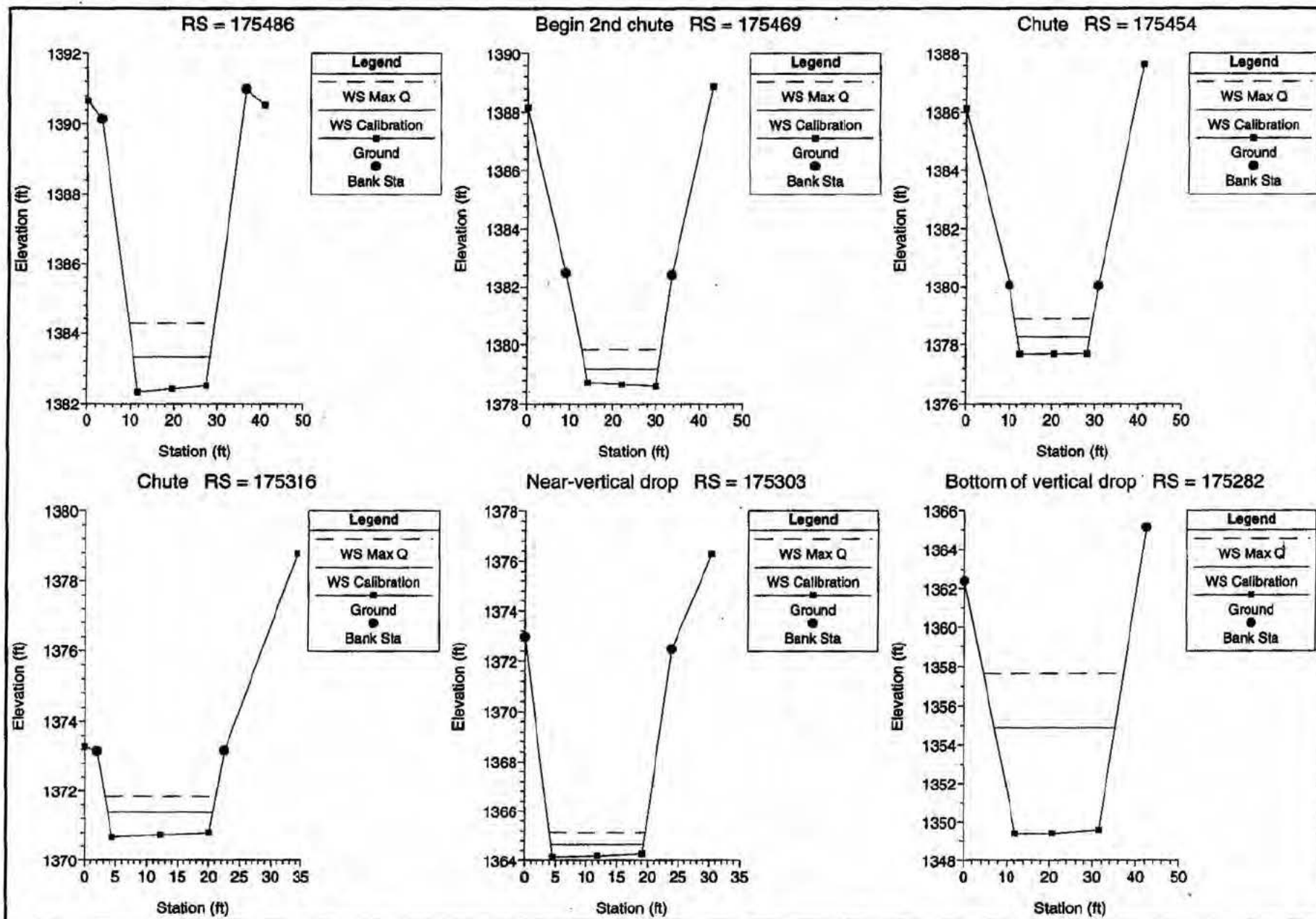


RS = 178157

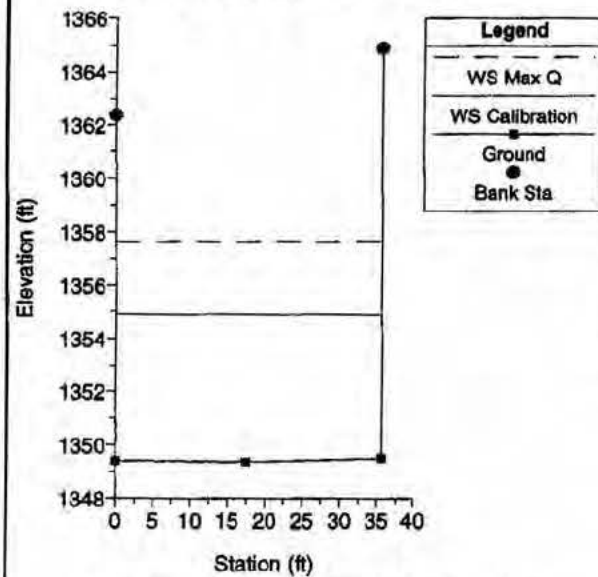




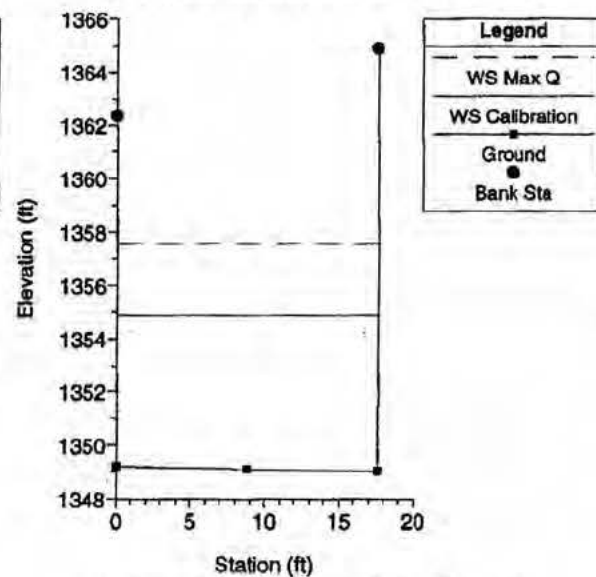




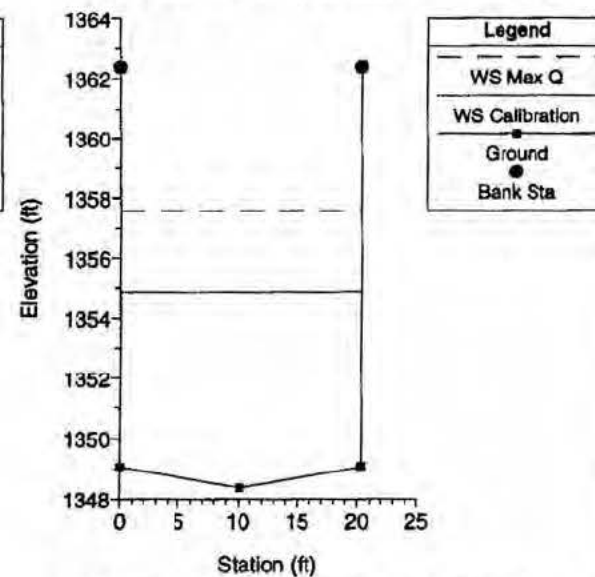
Pool at end of chutes RS = 175268



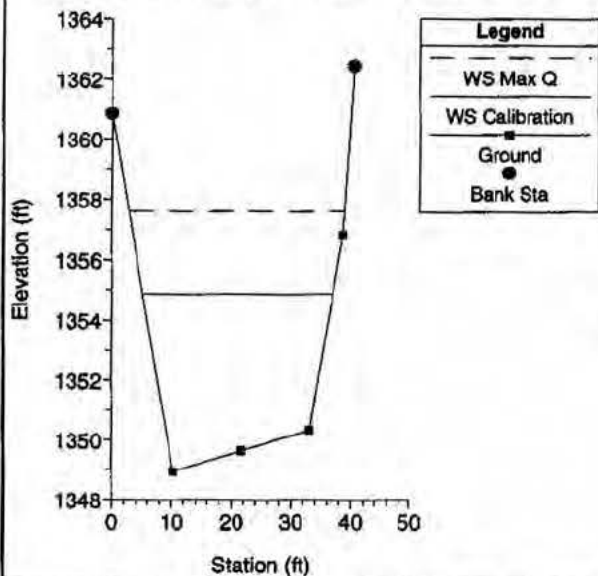
Pool and turn at end of chutes RS = 175250



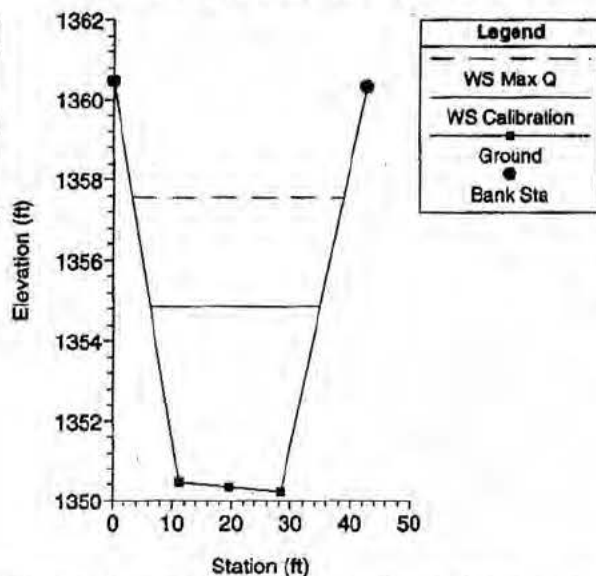
Pool and turn at end of chutes RS = 175240



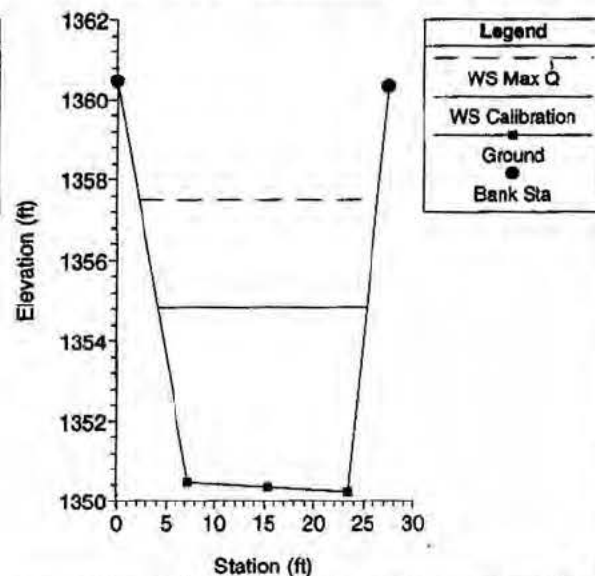
N. of bend to river flume RS = 175217

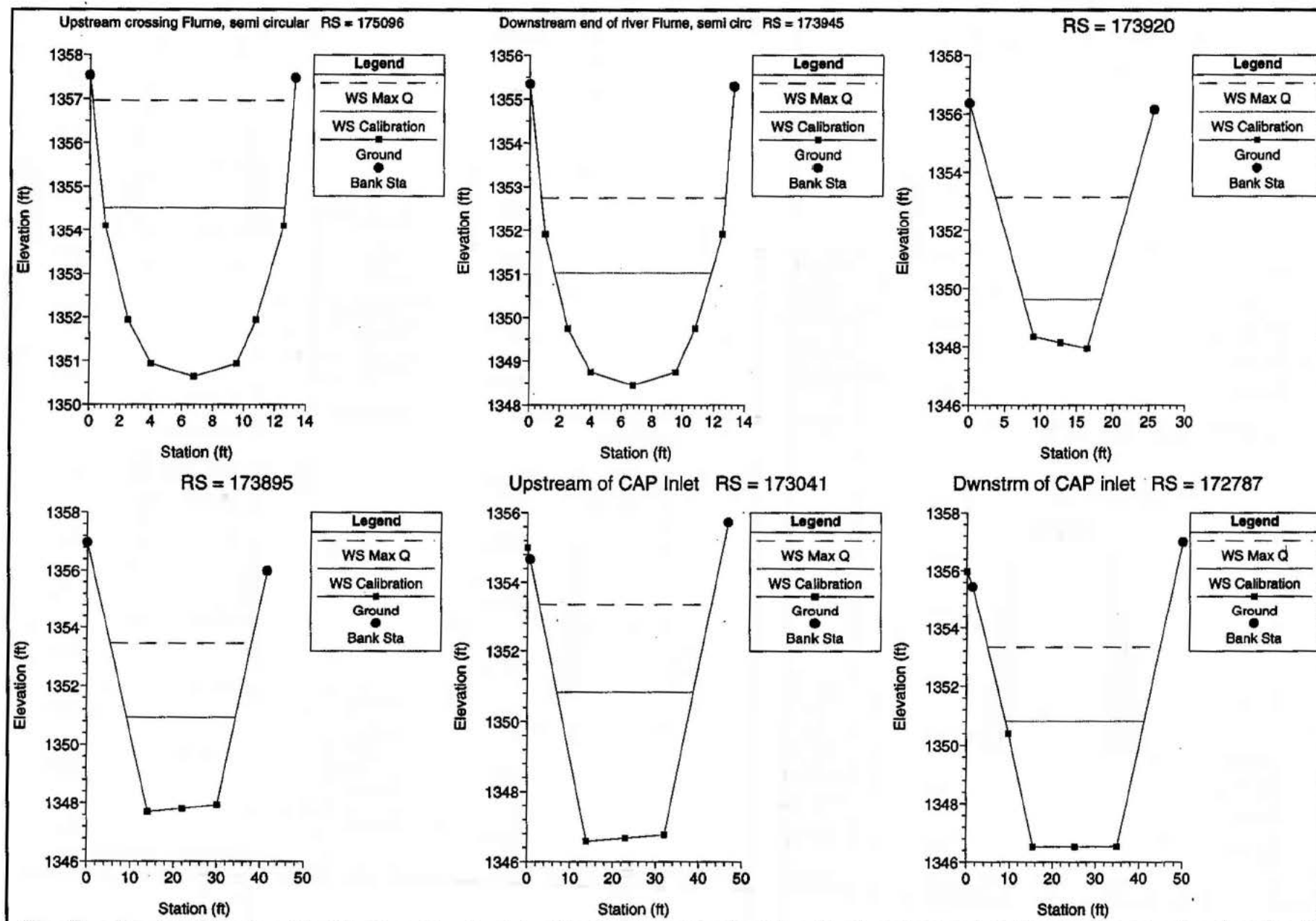


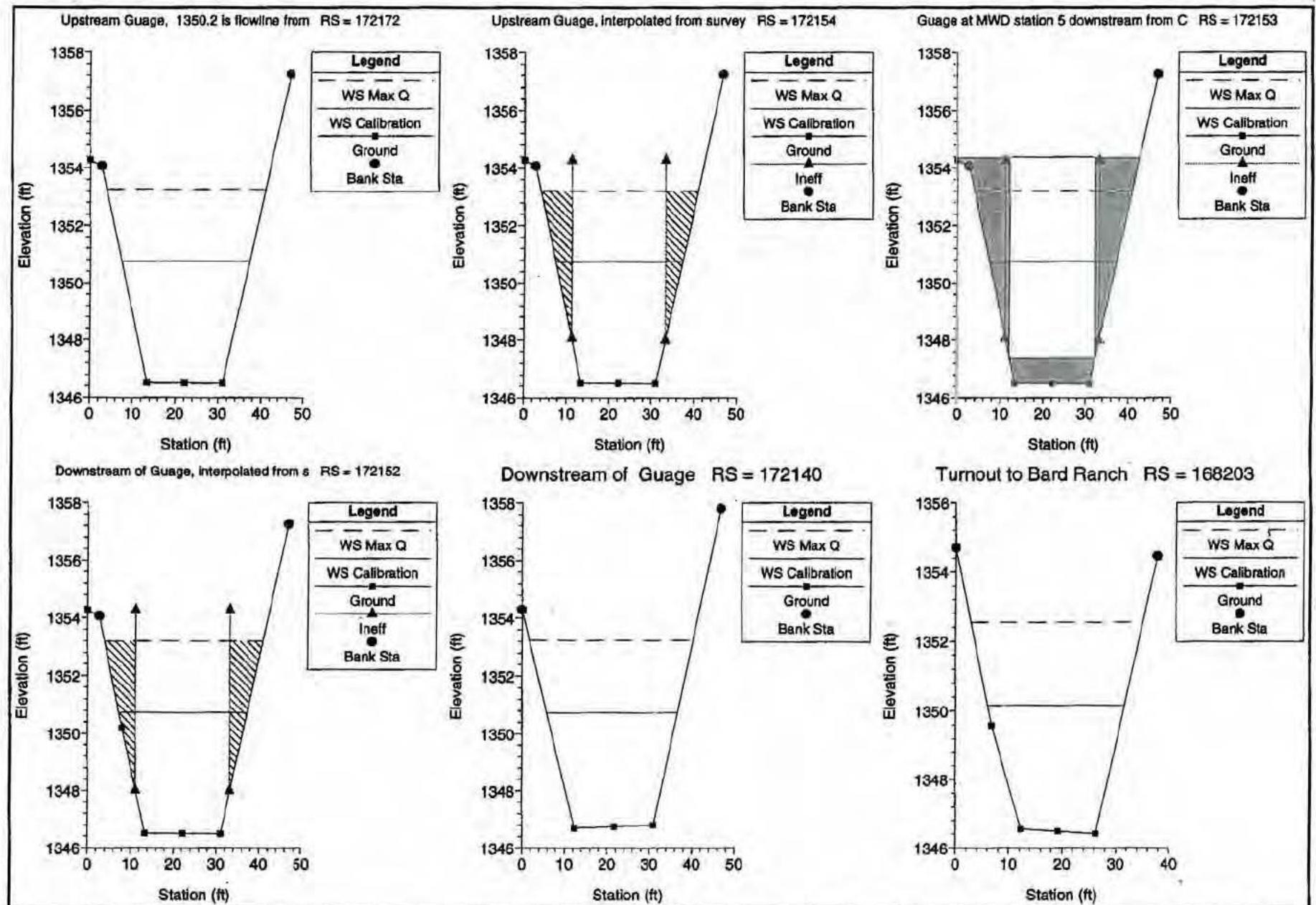
At bend to river flume RS = 175197

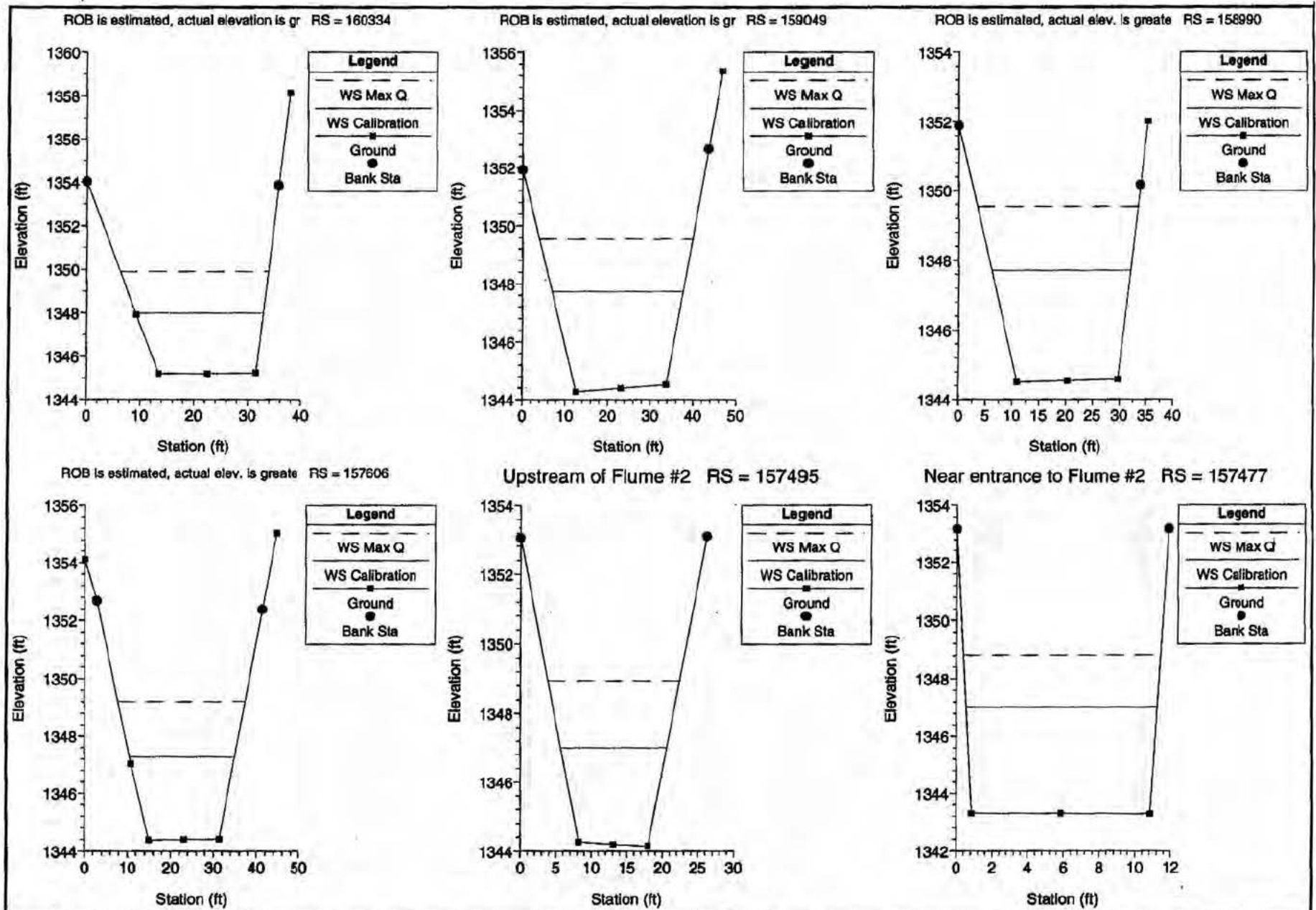


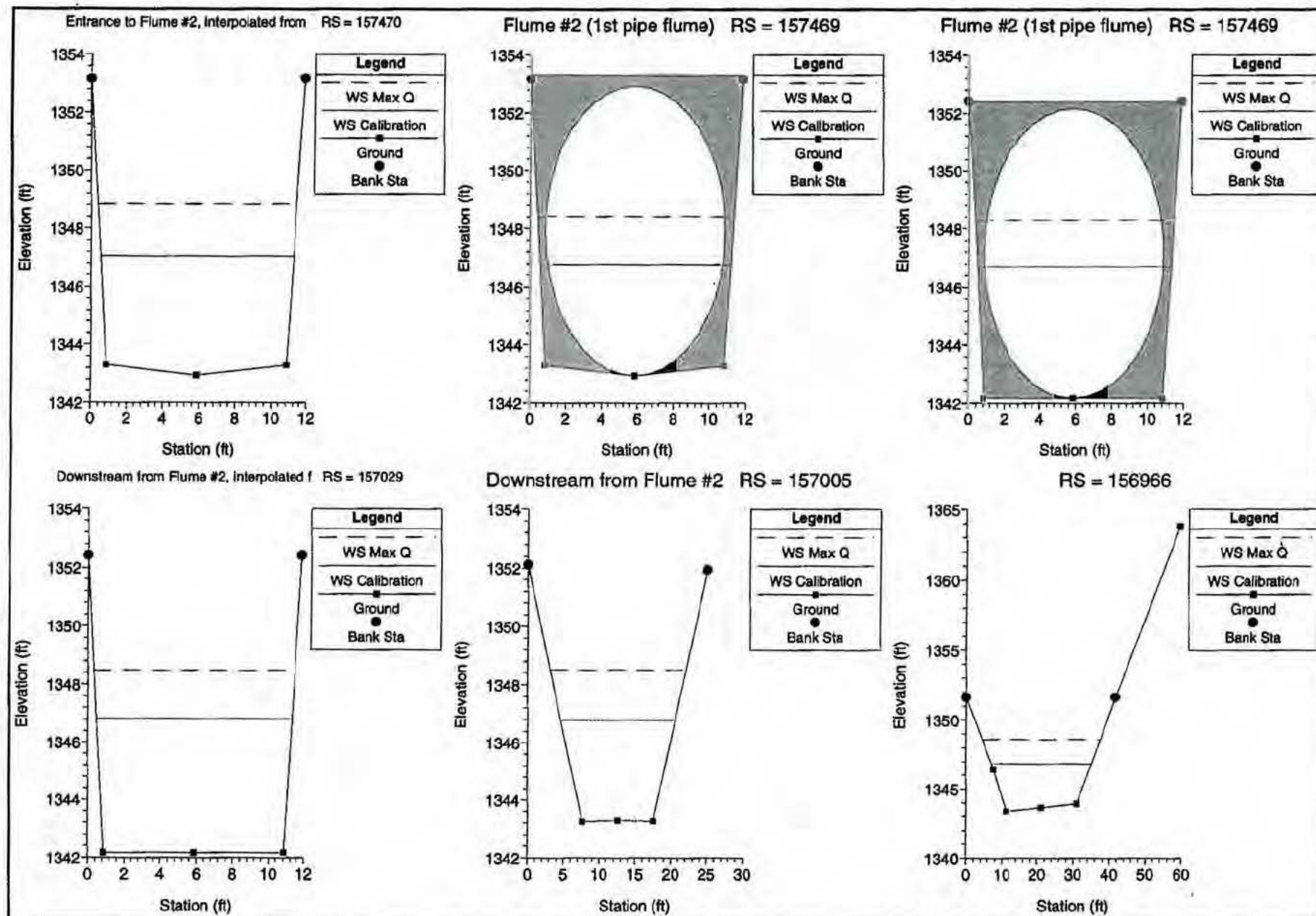
Between bend to river flume and river RS = 175177

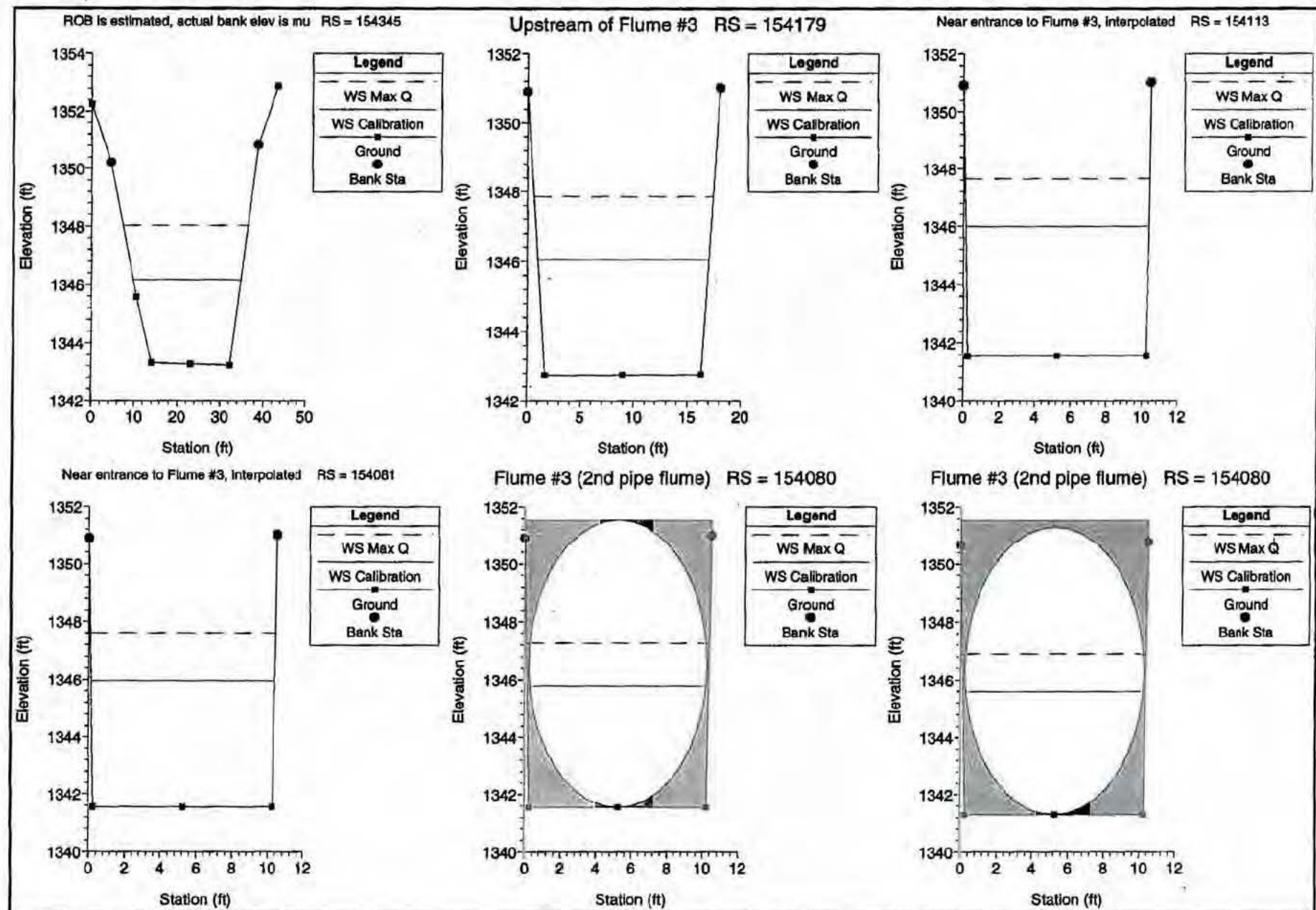


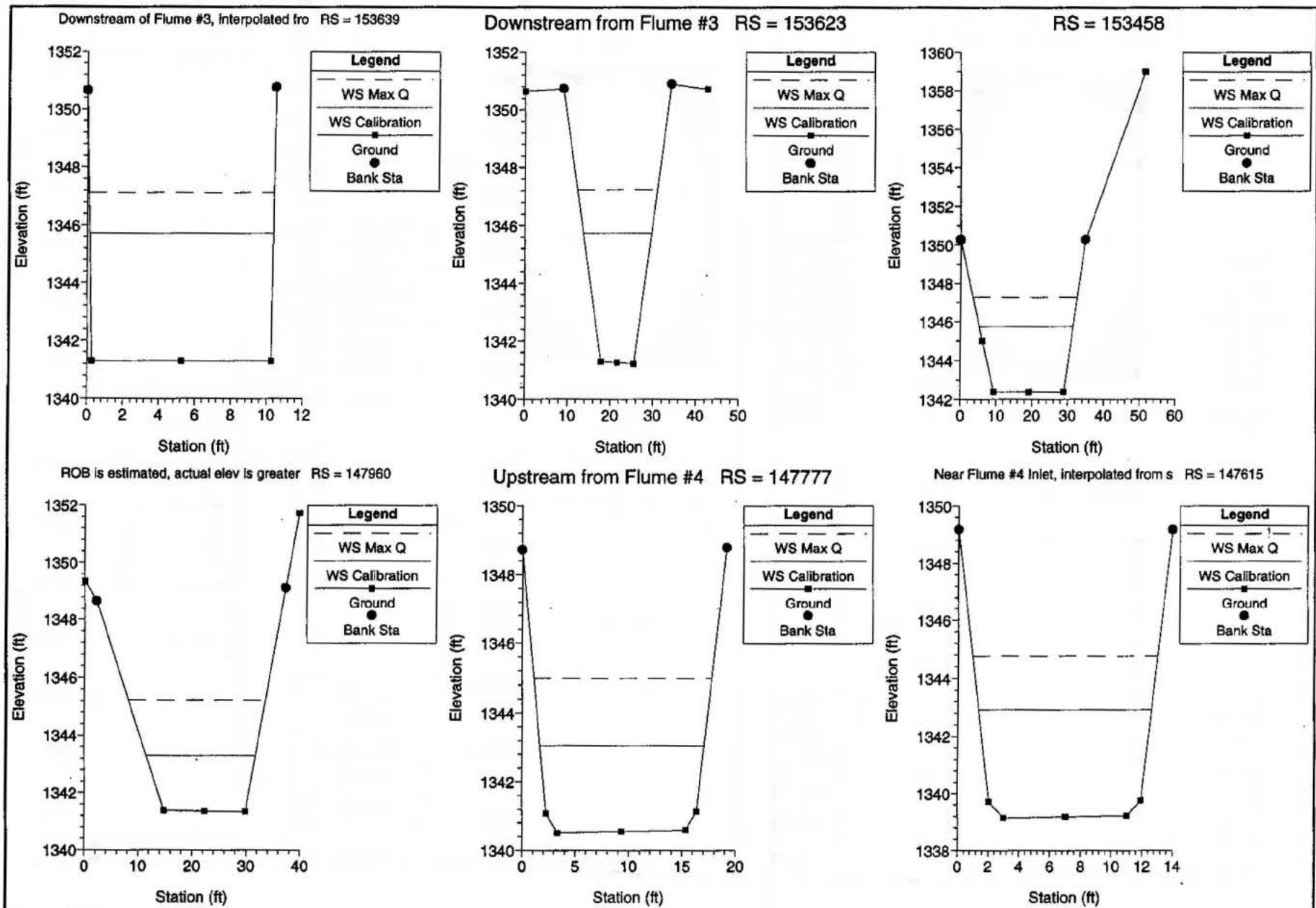


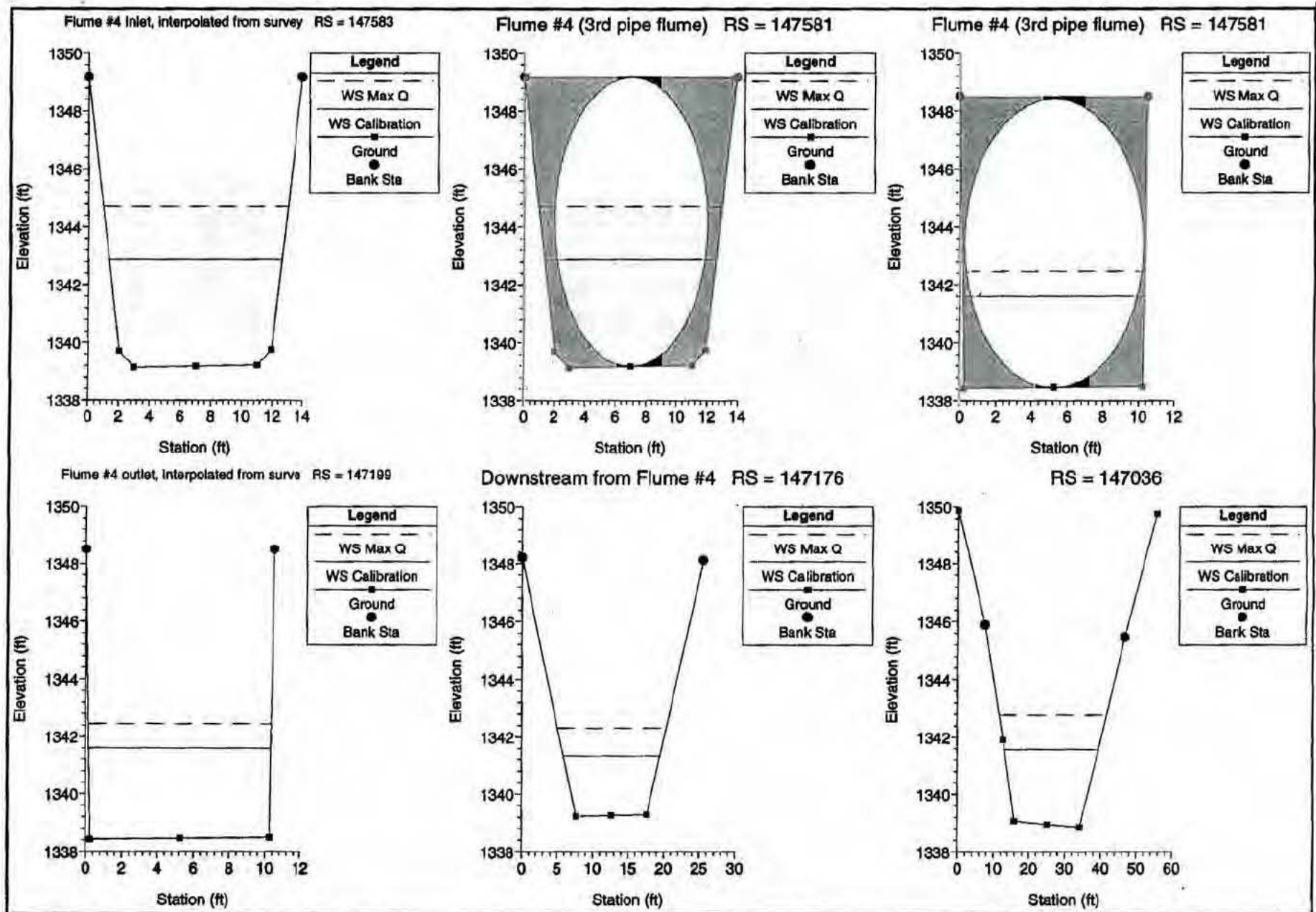


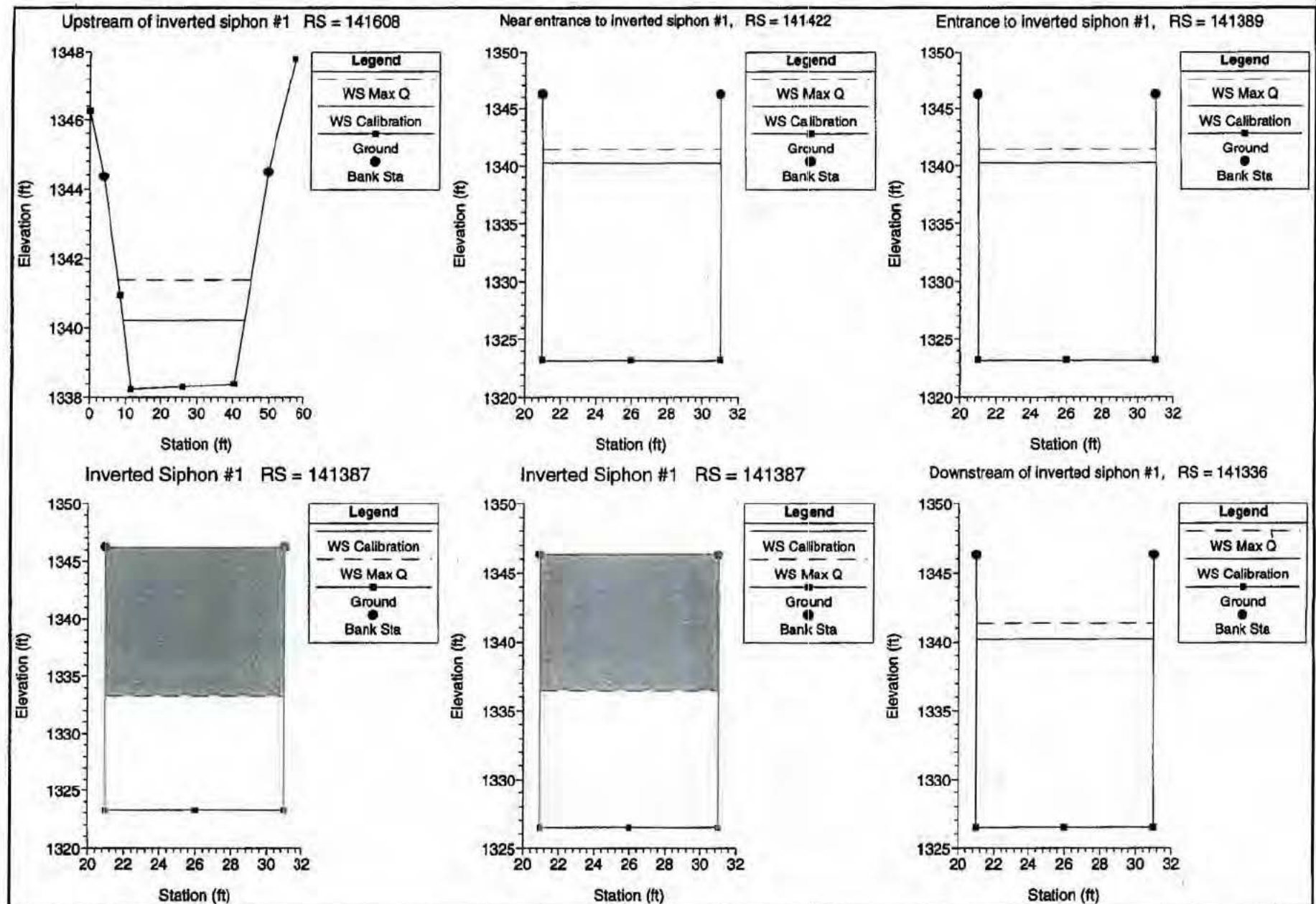


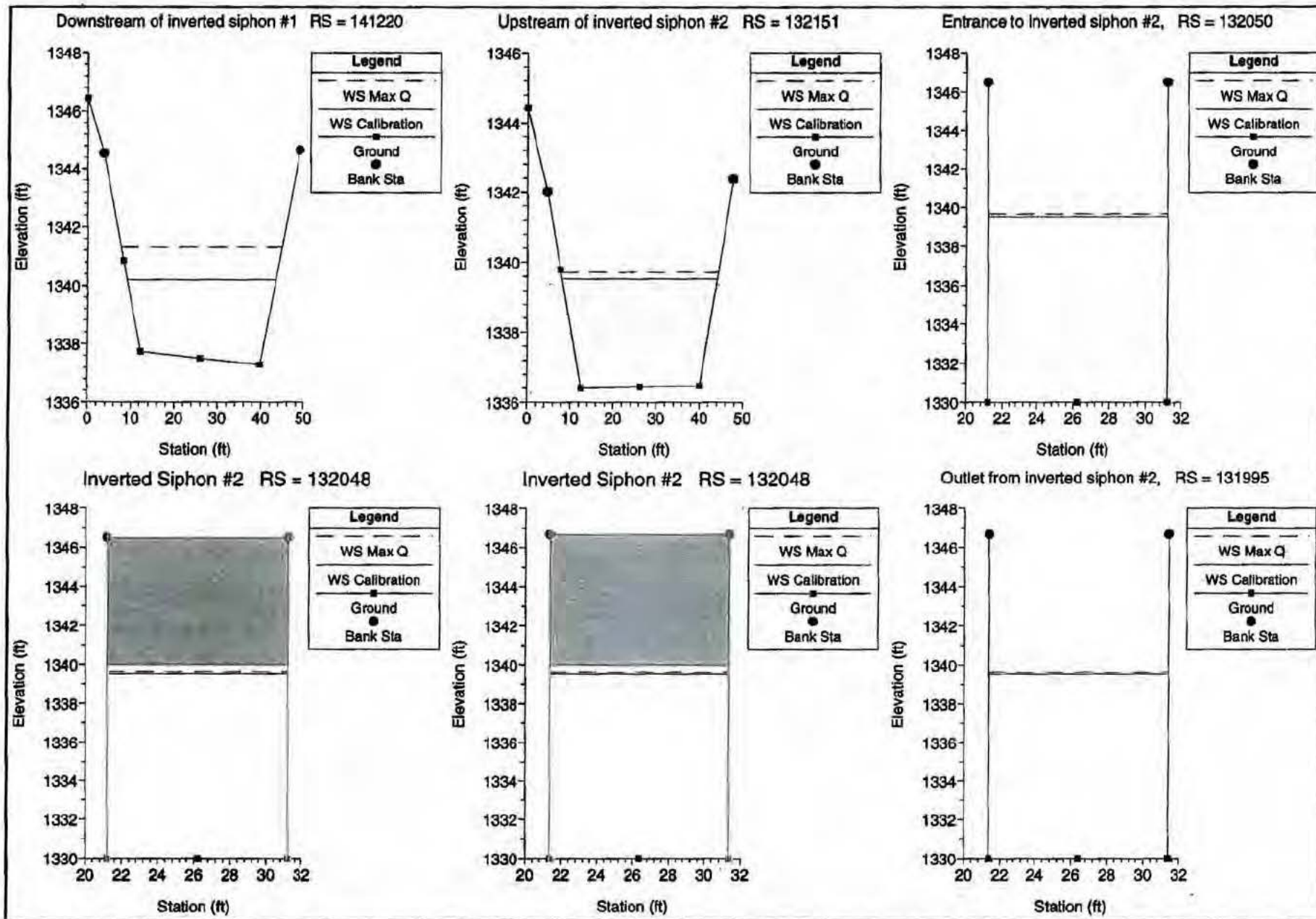


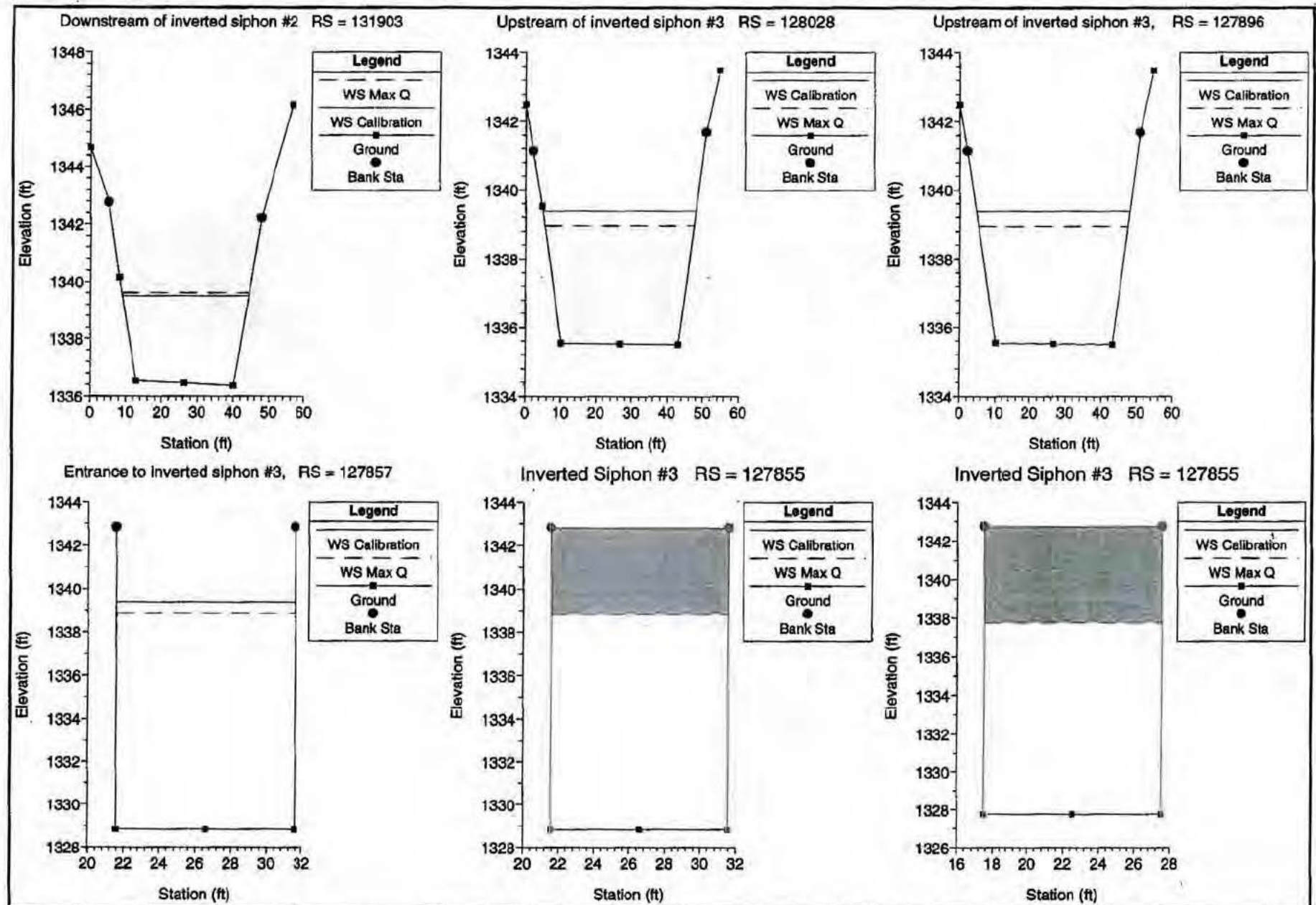


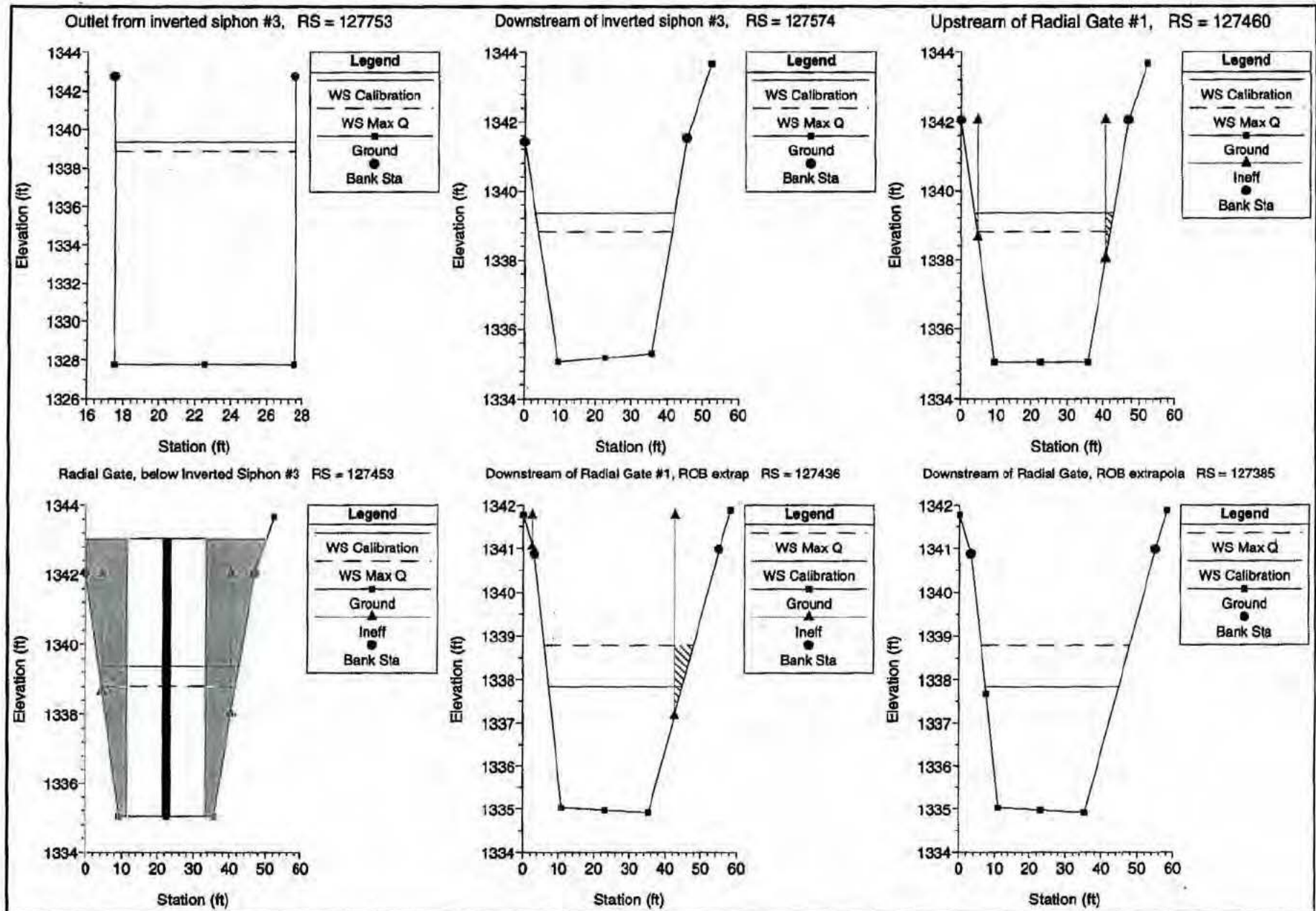




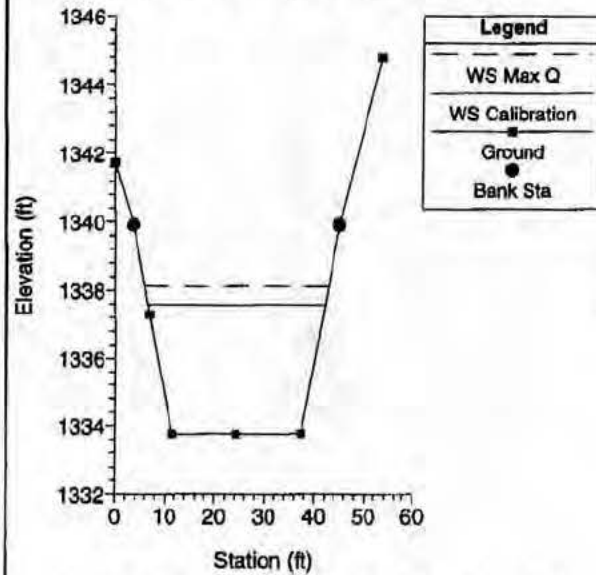




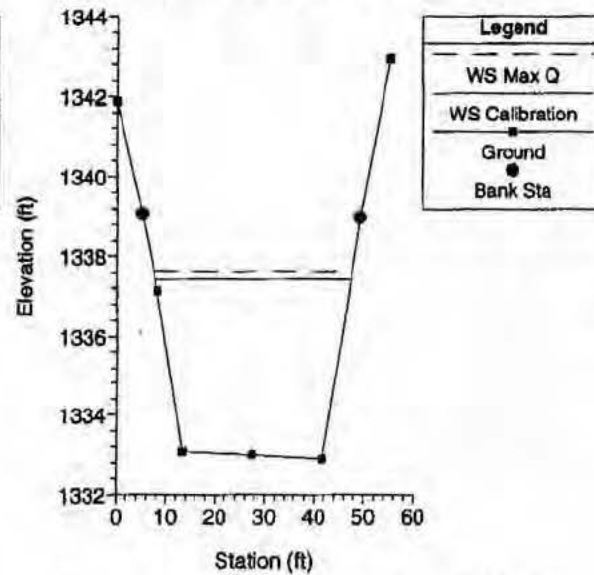




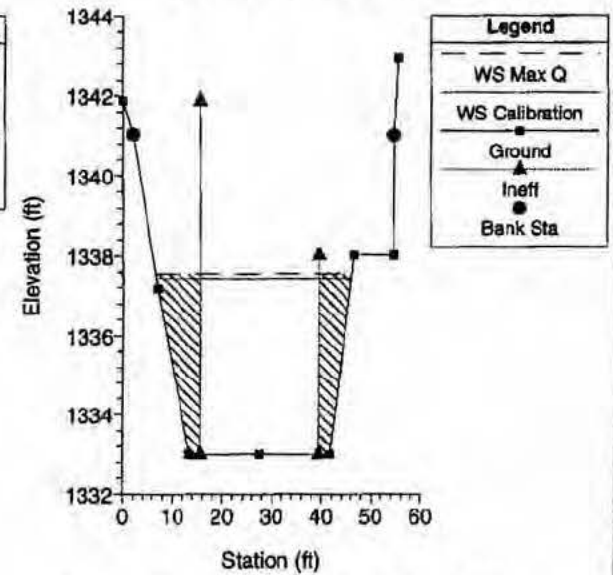
Near 36" flood inlet, RS = 121544



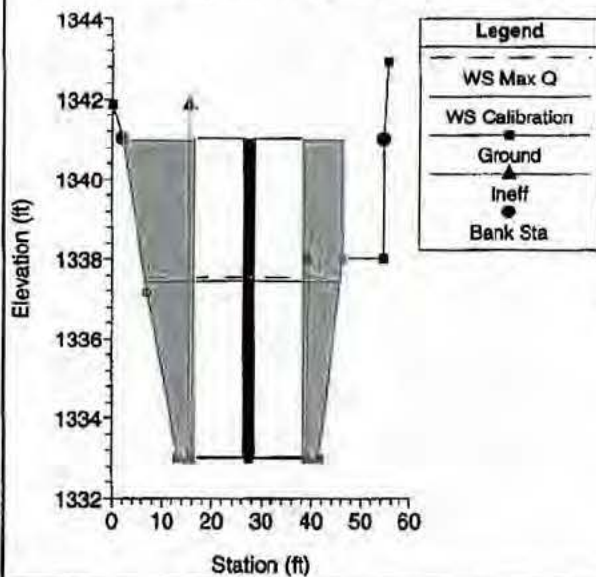
Upstream from Radial Gate #2 RS = 115117



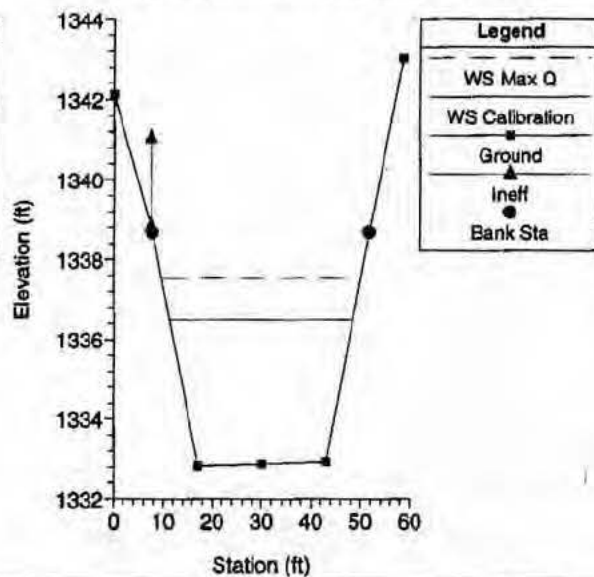
Upstream Radial Gate #2, RS = 115010



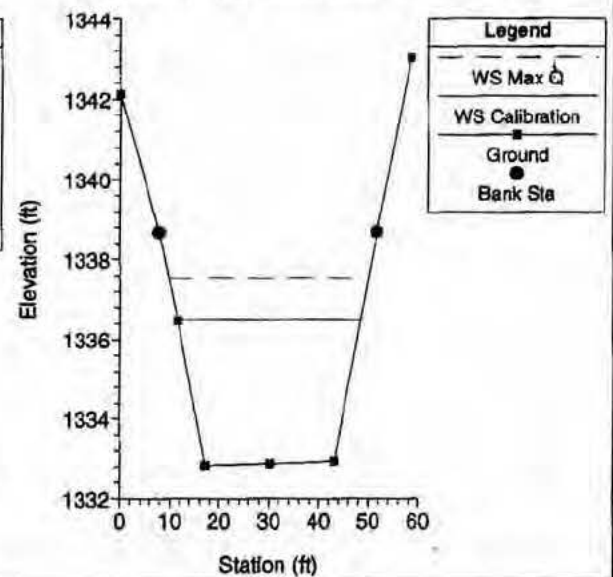
Radial Gate, Upstream of Grand Ave RS = 115009

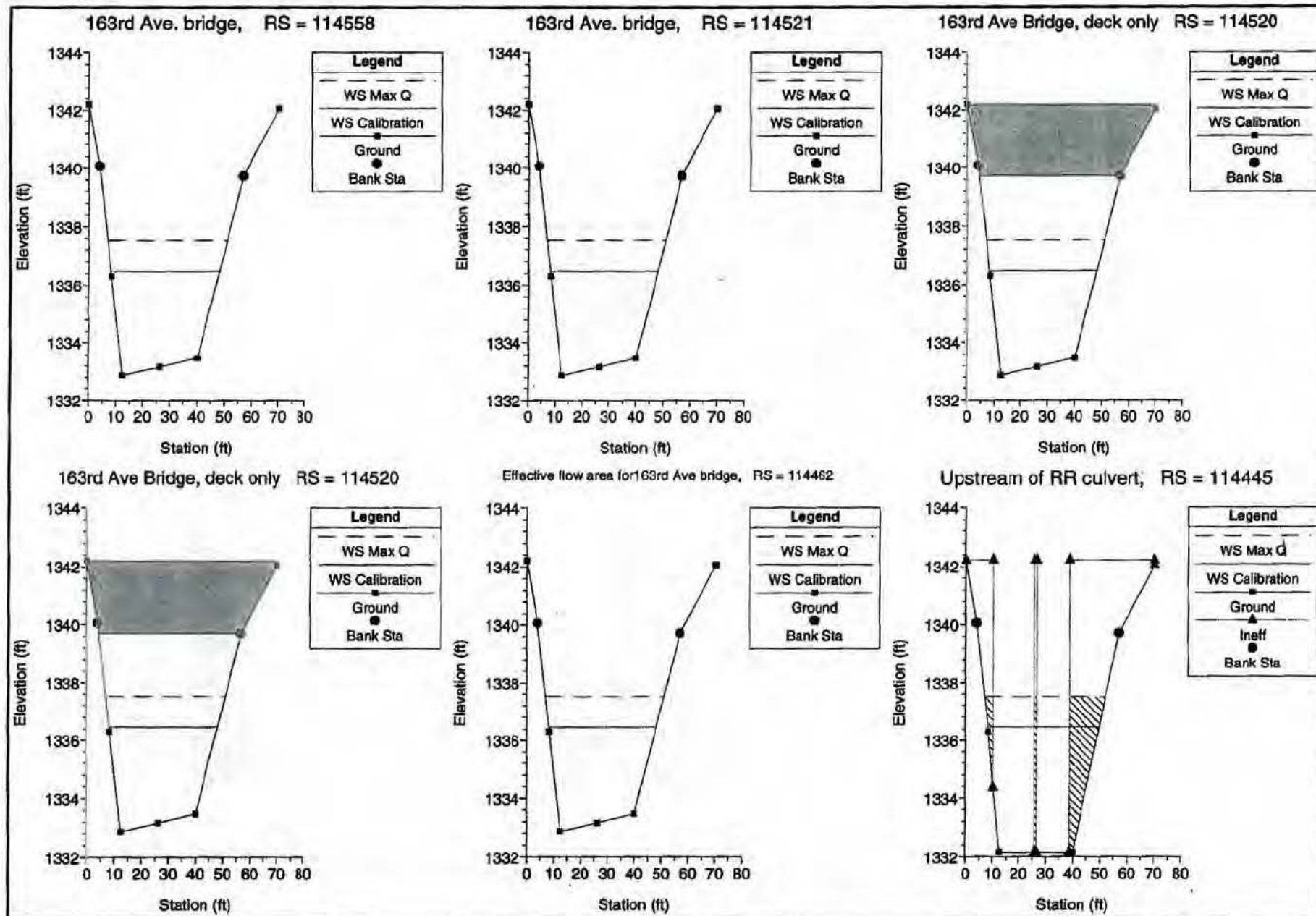


Downstream from Radial Gate #2, RS = 114992

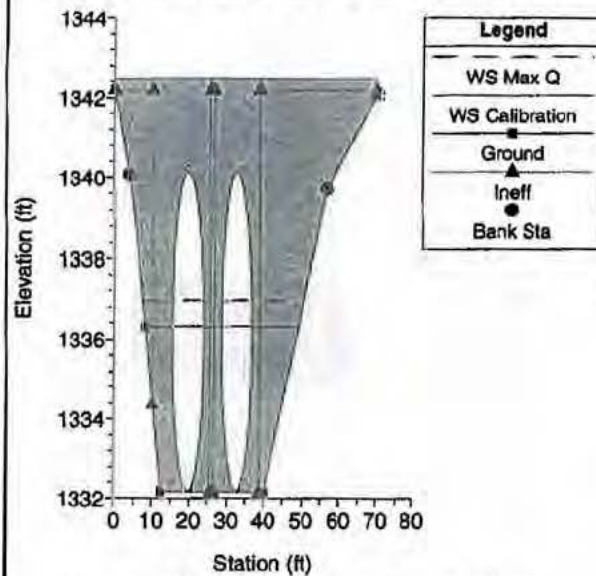


Downstream from Radial Gate #2 RS = 114940

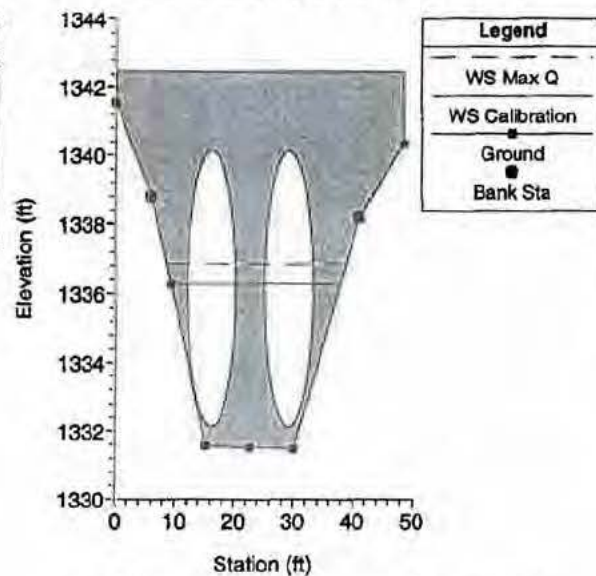




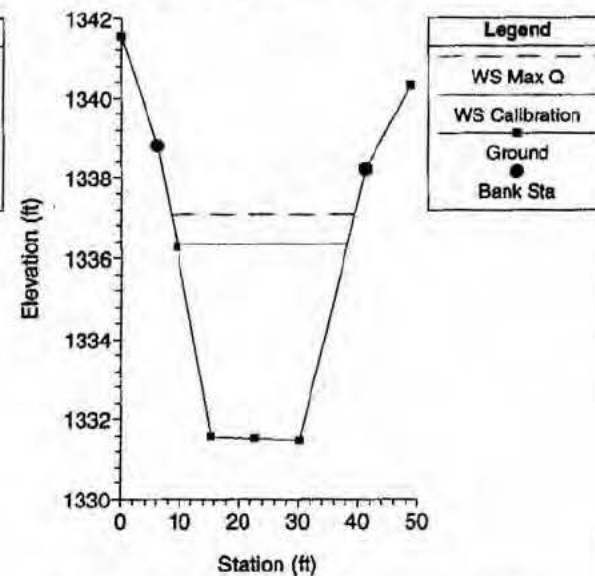
CMP Culverts at Sante Fe RR RS = 114443



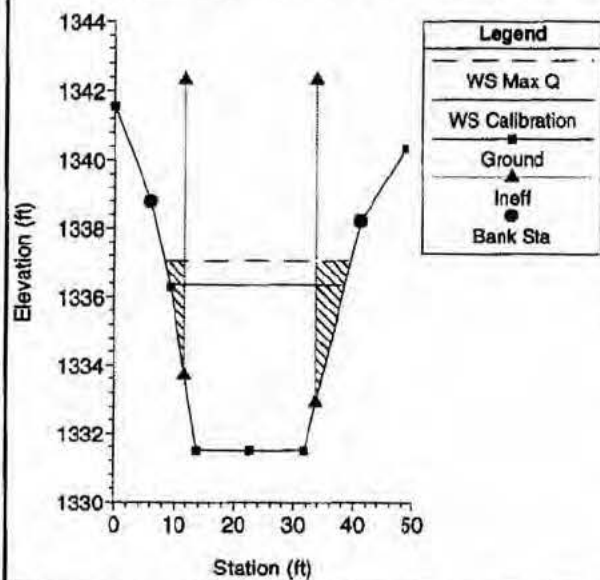
CMP Culverts at Sante Fe RR RS = 114443



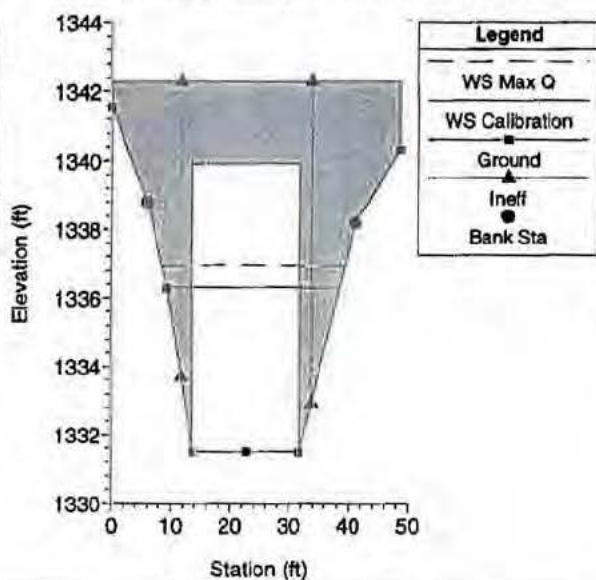
Between Santa Fe RR and Grand Ave RS = 114306



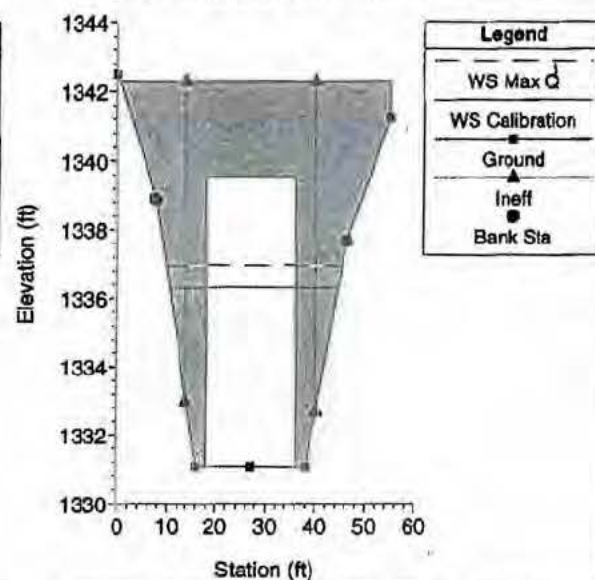
Upstream of box culvert at Grand Ave RS = 114284

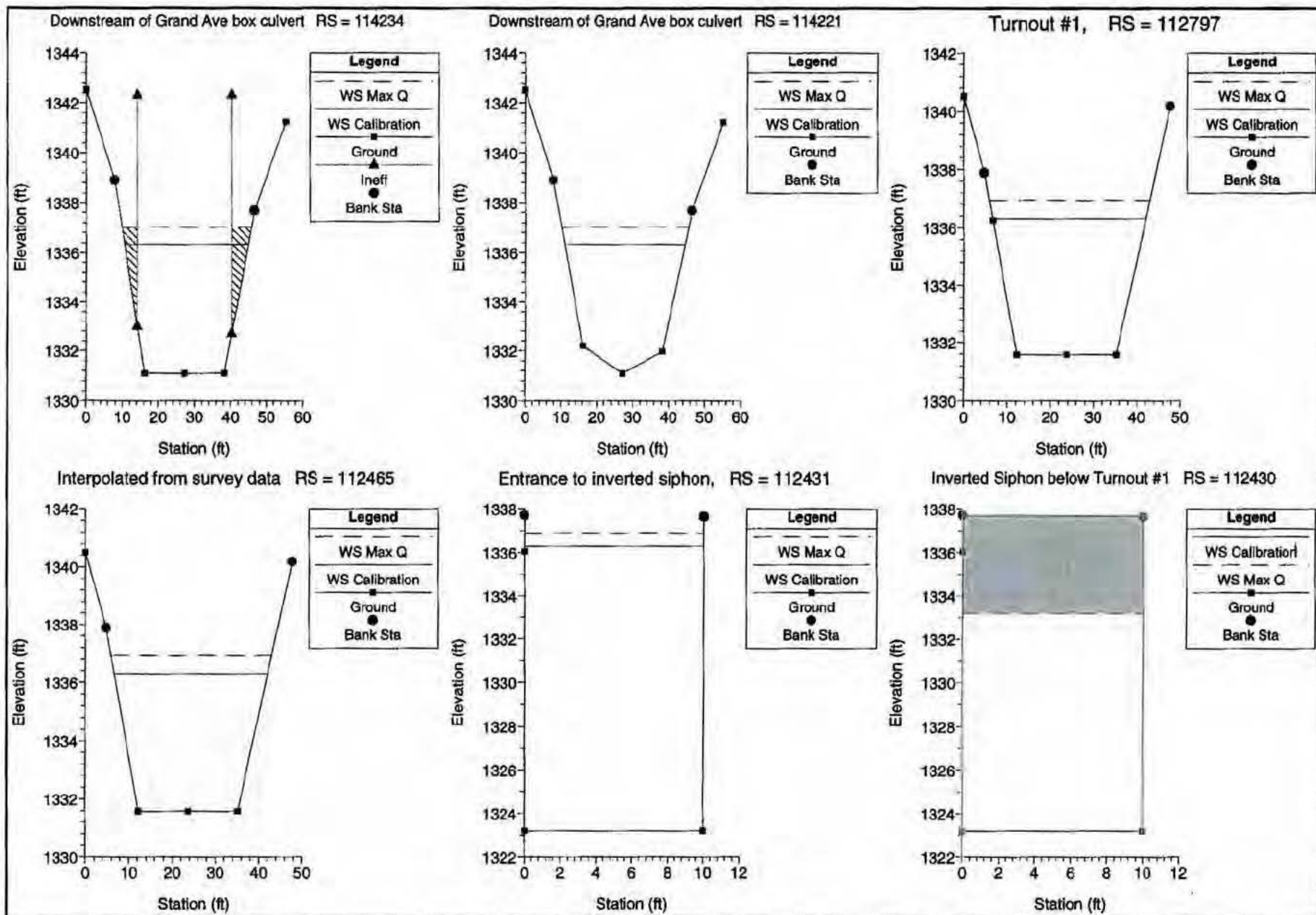


Box Culvert at Grand Avenue RS = 114282

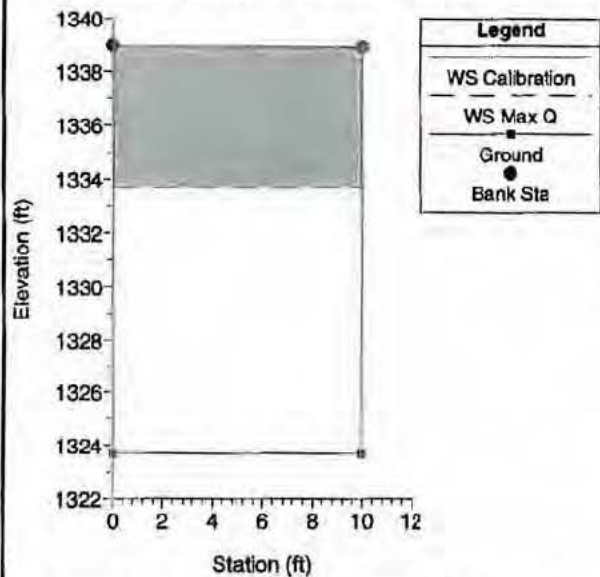


Box Culvert at Grand Avenue RS = 114282

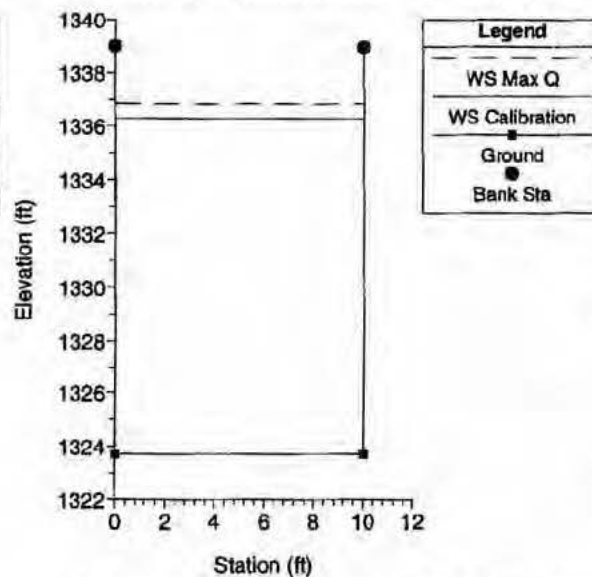




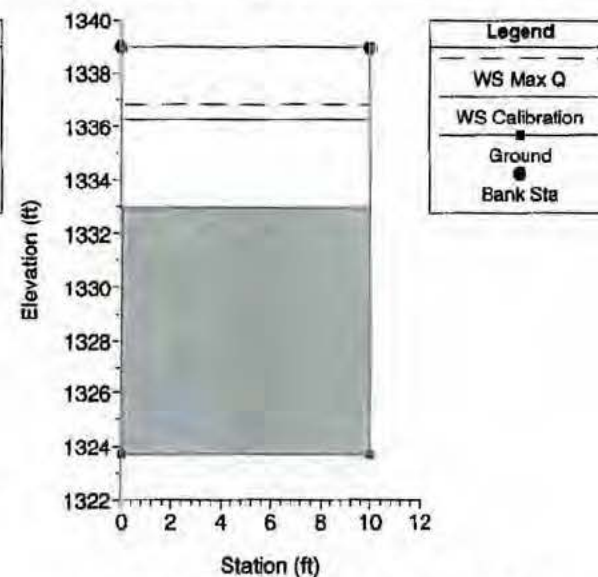
Inverted Siphon below Turnout #1 RS = 112430



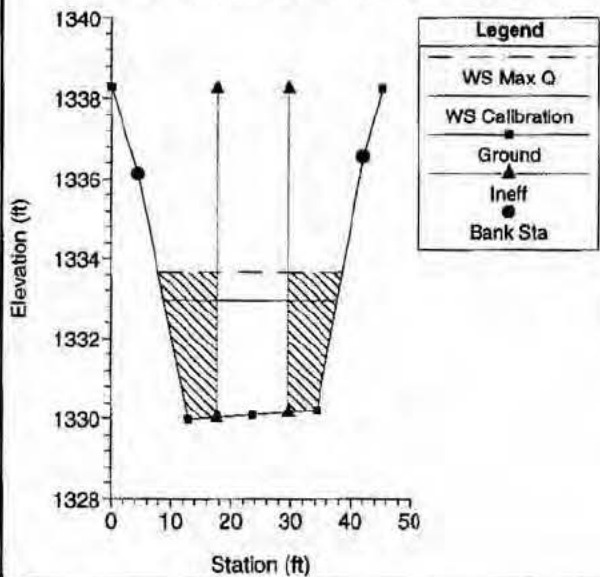
Entrance to check board structure RS = 112380



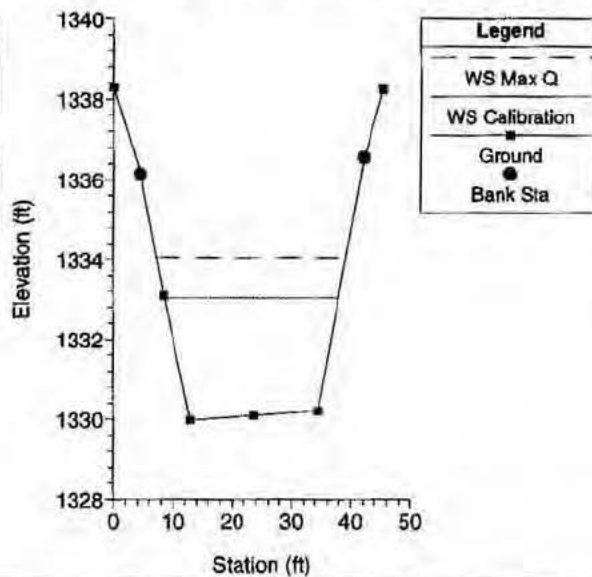
Checkboards below Turnout #1 & inverted RS = 112350



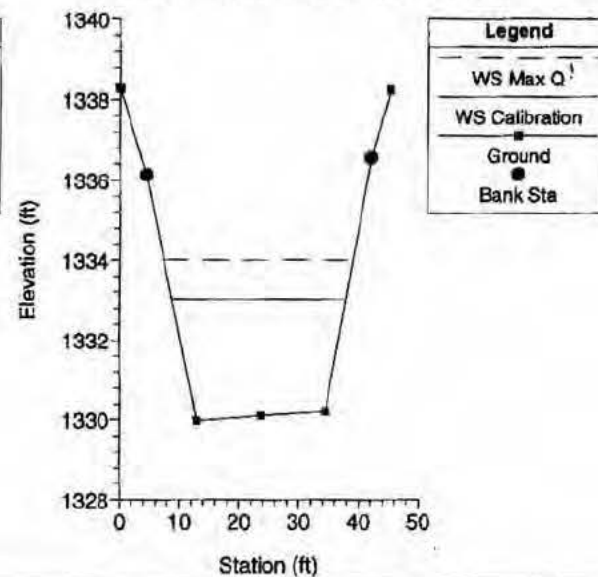
Downstream of check board, RS = 112349



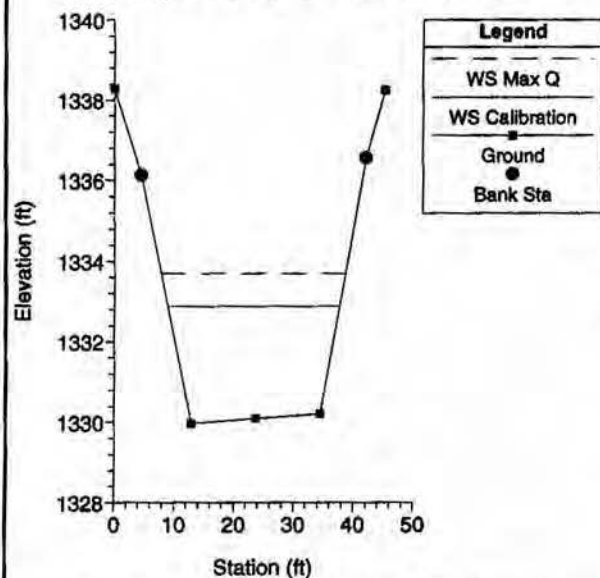
Downstream from check board structure RS = 112150



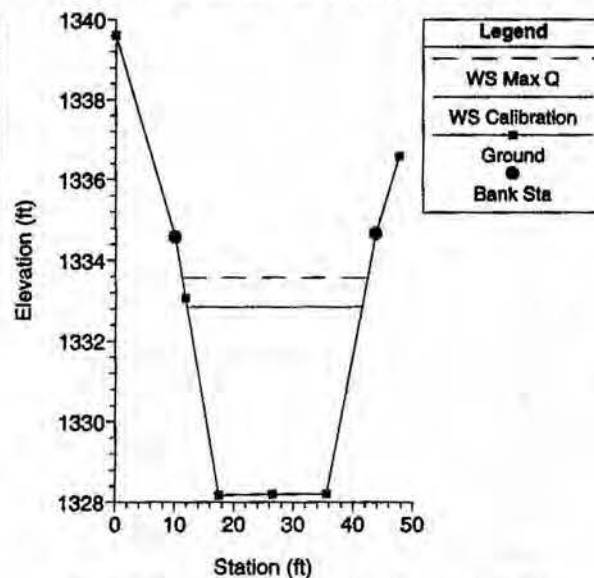
Interpolated X-section RS = 112000



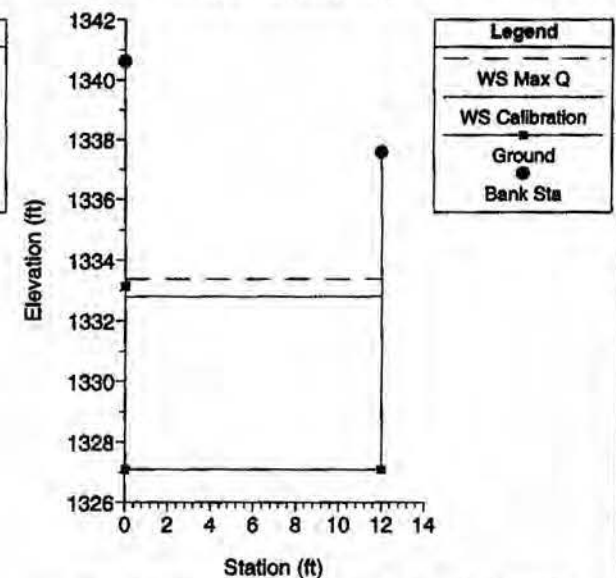
Interpolated X-sect RS = 110736



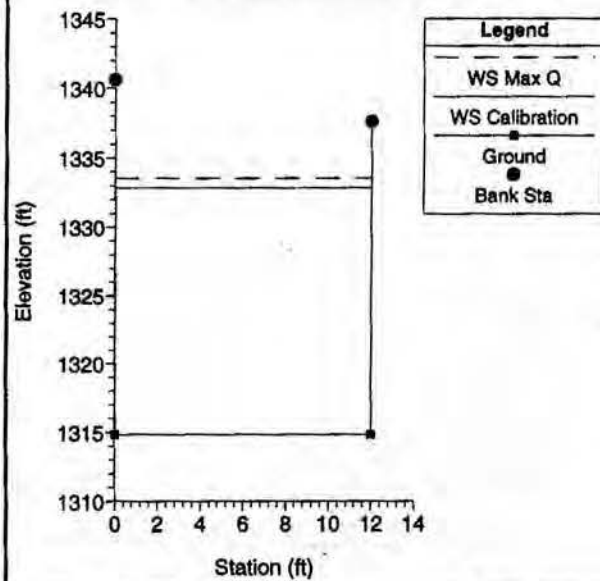
Upstream of McMicken siphon RS = 109473



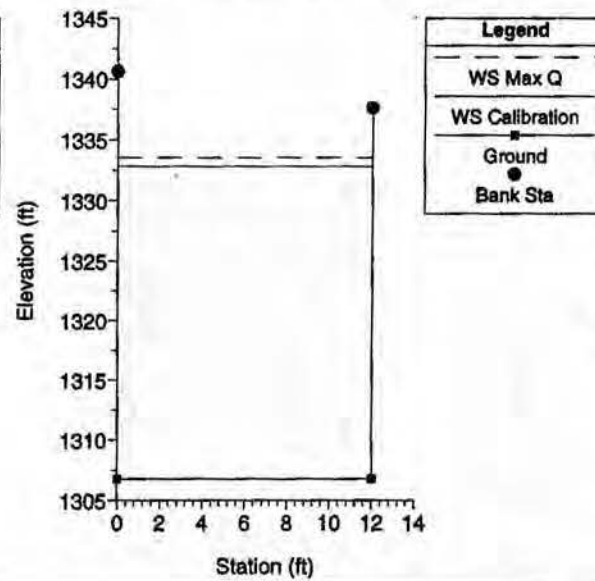
Throat and drop to inverted siphon at Mc RS = 109407



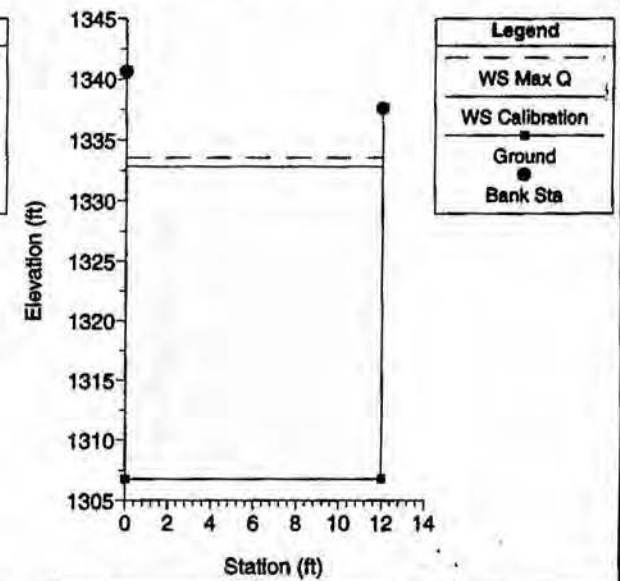
Throat and drop to McMicken inverted sip RS = 109393.5

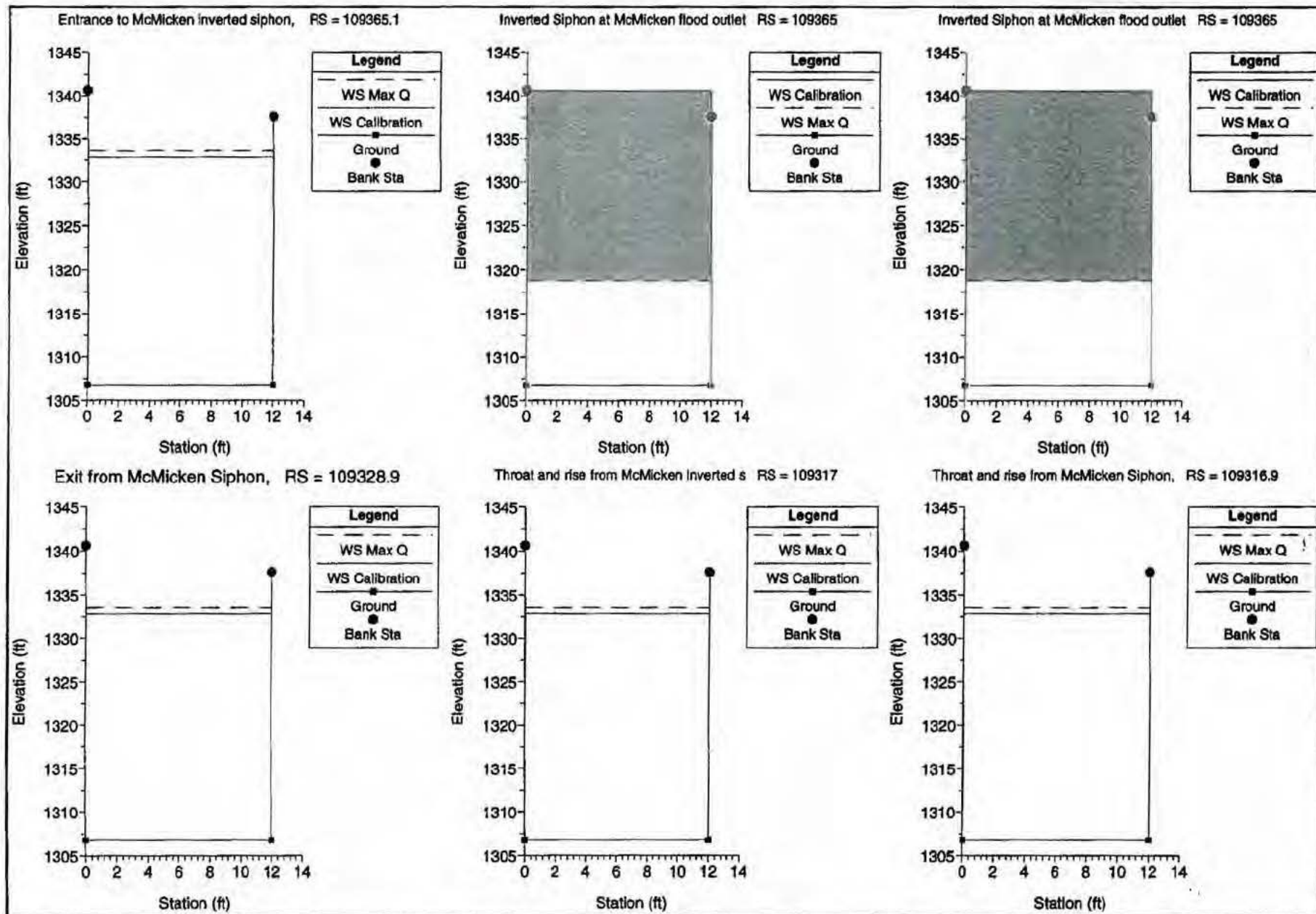


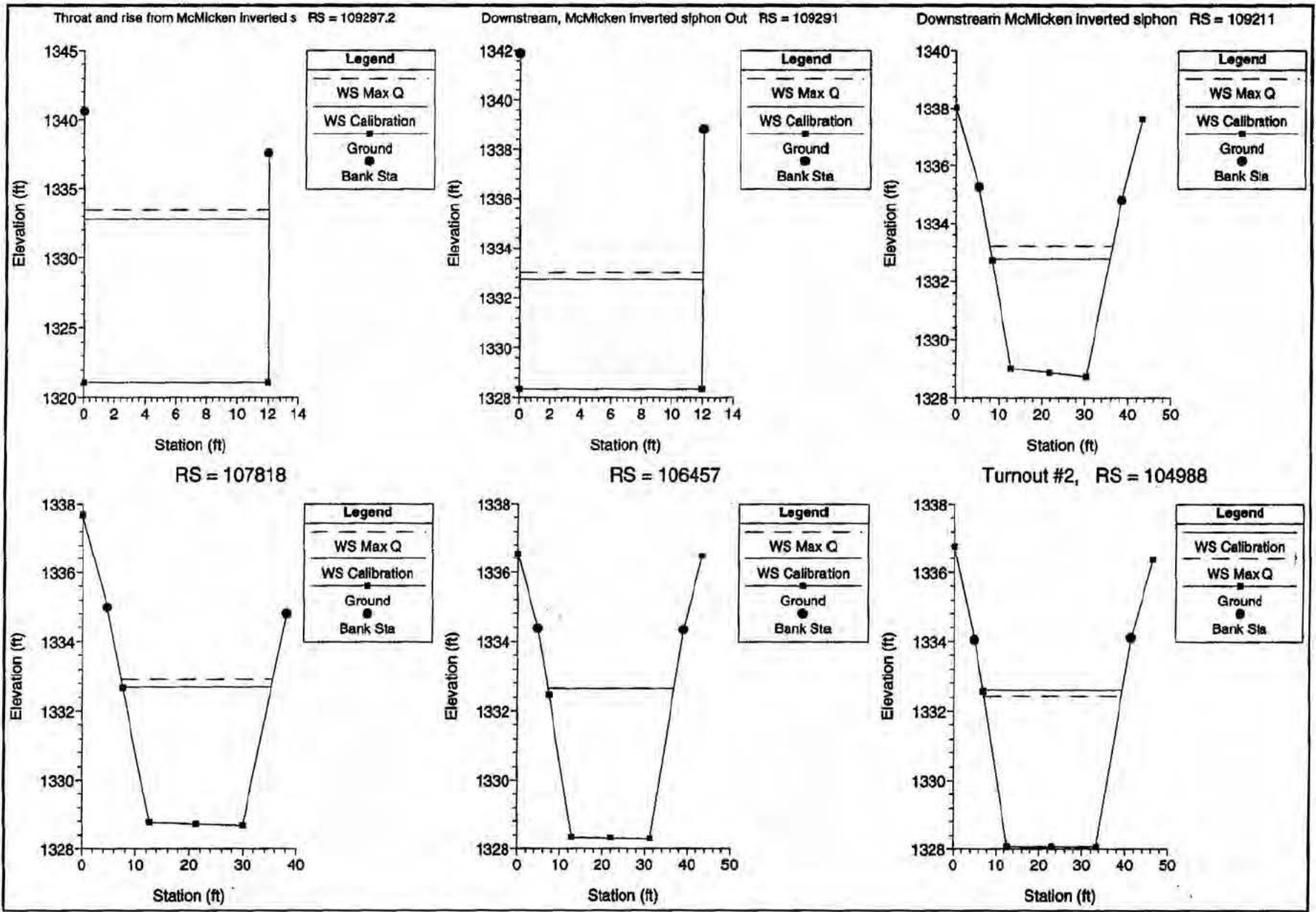
Throat and drop to McMicken inverted sip RS = 109377.1

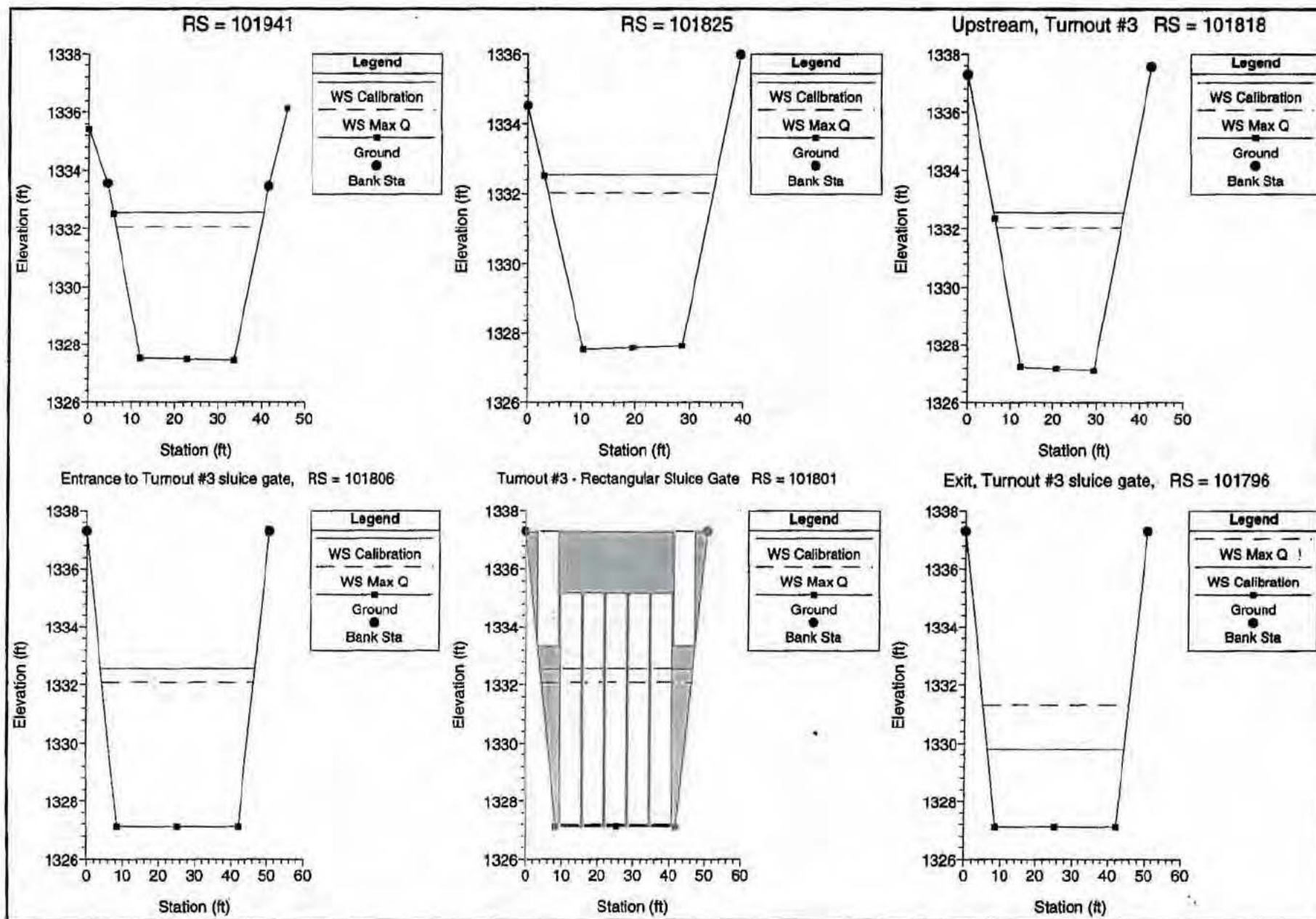


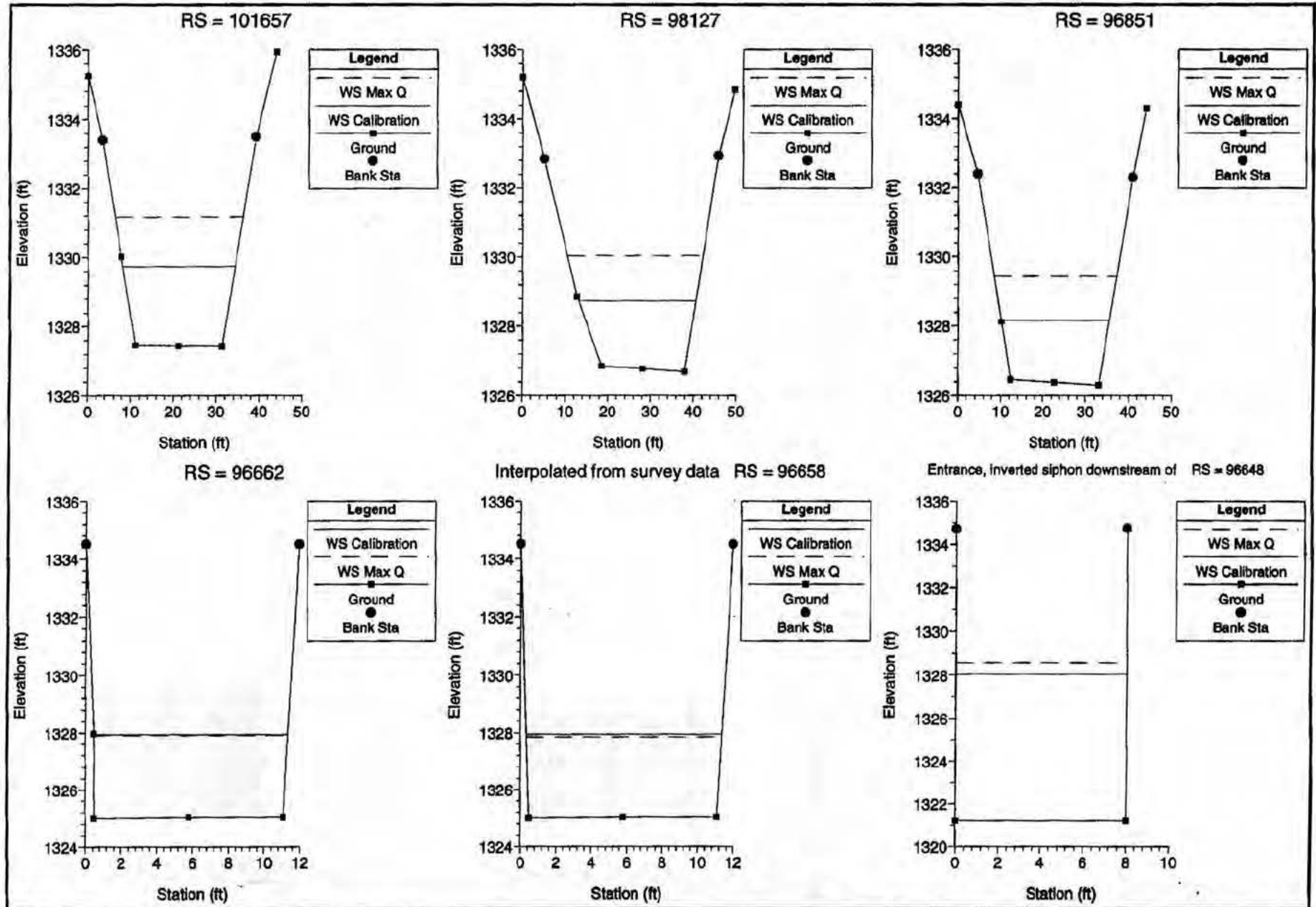
Throat and drop to McMicken inverted sip RS = 109377

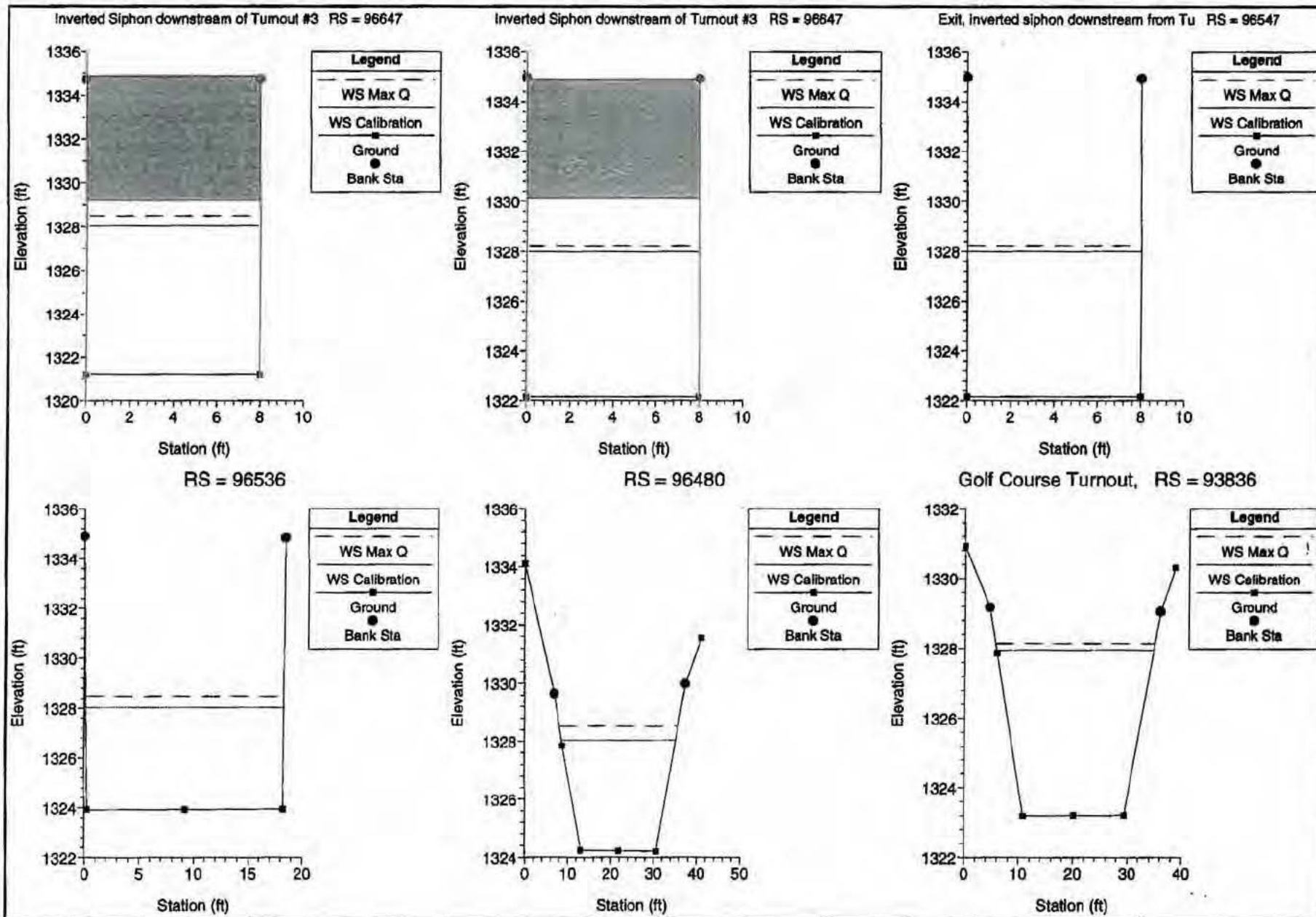


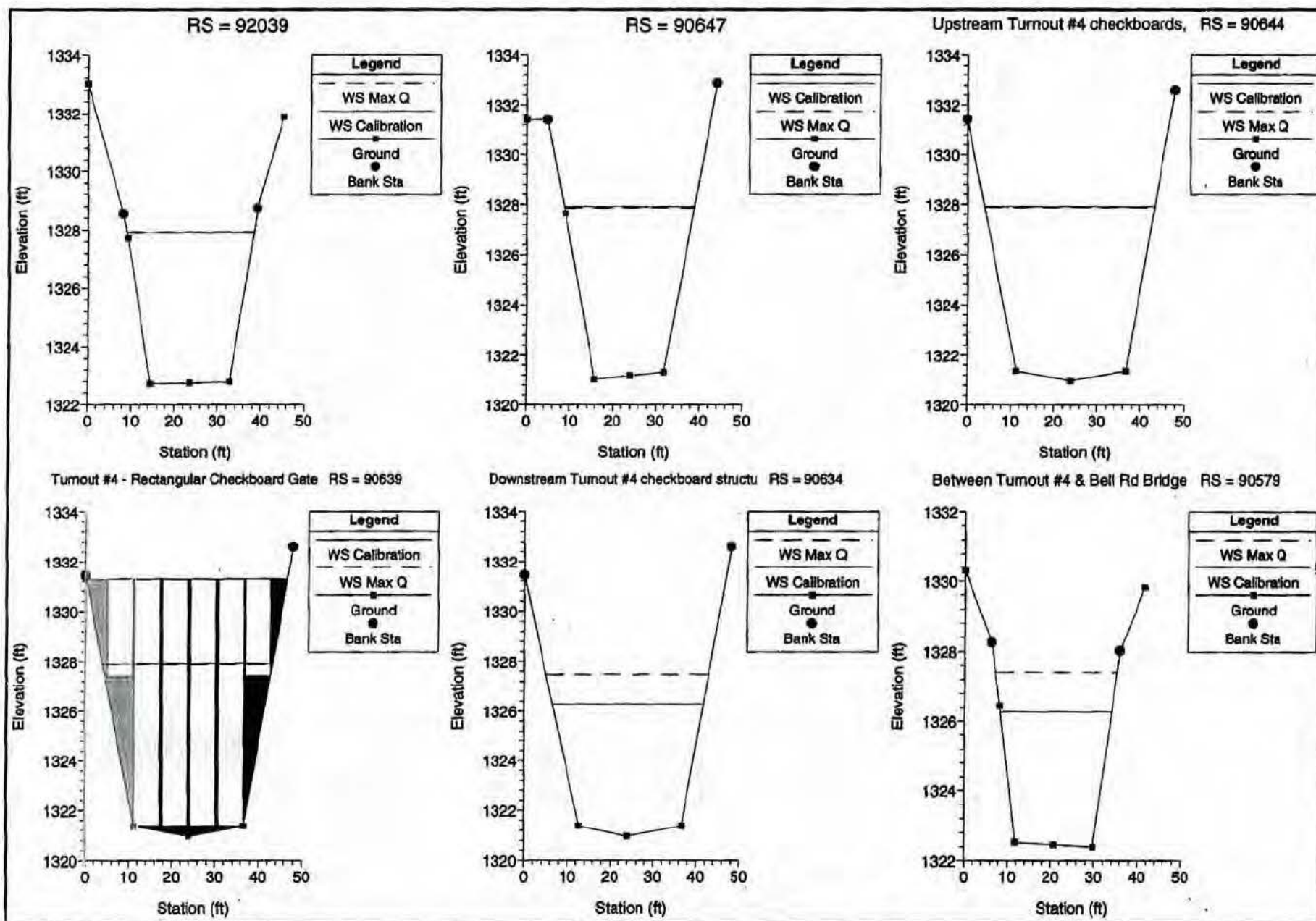


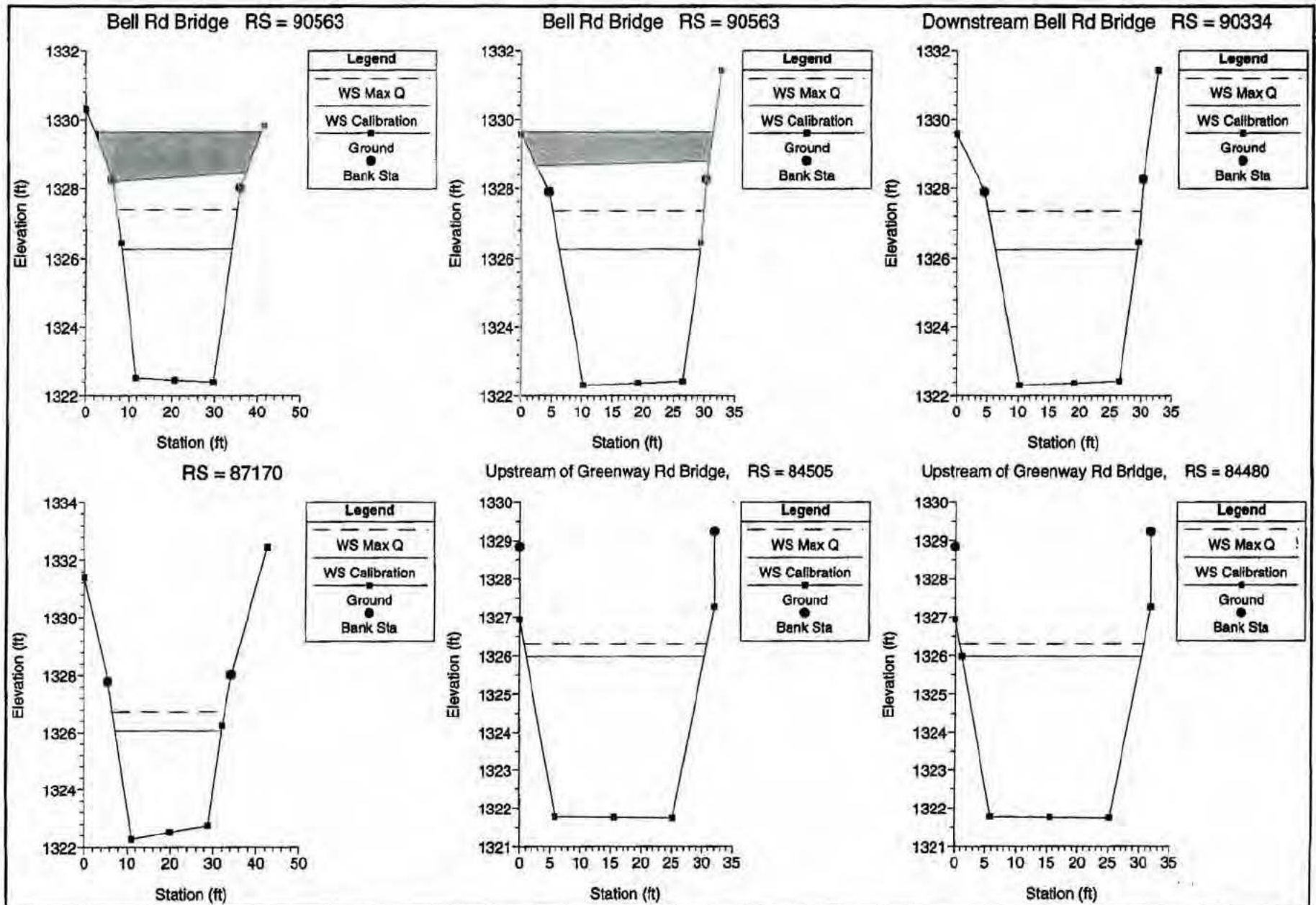


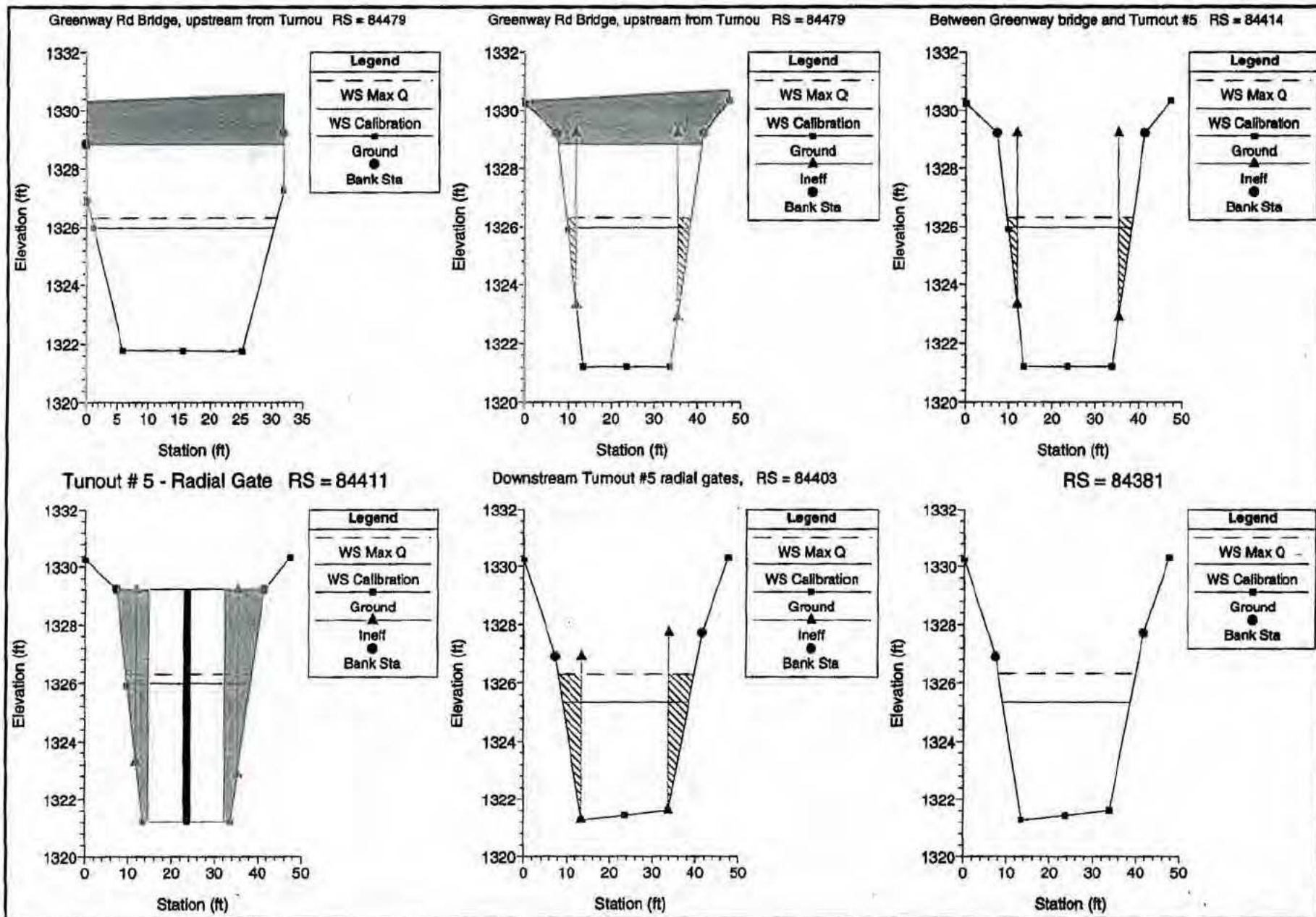




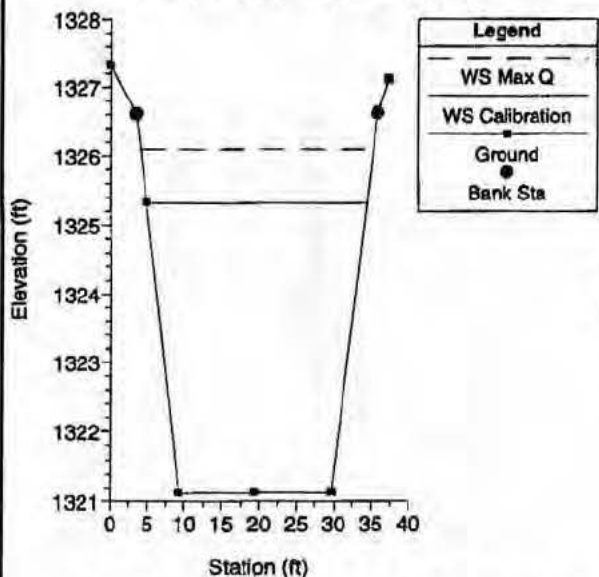




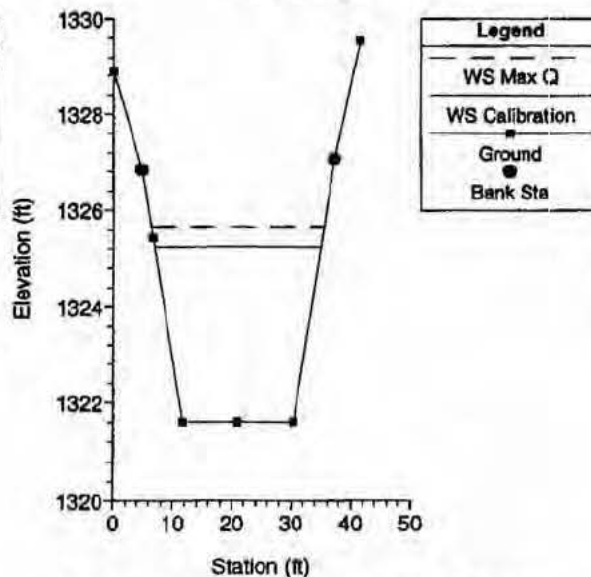




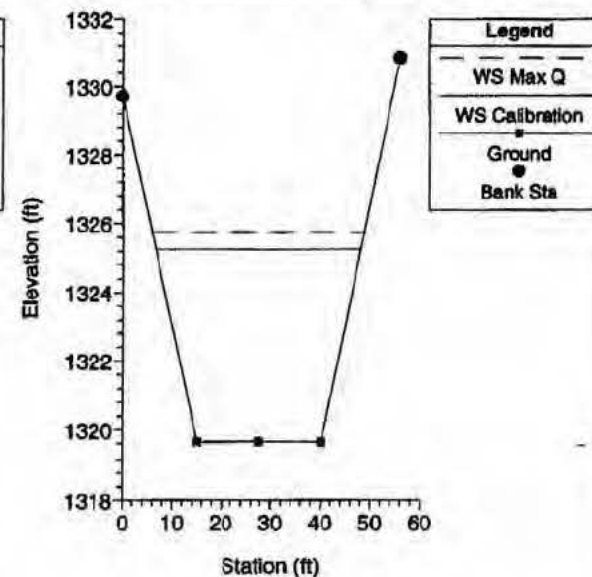
Turnout #5.03 RS = 81772



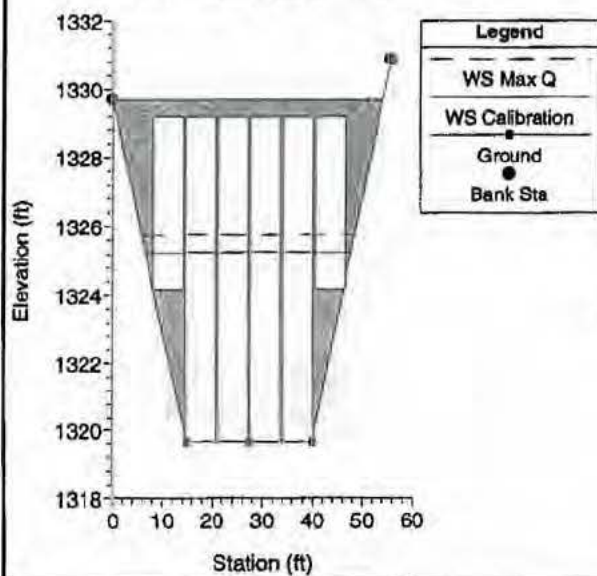
RS = 79040



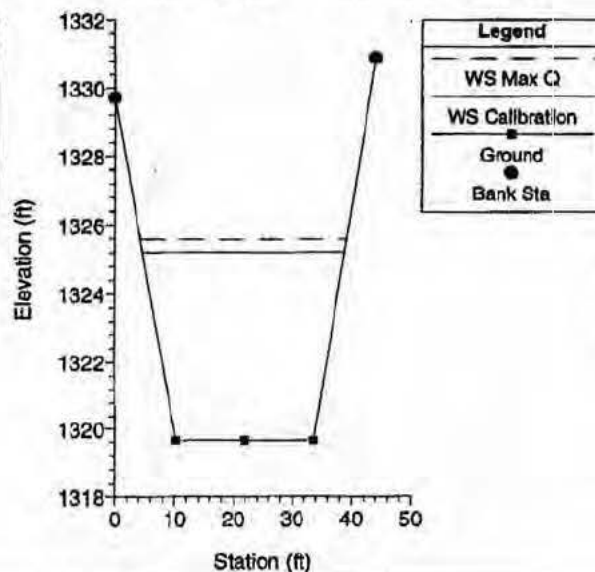
Upstream Turnout #6 sluice gate, RS = 79018



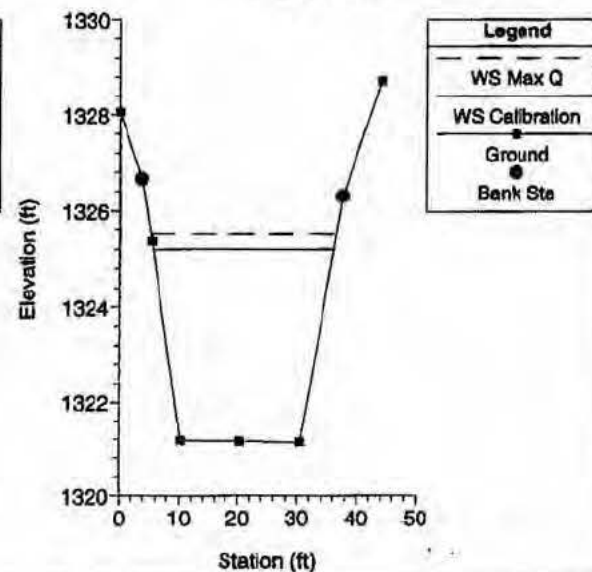
Turnout #6 - Rectangular Sluice Gate RS = 79013

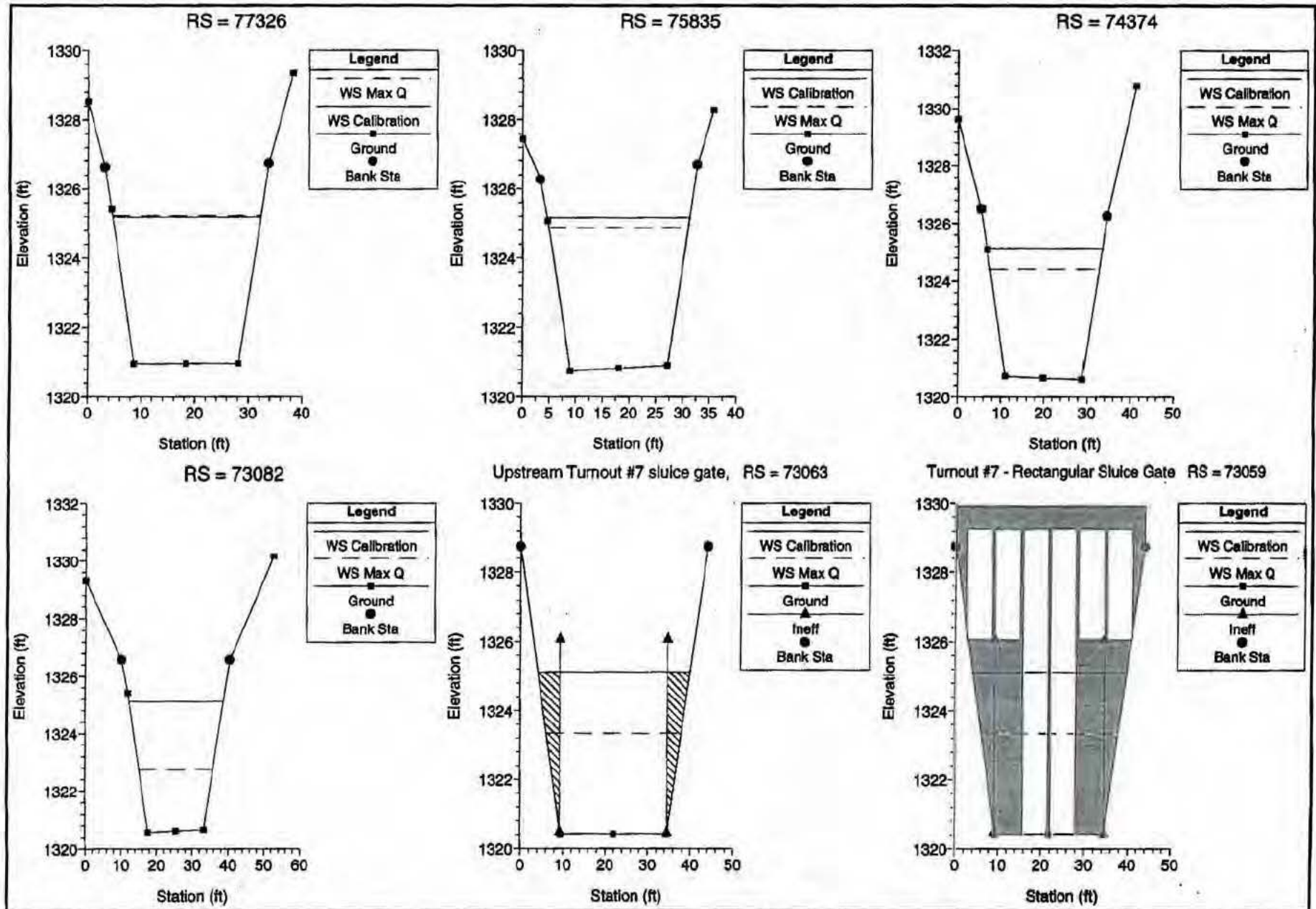


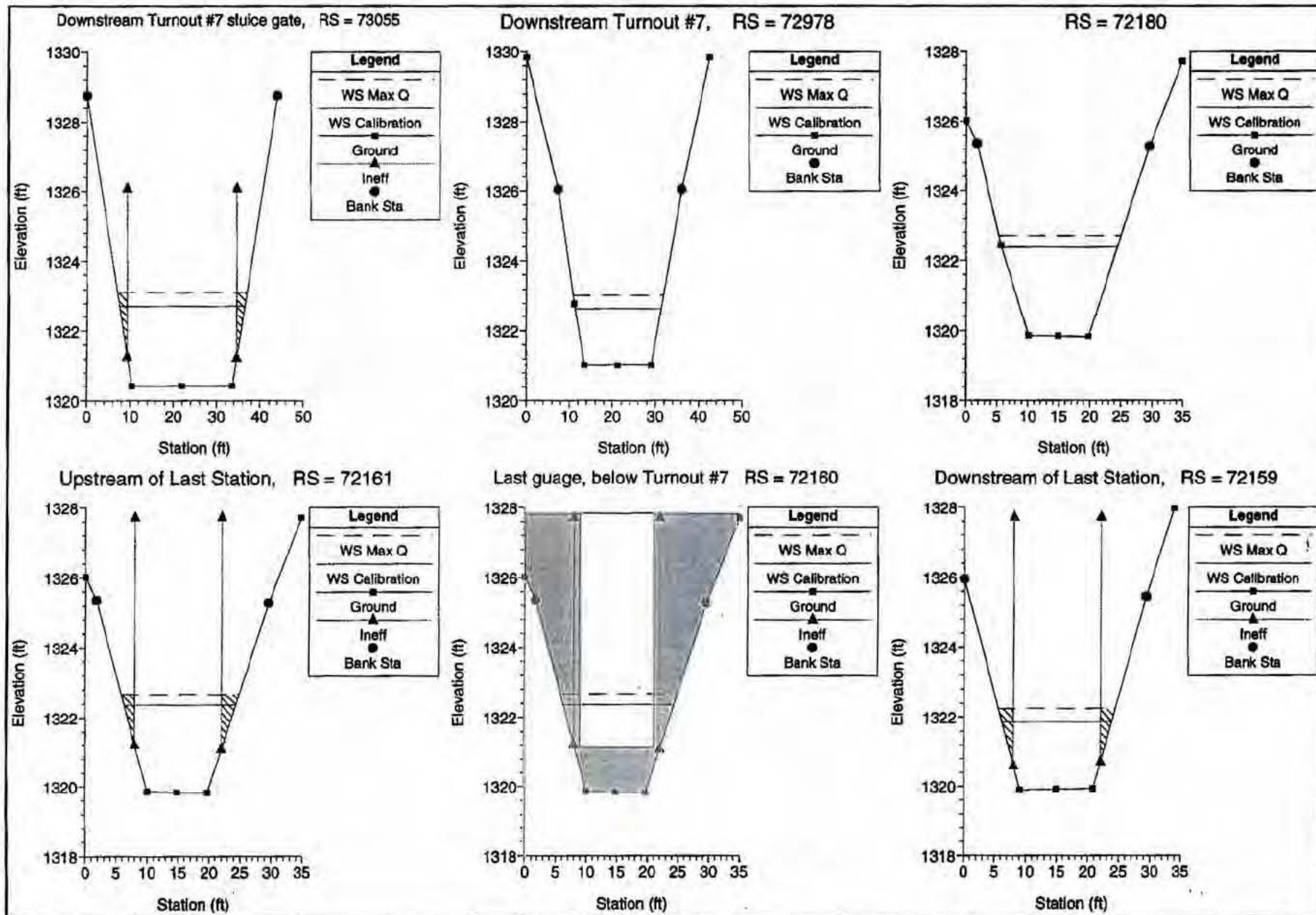
Downstream Turnout #6 sluice gate RS = 79010

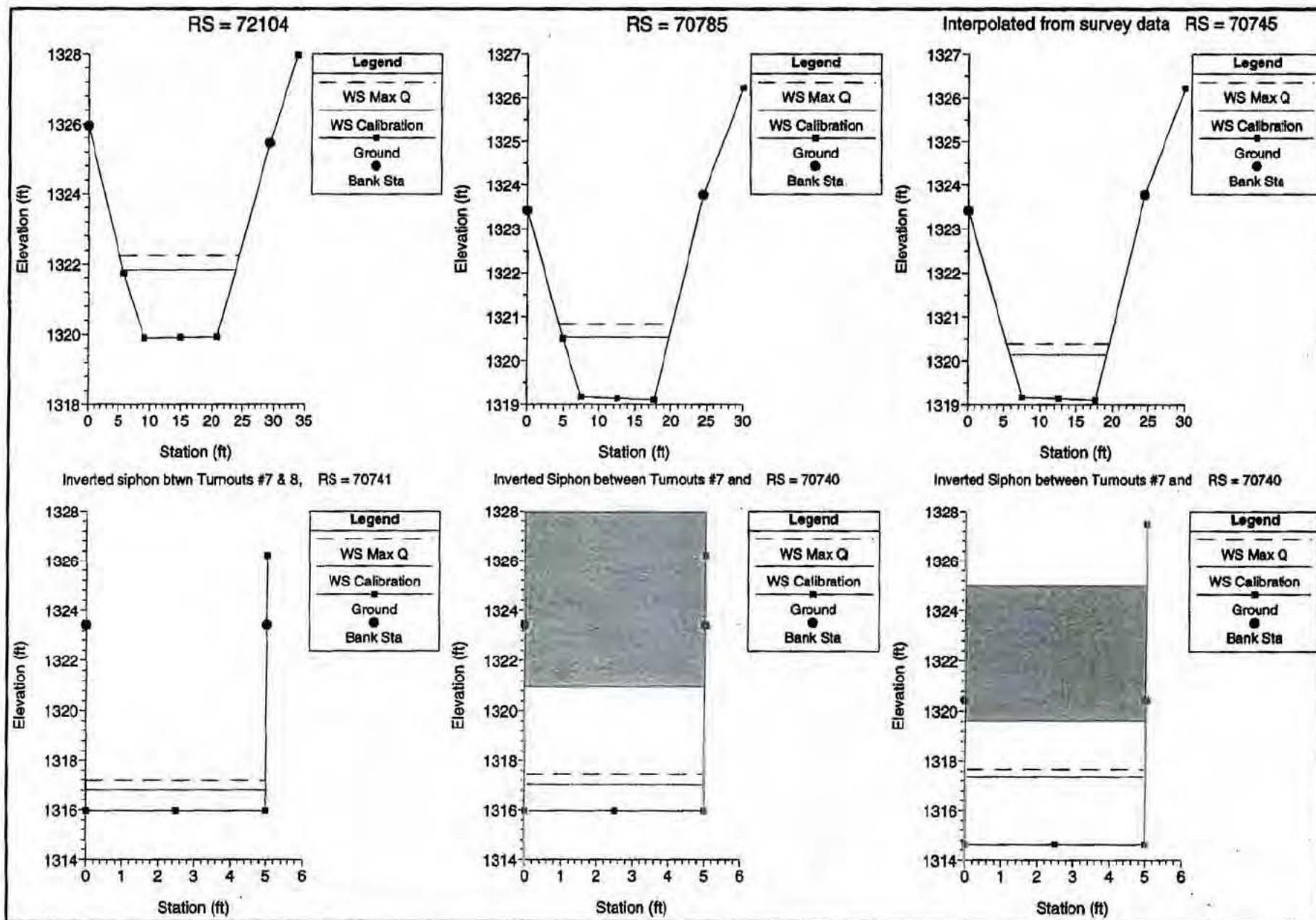


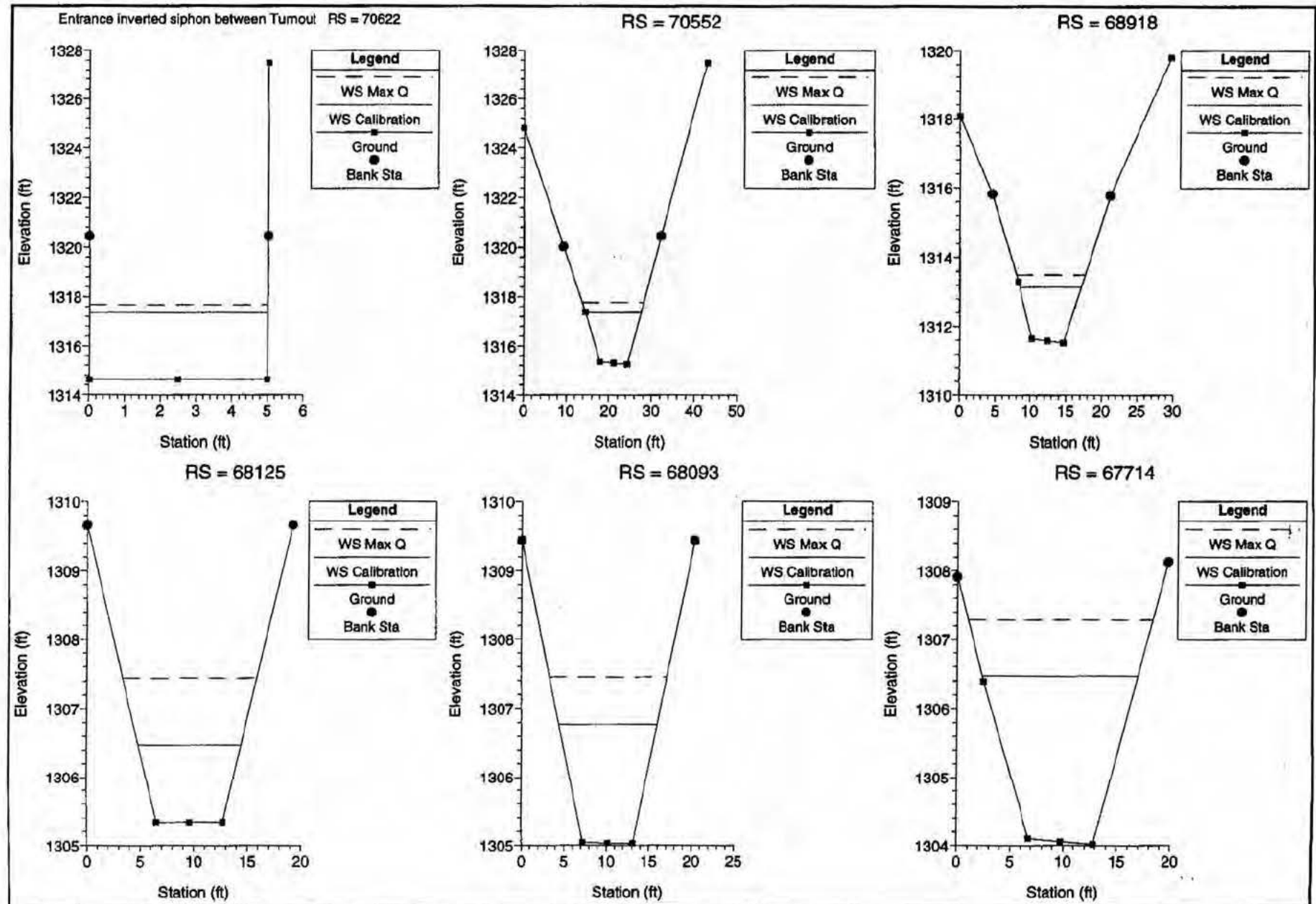
RS = 78987



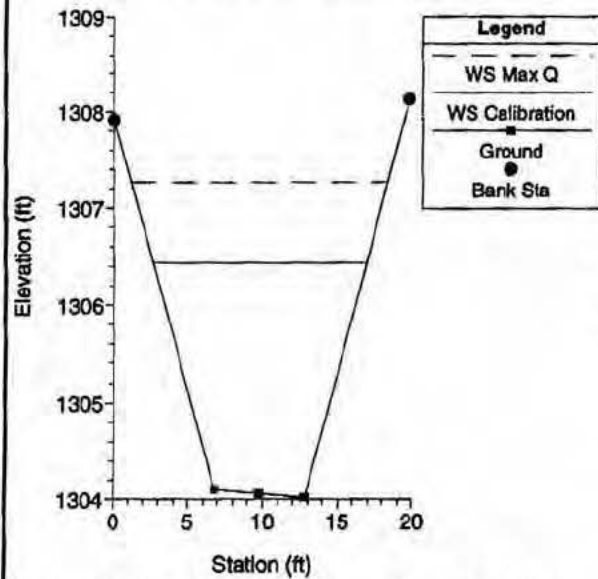




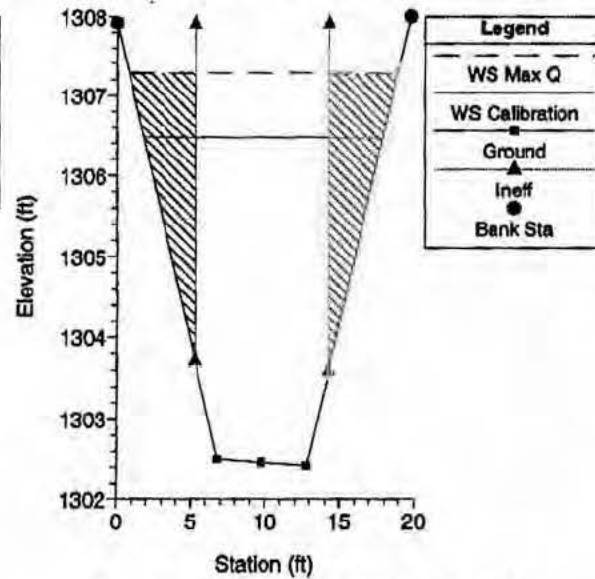




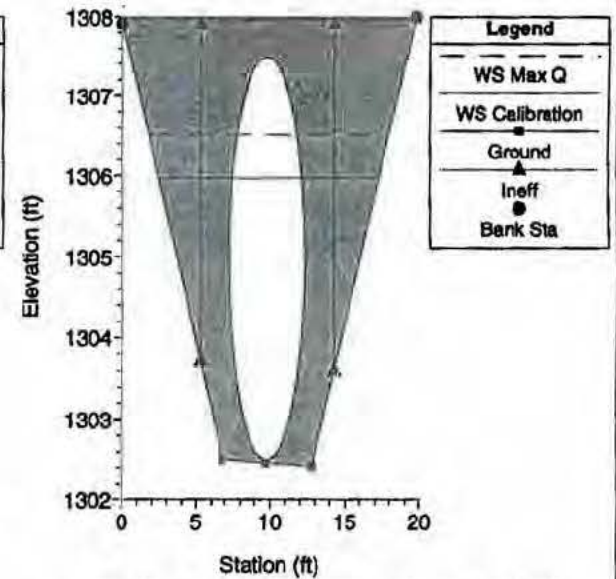
Upstream of drop to culvert at Turnout # RS = 67680



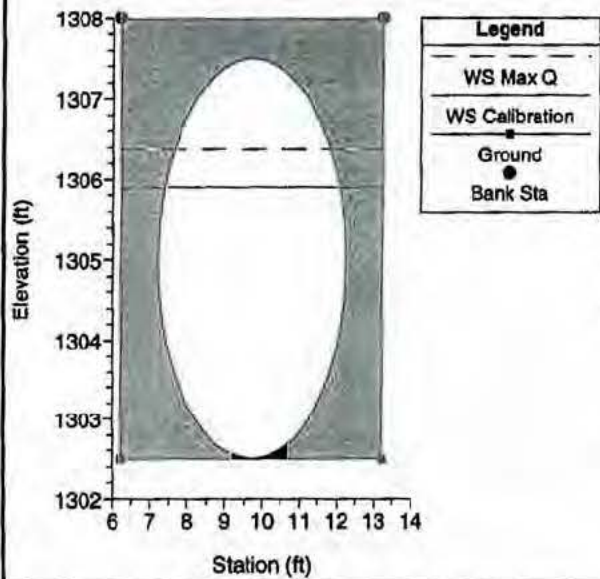
Upstream of culvert at Turnout #8, RS = 67672



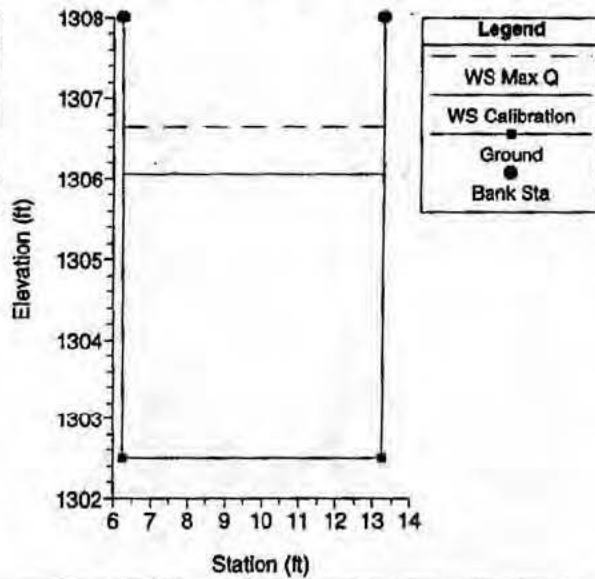
CMP Culvert upstream from Turnout #8 RS = 67670



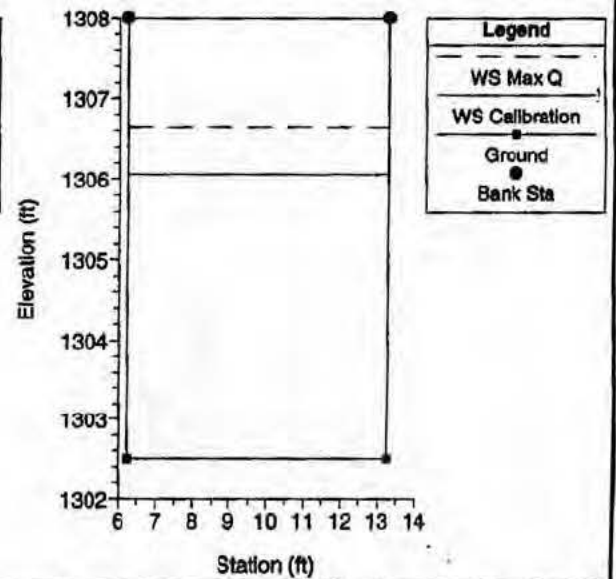
CMP Culvert upstream from Turnout #8 RS = 67670



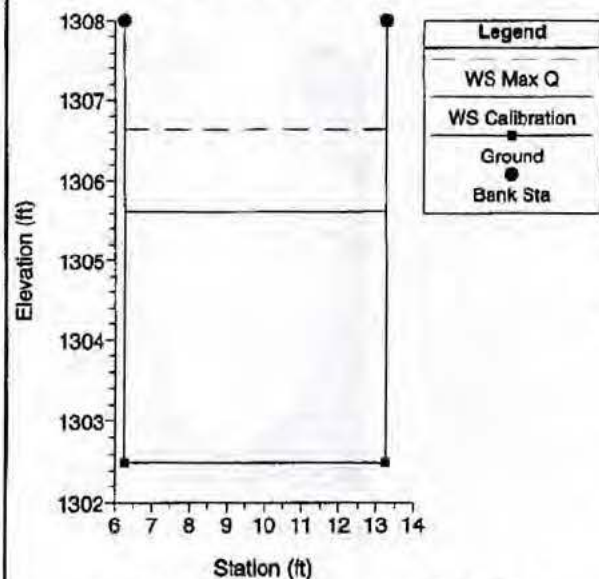
Upstream of TO#8, exit first culvert RS = 67648



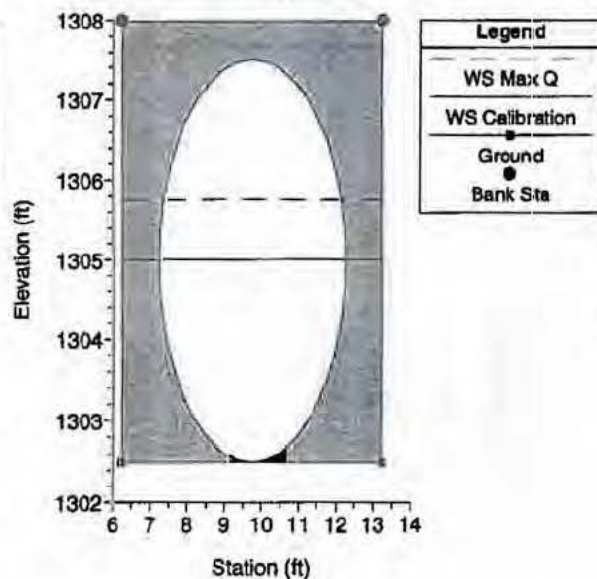
Turnout #8 - Rectangular Checkboard Gate RS = 67646.5



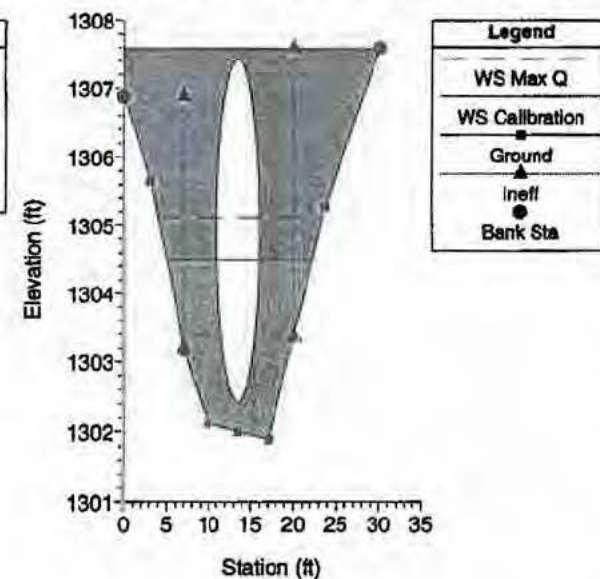
Downstream of Turnout #8 checkboard -ins RS = 67644



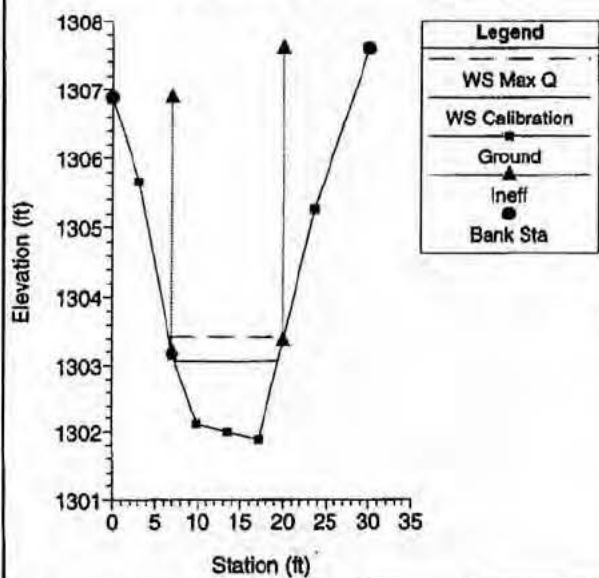
CMP Culvert downstream of Turnout #8 RS = 67643



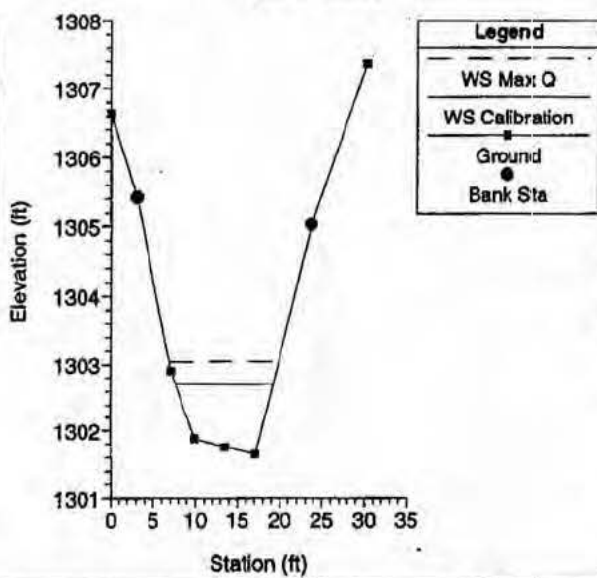
CMP Culvert downstream of Turnout #8 RS = 67643



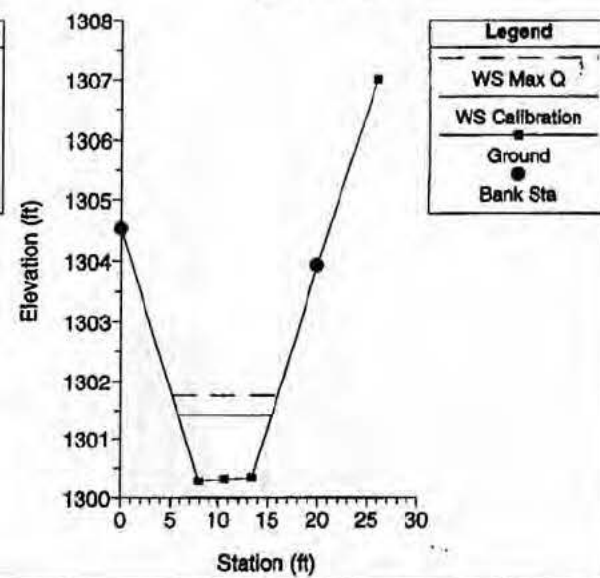
Culvert exit, downstream from turnout #8 RS = 67615

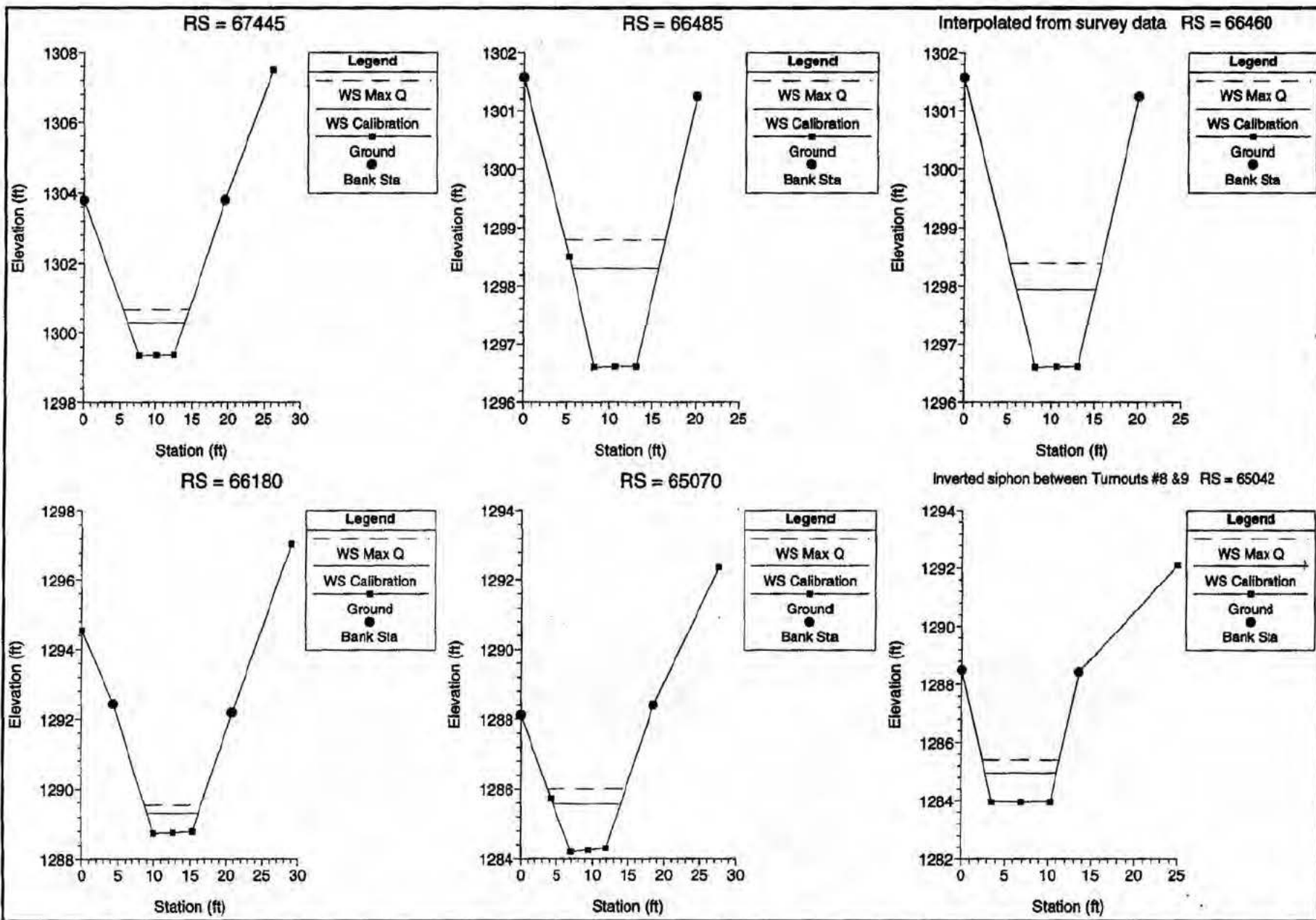


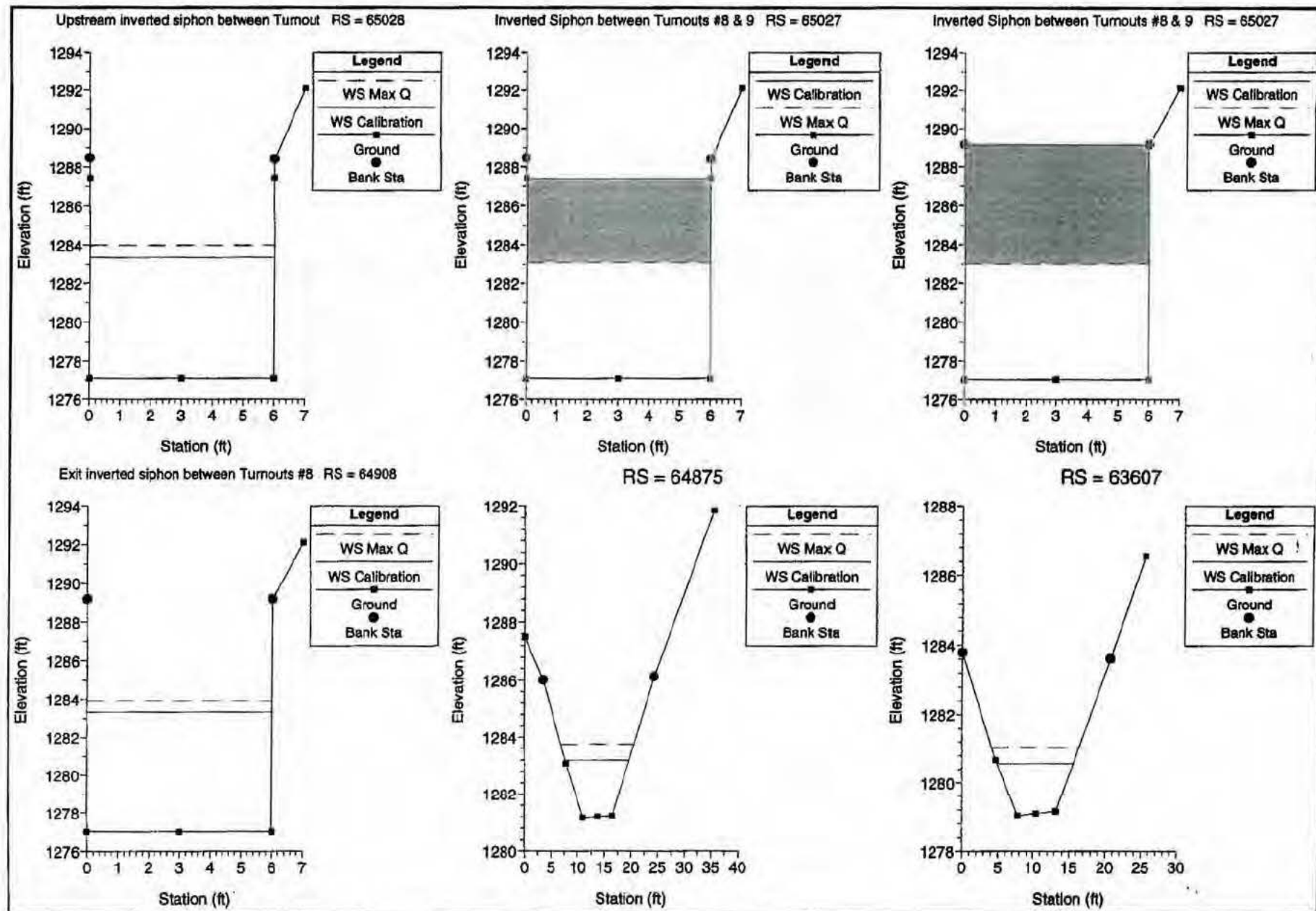
RS = 67590

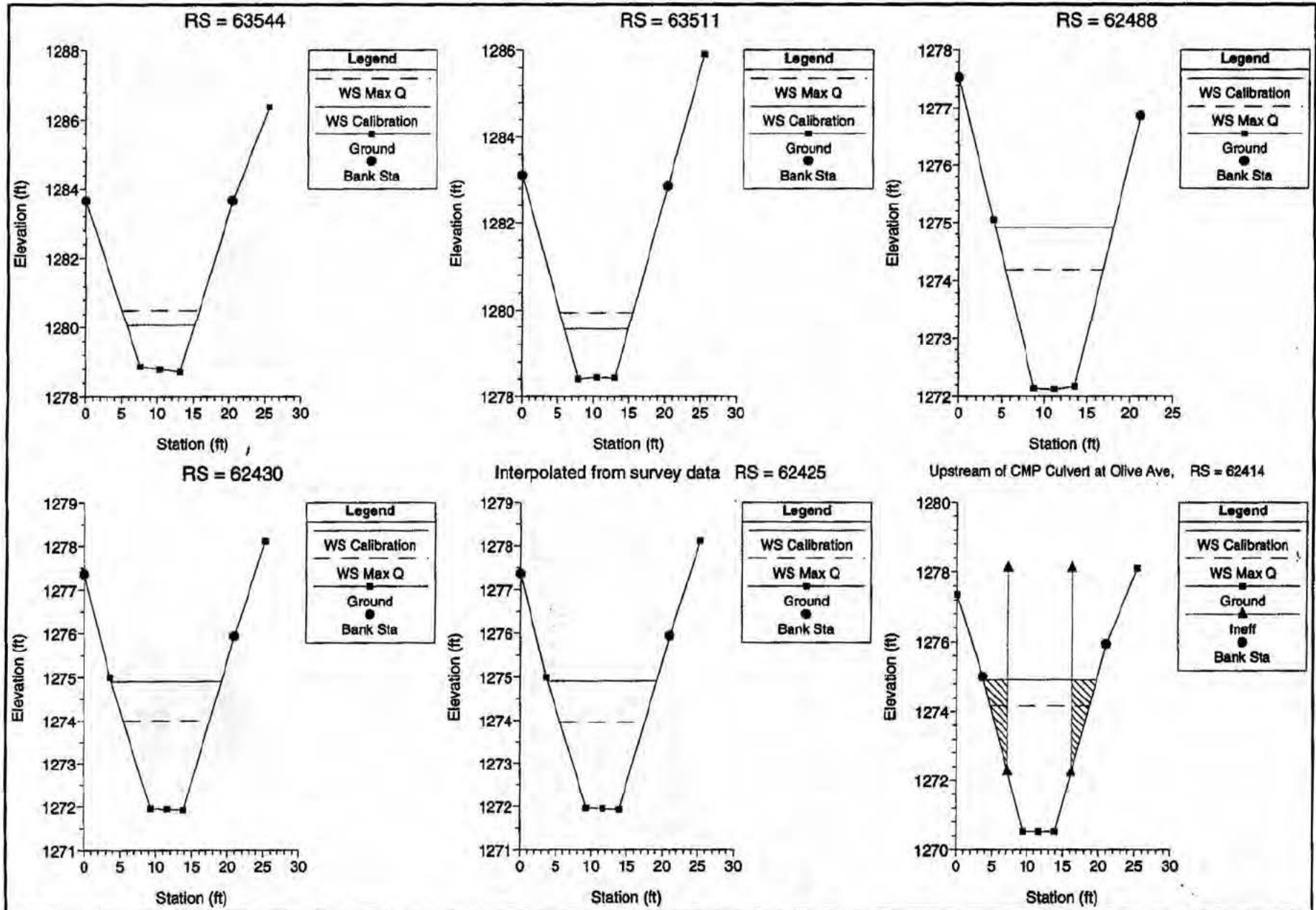


RS = 67474

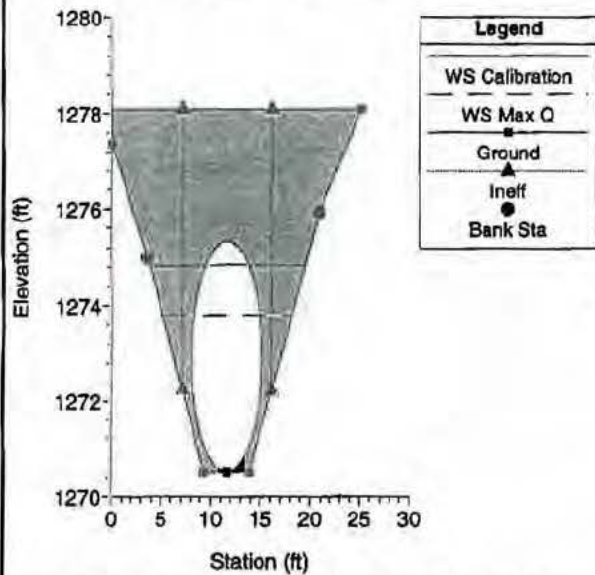




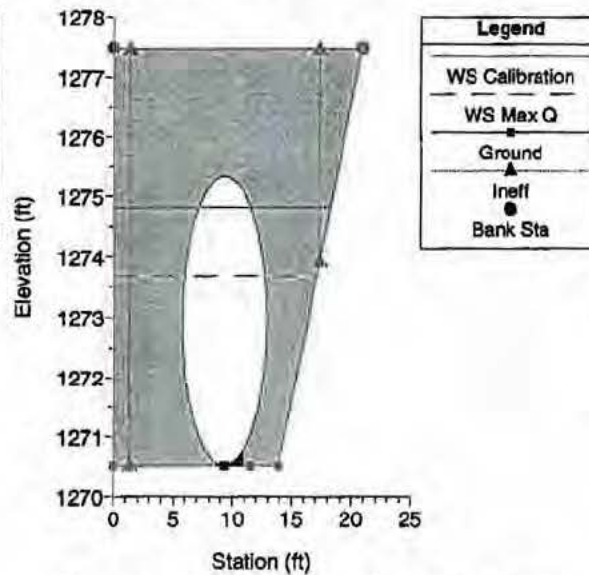




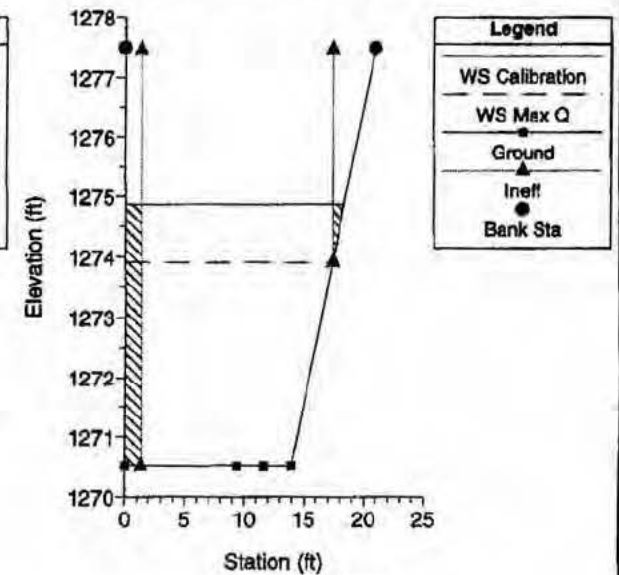
CMP Culvert at Olive Ave, upstream from RS = 62413



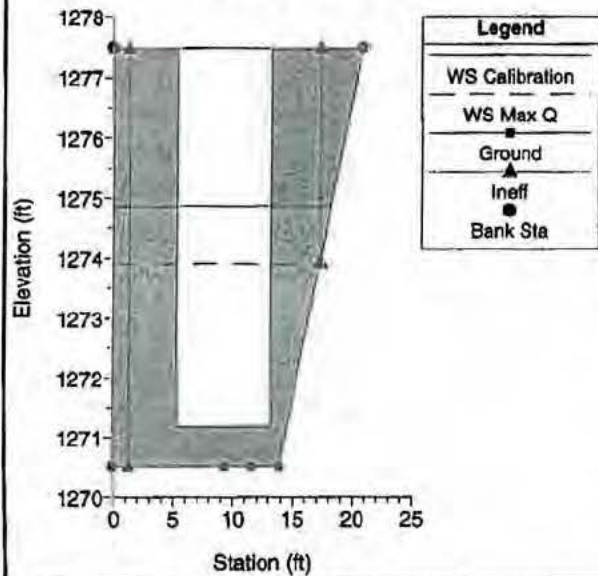
CMP Culvert at Olive Ave, upstream from RS = 62413



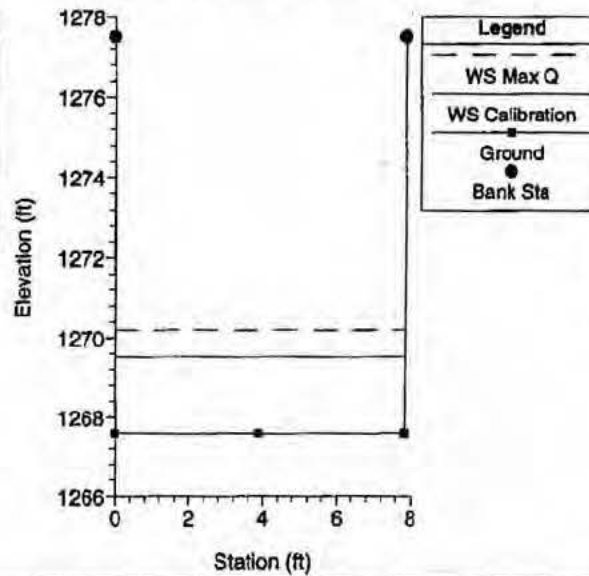
Between Culvert and Checkboard at turnout RS = 62370



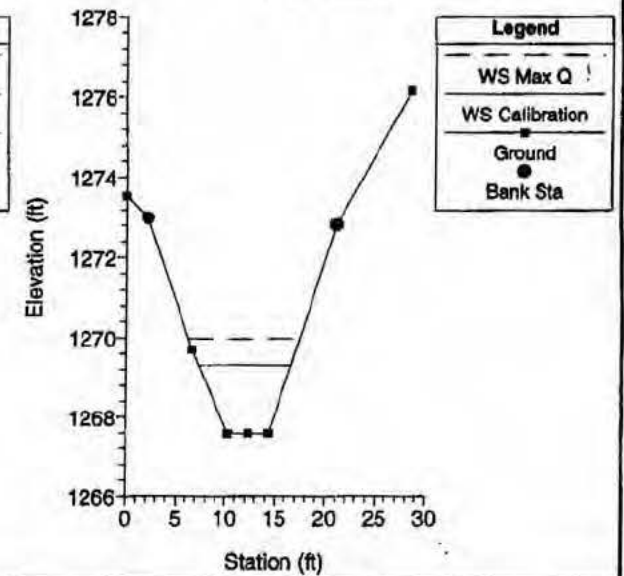
Turnout #9 - Rectangular checkboard gate RS = 62366

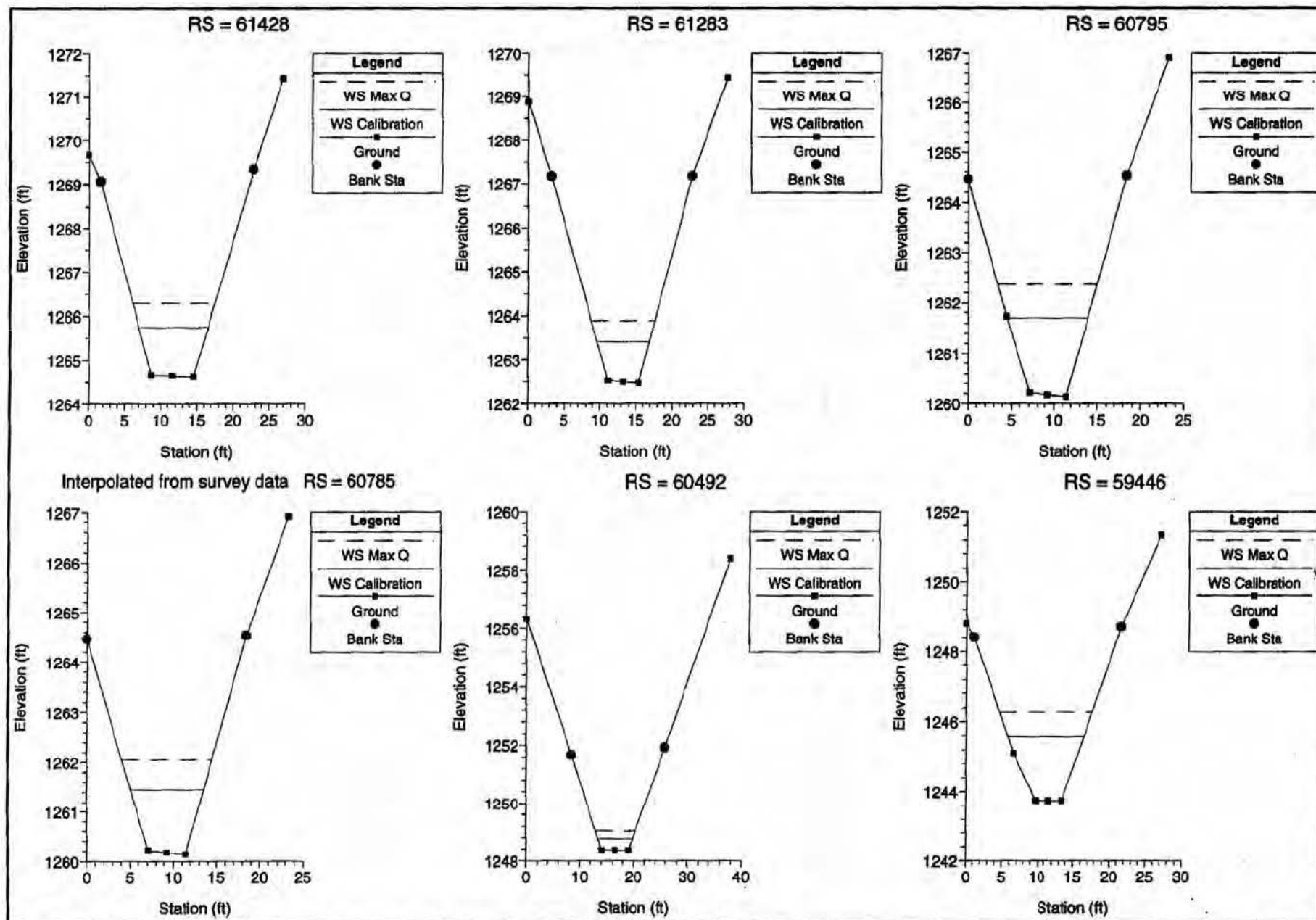


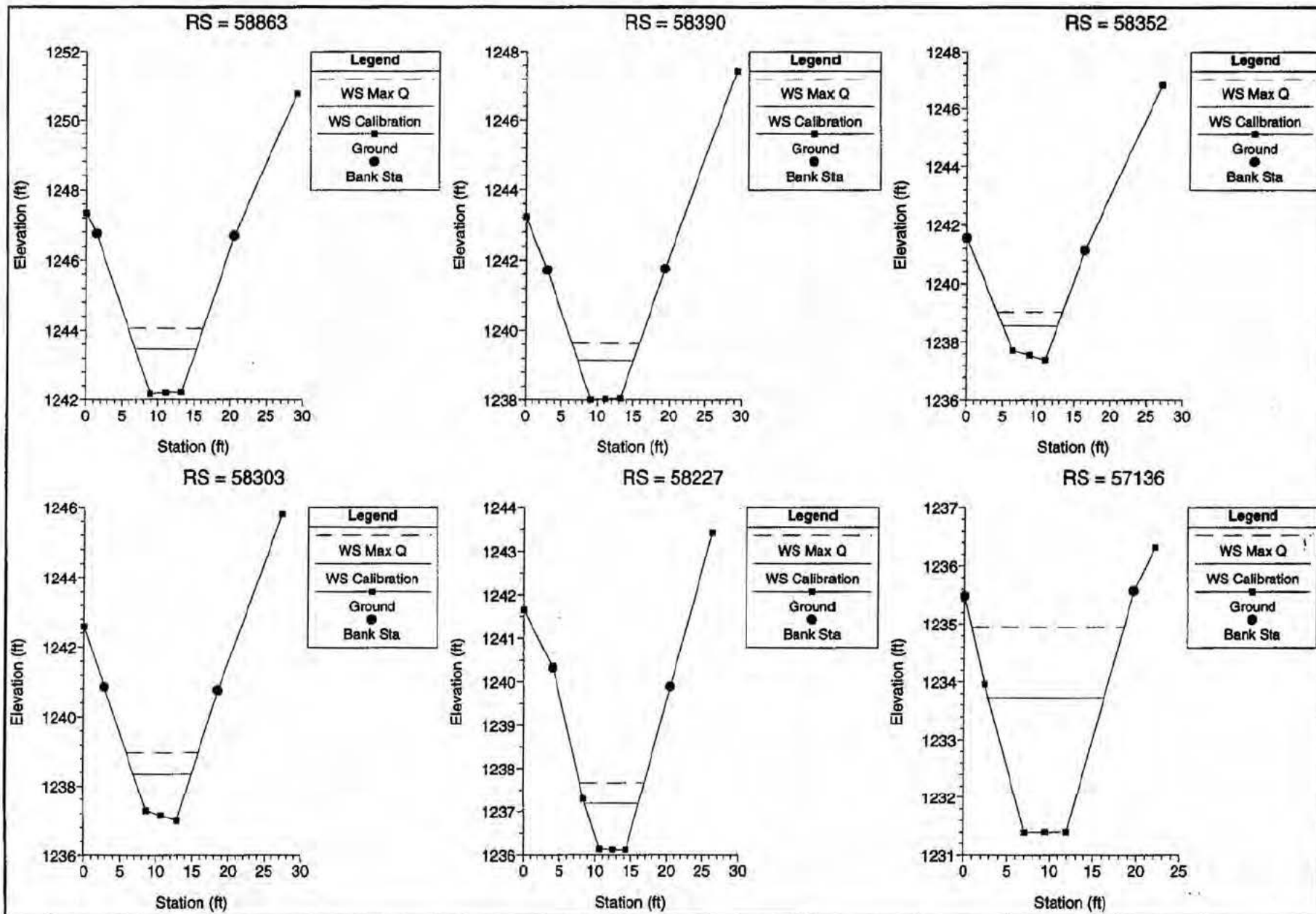
Downstream from Turnout #9 check board, RS = 62364



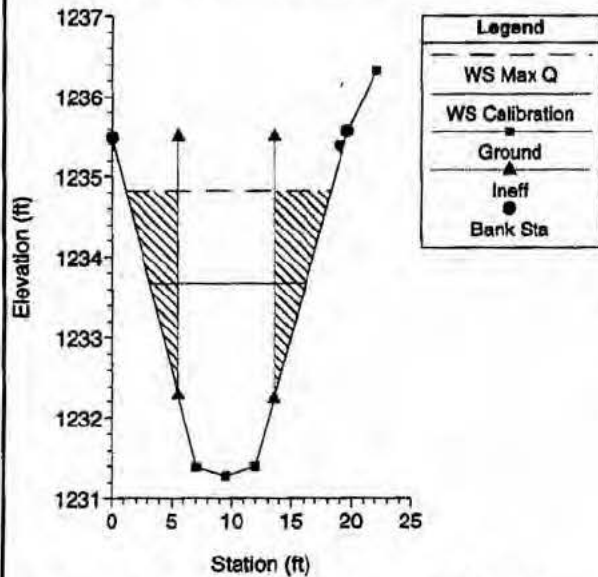
RS = 62307



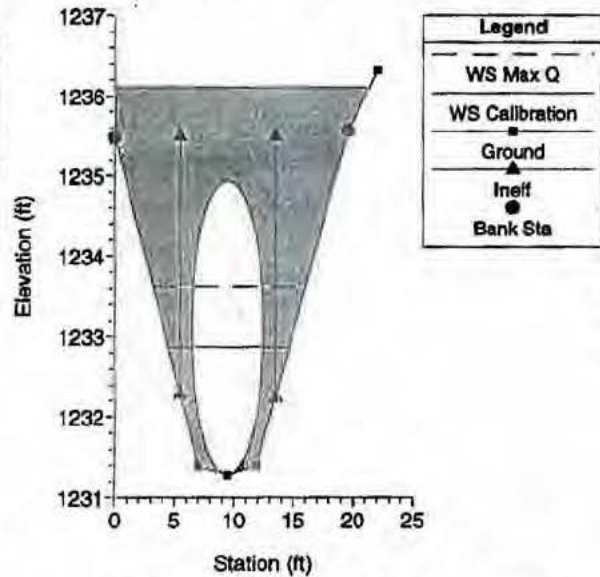




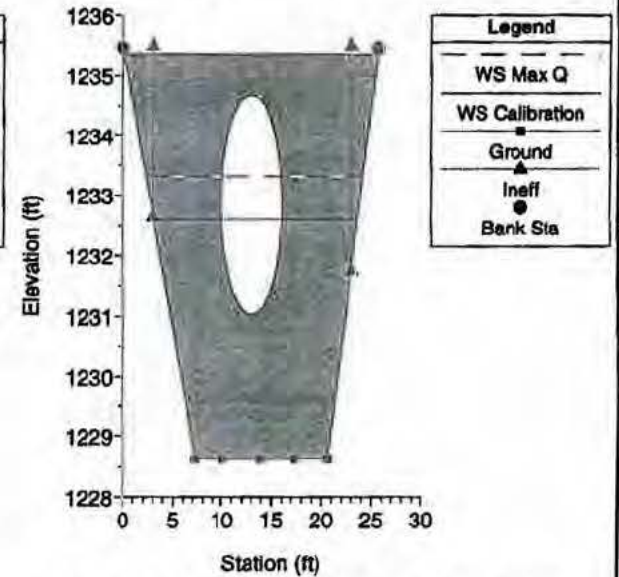
Upstream CMP Culvert at Northern Ave RS = 57118



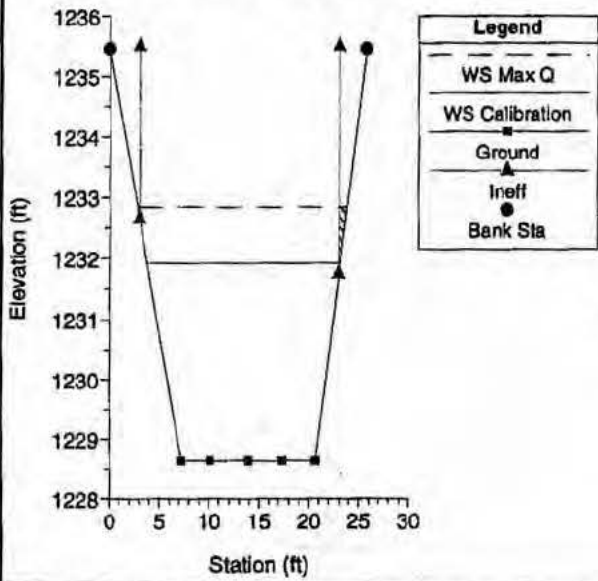
CMP Culvert at Northern Ave, upstream fr RS = 57117



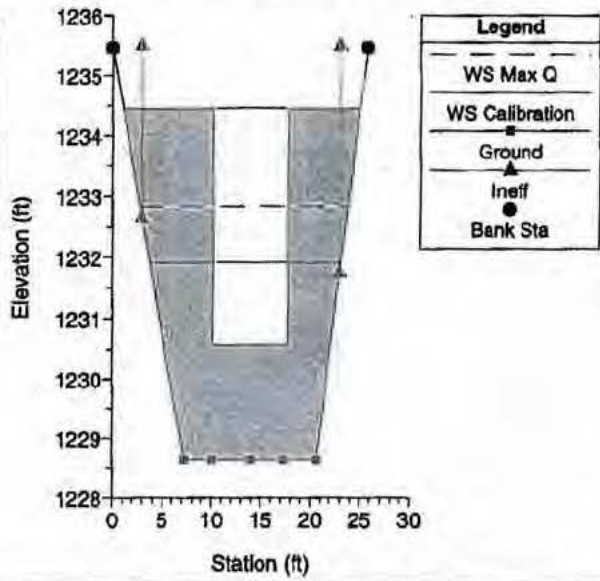
CMP Culvert at Northern Ave, upstream fr RS = 57117



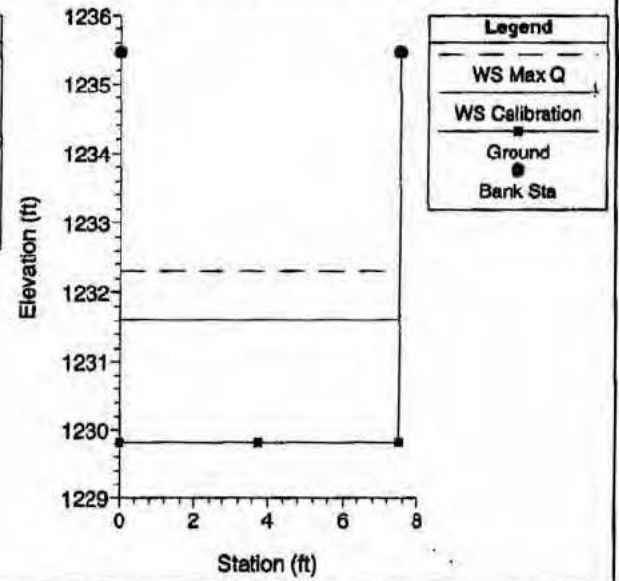
Between Culvert and Checkboard - Turnout RS = 57090

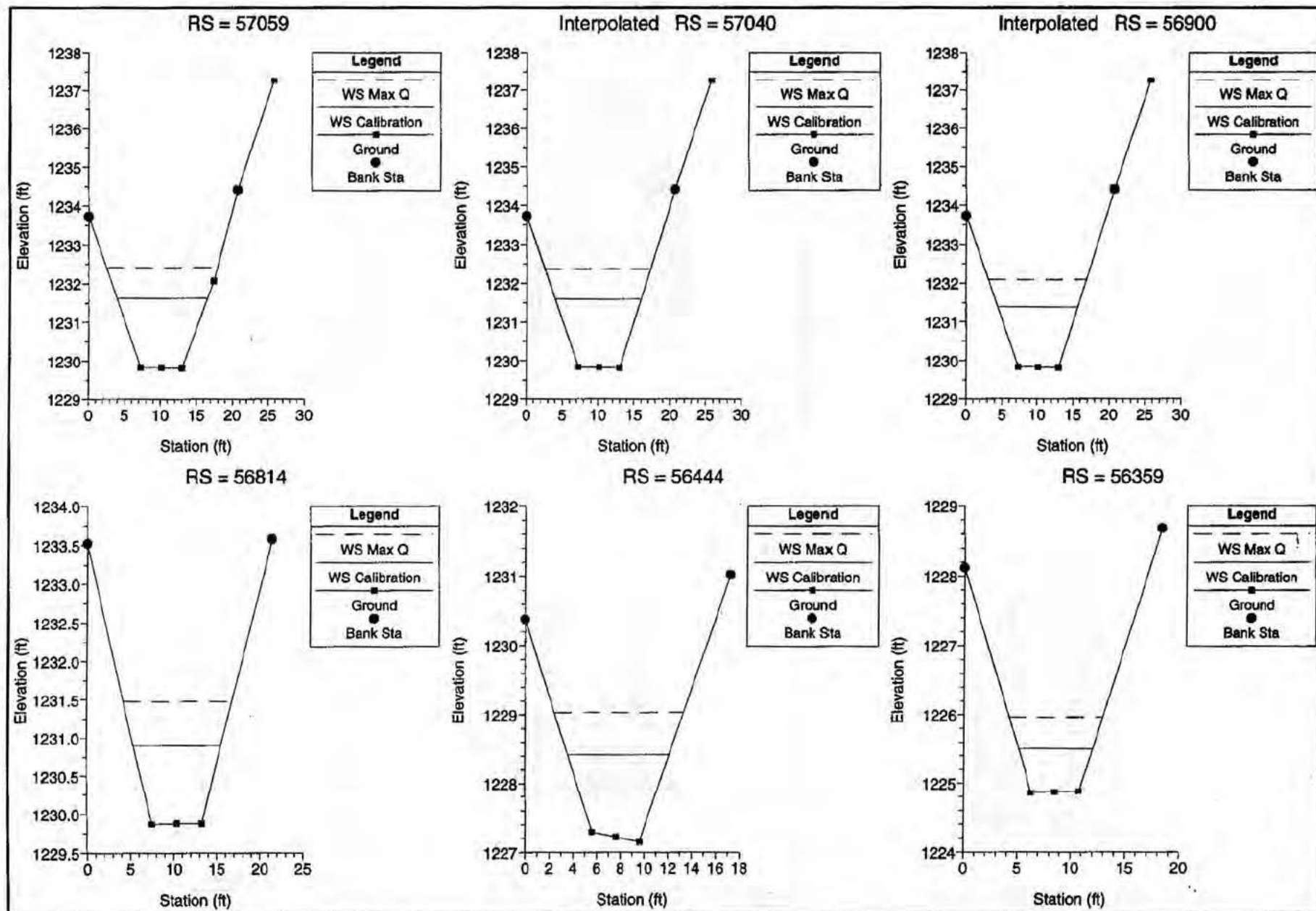


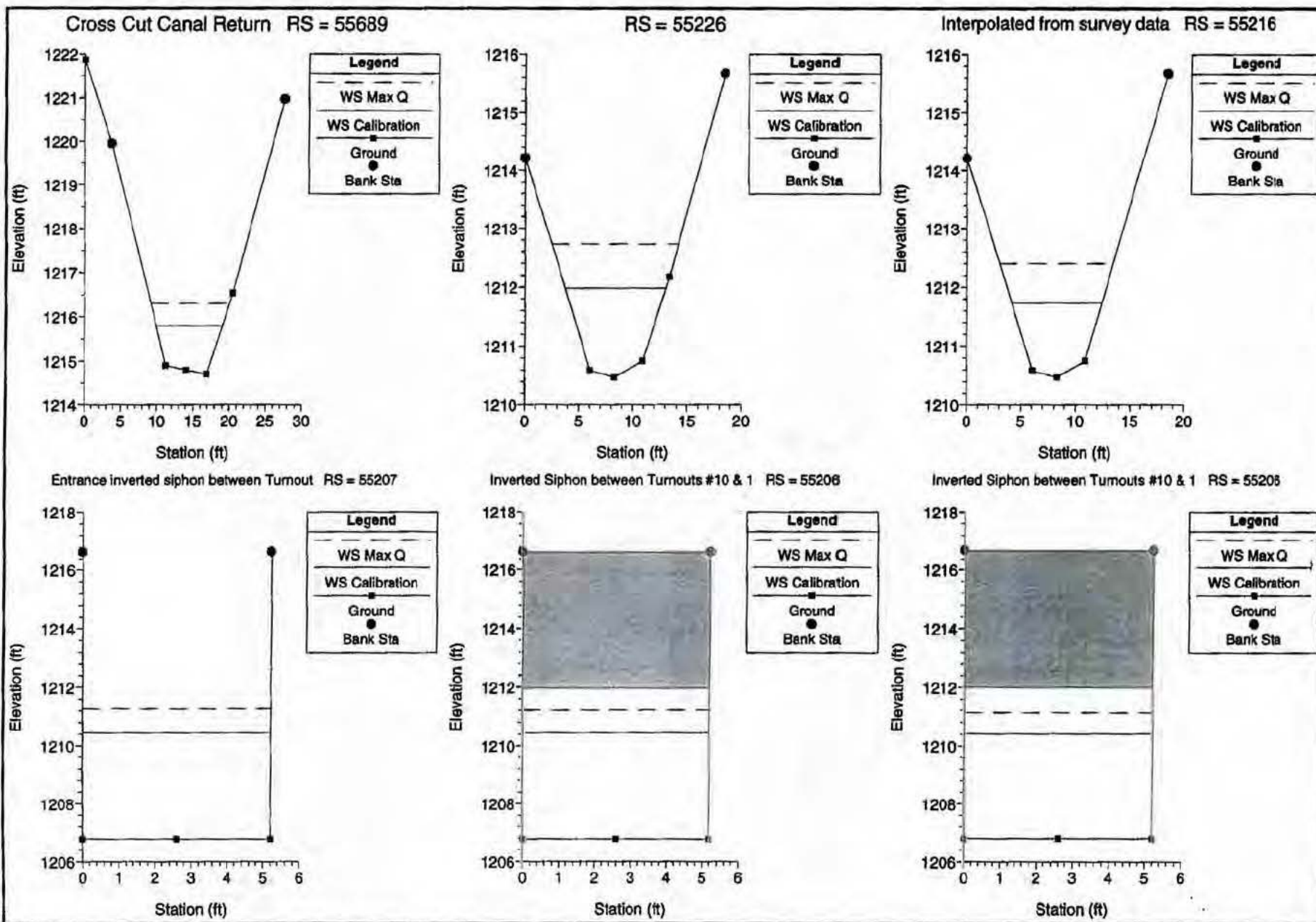
Turnout #10 - Rectangular Checkboard gate RS = 57083



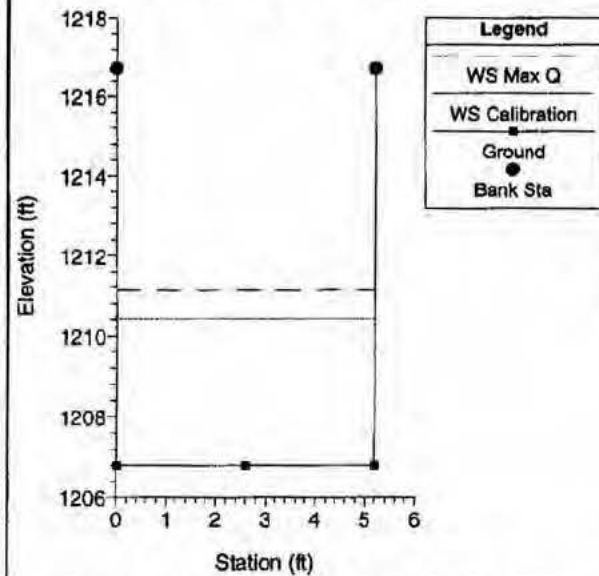
Downstream Turnout #10 checkboard, RS = 57081



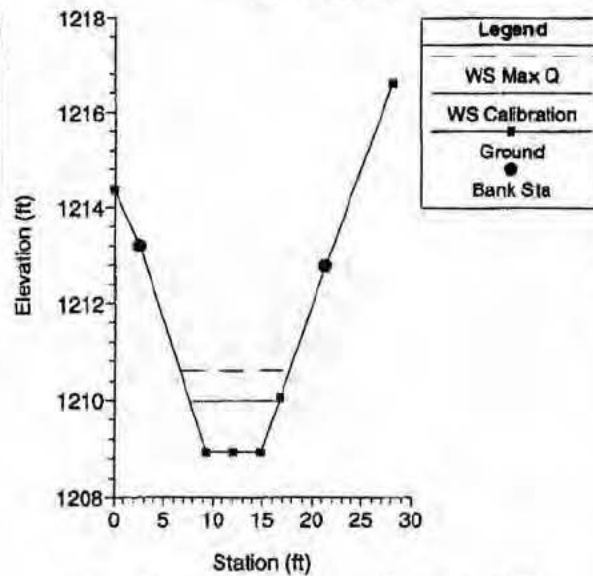




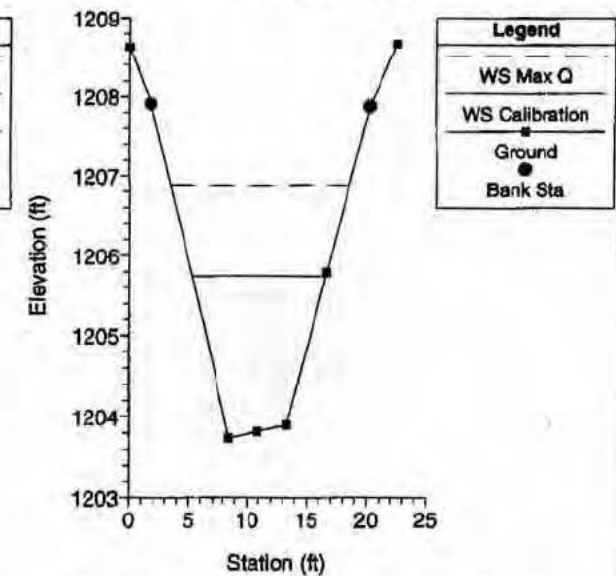
Downstream inverted siphon between Turno RS = 55107



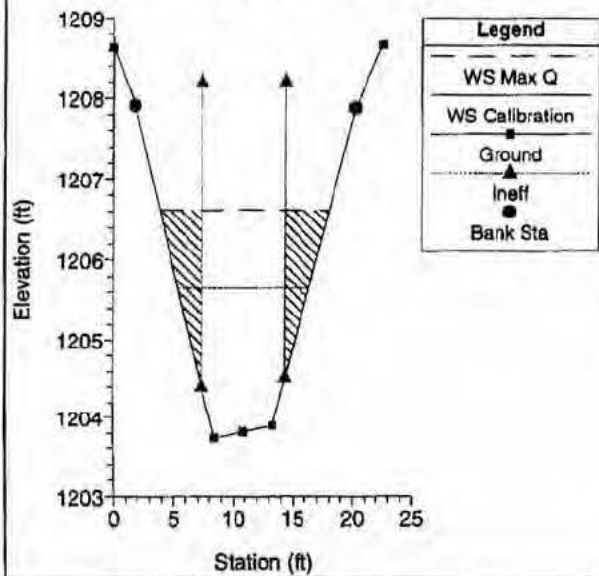
RS = 55076



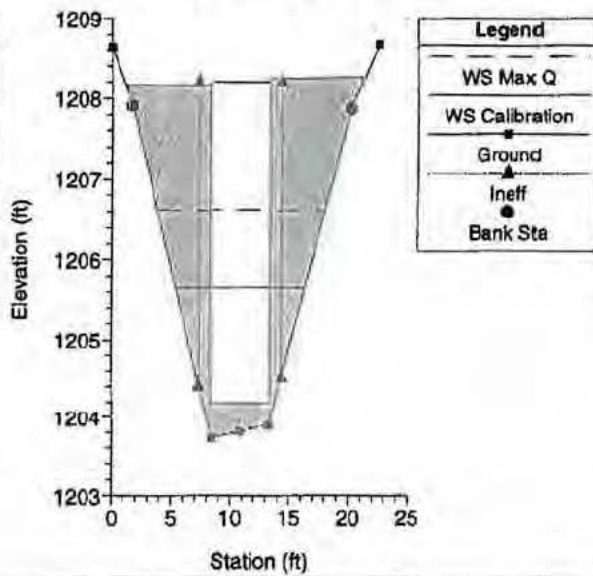
RS = 52886



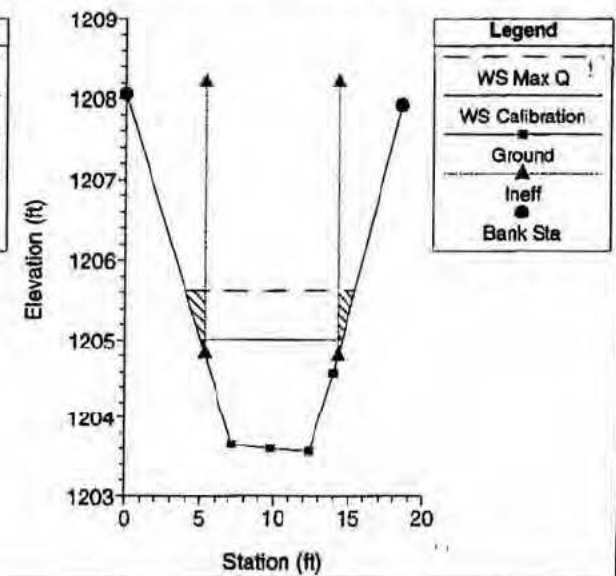
Upstream unused checkboard blwn Turnouts RS = 52861

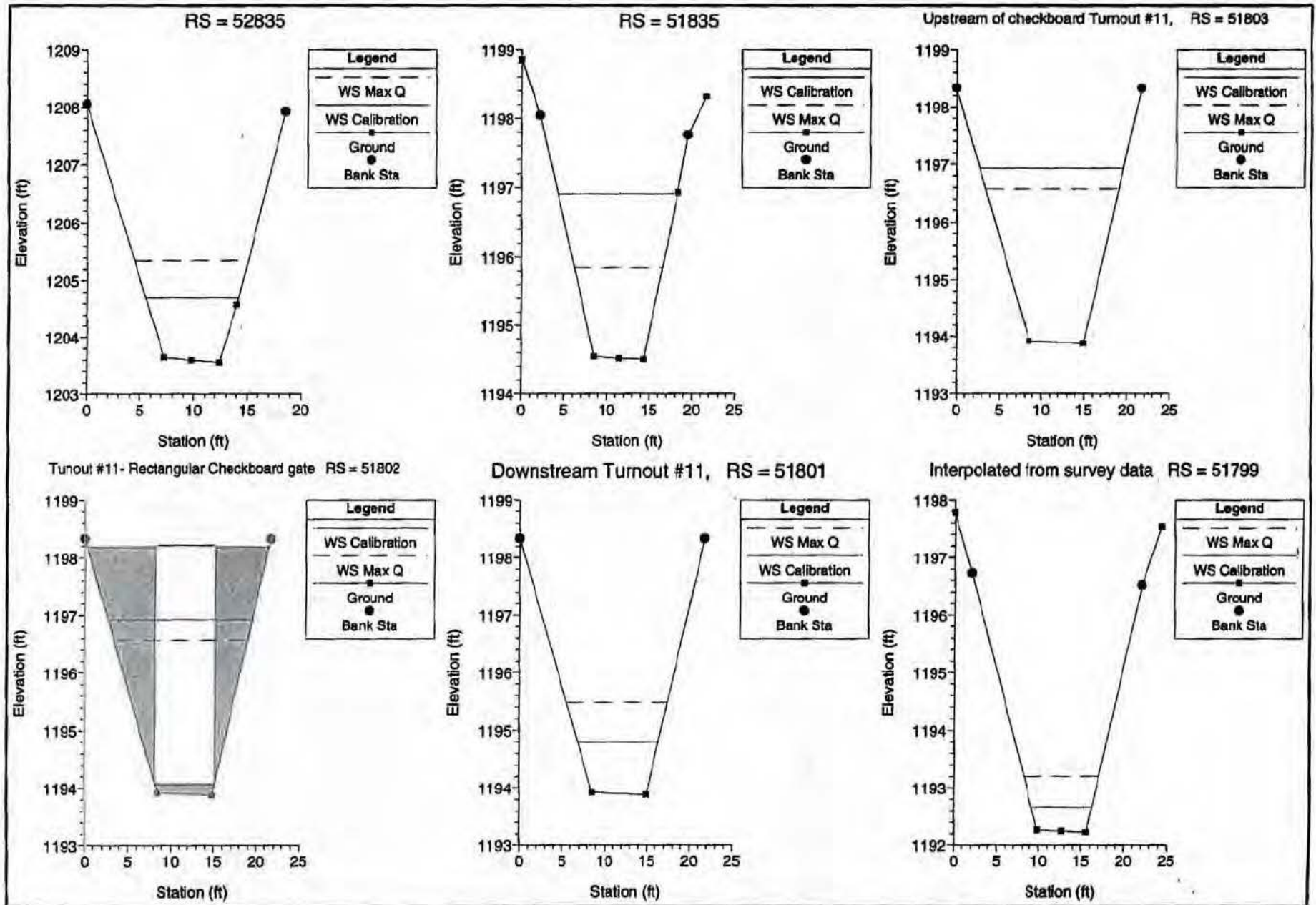


Between Turnouts #10 and 11, unused chec RS = 52860

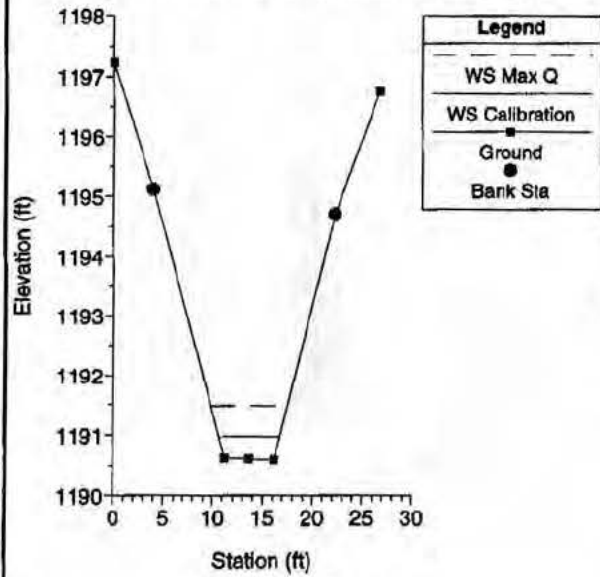


Downstream checkboard drop at unused tur RS = 52858

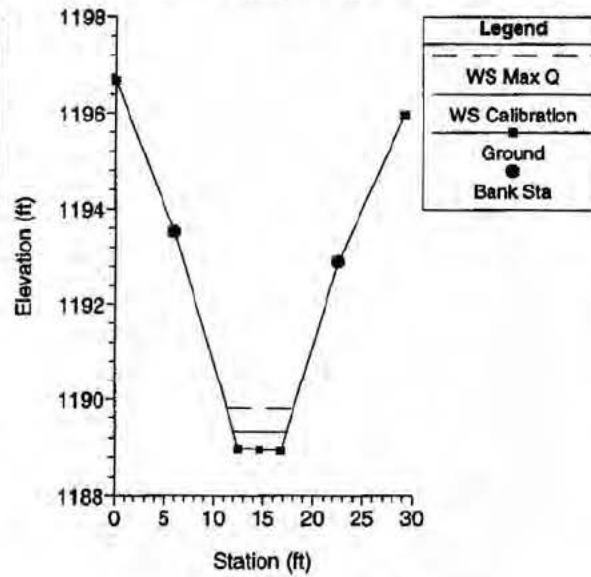




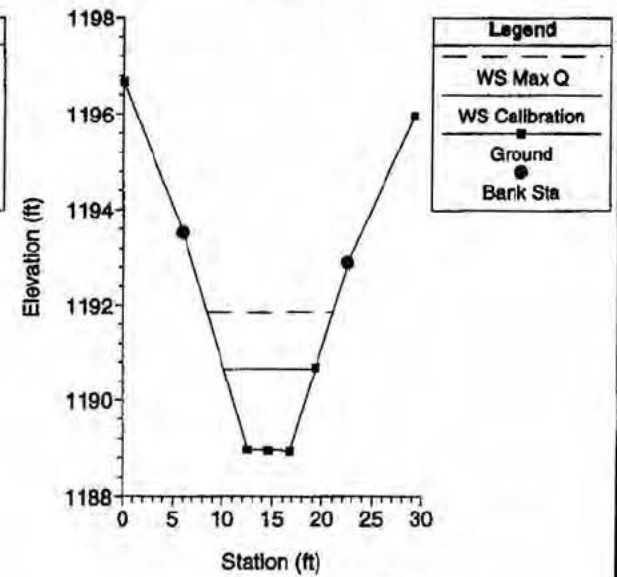
Interpolated from survey data RS = 51797



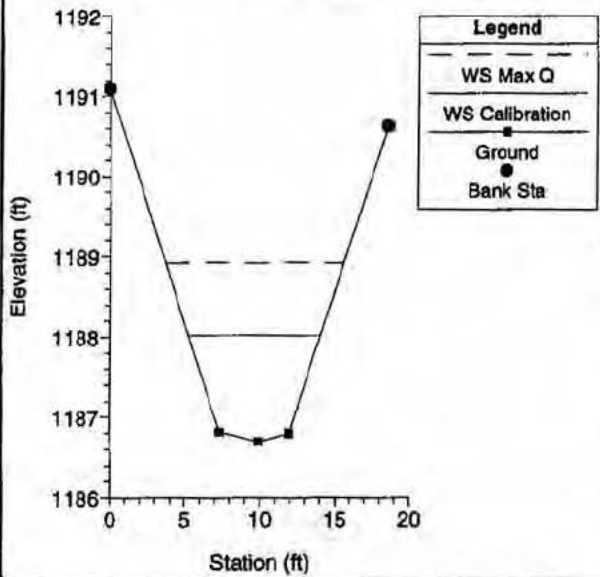
Downstream Turnout #11, RS = 51795



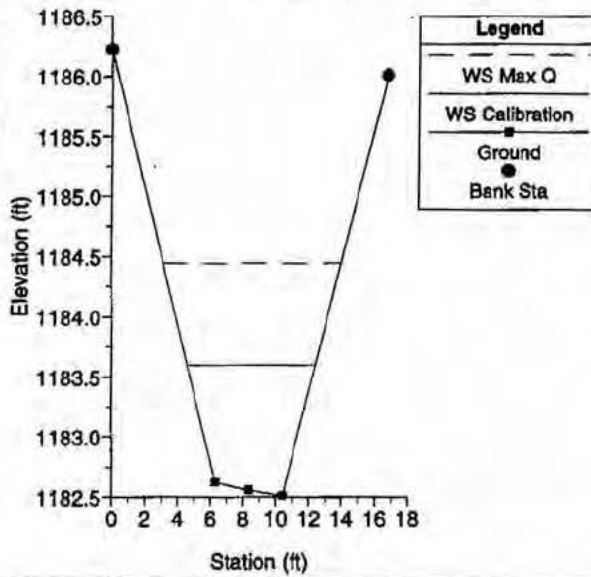
RS = 51758



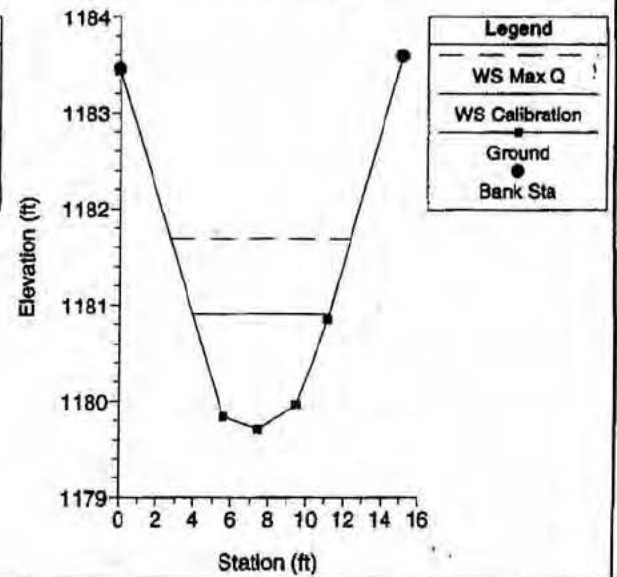
RS = 50260

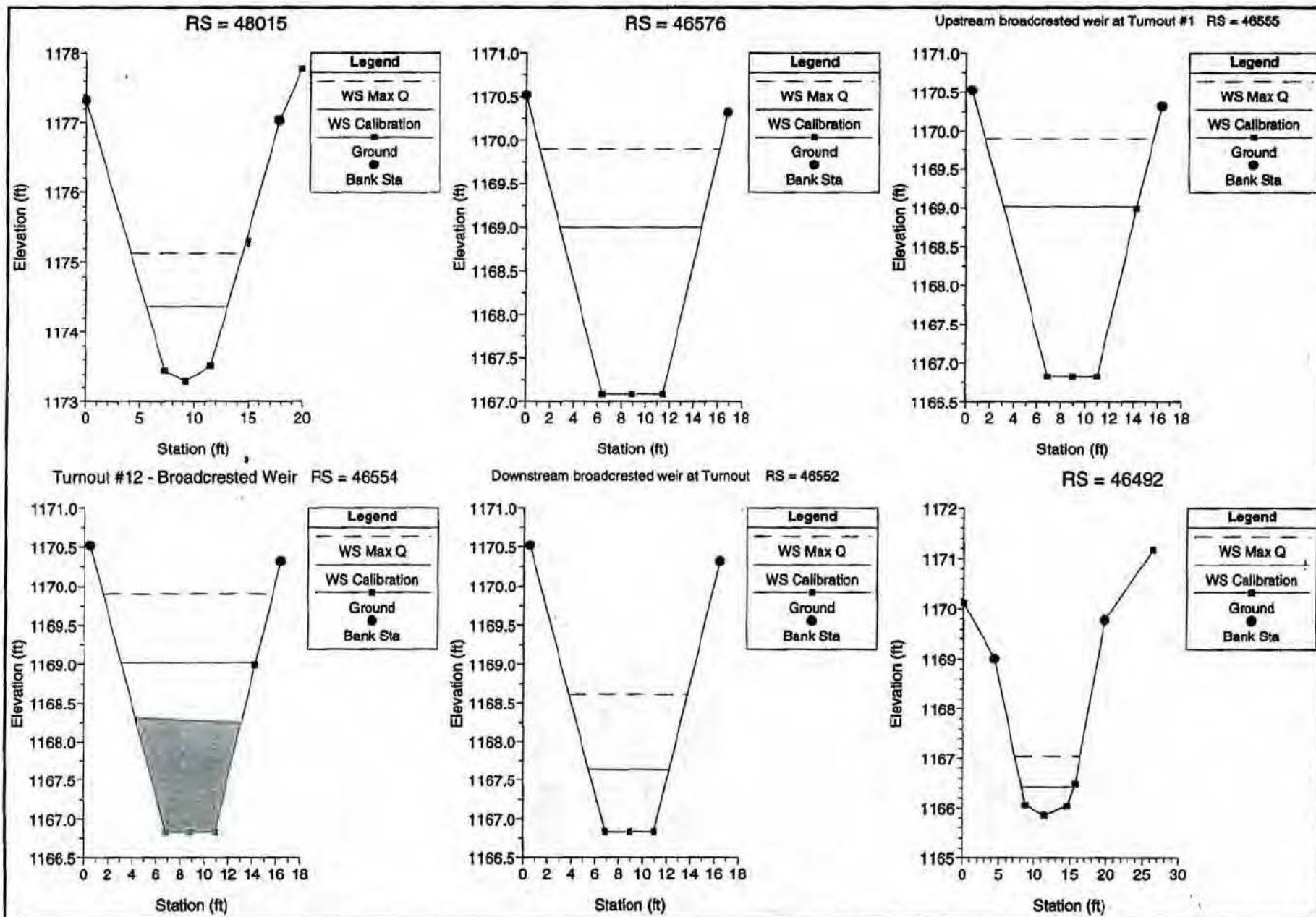


RS = 49239

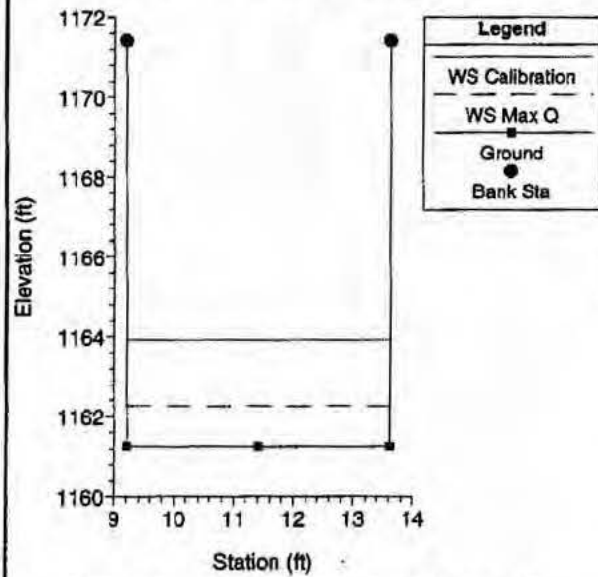


RS = 48847

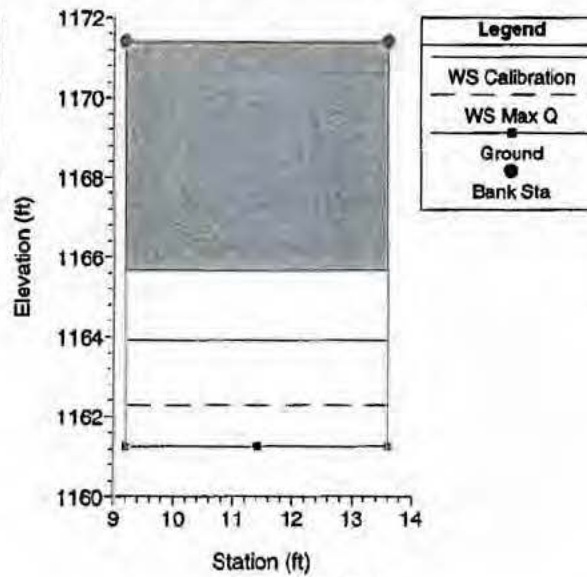




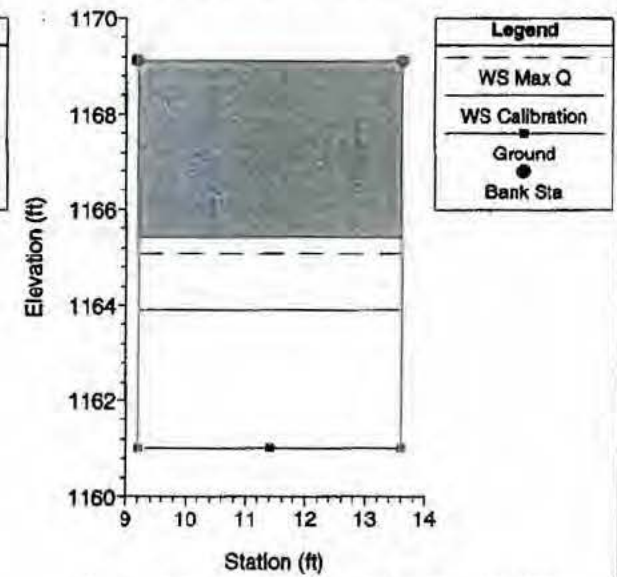
Upstream inverted siphon below Turnout # RS = 46476



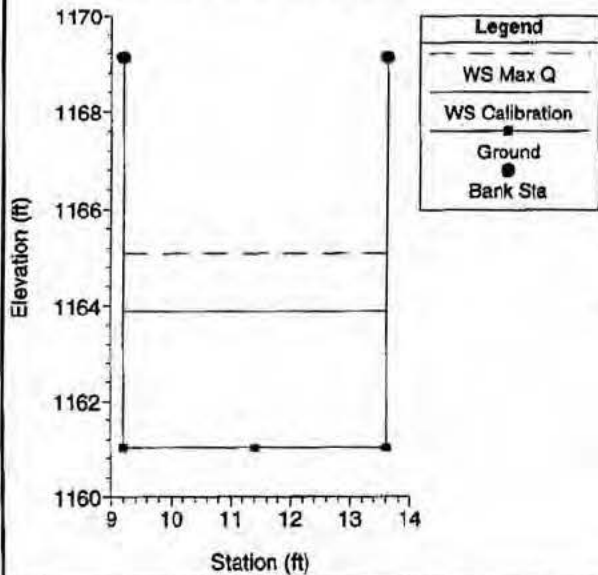
Inverted Siphon downstream from Turnout RS = 46475



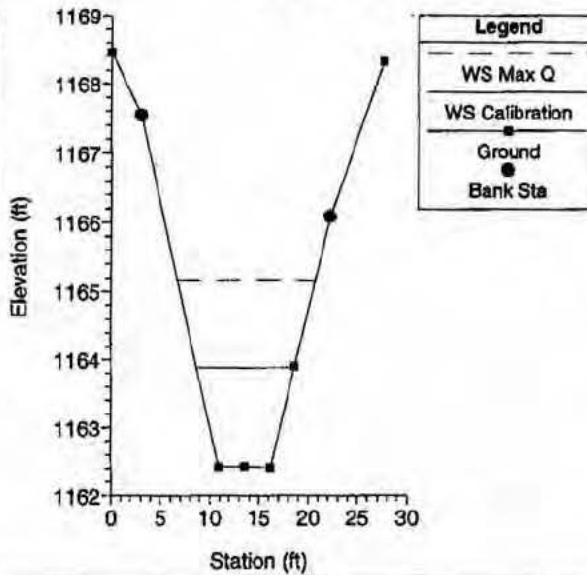
Inverted Siphon downstream from Turnout RS = 46475



Entrance inverted siphon below Turnout # RS = 46370



RS = 46344



Interpolated from survey data RS = 46000

