Final Report

Design Data Report for Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area

Prepared for

Bureau of Reclamation

Mid-Pacific Region

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CH2MHILL

Executive Summary

The Gray Lodge Wildlife Area (WA) (or refuge), located 65 miles north of Sacramento in the eastern Sacramento Valley, is owned and managed by the State of California Department of Fish and Game (CDFG) but depends on Biggs-West Gridley Water District (WD) (or District) for most of its water supply. Through an agreement with the Bureau of Reclamation (Reclamation) and other state agencies, Biggs-West Gridley WD conveys project water to the seasonal wetlands and irrigated pasture and crop land of Gray Lodge WA through a series of District-maintained canals and ditches to three delivery points at the boundary of Gray Lodge WA.

The passage of the Central Valley Project Improvement Act (CVPIA), Public Law 102-575, October 1992, Section 3406 (d), directed the U.S. Department of Interior, through Reclamation, to provide an additional allocation of 44,000 acre-feet of full Level 4 water supplies to Gray Lodge WA beginning in 2002 forward. Approximately 8,600 acre-feet of additional water is needed at the WA to meet the requirements of CVPIA. An Environmental Assessment/Initial Study (EA/IS) was completed for several refuge conveyance options in 1997 under the CVPIA Refuge Water Supply (RWS) Program, including conveyance improvements potentially required to convey water to Gray Lodge WA through Biggs-West Gridley WD. Several studies were completed subsequently based on the alternative “GRA-9” documented in the EA/IS.

In 2003, Biggs–West Gridley WD and Reclamation entered into Cooperative Agreement 03-FC-20-2049 (Cooperative Agreement) in support of the CVPIA RWS Program. The Cooperative Agreement covers long-term wheeling of water by Biggs–West Gridley WD to the Gray Lodge WA, including the funding and implementation of improvements to the Biggs–West Gridley WD distribution system for reliable conveyance of Level 4 refuge water to support full habitat development as required by Section 3406(d)(2) of CVPIA. The Cooperative Agreement covers several studies and phases of design (collectively referred to as the Gray Lodge WA Water Supply Project) to develop and implement the necessary system improvements. In 2004, two complementary studies were launched: the Canal Water Level, Flow Measurement, and Seepage Study (Measurement and Seepage Study) and the Design Data Study for Water District System Improvements (Design Data Study, documented by this Design Data Report) to determine the capital improvements necessary for the Biggs-West Gridley WD system to convey increased flows.

In 2004, a project goal statement for the Gray Lodge Water Supply Project was developed cooperatively by Reclamation and Biggs-West Gridley WD management, and approved by the Biggs-West Gridley WD Board of Directors. The goal statement was revised in 2005. The project’s goal statement as revised and adopted in 2005 is:

> *The goal of the project is to deliver a firm, reliable water supply of suitable quality to the boundary of Gray Lodge WA via the Biggs-West Gridley WD conveyance system in accordance with Cooperative Agreement 03-FC-20-2049 (Cooperative Agreement) between Reclamation and Biggs-West Gridley WD.*

A purpose of the Cooperative Agreement is to modify the Biggs-West Gridley conveyance system so that the project goal can be accomplished and project impacts, if any, can be mitigated.

The purpose of this Design Data Report is to recommend system improvements that would enable Biggs-West Gridley WD to deliver a firm, reliable water supply to the boundary of Gray Lodge WA. The scope of the study is to recommend system improvements necessary to convey CVPIA water amounts in excess of Biggs-West Gridley WD's annual allocation to Gray Lodge WA. The report discusses how the recommendations were developed by establishing design flows, conducting hydraulic modeling, determining necessary improvements, and estimating capital costs. The Design Data Report is intended to support the next steps required to implement the project, including preliminary design, permitting, design, and construction.

The basic technical approach of the Design Data Study consisted of these steps:

1. Develop data collection network in key locations in the Biggs–West Gridley WD system.
2. Document existing delivery patterns and operating conditions at Biggs–West Gridley WD as they relate to Gray Lodge WA deliveries.
3. Determine the best estimate of future deliveries to Gray Lodge WA.
4. Determine facility improvements required to deliver Level 4 water to Gray Lodge WA by using a hydraulic model.
5. Estimate capital costs of facility improvements.

All major stakeholders in the Design Data Study, including Reclamation, Biggs–West Gridley WD Board and management, and the California Department of Fish and Game, were involved throughout the study.

Improvements to Biggs–West Gridley WD required to convey Level 4 flows to Gray Lodge WA were determined by developing a hydraulic model of the delivery system using a U.S. Army Corps of Engineers hydraulic model (HEC-RAS). Major and minor structure modifications and canal reshaping were considered for improvements. Appraisal-level cost estimates were prepared for the recommended improvements based on the facility size, layout, and features presented in this report. The cost estimates are intended for planning purposes only and are not based on completed engineering designs and site investigations. These steps would be required at a later stage of project development to refine the cost estimates for any improvements that proceed beyond this phase of evaluations.

Table ES-1 summarizes the associated cost estimate for the construction of recommended improvements and non-construction-related costs required to implement the recommendations.

TABLE ES-1
Appraisal-level Cost Estimate Summary: Composite Alternative
Gray Lodge Design Data Report

Item	Cost
Field Cost (FC)	
Belding Lateral projects	$11,260,000
Schwind Lateral projects	$3,340,000
Traynor Lateral projects	$5,860,000
Rising River Lateral projects	$880,000
Cassady Lateral projects	$1,070,000
Total Field Cost*	**$22,410,000**
Non-contract Costs	
Engineering and design (10 percent of FC)	$2,240,000
Construction services and management (10 percent of FC)	$2,240,000
Legal and administrative (4 percent of FC)	$900,000
Permits and environmental documentation (6 percent of FC)	$1,340,000
Total Non-contract Cost	**$6,720,000**
Total capital cost (2008 basis)	**$29,130,000**

* Appraisal-level opinion of construction cost in 2008 dollars. Breakdown of pay items per lateral per improvement project are provided in Appendix E.

The recommended improvements set forth in the Design Data Report are all required to deliver Level 4 water delivery to Gray Lodge WA and do not provide betterment, systemic or otherwise, to the Biggs-West Gridley WD system, and therefore no portion of the costs of these improvements, as outlined in the Design Data Report, will be allocated to the District.

Subsequent phases of the Gray Lodge WA Water Supply Project will build upon the findings of the Design Data Study.

An updated EA/IS should be completed for improvements to Biggs–West Gridley WD. The EA/IS was completed in December 1997, based on technical studies and conceptual plans completed after the passage of the CVPIA, however, several refinements to the project have been made since 1997.

Implementation of preliminary design, final design, and construction phases would occur over the next 2 to 5 years, depending on funding. In addition to these activities, a seepage monitoring and mitigation plan will be initiated by Reclamation during the design phase of the project in consultation with and subject to acceptance by the District to monitor seepage conditions post-construction and mitigate short-term and long-term seepage impacts. The timeline in Figure ES-1 depicts the approximate schedule of remaining implementation phases.

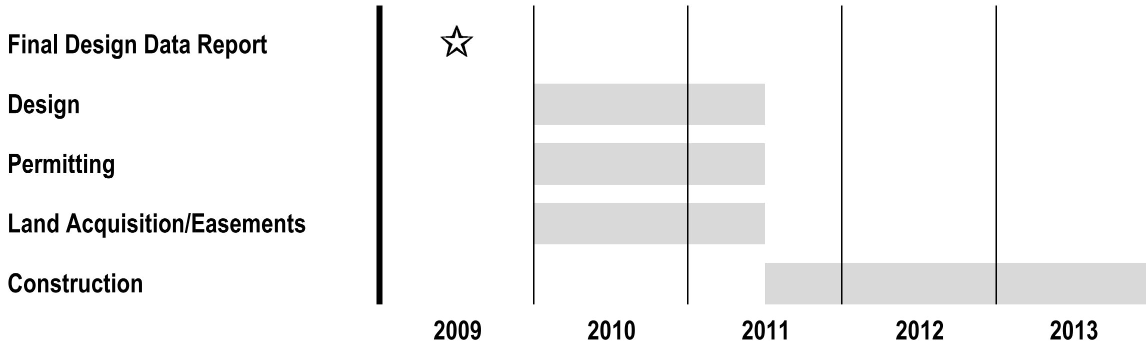

FIGURE ES-1
Proposed Implementation Schedule

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Acronyms and Abbreviations

BO	Biological Opinion
CC	Contract Cost
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
cfs	cubic feet per second
Cooperative Agreement	Cooperative Agreement 03-FC-20-2049
CVPIA	Central Valley Project Improvement Act
Decision Document	Decision Document: Report of Recommended Alternatives Refuge Water Supply and San Joaquin Basin Action Plan Lands
Design Data Report	Design Data Report for Conveyance of Refuge Water Supply to Gray Lodge WA
EA	Environmental Assessment
EA/IS	Environmental Assessment/Initial Study
FC	Field Cost
Gray Lodge Water Supply Project	CVPIA RWS Facilities Construction Program—Gray Lodge Water Supply Project
HEC-RAS	Hydraulic Engineering Center River Analysis System
ID	Irrigation District
Joint Board	Joint Water District Board
Measurement and Seepage Study	Canal Water Level, Flow Measurement, and Seepage Study
NEPA	National Environmental Policy Act
RD	Reclamation District
Reclamation	Bureau of Reclamation
RWS	Refuge Water Supply
Service	U.S. Fish and Wildlife Service
UPRR	Union Pacific Railroad
WA	Wildlife Area
WD	Water District

SECTION 1

Introduction

1.1 Purpose

Gray Lodge Wildlife Area (WA) (or refuge), located 65 miles north of Sacramento in the eastern Sacramento Valley, is owned and managed by the California Department of Fish and Game (CDFG) but depends on Biggs-West Gridley Water District (WD) (or District) for most of its water supply. Through an agreement with the Bureau of Reclamation (Reclamation) and other state agencies, Biggs-West Gridley WD conveys project water to the seasonal wetlands and irrigated pasture and crop land of Gray Lodge WA through a series of District-maintained canals and ditches to three delivery points at the boundary of Gray Lodge WA.

The passage of the Central Valley Project Improvement Act (CVPIA), Public Law 102-575, October 1992, Section 3406 (d), directed the U.S. Department of Interior, through Reclamation, to provide an annual allocation of 44,000 acre-feet of full Level 4 water supplies to Gray Lodge WA beginning in 2002 forward. Approximately 8,600 acre-feet of additional water is needed at the WA to meet the requirements of CVPIA.

The purpose of this Design Data Report is to recommend system improvements that would enable Biggs-West Gridley WD to deliver a firm, reliable water supply to the boundary of Gray Lodge WA. The scope of the study is to recommend system improvements necessary to convey CVPIA water amounts in excess of Biggs-West Gridley WD's annual allocation to Gray Lodge WA. The report discusses how the recommendations were developed by establishing design flows, conducting hydraulic modeling, determining necessary improvements, and estimating capital costs. The Design Data Report is intended to support the next steps required to implement the project, including preliminary design, permitting, design, and construction.

1.2 Background

The passage of CVPIA, Public Law 102-575, in 1992 required the U.S. Department of the Interior, through Reclamation, to provide "…firm water supplies of suitable quality to maintain and improve wetland habitat areas on units of the National Wildlife Refuge System in the Central Valley of California; on the Gray Lodge, Los Banos, Volta, North Grasslands, and Mendota state wildlife management areas; and on the Grasslands Resources Conservation District in the Central Valley of California" (Section 3406(d)). The total firm water supply required for optimum refuge management and habitat development is referred to as Level 4 in the *Report on Refuge Water Supply Investigations* (Reclamation, 1989) (referred to as the "1989 Report"). The existing average annual water deliveries calculated in 1989 are referred to as Level 2 refuge water supply. Table 1-1 lists the Level 2, Incremental Level 4, and total Level 4 water supplies for Gray Lodge WA. (Incremental Level 4 refers to the difference between Level 2 and Level 4 water supplies.)

TABLE 1-1
Water Supply Requirements for Gray Lodge WA
Gray Lodge Design Data Report

Month	Water Supply Requirement (ac-ft)		
	Level 2[a]	Incremental Level 4	Level 4[a]
January	1,050	270	1,320
February	1,050	270	1,320
March	1,050	270	1,320
April	1,050	270	1,320
May	2,500	580	3,080
June	3,500	900	4,400
July	2,500	580	3,080
August	2,850	670	3,520
September	7,100	1,700	8,800
October	6,750	1,610	8,360
November	4,600	1,120	5,720
December	1,400	360	1,760
Total	**35,400**	**8,600**	**44,000**
Conveyance losses[c]	5,202[b]	1,762[b]	6,964[b]
Total amount to be diverted	**40,602[b]**	**10,362[b]**	**50,964[b]**

[a] Reclamation, 1989. Level 4 needs include Level 2 quantities.
[b] Biggs-West Gridley WD provides Level 1, and the CVP (through exchanges) provides remaining Level 2.
[c] Reclamation and DFG, 1997. Conveyance loss of CVP water is 17 percent.

CVPIA Section 3406(d)(2) requires that refuges receive full Level 4 water supply by the year 2002; however, only a portion of Level 4 water supply is being wheeled to Gray Lodge WA via Biggs-West Gridley WD's conveyance system. The District's existing delivery system requires improvements to deliver a firm, reliable Level 4 water supply of suitable quality to the boundary of Gray Lodge WA to fulfill the obligations of CVPIA.

Numerous technical investigations and public involvement efforts were undertaken after the passage of the CVPIA. In 1995, Reclamation and the U.S. Fish and Wildlife Service published the *Decision Document: Report of Recommended Alternatives Refuge Water Supply and San Joaquin Basin Action Plan Lands.* The Decision Document summarized the results of planning studies and was a precursor to implementing environmental compliance activities.

An Environmental Assessment/Initial Study (EA/IS) was completed for several refuge conveyance options in 1997 under the CVPIA Refuge Water Supply (RWS) Program, including conveyance improvements potentially required to convey water to Gray Lodge WA through Biggs-West Gridley WD. Planning studies in 1998 through 2000 conceptually evaluated the required distribution system improvements. Included in that work were the following efforts on Biggs-West Gridley WD:

- Topographical survey of the main laterals
- Development of a hydraulic model for the canal system

- Estimation of peak flows required for the service area needs by month
- Establishment of criteria for use in developing facility improvement features
- Development of a draft list of system improvements and construction costs

In 2001, Reclamation and CDFG entered into a contract (referred to as the Water Supply Contract) establishing Reclamation's obligations under CVPIA to deliver water supplies to the Gray Lodge WA. The Water Supply Contract identifies the water types to be delivered to Gray Lodge WA: Level 2, Incremental Level 4, and full Level 4 water supplies. Under CVPIA, most of the Level 2 water supplies are provided from Central Valley Project (CVP) yield. Other water supplies are provided by an allotment from Biggs-West Gridley WD. A portion of Gray Lodge WA is within the Biggs-West Gridley WD boundary, and under certain state water rights, Biggs-West Gridley WD is responsible for delivering these water supplies (an allocation of an approximate allotment of 19,220 ac-ft) to Gray Lodge WA as one of its District landowners. Annually, Biggs-West Gridley WD provides an allocation to Gray Lodge WA and identifies the amount of state water rights water that will be delivered to Gray Lodge WA in a specific year. Under the Water Supply Contract, this District allocation counts toward the total Level 2 water supplies that Reclamation is responsible for providing to Gray Lodge WA. Incremental Level 4 water is acquired by Reclamation through several means; all surface water must be delivered through Biggs-West Gridley WD.

In 2003, Biggs-West Gridley WD and Reclamation entered into Cooperative Agreement 03-FC-20-2049 (Cooperative Agreement) in support of the CVPIA RWS Program. The Cooperative Agreement covers long-term wheeling of water by Biggs-West Gridley WD to the Gray Lodge WA, including the funding and implementation of improvements to the Biggs-West Gridley WD distribution system for reliable conveyance of Level 4 refuge water. The Cooperative Agreement covers several studies and phases of design to cooperatively develop and implement the necessary system improvements. The CVPIA RWS Facilities Construction Program—Gray Lodge Water Supply Project refers to this entire process of developing and implementing facility improvements to fulfill the Cooperative Agreement.

This Design Data Report for Conveyance of Refuge Water Supply to Gray Lodge WA was developed to compile, summarize, update, and build upon the information developed from 1998 to the present. Facility alternatives developed in the Design Data Report are based on the alternative "GRA-9" documented in the 1997 EA/IS described previously. In 2004, the Gray Lodge WA Water Supply Project was re-initiated with two complementary studies: the Canal Water Level, Flow Measurement, and Seepage Study (Measurement and Seepage Study) and the Design Data Study for Conveyance of Refuge Water Supply to Gray Lodge WA (Design Data Study, documented by this Design Data Report) to determine the capital improvements necessary for the Biggs-West Gridley WD system to convey increased flows. Technical work for these two studies was completed in parallel until 2005. The Measurement and Seepage Study was completed in 2005, although data collection has continued through the present. Analysis related to the Design Data Study was briefly postponed in 2006 and continued in January 2007. A timeline of project activities since project inception in 1989 through completion of the Design Data Report in 2009 is provided as Figure 1-1.

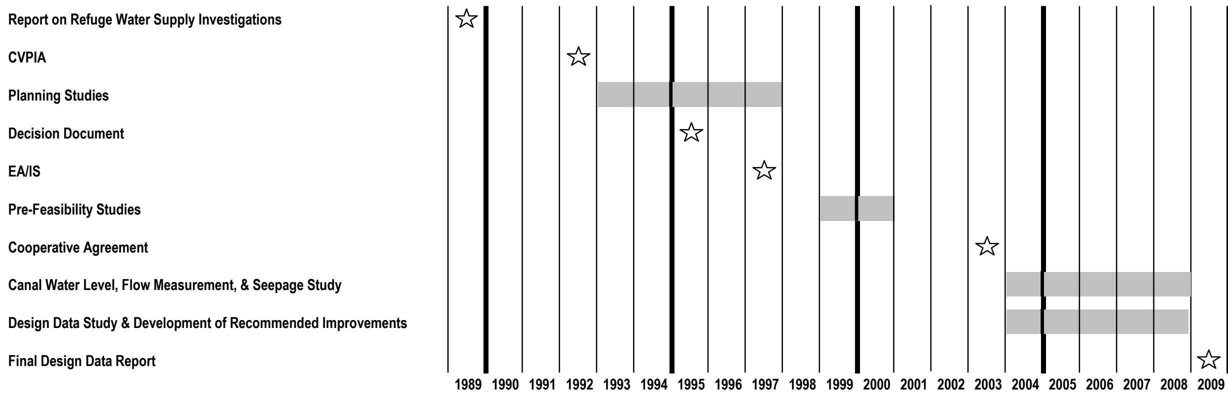

FIGURE 1-1
Gray Lodge WA Water Supply Project Timeline

1.3 Goals and Expectations

In 2004, a project goal statement and "measures of success" for the Gray Lodge Water Supply Project were developed cooperatively by Reclamation and Biggs-West Gridley WD management, and approved by the Biggs-West Gridley WD Board of Directors. The goal statement was revised in 2005. The project's goal statement as revised and adopted in 2005 is:

> *The goal of the project is to deliver a firm, reliable water supply of suitable quality to the boundary of Gray Lodge WA via the Biggs-West Gridley WD conveyance system in accordance with Cooperative Agreement 03-FC-20-2049 (Cooperative Agreement) between Reclamation and Biggs-West Gridley WD.*

A purpose of the Cooperative Agreement is to modify the Biggs-West Gridley conveyance system so that the project goal can be accomplished and project impacts, if any, can be mitigated.

The measures of project success upon completion of construction are the following:

- Biggs-West Gridley WD will be able to deliver annually the flow of water to Gray Lodge WA on the schedule identified in the Cooperative Agreement.
- There will be no adverse impacts to Biggs-West Gridley WD, its facilities, its operations, its customers, or others as a result of the project.

In October 2007 an additional goal statement was developed by the project participants including Reclamation, Biggs-West Gridley WD management, and consultants to Reclamation and Biggs-West Gridley WD to express the collective expectations for the Final Design Data Report:

> *The expectations of this study are to develop improvements alternatives to a level of detail where cost estimates and general design and hydraulic parameters such as water surface elevation, flow depth and velocity, structure type and size, and canal dimensions can be established for the Draft Design Data Report. This information will be used to discuss project feasibility, facilitate a decision between Reclamation and the district on a path forward towards project implementation, and to enable*

selection of a preferred composite alternative. The selected alternative will be developed after the Draft Design Data Report is reviewed and will be documented in the Final Design Data Report. Decisions that will remain open and will be addressed in the Final Design and Construction phases will include the following: refining structure sizes, dimensions, and locations; establishing specific right-of-way and turnout locations; establishing final maximum and minimum water surface elevations; assessment of canal seepage impacts and mitigation measures; and specifying structural and geotechnical design considerations, among others.

1.4 Approach

The basic technical approach to develop and recommend facility improvements consisted of these steps:

1. Develop a data-collection network in key locations throughout the Biggs-West Gridley WD system.
2. Document existing delivery patterns and operating conditions at Biggs-West Gridley WD as they relate to Gray Lodge WA deliveries.
3. Determine the best estimate of future deliveries to Gray Lodge WA.
4. Determine facility improvements required to deliver Level 4 water to Gray Lodge WA by using a refined hydraulic model.
5. Estimate the capital costs of facility improvements.

To accomplish these steps, two complimentary studies were initiated in 2004: the Measurement and Seepage Study (Appendix A), and the Design Data Study (documented by this Design Data Report).

First, the Measurement and Seepage Study provided a baseline of existing system conditions by directly measuring system flows, canal water levels, and shallow groundwater levels, which had not been measured at Biggs-West Gridley WD prior to 2004. Reclamation established a data-collection and monitoring network in the Biggs-West Gridley WD system consisting of 11 canal flow and water level meters, 11 water level sensors, and 7 pairs of shallow monitoring wells. Data collected between 2004 and 2007 were used to evaluate existing operating conditions along each lateral for the purpose of establishing and verifying baseline flow and water level trends. Data collection continued during the 2008 irrigation season and will remain part of the project record and baseline. Data collected subsequently in 2009 and possibly beyond will also be added to the project record. To address District concerns about potential increases in seepage resulting from increased flows, the study also evaluated a relationship between canal water levels and seepage to adjacent fields.

Next, some of the information gathered as part of the Measurement and Seepage Study was used as the basis for the development of the second study, the Design Data Study. This study used measurement data to calibrate the hydraulic model for current operations, estimate system capacity, estimate future increases in flows and design flows, and determine necessary capital improvements to Biggs-West Gridley WD facilities. The data collection effort completed during the Measurement and Seepage Study supported the following subtasks of the Design Data Study:

- **Develop systemwide design flows:** Canal flow data measured at selected locations throughout the canal system assisted with the determination of the existing hydraulic capacity (flow, in cubic feet per second) of each canal reach. Refuge managers determined the peak flow that Gray Lodge WA would request if full Level 4 deliveries were available. The set of empirically derived capacity flows, along with projected refuge flow increases, was used to determine and conceptually design required facility improvements. Appendix B describes how future deliveries to Gray Lodge WA were estimated and how these estimates were used with canal flow data to determine design flows.
- **Calibrate hydraulic model:** Facility improvements were determined for the Design Data Study by means of a computerized hydraulic model that represents the 2005 Biggs-West Gridley WD conveyance system. Canal flows and water level data were used to calibrate the model to ensure that model parameters such as roughness, structure dimensions, and typical gate openings represent reality.
- **Assess typical operating water levels and recommend facility improvements:** Future facility scenarios were analyzed with the calibrated hydraulic model. Initially, two system improvement alternatives, Alternative 1 and Alternative 2, were modeled to establish improvements that conveyed future flows while maintaining water levels (maximum and minimum) or by minimizing right-of-way acquisitions, respectively. Biggs-West Gridley WD reviewed the results of these models and provided site-specific comments on improvements. A third alternative, the Composite Alternative, was developed using knowledge gained by modeling Alternatives 1 and 2 and the District's review comments. New water-level control structures were also implemented in the Composite Alternative model where applicable. Using the systemwide design flows and established canal design guidelines, the Composite Alternative model was used to develop recommendations for system improvements as required to meet the study objectives. Construction costs for use in subsequent final design and implementation steps were also developed.

1.5 Study Participants

A core group of project participants was coordinated throughout the study. Reclamation was the lead agency in conducting the Design Data Study. Reclamation, Biggs-West Gridley WD, and the California Department of Fish and Game (CDFG) constitute the core group of agencies and organizations that worked with the CH2M HILL consultant team to provide technical expertise relative to the Biggs-West Gridley WD and Gray Lodge WA conveyance systems.

Gray Lodge WA is managed by the CDFG, which is responsible for sharing the cost of necessary improvements to provide Incremental Level 4 refuge water supply (8,600 ac-ft) to Gray Lodge WA. CVPIA requires that 25 percent of the acquisition cost of Incremental Level 4 water be provided by the State of California and 75 percent by the federal government.

Biggs-West Gridley WD also assisted with refinement of project goals, measurement site selection, and mapping, and provided necessary information on District operations and facilities. District landowners played a critical role in selecting monitoring well locations and granting access to their properties for data collection.

Flow and water level monitoring equipment installation and data collection were a cooperative effort between Reclamation and Biggs-West Gridley WD, with technical support from the CH2M HILL consultant team, specialty vendors, and contractors.

In 2006, an independent consultant review team was hired to assist Biggs-West Gridley WD in evaluating the technical aspects of the project and assessing the recommended improvements. The review team, led by Davids Engineering, had a significant role in the hydraulic modeling approach and development of improvements during 2007 and 2008.

1.6 Report Organization

This report is structured as follows:

- **Section 1** is the introduction.
- **Section 2** describes the study area, which encompasses Biggs-West Gridley WD and the delivery points in Gray Lodge WA.
- **Section 3** provides a summary of the data collection effort to establish baseline system conditions and evaluate seepage within key areas of Biggs-West Gridley WD. Measurement locations, the 5-year data collection process, and general flow and water level trends are described. The section also summarizes the conclusions of the seepage investigation and mitigation measures.
- **Section 4** describes Biggs-West Gridley WD facilities and operations. Systemwide design flows are developed by canal reach.
- **Section 5** describes the process and approach by which improvement recommendations were determined. The development of the hydraulic model is described, and the process of developing alternatives is explained. The design criteria for system improvements are also provided.
- **Section 6** describes facility improvements recommended for the Biggs-West Gridley WD system to accommodate Level 4 flows to Gray Lodge WA. Appraisal-level engineering drawings, construction considerations, and cost estimates are provided.
- **Section 7** recommends implementation steps for the proposed improvements.
- **Section 8** lists references cited in the report.

Appendixes provide relevant supplemental information:

- **Appendix A:** Measurement and Seepage Study Summary Technical Memorandum
- **Appendix B:** Biggs-West Gridley WD Existing Facilities and Operating Conditions Technical Memorandum

- **Appendix C:** Summary of Alternative Improvements
- **Appendix D:** Appraisal-level Drawings
- **Appendix E:** Appraisal-level Cost Estimates for Recommended Improvements
- **Appendix F:** Maps
- **Appendix G:** Additional Engineering Design Data for Composite Alternative

SECTION 2

Study Area

The scope of the Design Data Report is focused on the conveyance system of Biggs-West Gridley WD to the points of delivery at the northern boundary of Gray Lodge WA. Figure 2-1 provides a vicinity map of the study area. Figure F-1 shows the northern boundary of the refuge and the location of the water delivery points with respect to Biggs-West Gridley WD and more details of the study area. (See Appendix F for the Design Data Report maps.)

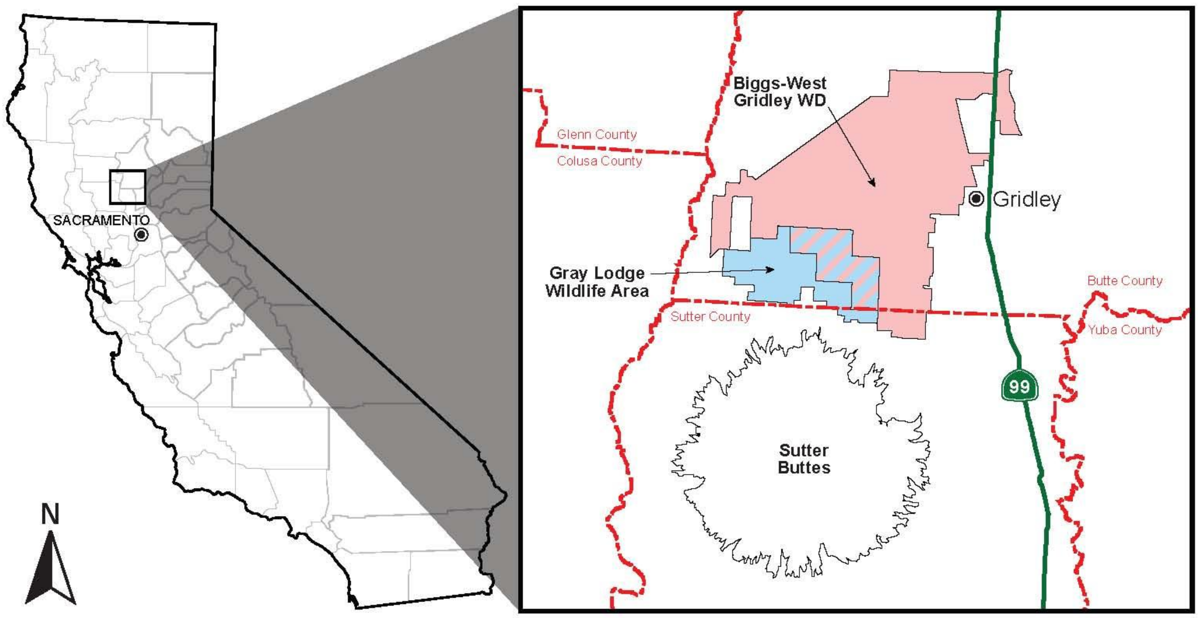

FIGURE 2-1
Project Vicinity Map

2.1 Gray Lodge WA

Gray Lodge WA is located in Butte County in the eastern Sacramento Valley, approximately 65 miles north of Sacramento. The position of the WA along the Pacific Flyway makes it an ideal habitat for migrating birds. More than 300 species of resident and migrant birds and animals inhabit the WA, particularly during winter. In December, nearly 1 million ducks and 100,000 geese arrive from as far away as Wrangle Island near Russia. Gray Lodge WA also provides recreational opportunities such as bird watching, hunting, and fishing.

Gray Lodge WA encompasses 9,200 acres, approximately 2,600 acres of which are within the Biggs-West Gridley WD service area (Reclamation et al., 2001). Water is used to maintain ponds and seasonal marshes and to irrigate moist soil units, crops, and pasture for waterfowl food, cover, and nesting. Irrigated pasture and crop habitat at Gray Lodge WA consist of corn, vetch, milo, mixed grasses, and safflower. These crops provide food and nesting cover for waterfowl.

With the firm water supply guaranteed by CVPIA, Gray Lodge WA has been able to implement significant improvements needed to manage the area in advance of receiving full Level 4 water supplies. Conveyance system improvements have consisted of improved pumps and distribution canals to better convey both surface and groundwater supplies to prime habitat areas. Habitat improvements have consisted of increases in the amount of irrigated pasture and cereal grains and the amount of semipermanent wetlands. Optimum habitat management can be fully implemented upon firm delivery of reliable Level 4 water supplies.

Under CVPIA, Gray Lodge WA has an annual Level 2 allocation of 35,400 acre-feet and an Incremental Level 4 allocation of 8,600 acre-feet, totaling 44,000 acre-feet of water per year. Because some of the land occupied by Gray Lodge WA is within Biggs-West Gridley WD boundaries, the refuge receives some Level 2 water from the District by entitlement. The District entitlement allocation counts toward Reclamation's full Level 2 obligation under CVPIA. The remaining water is supplied to the refuge by Reclamation; this water consists of both delivered surface water and groundwater pumped onsite. Surface water is delivered to the refuge by Biggs-West Gridley WD via the Schwind, Rising River, and Cassady Laterals when the District is operating, between mid-April and late January. The WA conveys water internally using a recently upgraded distribution system that is not included as part of this Design Data Report.

2.2 Biggs-West Gridley WD

Biggs-West Gridley WD is located in Butte County near the towns of Biggs and Gridley and consists of approximately 30,000 acres of land. Figure F-1 shows the District, its relation to the Gray Lodge WA boundaries, major water conveyance channels, drains, and roads. The District was formed in the 1940s to provide irrigation water, and it continues to deliver water today primarily to farmers with orchards, pastures, and rice fields. The District has senior water rights to approximately 160,000 acre-feet of water from the Feather River, which is diverted through the Thermalito Afterbay. From Thermalito, water flows through the Sutter Butte Canal to serve four Districts—Biggs-West Gridley WD, Richvale Irrigation District (ID), Sutter Extension WD, and Butte WD. These Districts make up the Joint Water District Board (Joint Board), which was formed in 1970 by a Joint Operating Agreement to provide for operation and maintenance of the Sutter Butte Canal. Biggs-West Gridley WD is allocated 29 percent of the 555,000 acre-feet of water annually acquired by the Joint Board through pre-1914 water rights.

From the Sutter Butte Canal, water is conveyed through the Biggs Extension Canal before reaching the Biggs-West Gridley WD. The Biggs Extension Canal is also a shared facility, maintained by Richvale ID and Biggs-West Gridley WD. Water delivered to Richvale ID and Biggs-West Gridley WD splits after the Biggs Extension Canal passes under Highway 99. Located immediately downstream from this split are the Biggs-West Gridley WD Headgates for the Belding Lateral. The Belding Lateral supplies the Ashley, Traynor, Schwind, and Green Laterals. In turn, the Traynor Lateral supplies the Gerst, Cassady, Rising River, and Spence Laterals. These conveyance facilities are shown on Figure F-1 in Appendix F. Reclamation District (RD) 833 is responsible for drainage service for Biggs-West Gridley WD and generally drains water toward the southwest. These drains, which cross the District, are also labeled on Figure F-1.

The scope of the Design Data Report includes the major laterals of the Biggs-West Gridley WD conveyance system from the Biggs Extension canal upstream of the Belding Lateral Headgates to just downstream of the water delivery points to Gray Lodge WA. The Biggs Extension and Gray Lodge WA water delivery points are labeled on Figure F-1.

SECTION 3

Field Data Collection and Analysis

3.1 Background

This section provides a summary of the Measurement and Seepage Study undertaken to support the Design Data Study. Additional details of the Measurement and Seepage Study are provided in a Technical Memorandum in Appendix A. The Measurement and Seepage Study was initially established in 2004 and updated in 2008 to:

- Provide a data baseline of existing conditions and estimate the existing capacity of Biggs-West Gridley WD canals
- Provide a data baseline to address seepage, water level, and flow capacity concerns specific to Gray Lodge WA deliveries
- Provide a basis for calibrating the hydraulic model for use in evaluating future changes in canal water levels and system flows that would result from conveying Gray Lodge WA deliveries through the Biggs-West Gridley WD distribution system
- Identify options to address increased seepage that could result from higher flows and water levels, facility improvements, and operational changes

Minimal data were available when the Design Data Study was initiated in 2004. To provide an accurate baseline of existing conditions, Reclamation initiated two field data collection efforts for the Measurement and Seepage Study:

- Flow and water level monitoring in portions of the canal system used for conveying water to Gray Lodge WA
- Shallow groundwater level monitoring in localized areas of the Traynor Lateral potentially affected by canal seepage

3.2 Monitoring Site Selection and Equipment Installation

Industry-standard measurement equipment was selected with input from the Irrigation Training and Research Center at California Polytechnic State University, San Luis Obispo, and Reclamation's water measurement experts. Pressure transducers produced by In-Situ were selected to measure canal water levels and groundwater levels.[1] Acoustic Doppler flow meters produced by SonTek were selected to measure canal flows.

[1] Pressure transducers were replaced by Reclamation in January 2008 with new equipment produced by MJK Automation.

Sites for all instruments were selected in cooperation with Biggs-West Gridley WD, Reclamation technical staff, and the CH2M HILL consultant team. The selected sites are shown on Figure F-2 in Appendix F. The following instruments were installed:

- Seven shallow groundwater monitoring well sites (two sensors per site) were selected along the Traynor Lateral in areas where Biggs-West Gridley WD expressed concern about seepage impacts on adjacent farm fields. Wells were drilled in pairs and aligned perpendicular to the canal. The first well of each pair was installed approximately 50 feet from the top inside edge of the canal bank, at least 15 feet from the seepage ditch adjacent to the canal, if present. The second well of each pair was placed 30 feet from the first well on a line perpendicular to the canal.
- Eleven water level measurement sites were selected to establish a baseline of water levels for all reaches affected by Gray Lodge WA deliveries. Sites on the Traynor Lateral also were selected adjacent to a pair of monitoring wells to verify a relationship between canal water levels and shallow groundwater levels.
- Eleven flow measurement sites were selected to monitor flows for all reaches affected by Gray Lodge WA deliveries. Flow measurement sites were selected based on canal topography and proximity to control features such as gates and weirs. A twelfth measurement site was added before the 2008 irrigation season to record flows at the head of the Cassady Lateral.

The CH2M HILL consultant team and Reclamation staff installed all water level sensors and monitoring wells in April 2004. Technical staff from the flow meter vendor, Hydroscientific West, installed all the flow meters in August 2004 with oversight provided by CH2M HILL. A typical water level sensor installation is shown in Figure 3-1, and a flow measurement site on the Belding Lateral is shown in Figure 3-2.

FIGURE 3-1
Typical Water Level Sensor Installation during Annual System Shutdown

FIGURE 3-2
Flow Measurement Site on the Belding Lateral

Some flow meters required service or replacement during the study; these meters were removed during the annual system shutdown period and repaired or replaced before the beginning of the spring irrigation season. Reclamation technical staff replaced all original canal water level sensors and monitoring well sensors at the end of the 2007 irrigation season because several of the sensors did not report reliable data. After the sensors were replaced, full data collection resumed.

3.3 Technical Evaluation and Analysis

Nearly 5 years' worth of data were used to evaluate existing operating conditions along each lateral, establish baseline flow and water level trends, and establish future flows with increased water delivery to Gray Lodge WA. The shallow groundwater data were combined with the canal water level data to evaluate the linkage between the canal water levels and seepage in adjacent fields.

3.3.1 Typical Flows into Biggs-West Gridley WD

Figure 3-3 shows several years of flows monitored at the head of the Biggs-West Gridley WD system. (The data are recorded for operating purposes by the Joint Water Districts Board and was not recorded as part of the Measurement and Seepage Study.) The data includes flows to all Biggs-West Gridley WD customers, including Gray Lodge WA. The general flow pattern into the District is characterized by an increase in flows for the start of the irrigation season on April 1 (with flood-up occurring typically any time between April 1 and early May) and a general decrease in flow rates from mid-August to late October. Flows increase again in November before a final decrease in late January to close out the irrigation season. The allotted season begins on April 1 and ends on October 31. In one season, the District delivers 75 to 80 percent of all water delivered that year before November 1 (during the allotted season). After November 1 through late January, water delivered is not part of the District's annual allotment (this is considered the "non-allotted season").

Several factors influence this seasonal distribution of flows through Biggs-West Gridley WD. A variety of crops are grown by District landowners, and each crop has different irrigation requirements in terms of quantity and timing of water. For example, orchards and pastures in the district are typically flood- or sprinkler-irrigated in several short events during the spring and summer months. These crops are not irrigated after October. In comparison, rice requires an initial flood-up of high flow over a period of several days at the beginning of the season, then continual low flows to maintain field water levels throughout the summer. Rice is not irrigated immediately preceding and during harvest, typically in September and October. In November, rice fields require a short flood-up period for decomposition. Because of these different irrigation requirements, the distribution of flow within the District over the course of the season is a function of the crops grown.

Crop distribution within Biggs-West Gridley WD has varied over several decades depending on market demand. Since 2003, the irrigated acreage within the District has averaged approximately 77 percent rice, 17 percent pasture, 6 percent orchard, and a very small percentage (less than 0.2 percent) of row crops. Rice irrigation practices, therefore, have a strong influence over the seasonal flow distribution within the District, and this is reflected in Figure 3-3.

The flow distribution shown in Figure 3-3 reflects a peak in flow into Biggs-West Gridley WD in late April through May, depending on how weather patterns influence rice planting and orchard and pasture irrigation demands. (For example, late spring precipitation may delay a first irrigation event until May, whereas a dry spring may demand an early April irrigation event.) During this time, orchards and pastures are irrigated, and rice fields are receiving peak flows to flood-up for the season. Conversely, flows ordered by Gray Lodge WA are lowest of the season in April and May. Peak flows recorded at the head of the Belding Lateral are 700 to 800 cfs between April and May; of this, approximately 25 to 35 cfs is conveyed to Gray Lodge WA. Flows taper slightly in late May or early June, when rice maintenance flows add to periodic irrigation events for other crops such as orchards and pasture. A harvest period results in a decrease in rice deliveries and a drop in canal flows from late August through October. Concurrently, Gray Lodge WA requests increasingly higher flows in September and October, when deliveries to the refuge typically peak. A sharp increase in early November occurs as rice decomposition water is delivered and Gray Lodge WA wetlands and duck clubs are flooded.

In the future, with delivery of full Level 4 water supplies to Gray Lodge WA, it is anticipated that the existing flow pattern to Gray Lodge WA will continue, but flows requested by Gray Lodge WA will be higher throughout the year.[2] Gray Lodge WA managers will continue to request peak flows in September and October, which is conversely the period of lowest water demand by other Biggs-West Gridley WD customers.

3.3.2 Analysis of Relationship of Operations, Canal Flows, and Water Levels

Typical for irrigation district canals, a majority of the Biggs-West Gridley WD canal reaches are maintained at a constant water level for most of the irrigation season despite large fluctuations in flow rates. This control is necessary to maintain a constant head over turnouts for stable irrigation deliveries. The District maintains this condition by manually operating control structures such as gates and weirs in response to flow changes. Known as upstream control, flows are set by operators at the head of the main canal, and flow changes are routed through the system with the objective of maintaining a constant water level immediately upstream of each check structure, thereby maintaining a constant flow through the turnouts.

Figure 3-4, a plot of the water level and flow data for an entire irrigation season along the Belding Lateral, demonstrates typical operating practices. During a typical peak irrigation season (May through August), operators maintained a relatively constant head in the canal as flows conveyed by this Belding Lateral reach fluctuated from approximately 200 cubic feet per second (cfs) to just over 500 cfs.

Data collected by this study indicate that, under existing conditions and canal flows, the District is able to maintain water level control to provide reliable, stable deliveries to their customers at a wide range of flows despite occasions when the District conveys flows that exceed the capacity of the irrigation system. However, based on the results of the hydraulic modeling (described in subsequent sections of this report), much of the system would be operated at or above its capacity, which would infringe upon the District's ability to control water levels at the flows necessary to serve Gray Lodge WA and meet customer demands. System improvements are required so the District can maintain the existing level of upstream controllability with increased flows to the refuge and for other reasons.

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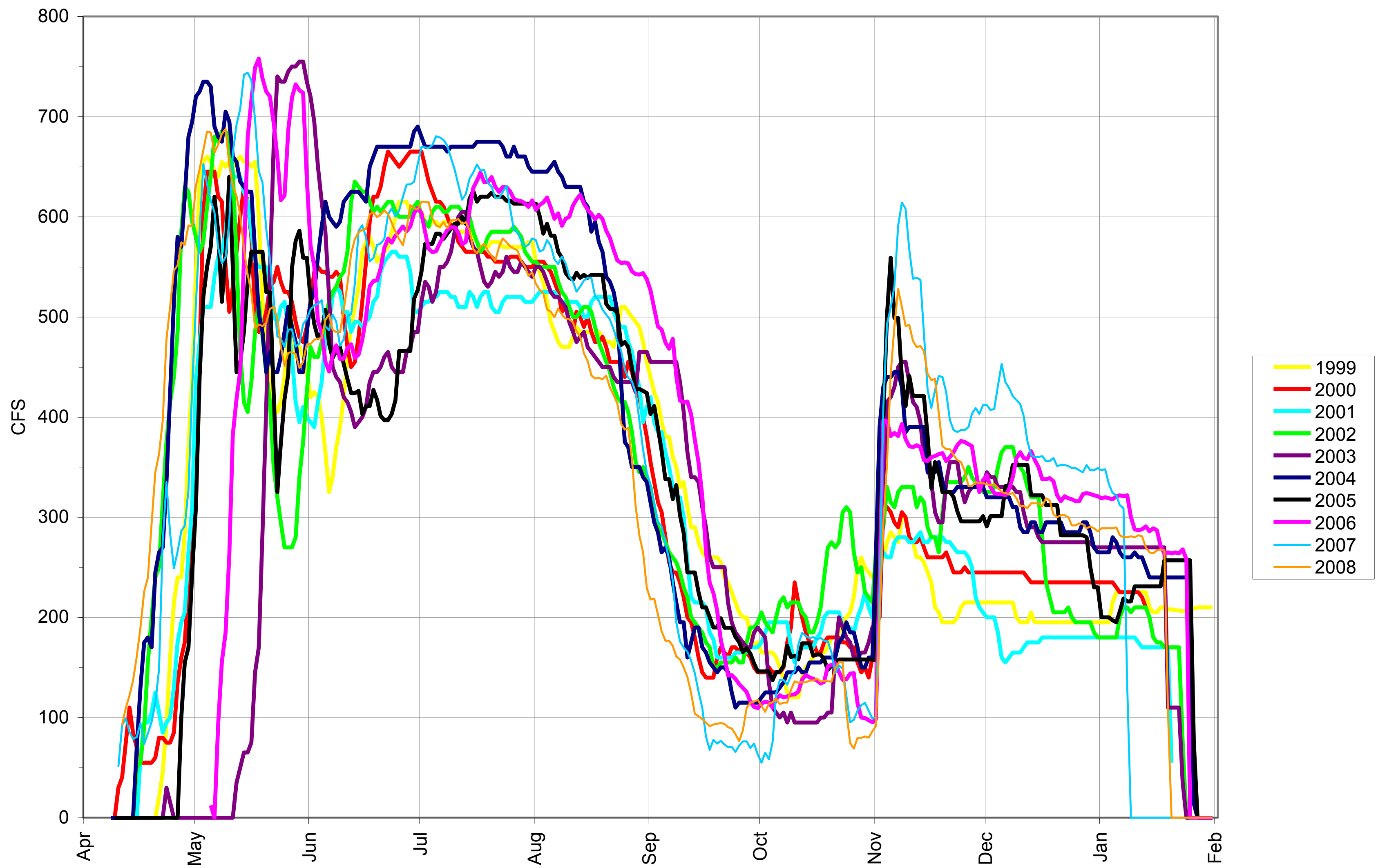
[2] Forsberg (CDFG), 2005.



Source: Joint Board Gauging Station.

FIGURE 3-3
Flow Summary, Head of the Belding Lateral, Joint Board Gauging Station

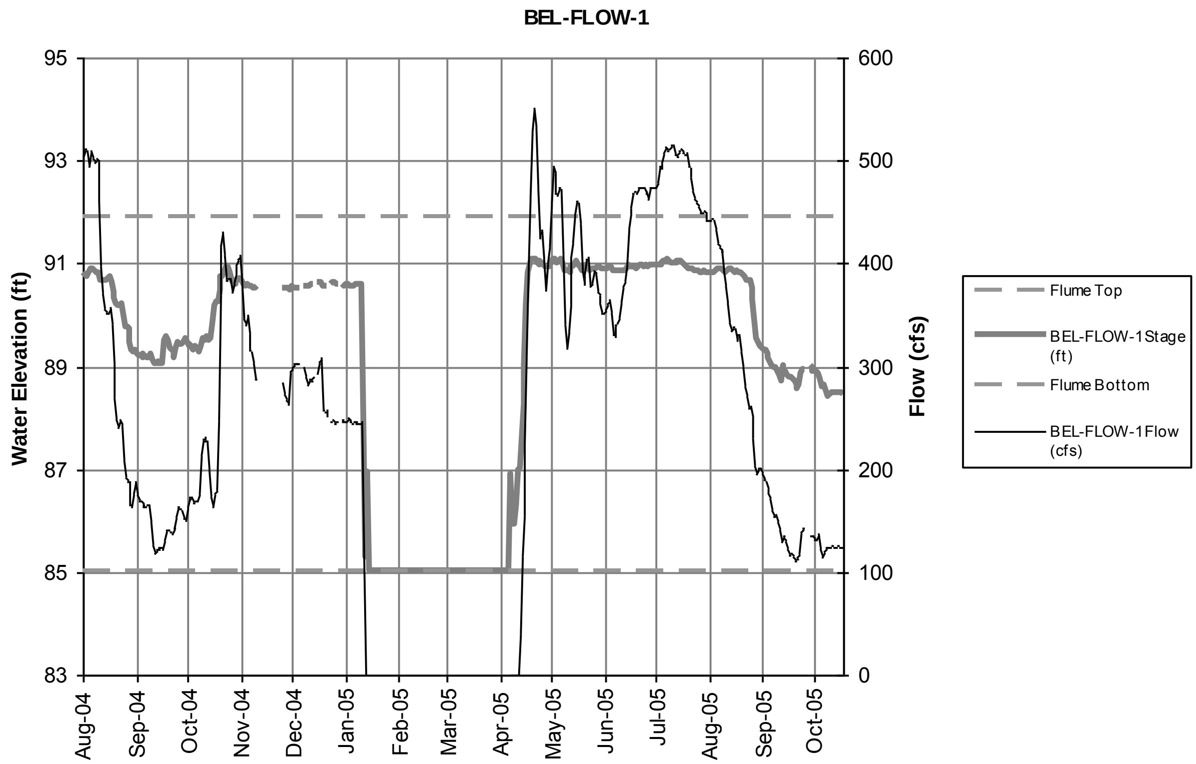


FIGURE 3-4
Flow and Water Level Data from the Belding Lateral

3.3.3 Influence of Canal Flow and Water Level Changes on Seepage Rates and Shallow Groundwater Levels

Biggs-West Gridley WD has expressed concern that increased flows in the District's earthen canals may increase seepage, which would adversely affect crops and impede farm operations adjacent to canals at certain times of the growing season. Orchards along the Traynor Lateral from Justeson Road to West Liberty Road and rice fields along the Rising River Lateral were identified as areas with the potential to be adversely affected by an increase in seepage.

Canal water level and shallow groundwater level data collected for the Measurement and Seepage Study establish a baseline for comparing the effect of future increased deliveries on canal water levels and shallow groundwater levels, including magnitude, timing, and duration. The water level data were used in the hydraulic model to determine facility improvements necessary to maintain existing water levels, particularly during critical times. If increased canal water levels are unavoidable at critical times of the year, then seepage mitigation methods may be pursued. A range of possible mitigation methods is provided in the Measurement and Seepage Study Technical Memorandum (Appendix A). A seepage monitoring and mitigation plan will be initiated by Reclamation during the design phase of the project in consultation with and subject to acceptance by the District to monitor seepage conditions post-construction and mitigate short-term and long-term seepage impacts.

The data collected confirm that shallow groundwater levels adjacent to the Traynor Lateral are correlated with water levels in the canal. Figure 3-5 illustrates the orientation of the shallow monitoring wells and the adjacent canal water level meter (the configuration and scale of the wells and water level meter are described in Section 3.2). Figure 3-6 offers sample data illustrating the correlation between canal water levels and groundwater levels. Note that shallow groundwater levels increase as the irrigation season begins. Canal water levels rise as the dry earthen canals are filled for the irrigation season in April and decrease as the fully charged canals are dewatered at the end of the season in January. Response time of shallow groundwater levels during dewatering is generally slower than at the start of the irrigation season. Sharp increases in groundwater levels over short durations are indicators of field irrigation along the canal.

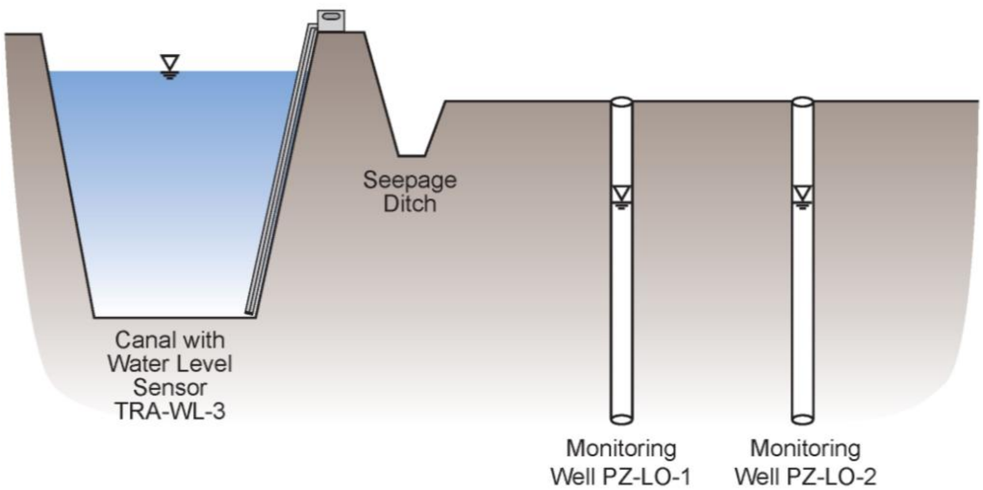


FIGURE 3-5
Typical Monitoring Well Installation

To provide an estimate of the magnitude of the effect of increased canal water levels on seepage rates and shallow groundwater levels in adjacent fields, a quantitative seepage analysis was performed at one location along the Traynor Lateral. The results of this finite element groundwater analysis provide a general impression of the sensitivity of the shallow groundwater levels to changes in the canal water levels. An increase in seepage from either increasing the canal water level by 6 inches or widening the canal bottom by 10 feet would result in an increase in shallow groundwater levels of less than 1 inch. This conclusion applies under the conditions assumed for modeling. More detail on this analysis is found in the Measurement and Seepage Study (Appendix A).

Numerous in-canal and out-of-canal methods are possible to reduce potential seepage in land adjacent to canals. Implementing conveyance facility improvements that maintain canal water levels at near-present conditions is one means of seepage control; however, in reaches where canal cross-sections will be disturbed, the existing sealing layer may be disrupted or a sand lens may be intercepted, which could result in increased seepage.

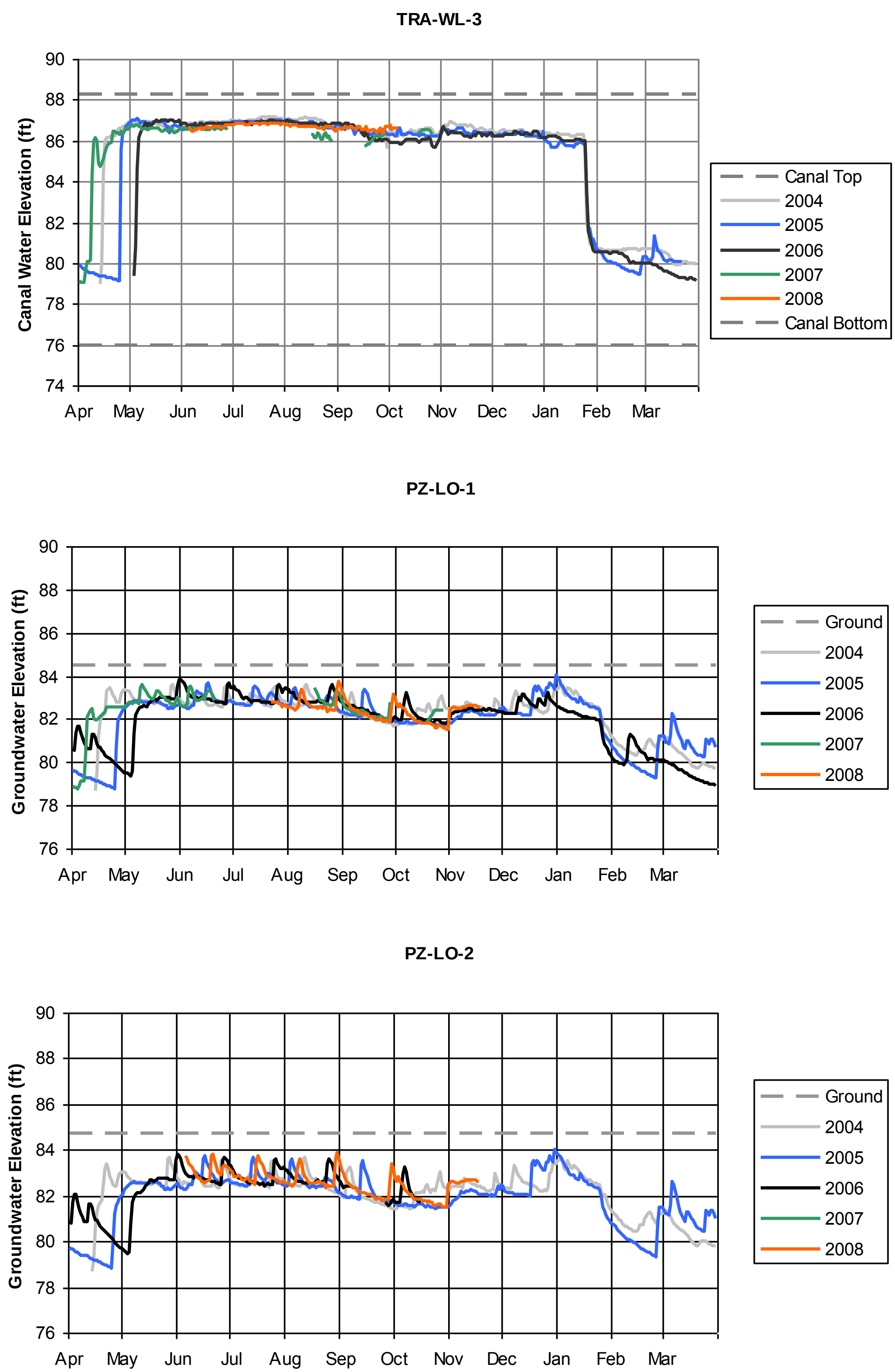


FIGURE 3-6
Canal Water Levels (TRA-WL-3) and Corresponding Shallow Monitoring Wells (PZ-LO-1 and PZ-LO-2)

SECTION 4

Existing Biggs-West Gridley WD Facilities and Future Design Flows

This section outlines the existing Biggs-West Gridley WD conveyance facilities that convey water to Gray Lodge WA, which provide the basis for determining facility improvements. Design flows for facility improvement sizing are also described in this section; these are based on existing peak water delivery flow rates and patterns, and an estimation of future water deliveries.

4.1 Water Conveyance through Biggs-West Gridley WD

Water conveyance from the Thermalito Afterbay to the Biggs-West Gridley WD headgates is described in Section 2. From the headgates, the Belding Lateral feeds the Ashley, Traynor, Schwind, and Green Laterals. In turn, the Traynor Lateral feeds the Gerst, Cassady, Rising River, and Spence Laterals. These conveyance facilities are shown on Figure F-1 in Appendix F.

The terminuses of the Schwind, Cassady, and Traynor Laterals are the points of delivery to Gray Lodge WA. Biggs-West Gridley WD manages deliveries to the refuge in conjunction with deliveries to other customers for agricultural irrigation and duck clubs.

4.2 Update of Existing Facilities Information

Current information on the Biggs-West Gridley WD conveyance facilities was collected to develop and calibrate a hydraulic model, evaluate the existing facility capacity, and determine improvements to the facilities. Facility information was obtained during field visits and interviews with Biggs-West Gridley WD operations staff conducted throughout the study period. More detailed information on existing facilities and operating conditions is provided in Appendix B.

The type of information gathered included typical operating strategies and gate operations of more than 25 lateral or sublateral headgate structures and check structures. Other facilities investigated were five culverts, 10 road crossings, 17 farm access bridges, three siphons, and three flumes. Required canal operating heads and observed operational problem areas for all laterals pertinent to refuge water delivery were documented. The information gathered was used to develop the hydraulic model to understand all capacity issues of the existing facilities. The locations of existing structures and conveyance facilities are shown in Figure F-3 in Appendix F.

In addition to gaining understanding of District operations, the study documented all physical changes to facilities since technical studies were conducted between 1998 and 2000. Most of the Belding, Schwind, Traynor, and Rising River Laterals have been modified since 1999, and therefore required resurveying. The modifications made by the District included reshaping or armoring sections of the canal banks. Additionally, Biggs-West Gridley WD had removed a structure on the Belding Lateral and replaced the Cassady Headgates. In 2005, a survey to obtain current canal geometry was conducted on the Belding Lateral from the railroad culverts to the Belding-Traynor Split, along the entire length of the Traynor and Rising River Laterals, and on the Schwind between the headgates and the Schwind flume.

4.3 Development of Design Flows, Including Level 4 Flows to Gray Lodge WA

To determine where system improvements would be required to convey Level 4 flows to Gray Lodge WA, it was necessary to estimate the peak flow that each canal reach was likely to carry in the future. These flows, collectively known as the "system design flows," were first estimated theoretically in 1999, then estimated again in 2007 using available empirical data from the Measurement and Seepage Study. The design flows were also developed to reflect how canal capacity would decrease incrementally from upstream to downstream to correspond to reduced supply requirements as water is delivered to customers along the canal.

For the purpose of the design flow development in 1999, the laterals of the Biggs-West Gridley WD conveyance system were divided into reasonable lengths (reaches) with starting and ending points based on prominent structures or road crossings along the canal. These reaches are shown on Figure F-2 in Appendix F, with labels such as BEL1 for the first reach of the Belding Lateral. Each different canal color on the map represents a different canal reach. The reaches are defined for study purposes, but are not used for District operations.

In 1999, design flows were estimated theoretically based on water demands from a California Department of Water Resources (DWR) land-use survey and irrigation criteria developed in coordination with Biggs-West Gridley WD. For each reach, irrigated crop land served by a canal and corresponding levels of ET were used to estimate irrigation demands. These demands were added from downstream to upstream to estimate total capacity requirements by reach. A more detailed description of this calculation is provided in Appendix B. This land-use-based approach was necessary at the time because little canal flow and water level data were available to provide an empirical estimate. Although land-use-based water demands are no longer the basis for design flows, for continuity the reaches defined in studies dating back to 1999 were used in 2007 when developing empirically based design flows. An update to the 1999 system design flows was necessary in 2007 for several reasons:

- **Changes to Biggs-West Gridley WD facilities and deliveries**
  - Rice growing cultural practices changed in the District after 2000. Generally, fields are flooded and drained more frequently, and 75 percent of rice decomposition water (decomp water) is delivered in November rather than October.
  - The District supported substantially more rice acreage after 2004 than in previous years.
  - The District made improvements to its canal system since 1999 that affected the hydraulic analysis.

- **Changes to Gray Lodge facilities and operations**
  - The Gray Lodge WA flows developed in 1999 reflected monthly volumes of water delivered evenly over the entire month, and therefore did not represent an accurate picture of the peak flows that would be requested from Biggs-West Gridley WD each month with full Level 4 deliveries. Also, water is ordered in 5-cfs increments, so estimated flows should be rounded accordingly.
  - To provide optimal habitat management with full Level 4 deliveries and to support mosquito-abatement efforts, refuge staff would prefer pulses of water and increased spring and early summer deliveries rather than slow, steady flows delivered primarily in the fall.
  - Gray Lodge WA completed on-refuge improvements since 1999, resulting in a modified preferred delivery schedule and somewhat different delivery points. The new delivery points are at the end of the Traynor, Schwind, and Cassady Laterals.
- **Availability of improved water measurement data**
  - Canal flow and water level data were available for 2004 through 2008 as a product of the Measurement and Seepage Study being conducted by Reclamation at Biggs-West Gridley WD.
  - Reclamation has collected flow and water level data using acoustic Doppler meters since 2004 for the three refuge delivery points.

4.3.1 Projected Gray Lodge WA Deliveries

In 2005, monthly Gray Lodge WA flows were determined by the refuge managers in coordination with Reclamation. Refuge managers accounted for flows that would be feasible with existing on-refuge infrastructure and for how the refuge would be managed if full Level 4 deliveries were available. Table 4-1 summarizes the peak flows, by month and by delivery point, that the Biggs-West Gridley WD distribution system must be able to convey to Gray Lodge WA in addition to the flows needed to satisfy irrigation water demands.

TABLE 4-1
Projected Refuge Design Flows with Level 4 Deliveries
Gray Lodge Design Data Report

Month	Level 4 Needs (ac-ft)[a]	Level 4 Design Flows (peak flow, cfs)[b]	Allocation to Delivery Points (peak flow, cfs)[b]		
			Traynor	Cassady	Schwind
January	1,320	90	45	20	25
February[c]	1,320	0	0	0	0
March[c]	1,320	0	0	0	0
April	1,320	60	30	10	20
May	3,080	65	35	10	20
June	4,400	70	40	10	20
July	3,080	75	40	15	20
August	3,520	120	70	15	35
September	8,800	135	80	15	40
October	8,360	165	100	20	45
November	5,720	125	70	20	35
December	1,760	90	45	20	25
Total	**44,000**				

[a] Level 4 needs as defined in Reclamation, 1989. These volumes are approximations only.
[b] Forsberg, 2005.
[c] In February and March, groundwater wells at Gray Lodge WA are used to serve refuge water needs.

Notes:

ac-ft = acre-feet
cfs = cubic feet per second

4.3.2 Design Flow Process and Results

The peak design flows by month were updated and revised in 2007 using the following process.

First, the peak hourly flow for each reach was determined by month using the data collected from August 2004 through October 2007 for the Measurement and Seepage Study. To determine flow in reaches where it was not measured directly, calculations (water balances) were performed using flow data from SonTek meters in nearby canal reaches upstream and downstream of the unmetered reach. Where necessary, land use information (acreage and crop type) was incorporated into the calculation to best represent actual conditions and water demands.

Next, by comparing the flow data collected at the refuge delivery points by Reclamation during the study and the maximum expected refuge flows in Table 4-1, the additional water expected with Level 4 deliveries was estimated for each delivery point by month. The additional flows expected, along with seepage losses, were added to the set of peak measured flows to determine the maximum flow the reach would experience in the future with Level 4 deliveries to Gray Lodge WA. These flows were rounded up to the nearest 10 cfs to obtain a conservative set of system design flows that included both peak Biggs-West Gridley WD operations and future Level 4 deliveries to Gray Lodge WA. In some reaches, the design flow was rounded higher than the nearest 10 cfs in response to reviewer comments.

The process for developing system design flows is conservative to allow for some future system changes that could occur, such as irrigated acreage, crop distribution, and irrigation practices, which influence system demands as described previously in Section 3.3.1. The design flow calculation for each reach adds the peak hourly flow recorded in a given month to the peak flow that Gray Lodge WA would request in a given month with Level 4 deliveries to estimate the maximum flow the reach would experience in the future. This approach provides a conservative yet prudent estimate of a peak demand condition and allows for future possible changes in cropping patterns and irrigation practices that impact system demands. A more detailed description of this calculation is provided in Appendix B.

Figure 4-1 shows an example of the design flow process for Reach BEL5. Data collected from August 2004 through January 2007 is plotted. First, data from applicable Gray Lodge WA deliveries[3] are combined with available flow data for Reach BEL5 to determine the actual flow attributable to Biggs-West Gridley WD irrigators, shown by the blue bars, and actual flow attributable to refuge deliveries, shown by the yellow bars. Next, when potential future peak flows (with full Level 4 refuge deliveries) are higher than actual Gray Lodge WA flows on a particular day, the additional increment is added on top of the existing flows, as shown by the green bars. Estimated seepage losses are included. The resulting plot shows that, if the reach was conveying peak District irrigator flow and peak flow to Gray Lodge WA at the same time, the peak flow in Reach BEL5 would have been approximately 265 cfs on May 26, 2006. Therefore, the design flow for Reach BEL5 is established at 270 cfs, indicated by the red line.

This process was used for each reach to determine the peak flow expected with Level 4 deliveries to Gray Lodge WA. A set of design flows was approved by the project team in 2008, as described in Appendix B. These flows, the Approved Design Flows, were used to determine where system improvements were necessary and as a basis for designing new facilities. The Approved Design Flows are shown in Table 4-2. The canal reaches are shown on Figure F-2 in Appendix F.

[3] Flows to the Schwind delivery point are conveyed by Reach BEL5.

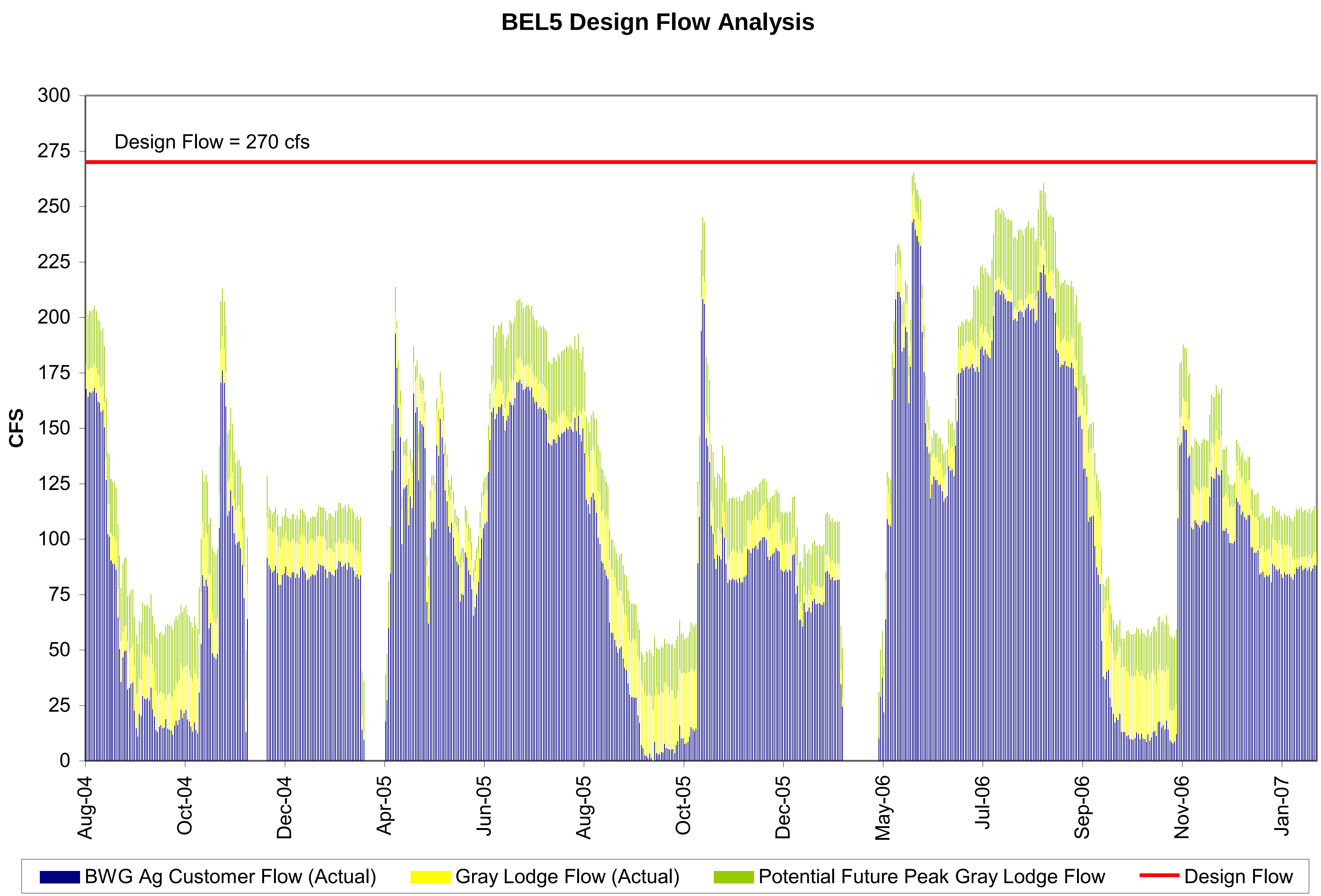


FIGURE 4-1
Development of Design Flow for Reach BEL5
BWG = Biggs-West Gridley

TABLE 4-2
Flows Expected with Level 4 Deliveries to Gray Lodge WA (Approved Design Flows)
Gray Lodge Design Data Report

Reach	Approved Design Flows (cfs)
ASH1	140
BEL1	850
BEL2	750
BEL3	680
BEL4	670
BEL5	270
BEL6	220
CAS1	85
CAS2	30
GERST	95
GREEN	110
SCH1	100
SCH2	85
SCH3	85
SPENCE	130
TRA1	380
TRA2	380
TRA3	370
TRA4	310
TRA5	220
TRA6	120
TRA7	110

SECTION 5

Determination of Recommended Facility Improvements

This section details how facility improvement recommendations were determined. First, previous Biggs-West Gridley WD survey information was compiled and updated as necessary. Second, appropriate hydraulic modeling software was chosen, and a Biggs-West Gridley WD canal system model was developed and calibrated. Next, the model was run using a set of flows the system would be expected to carry with additional water delivery to Gray Lodge WA. Different alternatives were developed to bracket the range of assumptions, facility improvements, and resulting impacts on the canal footprint. New control structures, farm crossings, highway crossings, siphons, and canal cross sections were developed for each alternative to adequately convey the increased flow rates, and these improvements were simulated using the hydraulic model. Finally, a comprehensive set of recommendations was developed and simulated using different aspects of these improvement alternatives.

The recommended set of facility improvements was developed to enable development of appraisal-level cost estimates and project assessment. The identified improvements represent general agreement between Reclamation and Biggs-West Gridley WD, reached in this stage of project development, regarding the improvements necessary to accomplish project objectives and mitigate project effects. While both parties recognize that the list may be revised based on more detailed analyses to be completed during final design, the final design will not depart substantially from the criteria and features outlined in the Design Data Report without the consent of all parties. During final design, the operational role of each major structure should be investigated cooperatively with Biggs-West Gridley WD to ensure that the specific structure type will achieve its desired function. These structure refinements would benefit the Gray Lodge Water Supply Project by enhancing Biggs-West Gridley WD's ability to run its system efficiently while reliably delivering water to Gray Lodge WA.

5.1 Canal System Survey

Detailed surveys of the canal system were conducted in 1999 and 2005. Cross-sections were surveyed every 500 feet along the lengths of the Belding, Schwind, Traynor, Rising River, and Cassady laterals from the Belding Headgates to 500 feet downstream of each of the three refuge delivery points. With the exception of the Cassady Lateral, sections of canal reworked or modified by Biggs-West Gridley WD after the 1999 survey were resurveyed in 2005. The Cassady Lateral was not considered a candidate for resurvey in 2005 because of minimal maintenance since 1999; therefore, changes to the channel's condition were negligible, and the 1999 survey data were considered adequate.

Surveys used NAD83 for horizontal datum and NAVD88 for vertical datum. Local National Geodetic Survey (NGS) monuments were used for primary control. NGS and the California Department of Transportation have since modified the primary control in the Central Valley and the GEOID model. To match previous work, GEOID99 was used in the 1999 and 2005 surveys.

Survey data was the basis for establishing canal stations for use in the hydraulic modeling and appraisal-level design activities. Prior to the surveying performed to support the Design Data Study, no formal canal stationing had been established for the Biggs-West Gridley WD supply distribution system. Unique stationing was established for the Belding, Schwind, Traynor, Rising River, and Cassady laterals starting at the downstream end of the laterals. Stationing increases from downstream to upstream. The stationing was established along an approximated centerline of the existing laterals (stationing was not based on geometric calculations).

In addition to canal cross-section and centerline profile surveying, field measurements of structure openings and gate positions verified key hydraulic dimensions.

All survey data obtained during the Design Data Study are part of the project record and available for use in subsequent design phases by the District and other study participants.

5.2 Hydraulic Model

The existing Biggs-West Gridley WD canal system has limited capacity for additional flow. Various canal structures, crossings, and canal sections require improvements to convey additional flows reliably to the boundary of Gray Lodge WA. Using established canal structure design guidelines and other guidelines established in conjunction with Biggs-West Gridley WD, a hydraulic model was used to develop a list of necessary facility improvements.

5.2.1 HEC-RAS

The U.S. Army Corps of Engineers Hydraulic Engineering Center's River Analysis System (HEC-RAS) is a simulation tool that performs one-dimensional steady and unsteady flow hydraulic calculations. Channel geometry and roughness, and the effects of structures such as bridges, culverts, weirs, and gates are considered in the computations. HEC-RAS is capable of assessing the change in water surface profiles resulting from channel modifications, which makes it an appropriate tool for modeling modifications to the Biggs-West Gridley WD canal system.

5.2.2 Development and Calibration of the Biggs-West Gridley WD Model

Over the past several years, Gray Lodge WA has modified its internal (on-refuge) delivery system downstream of the delivery points from Biggs-West Gridley WD. Gray Lodge WA system design data and operational information from refuge managers were used to set the optimal required water surface elevation for Gray Lodge WA at the Biggs-West Gridley WD delivery points. These elevations listed in Table 5-1 were used as the downstream boundary conditions in the model.

TABLE 5-1
Downstream Boundary Conditions (Water Level Elevations) Used for Hydraulic Model of Biggs-West Gridley WD
Gray Lodge Design Data Report

Canal	Station	Water Level Elevation (ft above sea level)[a]
Schwind Lateral	08+670	71.0
Cassady Lateral	29+350	73.9
Rising River Lateral	18+735	79.1 to 79.8[b]

[a] Vertical Datum NAVD88
[b] Rating curve developed for simulated boundary condition based on agreement between the District and Gray Lodge WA to maintain water level at 8 inches below Evans Reimer Rd Bridge top.

The Traynor, Belding, and Schwind laterals were calibrated using measured flow and water level data from May 4, 2005, at 12:00 a.m. to May 5, 2005, at 4:00 a.m. This date and time period were used because the flow rates were high to flood up the rice fields, and flow rates were steady, meaning no change in deliveries or gate positions. Information provided by Biggs-West Gridley WD ditch tenders was used to determine typical gate positions and weir heights on these days.[4] Manning's n-values (canal roughness factors) and other model parameters were adjusted as necessary, within a realistic range based on field observations, until simulated water levels closely matched measured data. Calibration was deemed successful when simulated water levels were within three inches of measured data at each corresponding station. After calibration, other flow profiles were simulated to determine the corresponding water surface profiles.

The model was recalibrated during the review phase. This process is discussed in Section 5.7.1.

5.2.3 Flow Profiles

Deliveries to Biggs-West Gridley WD customers and Gray Lodge WA vary throughout the year. Peak demand occurs at different times of the year for each of the canal sections. Flow profiles were developed to represent this variation in demand. A flow profile is an input for a HEC-RAS run which assigns a flow to each reach of the model, representing a potential system condition during a snapshot in time.

Different flow profiles were developed during the modeling effort to observe different aspects of system performance. The flow profile used to calibrate the model represented observed flows at the date, time, and location that water level data was collected. A different flow profile was created for use in the improvements models. This flow profile, the "Approved Design Flow" profile, represented the peak flows in all areas of the canal system throughout the delivery season. The development of the Approved Design Flow profile is explained in Section 4.3. This profile was used throughout the facility improvements development process as a peak capacity check (not to determine appropriate facility improvements). Profiles developed specifically to analyze different facility improvement alternatives are discussed in Sections 5.4 and 5.5.

[4] Water level data were not available for the Cassady Lateral for use in the calibration; as such, the modeling results were assessed to determine whether the response to moderate flow conditions was reasonable.

5.3 Design Assumptions and Guidelines

In October 2007, project team established several criteria and common design elements to guide the development of the alternative improvement recommendations described in this section. The following considerations were assumed to govern design decisions related to the removal, replacement, and location of structures. These considerations were regarded as guidelines to which exceptions were allowed where costs could be reduced or other advantages gained, or to stay within the design parameters provided the project objectives were not compromised:

- Existing Biggs-West Gridley WD structures will remain unless replacement or removal is required to convey Level 4 flows to Gray Lodge WA.
- Replacement structures will be constructed in approximately the same locations as existing structures.
- No additional structures will be added.

If modeling determined that structure or canal improvements were necessary to convey the design flows, the following guidelines were applied:

- In accordance with typical upstream-controlled systems, at a bifurcation point, one structure will be designed to provide constant upstream water level control, meaning that flow changes or disturbances will be routed through the structure. The other structure will be designed to provide flow rate control. In practice, this translates to the water-level control structure being designed to operate in an overpour manner, and the flow control structure being designed to operate in an undershot (submerged orifice) manner.
- Where existing flashboard check structures must be replaced to accommodate increased flows, weir and gate designs were considered that minimize water level variation over the expected ranges of flow rate variation.
- If undershot gates that currently control upstream water levels must be replaced to accommodate additional flow capacity, consideration was given to replacing the structure with an overflow structure because these are preferable for providing upstream water level control.

If modeling determined that check structures must be removed, new check structure design considered the following guidelines:

- Maintain a high water level, if necessary, during low-flow conditions so that all the turnouts in the upstream pool can receive water deliveries.
- Minimize the water level changes that occur throughout the length of the upstream pool as a result of canal flow rate changes.

The design guidelines listed in Table 5-2 were established for Biggs-West Gridley WD system improvements based on recognized design standards for canals and structures provided by Reclamation, and a review of standard earthen canal design and operations in Sacramento Valley irrigation districts. These guidelines were used for appraisal-level design of new facilities and incorporated into the hydraulic model. A more rigorous evaluation of improvements with respect to the guidelines will be conducted during the design phase.

TABLE 5-2
Design Guidelines for Biggs-West Gridley WD System Improvements
Gray Lodge Design Data Report

Parameter	Guidelines
Earth Channel Guidelines	
Maximum average channel velocity	3 ft/sec (locally higher at structure inlets and outlets)
Freeboard, minimum permissible[a]	18 inches for canals >200 cfs capacity 12 inches for canals ≤200 cfs capacity
Bottom width-to-depth ratio	2:1 for Q = 0 to 100 cfs 2.5:1 for Q = 500 to 1,000 cfs
Channel side slopes	1.5:1 for Q = 0 to 50 cfs 2:1 for Q > 50 cfs
Manning's roughness coefficient (n)	n = 0.025 to 0.06 (varies by season and reach; weed growth increases throughout the season and changes the n-value)
Service roads and levee widths	12 ft for Q = 0 to 100 cfs, one side of channel surfaced, one side unsurfaced 14 ft for Q > 100 cfs, one side of channel surfaced, one side unsurfaced
Structure Design Guidelines	
Sizing of canal control structures	Must maintain water surface elevation for upstream turnouts and convey peak flows. Sized for control at high, medium, and low flow profiles[b].
Siphons and culverts[c]	Major structures: velocity <9 ft/sec inside the structure opening, and head loss does not impact upstream freeboard Minor structures: velocity <5 ft/sec inside the structure opening, and head loss <6 in.
Structure freeboard, minimum permissible[d]	18 inches for structures >200 cfs capacity 12 inches for structures ≤200 cfs capacity
General configuration and design	Where appropriate, similar structure materials, designs, and configurations will be used throughout the system. Recommended structure types will be typical to standard irrigation practice. Poor approach and exit conditions will be minimized.

Source: Adapted from Reclamation, 1990.

[a] Biggs-West Gridley WD Board issued a letter to Reclamation on July 24, 2007, to indicate that freeboard requirements of 12 inches for canals up to and including 200 cfs capacity, and 18 inches for canals with greater than 200 cfs capacity, are acceptable.
[b] High, medium, and low flow profiles defined and presented in Section 5.6.2.
[c] Major structures defined as those with capacity >200 cfs, Minor structures defined as those with capacity <200 cfs.
[d] General guideline for structure freeboard. Structure function, operations, and site-specific conditions could require adjustments to freeboard during the design phase.

Notes:

Q = flow rate (cfs)
ft/sec = feet per second

Model results (and later, system improvements) were evaluated with respect to the guidelines listed, and problem areas were identified. If a canal reach or structure was unable to convey the design flows with appropriate freeboard, changes to the system were recommended that would meet the listed design guidelines. These changes were simulated by the hydraulic model. More detail on this approach is provided in the Sections 5.4 and 5.5.

Model parameters used in the model, including structure coefficients and Manning's n-values by cross-section, are included in Appendix G.

5.4 Facility Improvement Alternatives Approach

As discussed previously in Section 1.2, analyses and alternatives (Alternative 1, Alternative 2, and Composite Alternative) developed in the Design Data Study were extensions of the preferred alternative GRA-9, which was documented in the 1997 EA/IS (Reclamation and CDFG, 1997). Two alternative improvement scenarios were developed by the study participants to bracket the range of required facility improvements and to understand the potential range of impacts on the canal footprint. The Alternative 1 objective was to convey the additional flow through Biggs-West Gridley WD without raising the current water surface elevations in the canal. In general, this approach results in widening canal sections in flow-constrained reaches of the system and would likely require land acquisition. The Alternative 2 objective was to convey the additional flow while minimizing land acquisitions. This approach relaxes the requirement of maintaining existing water levels but in some areas results in higher water surface elevations in the canal with the existing canal cross section.

The Alternative 1 objective recognizes the sensitivity of seepage concerns to growers adjacent to the exciting canal system. Some crops may be particularly sensitive to seepage depending on crop type, proximity to an irrigation canal, and season. For orchards adjacent to canals, increased seepage may cause shallow groundwater to encroach into the root zone, which may have impact on orchard yields. For rice cropland, seepage is an issue during harvest when land must be drier to operate farm machinery and harvest the crop.

As described in Section 3, the data collected to support this Design Data Report confirmed a linkage between canal water surface elevations and shallow groundwater levels adjacent to the canal in some canal reaches. The Alternative 1 objective attempts to minimize increases in seepage by maintaining current water surface elevations, and therefore maintain groundwater levels adjacent to the canal to the extent possible. However, to achieve this objective and convey the design flows, some canals may need to be widened. Study participants noted that canal reshaping could temporarily disrupt a low-permeability (or "sealing") layer that has formed along an existing canal base, potentially increasing seepage in the short term.

The Alternative 2 objective recognizes landowners' sensitivity to right-of-way acquisition (reduction in productive land). As described previously, the Alternative 1 approach of minimizing seepage by maintaining current canal water levels may necessitate widening some reaches to convey the design flows. However, some district landowners may not be receptive to a right-of-way acquisition, making the Alternative 2 approach more desirable. Alternative 2 would allow some increase in water levels in constrained situations to minimize canal widening. Seepage mitigation may be required in these areas, however.

For each of these 2 alternatives, a list of recommended improvements was developed using HEC-RAS, and these results were reviewed by the project team and District board in conjunction with a field visit on June 10, 2008. The results of Alternatives 1 and 2 and input received during this field visit provided the basis for the development of a Composite

Alternative. The Composite Alternative was intended to utilize aspects of both Alternative 1 and Alternative 2 and incorporate additional facility concepts in a manner agreeable to the District and Reclamation. The Composite Alternative represents the set of recommended improvements for Biggs-West Gridley WD to convey the Level 4 flows to the Gray Lodge WA. A summary of the alternatives is provided in Table 5-3.

TABLE 5-3
Alternative Summary
Gray Lodge Design Data Report

Name	Objective	Notes
Alternative 1	Convey the additional flow without raising the current water surface elevations in the canals.	Utilizes observed canal water level data as baseline. Could result in need for land acquisition to allow for canal widening.
Alternative 2	Convey the additional flow while minimizing land acquisitions.	Improvements made that allow for increased water surface elevations in canals, thereby minimizing need for land acquisition.
Composite Alternative	Utilize aspects of Alternatives 1 and 2. Incorporate additional ideas based on feedback from District.	Basis for preferred alternative.

5.5 Alternatives 1 and 2

As described previously, the purpose of developing Alternatives 1 and 2 was to bracket the range of improvements required given desired objectives. Both alternatives were analyzed using HEC-RAS to confirm whether the capacity of the improved system was adequate to convey Level 4 flows to the Gray Lodge WA boundaries. Generalized structure types were modeled for these alternatives, as the project team decided to address the District's structure type preferences during development of the Composite Alternative. Controllability was also addressed during development of the Composite Alternative.

5.5.1 Capacity Analysis

A review of the collected flow data indicated that flow peaks determined for the Approved Design Flow profile do not occur in all reaches on the same month. Therefore, monthly flow profiles were developed to more accurately capture peak conditions that would be likely to occur in a given month. Flow profiles were created by month for Alternative 1 and Alternative 2 to evaluate the improved system capacity. May, June, August, September, October, November, and January were used to represent all of the possible flow profiles for the canal system. These months essentially captured all peak flows throughout the season in each reach of the canal system. The flow rates in the canals during July are similar to August and the flow rates during December are similar to January; therefore, profiles were not created for July and December. The profiles closely match flow data that were collected throughout the months of May through January (see Appendix A for collected data) and include Level 4 flows to Gray Lodge WA. Table 5-4 shows the seven monthly flow profiles and the Approved Design Flow profile that were used to analyze Alternatives 1 and 2.

TABLE 5-4
Alternatives 1 and 2 Flow Profiles
Gray Lodge Design Data Report

Canal/ Corresponding Reach	Canal Station (ft)	Approved Design Flow (cfs)	Monthly Flow Profile (cfs)						
			May	June	Aug	Sept	Oct	Nov	Jan
Belding/BEL1	694+62	850	850	695	767	663	238	518	268
Belding/BEL2	602+20	750	750	604	688	594	229	464	258
Belding/BEL3	536+10	680	680	556	659	588	227	464	258
Belding/BEL4	484+16	670	670	546	649	588	216	464	258
Belding/BEL5	400+44	270	270	200	270	220	140	250	120
Belding/BEL6	311+70	220	220	160	210	170	120	200	100
Schwind/SCH1	208+84	100	100	65	80	70	80	100	60
Schwind/SCH2	154+31	85	70	50	80	65	80	85	40
Schwind/SCH3	126+70	85	50	40	65	55	75	85	40
Cassady/CAS1	458+01	85	64	78	78	64	71	43	85
Cassady/CAS2	347+32	30	24	24	24	24	30	30	30
Traynor/TRA1	445+03	380	380	340	370	349	170	260	159
Traynor/TRA2*	395+10	380	340	340	370	349	170	240	159
Traynor/TRA3	353+22	370	338	307	370	349	169	233	159
Traynor/TRA4	328+04	310	257	289	310	289	171	203	139
Traynor Extension/TRA5	302+78	220	187	165	209	220	165	176	105
Rising River/TRA6	271+11	120	65	65	109	109	120	98	55
Rising River/TRA7	187+35	110	35	40	70	80	110	70	45

* Biggs-West Gridley WD determined and accepted an Approved Design Flow of 380 cfs for TRA2. Biggs-West Gridley WD, 2007.

The challenges of conveying these flows emerged as the modeling effort progressed. Reviews of interim model results and comparison with the design guidelines listed in Table 5-2 indicated that the capacities of some structures and canals were exceeded under some flow profiles. Indicators that a structure (check, gate, or bridge) capacity was exceeded included, for example:

- Overtopping
- Inadequate freeboard (criteria exceeded)
- Extended or significantly elevated upstream backwater effect (at fully open position)

If these indicators were present, the structure was recommended for replacement under the applicable alternative.

Indicators that canal capacity was exceeded included:

- Overtopping banks
- Inadequate freeboard (criteria exceeded)
- Canal constriction due to inadequate width, uneven depth, or inadequate drop caused backwater effect that impacted structure or canal freeboard upstream

If these indicators were present, the canal was typically recommended for reshaping. Canal improvement recommendations were developed on a case-by-case basis with respect to the alternative's objective.

Some situations required iteration within the hydraulic model to develop reasonable improvement recommendations, particularly when structures and canals both presented challenges to conveying the alternative flow profiles.

These key challenges to developing recommended improvements for both alternatives were identified on specific laterals:

- Belding Lateral:
  - Capacity limitations at the Garcia and Razorback siphons
  - Capacity limitations at the Garcia and Banion checks
  - Capacity limitations at the Union Pacific Railroad Crossing
  - Capacity limitations at the Bonslett Bridge
- Schwind Lateral:
  - Capacity limitations of culverts
  - Complicated structure arrangement and capacity limitations near West Liberty Road
- Traynor Lateral:
  - Inadequate freeboard at the Traynor Headgates
  - Capacity limitations and high water levels at Nugent Flume
  - Capacity limitations of the Colusa Highway Bridge
  - Canal capacity and topography limitations
  - Maintaining high water levels to deliver water to a few high turnouts, the Gerst Lateral, and the Jakey Lateral
  - Overtopping of structures if water levels are increased (Alternative 2 only)
- Rising River Lateral:
  - Maintaining low water levels during rice harvest while conveying peak flows to Gray Lodge WA (Alternative 1 only)
  - Maintaining canal water level at 8 inches below Evans Reimer Road Bridge top, per agreement with Gray Lodge WA

- Cassady Lateral:
  - Capacity limitations through several culverts and check structures during peak flows

5.5.2 Results

Appendix C contains the lists of recommended improvements for Alternatives 1 and 2. Both alternatives presented feasible solutions to convey the design flows,[5] but one emphasized the goal of not exceeding existing water levels (and minimizing seepage), and the other emphasized the goal of minimizing right-of-way acquisition. These two alternatives provided a way to examine the tradeoffs between meeting the two goals, which helped inform the decision-making process while developing and refining a Composite Alternative.

In comparing the improvements required for both alternatives, the following observations are made:

- In general, most structures that required replacement to meet the objective of Alternative 1 also required replacement for Alternative 2. For both alternatives, several control structures are operating at or above capacity and require replacement throughout the system to accommodate future flows for the following reasons (structures are labeled in Figure F-3):
  - Razorback Siphon: inadequate capacity
  - Railroad Culvert: inadequate capacity, retrofit needed
  - Garcia Siphon: inadequate capacity
  - Fields Flume: raise or replace to increase freeboard
  - North Weir: inadequate capacity
  - Division 2 Headgate: replace to increase freeboard
  - Bonslett Bridge: inadequate capacity
  - Schwind at West Liberty Road Structures: complexity over short distance
  - Nugent Flume: inadequate capacity and freeboard
- Replacement of multiple county bridges is required to meet either alternative's objective. (Replacing a county bridge could require more extensive permitting and design time than District-owned structures.)
- There is limited opportunity to provide good hydraulic control of water surface elevations at the design flows. The overall system has minimal drop in grade, resulting in minimal control; consequently, canals and structures tend to submerge at peak flows. Maintaining water elevations at their current levels to achieve Alternative 1's objective restricts improvement options because water level control can not be significantly improved. More water level flexibility is provided under the Alternative 2's objective. Controllability was addressed further in the Composite Alternative development.

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5 Alternatives 1 and 2 addressed improvements required for capacity only. Improvements to achieve adequate freeboard, controllability, or other reasons were addressed during refinements of the Composite Alternative.

- As expected, Alternative 1 requires more canal widening than Alternative 2, and therefore more right-of-way acquisition. Meeting the objectives for Alternative 1 requires widening over 2 miles of the Belding Lateral approximately 10 feet on each side, and 3 miles of the Traynor Lateral by 5 to 10 feet on each side. Alternative 2 would not require widening to accommodate additional canal capacity, saving more than 10 acres of right-of-way acquisition compared to Alternative 1.[6] Both alternatives would require raising canal banks to achieve adequate freeboard, which may result in additional widening, but less than that required for capacity improvements.

5.6 Composite Alternative

After reviewing the results of Alternatives 1 and 2, the District and Reclamation expressed their preferences for facility types, controllability, and operational characteristics of the improved system. The Composite Alternative was developed by considering these preferences and analyzing the improvements for capacity and controllability.

Developing the list of improvements for this alternative was originally approached with the objective of retaining the system's existing control characteristics, including designing within a range of water surface elevations to serve existing turnouts, and retaining existing structure locations and control structure types. As the study progressed, the design constraints posed by this approach became apparent. Different structure types and configurations necessary to provide adequate controllability and to address District preferences were incorporated where appropriate through a post-assessment of design attributes during analysis of the Composite Alternative. Assessments of controllability also may be performed independently by the District as part of its evaluation of proposed designs during later project phases.

5.6.1 Capacity Analysis

A different approach was taken for the Composite Alternative to check the capacity of the recommended canal and structure improvements. The seven monthly flow profiles above were combined to create two new profiles: Flow Profile 1 and Flow Profile 2 (shown in Table 5-5). Flow Profile 1 was used to represent the peak flows on the Belding and Schwind Laterals, and Flow Profile 2 was used to represent the peak flows on the Traynor, Rising River, and Cassady Laterals. Flow Profile 1 is a duplicate of the May profile shown in Table 5-4, when the Belding and Schwind laterals would typically convey peak flows. Flow Profile 2 is a combination of the August, September, October, November, and January flow profiles, when the Traynor, Rising River, and Cassady laterals would typically convey peak flows. The flow profiles were combined to reduce the number of model runs and to check controllability for flows expected to occur more frequently, during periods of normal operation. The approach is conservative because for each reach, the combined profile contains the peak flow of all months reflected by that profile.

[6] Assumptions used to develop preliminary right-of-way estimates are provided later in Section 6.

TABLE 5-5
Flow Profiles for Composite Alternative Capacity Analysis
Gray Lodge Design Data Report

Canal/Corresponding Reach	Canal Station (ft)	Flow Profile 1 (cfs)	Flow Profile 2 (cfs)
Belding/BEL1	694+62	850	767
Belding/BEL2	602+20	750	688
Belding/BEL3	536+10	680	659
Belding/BEL4	484+16	670	649
Belding/BEL5	400+44	270	270
Belding/BEL6	311+70	220	210
Schwind/SCH1	208+84	100	85
Schwind/SCH2	154+31	70	85
Schwind/SCH3	126+70	50	85
Cassady/CAS1	458+01	64	85
Cassady/CAS2	347+32	24	30
Traynor/TRA1	445+03	380	380
Traynor/TRA2	395+10	340	380
Traynor/TRA3	353+22	338	370
Traynor/TRA4	328+04	257	310
Traynor Extension/TRA5	302+78	187	220
Rising River/TRA6	271+11	65	120
Rising River/TRA7	187+35	35	110

5.6.2 Controllability Analysis

With additional flow in the canal system and with several water-level control structures being recommended for replacement, the system was checked for controllability. A canal system with controllability means that water-level control structures are sized appropriately to maintain a target water surface elevation over the range of flow rates in the canal throughout the season. Having control of the system is critical for the District and more importantly for the water users. Controllability of the system provides water users with a reliable or steady water supply and increases water use efficiency.

Controllability was analyzed using three additional flow profiles: High Profile, Medium Profile, and Low Profile (shown in Table 5-6), which represent more typical flow conditions where a high level of controllability is most important. These three profiles were created by Biggs-West Gridley WD's consultant and adopted by the project team. They are based on data collection, observations, and estimated Level 4 flows to Gray Lodge WA. The High Profile represents the higher end of the typical canal flow rates in the canal system rather than the absolute maximum flow rates.

TABLE 5-6
Flow Profiles for Controllability
Gray Lodge Design Data Report

Canal/ Corresponding Reach	Canal Station (ft)	High Profile (cfs)	Medium Profile (cfs)	Low Profile (cfs)
Belding/BEL1	694+62	680	430	200
Belding/BEL2	602+20	591	386	189
Belding/BEL3	536+10	529	354	181
Belding/BEL4	484+16	520	350	180
Belding/BEL5	400+44	190	130	80
Belding/BEL6	311+70	150	90	40
Schwind/SCH1	208+84	80	50	20
Schwind/SCH2	154+31	68	43	17
Schwind/SCH3	126+70	68	43	17
Cassady/CAS1	458+01	71	71	43
Cassady/CAS2	347+32	25	27	24
Traynor/TRA1	445+03	300	200	100
Traynor/TRA2	395+10	300	200	100
Traynor/TRA3	353+22	300	200	100
Traynor/TRA4	328+04	258	168	88
Traynor Extension/TRA5	302+78	170	120	70
Rising River/TRA6	271+11	90	60	30
Rising River/TRA7	187+35	82	55	27

The Approved Design Flow profile (Table 5-4), was used to determine whether a structure should be recommended for replacement. If an existing structure did not have the capacity to pass these peak flows (indicated by the factors described previously in Section 5.4.1), replacement was recommended. Water-level control structures recommended for replacement were then sized using the High, Medium, and Low profiles. Structures not recommended for replacement due to capacity to convey peak flows were checked for controllability.

Controllability was considered adequate if these parameters were met over the range of flow profiles:

- A control structure could maintain a consistent upstream water surface elevation.
- A structure did not become submerged.
- If applicable, a control structure could maintain a consistent upstream water level without fully opening or closing the control orifice.

Because peak flows would be expected for relatively short durations, it was considered acceptable to have gates or checks fully open when conveying the Approved Design Flow profile, as long as the flow could be passed without submergence or overtopping.

5.6.3 Results

Appendix C contains the lists of recommended improvements for the Composite Alternative. The recommended improvements are discussed in detail in Section 6.

In general, the District preferred the Alternative 1 approach throughout most of the system, so the recommended improvements for the Composite Alternative are more similar to Alternative 1 than Alternative 2. One exception is along the Rising River, where it was anticipated that obtaining right-of-way would be difficult, and increasing water levels during a short period of the year would be preferable.

To control project costs and because they are not essential for adequate project operation, neither automation nor remote monitoring and control were considered for implementation as part of this project. However, the recommendations were developed with the understanding that remote monitoring and control using SCADA and other technology could be implemented by the District using other funds.

After preliminary modeling of the Composite Alternative, long-crested weirs were implemented to address controllability concerns. The design and modeling approach of these structures is provided in the next section.

5.6.4 Long-crested Weirs

The existing water-level control structures in the Biggs-West Gridley WD system are checks consisting of multiple undershot gates or undershot gates in combination with flashboard weirs. Many of these structures are operated at or above capacity and will be unable to control water levels under higher flow conditions. To address controllability concerns expressed by Biggs-West Gridley WD and its consultant, the Composite Alternative includes the replacement of most water-level control structures with long-crested weirs.

Long-crested weirs maintain a near-constant water level over a wide range of flow rates because of an elongated crest length extending at an angle into the direction of flow that can pass changes in flow with relatively little change in head over the weir. A schematic of a long-crested weir is included in Appendix D. The basic design calculations are provided below.

Design

The weir equation shows that if the flow rate in the canal changes, the change in head over the weir can be minimized by increasing the crest length.

$$Q = cLh^{3/2}$$

Where:

Q = flow rate (cfs)
c = discharge coefficient ($ft^{(-1/2)}$-s^{-1})
L = effective crest length (ft)
h = head over weir (ft)

The length of the weir is calculated by establishing an accepted variation in delivery flow rate through an upstream turnout for a given change in canal flow rate. The turnout has an orifice design; therefore, the delivery flow rate is based on the drop in head across the turnout. The relationship between the turnout flow rate and the drop in head across the turnout is:

$$\frac{Q_2}{Q_1} = \sqrt{\frac{H_2}{H_1}}$$

Where:

Q_1 = turnout flow rate (cfs)
Q_2 = turnout flow rate after canal flow rate is changed (cfs)
H_1 = drop in head across the turnout (feet)
H_2 = drop in head across the turnout after canal flow rate is changed (feet)

To maintain a constant water surface elevation under a wide range of flows, the long-crested weirs would be extremely long and not cost-effective. To avoid excessive weir lengths, long-crested weirs can be combined with overshot gates. The gates can be sized with the following equation, derived from the orifice equation:

$$Q = 8.02CAH^{1/2}$$

For a fully contracted, submerged orifice, C = 0.61; therefore,

$$Q = 4.89AH^{1/2}$$

Where:

Q = flow rate (cfs)
A = area of gate opening (ft^2)
H = differential head across gate (ft)

Sizing for Biggs-West Gridley WD

Several assumptions were necessary to perform these calculations and simulate the long-crested weirs in the hydraulic model. The assumptions were discussed during several technical meetings between CH2M HILL and consultants to Biggs-West Gridley WD.

To establish the effective crest length, the following was assumed:

- A discharge coefficient of 2.7 $ft^{(-1/2)}$-s^{-1}, appropriate for duckbilled weirs and suggested in an Irrigation Training and Research Center (ITRC) report (Burt, 2003)
- A head of 1 foot over the top of the weir, which Biggs-West Gridley WD consultants suggested as an initial head flowing over the weir with adjustment as appropriate for each location

Biggs-West Gridley WD consultants suggested that the allowed fluctuation in delivery flow rate (through a turnout) be plus or minus 5 percent with neither the turnout gate nor check gate being adjusted. Fluctuations larger than this are believed to be problematic on the farm side of the delivery gate. Canal flows should be allowed to vary by 30 cfs, which would allow minor flow changes to be made within the operating day without having to make operational changes throughout the system. Both assumptions were determined largely by professional judgment and were determined to be reasonable and acceptable by the District.

Because surveyed turnout data were not available for this preliminary analysis, it was assumed that the existing drop across all turnouts in the system is 2 feet. This assumption was incorporated based on observations by the District's consultants and discussions with District employees and stakeholders. A detailed survey of turnouts is needed before final design begins to confirm or refine this assumption. For a 5 percent change in flow rate through the turnout, the allowable fluctuation in the canal water level is 0.21 feet when the canal flow rate changes by 30 cfs. These values were used with the weir equation to establish weir lengths.

It was assumed that the long-crested weir structures would include one or more overshot gates to accommodate large fluctuations in flow rate. These gates would be adjusted manually initially, but will be designed so that automation can be incorporated by the District at a later date. The gates were sized using the above equations and assumptions. During the design phase, overshot gates should be sized so that during rice harvest (when canal water levels are lowered), the full design flow can be passed through the gates, and no flow will be passed over long-crested weirs.

Submergence

Structures in the Biggs-West Gridley WD canals were sized to avoid submergence. For an installed long-crested weir, as the downstream water level approaches the weir crest elevation the structure may become submerged. Even if a weir is only partially submerged, the downstream water level can affect the upstream water level and therefore compromise the effectiveness of the weir. Also, submerged weirs cannot be used as accurate flow measurement devices.

Once the height and the length of the long-crested weirs were determined, each structure was checked for submergence. If the downstream water surface elevation plus the velocity head was greater than the weir crest elevation, submergence was likely, and the weir was re-sized.

Modeling Approach

The long-crested weirs were sized using hand calculations and then modeled to verify the predicted operations. HEC-RAS does not have an established modeling protocol for long-crested weirs, so a procedure was developed by CH2M HILL and Biggs-West Gridley WD consultants. The hydraulic model software does not allow a weir crest length greater than the width of the canal. It was decided to model the weir with a crest length equal to the canal width and increase the discharge coefficient to simulate a longer crest length.

To simulate the integrated overshot gates, sluice gates were modeled because of limitations in HEC-RAS. This assumption did not affect the results of the model. In the field, overshot gates will be easier to operate and maintain a target water surface elevation than sluice gates. Overshot gates are the District's preferred option for gates in combination with long-crested weirs.

The long-crested weirs were sized for the low flow profile, and the gates were sized to handle the difference between the high flow profile and the low flow profile. Under this combined sizing configuration, the long-crested weirs will be able to accommodate any small, unexpected change in flow rate, and the gates will handle larger changes in flow rate.

5.7 Review Process

The hydraulic model and recommended improvements for the Biggs-West Gridley WD were developed by CH2M HILL. The modeling was done in phases and reviewed by Biggs-West Gridley WD's consultants following each phase. Four models were reviewed in three phases:

- Calibration model
- Alternative 1 and Alternative 2 models
- Composite Alternative model

5.7.1 Calibration Model Review Phase

During review of the Calibration model, concern was raised by the District that the May calibration would not reflect the effects of thick weed growth in the canals during the late summer. Biggs-West Gridley WD's consultants assessed these conditions through a field visit on August 28, 2006. On this day, flow rates and water levels were recorded at various locations in the canal system, and data from these instruments were downloaded for use in the calibration. Gate openings of every check structure on the Belding, Schwind, Traynor, and Rising River Laterals were physically measured. Various laterals were visually inspected to estimate the amount of weed growth present. This information was used to re-calibrate the HEC-RAS model to address the concerns of the District.

Biggs-West Gridley WD's consultants documented their re-calibration effort and review of the Calibration model in a memorandum submitted on May 27, 2007. The consultants worked collaboratively with CH2M HILL to refine the original Calibration model and address the District's concerns. Key refinements to the Calibration model included the following:

- Manning's "n" values were adjusted in several areas of the system, particularly on the Traynor Lateral, to reflect thicker weed growth conditions.
- The expansion and contraction coefficients were increased near check structures and bridges.
- Ineffective flow areas were added near check structures and bridges.
- The cross-sections near the check structures and bridges that contained portions of the structures themselves were removed.
- The "high flow" modeling method for the bridges was changed from energy only to "pressure and/or weir flow."

The refined model was used as the baseline of the Alternative 1, Alternative 2, and Composite models.

5.7.2 Alternative 1 and Alternative 2 Review Phase

After each alternative was developed, the models and list of improvements were presented to the Biggs-West Gridley WD manager and consultants and Reclamation for review and comment. The District's consultant performed a light review of the model and list of improvements. A more thorough review of the suggested improvements was performed prior to development of the Composite Alternative.

Alternative 1 was presented to the project team during a conference call on January 8, 2008. CH2M HILL described the HEC-RAS modeling process, the design challenges, and the recommended improvements for each reach. A detailed system improvements table was provided to the team. The District's consultants were provided with a copy of the hydraulic model for a technical review, and the consultants provided minor comments on the technical details of the modeling, which CH2M HILL addressed in the Alternative 1 model. Implementing changes from the comments received did not cause significant changes to the initial modeling results.

Alternative 2 was presented to the project team on February 26, 2008, during a conference call. The District's consultants were provided with a copy of the hydraulic model and draft list of improvements on March 3, 2008. A cursory comparison of right-of-way needs for Alternatives 1 and 2 was discussed. The District's consultants provided minor comments on the technical details of the modeling. These comments were addressed by CH2M HILL in the working model. Implementing changes from the comments received did not cause significant changes to the initial modeling results.

A technical modeling workshop was held with Reclamation, CH2M HILL, and the District's consultants on May 20, 2008, to review and compare the results of both alternative models, better understand the assumptions and development of the models, and establish an approach to the Composite Alternative. The results of this meeting were presented at a meeting among all parties involved in the project, including the District Board of Directors and staff, at a meeting and field visit on June 10, 2008. All parties visited key system locations that required input from the District manager and operators on preferred system operations. All structures listed in Alternative 1 or Alternative 2 as requiring replacement were reviewed.

All parties agreed that the major structures listed in Section 5.5.2 should be replaced or rehabilitated. The project team agreed that, during development of the Composite Alternative, additional structures would be assessed for replacement or rehabilitation to achieve freeboard, ensure structural stability, or for other reasons.

Discussion and review of the model and the recommended improvements by study participants resulted in the final list of recommended facility improvements for the Composite Alternative.

5.7.3 Composite Alternative Review Phase

The Composite Alternative model and list of recommended improvements were presented to Reclamation, the District, and the District's consultants on October 3, 2008. The District's consultants provided comments to the project team on October 22. Comments were discussed by the project team on a conference call on October 24. At that time, the recommendations had not been presented to the District Board of Directors. Minor comments were submitted on the hydraulic model and implemented by CH2M HILL.

The District's consultants agreed with most recommendations in the Composite Alternative, including the replacement of control structures and check configurations. The District's consultants recommended the replacement of three additional structures that were not originally recommended for replacement in the Composite Alternative list of improvements: the Garcia Check, Banion Check, and Check #1695. Reclamation agreed that because the Garcia and Banion checks would be operating close to their design capacity at peak design flows, it would be prudent and reasonable to replace them to provide controllability and a margin of safety.

Check #1695 was reevaluated to determine whether it has adequate control. By further adjusting the check structure, water level could be matched during high and low flows, and there was adequate room to accommodate additional fluctuations in flow. At the current appraisal-level of analysis, it was agreed that this check will provide adequate control without being replaced.

The replacement of two county bridges was also discussed during the conference call. The West Liberty Road Bridge on the Traynor Lateral will be considered during the design phase. The Evans Reimer Road Bridge on the Rising River Lateral is recommended for replacement.

SECTION 6

Recommended Biggs-West Gridley Facility Improvements

Modifications to portions of the existing channels and some of the existing structures are necessary to enable reliable water deliveries of sufficient quantity (volume and timing) to Gray Lodge WA according to project objectives. The basis for the recommended improvements described below is the Composite Alternative model, described in Section 5. The recommended set of facility improvements was developed to enable development of appraisal-level cost estimates and project assessment. The identified improvements represent general agreement between Reclamation and Biggs-West Gridley WD, reached in this stage of project development, regarding the improvements necessary to accomplish project objectives and mitigate project effects. While both parties recognize that the list may be revised based on more detailed analyses to be completed during final design, the final design will not depart substantially from the criteria and features outlined in the Design Data Report without the consent of all parties. This complete list of recommended improvements is provided in Appendix C. The following facility improvements are presented here:

- 26 facility improvements on the Belding Lateral
- 12 facility improvements on the Schwind Lateral
- 16 facility improvements on the Traynor Lateral
- Four facility improvements on the Rising River Lateral
- Eight facility improvements on the Cassady Lateral

6.1 Belding Lateral Improvements

The existing condition of the Belding Lateral is characterized by uneven canal widths, uneven canal elevations, and structures that do not have adequate capacity to pass the design flows, provide adequate water level control, or both. The existing system operates at or above its capacity at some locations and at some times. Additionally, overgrowth downstream of the Colusa Highway Bridge is impeding flow. Flow capacity would be improved by establishing an efficient trapezoidal canal cross-section, replacing some of the existing structures, and clearing overgrowth.

Details of the improvements required to ensure reliable delivery are listed in this section. See Figure F-4 in Appendix F for improvement locations.

B-1: Razorback Siphon Removal and Drainage Reconfiguration

Remove the Razorback Siphon and replace with a trapezoidal earthen canal section to increase capacity and reduce head loss across this structure. Install two 8-foot-by-6-foot cross-drainage box siphons for the Dietzler Ditch (RD 833 drain). Design and construction of this improvement will require coordination with RD 833. The capacity of the drainage structure will be assessed during subsequent design phases.

Razorback Siphon

B-2: Canal Modifications (Freeboard) from Station 607+73 to 603+89

Reconstruct 384 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-3: Railroad Culverts Capacity Improvements

Install two additional 8-foot-diameter pipes under Union Pacific Railroad (UPRR) tracks to increase capacity and reduce head loss across this structure. Bore and jack the new pipe casing.

Railroad Culverts

B-4: Canal Modifications (Freeboard) from Station 596+65 to 591+50

Reconstruct 515 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-5: Garcia Check Replacement

Remove the existing Garcia Check structure and replace it with 70-foot long-crested weir with three 3.3-foot-wide overshot gates.

Garcia Siphon

B-6: Garcia Siphon Removal and Drainage Reconfiguration

Remove the Garcia Siphon and replace with a trapezoidal earthen canal section to increase capacity and reduce head loss across this structure. Install two 8-foot-by-6-foot cross-drainage box siphons for the RD 833 drain. Design and construction of this improvement will require coordination with RD 833. The capacity of the drainage structure will be assessed during subsequent design phases.

Typical Existing Reach of the Belding Lateral

B-7: Canal Modifications (Freeboard) from 558+51 to 548+69

Reconstruct 982 linear feet of canal from the Biggs-Princeton (Afton) Road Bridge to the Garcia Siphon to raise freeboard to at least 18 inches on the west bank and widen the top of both canal banks to a 14-foot minimum width.

B-8: Biggs/Princeton (Afton) Road Bridge Replacement

Remove existing bridge and replace with 2-foot-deep flat slab bridge with asphalt concrete (AC) driving surface to reduce flow restriction and add additional freeboard. Culvert depth below bridge should be at least 7 feet.

Afton Road Bridge

B-9: Canal Modifications (Freeboard) from Station 546+47 to 535+13

Reconstruct 1,134 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-10: Banion Check Replacement

Remove the existing Banion Check structure and replace it with 70-foot long-crested weir with three 4.5-foot-wide overshot gates.

B-11: Canal Modifications (Freeboard) from Station 527+73 to 517+33

Reconstruct 1,040 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-12: Canal Modifications (Freeboard) from Station 512+20 to 401+70

Reconstruct 11,050 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-13: Fields Flume Replacement

Remove and replace the Fields Flume with a higher capacity 26-foot-by-8.5-foot concrete flume to increase freeboard. Install 2-foot-wide walkways. Widening of the structure and a wasteway to spill excess water will be evaluated during final design.

Fields Flume

B-14: Canal Modifications (Widening) from Station 535+32 to 405+24

Reconstruct 13,008 linear feet of canal. Widened canal will have a bottom width of 30 feet and be 10 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

B-15: North Weir Replacement

Remove and replace the North Weir with a 67-foot long-crested weir with two 4-foot-wide overshot gates.

North Weir

B-16: Division 2 Headgates Replacement

Remove and replace the Division 2 Headgates at the Belding/Traynor Split with three new 4-foot-wide sluice gates to improve control. Replace the farm crossing with 2-foot-thick flat-slab deck and at least 7-foot culvert opening. Increase height of adjacent canal banks to achieve 18 inches freeboard.

Division 2 Headgates

B-17: Canal Modifications (Freeboard) from Station 381+70 to 346+70

Reconstruct 3,500 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-18: Check #1889 Replacement

Remove and replace Check #1889 structure with a new 45-foot long-crested weir and 4-foot-wide overshot gate.

Check #1889

B-19: Canal Modifications (Freeboard) from Station 343+10 to 309+72

Reconstruct 3,338 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-20: Check #1845 Replacement

Remove and replace Check #1845 structure with a new 83-foot long-crested weir and two 3.5-foot-wide overshot gates.

Check #1845

B-21: Canal Modifications (Freeboard) from Station 300+32 to 211+71

Reconstruct 8,861 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

B-22: Farm Crossing #1786 Replacement

Remove existing Farm Crossing at Station 300+20 and replace with 2-foot-deep flat slab bridge with aggregate base backfill for driving surface to reduce flow restriction and add additional freeboard.

Farm Crossing #1786

B-23: Farm Crossing #1719 Replacement

Remove existing Farm Crossing at Station 264+20 and replace with 2-foot-deep flat slab bridge with aggregate base backfill for driving surface to reduce flow restriction and add additional freeboard.

Farm Crossing #1719

B-24: Farris Road Bridge Replacement

Remove existing Farris Road Bridge and replace with 1.7-foot-deep flat slab bridge with asphalt concrete driving surface to reduce flow restriction and add additional freeboard. Opening under bridge should be 8.5 feet high.

Farris Road Bridge

B-25: Bonslett Bridge Replacement

Remove and replace the Bonslett Bridge structure with a new 6-foot by-5-foot bridge-box culvert structure and 50-foot long-crested weir to increase capacity and decrease head loss across this structure. Construct a new 4-foot-wide manual overshot gate in the center of the long-crested weir.

B-26: Replace Seepage Drains

Replace 84,400 linear feet of seepage drains where impacted by canal modifications.

6.2 Schwind Lateral Improvements

The Schwind Lateral branches off from the Belding Lateral just downstream from the Bonslett Bridge. The Schwind Lateral exhibits the same characteristic found in the Belding Lateral of varying canal cross section that limits flow and lacks sufficient freeboard. Several existing structures limit canal capacity to less than that necessary to achieve project objectives.

Details of the improvements required to ensure reliable delivery are listed in this section. See Figure F-4 for improvement locations.

S-1: Canal Modifications (Freeboard) from Station 211+70 to 196+40

Reconstruct 1,530 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

S-2: Canal Modifications (Freeboard) from Station 186+46 to 93+64

Reconstruct 9,282 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

S-3: Farm Crossing #7137 Replacement

Remove and replace the farm crossing and culvert #7137 just upstream of Schwind Flume structure with a 9-foot-by-4-foot concrete box culvert/crossing to increase capacity and decrease head loss across this structure.

S-4: Schwind Flume Replacement

Remove and replace the Schwind Flume structure with a similar flume, 60 feet long by 8 feet wide by 5 feet deep to increase capacity and freeboard while decreasing head loss across this structure. Integrate check bays on both sides of flume structure to allow for spill.

Schwind Flume

S-5: Farm Crossing #1522 Replacement

Remove existing farm crossing at Station 161+03 and replace crossing with a 37-foot long-crested weir with a 3-foot-wide overshot gate to reduce flow restriction and add additional freeboard. Integrate new flat slab deck crossing.

Farm Crossing #1522

S-6: Farm Crossing #1491 Replacement

Remove and replace farm crossing culvert just downstream of Colusa Highway with a 9-foot-by-4-foot concrete box culvert under crossing to increase capacity and decrease head loss across this structure.

Farm Crossing Downstream of Colusa Highway

S-7: Canal Modifications (Widening) from Station 148+09 to 131+04

Reconstruct 1,705 linear feet of canal. Widened canal will have a bottom width of 14 feet and be 8 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

S-8: Farm Crossing #1438 Replacement

Remove and replace the farm crossing culvert just upstream of West Liberty Road with a 7-by-4-foot concrete box culvert/crossing to increase capacity and decrease head loss across this structure.

S-9: Farm Crossing #5021 Removal and Replacement with Siphon

Remove existing farm crossing at Station 100+12. Replace Crossing #5021, Culvert #5006, and Culvert south of West Liberty Road with 162-foot-long by 6-foot-diameter siphon. See improvements S-10 and S-11.


Farm Crossing #5021

S-10: Culverts #5006 Removal

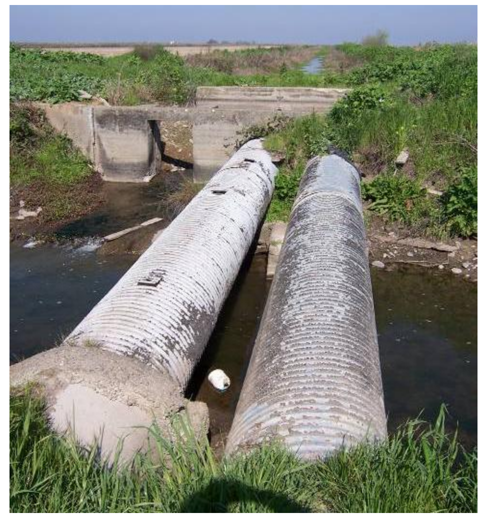
Remove two 140-foot-long by 3-foot-diameter CMP culverts over drain and under West Liberty Road.

S-11: Culvert South of West Liberty Road Removal

Remove the 26-foot-long by 4-foot-diameter CMP culvert south of West Liberty Road.

S-12: Replace Seepage Drains

Replace 5,970 linear feet of seepage drains where impacted by canal modifications.


Culverts #5006

6.3 Traynor Lateral Improvements

The current condition of the existing Traynor Lateral is characterized by unstable, steep channel side slopes and an uneven grade. The canal does not provide optimal flow carrying capacity or efficiency. Overgrowth is impeding flow near the Evans Reimer Road Bridge. Flow capacity would be improved by setting a positive grade and providing an efficient trapezoidal design, and by clearing the overgrowth near Evans Reimer Road.

Details of the required and recommended improvements are listed in this section. See Figure F-4 for improvement locations.

T-1: Canal Modifications (Widening) from Station 445+03 to 418+73

Reconstruct 2,630 linear feet of canal. Widened canal will have a bottom width of 30 feet and be 11 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

T-2: Canal Modifications (Widening) from Station 445+03 to 415+72

Reconstruct 2,931 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

T-3: Traynor Headgates Replacement

Remove and replace the Traynor Headgates with a 62-foot long-crested weir with two 3-foot-wide overshot gates to increase freeboard and improve control.

Traynor Headgates

T-4: Nugent Flume Replacement

Remove and replace the Nugent Flume with a higher-capacity 60-foot-long by 22-foot-wide by 10.5-foot-deep concrete flume. Improve canal 500 feet upstream and downstream of new flume to match the freeboard of the flume. Install two check bays, one on either side of flume, for spill. Maintain a box culvert under flume for RD 833 drainage.

Nugent Flume

T-5: Canal Modifications (Widening) from Station 417+88 to 379+21

Reconstruct 3,867 linear feet of canal from Nugent Flume to Farm Crossing #2633. Widened canal will have a bottom width of 34 feet and be 11 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

T-6: Canal Modifications (Freeboard) from Station 405+80 to 373+25

Reconstruct 3,255 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

T-7: Canal Modifications (Widening) from Station 379+06 to 352+84

Reconstruct 2,622 linear feet of canal from Farm Crossing #2633 to the Colusa Highway Bridge. Widened canal will have a bottom width of 16 feet and be 10 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

T-8: Canal Modifications (Freeboard) from Station 368+55 to 357+95

Reconstruct 1,060 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

T-9: Farm Crossing #2633 Replacement

Remove existing farm crossing at Station 379+07 and replace with 2-foot-deep flat slab bridge with aggregate base backfill for driving surface.

T-10: Control Structure Installation at Station 354+00

Construct a new 48-foot long-crested weir at station 354+00 with two 3-foot-wide manual overshot gates. This structure will add the necessary control to the system in this area.

T-11: Canal Modifications (Freeboard) from Station 354+00 to 352+82

Reconstruct 118 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

T-12: Colusa Highway Bridge Replacement

Colusa Highway Bridge

Remove existing Colusa Highway Bridge and replace with 3-foot-deep flat slab bridge with 2-foot-thick center pier and asphalt concrete driving surface to reduce flow restriction and add additional freeboard.

T-13: Canal Modifications (Widening) from Station 352+53 to 299+36

Reconstruct 5,317 linear feet of canal from Colusa Highway Bridge to West Liberty Road Bridge. Widened canal will have a bottom width of 16 feet and be 10 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

T-14: Canal Modifications (Freeboard) from Station 343+95 to 299+33

Reconstruct 4,462 linear feet of canal to raise freeboard to at least 18 inches and provide a 14-foot minimum top width for the canal banks.

T-15: Canal Modifications (Widening) from Station 298+36 to 271+11

Reconstruct 2,725 linear feet of canal to the Traynor Extension from West Liberty Road Bridge to the Rising River Headgates. Widened canal will have a bottom width of 12 feet and be 10 feet deep with 2:1 side slopes. A 14-foot minimum top width will be provided for canal banks.

T-16: Replace Seepage Drains

Replace 29,300 linear feet of seepage drains where impacted by canal modifications.

6.4 Rising River Lateral Improvements

Several improvement options were considered on the Rising River. The channel has adequate capacity to accommodate the increased flows to Gray Lodge WA; however, seepage from the canal may increase water levels in adjacent fields when flows increase above existing conditions and water levels are not being controlled for irrigation deliveries. This could be problematic for orchards and for access to rice fields during planting and when fields must remain dry for farm equipment. The following five options were presented to the project team:

- Widen the canal to maintain water levels at or near existing conditions
- Lower the minimum water level required to deliver water to Gray Lodge WA by installing a pump at the delivery point
- Allow water levels to increase and install sub-surface drainage or seepage ditches
- Allow water levels to increase and prevent additional seepage by lining the canal section
- Allow water levels to increase and mitigate by providing reimbursement for affected crops

Stakeholders have not decided which alternative to will be best for all parties involved, so it was assumed for the Design Data Report that the existing Rising River cross section will be used and water levels will increase. If this assumption is carried forward through final design, a seepage mitigation option described in Appendix A may be used.

R-1: Canal Modifications (Freeboard) from Station 270+59 to 221+30

Reconstruct 4,929 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

R-2: Check #2802 Replacement

Remove and replace the flashboard check structure with a 19-foot long-crested weir with one 4-foot-wide overshot gate to increase capacity and freeboard while decreasing head loss across this structure.

Flashboard Check #2802

R-3: Canal Modifications (Freeboard) from Station 200+00 to 194+30

Reconstruct 570 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

R-4: Evans Reimer Bridge Replacement

Remove existing Evans Reimer Bridge and replace with 2-foot-deep flat slab bridge with 1-foot-thick center pier and asphalt concrete driving surface to reduce flow restriction and add additional freeboard.

Evans Reimer Road Bridge

6.5 Cassady Lateral Improvements

The existing condition of the Cassady Lateral is characterized by uneven canal elevations, overgrowth, inadequate access roads, and structures that do not have adequate capacity to pass the design flows, provide adequate water level control, or both. Flow capacity would be improved by providing an efficient trapezoidal design, replacing some of the existing structures, and cleaning overgrowth.

Details of the required improvements are listed in this section. See Figure F-4 for improvement locations.

C-1: Canal Modifications (Freeboard) from Station 450+63 to 364+56

Reconstruct 8,607 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks

C-2: Farm Crossing #1226 Replacement

Remove and replace Farm Crossing #1226 at station 394+00 upstream of Bonslett's driveway with an 8-foot-by-4-foot concrete box culvert with integrated farm crossing to increase capacity and reduce head loss across this structure.

Culvert Upstream of Bonslett Driveway

C-3 and C-4: Structures #1199 and #1198, Bonslett's Driveway Culvert/Crossing and Bonslett Weir, Replacement

Remove and replace the farm crossing culvert at Bonslett's driveway with a 7-foot-by-4-foot concrete box culvert and flashboard weir with a 56-foot long-crested weir and a 3-foot-wide long overshot gate to increase capacity and reduce head loss across this structure. Replace customer turnouts and provide a concrete apron downstream of the weir to control erosion.

Bonslett Weir #1198

Bonslett Driveway Culvert and Crossing #1199

C-5: Culvert #1163 Replacement

Replace the culvert at station 364+57 with a 27-foot long-crested weir with a 3-foot-wide overshot gate to increase capacity and reduce head loss across this structure.

Concrete Pipe Culvert #1163

C-6: Canal Modifications (Freeboard) from Station 357+36 to 340+22

Reconstruct 1,714 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

C-7: Canal Modifications (Freeboard) from Station 336+13 to 326+33

Reconstruct 980 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

C-8: Canal Modifications (Freeboard) from Station 319+82 to 300+00

Reconstruct 1,982 linear feet of canal to raise freeboard to at least 12 inches and provide a 14-foot minimum top width for the canal banks.

6.6 Design Phase Considerations

At the existing level of design, structure improvements and replacements are recommended primarily for hydraulic capacity purposes and minimum freeboard criteria at peak design flows. The facility improvements listed in Appendix C have been developed in coordination with Biggs-West Gridley WD. More detailed analysis and design is required for the listed improvements and will occur in the design phase of the Gray Lodge Water Supply Project. Listed below are design phase considerations that were identified during the development of the Design Data Report that require further analysis.

6.6.1 Additional Structure Evaluations

During the Composite Alternative review phase, Biggs-West Gridley WD and their consultants identified additional structures to be replaced under this project for reasons other than inadequate hydraulic capacity. These structures are not included in the project cost estimate, but they are identified for further evaluation in the design phase:

- **Farm Crossing #1366:** Hydraulic modeling estimated increased velocities downstream of this farm crossing. Measures to prevent bed scouring resulting from increased velocities will be considered during the design phase.
- **Farm Crossing #2010:** Hydraulic modeling estimated increased velocities downstream of this farm crossing. Measures to prevent bed scouring resulting from increased velocities will be considered during the design phase.
- **Structure #1060:** Consider replacement during final design to reduce head loss through the culvert under high flow conditions.
- **West Liberty Road Bridge:** The District is concerned that the check structure downstream will have a difficult time controlling the water surface elevation because of the small pool size between the bridge and the check. If it becomes apparent during the design phase that there would be a structural or operational risk to retain this structure, the structure would be reconsidered for replacement.

6.6.2 Turnout Survey

A detailed survey of all turnouts in Biggs-West Gridley WD is required for final design. Design of new structures is highly dependent on turnout locations, invert elevations, and configurations with respect to entrance and exit water surface elevations. Accurate turnout elevation data is necessary for sizing the long-crested weirs—both length and height of weir—to ensure stable water surface elevations and thus stable deliveries through the turnouts. As of November 2008, Reclamation is organizing a detailed turnout survey with plans to complete the survey prior to starting the design phase.

6.6.3 Seepage Mitigation Methods

Section 3 provides a summary of a preliminary seepage investigation. As discussed, there are existing areas of seepage (shallow groundwater) adjacent to canals. If water levels increase from baseline levels, remain at existing levels for longer durations, or occur at different times, existing areas of seepage could worsen or new areas of seepage could emerge. A more in-depth analysis of seepage at specific locations is required during the design phase. Several seepage mitigation approaches are possible:

- Restricting canal water levels, flow durations, and timing to existing conditions
- In-canal methods, such as lining
- Out-of-canal methods, such as interception drains and/or pumps

Seepage may best be addressed by restricting canal water levels to their baseline levels (see Appendix A). Restricting water levels to existing conditions may avoid aggravation of seepage problems in canal reaches where the cross-section will not be disturbed, provided that the timing and duration of operation at those levels does not change relative to historical conditions. Therefore, it is recommended that the improvements allow canal water levels to be maintained at current levels to a reasonable extent. This approach was taken in the Composite Alternative except on the Belding Lateral just upstream of the Division 2 Headgates, where water levels were intentionally allowed to increase for operational benefits at this major control point. However, it is recognized that localized areas of seepage may be detected. Also, in reaches where canal cross-sections will be disturbed, the existing sealing layer may be disrupted or a sand lens may be intercepted, which could result in increased seepage. These effects could be mitigated if deemed appropriate.

If it is determined that increased seepage is unavoidable through canal water level restrictions or other means after improvements are implemented, canal seepage could be reduced by either in-canal methods (such as lining) or out-of-canal methods (such as interception drains and associated pumping). (Replacement of existing seepage ditches is assumed as part of the Composite Alternative.) Suitable seepage mitigation options are described in detail in Appendix A. Costs vary depending on the site preparation work and amount of maintenance required. If mitigation measures are chosen for the advancement of the Gray Lodge Water Supply Project, canal lining methods and interception drains/pumping should be developed beyond a conceptual level. The extent and type of the seepage mitigation system will be refined based on additional fieldwork and subsurface investigations in future project design phases. Additionally, Reclamation will develop a seepage monitoring and mitigation plan during the design phase subject to acceptance by the District to continue to address seepage at Biggs-West Gridley WD. This future study will include development of an operations model to understand changes in magnitude, timing, and duration of canal water levels that will occur after the project is implemented.

6.6.4 Canal Automation

During the design phase, new water-level control structures will be designed so that in the future Biggs-West Gridley WD can install automated controls. Although not required for delivery to Gray Lodge WA and not included as a project cost, automation is a more efficient and reliable way to deliver water because it reduces spills and maintains proper operating water levels and/or flows.

6.7 Construction Considerations

Before the suggested facility improvements can be implemented, issues affecting construction activities must be addressed. General construction methods must account for system operations and seasonal constraints. Impacts on landowners, such as easement issues, also must be addressed. Because easement mapping records are inadequate, property and boundary surveys must be an immediate priority during the implementation phase.

6.7.1 Construction Methods

Generally, construction activities will include the demolition of existing structures, excavation to accommodate new structures and channel improvements, cast-in-place concrete work, and earthwork to reshape canals so they meet design criteria.

UPRR Crossing

Key design considerations for the new 60-inch pipe to be installed at the UPRR crossing near the head of the Belding Lateral include complying with UPRR requirements and minimizing the risk of settlement or heaving. UPRR will likely require the pipe to be placed in a casing and comply with other UPRR standards that include depth of cover, pipe length, thickness, and materials. Coordination with UPRR should be started as early as possible during the final design phase because UPRR has design, construction, and timelines that must be met.

Timing

Ideally, construction would be carried out during the months of February, March, and April; when the canal system is dewatered. However, compliance with the Endangered Species Act may limit the months in which construction may occur. In the event that construction can occur only during months of the irrigation season, bypass structures may be required at major structures. There may be additional limitations on the timeframe for construction activities because winter months can pose precipitation challenges that make earthwork difficult and require supplemental dewatering. For the purposes of completing the cost estimate including bypasses, a preliminary construction sequencing plan was developed and is provided in Section 7.5.

6.7.2 Easements

Implementing the proposed improvements may require the purchase of rights-of-way for temporary and permanent easements.

Temporary easements will be negotiated on a landowner-by-landowner basis depending on areas needed for construction access or material laydown identified during the project’s design phase project. For this appraisal-level estimate, a temporary easement equal to the permanent easement estimate has been assumed for the purpose of estimating costs.

Permanent easements will be necessary along canals were widening or freeboard improvements are recommended. At this appraisal level, the following assumptions have been made to estimate the necessary permanent easement required for the identified improvements:

- An average typical cut section with the center line aligned with the existing canal was assumed for quantity calculations.
- In areas where the canal banks are being raised to accommodate additional freeboard, a 2:1 slope was used to determine permanent easements.

- Where the canal is widened, additional easement was estimated to be the width added to the canal section incorporating 2:1 canal side slopes.
- For structures recommended for replacement, permanent easement was calculated to be 10 feet on either side of the canal for a distance of 50 feet.

Permanent easement estimated for each reach of the system is identified in Table 6-1. These estimates will be refined during the project's design phase.

TABLE 6-1
Required Permanent Easement
Gray Lodge Design Data Report

Lateral	Easement (acres)
Belding	10
Schwind	2
Traynor	10
Rising River	1
Cassady	2
Total acreage	**25**

Biggs-West Gridley WD has little information regarding property boundaries of local landowners. Reclamation is in the process of working with the District and local agencies to determine the appropriate property boundaries. Rights-of-way resulting from the improvements could require significant effort and negotiation during final design.

6.7.3 Landowner Concerns

The only currently identified area of concern is along the Cassady Lateral, upstream of Peterson's Check to the Bonslett Weir. This is a private reach of canal, so any improvements to this section would require landowner permission or negotiation. Biggs-West Gridley WD has indicated that it is working to obtain right-of-way for this canal section. The provision of reliable water to Gray Lodge WA along the Cassady is dependent upon Biggs-West Gridley WD having unrestricted access to maintain this canal section. The Cassady improvements assume that Biggs-West Gridley WD will obtain right-of-way before construction occurs.

6.8 Drawings

Appraisal-level drawings were prepared for typical, representative improvements and are provided in Appendix D. The purpose of the drawings is to illustrate the primary features of the improvements in terms of size, layout and orientation, and key hydraulic dimensions. The drawings also show the approximate level of detail upon which the construction cost opinions, presented in the following section, are based.

6.9 Appraisal-level Estimates of Construction and Total Capital Costs

Appraisal-level cost estimates were prepared for each of the improvements and were based on the facilities' size, layout, and features presented in this report. Quantity takeoffs for estimating purposes were developed at the level of detail illustrated in the drawings provided in Appendix D. Cost information used in preparing the estimates included cost estimates for similar completed projects, vendor quotes for equipment such as canal gates, and cost-estimating database tools. The cost estimates are not based on completed engineering designs and site investigations. These steps will be required at a later stage of project development to refine the cost estimates for any improvements that proceed beyond this phase of evaluations.

6.9.1 Contract Cost

The Contract Cost (CC) includes directly related costs for a contractor to complete a specific improvement (for example, remove and replace a check structure) under the overall program. This includes the individual unit-cost items that are known at this time, such as excavation, cast-in-place concrete construction, and dewatering. Typical unit costs, which include all associated equipment and labor costs for that activity, are listed in Table 6-2. The unit costs used in this appraisal-level estimate have contractor overhead and profit embedded.

TABLE 6-2
Construction Cost Assumptions
Gray Lodge Design Data Report

Parameter	Assumption
Excavation	Local excavation to remove, temporarily store, and replace dirt as needed to build each project.
Fill and compaction	Engineered fill as part of a new facility, such as canal bank construction (includes placement, compaction, trimming to final grade, and related activities).
Concrete demolition	Demolition, hauling (20 miles assumed), and disposal of existing concrete structures such as headwalls, flumes, slabs, and concrete pipes.
Concrete placement	Forming, rebar, placing concrete, finishing, and all related activities for building cast-in-place concrete structures such as new headwalls, flumes, box culverts, and related appurtenances.
Haul to disposal	Removing excess earth and loose placement in a designated disposal site. Haul distance assumed to 20 miles.
Import from borrow	Excavation at borrow site, 20 mile haul, and loose dumping at the project site.
Overshot gates	Costs based on vendor quotes for Rubicon brand overshot gates with no automation. Have compatibility to be automated in future.
Dewatering	Pumps, ditches, sumps, and all other temporary equipment and operations to maintain a dewatered construction site and dispose of shallow groundwater into adjacent canal. Main system will either be isolated or bypassed during structure construction.
Bore and jack	Estimate includes direct jack of concrete pipe with an open-faced cutting machine. Borings during design may indicate need for closed face due to groundwater, resulting in additional costs.

To complete the estimate at the CC level, mobilization and design contingency are added to the summation of the detailed estimates for a given lateral. The mobilization allowance is 5 percent. The design contingency represents the items yet to be identified or items yet to be designed to a level that can be quantified. The design contingency also represents a level of risk associated with the potential change in scope of work for the project. As the project design progresses, the design contingency factor will decrease and ultimately be removed from total capital costs estimate at the final design stage. For this appraisal-level estimate, the design contingency shown in the detailed tables of Appendix E is at approximately 15 percent.

To bring the CC to the Field Cost (FC) level, land-acquisition costs are listed, and a construction contingency is added to the CC. The acreage basis for land-acquisition costs is provided in Table 6-1. Construction contingency is an allowance intended to account for costs resulting from changes in designs and or different site conditions encountered in the field. For this appraisal-level estimate, a construction contingency of approximately 25 percent is applied to the CC. As the design phase progresses, the construction contingency factor will decrease in similar manner as the design contingency.

The detailed cost estimates taken to the FC level for each lateral is presented in tables in Appendix E.

6.9.2 Non-contract Cost

Once the construction costs for each major feature of each lateral are developed based on the unit costs and design and construction contingencies, non-contract costs are added to develop the total capital cost. Add-on percentages are assumed as follows:

- Engineering and design: 10 percent of FC
- Construction services and management: 10 percent of FC
- Legal and administrative: 4 percent of FC
- Permits and environmental documentation: 6 percent of FC

6.9.3 Definition of Estimate Class

Capital cost estimates were developed for the required improvements on the Belding, Schwind, Traynor, Rising River, and Cassady Laterals. A Class 5 cost estimate was prepared in accordance with the guidelines of the Association for the Advancement of Cost Engineering International and is comparable to an appraisal-level cost estimate as described by Reclamation:

> ***Appraisal Estimate***. *Appraisal cost estimates are used in appraisal reports to determine whether more detailed investigations of a potential project are justified. These estimates may be prepared from cost graphs, simple sketches, or rough general designs which use the available site-specific design data. These estimates are intended to be used as an aid in selecting the most economical plan by comparing alternative features such as dam types, dam sites, canal or transmission line routes, and powerplant or pumping plant capacities. Appraisal cost estimates are not suitable for requesting project authorization or construction fund appropriations from the Congress due to the early stage of project development. (Reclamation, 2007).*

A Class 5 estimate is prepared when only limited information (such as proposed facility type, location, and the capacity) is known. Purposes of this order-of-magnitude estimate include, but are not limited to, market studies, assessment of viability, evaluation of alternative schemes, project screening, location and evaluation of resource needs and budgeting, and long-range capital planning. Examples of estimating methods used include cost-capacity curves and factors, scale-up factors, and parametric and modeling techniques. The expected accuracy ranges for this class estimate are -20 to -50 percent on the low side and +30 to +100 percent on the high side.

The cost estimate, which excludes any resulting conclusions on project financial or economic feasibility or funding requirements, has been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project and resulting feasibility will depend on actual labor and material costs, schedule, continuity of personnel and engineering, and other variable factors. Therefore, the final project costs will vary from the estimate presented in this report. Because of these factors, project feasibility, benefit/cost ratios, risks, and funding needs must be carefully reviewed before making specific financial decisions or establishing project budgets to help ensure proper project evaluation and adequate funding.

6.9.4 Total Capital Cost Tables

Table 6-3 summarizes the total project costs. Appendix E contains tables that detail contract costs for the projects by major lateral.

The updated capital costs are significantly higher than previous estimates, the most recent of which were completed in 2000 and 2006. Several factors have contributed to the increase in estimated capital costs. These include revised peak flow capacity requirements, more detailed definition of the specific improvements and related construction activity, addition of new improvements to the 2000 list, revised allowances for non-construction costs such as construction management and administration, and a significant increase in the general rate of inflation for construction materials such as concrete and steel in the last several years.

TABLE 6-3
Appraisal-level Cost Estimate Summary: Composite Alternative
Gray Lodge Design Data Report

Item	Cost
Field Cost (FC)	
Belding Lateral projects	$11,260,000
Schwind Lateral projects	$3,340,000
Traynor Lateral projects	$5,860,000
Rising River Lateral projects	$880,000
Cassady Lateral projects	$1,070,000
Total Field Cost*	**$22,410,000**
Non-contract Costs	
Engineering and design (10 percent of FC)	$2,240,000
Construction services and management (10 percent of FC)	$2,240,000
Legal and administrative (4 percent of FC)	$900,000
Permits and environmental documentation (6 percent of FC)	$1,340,000
Total Non-contract Cost	**$6,720,000**
Total capital cost (2008 basis)	**$29,130,000**

* Appraisal-level opinion of construction cost in 2008 dollars. Breakdown of pay items per lateral per improvement project are provided in Appendix E.

SECTION 7

Recommended Implementation Steps

This section describes the primary implementation steps to advance the Gray Lodge Water Supply Project from the Design Data Report phase into design phases and through full implementation.

7.1 East Sacramento Valley Study Area EA/IS Supplement

An environmental assessment and initial study (EA/IS), titled *Conveyance of Refuge Water Supply Environmental Assessment and Initial Study: East Sacramento Valley Study Area, Sutter National Wildlife Refuge, and Gray Lodge Wildlife Area*, (Reclamation and CDFG, 1997) was completed for improvements to Biggs-West Gridley WD in December 1997 based on technical studies and conceptual plans completed after the passage of the CVPIA.

Based on findings in this report, a supplement to the 1997 EA/IS is likely required prior to construction. The recommended improvements are generally consistent with the alternative recommended in the 1997 EA/IS (Alternative GRA-9: Use Biggs-West Gridley WD Facilities with Improvements), but the number of facility improvements is more extensive. Four of the facility improvements identified in the 1997 EA/IS (removal of the Razorback and Garcia siphons and replacement of the Nugent Flume and Colusa Highway Bridge) were also identified in this Design Data Report. In addition, this report identified 56 new facility improvements (major structure, minor structure, and canal) not included in the 1997 EA/IS.

It appears that although numerous facilities in addition to those addressed in the 1997 EA/IS are required to implement the project, the resultant level of impact might remain less than significant. The potential for impacts will need to be verified through a full biological resources survey. Reclamation will need to coordinate with both the Service and CDFG to ensure that all federal Endangered Species Act and California Endangered Species Act –related impacts, including those to giant garter snake, are either addressed through the existing Service BO or additional consultation. It is anticipated that this consultation will be a multi-month process; therefore, it is recommended that the process be started immediately to prevent unnecessary delay while designs are completed. Work completed to date and recommended next steps are discussed in the following sections.

7.1.1 Biological Field Review

As part of the evaluation process, a field review was conducted on March 20, 2009. The following observations were made:

- Approximately 11 acres of potential giant garter snake (*Thamnophis gigas*) habitat could be impacted by the project, the majority of which would be classified as low- to moderate-quality aquatic or upland given the poor vegetative cover. One portion of the proposed impact area along the Schwind Lateral adjacent to Gray Lodge WA would be considered good quality, as previously identified in 1997 EA/IS.

- Presence of rodent holes and small cracks in the levee along the canal that potentially could be occupied by giant garter snake during the period of inactivity from October 1 through May 1.
- Potential wetland area along the Belding Lateral.

It is recommended that a more in-depth field survey by a Service-approved biologist confirm the findings of the March 20, 2009 field review. It is recommended that this biologist identify and classify areas of giant garter snake habitat in the project area, using the project footprint to calculate temporarily disturbed and permanent loss of upland and aquatic areas. The biologist would also need to conduct a wetland delineation and determine if the burrows along the canal could be potentially used by giant garter snakes during their hibernation or other species of concern. This effort would be required to support the necessary National Environmental Policy Act (NEPA)/California Environmental Quality Act (CEQA) documentation and federal and state Endangered Species Act consultation.

7.1.2 Recommended Environmental Documentation Approach

The need to evaluate the impacts of numerous additional facilities requires that the lead NEPA (Reclamation) and CEQA (CDFG) agencies determine how to procedurally evaluate potential new impacts. CEQA Guidelines Section 15162 (http://ceres.ca.gov/ceqa/guidelines/art11.html) addresses the preparation of a supplemental negative declaration, stating that a supplemental document is appropriate if "…on the basis of substantial evidence in the light of the whole record":

> "(1) Substantial changes are proposed in the project which will require major revisions of the previous EIR or negative declaration due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects";
>
> "(2) Substantial changes occur with respect to the circumstances under which the project is undertaken which will require major revisions of the previous EIR or Negative Declaration due to the involvement of new significant environmental effects or a substantial increase in the severity of previously identified significant effects"; or
>
> "(3) New information of substantial importance, which was not known and could not have been known with the exercise of reasonable diligence at the time the previous EIR was certified as complete or the Negative Declaration was adopted…
>
> "Section 15164 of the CEQA Guidelines identifies that an "addendum" may be prepared "(a)… if some changes or additions are necessary but none of the conditions described in Section 15162 calling for preparation of a subsequent EIR have occurred," and "(b) … if only minor technical changes or additions are necessary or none of the conditions described in Section 15162 calling for the preparation of a subsequent EIR or negative declaration have occurred."

Reclamation's NEPA Handbook is currently under revision, but the decision whether to prepare a supplemental environmental assessment/finding of significant impact is generally driven by the same factors as whether to prepare a new initial study/negative declaration.

On the basis of the approach used in the 1997 document with respect to the identification of mitigation to address potential impacts, it is likely that any new significant impacts could be mitigated to a less-than-significant level. Although numerous new facilities are required, construction-related impacts would likely be either generally minor, or would impact the same types of habitats identified in the original EA/IS. Therefore, a supplemental CEQA document might not be required, and an addendum could potentially be prepared to address the proposed additional facilities. CDFG would need to provide input because they are the lead CEQA agency and the EA/IS was issued more than 10 years ago.

7.1.3 Current Project Description and 1998 Biological Opinion

On December 7, 1998, the Service issued a Programmatic *Biological Opinion on Conveyance of Refuge Water Supply Project, West and East Sacramento Valley, California* (BO). The Service BO assessed the effects of the proposed project on the giant garter snake, in accordance with Section 7 of the Endangered Species Act of 1973, as amended. The consultation addressed the effects of improvements to water conveyance facilities that are necessary to deliver Level 4 water to the refuge boundaries.

Surveys of the project area were conducted during the fall of 1995 and 1996 to determine whether the project would affect any federally listed or species proposed for listing. The Service BO determined the following were not found in the area to be impacted by the structural modifications:

- Elderberry bushes
- Vernal pool habitat
- Palmate-bracted bird's beak habitat
- Sacramento splittail

The Service BO identified a 5.5-acre maximum of permanent loss of upland and aquatic giant garter snake habitat at the Gray Lodge WA, but the 2009 field review identified a potential disturbance of giant garter snake habitat twice that size. A majority of the observed approximate 11 acres would be only temporarily disturbed and would need to be restored to a level of quality that is equal to, or greater than, pre-project conditions following the guidelines listed in the *Mitigation Criteria for Restoration and/or Replacement of Giant Garter Snake Habitat*. Permanent loss would need to be compensated through habitat preservation at a 3:1 replacement ratio.

A cumulative permanent loss of up to 24.5 acres of giant garter snake upland habitat and 29.5 acres of aquatic habitat can be authorized for the 25 modifications identified under the Service BO. If permanent loss of giant garter snake upland habitat or aquatic habitat exceeds the 5.5 acres allotted to Gray Lodge WA, it would be potentially feasible to use the acreage allotment of Sutter WA (16.5 acres upland habitat/21.5 acres aquatic habitat). Service consultation would then need to be reinitiated for activities associated with Sutter WA.

7.1.4 Programmatic Consultation Guidelines

Appendix A of the Service BO identifies 25 additional major structural modifications, which have not yet been designed. The Service BO uses a programmatic approach for authorizing take for these modifications. The following criteria must be met for take of giant garter snake to be authorized under the Service BO, for each major structural modification:

1. Habitat loss at each site will not exceed the amount specified for that site in Appendix A of the Service BO.
2. The total cumulative amount of permanent giant garter snake habitat loss for all projects listed in Appendix A of the Service BO has not exceeded 24.5 acres of upland habitat or 29.5 acres of aquatic habitat (as identified above).
3. The activity has been designed to minimize impacts to giant garter snakes and their habitat to the maximum extent practicable, through consultation between design engineers and a Service-approved biologist familiar with giant garter snake habitat needs.
4. The activity will comply with the terms and conditions of the Service BO.

The Service BO authorized take for the 4 major modifications that were at 50 percent design level, and for the 83 minor modifications along the Glenn-Colusa Irrigation District Main Canal. Accordingly, the four structure improvements (removal of the Razorback and Garcia Siphons, and replacement of the Nugent Flume and Colusa Highway Bridge) still included as part of the proposed project are already addressed in the Service BO.

The Service BO can authorize take for the 25 currently undesigned major modifications only after those activities have been appended to the Service BO. Although the revised proposed project would include 56 new improvements, the total acreage to be disturbed appears to be within the bounds of what was considered in the Service BO. This would need to be verified with the Service to ensure their acceptance. The following procedure is identified to authorize take for 25 major structural modifications using a programmatic approach under the Service BO:

1. Reclamation will submit a letter requesting that the proposed activity be appended to the Service BO and provide the Service with the following:
    a. A site plan scaled 1 inch = 20 feet with an overlay showing habitat types at the site (open water, marsh, rice field, and disturbed upland), and differentiating areas to be temporarily and permanently impacted.
    b. Information on the number of acres of habitat to be temporarily and permanently impacted for each habitat type.
    c. A project description, including details related to the types of disturbance, project timing, and a discussion of how impacts are minimized to the maximum extent practicable relative to the Service's *Standard Avoidance and Minimization Measures During Construction Activities in Giant Garter Snake Habitat.*

2. The Service will review the information provided to determine whether the activity meets the criteria for being appended to the Service BO, or whether a separate BO is necessary.
3. If the Service determines that the activity is appropriate for inclusion under the Service BO, then the Service will provide a letter appending the activity to the Service BO.

7.1.5 California Environmental Quality Act California Department of Fish and Game Coordination

Section 2080 of the Fish and Game Code prohibits "take" of any species that is determined to be an endangered species or a threatened species, including the giant garter snake, which is considered "threatened" by CDFG. Because the Service has already consulted on the impacts of the project, CDFG might determine that a consistency determination is all that is needed to comply with the incidental take already approved by the Service. Consistency determinations are written under Section 2080.1 of the Fish and Game Code. Reclamation will need to coordinate with CDFG regarding the necessary consultation process.

7.2 Permitting

The permits listed in Table 7-1 are anticipated to be required for the implementation of facility improvements. Permitting is anticipated to require a minimum of 6 to 12 months.

TABLE 7-1
Permits Required for the Conveyance of Level 4 Refuge Water Supply
Gray Lodge Design Data Report

Agency	Requirement	Applicability	Compliance Procedure
U.S. Army Corps of Engineers	Nationwide or Individual Permit	Work requiring discharge of fill to surface waters	Submit Preconstruction Notification or (if necessary) Section 404 Permit Application. Wetland delineation should be performed to determine if impacts are greater than 0.5 acres of jurisdictional wetlands. An individual permit application could take from 18 to 24 months to complete if required.
U.S. Fish and Wildlife Service	Endangered Species Act	All project activities	Confirm applicability of existing Programmatic Biological Opinion. If not applicable, Section 7 consultation would be required prior to U.S. Army Corps of Engineers' Section 404 permit approval.
California Department of Fish and Game	Streambed Alteration Agreement (Level 1 Stability Analysis [LSAA] or 1600 permit)	Alteration to a stream channel	Submit LSAA application.

TABLE 7-1
Permits Required for the Conveyance of Level 4 Refuge Water Supply
Gray Lodge Design Data Report

Agency	Requirement	Applicability	Compliance Procedure
California Department of Fish and Game	California Endangered Species Act (CESA) compliance	CESA (2081) compliance may be required if endangered species are present or potentially effected	CESA compliance is initiated by CDFG and usually takes 30 to 60 days if required.
State Water Resources Control Board	General Construction Activity Stormwater Permit	Projects with disturbance to greater than 1 acre	Submit Notice of Intent. Require contractor to implement Stormwater Pollution Prevention Plan.
Central Valley Regional Water Quality Control Board	Water Quality Certification	Work requiring discharge of fill to surface waters	Submit Section 401 Water Quality Certification application, including best management practices.
State Historic Preservation Officer (SHPO)	National Historic Preservation Act consultation	Alteration of structures that could be eligible for the National Register of Historic Places	Review of archeological and historical resources information by SHPO. Section 106 consultation with SHPO also will be required for Section 404 permit will be issued.
Butte County Air Quality Management District (AQMD)	Air quality permit	Contractor equipment and fugitive dust	Submit application to AQMD.
Various	Encroachment permits	Construction within rights-of-way or property	Coordinate with Union Pacific Railroad, Butte County Public Works, and potentially other agencies, and seek permits as needed.

7.3 Continued Data Collection

The data collection efforts of the Measurement and Seepage Study are planned through at least January 2011. Data collected over the past several years provide a consistent baseline of canal and groundwater levels and canal flow rates and subsequent data will be added to the project record. Data collected in 2008 were consistent with data collected in previous years, so updates to the hydraulic model and design flow profiles were not necessary. Continuation of the data collection efforts may be beneficial during final design and for monitoring of facility improvement performance after project implementation.

Equipment installations were intended to be temporary to assist with the Design Data Report. Because the canal water level sensors are housed in PVC tubing with non-permanent anchors into the canal banks, they are particularly susceptible to damage from canal operations, maintenance, and vandalism. The sensor housings were replaced before the 2008 irrigation season, but still require regular maintenance. The monitoring well installations are sound for long-term operation. Acoustic Doppler flow meters installed in concrete flumes or canal bottoms should be considered long-term installations, but anchoring and sediment issues should be checked annually during reinstallations. Flow meters installed in geotextile-lined sections of the earthen canals may require refurbishing if pondweed growth and sediment deposit is evident. Construction of a concrete-lined section of canal or flume may be required at various locations if permanent flow measurement stations are desired. All measurement equipment should be regularly maintained and data regularly downloaded.

7.4 Final Design

The final design phase will include the following items:

- Obtaining all temporary and permanent easements/rights-of-way
- Geotechnical investigation to support structure design (gathering available geotechnical data from projects in the immediate area, developing new data from exploration at some locations)
- Development of a seepage monitoring and mitigation plan, including development of an operations model to better understand the effects of proposed system improvements and operational changes on seepage
- Drawings developed to the 30 percent, 60 percent, 90 percent, and 100 percent levels
- Specifications
- Engineer's cost estimate
- Bid documents
- A refined construction sequencing plan

7.5 Construction

The construction phase is initiated with bidding services. This includes advertising for bids, issuing contract addendums, conducting a pre-bid meeting, evaluating bids, and awarding the contract.

A detailed construction sequencing plan likely will not be developed until an overall procurement and funding plan is in place (for example, single contract, phased construction contracts, multiple contracts, multiple contractors). Such a procurement plan could be developed in parallel with the design phase of this project. A final construction sequencing plan would be developed in coordination with Biggs-West Gridley WD, affected landowners, and Gray Lodge WA managers. A preliminary construction sequencing plan has been developed to estimate the costs of temporary bypasses and for consideration in future phases of the project.

As described previously, recent historical data indicate that the Biggs-West Gridley WD system typically delivers water from early to mid-April through mid- to late January to meet agricultural and refuge demands. Ideally, all construction would occur during the non-irrigation season; however, the window for construction would be only 3 months long and during the wettest portion of year, which would significantly extend the overall duration of the construction program. Thus, a construction sequence that significantly extends the construction (non-irrigation) season is recommended.

7.5.1 Preliminary Construction Plan

Structures upstream of the Division 2 Headgates on the Belding Lateral would be bypassed to allow for uninterrupted operation during construction, which could occur during any time of the year. The exception to this will be the two additional 8-foot-diameter pipes bored and jacked under the UPRR. Because of the limited ability to bypass the railroad, it is assumed that there will be no irrigation flows in the upper Belding Lateral during the structure modifications under the UPRR.

The bypass channels will be constructed to handle maximum expected irrigation flows as identified during system modeling. There will be no flow control devices within the temporary bypass channels. As such, a minimal number of structures will be bypassed at any one time to maintain some controllability on reaches of Belding Lateral without a construction bypass. The cost of the proposed bypasses is included in the overall cost estimate provided in Section 6. The structures requiring bypasses include:

- Razorback Siphon
- Garcia Check
- Garcia Siphon
- Banion Check
- Afton Bridge
- Fields Flume
- North Weir

Construction required for channel improvements (such as reshaping or earthwork to meet freeboard requirements) on the Belding Lateral would occur in the normal off-season and would not require bypasses. For planning purposes, it is assumed that construction would take place over 3 consecutive years. No bypasses are planned for construction on the laterals downstream of the Traynor-Belding split. These laterals will be shut down, one at a time per year, during an extended non-irrigation season to allow for construction in the dry.

The concept for an extended non-irrigation season would include shutting off deliveries on one lateral below the Division 2 Headgates on October 1 (or similar date that is acceptable to the District based on further planning and discussions with affected customers) while delivering water to the other laterals according to a typical pattern. For the lateral that is shut down, the construction season extends from approximately 3 months to approximately 6.5 months. Affected agricultural customers and Gray Lodge WA would need to make adjustments to their typical fall and winter water delivery schedules for one season.

In the case of Gray Lodge WA, operations would be different for 3 years, with one of its three delivery points shut down in each year. Deliveries to the Gray Lodge WA would be coordinated to provide sufficient flow through the two open delivery points. For land served by the delivery point that is shut down, Gray Lodge WA could flood up earlier than normal or use onsite groundwater wells to partially make up the difference.

This conceptual construction sequencing plan would have impacts on agricultural and refuge customers of Biggs-West Gridley WD; however, the plan is designed to minimize those impacts and assure that Gray Lodge WA would be able to receive water from two of its three delivery points as per typical operations during the fall season.

Any construction sequencing plan would require significant public involvement and advanced notice and planning for all affected customers. A more detailed construction sequencing plan will be developed during the design phase as permitting requirements are determined which may also impact the potential construction season.

7.6 Preliminary Implementation Schedule

Implementation of preliminary design, final design, permitting, land acquisition, and construction phases would occur over the next 2 to 5 years, depending upon funding. The timeline in Figure 7-1 depicts the approximate schedule of remaining implementation phases. This schedule would be updated in the final design phase of the project.

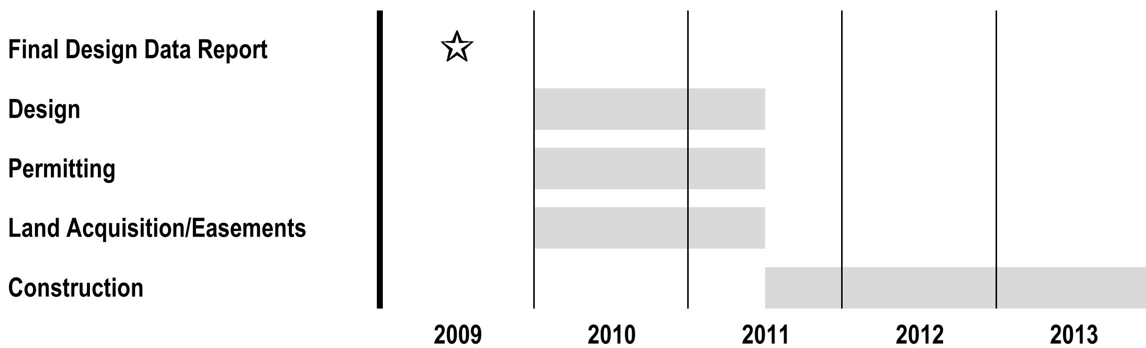


FIGURE 7-1
Proposed Implementation Schedule

SECTION 8

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Appendix A
Measurement and Seepage Study Summary Technical Memorandum

Gray Lodge Wildlife Area/Biggs–West Gridley Water District Canal Water Level, Flow Measurement, and Seepage Study Summary

PREPARED FOR: Bureau of Reclamation

PREPARED BY: CH2M HILL

DATE DEVELOPED: January 11, 2005

DATE UPDATED: May 2009

1. Background

In support of the Central Valley Project Improvement Act (CVPIA) Refuge Water Supply Program, the Bureau of Reclamation (Reclamation) and Biggs–West Gridley Water District (WD) entered into a joint agreement in 2003 for funding and implementation of improvements to Biggs–West Gridley WD facilities for the reliable conveyance of full Level 4 refuge water supply to Gray Lodge Wildlife Area (WA) (or refuge). The study area map (Design Data Report, Appendix F, Figure F-1) shows the location of Biggs–West Gridley WD and Gray Lodge WA and pertinent facilities.

The agreement requires several studies and levels of design to identify and implement system improvements. Currently, the project consists of two parts:

1. Design Data Study for Conveyance of Refuge Water Supply to Gray Lodge WA (Design Data Study) (documented by the Design Data Report)
2. The Canal Water Level, Flow Measurement, and Seepage Study (Measurement and Seepage Study)

The Design Data Study will update recommended facility improvements, establish design flows, and update capital cost estimates to support the final design and construction.

The Measurement and Seepage Study was undertaken to support the Design Data Study. Because minimal data were available when the Design Data Study was initiated, the Measurement and Seepage Study was established to collect the necessary data to evaluate future changes in canal flows and water levels resulting from anticipated Gray Lodge WA deliveries, to support the development of the hydraulic model, and to establish system design flows. The study was also conducted to identify and provide general information on alternative canal seepage mitigation measures and costs for consideration during final design.

The technical memorandum is structured as follows:

- **Section 2** provides a summary of the Measurement and Seepage Study.
- **Section 3** describes the technical approach of the data collection process at Biggs–West Gridley WD.
- **Section 4** presents water level and seepage data collected in the field between April 2004 and October 2008, and flow data collected between August 2004 and October 2008. This section analyzes the water level and monitoring well data, gives an estimate of expected seepage from a localized geotechnical analysis, and presents the relationship among canal flows, water levels, and operating conditions.
- **Section 5** presents potential seepage mitigation measures, should implementation of the Gray Lodge WA refuge facilities construction program cause seepage beyond existing levels.
- **Section 6** describes the relationship between this study and the Design Data Study.
- **Section 7** lists references used in the memorandum.

Finally, relevant supporting information and all data collected for this study are presented in Attachments A-1 through A-5:

- **Attachment A-1:** Canal Flow Data
- **Attachment A-2:** Canal Water Level Data
- **Attachment A-3:** Canal Stage Data (from Flow Meters)
- **Attachment A-4:** Shallow Groundwater Level Data
- **Attachment A-5:** Boring Logs from Well Installation

2. Study Summary

A summary of the Measurement and Seepage Study is presented here:

- Canal water level, canal flow, and shallow groundwater level data were collected within Biggs–West Gridley WD during the 2004 through 2008 irrigation seasons for two purposes. The first purpose was to provide a baseline for comparison purposes to address seepage, water level, and flow capacity concerns specific to Gray Lodge WA deliveries. The second purpose was to provide a basis for calibrating the hydraulic models and to develop facility improvement design flows for the Design Data Study.
- The general flow pattern in the Biggs–West Gridley WD system is characterized by a ramp-up in flows for the start of the irrigation season on April 1(with flood-up occurring typically any time between April 1 and early May) and a general decrease in flow rates from mid-August to late October. Flows increase again in November before a final decrease in late January to close out the irrigation season. The allotted season begins on April 1 and ends on October 31. In one season, the District delivers 75 to 80 percent of all water delivered that year before November 1. After November 1 through late January, water delivered is not part of the District's annual allotment. In the future with delivery of full Level 4 water supplies to Gray Lodge WA, it is anticipated that the existing flow pattern to Gray Lodge WA will continue, but flows requested by Gray Lodge WA will be higher throughout the year.

- High canal water levels typically occur throughout Biggs-West Gridley WD canal system during the majority of the irrigation season. High canal water levels are an operating objective to enable deliveries to high-elevation turnouts and, in some canal reaches, an unavoidable consequence of inadequate hydraulic capacity.
- Various canal lining and out-of-canal measures are available to control potential seepage in land adjacent to canals. Additionally, in canal reaches where the cross-section will not be disturbed, maintaining water levels at near-present conditions is a means of seepage control provided that the timing and duration of operation at those levels do not change relative to historical conditions. However, in reaches where canal cross-sections will be disturbed, the existing sealing layer may be disrupted or a sand lens may be intercepted, which could result in increased seepage. A seepage monitoring and mitigation plan will be initiated by Reclamation during the design phase of the project in consultation with and subject to acceptance by the District. This future study will tie into an operations model to understand changes in magnitude, timing, and duration of canal water levels that will occur after the project is implemented. The future seepage and operations study will be included in the design contract with Reclamation.

3. Technical Approach

In 1999, Biggs–West Gridley WD expressed concern that increased flows to Gray Lodge WA would increase seepage in lands adjacent to canals and raise canal flows and water levels beyond system capacity. Lands adjacent to the Traynor Lateral southward from Justeson Road to West Liberty Road were identified as areas with the potential to be adversely affected by an increase in seepage. Biggs–West Gridley WD also expressed concern over the potential for increased seepage along the Rising River, which would impede farm operations in rice fields adjacent to canals at certain times of the growing season. Although rice is flooded during much of its growing season, rice fields must be dry before mechanical equipment may be brought in for harvesting. Therefore, increased seepage at certain times of the year along the Rising River may be unacceptable, particularly during peak refuge deliveries in the fall.

At project conception, minimal data on canal flow, canal water level, and groundwater level for the Biggs–West Gridley WD conveyance system were available to provide an accurate baseline of existing conditions.[1] A baseline of data was also needed as a means to compare the effects of future increased deliveries on canal water levels and shallow groundwater levels. To address the district's concerns, Reclamation launched two field data collection efforts: (1) flow and water level monitoring in portions of the canal system used for conveying water to the Gray Lodge WA, and (2) shallow groundwater level monitoring in localized areas of the Traynor Lateral potentially impacted by canal seepage.

Sites for all meters were selected in cooperation with Biggs–West Gridley WD, Reclamation technical staff, and the consultant team. Biggs–West Gridley WD and district landowners played a critical role in selecting shallow monitoring well locations in areas of seepage concern. Industry-standard measurement equipment was selected with input from the

[1] The Joint Water District Board collected flow data daily using a staff gauge and rating table at the head of the Belding Lateral, just downstream of the Highway 99 bridge. No data was collected and logged within the Biggs-West Gridley WD service area to describe localized conditions.

Irrigation Training and Research Center at California Polytechnic State University, San Luis Obispo, and Reclamation's water measurement experts. Initially, pressure transducers manufactured by In-Situ were selected to measure canal water levels and groundwater levels. The In-Situ pressure transducers were replaced before the 2008 irrigation season with transducers manufactured by MJK Automation because several of the original sensors did not report reliable data near the end of their life. Acoustic Doppler flow meters produced by SonTek were selected to measure canal flows.

The consultant team and Reclamation staff installed all water level sensors and shallow monitoring wells in 2004. The new pressure transducers were installed in 2007, prior to the 2008 irrigation season, as previously described. Hydroscientific West technical staff installed flow meters in August 2004 with oversight provided by the consultant team. An additional meter on the Cassady Lateral was installed in April 2008 with oversight provided by Reclamation technical staff. Instrument locations and elevations were surveyed by the consultant team.

Each instrument collects data every 15 minutes and stores it in a data-logger at the device until downloaded by the user. Data is downloaded approximately once per month. Following downloading, all data is compiled in a database and evaluated to determine meter functionality. Data are made available monthly to stakeholders upon request. Concerns about data are addressed during monthly meetings held with the stakeholder group.

Data collected between 2004 and 2007 was used to evaluate existing operating conditions along each lateral and to establish baseline flow and water level trends. Data collected between 2004 and 2007 were used to evaluate existing operating conditions along each lateral and to establish baseline flow and water level trends. Data collection continued during the 2008 irrigation season and will remain part of the project record.[2] The shallow groundwater data were combined with the canal water level data to evaluate the linkage between the canal water levels and seepage in adjacent fields. Data were also collected to support the Design Data Study to calibrate the hydraulic models of the canal system, and to evaluate proposed system improvements. Details on the water measurement activities are provided in the Sections 3.1 through 3.7.

It is important to note that the intent and scope of the Measurement and Seepage Study was to investigate the canal flow and water levels and shallow groundwater levels as appropriate to an appraisal-level design study. More intensive seepage monitoring and geotechnical work is necessary during subsequent design phases of the project.

3.1 Site Selection and Installation of Monitoring Equipment

Canal flow, water level, and groundwater level monitoring sites at Biggs–West Gridley WD are shown on the study area map, Figure F-1. All site locations were surveyed in April 2004 prior to the start of the irrigation season.

3.1.1 Water Level Sensors

Eleven water level measurement sites were selected to establish a baseline of water levels for all reaches impacted by Gray Lodge WA deliveries. Sites on the Traynor Lateral were also

[2] Data collected subsequently in 2009 and possibly beyond will also be added to the project record.

selected adjacent to a pair of shallow monitoring wells to verify a relationship between canal water levels and shallow groundwater levels.

3.1.2 Shallow Monitoring Wells

Fourteen shallow monitoring well sites were selected along the Traynor Lateral in areas where Biggs-West Gridley WD expressed concern about seepage impacts to adjacent farm fields. Prior to installation, landowners at each site were consulted to determine specific impacts to their fields and to select well locations that would not interfere with farm operations. Wells were drilled in pairs and aligned perpendicular to the canal. Monitoring well locations along the Traynor Lateral are shown on Figure F-1. Table A-1 lists each monitoring well and corresponding landowners of each field.

TABLE A-1
Shallow Monitoring Well Name and Corresponding Landowners and Land Use

Monitoring Well Name	Landowner	Land Use
PZ-LI-1 PZ-LI-2	Gary Little	Orchard
PZ-LI-3 PZ-LI-4	Brent Little	Orchard
PZ-ON-1 PZ-ON-2 PZ-ON-3 PZ-ON-4	Bob Onyett	Pasture
PZ-TA-1 PZ-TA-2	Bo Taylor	Orchard
PZ-LO-1 PZ-LO-2	Ken and Katrina Long	Pasture
PZ-OR-1 PZ-OR-2	Mark Orme	Fallow for first 2 years of study, then orchard

Shallow Monitoring Well Installation. The week of April 5, 2004, 14 borings were advanced to a depth of 15 feet below ground surface by Taber Drilling using a CME-45 truck-mounted drill rig with an 8-inch-diameter hollow-stem continuous-flight auger. Disturbed samples were collected at 5-foot intervals using a standard (2-inch outside-diameter) split-spoon sampler in general accordance with requirements of the Standard Penetration Test (SPT) as described in ASTM D1586. The sampler was advanced using a 140-pound hammer with 30-inch drop, driven by a rope-and-cathead system. Boring logs are included as Attachment A-5. The boring locations are identified as monitoring well sites on the study area map.

During the drilling program, soil samples were classified by a geotechnical specialist from the consultant team in general accordance with the Unified Soil Classification System (USCS) visual-manual procedure for soil classification (ASTM D2488). Soil classifications and descriptions were recorded in boring logs.

A 2-inch outside-diameter slotted PVC pipe was installed in each boring from the bottom to within 2 feet of the ground surface and backfilled with well sand. The upper 2 feet of the boring was grouted to reduce surface infiltration. A 6-inch steel surface casing with locking cap was installed to protect the well from accidental damage. The wells were installed in pairs, with each pair aligned with a canal water level sensor. The first well of each pair was installed approximately 50 feet from the top inside edge of the canal bank, at least 15 feet from the seepage ditch adjacent to the canal, if present. The second well of each pair was placed 30 feet from the first well on a line perpendicular to the canal. A typical installation is shown in Figure A-1.

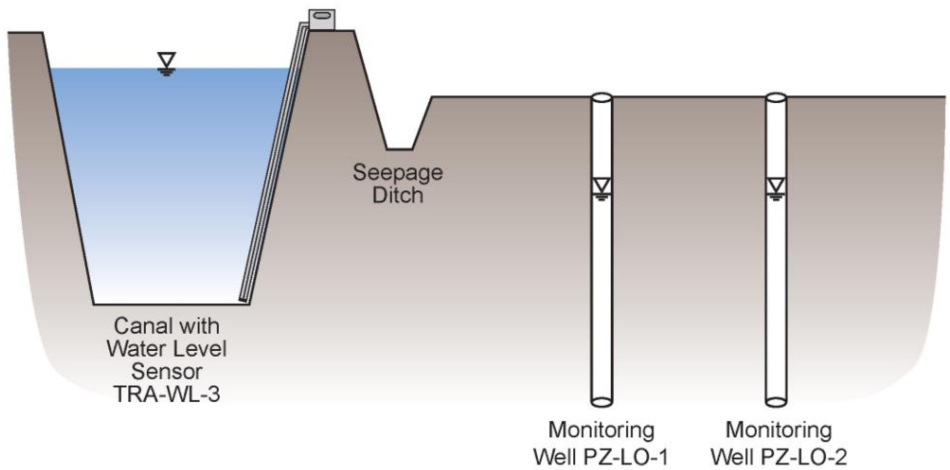


FIGURE A-1
Typical Monitoring Well Installation

3.1.3 SonTek Flow and Water Level Meters

Eleven flow measurement sites were selected to monitor flows for all reaches impacted by Gray Lodge WA deliveries. Sites were also selected based on canal topography and proximity to control features such as gates and weirs.

SonTek's Argonaut SL and Argonaut SW were selected for canal flow and water level measurement.[3] Acoustic Doppler current meters were selected because they perform well in small channels with stratified flow conditions and varying water levels. These meters measure water level and vertically integrated velocity at a time interval selected by the user. Data is stored in the instrument. Flow is computed using cross section information for the particular site, which is entered using the instrument software. Meters are powered by solar panels installed at each site. The general process used to install SonTek Argonauts is depicted in Figures A-2 through A-4.

Geotextile liners were installed at five locations in Biggs–West Gridley WD canals the week of April 5, 2004. Their function was to reduce interference by pondweed growth and to provide a stable cross section for flow measurement in areas where no permanent structure

[3] Because the flow meters chosen for the study also detected water levels, this data also contributed to the baseline water level data collected by water level meters.

existed for mounting the meter. Installation was accomplished through contracting and coordination with Reclamation.

Solar panels, power controls, and conduit were installed by a SonTek vendor, Hydroscientific West, the week of June 14, 2004. SonTek installations were not completed prior to the 2004 irrigation season because of equipment and contracting delays.

Divers installed the SonTek Argonauts on canal bottoms at the selected locations on August 11, 2004. Hydroscientific West provided oversight during installation, verified proper equipment function, and provided equipment training during the following week. Data were downloaded approximately once per week for the first month of operation and once per month thereafter.

In September 2004 it was discovered that the SonTek Argonaut on the Rising River (RIS-FLOW-1) had not been functioning properly since its installation. This meter was removed and repaired during the Biggs–West Gridley WD system shutdown in February 2005 and replaced prior to the start of the 2005 irrigation season in April. Data recorded by the meter thereafter was intermittent because significant silt buildup during the irrigation season interfered with the Doppler technology. In 2007, an additional flow meter was installed at the head of the Cassady Lateral.

FIGURE A-2
Canal Lining

FIGURE A-3
Installed SonTek Control Panels

FIGURE A-4
Diver Installing Flow Meter

3.2 Flow Meter Verification

After the installation of the SonTek Argonauts, Hydroscientific West verified the meter functionality at some flume locations by conducting spot-checks with an independent flow measurement device, the FlowTracker Handheld ADV (Acoustic Doppler Velocimeter). The Argonauts along the Green Lateral (GRE-FLOW-1) and the Schwind Lateral (SCH-FLOW-1), for example, showed excellent consistency with the handheld meters, differing only by 1 to 3 percent.

At all other sites (geotextile-lined sites and some flumes), the SonTek RiverCat was used to verify the Argonaut flow and velocity measurements. The process of verifying the Argonaut flow and velocity measurements with the RiverCat in the field is shown in Figure A-5. The RiverCat uses acoustic Doppler technology to measure several discrete velocity profiles and water levels. The entire cross section is captured as the user moves the instrument across the width of the canal, stopping approximately every foot for measurements. This time-intensive method produces a direct velocity and flow determination. This is more accurate than the SonTek Argonaut, which measures a mean water velocity and relies on a user-provided cross section and a theoretical equation to indirectly determine flow.

FIGURE A-5
RiverCat Verifying Argonaut Measurements

Data used for meter verification and calibration at geotextile-lined sites were obtained over several field sessions with the RiverCat. To verify an Argonaut, the RiverCat data were compared to a 5-hour average of the Argonaut data before and after the RiverCat measurement event. An Argonaut was deemed reliable if the RiverCat and the Argonaut measurements consistently differed by less than 5 percent. At sites where the results of the RiverCat and the Argonaut differed consistently by more than 5 percent, the Argonauts were calibrated. Most geotextile-lined sites required calibration. Table A-2 summarizes the flow meter verification and calibration results for each flow meter.

TABLE A-2
Flow Meter Verification and Calibration

Flow Meter	Installation	Verification Method	Verification Confidence Before Calibration[a]	Calibration Required	Confidence After Calibration
ASH-FLOW-1	Flume	FlowTracker	70%	Yes	> 95%
BEL-FLOW-1	Flume	FlowTracker	> 98%	Yes[b]	95%
GRE-FLOW-1	Flume	FlowTracker	> 98%	No	NA
SCH-FLOW-1	Flume	FlowTracker	97%	No	NA
BEL-FLOW-2	Geotextile-lined	RiverCat	86%	Yes	95%
BEL-FLOW-3	Geotextile-lined	RiverCat	87%	Yes	94%
TRA-FLOW-1	Geotextile-lined	RiverCat	> 98%	No	NA
TRA-FLOW-2	Geotextile-lined	RiverCat	79%	Yes	> 95%
TRA-FLOW-3	Flume	RiverCat and FlowTracker	97%	No	NA
GER-FLOW-1	Geotextile-lined	RiverCat	55%	Yes	90%
RIS-FLOW-1	Geotextile-lined	RiverCat	39%	Yes	90%

Notes:

[a] Percent Confidence = 100% – (Average percent difference between Argonaut and meter used for verification)
[b] Calibration for BEL-FLOW-1 (Fields Flume) was not required until after the meter was removed and replaced in April 2005.

3.3 Flow Meter Calibration

Calibration was necessary at some sites to fine-tune the flow measurement accuracy of the Argonaut. The Argonaut measures the vertically averaged water velocity in line with the meter in the direction of flow. The vertically averaged water velocity varies horizontally over the cross section of canal, the edges of which are outside the meter's line of sight. Thus the velocity measured by the Argonaut may not exactly equal the mean velocity over the entire cross section. Therefore, the relationship between measured and mean velocity must be established. This relationship can be determined theoretically or empirically. By default, an Argonaut uses a theoretical velocity calculation to report flow. These flows reported by the Argonaut were verified as described in Section 3.2 to determine if it was necessary to empirically calibrate the meter to improve data accuracy.

Data were collected for meter calibration by using the RiverCat during 14 field visits that spanned most months of the irrigation season, thus capturing a variety of flow conditions. Together, Reclamation field staff and the consultant team collected calibration data with the RiverCat and adjusted the instruments as needed. A range of velocity, flow, and water level values obtained from several RiverCat runs were compared to the values recorded by the Argonauts. These data were used to develop an empirical relationship between channel velocity and flow at a particular site. Generally, the more data used to develop the relationship, the more accurate the calibration. Complicated relationships generally required more RiverCat runs to establish an acceptable level of accuracy. This information was entered into the Argonaut user interface to calibrate the Argonauts as necessary. Once an empirical relationship had been established, all data could be back-calculated using the relationship to obtain a more accurate data set.

By the end of the second year of monitoring, all meters were calibrated to 90 percent accuracy or greater, as detailed in Table A-2. Meter verification and calibration continued by Reclamation technical staff after 2005, and meter confidence continued to improve.

3.4 Data Collection Periods

Data were collected for the time periods in Table A-3.

A Microsoft Excel database was created to maintain data from all locations during the collection periods. Analysis was also performed using Excel.

3.5 Other Data Collection

3.5.1 Joint Water District Board Flow Meter

The Joint Water District Board (Joint Board) monitors flows into the Biggs–West Gridley WD system daily at a station downstream of the head gates of the Belding Lateral located west of the Highway 99 bridge. Flows are determined by water level logger and rating table, a relationship based on several years of collected data. A summary of these flows from 1999 to May 2005 is presented in Section 4.1. These data are considered the best available for the head of the Biggs–West Gridley WD system, and the rating table was not recalibrated as part of the Measurement and Seepage Study.

TABLE A-3
Data Collection Periods by Type

Data Collection Type	Data Collection Period(s)	Notes
Canal Flow Except Rising River	Aug 2004 to Jan 2005 Apr 2005 to Jan 2006 May 2006 to Jan 2007 Apr 2007 to Jan 2008 Apr 2008 to present	
Canal Flow for Rising River	Apr 2005 to Oct 2005 May 2006 to Feb 2007 Apr 2007 to Feb 2008 Apr 2008 to present	This meter did not function in 2004; it was repaired by the start of the 2005 irrigation season. Intermittent data were recorded during subsequent seasons because of silt buildup on the Doppler sensors.
Canal Water Level	Apr 2004 to Mar 2005 Apr 2005 to Mar 2006 Apr 2006 to Mar 2007 Apr 2007 to Mar 2008 Apr 2008 to present	Monitoring continued year-round at all sites. Data were not reported when sensor was malfunctioning. Several sensors reported malfunctions in 2007. All sensors were replaced in Apr 2008.
Groundwater Level	Apr 2004 to Mar 2005 Apr 2005 to Jan 2006 Apr 2006 to Jan 2007 Apr 2007 to Jan 2008 Apr 2008 to present	Monitoring continued year-round at all sites. Data were not reported when sensor was malfunctioning. Several sensors reported malfunctions in 2007. All sensors were replaced in Apr 2008.

3.5.2 Gray Lodge WA Flow Meters

Reclamation maintains flow meters at all three delivery points to Gray Lodge WA to provide accurate data for billing purposes. Doppler meters produced by Mace are maintained at the Cassady and Schwind delivery points. Similarly, a Mace meter was maintained at the delivery point on the Rising River until the 2005 irrigation season, when Reclamation installed a SonTek meter. All meters installed at Gray Lodge WA delivery points recorded data on 30-minute intervals prior to 2008. Starting in April 2008, meters were set to record data on 15-minute intervals. Meter accuracy is evaluated regularly by Reclamation staff. Reclamation replaced all three flow meters in April 2008 with new SonTek flow meters, which are set to record data in 15-minute time increments.

3.5.3 Biggs–West Gridley WD Meters

Biggs–West Gridley WD has two meters installed in its system. A Starflow meter is installed at the Nugent Flume, but has not been calibrated. A second meter, a SonTek Argonaut, was installed at the head of the Cassady Lateral prior to the start of the 2005 irrigation season. This meter was replaced before the 2008 irrigation season with another SonTek Argonaut. Data from the Biggs–West Gridley WD meters were not included in this evaluation.

3.6 Field Observations on Existing Conditions and Operating Practices

The study participants recognized that an investigation of seepage issues and data collection efforts must be undertaken in the context of district operations. District operations were therefore examined at an appraisal level to determine how additional deliveries to the refuge could impact water levels given current operating practices and requirements.

The technical team observed typical operating conditions of the canal system throughout the irrigation season and worked with district management and operations staff to increase understanding of major flow divisions, refuge deliveries, operating pools, and customer turnout requirements. During field visits, photos and field notes were taken to document typical canal levels at different times. Reaches requiring high constant head to serve customer turnouts were documented. Figures A-6 and A-7 show the high water levels typically maintained in the Traynor and Belding Laterals.

FIGURE A-6
Nugent Flume on Traynor Lateral at Near-Peak Flow Condition Showing High Water Levels

Delivery data and demand patterns for agricultural customers and Gray Lodge WA were also examined. Typical ranges of canal water levels adjacent to fields where seepage is a concern were noted by using the water level data collected for this study. All operational information documented was incorporated into hydraulic modeling as part of the Design Data Study.

Refer to Section 4.3 for further discussion about the influence of district operations on canal levels and seepage.

FIGURE A-7
Banion Check Structure on Belding Lateral Showing High Water Levels

3.7 Project Coordination and Involvement

All major stakeholders, including the consultant team, Biggs–West Gridley WD management, Reclamation, and the California Department of Fish and Game, were engaged throughout the Measurement and Seepage Study. Monthly coordination conference calls were held among all parties to provide a forum for addressing the study approach, monitoring activities, equipment functionality, and data trends. Additional interaction occurred between meetings as necessary. Reclamation staff regularly assisted the consultant team with field activities such as meter calibration and data collection efforts.

The technical team frequently consulted the Biggs–West Gridley WD general manager, office manager, and operations staff throughout the project to understand district operations and to address concerns. The consultant team and Reclamation staff also attended several Biggs–West Gridley WD board meetings to discuss the study's progress with the manager and board members.

District landowners were interviewed prior to monitoring well installation to ensure their understanding and consensus on the study goals. Landowners were also informed about study activities through their involvement as district board members and by the district's quarterly newsletter.

4. Technical Evaluation and Analysis

4.1 Data Baseline

The baseline of data collected from 2004 to 2007 as part of the Measurement and Seepage Study was critical to understanding flows and water levels throughout the system, and to understanding the response of shallow groundwater levels along the Traynor Lateral during peak and typical operating conditions. This section presents a summary of peak values and general trends in the collected data. Data collection continued through 2008 and will remain part of the project record.

4.1.1 Canal Flows

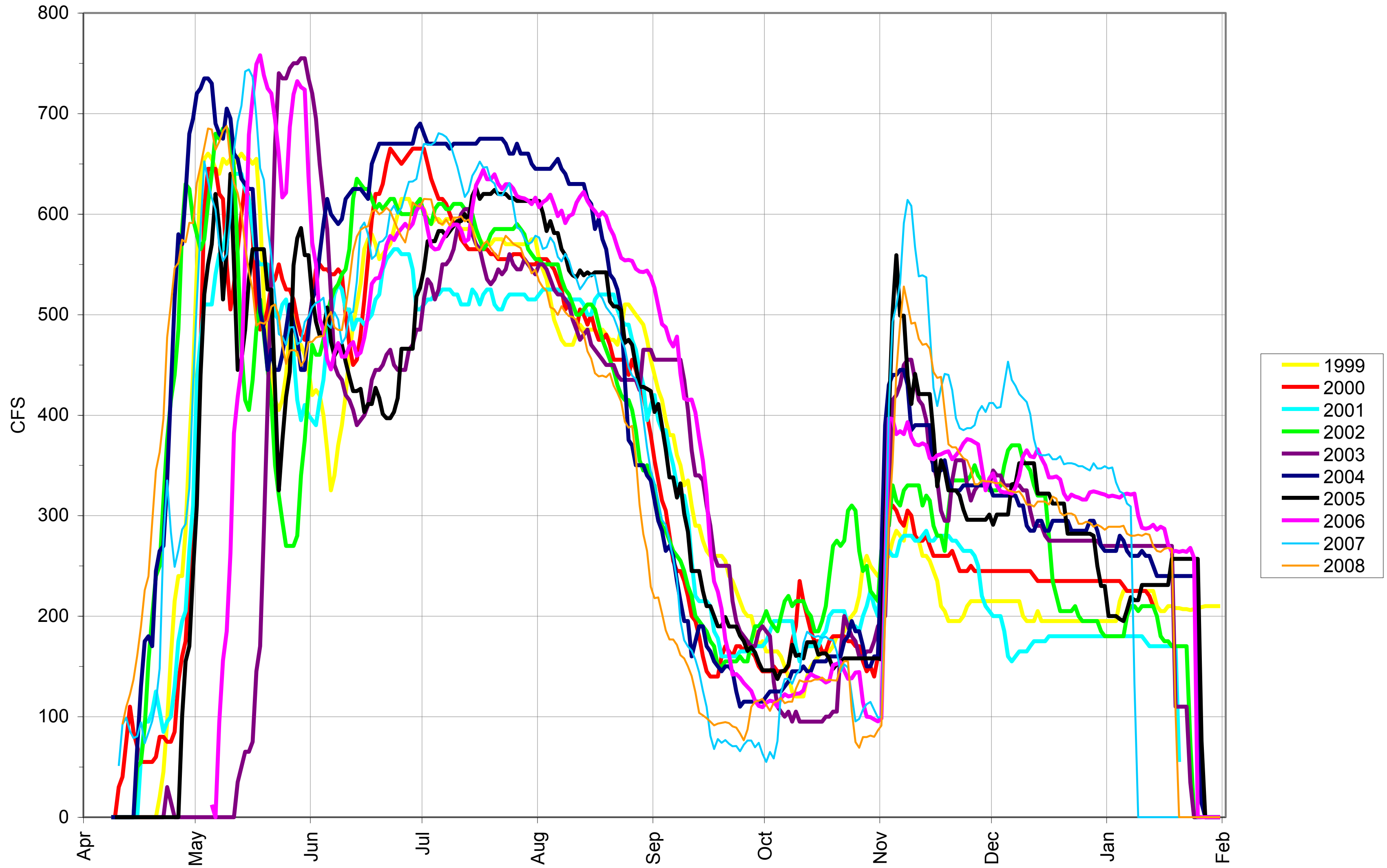
Flow data at key locations are valuable for identifying potential relationships with shallow groundwater, understanding canal hydraulics, and understanding the magnitude, timing, duration, and distribution of actual water deliveries throughout the service area. With the exception of the Joint Board gauging station at the head of the Belding Lateral, flow measurement was very limited or nonexistent throughout the Biggs–West Gridley canal system prior to 2004.

Examination of the Joint Board gauge data is significant because it represents all deliveries of surface water to Gray Lodge WA and Biggs–West Gridley WD, thus representing recent systemwide delivery patterns and peak flows. Maximum annual flows at the head of the Belding Lateral vary between approximately 600 and 800 cubic feet per second (cfs). The maximum flow seen at the head of the Belding Lateral between 1999 and 2008 is 758 cfs, recorded May 17, 2006.

In 2006, Biggs-West Gridley WD installed an additional flow meter on the Belding Lateral approximately 1 mile downstream of the Joint Board gauging station, labeled as BELDING-BWG-FLOW on Figure F-1. This meter recorded a peak flow of 768 cfs on May 16, 2006.

According to Biggs–West Gridley WD, maximum capacity of flow through the Belding head gates is approximately 900 cfs. It is important to note that the flow measured 1999 through 2008 as shown in Figure A-8 included some CVPIA water being provided to Gray Lodge WA by Reclamation under the combined agreement described in Section 1.

The distribution of flows in the Biggs–West Gridley WD system from 2004 through 2008 were recorded at the eleven SonTek Argonaut acoustic Doppler monitoring stations on the Belding, Ashley, Traynor, Green, Schwind, and Gerst Laterals. These flows are shown in Attachment A-1, Canal Flow Data. Data collected shows the ramp-up in flows for the start of the irrigation season in April and a general decrease in flow rates from mid-August to late October. The recent flow data shows an increase in flows in November for rice decomposition and duck club flood-up, and a final decrease in late January to close out the delivery season. This recent seasonal flow pattern is expected to continue into the future, and facility improvements developed in the Design Data Study are based upon these observed flow data.



Source: Joint Board Gauging Station.

FIGURE A-8
Flow Summary, Head of the Belding Lateral, Joint Board Gauging Station

The maximum flow recorded in 2004 through 2005 at each of the flow monitoring stations is listed in Table A-4. These values are useful to judge typical flow peaks and patterns in each lateral for the Design Data Study.

TABLE A-4
Maximum Flow Recorded at Each Flow Monitoring Site from 2004 through 2005

Flow Meter	Location	Maximum Flow (cfs)	Notes
ASH-FLOW-1	Ashley Lateral, 1,000 ft downstream of Riceton Highway	111	Rectangular concrete flume
BEL-FLOW-1	Belding Lateral, in Fields Flume	550	Rectangular concrete flume
BEL-FLOW-2	Belding Lateral, 1,630 ft downstream of Traynor-Belding split	174	Geotextile-lined cross section
BEL-FLOW-3	Belding Lateral, 630 ft upstream of the Bonslett Bridge	130	Geotextile-lined cross section
GRE-FLOW-1	Green Lateral, 2,170 ft downstream of the Green-Schwind split at RD 388 drain crossing	79	Rectangular concrete flume
SCH-FLOW-1	Schwind Lateral, 650 ft upstream of Colusa Highway bridge at RD 388 drain crossing	57	Rectangular concrete flume
TRA-FLOW-1	Traynor Lateral, 300 ft downstream of West Liberty Road bridge	135	Geotextile-lined cross section
TRA-FLOW-2	Traynor Lateral, 860 ft downstream of Colusa Highway	280	Irregular cross section, concrete-lined bottom
TRA-FLOW-3	Traynor Lateral, in Nugent Flume	282	Rectangular concrete flume
GER-FLOW-1	Gerst Lateral, 570 ft downstream Gerst-Traynor split	78	Geotextile-lined cross section
RIS-FLOW-1	Rising River, 4,400 ft downstream of the Rising River Head Gates	55	Geotextile-lined cross section

Although flow data from the uncalibrated Biggs–West Gridley WD meters were not used for this study, it should be noted that data from the district's Starflow meter at the Nugent Flume compared well with the data retrieved from the SonTek Argonaut, TRA-FLOW-3, also installed at the Nugent Flume as part of this study. Figure A-9 shows that the two meters tracked very similarly to one another during a typical irrigation season, although the Starflow meter typically measures a slightly higher flow than the Argonaut. Because the Argonaut at this location measured within 3 percent of the RiverCat and FlowTracker during meter verification described in Section 3.2, study analysis was based solely on data from the Argonaut.

4.1.2 Canal Water Levels

Canal water level data were continuously recorded to better understand how the system is typically operated and to analyze relationships with shallow groundwater levels along the Traynor Lateral. Canal water surface elevations recorded by the data loggers were used to establish a canal water level baseline for the Design Data Study and assist with the development and calibration of the hydraulic model. The data were also used to examine existing freeboard conditions at the flow measurement stations. Minimum freeboard was used in the Design Data Study as an indicator of current canal capacity and typical Biggs-West Gridley operational practices.

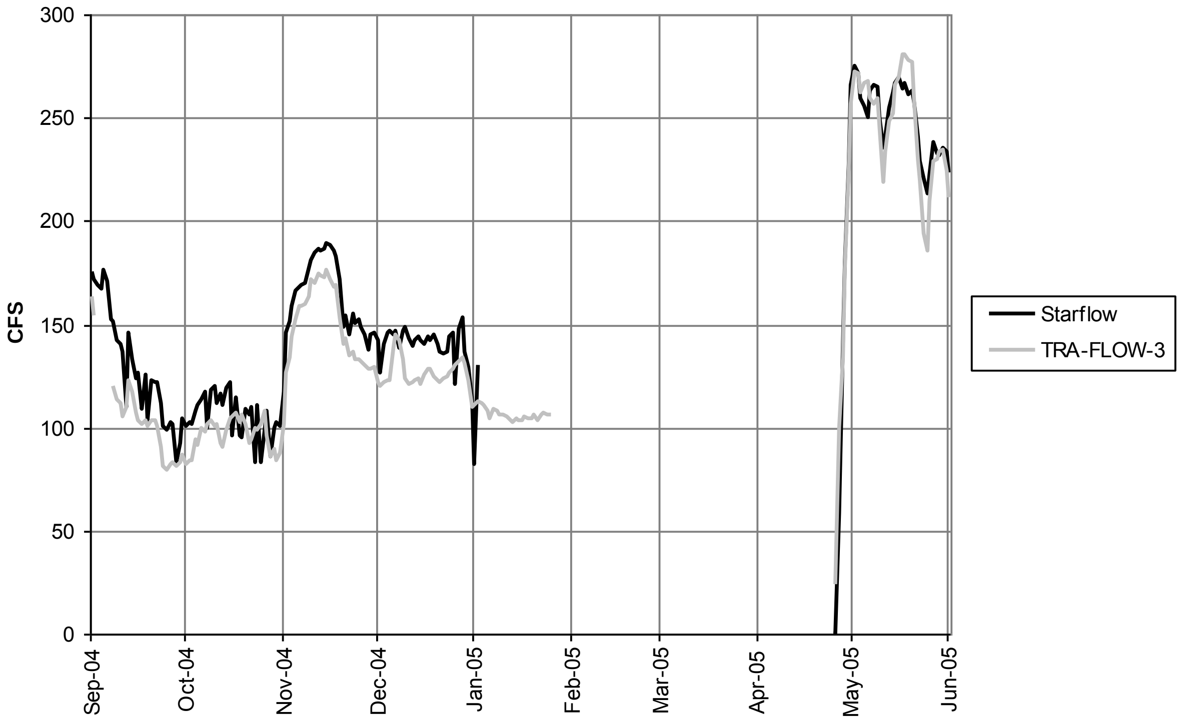


FIGURE A-9
Comparison of Biggs–West Gridley WD Starflow Meter and TRA-FLOW-3 at the Nugent Flume

Canal water level data collected by the eleven water level sensors are provided in Attachment A-2. Stage data as recorded at SonTek flow measurement sites along with the corresponding flow data are provided in Attachment A-3. The flow data are presented on the secondary axis to illustrate the variation in canal flows for various water levels throughout the operating season.

Freeboard was determined by subtracting the water level surface elevation from the surveyed top-of-canal or top-of-flume elevation at that location. Minimum freeboard varied between zero inches (overtopping) to between 2 and 3 feet, depending on the canal section. The measurement sites that reported less than 1 foot of freeboard are listed in Table A-5.

TABLE A-5
Canal Water Level and SonTek Flow/Stage Monitoring Stations Observing Less Than 1 Foot of Freeboard

Lateral	Freeboard Less than 6 Inches	Freeboard of 6 Inches to 1 Foot
Ashley		ASH-FLOW-1 (1,000 ft downstream of Riceton Hwy)
Belding	BEL-WL-5 (near Schwind/Green Split)	BEL-WL-HD (upstream of RR) BEL-WL-3 (near Traynor split) BEL-FLOW-1 (Fields Flume) BEL-FLOW-3 (630 ft upstream of the Bonslett Bridge)
Green		GRE-FLOW-1 (flume crossing RD 833 drain)
Traynor	TRA-FLOW-3 (Nugent Flume)	
Schwind		SCH-WL-1 (3/4 mile upstream of West Liberty Road) SCH-FLOW-1 (flume crossing RD 833 drain)
Rising River		RIS-WL-1 (1/2 mile upstream of Evans Reimer Road)

Notes:

Canal Water Level data (indicated by "WL" in the naming system) include data from April 2004 to October 2005.
SonTek data (indicated by "FLOW" in the naming system) include data from August 2004 to October 2005.

4.1.3 Shallow Groundwater Levels

Attachment A-4 shows groundwater level data from two adjacent shallow monitoring wells (bottom two graphs) and canal stage data from the nearest corresponding canal water level meter (top graph).

The 2004-2005 data show that groundwater levels show a marked response to the initial change in the canal water level, but groundwater levels increase at a slightly slower rate than the canal water level. Similar observations resulted from data collected in 2006 through 2008.

The data show that as the Traynor Lateral filled with water in April and the beginning of May, shallow groundwater levels at the monitoring well locations also increased over the next several days. The increase in groundwater levels ranged from 1.5 feet to approximately 4 feet above the initial levels recorded prior to flood-up. The practice of flood irrigation complicates determining the relationship between seepage and canal water levels. Flood irrigation contributes significantly to perched groundwater levels during the irrigation season. This is evidenced by the "spikes" (sharp increase then decrease of level over a relatively short time) in groundwater levels shown in the graphs in Attachment A-4. Aside from periods of flood irrigation, the shallow groundwater levels remain generally stable for much of the irrigation season because canal water levels also remain fairly constant.

Orme's property was not in production in 2004 and 2005, and therefore not irrigated. This condition enables a clearer comparison between canal and shallow groundwater levels, shown by the data recorded at the monitoring well pair PZ-OR-1 and PZ-OR-2 in his field and the corresponding canal water level sensor, TRA-WL-3. Groundwater levels at PZ-OR-1 and PZ-OR-2 do not show the irrigation "spikes" evident in other monitoring well pairs. In 2006 and 2007, the field was planted with trees and irrigated. The irrigation events are evident on the graphs as "spikes" where the shallow groundwater level is raised by 6 inches to 1 foot higher than before the field was irrigated.

The data show only that minor increases in canal water level result in very slight increases in shallow groundwater levels.

4.1.4 Quality Control of Collected Data

As expected with most data collection efforts of this magnitude, several instances occurred when data were not recorded by the flow meters, canal water level sensors, or monitoring wells because of a variety of reasons. Monthly field visits revealed most problems, which were identified and corrected quickly to minimize the loss of data. Because of the relatively small data gaps, the results of the Measurement and Seepage Study were not compromised.

A quality control process was established to review all collected data and check for potential errors. After each data download, the recorded data was checked for missing or suspect data, or for "flags" in the data (such as a flow meter reporting "-1" when data is not detected). The data set was adjusted using the established quality control process to produce the most accurate data set possible.

The quality control process consisted of the following quality checks and corresponding data adjustments (Table A-6).

TABLE A-6
Quality Control Conditions and Data Adjustments

Condition	Data Adjustment
Missing data point	Estimate by data value immediately preceding. For more than 1 hour of missing data, do not estimate (becomes "data gap").
Spike (irregular data point compared to adjacent data)	Estimate by data value immediately preceding. If data is questionable for more than 1 hour, remove data (becomes "data gap").
Low flow condition (signaled by negative flow, spike, or "-1")	Estimate flow as "zero". Approximate stage by data point immediately preceding. If at beginning of season when system is still shut down, approximate stage by first stage detected in season.
Beam malfunction (for Acoustic Doppler)	Estimate flow and stage with previous data point. Remove data if beam malfunction is sustained longer than 1 hour.

Table A-7 lists typical problems encountered by each type of equipment during the study which resulted in occasional data gaps.

TABLE A-7
Typical Problems Resulting in Data Adjustments or Gaps

Equipment Type	Typical Problems
Acoustic Doppler Flow Meters	Sediment build-up over acoustic beams Pondweed growth interfering with vertical acoustic beam Power supply interruption (one unit only) Instrument not properly deployed after data accessed
Canal Water Level Sensors	Battery low or drained Instrument not properly deployed after data accessed
Shallow Monitoring Wells	Battery low or drained Instrument not properly deployed after data accessed

4.2 Influence of Canal Water Level Changes on Seepage Rates and Shallow Groundwater Levels

To estimate the magnitude of the effect of increased canal water levels on shallow groundwater levels in adjacent fields, a quantitative seepage analysis was performed at one location along the Traynor Lateral. The location was selected because fields adjacent to this section of the Traynor Lateral were not flood-irrigated during the 2004 season, as described in Section 4.1.3. This lack of irrigation facilitated evaluation of the extent to which increased canal water levels influence shallow groundwater, because the complicating effects of applied irrigation water were not present.

4.2.1 Analysis of Operational Relationship between Canal Flows and Water Levels

For the purposes of the seepage analysis, a generalized subsurface soil profile was determined to describe a conceptual model of the soil conditions in the areas of seepage concern. This soil profile was based on the boring logs of two shallow groundwater monitoring wells located along the Traynor Lateral (PZ-OR-1 and PZ-OR-2). There were three layers in the conceptual model: berm fill, native loose clayey sand (SC), and native hard clay (below elevation 76 feet). No laboratory permeability or other classification testing was performed. Relevant boring logs are included in Attachment A-5.

A simplified seepage analysis was performed using the finite element groundwater modeling function of the computer program Slide, a 2D limit equilibrium slope stability analysis tool developed by Rocscience. Approximate ranges of soil properties were used. The discrete soil layers were assumed to have uniform horizontal and vertical permeability. The coefficient of permeability (K) for the native loose clayey sand and the berm fill material was assumed to range between 3×10^{-5} and 3×10^{-3} feet/second. This was based on textbook recommendations for the range of the coefficient of permeability for loose clayey sand (Das, 1990). The hard clay layer was assumed to have a very low permeability (3×10^{-7} ft/s).[4] Analyses were performed for both the assumed “high” and “low” coefficients of permeability so as to bracket the range of possible seepage rates.

Permeability of the canal bed was assumed to be that of the native soils adjacent to the canal, as no borings were drilled within the canals or associated berms to allow for evaluation of bed conditions. The potential to encounter more pervious soils within the canal bed if the canal is widened does exist. This potential would be evaluated during a design phase as part of a design-level geotechnical study.

The water level meter TRA-WL-3 and corresponding monitoring well pair PZ-OR-1 and PZ-OR-2 were selected for the analysis. One canal water surface elevation at TRA-WL-3 from the middle of the 2004 irrigation season (July 13, 2004) was used in the analyses (87.03 feet). A second water surface elevation corresponding to a hypothetical increase in the canal water level of 6 inches (87.53 feet) was also used in the analysis. For reference, the canal bottom at the location of TRA-WL-3 is at an elevation of 77.3 feet, and the outside ground surface elevations at the groundwater monitoring well locations are 84.32 feet (PZ-OR-1) and 85.08 feet (PZ-OR-2).

[4] At this stage of preliminary evaluation no data were available to allow modification of the ratio of Kh to Kv. These data would be evaluated during a design phase as part of a design-level geotechnical study.

4.2.2 Results

The results of this analysis provide a general impression of the sensitivity of the shallow groundwater levels to changes in the canal water levels: Raising the water level in the canal by 6 inches resulted in an increase in the corresponding seepage rate of less than 5 percent. This conclusion applies to the selected site under the conditions assumed for modeling.

Additionally, a rudimentary quantitative evaluation was performed to examine the seepage effect from widening the bottom of canal by 10 feet, since canal widening is a potential means to increase canal capacity. The maximum measured water surface elevation was maintained while the canal was widened. Results of the analyses show that the increase in the seepage rate from widening the canal by 10 feet was also less than 5 percent.

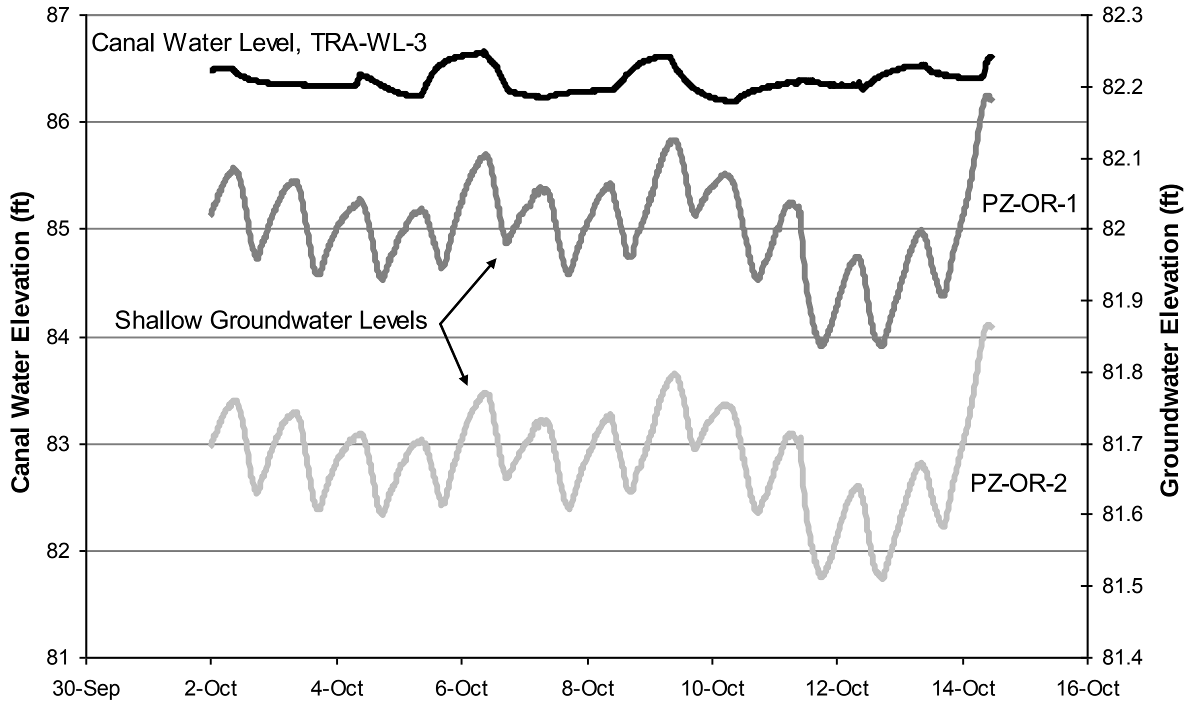
The small increase in seepage rate resulted in a slight change in corresponding shallow groundwater level. An increase in seepage from either increasing the canal water level by 6 inches or widening the canal bottom by 10 feet would result in an increase of less than 1 inch in shallow groundwater levels.

The approximation is conservative since the range of coefficients of permeability used in these analyses brackets all possible values for the soil type identified in the boring log (loose clayey sand). Slight increases in canal water level will not significantly increase the shallow groundwater level in the adjacent fields.

It should be noted that these analyses were based on assumed ranges of permeability for loose clayey sand material, as identified in two shallow borings adjacent to the lateral. Layers of clean sand not detected in the borings may result in higher values of permeability and increased canal leakage. Additionally, this analysis does not account for potential disruption of the sealing layer if the canal cross-section is altered during widening. These issues would be addressed in a more detailed study conducted in conjunction with the design phase of the project.

4.2.3 Data Comparison Check

Data in 15-minute intervals from the water level sensors TRA-WL-3 and the shallow groundwater monitoring sensors PZ-OR-1 and PZ-OR-2 were used to spot-check the validity of the seepage analysis. Upticks in the measured water levels corresponding to upward movement of canal water levels were observed on October 6 and 9, 2004. Data from this period are provided in Figure A-10. Figure A-10 demonstrates that changes in canal water levels of approximately 6 inches result in very slight changes in groundwater levels.



Note: Data collected in 2004.

FIGURE A-10
Sensitivity of Shallow Groundwater Levels to Changes in Canal Water Levels

(Note that groundwater elevation scale on the right y-axis has been exaggerated to show these slight changes.) Minor diurnal variation in the groundwater level data is caused by the fluctuation of ambient temperature on the measuring device. Water levels in the toe drain would also likely respond to canal water level changes, which would in turn affect shallow groundwater levels. The toe drain water levels were observed to be similar to the shallow groundwater levels in the adjacent wells.

4.3 Analysis of Relationship of Operations to Canal Flows and Water Levels

As noted in Section 3.6, any evaluation of seepage concerns within Biggs–West Gridley WD should consider how the canal reaches within the system are operated. Most reaches of the system are checked up by downstream control structures to maintain constant high heads in the canal. The check structures are adjusted by means of slide gates or flashboards to accommodate changes in flow while maintaining a constant head in the canal upstream. The purpose for keeping the canal at a high level is to develop the head required to deliver water through customer turnouts—particularly turnouts that are raised significantly above canal invert.

This examination of data demonstrates that increases in canal flow (for example, because of larger deliveries to Gray Lodge WA) generally do not cause increases in seepage or increases in shallow groundwater adjacent to canals; rather, water levels maintained at constant levels are the dominant influence. In the Biggs–West Gridley WD system, a majority of the canal reaches are maintained at a constant head for the majority of the summer irrigation season (May through August), illustrated by flow and level data along the Belding Lateral in Figure A-11 and Traynor Lateral in Figure A-12. The 2005 Belding Lateral data show that water levels were maintained about elevation 91 feet, but flow ranged from 200 to 550 cfs. The Traynor Lateral is one of the reaches with seepage concerns. The data shows that the canal is generally held at 86.5 feet, whereas flows vary from 90 to 270 cfs. The shallow groundwater along the Traynor Lateral tracks closely with the steady canal water levels except during irrigation events, as shown in Attachment A-4.

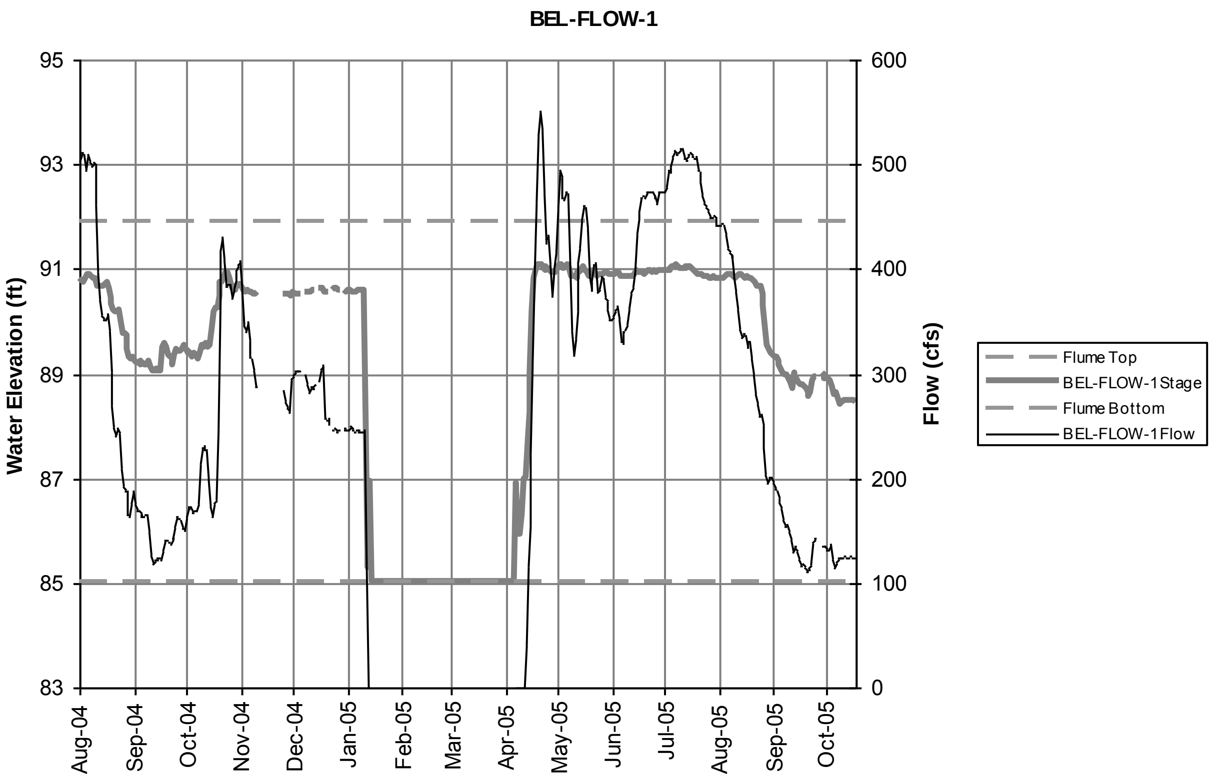


FIGURE A-11
Flow and Water Level Data from the Belding Lateral

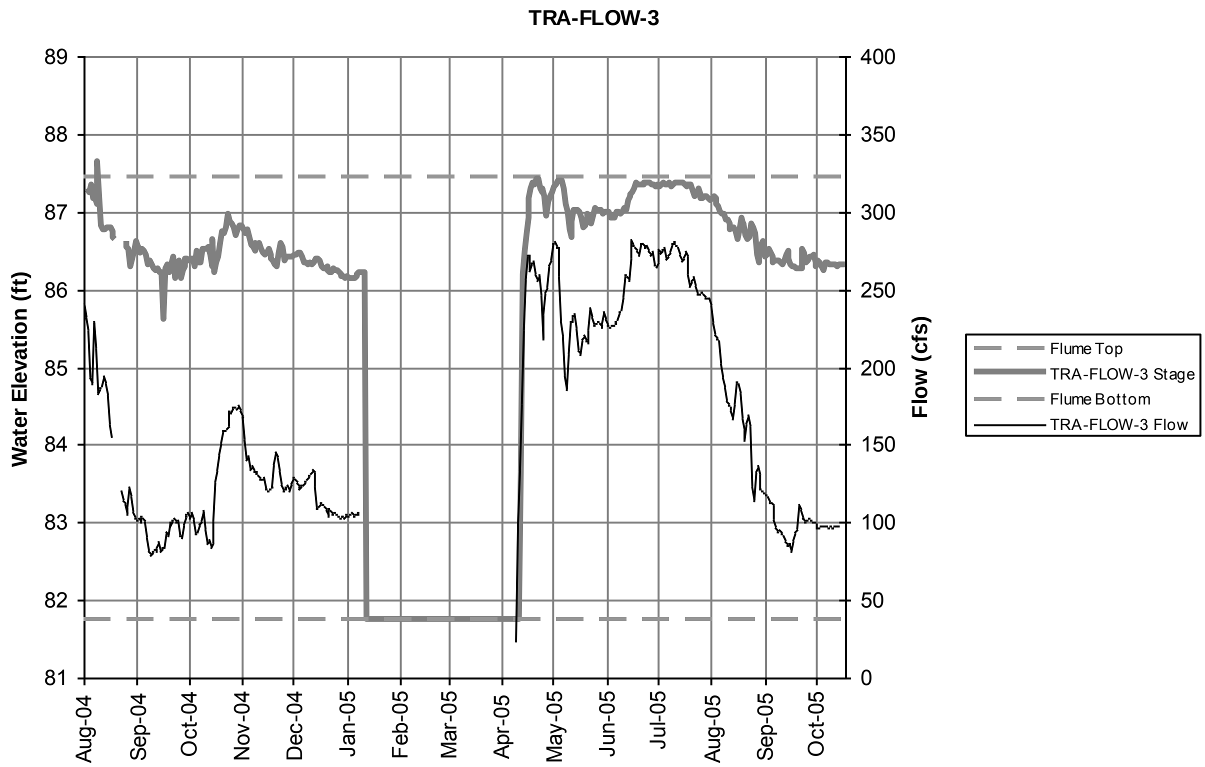


FIGURE A-12
Flow and Water Level Data from the Traynor Lateral

Seepage is also a concern along the Rising River between September and October, when adjacent rice fields are drained for harvest. This season coincides with the time Gray Lodge WA floods wildlife ponds from its delivery point off the Rising River; therefore, flows in the Rising River are expected to be highest when seepage is least desirable. Water levels on the Rising River are maintained for Biggs-West Gridley WD irrigation customer deliveries between April and early September, but during rice harvest from mid-September to October, checks remain open, allowing the water level in the canal to decrease while conveying peak flows to Gray Lodge WA. This seasonal water level pattern is shown in Figure A-13. This information will be considered in the Design Data Study to determine facility improvements.

RIS-FLOW-1 recorded inconsistent data during the study because silt frequently blocked meter sensors in this area. Available data from this meter are provided in Attachment A-1, Figure A1-11.

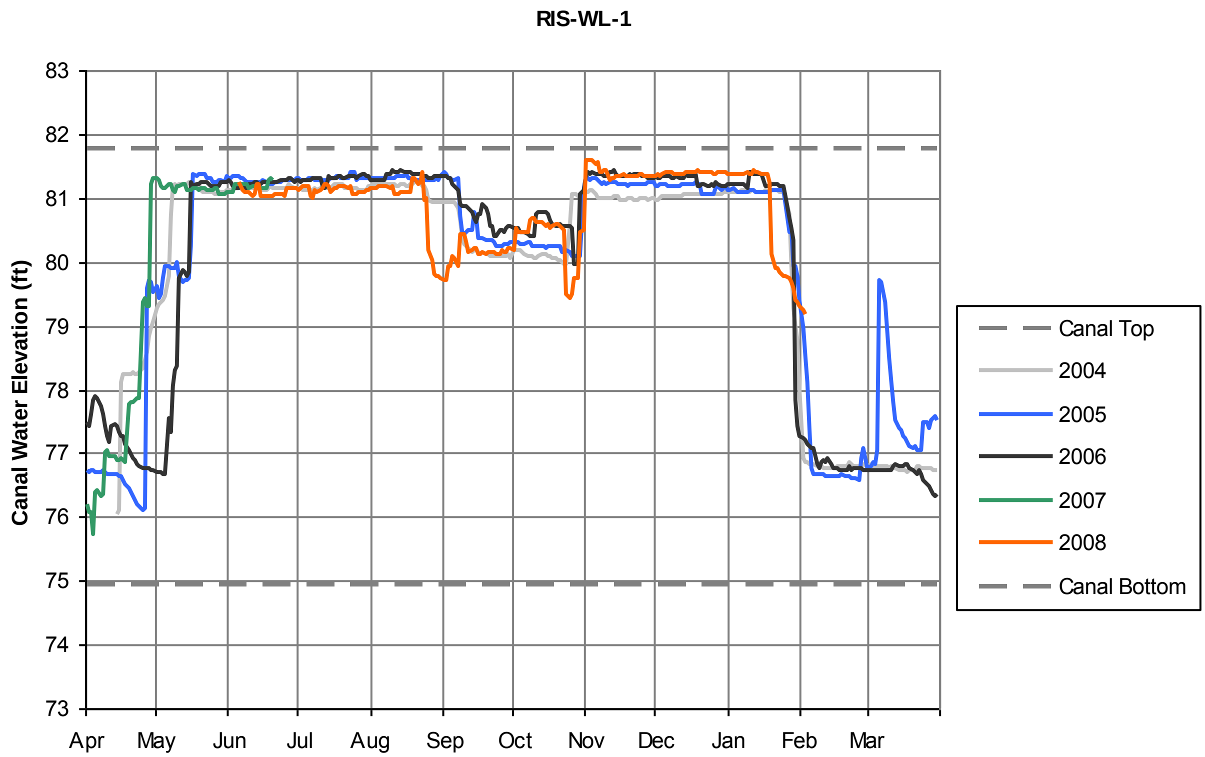


FIGURE A-13
Water Level Data from the Rising River

5. Seepage Mitigation Methods

Increased flows alone do not result in increased seepage. However, if these increased flows cause increased water levels in areas or during times when water levels are not being controlled for irrigation deliveries, the increased water levels could cause additional seepage. If it is determined that an increase in seepage is unavoidable and should be mitigated, then the most appropriate option among the mitigation methods presented here should be further developed. It is recommended that a seepage monitoring and mitigation plan be developed during the design phase, which will incorporate additional information obtained during construction.

Canal seepage could be reduced either by canal lining methods or by methods outside the canal. Canal lining methods are available to prevent nearly all seepage. Costs vary depending on the site preparation work and amount of maintenance required. Methods for canal lining and out-of-canal approaches are described in this section.

Alternatively, it may be determined that increased seepage is best mitigated by restricting canal water levels to their existing levels. Under this scenario, there may be specific local reaches with seepage concerns that need to be addressed.

5.1 Canal Lining within the Channel Prism

Earth lining is the most common form of seepage control. The canal prism is shaped, and a layer of clay 6 to 12 inches thick is placed as a liner. The liner is compacted and kept submerged most of the time to prevent liner cracking. Reclamation advocates compacted earth-lined canals for seepage reduction if the haul distance of an appropriate (clayey) lining material is approximately less than 2 miles (Farrar, 2005).

Aside from compacted earth lining, canal-lining options are grouped into four broad categories:

- Concrete
- Exposed geomembrane
- Concrete covered geomembrane
- Fluid applied membrane

Each method may be applied across the entire channel prism or the bottom only. Reclamation has carried out a number of comprehensive canal-lining demonstration projects and has published the results in *Canal-Lining Demonstration Project: Year 10 Final Report* (Reclamation, 2002).

Table A-8 summarizes the associated construction and maintenance costs, preliminary benefit/cost (B/C) ratios,[5] service life, and effectiveness of each canal-lining technique. Advantages and limitations are also listed for each alternative. Costs for petroleum-related materials and even earthwork have increased recently, so the values listed are likely low.

Also, the total size of the project has a significant impact on cost, as does the amount of grading and earthwork needed to prepare the surface to receive the lining.

5.1.1 Concrete

The term “concrete” applies to roller-compacted concrete, shotcrete, and grout-filled mattresses. Although concrete does have a measurable permeability, initially it may be considered watertight. As it ages, cracks develop as a result of shrinkage during curing, thermal expansion and contraction, and subgrade movement. Also, because the field application of shotcrete is difficult, holes develop at those locations where the shotcrete thickness is less than 1 inch. Grout-filled mattresses also crack at locations where the shotcrete thickness is less than 1 inch. Typically this occurs when concrete is applied on rocky subgrade. In general, cracks tend to lengthen and grow in numbers over time. Experience shows that they do not, however, widen. Ponding tests indicate a seepage reduction of 60 to 90 percent and long-term effectiveness estimated at 70 percent. Concrete requires little maintenance and is very durable, and water district personnel are familiar with concrete maintenance.

[5] Benefit/cost (B/C) ratios have been calculated by Reclamation based on initial construction costs, maintenance costs, durability (service life), and effectiveness as determined by pre- and post-construction ponding tests.

TABLE A-8
Comparison of Canal Lining Methods

Method	Costs			Service Life (years)	Percent Effectiveness	Advantages	Limitations
	Construction ($/ft^2)	Maintenance ($/ft^2/year)	B/C Ratio				
Concrete	2.40–2.91	0.006	3.0–3.5	40–60	70%	Excellent durability; familiar, easy to maintain	Random cracking (reduces effectiveness); unfamiliar to Biggs–West Gridley WD
Exposed Geomembrane	0.98–1.91	0.0125	1.9–3.2	10–25	90%	Very effective	Susceptible to mechanical damage and vandalism; materials degrade (from UV exposure); difficult to maintain; unfamiliar to Biggs–West Gridley WD
Geomembrane with Concrete Cover	3.04–3.18	0.006	3.5–3.7	40–60	95%	Very effective; best long-term performance; maintain concrete only	Construction costs; unfamiliar to Biggs–West Gridley WD
Fluid-applied Membrane	1.75–5.41	0.0125	0.2–1.5	10–15	90%	Niche applications (steel flumes or existing concrete-lined canals)	Construction costs variable; difficult to apply material consistently

Notes:

Table adapted from *Canal-Lining Demonstration Project: Year 10 Final Report*, p. ES-1 (Reclamation, 2002). Unit costs escalated to 2008 dollars according to the *Engineering News-Record* 20-City Index.

5.1.2 Exposed Geomembrane

Geomembranes include synthetic linings, plastic linings, and flexible membrane linings. The permeability of geomembranes is so low that seepage is effectively reduced by approximately 90 percent. Exposed geomembranes are, however, susceptible to damage from animal traffic, vandalism, and cleaning operations. This damage decreases their effectiveness. Also, geomembranes typically stiffen over time, making them less flexible and, therefore, less resistant to damage. The rate of stiffening depends on geomembrane thickness, its location in the canal, and the condition of the subgrade. Generally, degradation rates decrease with an increase in geomembrane thickness. Geomembranes also exhibited less degradation below the water line than above it, where the material is exposed directly to ultraviolet rays.

Because of their low density, all geomembranes need to have anchor trenches at all exposed edges. It is also preferable to have the canal full of water year-round, because the lift effect of wind can cause the geomembrane to rise and tear loose from its anchorage.

Solvents or heat fusion are used to join seams. Some geomembranes have a fabric reinforcement which increases the tensile strength. Tears will often propagate as the water gets under the material, and large torn sections create water barriers in the canal if not identified quickly. Selection of the material is dependent on anticipated service conditions and longevity.

5.1.3 Geomembrane with Concrete Cover

This method combines the previous two. The geomembrane provides the water barrier, and the concrete protects it from weathering and damage. Only the concrete requires maintenance. Although this option is initially the most expensive, its effectiveness and benefit/cost ratio are the highest of all the alternatives presented.

5.1.4 Fluid-Applied Membrane

Fluid-applied membranes are spray-applied synthetic liners. This reduces the need for very smooth surfaces, and no joints are present. Because these linings have low strength, failure is frequent except with hard subgrade applications. Adverse weather in the late fall and early spring makes quality control at the time of application difficult. These types of lining may have special niche applications such as the lining of existing steel flumes or concrete channels. Fluid-applied linings for earth canals are not recommended for this potential application.

5.1.5 Bottom-Only Geomembrane

A geomembrane may be applied to the canal bottom and covered with 6 to 12 inches of soil as a bottom-only approach. Two significant advantages of bottom-only canal lining are its relatively easy installation and maintenance. (Installation and maintenance of the sides are typically more problematic.) Also, in some cases this is the only option that is aesthetically pleasing. The effective reduction in seepage, ranging from 20 to 50 percent, is less than that achieved by fully lined canals. The anchor trenches required on all sides create higher potential for water getting under the membrane. The costs are approximately the same as for exposed geomembranes. While the construction and maintenance costs may be reduced slightly, the unit cost of materials may increase slightly because of the smaller amount of material purchased.

5.2 Out-of-Canal-Prism Methods

In addition to canal lining, seepage may be mitigated by out-of-prism methods. Three such mitigation measures are cutoff walls, seepage canals, and relief wells.

5.2.1 Cut-off Walls

The seepage path out of the canal can be increased by placement of a soil-bentonite slurry wall or a cement-bentonite wall excavated sufficiently deep to reduce shallow seepage. The wall is excavated either through the center of the existing canal embankment or at the downstream toe. After the trench is backfilled, the ground surface is restored. Many major levees have slurry walls installed to increase stability and reduce seepage; however, if the wall does not go sufficiently deep, only limited seepage reduction is provided.

5.2.2 Seepage Canals

An existing drainage canal can be cleaned and pumped as a means to intercept and reduce seepage. Usually, this water must be pumped back into the main canal continuously, because if the seepage canal is allowed to fill, outward migration will occur. Biggs–West Gridley WD currently operates seepage canals.

5.2.3 Relief Wells

Relief wells intercept underseepage and provide a controlled outlet for the water. They typically have inside diameters between 6 and 18 inches, depending on the maximum design flow. This mitigation method is particularly effective when a pervious substratum is overlain by more impervious top strata. This method provides a reduction in seepage; it does not prevent seepage.

An advantage of relief wells is that they require little space and disrupt only a localized area during installation (compared to seepage canals). They can be expanded easily by pumping more, if necessary. Also, wells may be economically installed to greater depths than cutoff walls.

A disadvantage of relief wells is that they require periodic maintenance and frequently suffer a loss in efficiency resulting from clogged well screens. Another disadvantage is that pumped seepage quantities must be disposed back into the canal or another site. Finally, wells may actually increase the rate of seepage as the gradient between the water surface in the canal and the well increases.

A summary of out-of-canal-prism techniques is presented in Table A-9.

TABLE A-9
Comparison of Out-of-Canal-Prism Seepage Mitigation Methods

Method	Cost	Service Life	Advantages	Limitations
Cut-off Wall	Depends upon investigation of local conditions and extents of construction.	25 to 50 years	Effective if constructed properly.	Expensive. May not be deep enough to be effective.
Seepage Canals	Depends upon investigation of local conditions and extents of construction.	50 years	Extensive use in Sacramento Valley; effective if system designed well.	Requires O&M on second conveyance system; weed control; Pump O&M.
Relief Wells	Depends upon investigation of local conditions and extents of construction.	40 years	Can be effective in a very localized seepage area.	O&M of pumping system; creates additional seepage potentially

5.3 Maintain Canal Levels at Present Levels

Canal seepage is largely dependent upon head in the canal. Therefore, implementing conveyance facility improvements that maintain water levels at near-present conditions is one means of seepage control. Facility improvements developed by the Design Data Study and future canal operations would need to account for absolute peak levels and peak water levels in some reaches during months of concern. Despite efforts to control seepage by maintaining water levels, in reaches where canal cross-sections will be disturbed, the existing sealing layer may be disrupted or a sand lens may be intercepted, which could result in increased seepage. A seepage monitoring and mitigation plan will be initiated by Reclamation during the design phase of the project in consultation with and subject to acceptance by Biggs-West Gridley WD to monitor seepage conditions post-construction and mitigate short-term and long-term seepage impacts.

5.4 Summary of Mitigation Methods

The analysis in Section 3.2 demonstrates that if the improved conveyance system can maintain water levels within 6 inches of current water levels, the impact on shallow groundwater is negligible. Thus, an appropriate objective of the Design Data Study is to develop facilities improvements such that canal water levels are maintained at current levels. However, where canal cross-sections are modified to increase canal capacity and maintain water levels, the existing sealing layer may be disrupted, resulting in localized seepage. It is recognized that localized areas of seepage concern may remain and, if deemed appropriate, could be mitigated. The mitigation methods described here have been screened at a conceptual level appropriate to future project design phases. It is recommended that if mitigation measures are required for the advancement of the Gray Lodge WA Water Supply Project, canal lining methods should be investigated further. The extent and type of the lining be refined based on additional field work and subsurface investigations. As mentioned previously, a seepage monitoring and mitigation plan will be initiated by Reclamation in coordination with the District during the design phase of the project to monitor seepage conditions post-construction and mitigate short-term and long-term seepage impacts.

6. Integration with Design Data Study for Conveyance of Refuge Water Supply to Gray Lodge WA

The Measurement and Seepage Study is a supporting investigation for the Design Data Study initiated in 1999-2000 and continued from 2004 to late 2008. Technical work for these two studies was completed in parallel since 2004. The scope of the Measurement and Seepage Study was developed to increase the validity of conclusions reached by the Design Data Study and address these key questions:

- How will the refuge water supply conveyance improvement program document and address current seepage and canal water level concerns resulting from increased deliveries to Gray Lodge WA?
- How can the Biggs–West Gridley WD and Gray Lodge WA water demand projections be verified in the absence of systemwide flow measurement data?
- How can the accuracy of hydraulics modeling be verified?

In addition to providing necessary information to address seepage concerns, the data collected for this study were utilized and integrated into the Design Data Study in the following subtasks:

- **Develop systemwide design flows:** Canal flow data measured at key locations throughout the canal system assisted with the determination of the engineered hydraulic capacity (flow in cfs) of each reach of canal. This set of empirically derived capacity flows was used to determine and design required facility improvements.
- **Establish data baseline:** The data collected during the study provide a baseline of existing flows, canal water levels, and groundwater levels to compare with future conditions after facility improvements are in place and Level 4 water is delivered to Gray Lodge WA.
- **Calibrate hydraulic model:** Facility improvements were determined in the Design Data Study by means of a hydraulic model that represents the Biggs–West Gridley WD conveyance system. Canal water level data were used to calibrate the model, ensuring that model parameters such as roughness, structure dimensions, and typical gate openings represent actual system conditions.
- **Establish bounds on water level increases:** Future facility scenarios were analyzed with the calibrated hydraulic model. Improvements for one alternative set of recommendations were adjusted so that future water levels would not exceed existing water levels to the extent possible. Maximum water levels recorded in 2004 through 2007—both the absolute maximum and the maximum in months of concern—were used as constraints to determine facility improvements.
- **Develop facility improvements:** In general, system improvements will be designed to minimize increases in water levels due to increased Gray Lodge WA deliveries, particularly during critical times. If increased canal water levels at critical times of the year are unavoidable, then seepage mitigation measures described in this technical memorandum may be pursued. The Design Data Study will recommend a set of improvements based on data collected by this study and on hydraulic modeling of

future Gray Lodge WA deliveries. During the subsequent design phase of the project when improvements are refined, Reclamation will launch a seepage monitoring and mitigation plan to continue to address seepage at Biggs-West Gridley WD, subject to acceptance by the District. This future study will tie into an operations model to understand changes in magnitude, timing, and duration of canal water levels that will occur after the project is implemented. The future seepage and operations study will be included in the design contract with Reclamation.

7. References

Bureau of Reclamation. 2002. Canal-*Lining Demonstration Project: Year 10 Final Report*. November.

Das, B.M. 1990. *Principles of Foundation Engineering.* 2nd Edition. PWS Publishing.

Farrar, Jeff (Bureau of Reclamation Technical Service Center). 2005. Personal communication with CH2M HILL staff.

Attachment A-1
Canal Flow Data

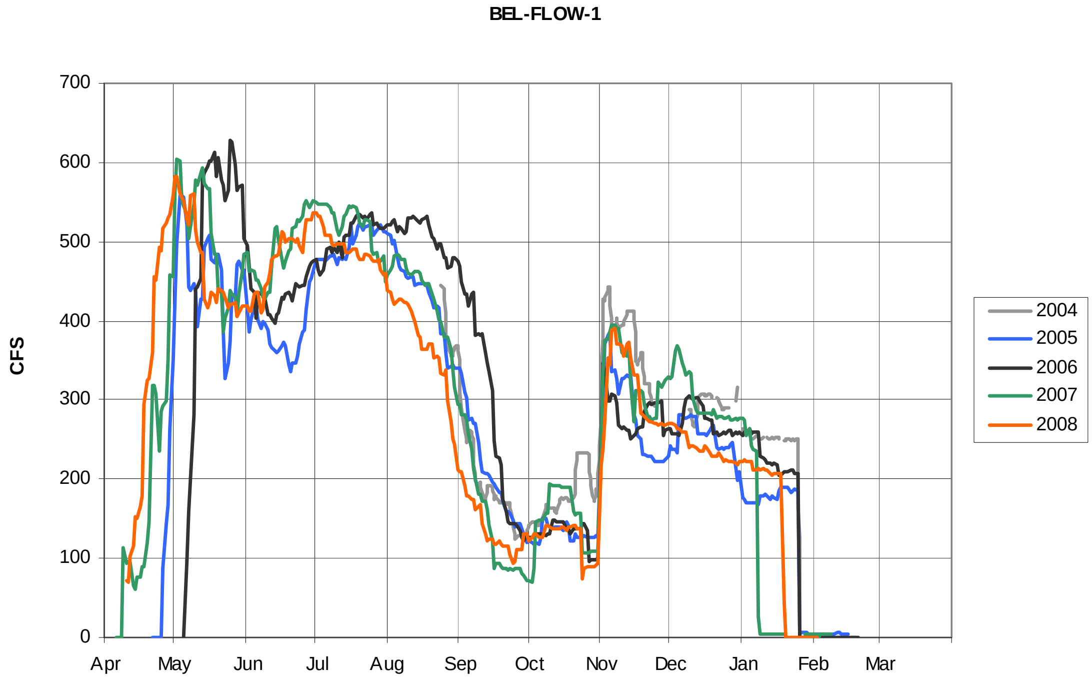


FIGURE A1-1
Canal Flow Summary—BEL-FLOW-1

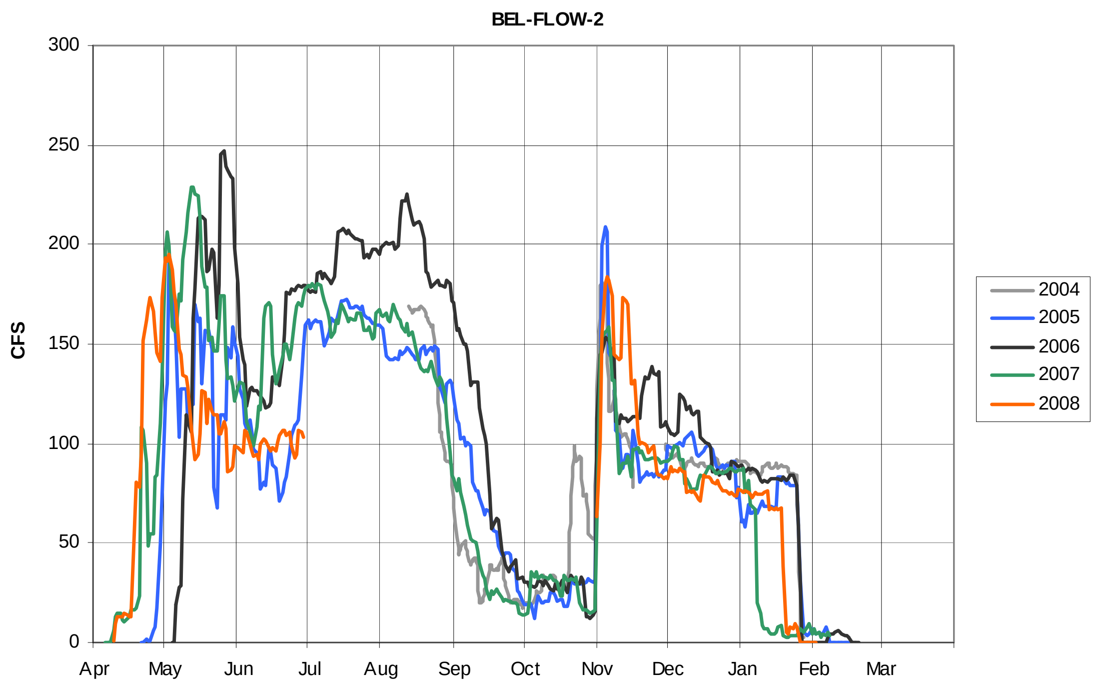


FIGURE A1-2
Canal Flow Summary—BEL-FLOW-2

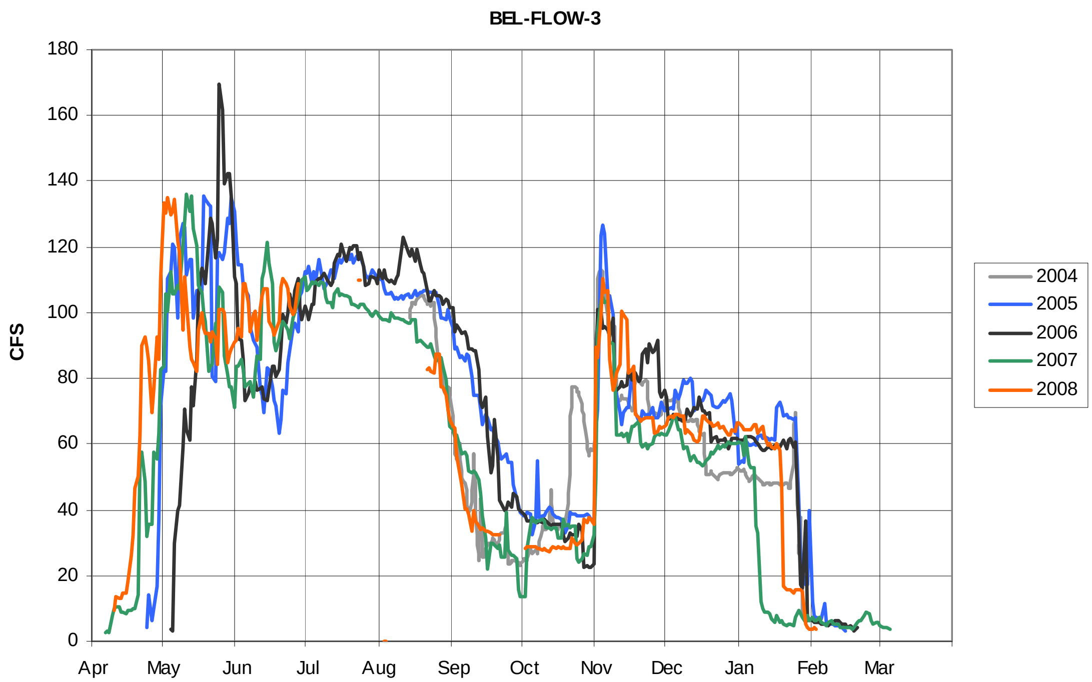


FIGURE A1-3
Canal Flow Summary—BEL-FLOW-3

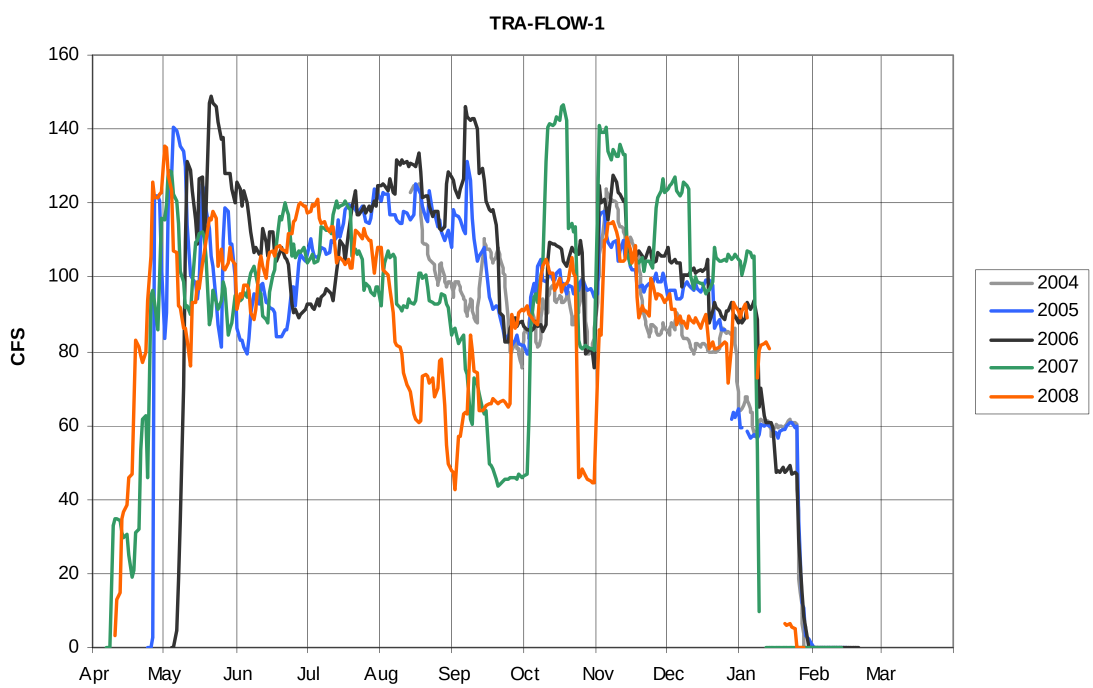


FIGURE A1-4
Canal Flow Summary—TRA-FLOW-1

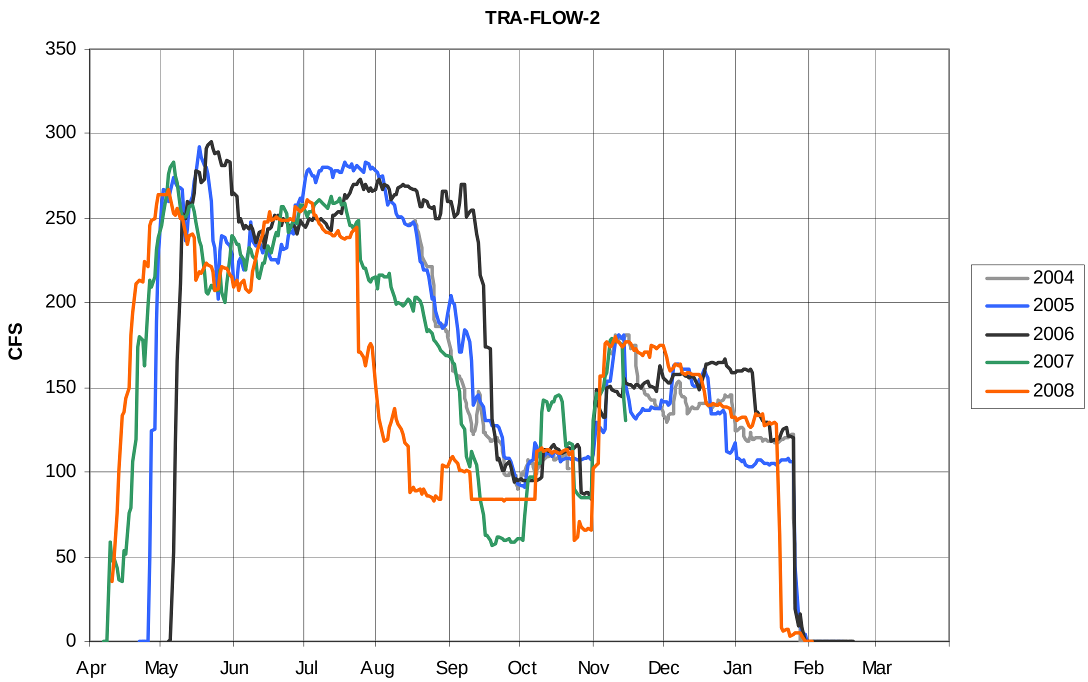


FIGURE A1-5
Canal Flow Summary—TRA-FLOW 2

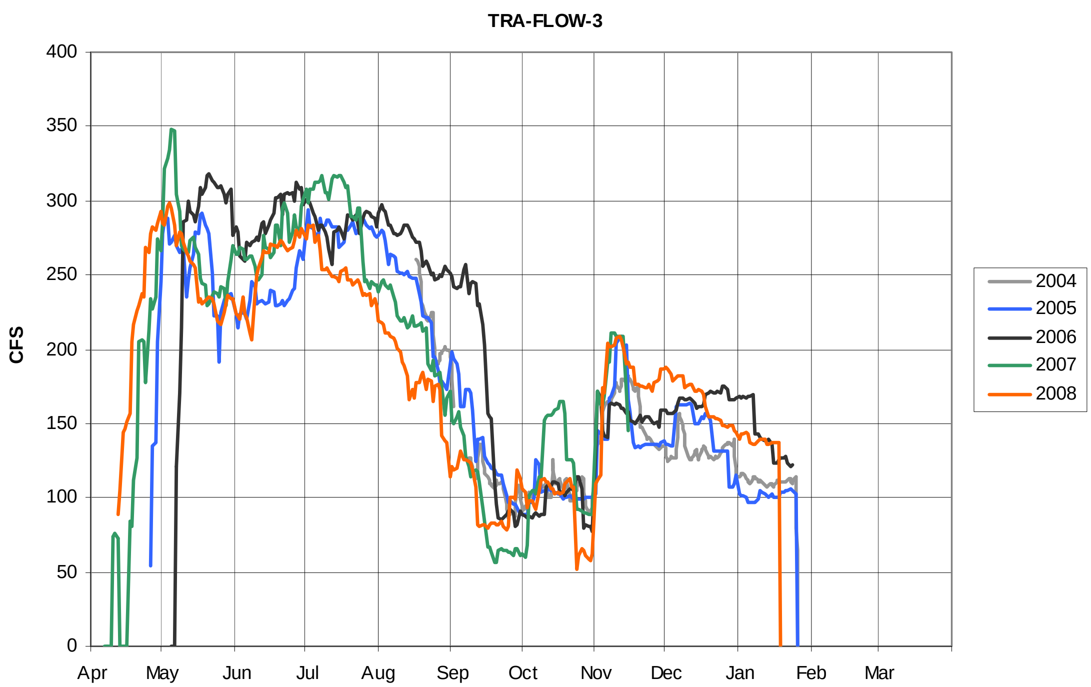


FIGURE A1-6
Canal Flow Summary—TRA-FLOW-3

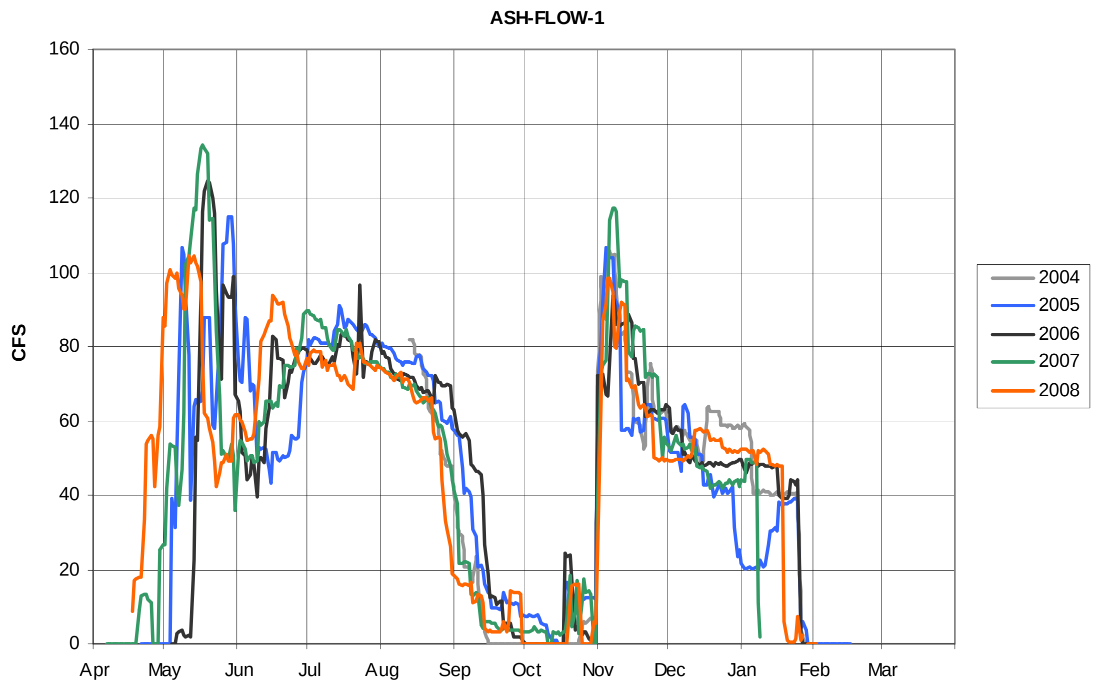


FIGURE A1-7
Canal Flow Summary—ASH-FLOW-1

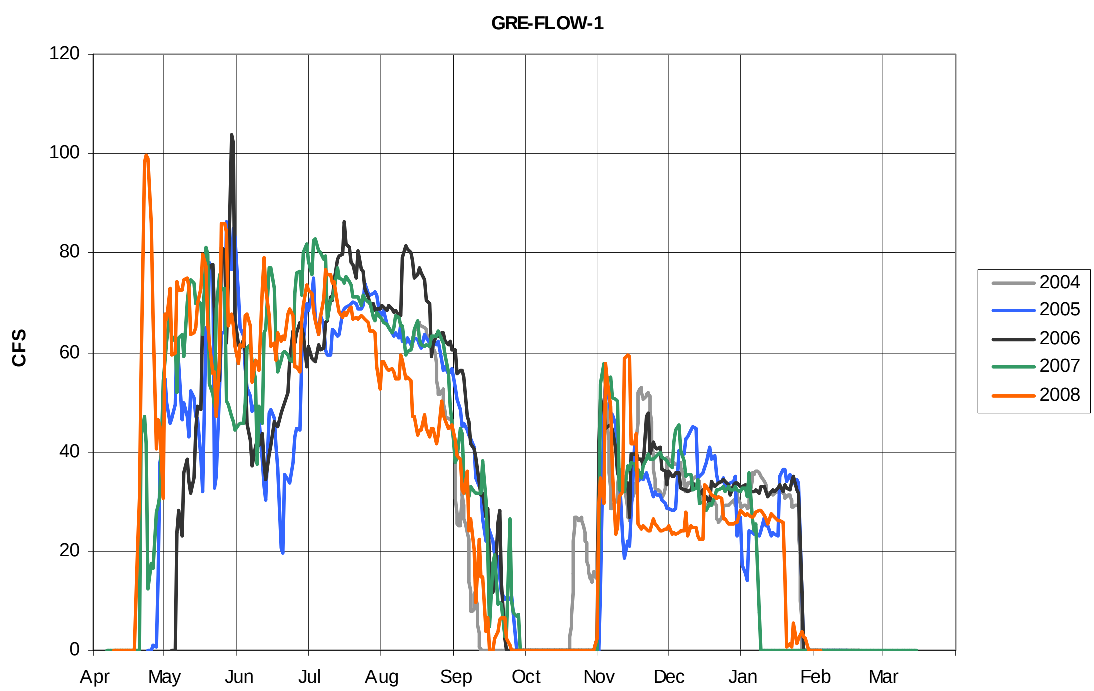


FIGURE A1-8
Canal Flow Summary—GRE-FLOW-1

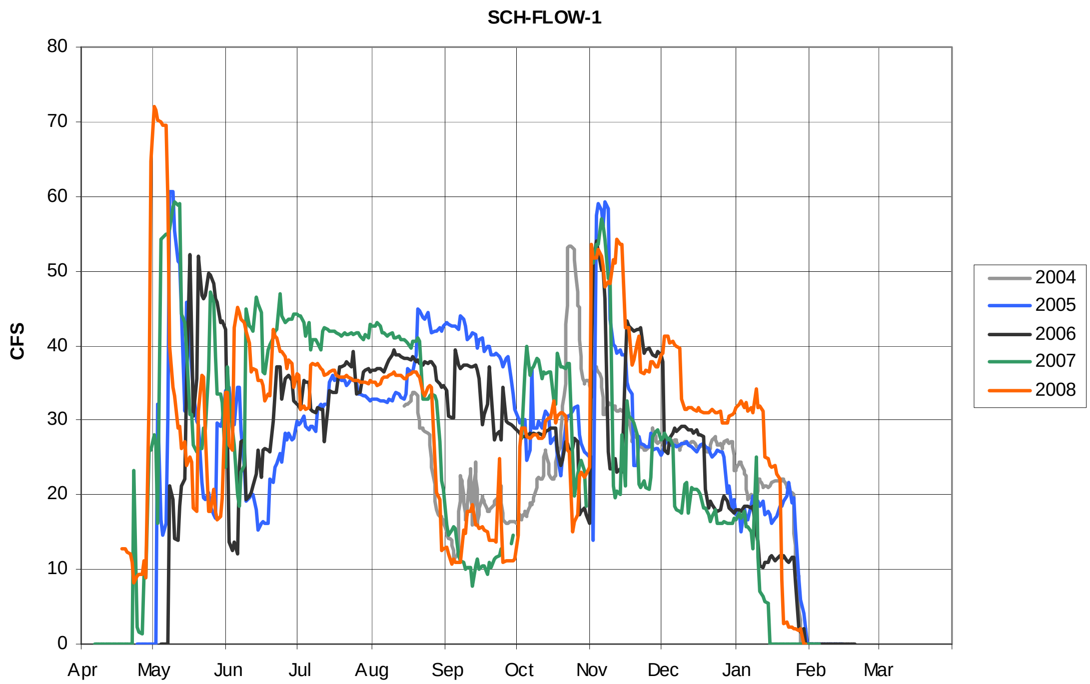


FIGURE A1-9
Canal Flow Summary—SCH-FLOW-1

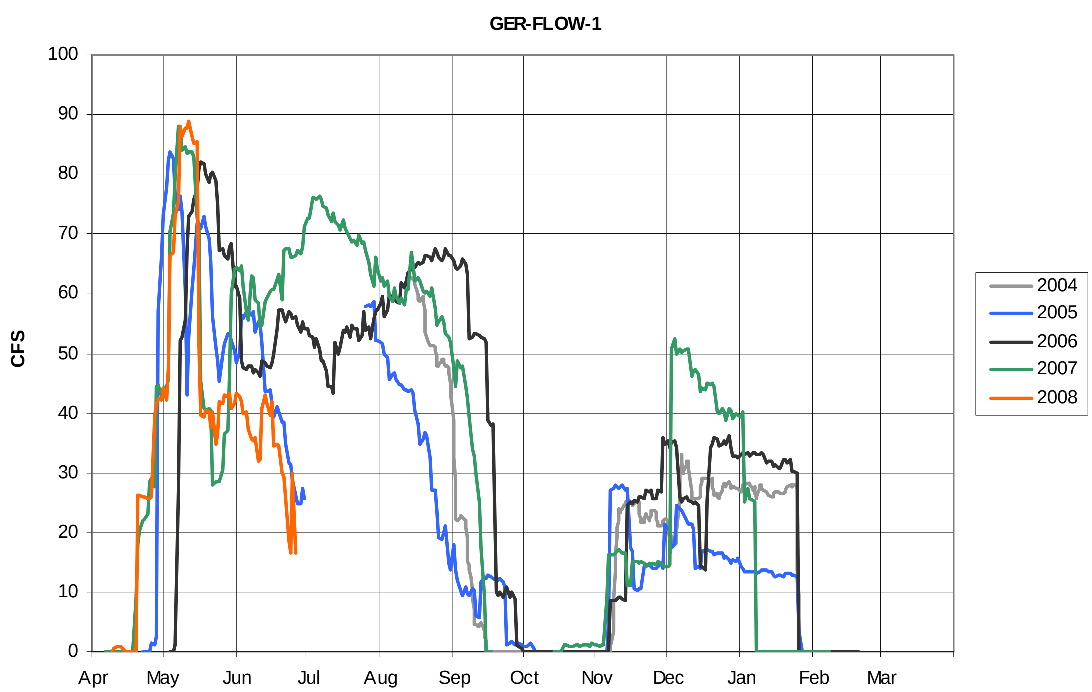


FIGURE A1-10
Canal Flow Summary—GER-FLOW-1

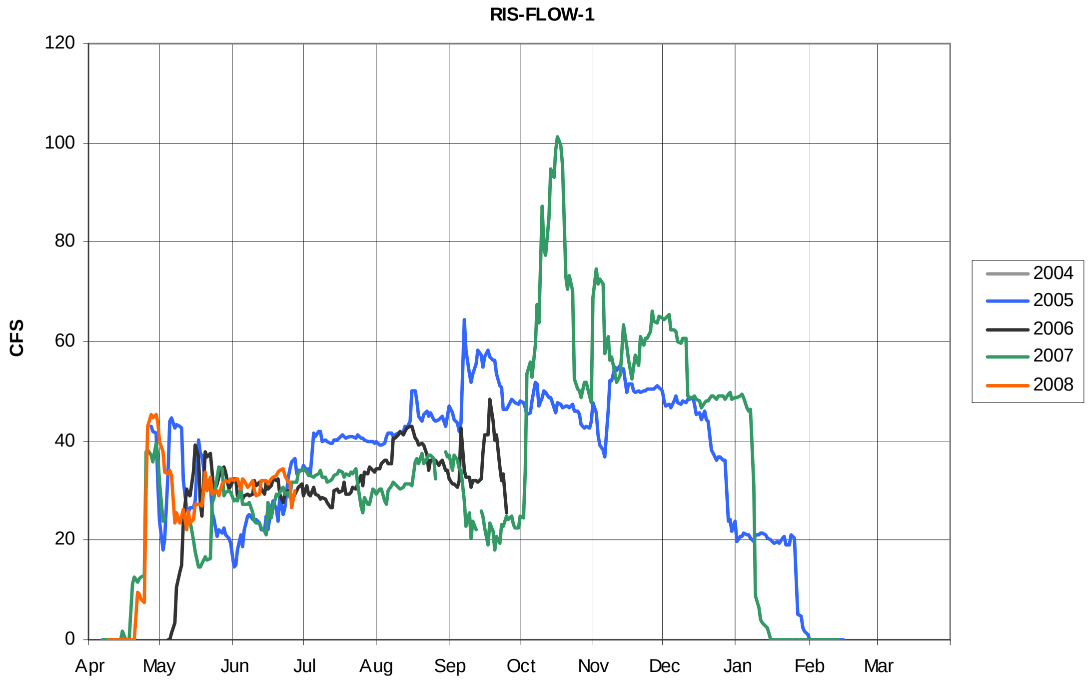


FIGURE A1-11
Canal Flow Summary—RIS-FLOW-1

Attachment A-2
Canal Water Level Data

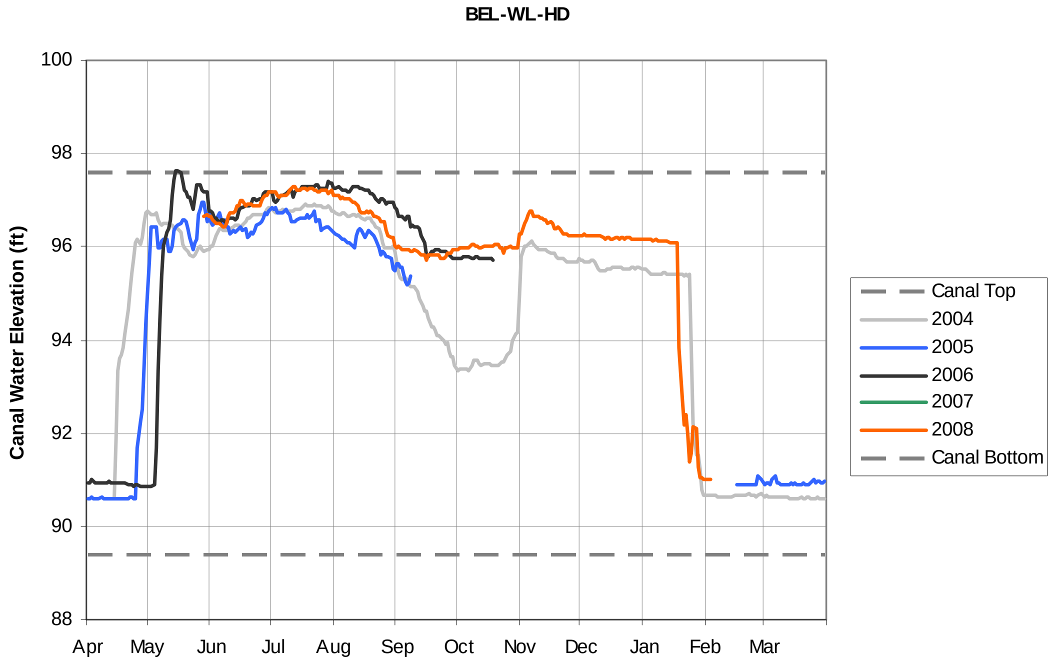


FIGURE A2-1
Belding Canal Water Elevation—BEL-WL-HD

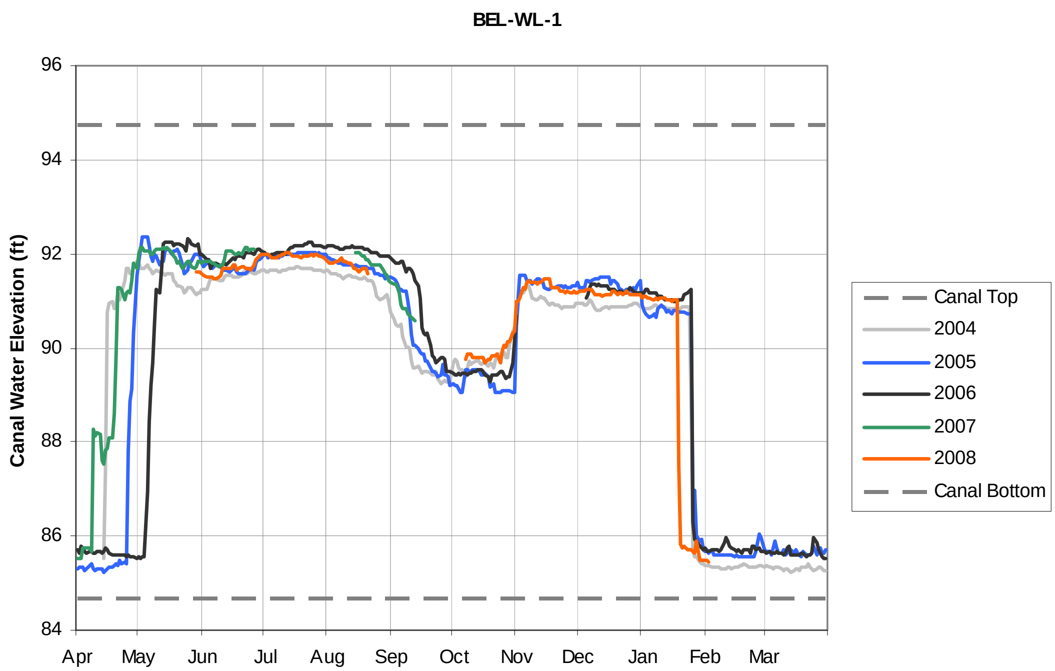


FIGURE A2-2
Belding Canal Water Elevation—BEL-WL-1

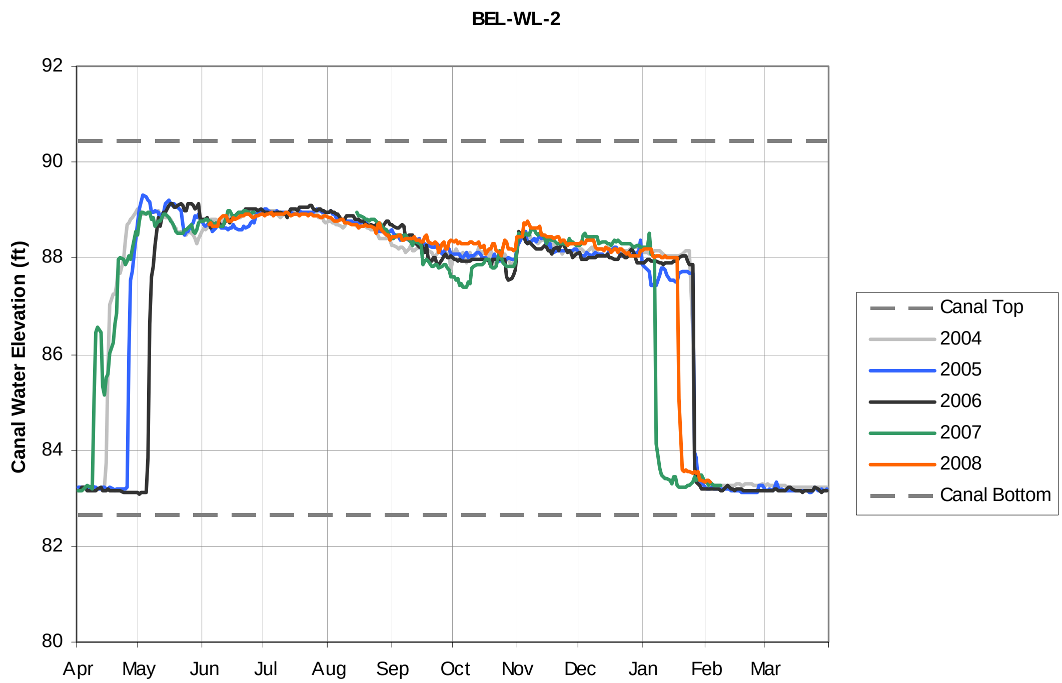


FIGURE A2-3
Belding Canal Water Elevation—BEL-WL-2

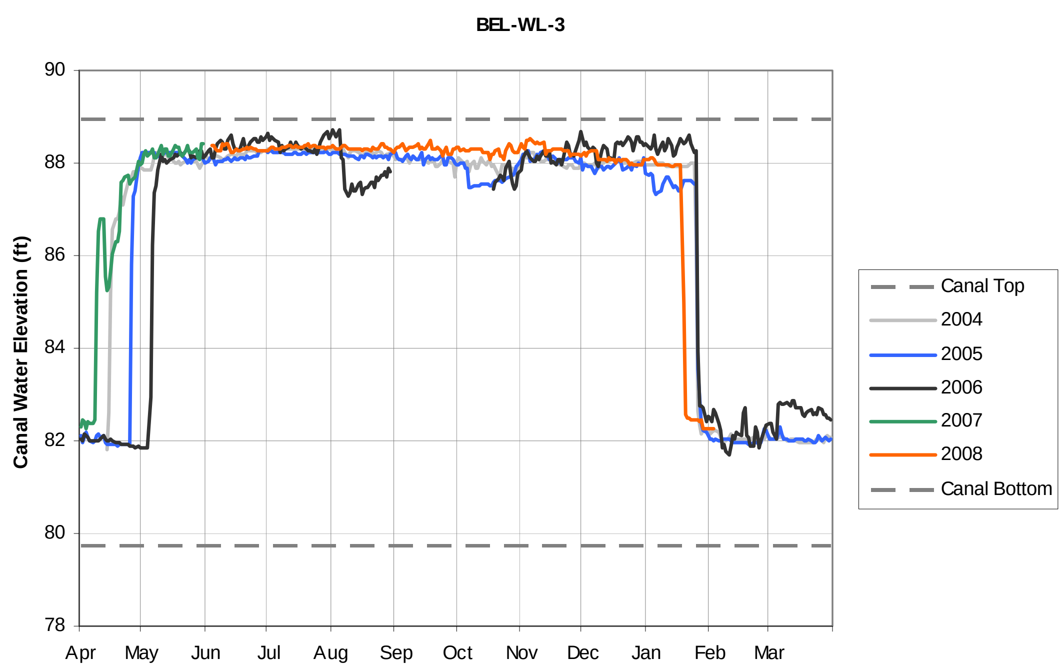


FIGURE A2-4
Belding Canal Water Elevation—BEL-WL-3

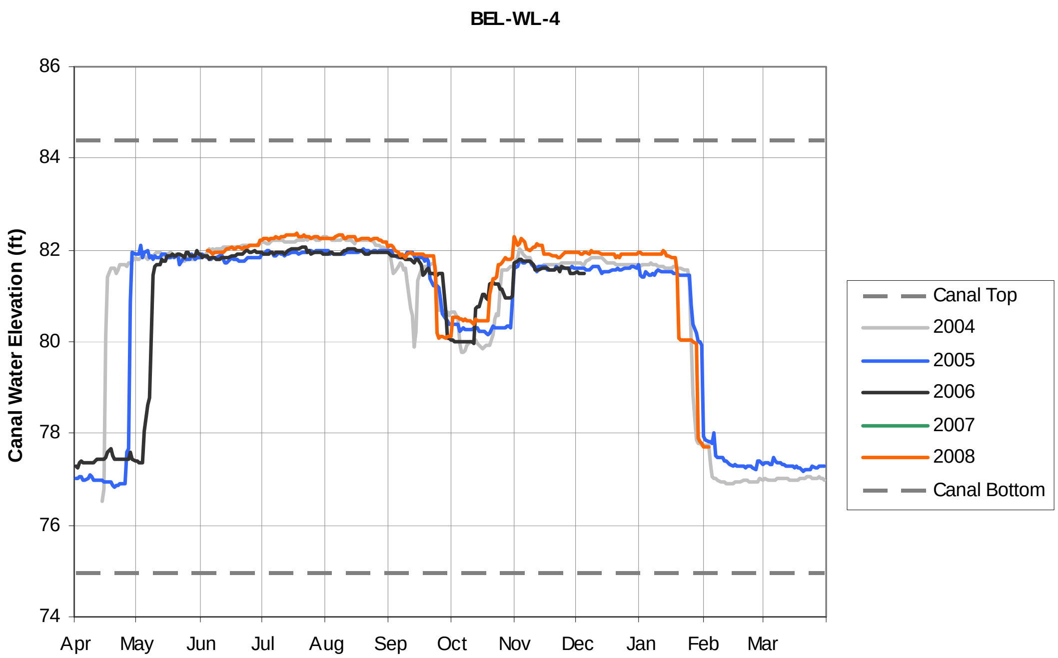


FIGURE A2-5
Belding Canal Water Elevation—BEL-WL-4

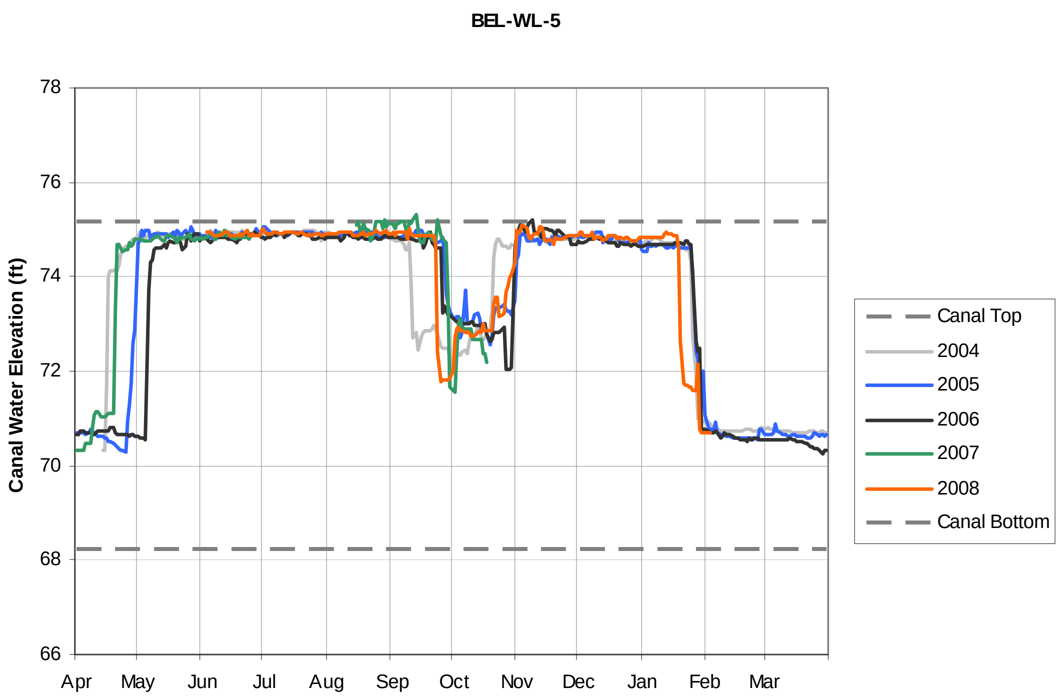


FIGURE A2-6
Belding Canal Water Elevation—BEL-WL-5

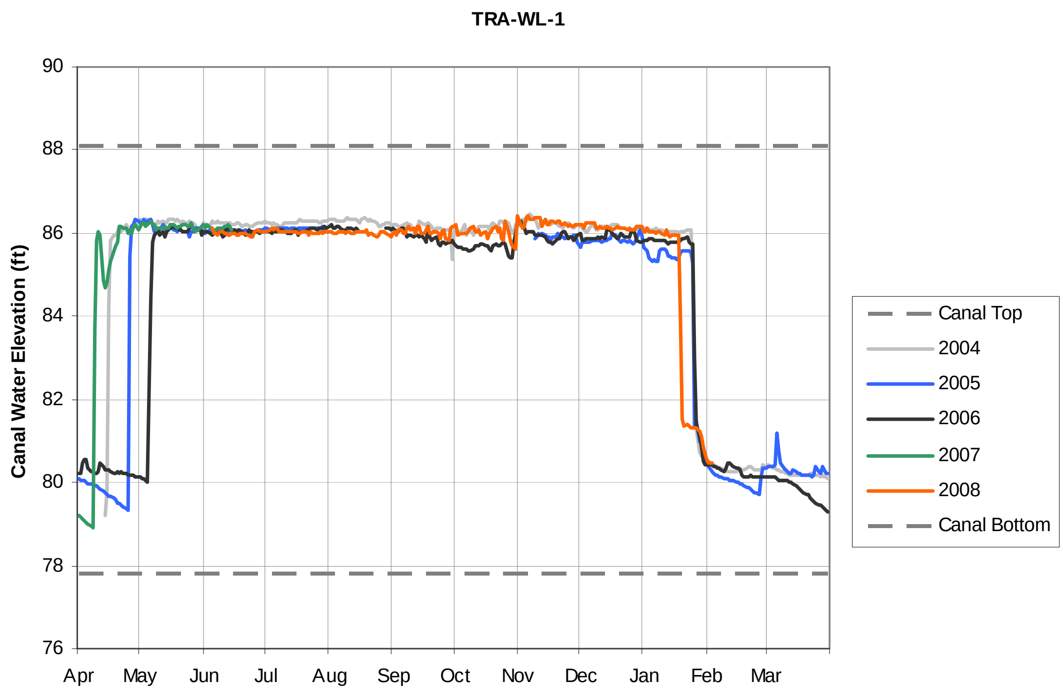


FIGURE A2-7
Traynor Canal Water Elevation—TRA-WL-1

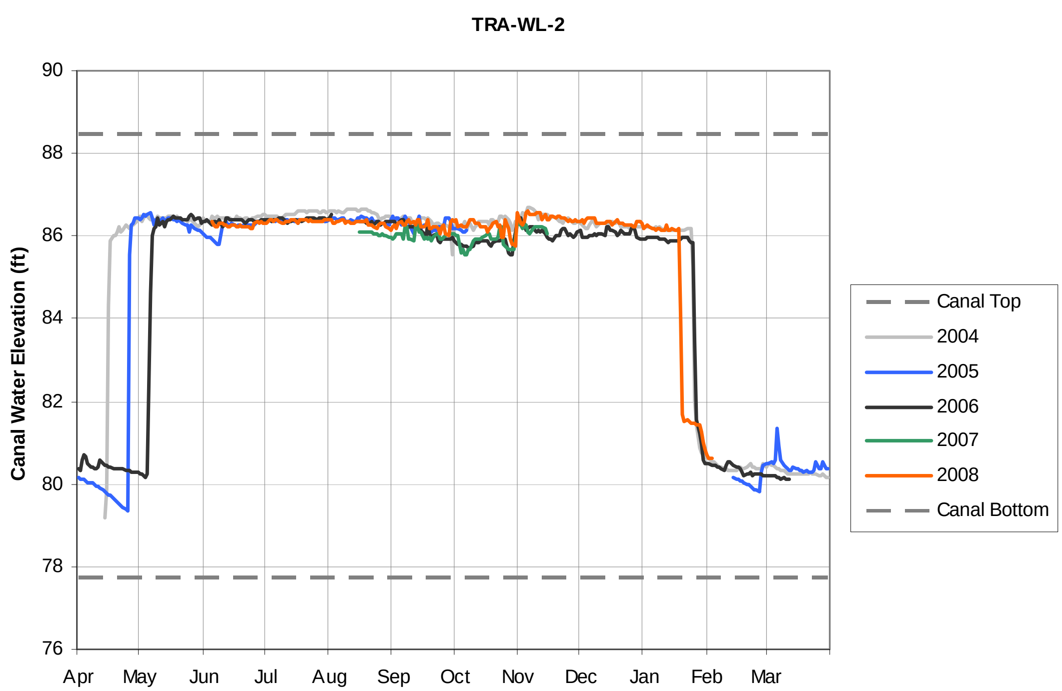


FIGURE A2-8
Traynor Canal Water Elevation—TRA-WL-2

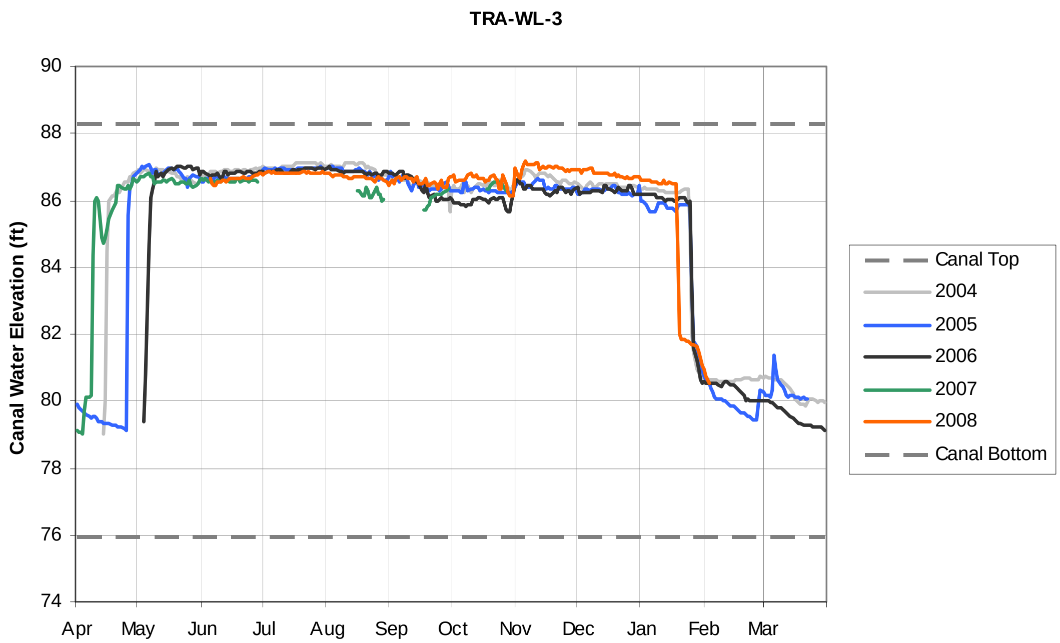


FIGURE A2-9
Traynor Canal Water Elevation—TRA-WL-3

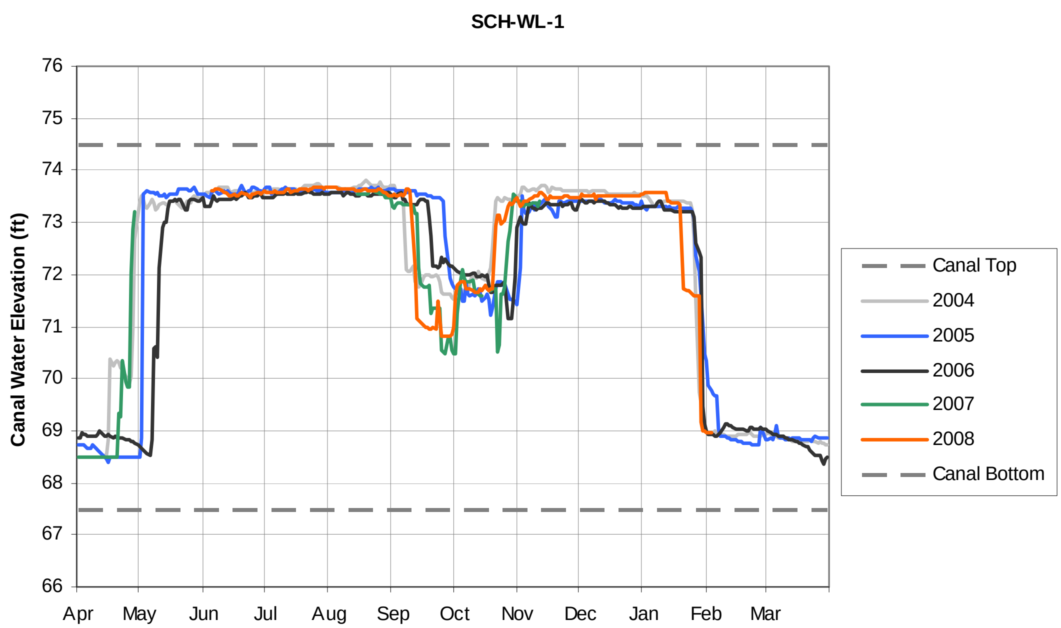


FIGURE A2-10
Schwind Canal Water Elevation—SCH-WL-1

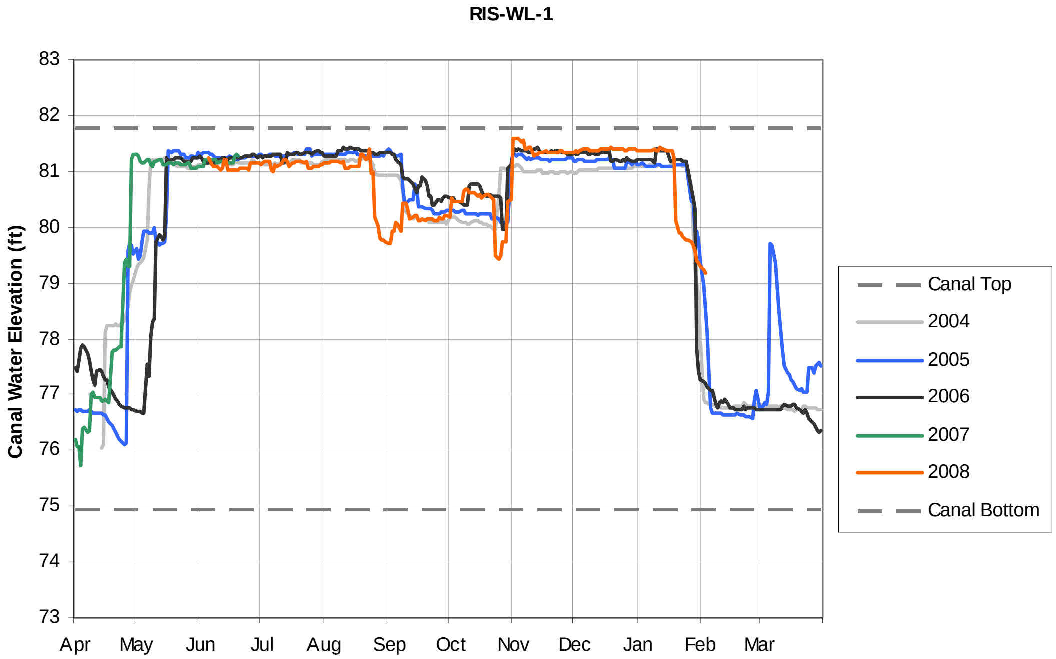


FIGURE A2-11
Rising River Canal River Elevation—RIS-WL-1

Attachment A-3
Canal Stage Date (from Flow Meters)

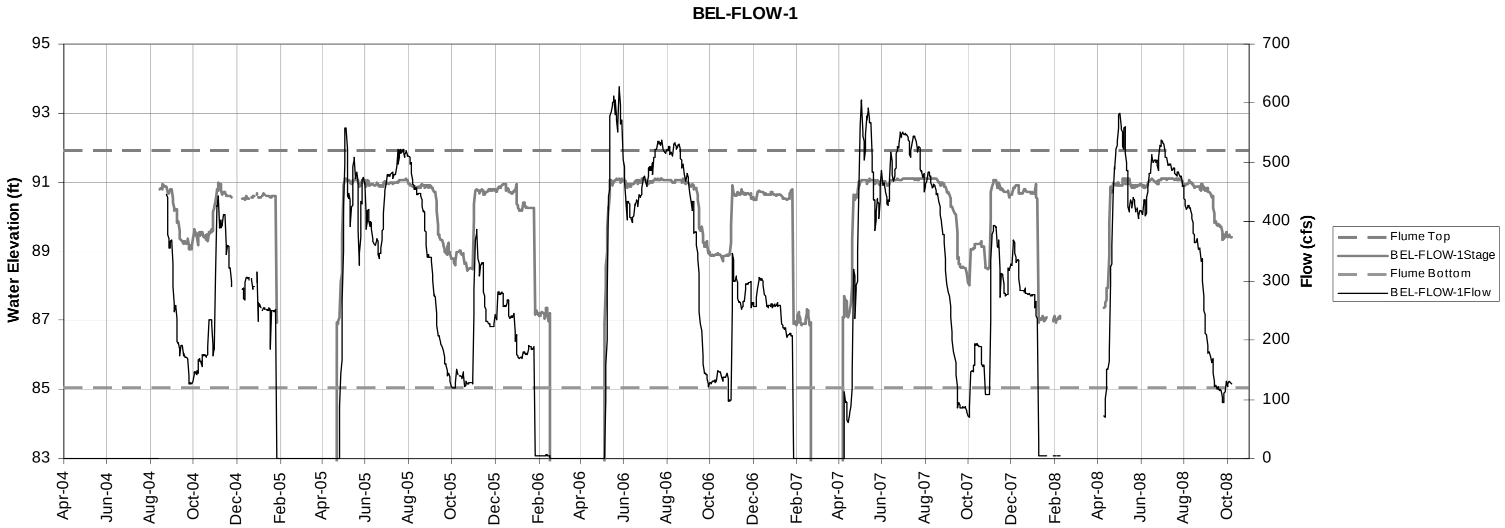


FIGURE A3-1
BEL-FLOW-1 Flow and Stage Data

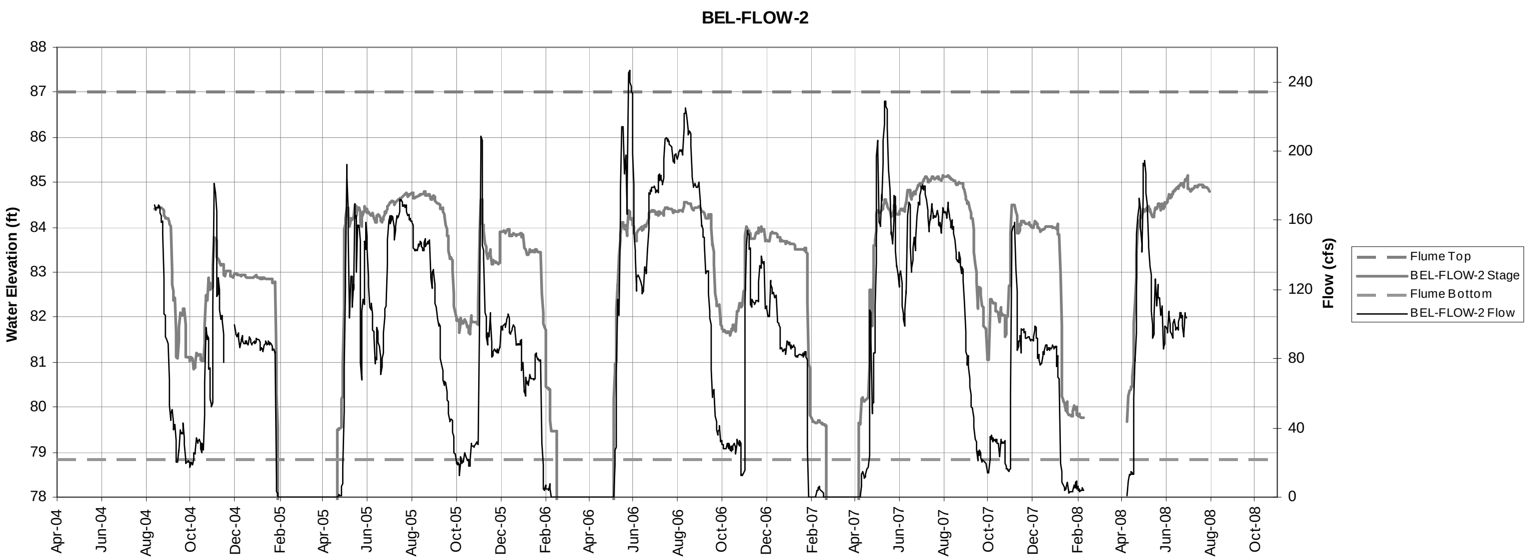


FIGURE A3-2
BEL-FLOW-2 Flow and Stage Data

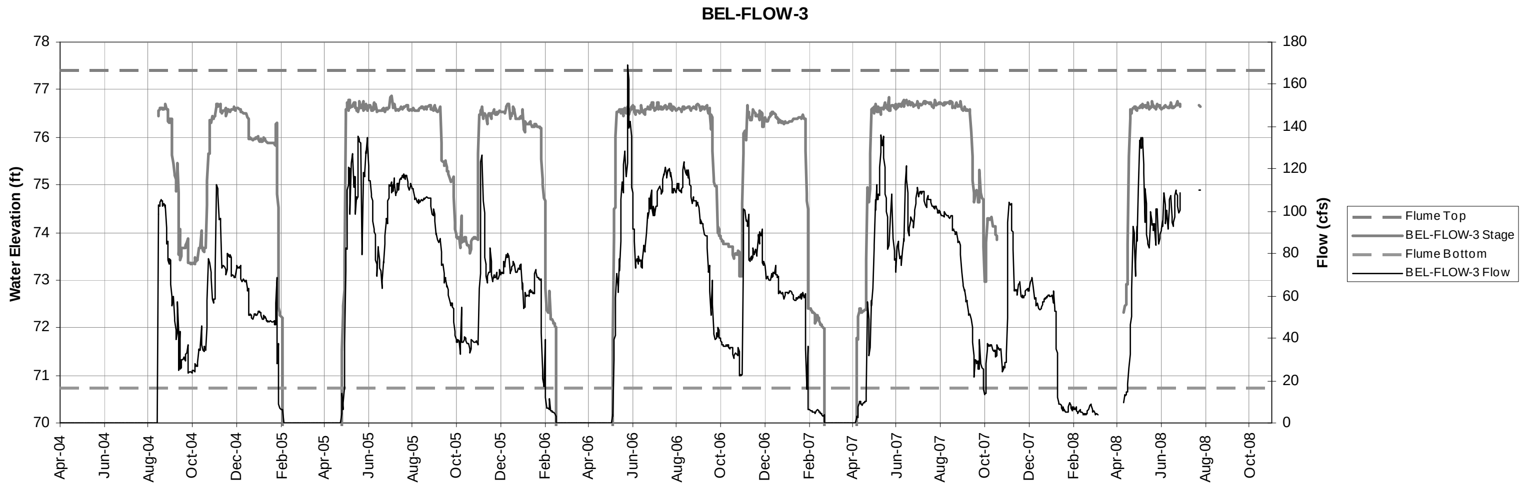


FIGURE A3-3
BEL-FLOW-3 Flow and Stage Data

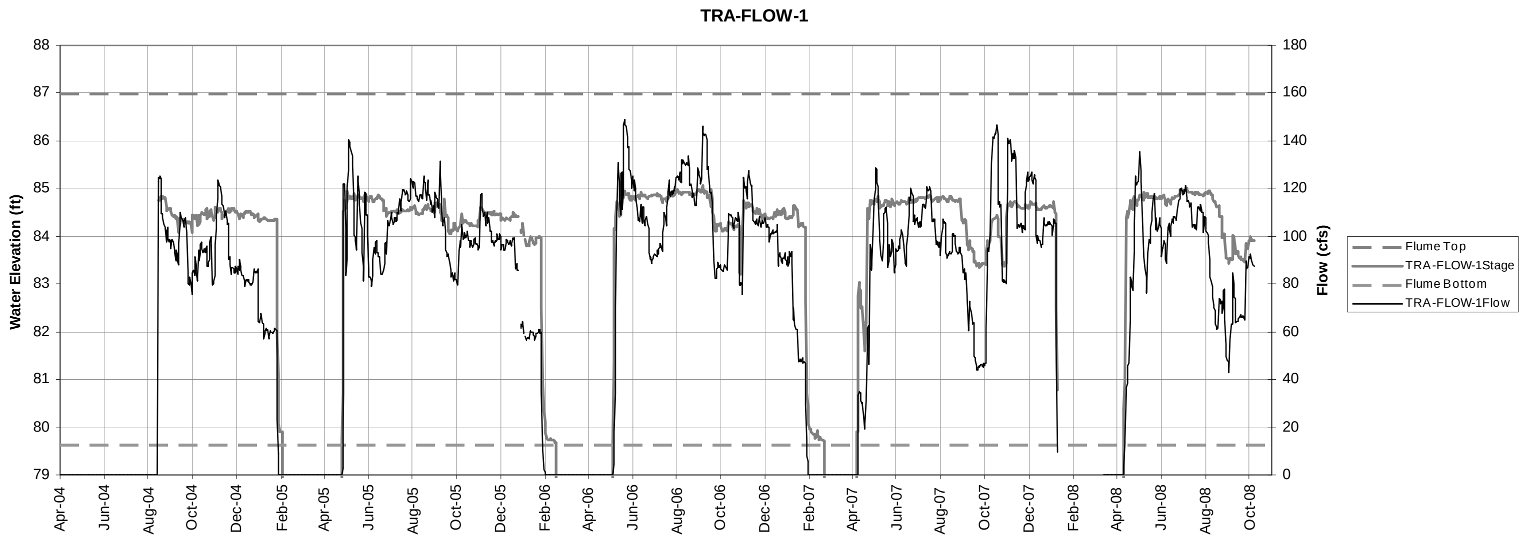


FIGURE A3-4
TRA-FLOW-1 Flow and Stage Data

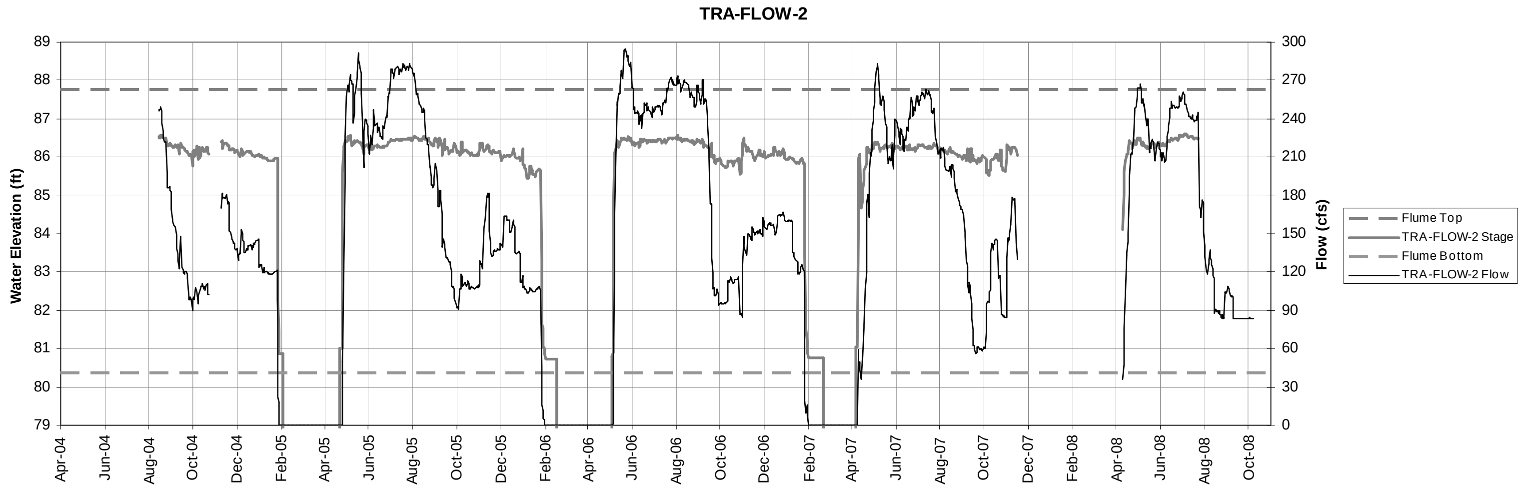


FIGURE A3-5
TRA-FLOW-2 Flow and Stage Data

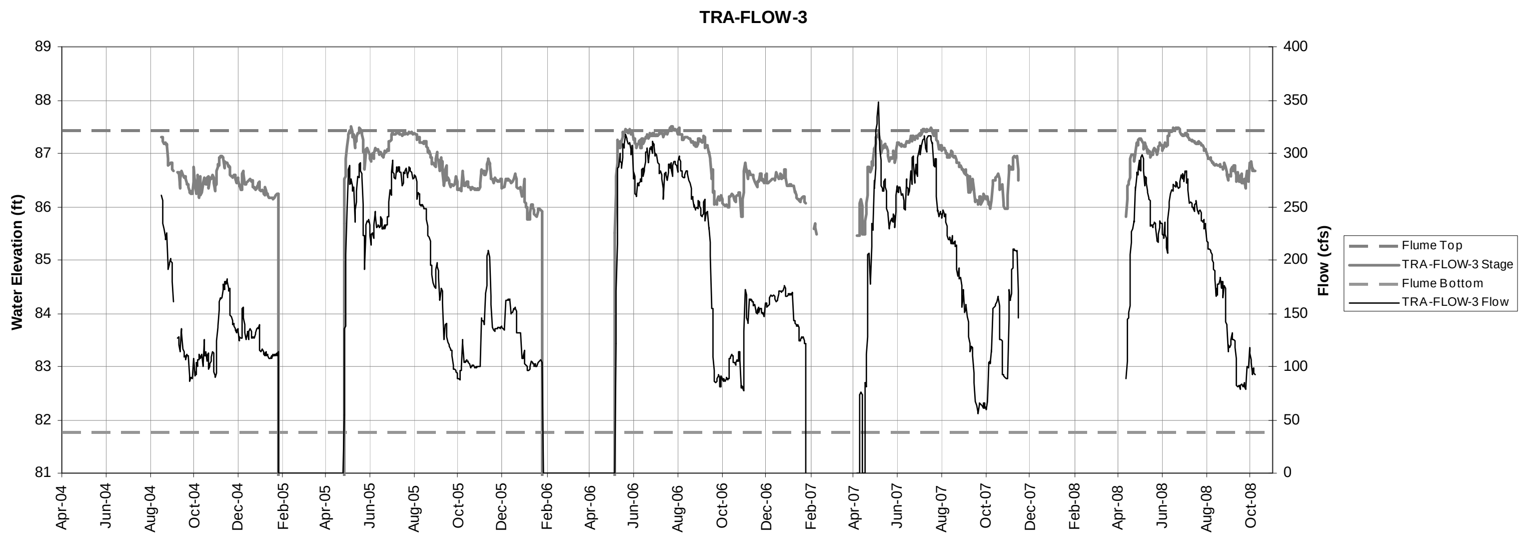


FIGURE A3-6
TRA-FLOW-3 Flow and Stage Data

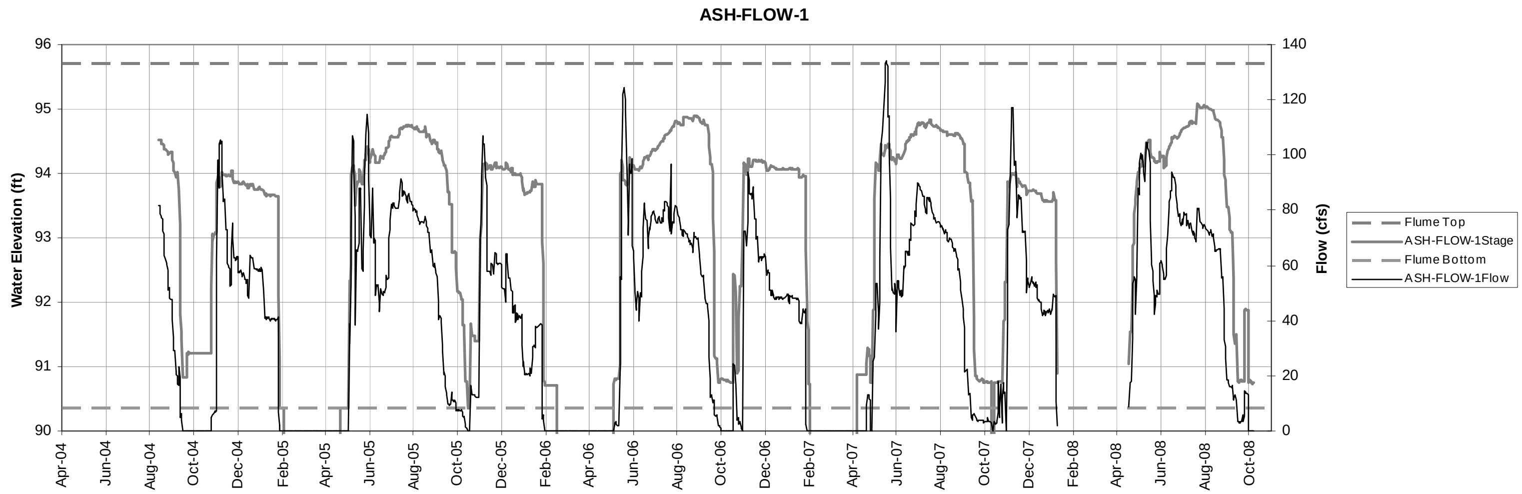


FIGURE A3-7
ASH-FLOW-1 Flow and Stage Data

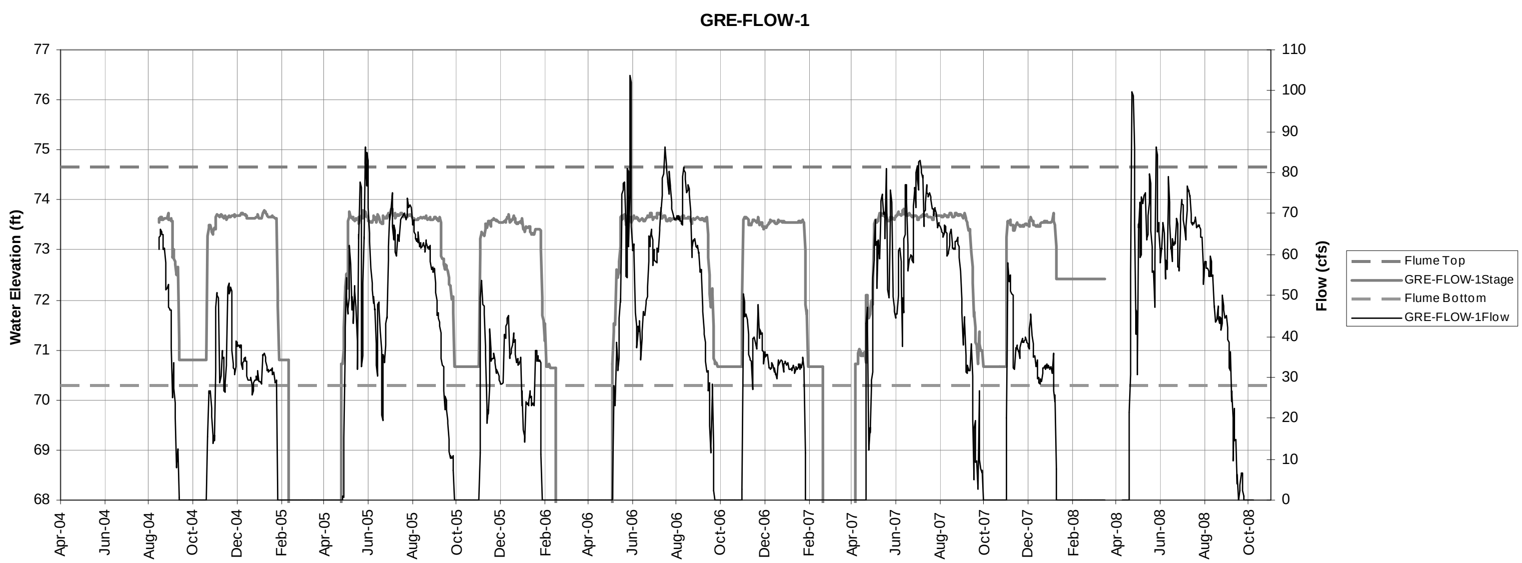


FIGURE A3-8
GRE-FLOW-1 Flow and Stage Data

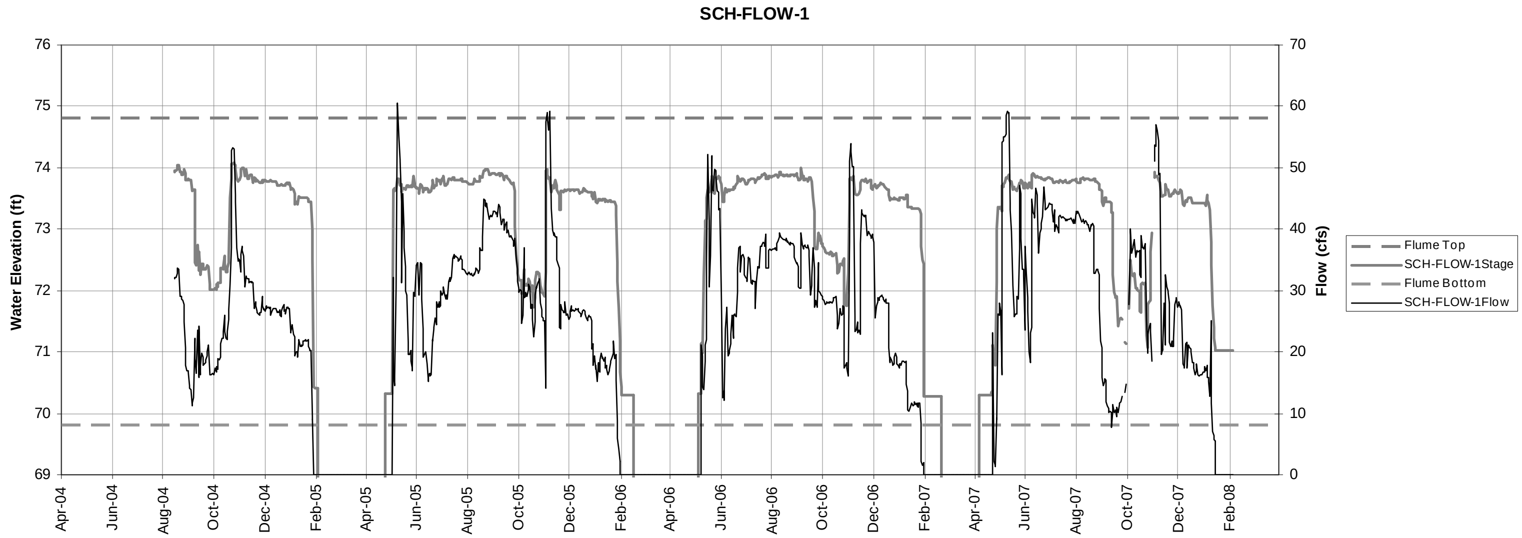


FIGURE A3-9
SCH-FLOW-1 Flow and Stage Data

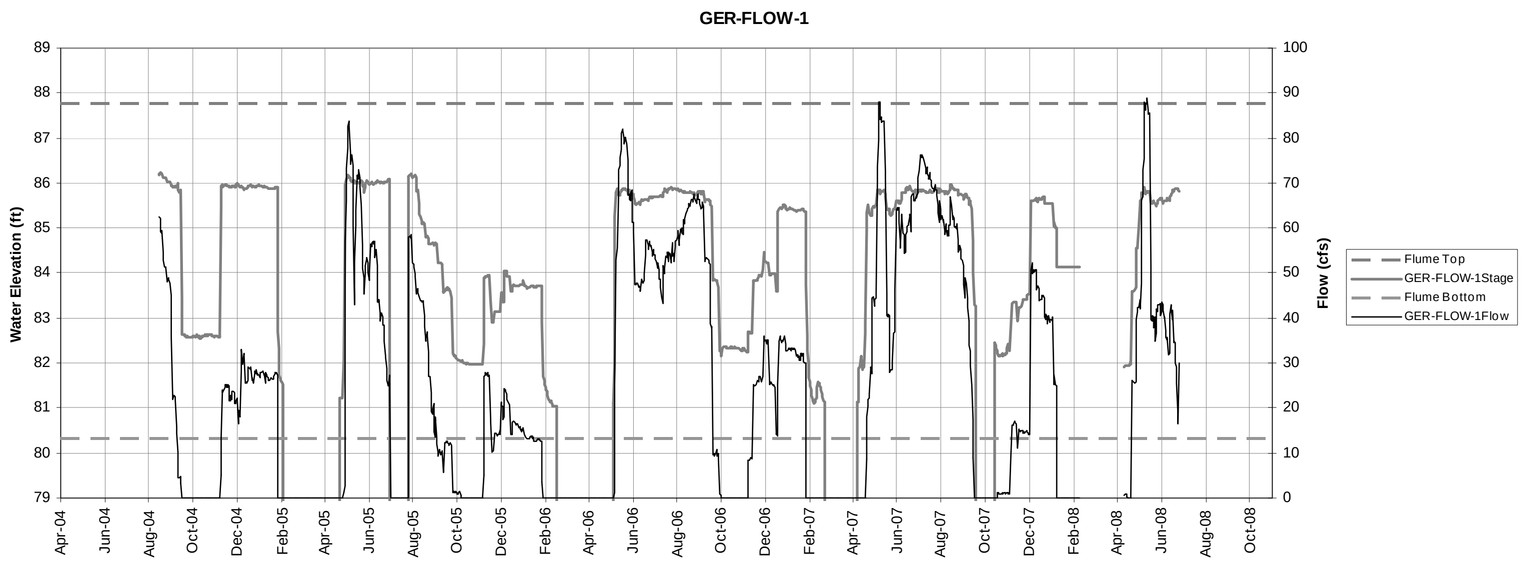


FIGURE A3-10
GER-FLOW-1 Flow and Stage Data

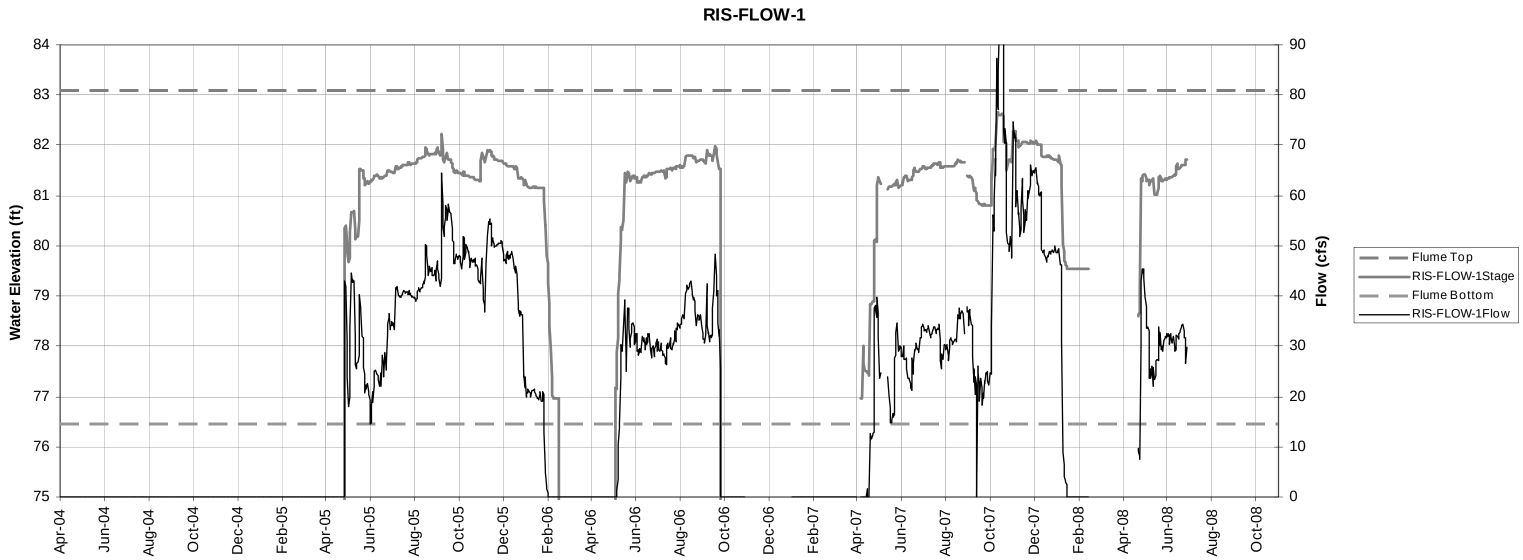
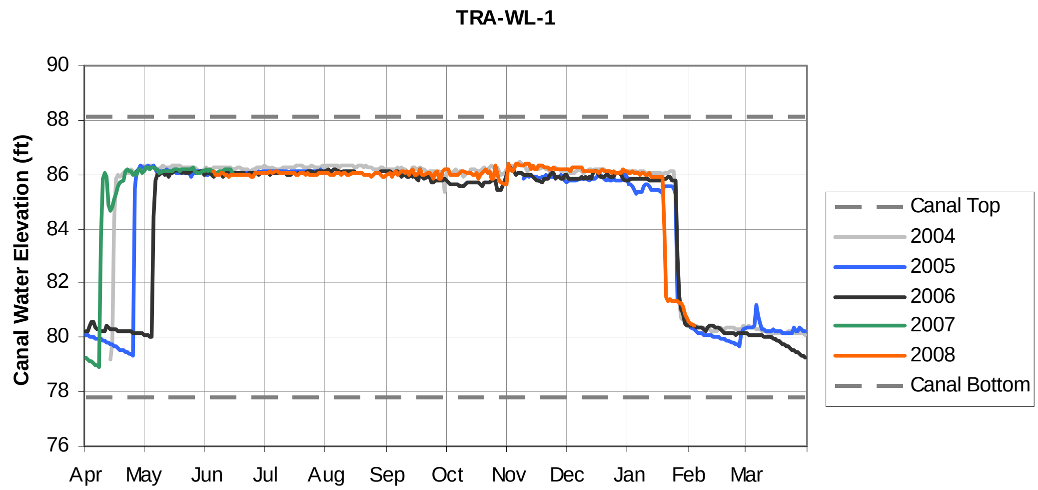
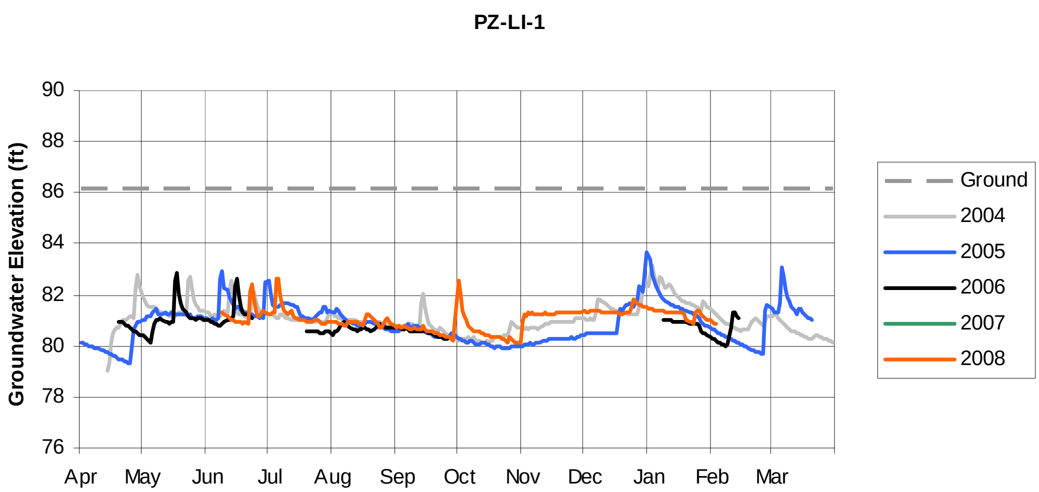
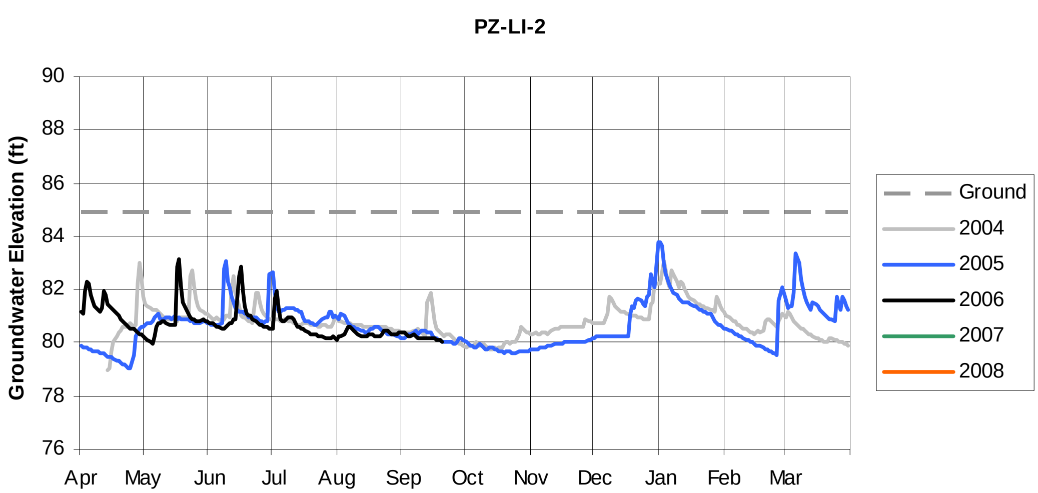


FIGURE A3-11
RIS-FLOW-1 Flow and Stage Data

Attachment A-4
Groundwater Level Data with Corresponding Canal Water Levels

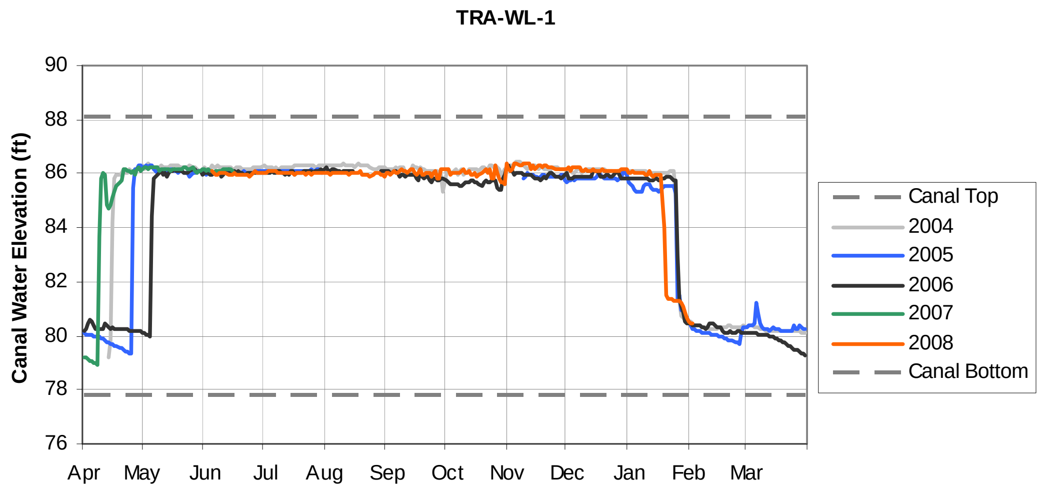


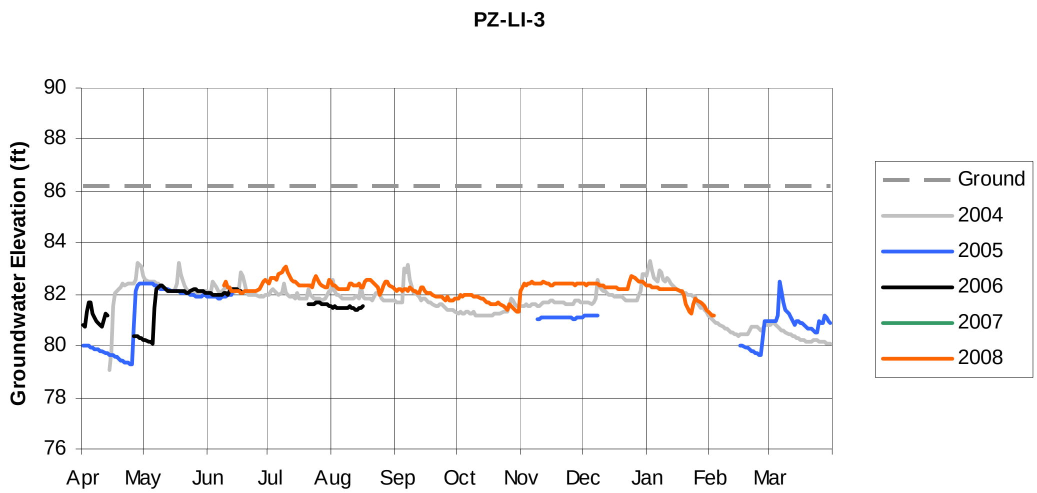




Note: PVC casing w as damaged in September 2007, resulting in w ell blockage. Sensor w as not replaced in 2008.

FIGURE A4-1
Canal Water Levels (TRA-WL-1) and Corresponding Shallow Wells (PZ-LI-1 and PZ-LI-2)





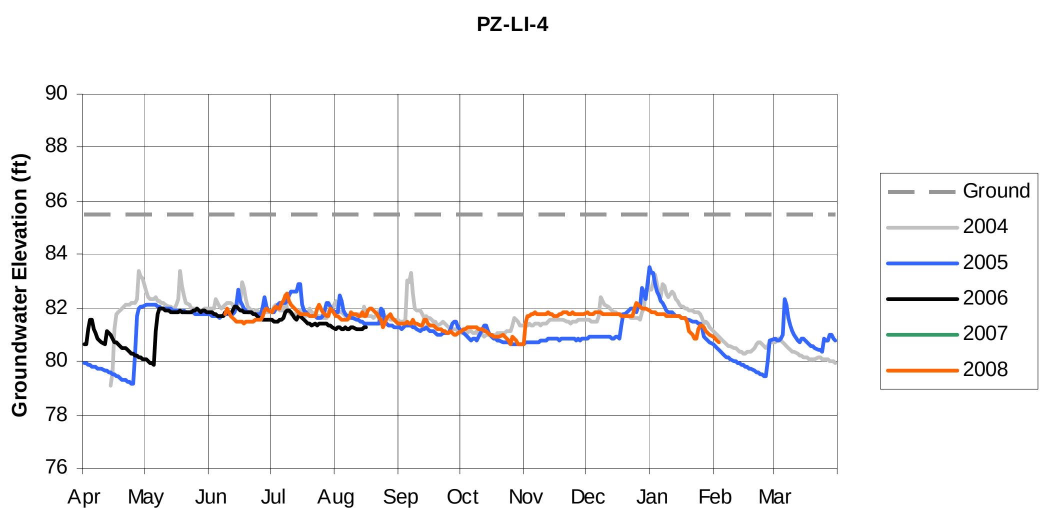
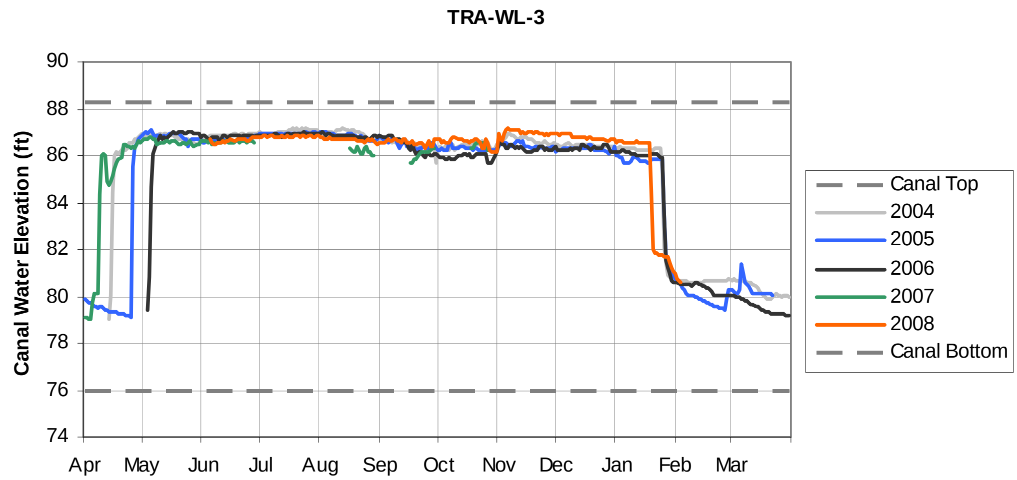
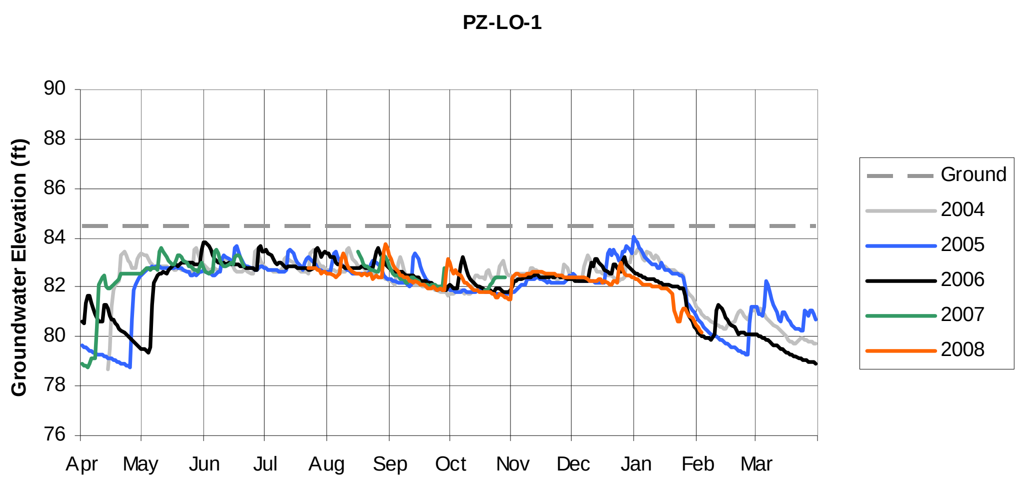


FIGURE A4-2
Canal Water Levels (TRA-WL-1) and Corresponding Shallow Wells (PZ-LI-3 and PZ-LI-4)





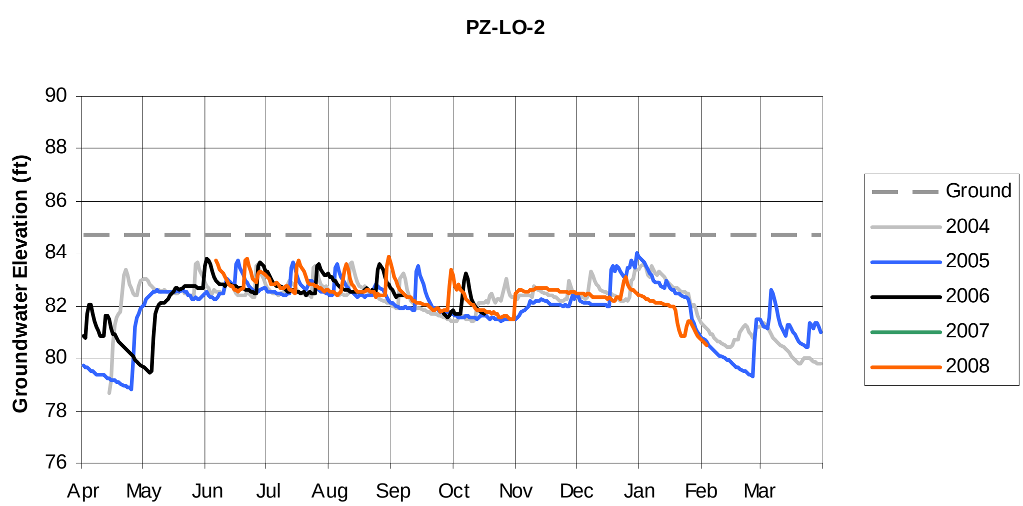
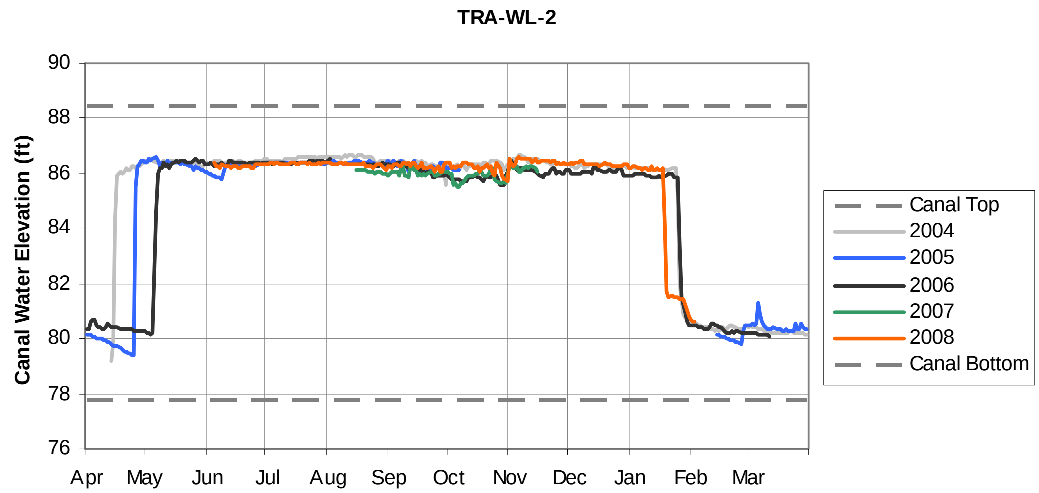
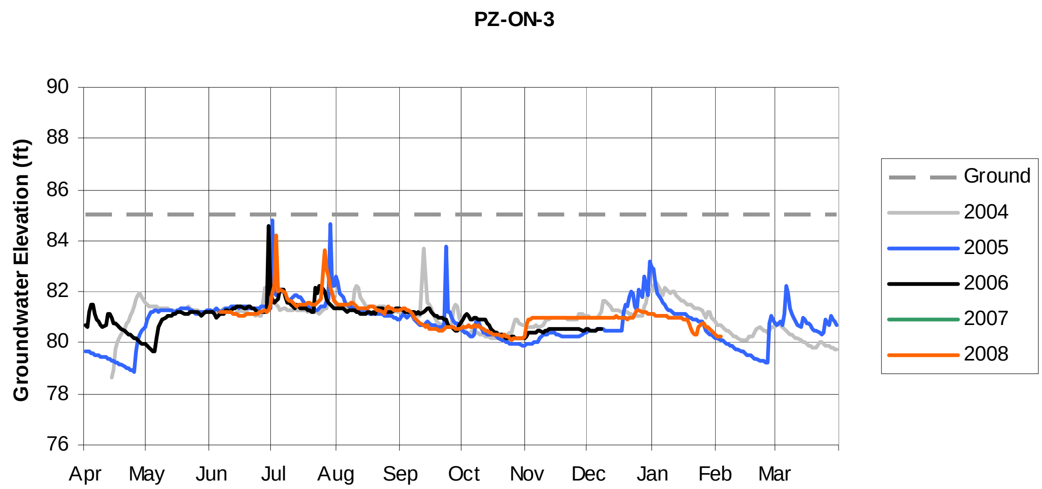


FIGURE A4-3
Canal Water Levels (TRA-WL-3) and Corresponding Shallow Wells (PZ-LO-1 and PZ-LO-2)





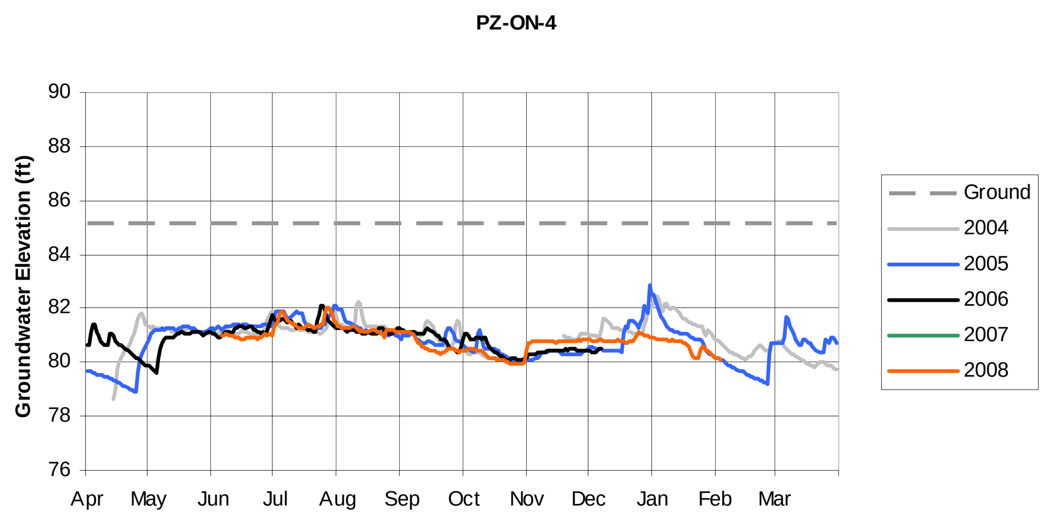
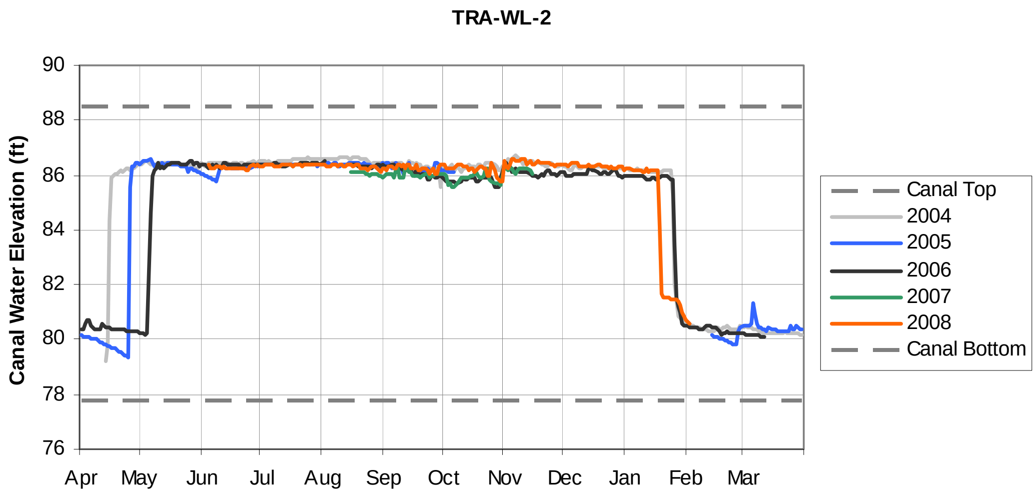
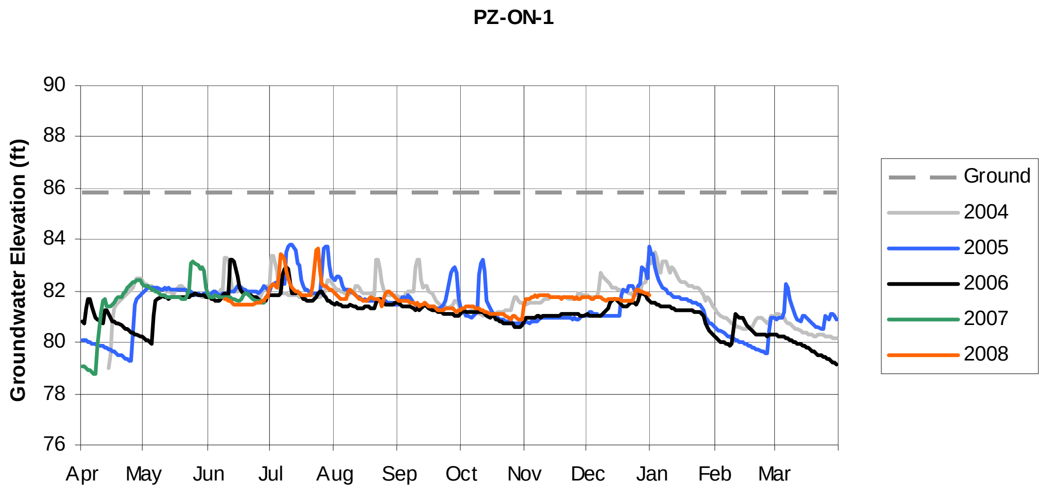


FIGURE A4-4
Canal Water Levels (TRA-WL-2) and Corresponding Shallow Wells (PZ-ON-1 and PZ-ON-2)





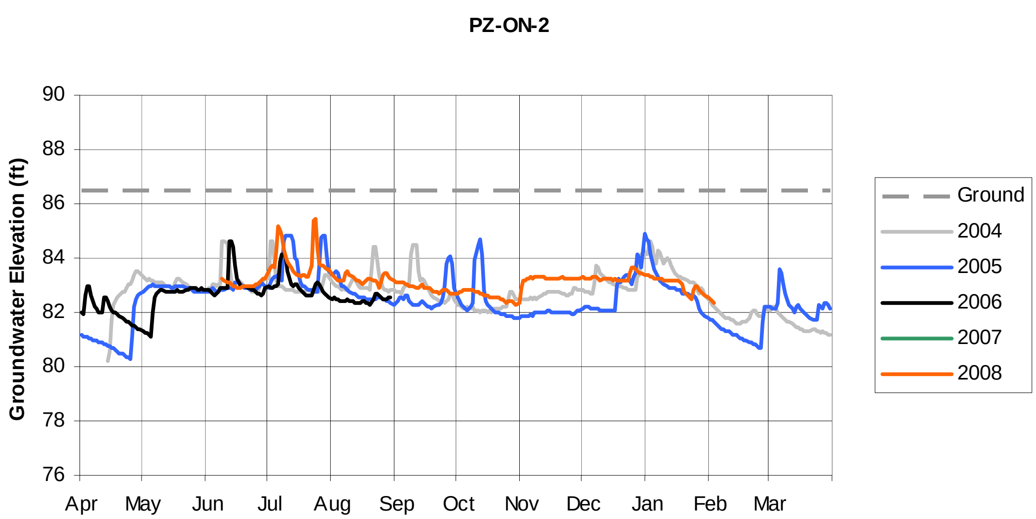
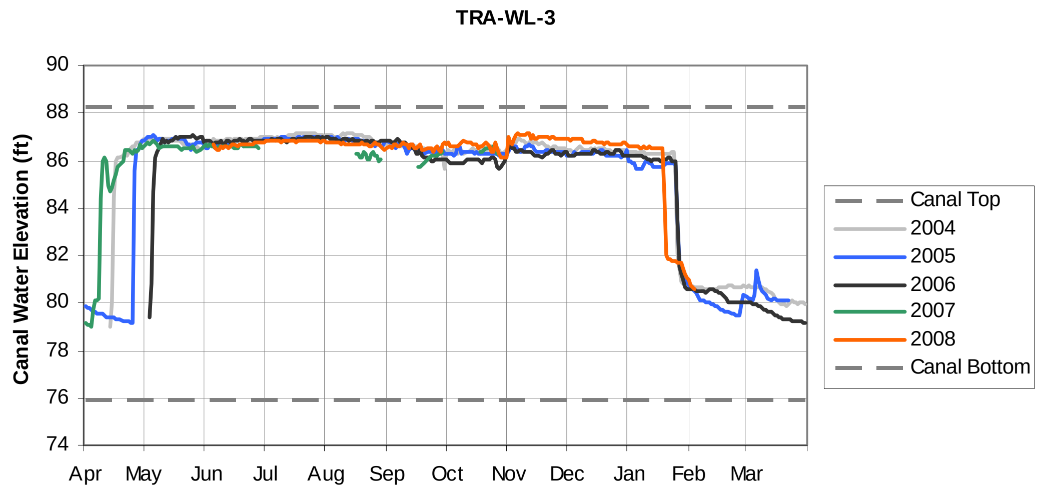
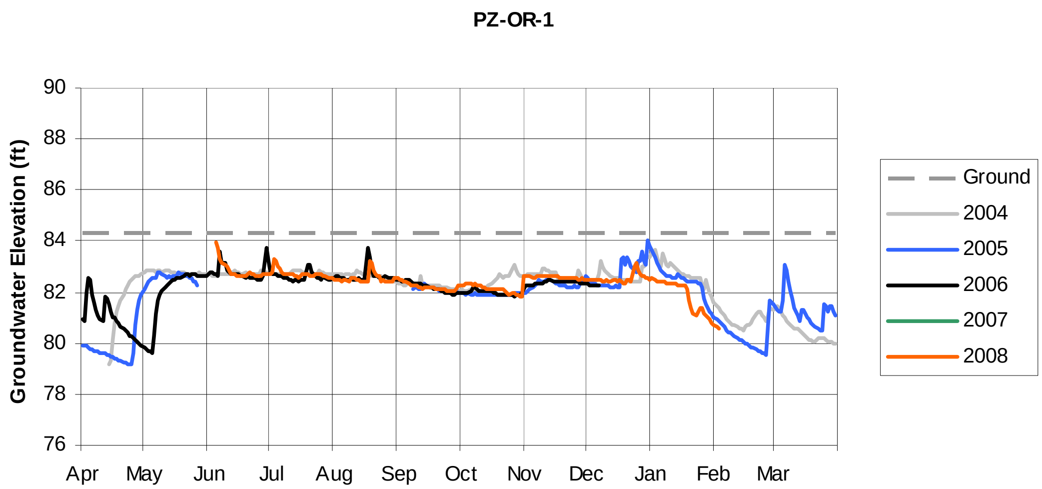


FIGURE A4-5
Canal Water Levels (TRA-WL-2) and Corresponding Shallow Wells (PZ-ON-3 and PZ-ON-4)





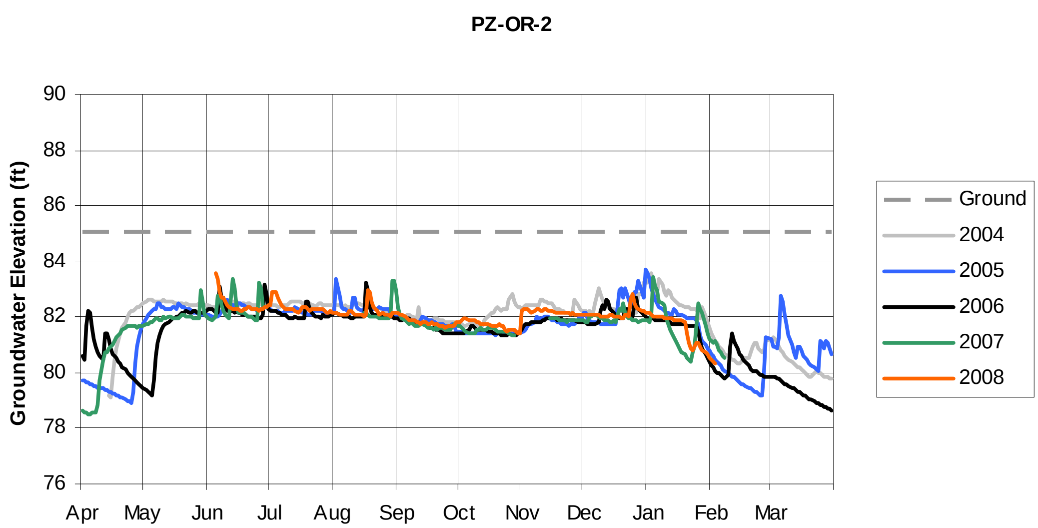
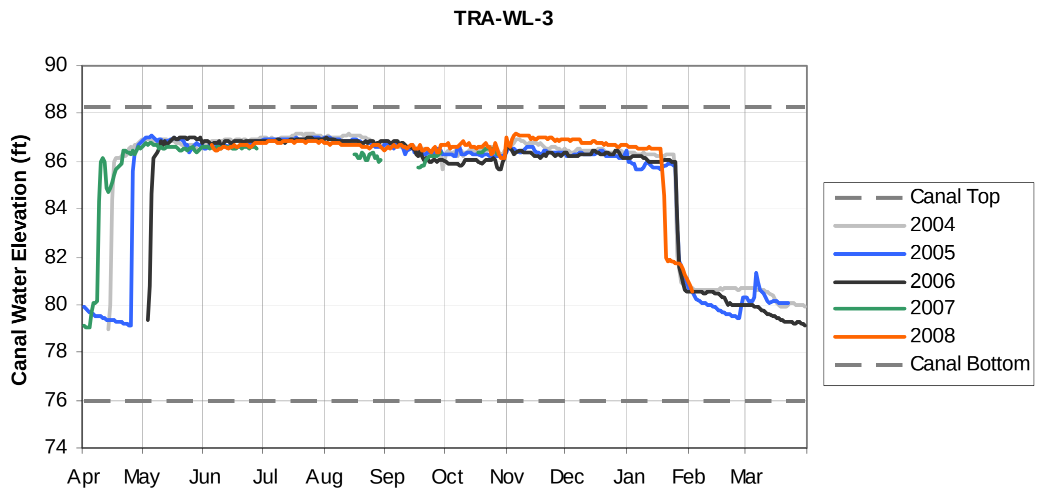
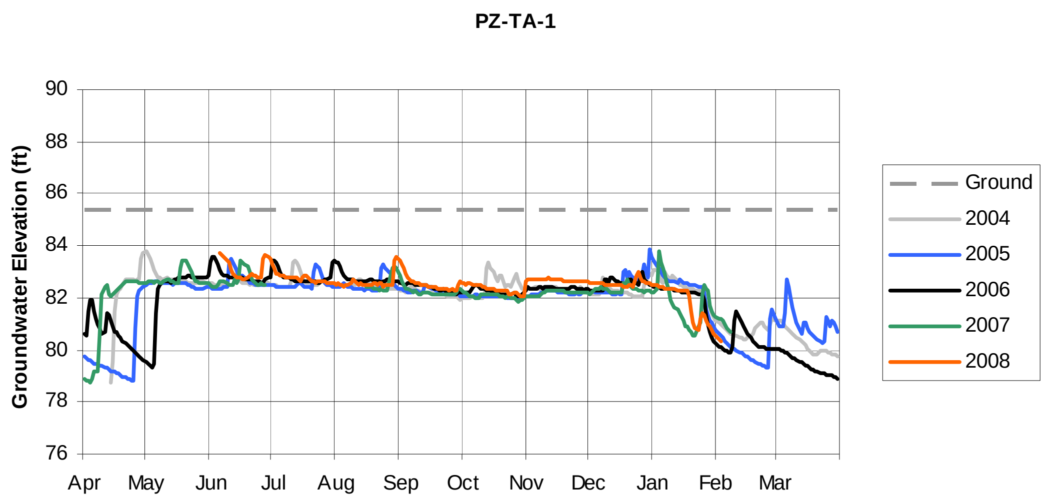


FIGURE A4-6
Canal Water Levels (TRA-WL-2) and Corresponding Shallow Wells (PZ-OR-1 and PZ-OR-2)





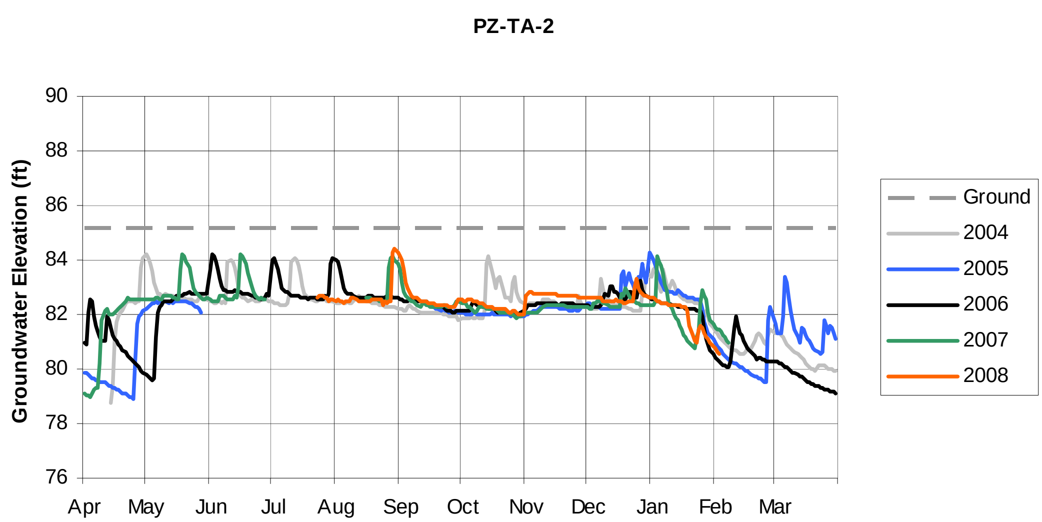


FIGURE A4-7
Canal Water Levels (TRA-WL-3) and Corresponding Shallow Wells (PZ-TA-1 and PZ-TA-2)

Attachment A-5
Boring Logs from Well Installation

PROJECT NUMBER:	BORING NUMBER: LI-1 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers
LOCATION : 375 feet North of West Liberty at Traynor Lateral

ELEVATION : NA
DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 5.6 ft below ground surface
START : 4/7/04 10:45
END : 4/7/04 11:42
LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					SANDY LEAN CLAY (CL), light brown, dry, very stiff	
					Similar, brown, moist	
5	5.0 - 6.5	1.5	1-SS	3-4-10 (14)	SANDY LEAN CLAY/CLAYEY SAND (CL/SC), orangish brown, moist, stiff, 90% of the sand fine grained	11:04
						Estimate first hit water
10	10.0 - 11.5	1.5	2-SS	3-14-15 (29)	Top 8": CLAYEY SAND (SC), orangish brown, wet, medium dense Middle 6": WELL GRADED SAND/CLAYEY SAND (SW/SC), orangish brown, wet, medium dense, well graded Bottom 4": LEAN CLAY (CL), gray with brown spots, moist, hard	11:16 6" sand Driller notes hard and firm layers at 11'-14'
15	14.0 - 15.5	1.5	3-SS	5-11-19 (30)	LEAN CLAY (CL), gray with brown spots, moist, hard, 14' - 14.8' CLAYEY SAND (SC), brown, wet, dense, fine grained, 14.8' - 15.5'	11:42 begin well
					Bottom of Hole at 15.5 ft below ground surface 4/7/04 11:42	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: LI-2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers LOCATION : 375 feet North of West Liberty at Traynor Lateral

ELEVATION : NA DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 5.4 ft below ground surface START : 4/7/04 17:21 END : 4/7/04 18:21 LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
					SANDY LEAN CLAY (CL), light brown, dry, hard	17:21
					Similar, moist, stiff	
5	5.0				Similar, more moisture	
	5.0–6.5	1.5	1-SS	5-3-5 (8)	CLAYEY SAND (SC), brown, wet, loose, medium to fine grained	Likely water table, sample wet
10	10.0–11.5	1.5	2-SS	8-15-24 (39)	Top 12": WELL GRADED SAND/CLAYEY SAND (SW/SC), brown and orange brown, wet, dense, well graded Bottom 6": LEAN CLAY (CL), gray with brown sand, moist, hard	17:50
15	14.0–15.5	1.5	3-SS	6-16-24 (40)	SANDY LEAN CLAY (CL), gray with brown bands, wet, hard, fine sand	18:21
					Bottom of Hole at 15.5 ft below ground surface 4/7/04 18:21	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: LI-3 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers

LOCATION : 1300 feet North of W. Liberty, S. of Traynor Lateral

ELEVATION : NA

DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 6.2 ft below ground surface

START : 4/8/04 09:14

END : 4/8/04 10:04

LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5					
		1.2	1-SS	2-1-1 (2)	CLAYEY SAND (SC), brown, moist, very loose, well graded	
	4.0					
5	5.0					
		1.0	2-SS	2-2-2 (4)	WELL GRADED SAND/CLAYEY SAND (SW/SC), orange brown, moist to wet, very loose	9:25
	6.5					
10	10.0					
		0.8	3-SS	1-2-5 (7)	WELL GRADED SAND (SW), brown, wet, loose, well graded, with small gravel	9:50
	11.5					
	14.0					
15		1.5	4-SS	5-5-10 (15)	SANDY LEAN CLAY/LEAN CLAY (CL), gray with orange stains, moist, stiff	10:04
	15.5					
					Bottom of Hole at 15.5 ft below ground surface 4/8/04 10:04	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: LI-4 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers
LOCATION : 1300 feet North of W. Liberty and Traynor Lateral
ELEVATION : NA
DRILLING CONTRACTOR : Taber
DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer
WATER LEVELS : 5.8 ft below ground surface
START : 4/8/04 11:50
END : 4/8/04 12:35
LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 – 4.0	1.7	1-SS	2-2-2 (4)	SANDY LEAN CLAY/CLAYEY SAND (CL/SC), orange brown, moist, soft	
5	5.0 – 6.5	0.3	2-SS	1-1-1 (2)	CLAYEY SAND (SC), orange brown, wet, very loose, well graded	11:59
10	10.0 – 11.5	0.7	3-SS	1-2-5 (7)	POORLY GRADED SAND (SP), grayish blue, wet, loose, fine and medium grained	12:10 - Sand flows into casing Catcher used
15	14.0 – 15.5	1.5	4-SS	5-7-19 (26)	CLAYEY SAND/SANDY LEAN CLAY (SC/CL), light brown, wet, medium dense	12:35
					Bottom of Hole at 15.5 ft below ground surface 4/8/04 12:35	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: LO-1 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers LOCATION :

ELEVATION : NA DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 5.6 ft below ground surface START : 4/9/2004 END : 4/9/04 18:00 LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5					
	4.0	1.5	1-SS	3-7-13 (20)	FAT CLAY (CH), brown, moist, very stiff, roots to 3'	
5	5.0					
	6.5	1.5	2-SS	1-12-15 (27)	SILTY CLAY WITH SAND (CL-ML), brown, moist, very stiff	
10	10.0					
	11.5	1.5	3-SS	5-10-12 (22)	SANDY LEAN CLAY (CL), light brown with orange spots, moist, very stiff	
	14.0					
15	15.5	1.5	4-SS	6-10-19 (29)	LEAN CLAY (CL), light brown with orange and black spots, moist, very stiff	18:00
					Bottom of Hole at 15.5 ft below ground surface 4/9/04 18:00	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: LO-2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers
LOCATION :
ELEVATION : NA
DRILLING CONTRACTOR : Taber
DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer
WATER LEVELS : 5.3 ft below ground surface
START : 4/9/04 17:19
END : 4/9/04 17:56
LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5					
	4.0	1.5	1-SS	10-11-11 (22)	CLAYEY SAND (SC), brown, moist, medium dense, fine grained	
5	5.0					
	6.5	1.5	2-SS	4-8-16 (24)	SANDY LEAN CLAY/LEAN CLAY (CL), orange brown with light brown spots, moist, very stiff	
10	10.0					
	11.5	1.5	3-SS	15-18-23 (41)	CLAYEY SAND/SANDY LEAN CLAY (SC/CL), light brown with orange, wet, hard, layers of each 1" to 8" thick	
	14.0					
15	15.5	1.5	4-SS	9-13-23 (36)	LEAN CLAY (CL), light brown with orange and black spots, moist, hard	17:56
					Bottom of Hole at 15.5 ft below ground surface 4/9/04 17:56	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: ON-1 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers

LOCATION :

ELEVATION : NA

DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 5.7 ft below ground surface

START : 4/9/04 09:37

END : 4/9/04 10:23

LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 – 4.0	1.2	1-SS	4-5-6 (11)	CLAYEY SILT (ML), light brown with orange stains, moist, stiff	
5	5.0 – 6.5	1.5	2-SS	7-11-16 (27)	Similar, very stiff	
10	10.0 – 11.5	1.5	3-SS	6-10-16 (26)	CLAYEY SAND (SC), light brown, wet, medium dense	10:03
15	14.0 – 15.5	1.5	4-SS	10-13-22 (35)	SANDY LEAN CLAY/CLAYEY SAND (CL/SC), light orange brown, wet, dense, fine sand	10:23
					Bottom of Hole at 15.5 ft below ground surface 4/9/04 10:23	
20						
25						
30						

CH2MHILL	PROJECT NUMBER:	BORING NUMBER: ON-2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers   LOCATION :

ELEVATION : NA   DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 5.7 ft below ground surface   START : 4/9/04 09:40   END : 4/9/04 10:30   LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 4.0	1.0	1-SS	2-4-11 (15)	SANDY SILT (ML), light brown, moist, stiff, fine sand	Catcher used
5	5.0 6.5	1.5	2-SS	12-20-16 (36)	WELL GRADED SAND (SW), gray and blue, moist, dense	Catcher used
10	10.0 11.5	1.2	3-SS	5-10-32 (42)	LEAN CLAY (CL), gray with orange stains, wet, hard	10:00 sand heaving some into auger Catcher used
15	14.0 15.5	1.5	4-SS	19-32-48 (80)	Similar, orange brown with light brown stains	10:30
					Bottom of Hole at 15.5 ft below ground surface 4/9/04 10:30	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: ON-3 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers | LOCATION :

ELEVATION : NA | DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 4.5 ft below ground surface | START : 4/9/2004 | END : 4/9/04 12:40 | LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 – 4.0	1.5	1-SS	10-13-20 (33)	LEAN CLAY/SANDY LEAN CLAY (CL), very light brown and orange brown, dry , hard	
5	5.0 – 6.5	1.5	2-SS	1-2-2 (4)	CLAYEY SAND/POORLY GRADED SAND (SC/SP), brown, wet, very loose, fine grained	
10	10.0 – 11.5	1.5	3-SS	2-3-6 (9)	SANDY LEAN CLAY (CL), orange brown and gray, wet, stiff, fine sand	
15	14.0 – 15.5	1.5	4-SS	2-9-16 (25)	SANDY LEAN CLAY (CL), orange brown with some white bands, wet, very stiff	12:40
					Bottom of Hole at 15.5 ft below ground surface 4/9/04 12:40	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: ON-4 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers
LOCATION :
ELEVATION : NA
DRILLING CONTRACTOR : Taber
DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer
WATER LEVELS : 6.8 ft below ground surface
START : 4/9/2004
END : 4/9/04 12:33
LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
						Cathead not dropping real smooth
	2.5 - 4.0	1.5	1-SS	10-19-24 (43)	SILTY CLAY (CL-ML), very light brown, dry, hard	Catcher used
5	5.0 - 6.5	1.0	2-SS	6-8-18 (26)	CLAYEY SAND (SC), brown, wet, medium dense, fine grained	Catcher used
10	10.0 - 11.5	1.5	3-SS	3-11-13 (24)	SANDY LEAN CLAY (CL), orange brown, wet, stiff	Catcher used
15	14.0 - 15.5	1.5	4-SS	10-14-25 (39)	SANDY SILTY CLAY (CL-ML), orange brown, wet, hard	12:33
					Bottom of Hole at 15.5 ft below ground surface 4/9/04 12:33	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: OR-1 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers LOCATION :

ELEVATION : NA DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 4.7 ft below ground surface START : 4/8/04 19:15 END : 4/8/04 20:05 LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5–4.0	1.0	1-SS	1-1-2 (3)	SANDY LEAN CLAY (CL), brown, moist, soft	Catchers used
5	5.0–6.5	0.3	2-SS	0-1-5 (6)	CLAYEY SAND (SC), brown, wet, loose, coarse-medium grained	19:24
10	10.0–11.5	1.5	3-SS	8-15-17 (32)	LEAN CLAY (CL), gray with orange stains, moist, hard	19:38
15	14.0–15.5	1.5	4-SS	14-20-23 (43)	SANDY LEAN CLAY (CL), brown-light brown, moist, hard	20:05
					Bottom of Hole at 15.5 ft below ground surface 4/8/04 20:05	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: OR-2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers
LOCATION :
ELEVATION : NA
DRILLING CONTRACTOR : Taber
DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer
WATER LEVELS : 5.5 ft below ground surface START : 4/8/04 15:37 END : 4/8/04 16:24 LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 4.0	0.8	1-SS	2-1-2 (3)	CLAYEY SAND (SC), brown, moist, very loose	Catcher used
5	5.0 6.5	1.0	2-SS	2-1-1 (2)	Similar, wet	15:44
10	10.0 11.5	1.5	3-SS	8-15-19 (34)	LEAN CLAY/SILTY CLAY (CL/CL-ML), gray with orange bands and spots, moist, hard	15:56
15	14.0 15.5	1.5	4-SS	6-12-18 (30)	CLAYEY SAND/SANDY LEAN CLAY (SC/CL), orange brown, moist, hard	16:24
					Bottom of Hole at 15.5 ft below ground surface 4/8/04 16:24	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: TA-1 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers LOCATION :

ELEVATION : NA DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 6.4 ft below ground surface START : 4/9/2004 END : 4/9/2004 LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 4.0	1.5	1-SS	6-9-10 (19)	CLAYEY SAND (SC), brown, moist, medium dense, fine grained	
5	5.0 6.5	1.5	2-SS	4-6-7 (13)	Similar, orangish brown, loose	15:14
10	10.0 11.5	1.5	3-SS	5-13-16 (29)	CLAYEY SAND/SANDY LEAN CLAY (SC/CL), light brown, moist, very stiff	
15	14.0 15.5	1.5	4-SS	6-10-18 (28)	LEAN CLAY/SANDY LEAN CLAY (CL), orange brown, moist, very stiff	
					Bottom of Hole at 15.5 ft below ground surface 4/9/2004	
20						
25						
30						

PROJECT NUMBER:	BORING NUMBER: TA-2 SHEET 1 OF 1

SOIL BORING LOG

PROJECT : Biggs - West Gridley Piezometers LOCATION :

ELEVATION : NA DRILLING CONTRACTOR : Taber

DRILLING METHOD AND EQUIPMENT : CME-45, 8" Hollow Stem Auger, Rope with Cat Head Hammer

WATER LEVELS : 6.0 ft below ground surface START : 4/9/2004 END : 4/9/2004 LOGGER : A.Evans

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL (ft)	RECOVERY (ft)	#TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION
	2.5 – 4.0	1.5	1-SS	11-23-23 (46)	CLAYEY SAND (SC), brown, moist, dense, very fine grained	
5	5.0 – 6.5	1.5	2-SS	1-22-28 (50)	SANDY LEAN CLAY (CL), yellowish brown with orange spots, moist, hard	
10	10.0 – 11.5	1.5	3-SS	13-82-50/5" (132/11")	SANDY LEAN CLAY (CL), light brown, wet, very dense	15:13
15	14.0 – 15.5	1.5	4-SS	12-18-35 (53)	SANDY LEAN CLAY (CL), orangish brown, moist, hard	
20					Bottom of Hole at 15.5 ft below ground surface 4/9/2004	
25						
30						

Appendix B
Biggs-West Gridley WD Existing Facilities and Operating Conditions Technical Memorandum

Gray Lodge Wildlife Area Water Supply Project: Biggs-West Gridley WD Existing Facilities and Operating Conditions

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COPIES: Bernoy Bradford/Biggs-West Gridley WD

DATE DEVELOPED: May 18, 2007

DATE UPDATED: May 2009

Introduction

Purpose of Technical Memorandum

This technical memorandum updates previously collected information on the Biggs-West Gridley Water District (WD) (or District) system as part of the Bureau of Reclamation's (Reclamation's) Gray Lodge Wildlife Area (WA) (or refuge) Water Supply Project. This updated information will be the foundation on which to develop necessary system improvements that will be documented in the Design Data Report for the Gray Lodge WA Water Supply Project (Design Data Report). Critical steps in the development of the Design Data Report are discussed in this memorandum:

- Documenting existing facility conditions and operations
- Establishing system design flows for facility improvements
- Establishing system design criteria for facility improvements

This memorandum is not intended to provide details of all aspects of the Biggs-West Gridley WD system and its operations, but is intended to document facilities and conditions of the system that may be critical to future conveyance of refuge water. This memorandum documents the analysis and approach used to develop the design flows using flow data through the 2006 season and expected future conditions at Gray Lodge WA. The system design criteria and the next steps for updating the existing conveyance facilities are also outlined.

The following activities have contributed to the information update:

1. A field visit was conducted with Biggs-West Gridley WD management staff in September 2004. Each structure and canal reach previously identified for improvement

was visited, with the exception of a private reach of the Cassady Lateral, which was visited in April 2005. Areas of the system modified by Biggs-West Gridley WD between 1999 and 2005 (such as canal bank reshaping) were identified. These modified portions of the system were re-surveyed so that the analysis would reflect current conditions. Dimensions of key structures were verified during field visits in spring 2005. Biggs-West Gridley WD has indicated that some minor canal re-shaping has occurred since 2005 as part of regular maintenance activities. These modifications are not considered significant enough to impact the results of the Design Data Report, so modifications completed after the 2005 survey will not be included in the hydraulic analysis. A summary of information collected in the field is provided in the Existing Facility Conditions and Operations section of this technical memorandum.

2. Canal flow data for the Measurement and Seepage Study from August 2004 through January 2006 (where available) have been compiled and evaluated to verify peak existing flow conditions for each major lateral. Annual flow data for each of the three primary Gray Lodge WA delivery points from 2004 to 2006 have been compiled and summarized. Data collected through the end of the 2006 irrigation season will be summarized in the Design Data Report. Data collected after the 2006 season will be summarized in a separate memorandum and evaluated for any trends that would impact the results of the design phase of the project.

3. In February 2005, Gray Lodge WA managers from the California Department of Fish and Game (CDFG) reviewed the Gray Lodge WA water supply requirements outlined in 1998 to determine if they were still valid. The water supply requirements had changed, and the outcome of the review is summarized in Table B-3. In May 2007, Gray Lodge WA managers again reviewed the Gray Lodge WA water supply requirements and confirmed that the February 2005 requirements had not changed.

The information summarized in this memorandum will be used to assist with the development and application of the hydraulic model. The model is used to evaluate Biggs-West Gridley WD facility capacity and determine necessary improvements. Hydraulic issues noted by Biggs-West Gridley WD staff will be analyzed with the hydraulic model. All information analyzed subsequent to this memorandum will be incorporated into the final Design Data Report.

This technical memorandum is organized into the following sections:

- Introduction
- Existing Facility Conditions and Operations
- Future System Design Flows
- System Design Criteria
- Next Steps
- Attachments

Project Background

In 2003, Biggs-West Gridley WD and the Reclamation entered into Cooperative Agreement 03-FC-20-2049 (Cooperative Agreement) in support of the Central Valley Project Improvement Act (CVPIA) Refuge Water Supply (RWS) Program. The Cooperative

Agreement covers the long-term wheeling of water by Biggs-West Gridley WD to the Gray Lodge WA, including the funding and implementation of improvements to the Biggs-West Gridley WD distribution system for reliable conveyance of Level 4 refuge water to support full habitat development as required by Section 3406(d)(2) of CVPIA. The Cooperative Agreement requires several studies and phases of design (collectively referred to as the Gray Lodge WA Water Supply Project) to cooperatively develop and implement the necessary system improvements.

Previous technical work completed in late 1999 and early 2000 under the RWS Program suggested required distribution system improvements. The previous work included a topographical survey of the Biggs-West Gridley WD main laterals, development of a computerized hydraulic model (HEC-RAS) for the canal system, estimates of peak flows required for Biggs-West Gridley WD service area needs by month, criteria for use in developing facility improvement features, and a draft list of system improvements with roughly estimated construction costs.

Technical work for two complementary studies in support of the Gray Lodge WA Water Supply Project was performed from 2004 to 2008: a Canal Water Level, Flow Measurement, and Seepage Study (Measurement and Seepage Study), and a Design Data Study for Conveyance of Refuge Water Supply to Gray Lodge WA (Design Data Study). A Design Data Report is being prepared to document the Design Data Study.

Study Area

Gray Lodge WA

Gray Lodge WA encompasses 9,200 acres, approximately 2,600 acres of which are within the Biggs-West Gridley WD service area. Water is used to maintain ponds and seasonal marshes and to irrigate moist soil units, crops, and pasture for waterfowl food, cover, and nesting. Irrigated pasture and crop habitat at Gray Lodge WA consist of corn, vetch, milo, mixed grasses, and safflower. These crops provide food and nesting cover for waterfowl.

Gray Lodge WA has an annual Level 2 contractual allotment of 35,400 acre-feet and an Incremental Level 4 CVPIA water supply of 8,600 acre-feet, totaling 44,000 acre-feet per year (total Level 4 CVPIA water supply). Because some of the land occupied by Gray Lodge WA is within Biggs-West Gridley WD boundaries, the refuge receives some water from the District by entitlement, which counts toward their Level 2 supply. The remaining water is supplied to the refuge either by Reclamation, which wheels surface water through Biggs-West Gridley WD facilities, or by groundwater pumped onsite. Surface water is delivered to the refuge by Biggs-West Gridley WD via the Schwind, Rising River, and Cassady Laterals when the District is operating, between mid-April and late January. Gray Lodge WA conveys water internally using a recently upgraded distribution system that is not included as part of these studies.

Biggs-West Gridley WD

Biggs-West Gridley WD is located in Butte County near the towns of Biggs and Gridley and consists of approximately 30,000 acres of land. Deliveries within the Biggs-West Gridley WD system are made primarily to farmers with orchards, pastures, and rice fields. Water is also delivered to Gray Lodge WA. Figure F-1 in Appendix F of the Design Data Report shows the refuge boundaries and major water conveyance channels, drains, and roads.

Biggs-West Gridley WD, Richvale Irrigation District (ID), Sutter Extension WD, and Butte WD make up the Joint Water District Board (Joint Board), which conveys water that originates from the Feather River. This water is conveyed to the Biggs Extension Canal via the Sutter Butte Canal. The Biggs Extension Canal is a shared facility with Richvale ID. Richvale ID water splits from Biggs-West Gridley WD water after the Biggs Extension Canal passes under Highway 99. Located immediately downstream from this bifurcation are the Biggs-West Gridley WD headgates for the Belding Lateral. The Belding Lateral supplies the Ashley, Traynor, Schwind, and Green Laterals. In turn, the Traynor Lateral supplies the Gerst, Cassady, Rising River, and Spence Laterals. Reclamation District (RD) 833 is responsible for drainage service for the Biggs-West Gridley WD and generally drains water toward the southwest.

The focus of the Design Data Study includes the major laterals of the Biggs-West Gridley WD conveyance system from the headgates of the Belding Lateral to just downstream of the water delivery points to Gray Lodge WA. For the purpose of the Design Data Report and design flow analysis discussed later, the laterals of the Biggs-West Gridley WD conveyance system were divided into reasonable lengths (or “reaches”) with starting and ending points based on lateral headgates, other prominent points along the canal, or major road crossings. These reaches are labeled BEL1, BEL2, BEL3, and so on in Figure F-2 (Appendix F of the Design Data Report). Each different canal color on the map represents a different canal reach. The reaches are defined for study purposes, but are not used for District operations.

Existing Facility Conditions and Operations

This section documents Biggs-West Gridley WD facility conditions and typical operations as they existed during the Design Data Study, between 2004 and 2007. To set the stage for this discussion, modifications made to the system since the previous condition assessment in 1999 are described first.

Modifications to the Biggs-West Gridley WD System Since 1999

On September 28, 2004, Biggs-West Gridley WD and CH2M HILL staff visited most of the Biggs-West Gridley WD laterals and structures to determine what modifications Biggs-West Gridley WD has made to its system since the 1999 canal survey. The Cassady Lateral was visited on April 21, 2005. Modifications have included reshaping, adding rock to canal banks, replacing a farm crossing, and removing a small check structure. Each structure and canal reach previously identified for improvement also was visited.

The following canal reaches have been modified since 1999 and were resurveyed during February and March 2005: the area near the inlet and outlet of the Razorback Siphon; the Belding Lateral from the Railroad Culverts to the Belding-Traynor Split; the Traynor and Rising River Laterals from the Belding-Traynor Split all the way to the Gray Lodge WA boundary at Evans-Reimer Road; and the Schwind Lateral from the Green-Schwind Split to the flume crossing the RD 833 drain. Specific modifications by reach are detailed in the following sections and summarized in Attachment C-1.

During the April 2005 visit to the Cassady Lateral, Biggs-West Gridley WD indicated that some portions of the lateral had been reshaped. However, because of access restrictions for the privately owned portions of the Cassady Lateral, the Cassady was not resurveyed. Structure opening measurements and photos of existing canal conditions were taken in April 2005.

Biggs-West Gridley WD Operations and Facility Notes

During the field visit on September 28, 2004, Biggs-West Gridley WD provided facility operations information pertaining to each canal reach. Notes on system operations also have been collected during fieldwork conducted throughout 2004 and 2005, and through interviews with Biggs-West Gridley WD staff. This information is summarized below and in Attachment B-1. The Biggs-West Gridley WD structures on the Belding, Schwind, Traynor, Rising River, and Cassady Laterals are shown in Figure F-3 of the Design Data Report, Appendix F.

Typical Biggs-West Gridley WD Operating Procedures

Biggs-West Gridley WD supplies water to its member landowners for irrigation, duck club maintenance, and rice decomposition. The general manager, ditch tenders, and landowners (or growers) typically use the following procedure from water order through delivery:

- At the beginning of the irrigation season, a grower submits an application form to the district stating his intent to irrigate, and the crop type and acreage to be irrigated during the upcoming season.
- During the irrigation season, shortly before a grower intends to irrigate, he contacts the ditch tender assigned to his area of the district to request a water delivery. A grower must request water by 3:00 p.m. the day prior to irrigation.
- All ditch tenders meet daily at 3:00 p.m. to plan for deliveries the following day. Following the meeting, the Joint Water District Board (Joint Board) manager is contacted and provided with Biggs-West Gridley WD’s total water order. The Joint Board manager adds the water orders from all joint districts and submits the total order to Oroville Reservoir operators.
- Each day, changes to the Belding Headgates, the head of Biggs-West Gridley WD’s system, are made at 7:00 a.m. If necessary, adjustments are made to the gates again between 9:30 and 10:00 a.m.
- During the day, ditch tenders make adjustments to gates and weirs as necessary to deliver water to growers. Only ditch tenders are allowed to operate grower turnouts. However, individual ditch tenders manage their assigned area as they determine appropriate. All adjustments are made manually because control structures and grower turnouts are neither automated nor remotely operated.
- Rice growers request one or two higher-flow deliveries for field flood-up at the beginning of the season, then flow is reduced to an amount that maintains field water levels. Maintenance flows may be adjusted throughout the season depending on weather.

- If growers choose, orchards and pastures may be put on a cyclic irrigation rotation. Ditch tenders cycle through water deliveries to each field approximately every other week, then the cycle begins again. The cycles begin at the start of the irrigation season and continue through October, when irrigation to orchards and pasture stops. The number of times per year that orchard and pasture growers can irrigate is limited by the District.
- Irrigation demands at the beginning of the season are typically high. If possible, one irrigation cycle to orchards and pastures is completed before rice flood-up begins to minimize system capacity constraints.
- After November 1, water is only delivered to support duck clubs and Gray Lodge WA or for rice decomposition. Landowners must request water the day prior to delivery.

Gray Lodge WA also requests water delivery using an established procedure. The following occurs annually:

- Per the water service agreement, a monthly schedule of "Preliminary Anticipated Water Needs" is developed by Gray Lodge WA managers and submitted to Reclamation by March 1. This schedule is a prediction of the water Gray Lodge WA will request during the year, but Gray Lodge WA managers are not bound to adhere to this schedule.[1]
- In April, following notification of the State Water Project availability, Biggs-West Gridley WD determines Gray Lodge WA's allotment for the year, and communicates this amount to Gray Lodge WA managers. Based on this allotment, Gray Lodge WA managers submit a revised delivery schedule to Biggs-West Gridley WD.
- During the irrigation season, Gray Lodge WA managers request each water delivery by contacting the ditch tender before 3:00 p.m. the day before delivery is requested. Water is ordered by flow rate in 5 cubic foot per second (cfs) increments. Delivery scheduling conflicts, if they occur, are negotiated and settled between the ditch tender and Gray Lodge WA managers.

Biggs Extension Canal (Upstream of Belding Headgates)

The Biggs Extension Canal is a shared facility with Richvale ID. The Biggs Extension Canal is fed by the Sutter Butte Main. The shared capacity of the Biggs-West Gridley WD is 64 percent, according to its operating contract. Biggs-West Gridley WD has indicated that the design capacity of the headgates to the Belding Lateral is 2,000 cubic feet per second (cfs); however, the required head to deliver water to Richvale ID limits the capacity of the Biggs Extension Canal to about 900 cfs. According to Biggs-West Gridley WD staff, Richvale ID accepts deliveries each year from April through December.

Biggs-West Gridley WD typically utilizes more than 64 percent of the capacity without complaint by Richvale ID, and it is not clear whether flows in excess of the 64 percent capacity will be available to Biggs-West Gridley WD in the future. To date, this issue has not been discussed with the Richvale ID staff but should be included as part of future technical tasks.

[1] Personal communication with Mike Womack and Andy Atkinson, Department of Fish and Game. Notes from Gray Lodge Feasibility Study/Design Flow Meeting, January 27, 2005.

To deliver water to Richvale ID from the Biggs Extension Canal, the water surface of the canal typically is 4 inches above the Highway 99 Bridge soffit. The water surface elevation must be kept high from April through January each year to serve Richvale ID. Currently, Caltrans is designing a replacement bridge for the Highway 99 Bridge over the Biggs Extension Canal; this could affect the hydraulics in the future.

Bathtubbing (a canal erosion condition that widens a canal and steepens its banks) has occurred along the Biggs Extension Canal. No improvements have been made to this section of canal since 2000. Further verification of hydraulic capacity may be required for the Biggs Extension Canal.

Belding Headgates to Railroad Culverts—Reach BEL1

Reach BEL1 extends from the Belding Headgates, just downstream of the Highway 99 Bridge, to the Railroad Culverts.

A gauging station for the Joint Board is located just downstream of the Highway 99 Bridge. The station contains a water level logger and a rating table to determine flow at this point. The Joint Board maintains data from this gauging station. Because there have been questions regarding the accuracy of this station, Biggs-West Gridley WD installed a SonTek Argonaut, an acoustic Doppler meter (SonTek meter), in the Belding downstream of the Joint Board gauging station in late 2005.

Scouring may be occurring as a result of high velocities (greater than 5 feet per second [ft/s]) between the Belding Headgates and Razorback Siphon. The canal narrows just upstream of the Railroad Culverts; there is minimum freeboard there.

Some improvements have been made to this reach of canal since 2000. The section of canal near the inlet and outlet of the Razorback Siphon was re-shaped. Also, the small check just downstream of the concrete lining near the Belding-Ashley Split on the Belding was removed.

Razorback Siphon. This structure consists of a 60-inch by 140-inch submerged box culvert and 84-inch corrugated metal pipe (CMP) siphon to move water under the RD 833 drain known as the Dietzler cross ditch. The siphon typically overtops by 2 inches during peak flows. The 84-inch CMP siphon was added approximately 30 years ago to increase capacity. RD 833 has jurisdiction over the Dietzler ditch in this area.

Railroad Culverts. This structure consists of a 90-inch upper and 84-inch lower pipe to convey water under a railroad crossing. The lower pipe was submerged on September 28, 2004, during the site visit, but the upper pipe was visible. The canal is overtopped just upstream of this siphon at peak flow conditions. No changes have been made to the structure since 2000.

Belding Lateral: Railroad Culverts to Riceton Highway—Reach BEL2

This reach of the Belding has been reshaped since 2000. Downstream of the Railroad Culverts, water must make a 90-degree turn to continue to the Belding. It is challenging for the District to operate this reach of canal to convey peak flow through the Garcia Check and Garcia Siphon without overtopping the canal banks.

Belding-Ashley Split. The Belding Lateral (at the Garcia Check) is operated so the staff gauge on the Ashley Headgates structure reads 4.0 or 4.1.

Garcia Check. This check is required to make upstream farm deliveries and to convey water to the Ashley Lateral. It consists of two 36-inch and four 42-inch flashboard bays. An upstream weir no longer exists, making this check more critical to supply upstream demands during off-peak flows. Biggs-West Gridley WD maintains the check wide open throughout the summer months, but a head differential is still noted at the check.

Garcia Siphon. This structure consists of a 68-inch by 140-inch submerged box culvert and a 72-inch CMP siphon to convey water under a drain. Banks occasionally overtop between the Garcia Check and the Garcia Siphon. This may be caused by backwater from the Garcia Siphon or inadequate channel capacity.

Belding Lateral: Riceton Highway to Belding-Traynor Split—Reaches BEL3 and BEL4

Since 2000, the reach from the Banion Check to Farris Road was reshaped, widened, dredged, and partially rocked. The canal was dredged on the east side between the North Weir and Belding-Traynor Split.

Banion Check. The Banion Check consists of eight bays, each 38 inches wide. The four center bays have slide gates and the remaining four have flashboards. During peak flow periods, all flashboards are removed, but high water is still noted upstream of the check.

Fields Flume. This flume conveys flows over a drain. As a result of downstream canal modifications, the flume overflows less often than it did in 1999, when it was slated for replacement, but water levels are still high in the flume. The current underdrain operates without any problems.

North Weir. Consists of four 36-inch rectangular openings, two with slide gates, and the others with flashboards. An additional 36-inch diameter pipe with slide gate remains fully open during peak flows. A water level measuring 1.1 feet on the staff gauge results in only a small amount of water for the adjacent high fields. Downstream of the weir, the water level is kept high with minimal freeboard.

Belding Lateral: Belding-Traynor Split to Green-Schwind Headgates—Reaches BEL5 and BEL6

Division 2. The gates at the Belding-Traynor Split, also known as the Division 2 Headgates, are a combination bridge-culvert-gate structure with three bays. The outer two bays have slide gates and the middle bay has flashboards, which are operated to serve upstream turnouts. These gates have never been operated in the fully open position. The structure has inadequate deck elevation to allow water to be checked up sufficiently to both service upstream turnouts and convey adequate flows through the gates.

Bonslett Bridge. This farm crossing consists of three 36-inch culverts that also function as a check structure (using flashboards) to make upstream deliveries. No changes have been made to this structure in several years.

Schwind Lateral: Schwind Headgates to West Liberty Road—Reaches SCH1, SCH2, and SCH3

Since 2000, canal banks have been widened and raised along this reach from the Belding-Schwind Split to the RD 833 drain.

Farm Crossings. Biggs-West Gridley WD noted that it is unable to convey enough water through two 48-inch and one 42-inch farm crossings on the Schwind and suggested they be replaced. One crossing is located just upstream of the flume crossing the RD 833 drain. The second crossing is located approximately 0.25-mile downstream of the Colusa Highway. The third crossing is farther downstream, approximately 0.5-mile upstream of the culverts and crossings near West Liberty Road.

Multiple Crossings/Structures at West Liberty Road. Several structures move water through the section near West Liberty Road. A culvert conveys flows under a farm crossing immediately north of West Liberty Road. Two 36-inch pipes then extend over a drain and continue under West Liberty Road, where they empty into the continuation of the Schwind earthen channel. Finally, flows are conveyed through a culvert under a farm crossing immediately south of West Liberty Road. If improvements occur in this area, Biggs-West Gridley WD requests the ability to drain overflow if water backs up before reaching the Gray Lodge WA.

Traynor Lateral: Traynor Headgates to 0.75-mile Upstream of Colusa Highway—Reach TRA1

Since 2000, this section of canal has been widened by 6 feet at the top, dredged on both sides, and rocked on the east side. Water levels are high in the canal below the Nugent Flume.

Traynor Headgates. The Traynor Headgates (also known as the Division 3 Headgates) consist of five 48-inch bays, four with slide gates and one with flashboards. Biggs-West Gridley WD indicated that the headgates overtop regularly because the 300 cfs capacity is inadequate and there is a flat section of canal downstream. The Division 2 Headgates also overtop, possibly from backwater from the Traynor Headgates. In the summer, this structure is maintained at the fully open position to convey the needed flow. Therefore, the gates do not provide good hydraulic control in the summer and are only effective during times of lower flow. The District is unable to measure the flow through these gates.

Nugent Flume. This structure conveys water from the Traynor Lateral over a drain. The capacity of the flume is not adequate to convey necessary flows downstream. Biggs-West Gridley WD has lined the top of the flume with cement blocks to prevent overtopping, but this likely has not affected the flow capacity of the flume. A pump just downstream of Nugent Flume was installed to pump water from the drain to the Traynor Lateral, but it is no longer used.

Traynor Lateral: 0.75-mile Upstream of Colusa Highway to Colusa Highway—Reach TRA2

Since 2000, this section of canal has been dredged, widened on one side, and the banks built up a few inches. Biggs-West Gridley WD noted that there was a major break in this part of the system in 1998 or 1999 caused by rodent burrowing.

Traynor Lateral: Colusa Highway to West Liberty Road—Reaches TRA3 and TRA4

Water levels are kept high in this reach to serve customers on the Gerst Lateral. High water levels upstream of the Gerst Headgates are caused by backwater from the West Liberty Road Gates. This section of canal has been dredged on both sides since 2000.

Traynor Lateral and Rising River Lateral: West Liberty Road to Evans-Reimer Road—Reaches TRA5 and TRA6

This section of canal has been dredged on both sides since 2000.

West Liberty Road Structures. One bridge and two flow control structures are in the immediate vicinity of West Liberty Road: the West Liberty Road Bridge, a slide gate check with 44-inch openings just downstream of the bridge on the Traynor Lateral, and a three-bay gate check on the Spence Lateral. To make deliveries to the Gerst Lateral, the staff gauge on the Traynor structure downstream of West Liberty Road needs to measure 8.6 feet to 8.8 feet. Under very high flow conditions, it reads 9.0 feet. Also, to irrigate Onyett's field on the east side of the canal in reach TRA3, the staff gauge must read 8.7 feet. According to Biggs-West Gridley WD, the flow capacity of the gates at West Liberty Road is adequate. Because it is necessary to check water up at West Liberty Road to serve the Gerst Lateral, flows are inadequate on the Traynor downstream of the bridge. Conveying enough flow down the Spence also has been problematic for the District.

Gerst Lateral—Reach GERST

Typically, there is only a 3-inch drop through the Gerst Headgates structure when running full in the summer. To make deliveries to the Gerst, water levels are maintained high in the Traynor Lateral at West Liberty Road. Several high fields along this reach require the high water level in the Gerst. No changes have been made to the Gerst reach since 2000.

Cassady Lateral—Reaches CAS1 and CAS2

Capacity may be inadequate in the upper Cassady Lateral. Several restrictions in the canal and inadequate hydraulic gradient may be causing backwater upstream. Biggs-West Gridley WD noted that operators can move only 45 cfs through the upper reaches of the Cassady, but orders may add up to as much as 80 cfs.

No changes have been made to the Cassady Lateral since 2000. Biggs-West Gridley WD has access issues with landowners along a reach of the Cassady, which will need to be resolved before any improvements can be implemented.

Cassady Headgates. The farm crossing serving as the headgates to the Cassady Lateral was replaced in March 2005 with a 48-inch culvert with slide gate.

Petersen's Flume/Check. This check consists of two 42-inch openings for flashboards. Biggs-West Gridley WD believes that the capacity of this structure should be evaluated to determine whether there are restrictions in the system. No significant head loss has been observed at this structure.

Private Crossing. This structure is a 48-inch culvert in the private reach of the Cassady. Water backs up throughout this section of canal. There are a couple of fallen trees that cross the Cassady upstream of the 48-inch culvert that could affect higher flows. The private reach of the Cassady is not maintained by Biggs-West Gridley WD or adjacent land owners. The upper banks and top of levee are overgrown with dense vegetation.

Bonslett's Driveway and Weir. This check is located downstream of the private reach of canal and used to make deliveries to two upstream turnouts. It is difficult for the District to keep the water checked up and convey adequate flow through this section to meet downstream deliveries. It is believed to be capable of passing 20 cfs when head is maintained to make deliveries.

Measured Flow Data

Measured flow data were evaluated to determine the distribution of existing flows in the reaches of the Biggs-West Gridley WD system. In general, peak flows through the system occur between late April through May, depending on weather patterns and resulting irrigation demands. A secondary flow peak typically occurs in late June through late August. The system is typically shut down between the last week of January and mid-April. Variations of this flow pattern for individual reaches were analyzed as part of design flow development.

Flow Data at the Head of the System from the Joint Board and Biggs-West Gridley WD

All flows into the Biggs-West Gridley WD system are monitored daily by the Joint Board at a station downstream of the headgates of the Belding Lateral, located west of the Highway 99 Bridge. A water level logger records stage throughout the day. A summary of these flows from the 1999 to 2008 irrigation seasons is shown in Figure B-1. Examination of the Joint Board gauge data is significant because it represents all deliveries of surface water to Gray Lodge WA and Biggs-West Gridley WD, thus representing recent systemwide delivery patterns, timing of peak flows, and year-to-year variation. Maximum flows occur in late April through May, depending on how weather patterns influence rice planting and irrigation demands. Maximum annual flows at the head of the Belding Lateral vary between approximately 600 cfs and 800 cfs.

In late 2005, Biggs-West Gridley WD installed a SonTek meter approximately 1 mile downstream of the Joint Board gauge. The District believed that this technology would provide more accurate data than the level recorder and rating table used by the Joint Board. Data from this SonTek meter provided a basis for establishing a future design flow for the upper reaches of the Belding Lateral.

Peak annual flows at the head of the Belding vary between approximately 650 cfs and 770 cfs. The maximum flow seen at the Joint Board gauge at the head of the Belding Lateral from 2000 to 2008 was 758 cfs, recorded on May 17, 2006. The maximum flow recorded in 2006 by the meter owned and maintained by Biggs-West Gridley WD was approximately 770 cfs on May 16. Note that the flow measured during this period included some CVPIA refuge water being provided by Reclamation under the Cooperative Agreement described in the Introduction section of this technical memorandum.

Flow Data from Measurement and Seepage Study

To track and record the distribution of flows in the Biggs-West Gridley WD system, SonTek meters were installed at 11 locations in Biggs-West Gridley WD laterals. The sites are labeled in Figure F-1 (Design Data Report, Appendix F). Flow data from these units are available from August 14, 2004, to October 2008, and will be summarized in the Design Data Report.

Biggs-West Gridley WD Data from Starflow Meter at Nugent Flume

Biggs-West Gridley WD maintains a Starflow meter at the Nugent Flume just downstream of the TRA-FLOW-3 SonTek meter site. The Starflow meter is an acoustic Doppler instrument set to record flow every hour. The Starflow meter and SonTek meter have tracked well together during the data collection period. Although the Starflow meter data are, on average, 10 percent higher than the SonTek meter data, the two meters remain within one standard deviation of each other. Also, given that the expected accuracies of the meters are +/- 5 percent, the two instruments are in acceptable agreement.

Flow Data from Gray Lodge WA Meters

Gray Lodge WA deliveries from Biggs-West Gridley WD occur through the Cassady, Schwind, and Rising River Laterals. Annual and monthly peak deliveries for these laterals will be summarized in the Design Data Report. In 2004, Reclamation installed acoustic Doppler meters on the Cassady, Schwind, and Rising River Laterals just past the Gray Lodge WA boundary for monitoring the refuge deliveries. See Figure F-1 of the Design Data Report (Appendix F) for locations of the Gray Lodge WA meters.

Measured Water Level Data

Eleven water level sensors (In-Situ pressure transducers) were installed to complement the water level data received from the SonTek meters. Water level data were collected to establish a baseline to be used in evaluation of future flows with various system improvements, and to be incorporated into the hydraulic model calibration process. The system water level data will be summarized in the Design Data Report.

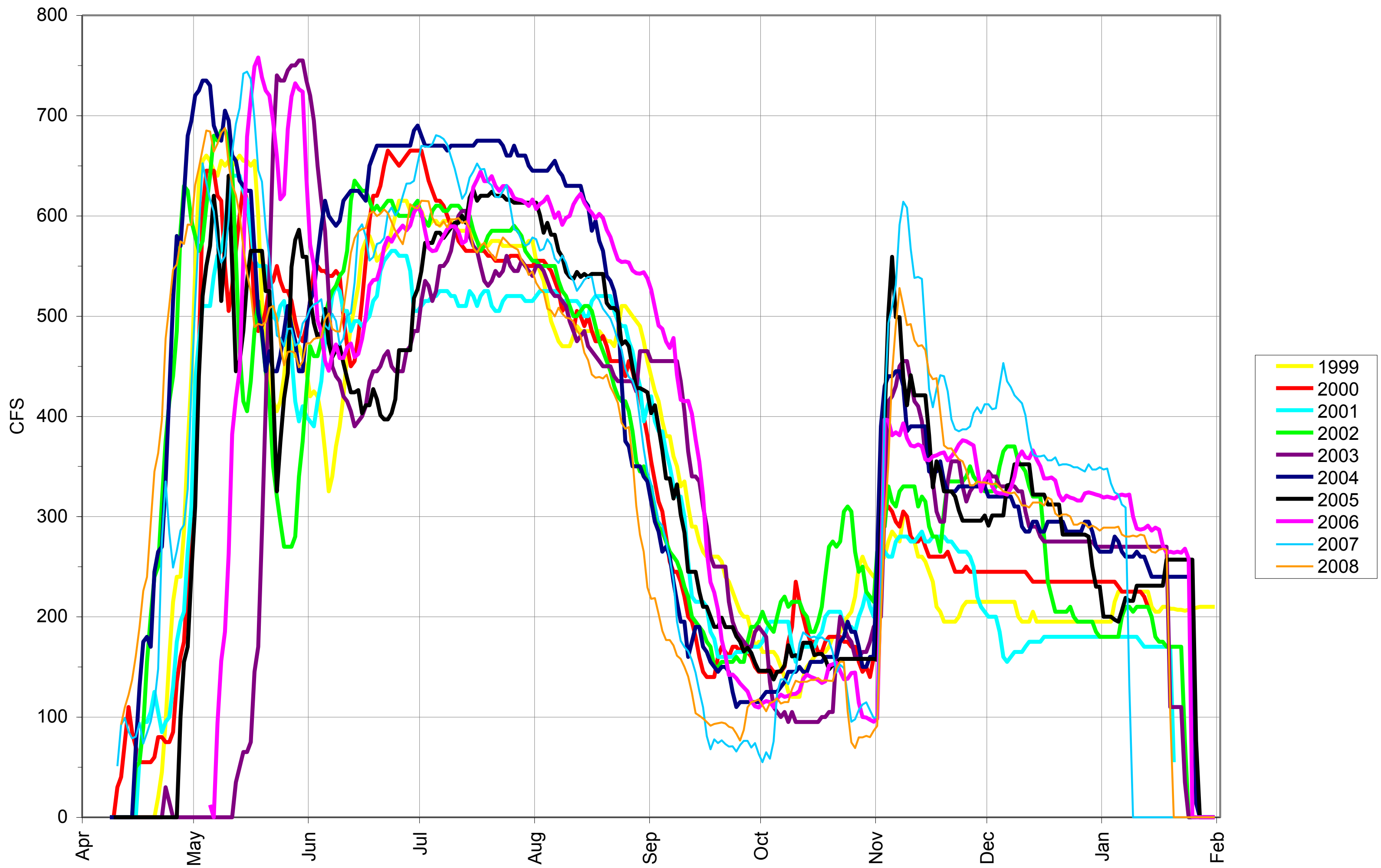
Future System Design Flows

To identify and properly size system improvements required to convey future Level 4 flows to Gray Lodge WA, it was necessary to estimate the total peak flow that each canal reach will likely convey in the future. These flows, collectively known as the “design flows,” were first estimated theoretically in 1999, then estimated again in 2007 using available empirical data from the Measurement and Seepage Study. The design flows were also developed to reflect how canal capacity would decrease from upstream to downstream; as water is delivered to customers along the canal, design capacity downstream is incrementally decreased to correspond to reduced supply requirements. Both the 1999 and 2007 approaches are discussed in this section.

1999 Design Flow Approach

In 1999, prior to the Measurement and Seepage Study and associated data collection efforts, canal design flows were estimated using a theoretical approach that relied on standard service criteria and land use information. For this approach, the laterals of the Biggs-West Gridley WD conveyance system were divided into reasonable lengths (reaches) with starting and ending points based on prominent structures or road crossings along the canal.

These reaches are shown in Figure F-2 of the Design Data Report with labels such as BEL1 for the first reach of the Belding Lateral. Each different canal color on the map represents a different canal reach. The capacity requirements of each reach were determined by adding projected Gray Lodge WA deliveries and projected deliveries to crops served by each canal, as discussed below.



Source: Joint Board Gauging Station.

FIGURE B-1
Flow Summary, Head of the Belding Lateral, Joint Board Gauging Station

Projected Gray Lodge WA Delivery Requirements

First, flows to each delivery point to Gray Lodge WA (including Level 4 deliveries) were estimated with Gray Lodge WA managers. Table B-1 summarizes Gray Lodge WA delivery requirements as determined in 1998.

TABLE B-1
Water Supply Requirements for Gray Lodge WA—Developed in 1998

Month	Level 2 Needs[a] (ac-ft)	Level 2 Needs[a] (cfs)	Level 4 Needs[a] (ac-ft)	Level 4 Design Flows[b] (cfs)	Allocation to Delivery Points-50%-20%-30%		
					Traynor	Cassady	Schwind
January	1,050	18	1,320	22			
February	1,050	18	1,320	22			
March	1,050	18	1,320	22	11	4	7
April	1,050	18	1,320	22	11	4	7
May	2,500	42	3,080	55	28	11	17
June	3,500	59	4,400	75	38	15	23
July	2,500	42	3,080	55	28	11	17
August	2,850	48	3,520	60	30	12	18
September [d]	7,100	119	8,800	*168*	84	34	50
October	6,750	113	8,360	140	70	28	42
November	4,600	77	5,720	96	48	19	29
December	1,400	24	1,760	30	15	6	9
Total	**35,400**		**44,000**				
Conveyance losses	5,202[c]		6,964[c]				
Total amount to be diverted	**40,602[c]**		**50,964[c]**				

[a] Reclamation, 1989. Report on Refuge Water Supply Investigations. March. Level 4 needs include Level 2 quantities.
[b] CDFG, 1994. Gray Lodge WA, Water Management Coordinator. February 4.
[c] Biggs-West Gridley WD provides Level 1, the Central Valley Project (CVP) through exchanges provides remaining Level 2. Conveyance loss of CVP water is 17 percent.
[d] Peak demand increased from 150 cfs to 168 cfs per meeting on December 7, 1998.

Notes:
ac-ft = acre-feet
cfs = cubic feet per second

Biggs-West Gridley WD Customer Flows

Next, crop land use was evaluated for each reach based on California Department of Water Resources (DWR) survey information. Land served by each reach was classified by acre as “pasture,” “orchard,” “rice,” or “not irrigated.” The survey accounted for approximately 28,050 acres. Also, in cooperation with Biggs-West Gridley WD staff, standard criteria were developed for District irrigation service, as summarized in Table B-2. These criteria, along with crop land use information, were used to establish monthly *land-use-based* flows required by Biggs-West Gridley WD canals and laterals to meet required level of service for the District service area.

TABLE B-2
Biggs-West Gridley WD Crop Irrigation Guidelines—Developed in 1999

Month	General Guidelines	Notes
January/ February	Biggs-West Gridley WD Canal system shutdown	Refuge on wells if necessary
March	Orchard and pasture irrigation only; 12 cfs per typical 160-acre delivery; up to one-third orchards, one-quarter pasture users "on" at any given time.	Possible pre-irrigation if very dry winter
April	Rice—13 inches flood-up, all fields in District served within 21 days. Orchards and pasture same as above.	Flood-up could occur in April or May
May	Rice—maximum of 10 inches applied following draining, all fields covered within 21 days. Orchards and pasture same as above.	
June/July/ August	Rice—maintenance flows, make up for 1 in 10 year maximum evapotranspiration. Up to 3.2 cfs per 100 acres max continuous flows. Orchards and pastures same as above.	
September	Rice—assume possibly late harvest, full maintenance flows over three-quarters of month. Orchards and pastures same as above.	Harvest typically starts in mid-September, would result in lower maximum September flows
October	Rice fields—up to 75 percent of all rice fields in decomp. Apply 10 inches, all fields served over 18 days. Duck club flooding starts, apply 30 inches, all fields served over 30 days. Orchards and pasture get last irrigation.	
November/ December	Rice fields—decomp maintenance flow of 1 cfs per 100 acres. Duck club maintenance of 2 cfs per 100 acres.	System shutdown late December

1999 Design Flow Calculation

Finally, design flows were determined for each reach by adding estimated Level 4 refuge deliveries to Biggs-West Gridley WD service flows, by month, accounting for seepage losses at 1 percent of flow per mile. The peak flow out of all months was selected as the design flow for a given reach. The 1999 design flows are summarized below with the 2007 updated design flows in Table B-3.

Although land-use based water demands are no longer the basis for design flows, the reaches defined in studies dating back to 1999 have remained for developing the empirically derived design flows. A discussion of this approach follows.

2007 Design Flow Approach

An update to the 1999 design flows was necessary in 2007 for several reasons:

- Availability of improved water measurement data
  - Canal flow data were available for 2004, through 2007 as a product of the Measurement and Seepage Study being conducted by Reclamation at Biggs-West Gridley WD. Data from 12 flow meters provided a recent and more accurate representation of the quantity and distribution of flows throughout the District.
  - Reclamation has collected flow and water level data using acoustic Doppler meters since 2004 for the three refuge delivery points.
  - Biggs-West Gridley WD installed and calibrated a SonTek meter at the head of its system on the Belding Lateral prior to the 2006 season. The District believes this data provide a better representation of flows entering its system than data collected by the Joint Board with a rating table and recorder.
- Changes to Biggs-West Gridley WD facilities and deliveries
  - Rice-growing cultural practices changed in the District between 2000 and 2004. Generally, fields are flooded and drained more frequently, and most rice decomp water (approximately 75 percent) is delivered in November rather than October.
  - Biggs-West Gridley WD supported substantially more rice acreage in 2004 and subsequent seasons than in previous years.
- Changes to Gray Lodge WA facilities and operations
  - The Gray Lodge WA flows developed in 1999 reflected monthly volumes of water delivered evenly over the entire month, and therefore did not represent an accurate picture of the *peak* flows that would be requested from Biggs-West Gridley WD each month with full Level 4 deliveries. Also, water is ordered in 5-cfs increments, so estimated flows should be rounded accordingly.
  - To provide optimal habitat management with full Level 4 deliveries and to support mosquito-abatement efforts, refuge staff would prefer pulses of water and increased spring and early summer deliveries rather than slow, steady flows delivered primarily in the fall.
  - Gray Lodge WA completed on-refuge improvements since 1999, resulting in a modified preferred delivery schedule and somewhat different delivery points (Traynor, Schwind, and Cassady Laterals) to optimize refuge habitat operations.

Therefore, the design flows were updated in 2007 to reflect changes to Biggs-West Gridley WD and Gray Lodge WA facilities and operations and to incorporate improved water measurement data. The design flows were estimated in 2007 using several empirical data sources and other relevant information used in the 1999 analysis:

- The maximum flow Gray Lodge WA would likely request at each delivery point if full Level 4 deliveries were available, determined by the refuge managers

- Flow data at each Gray Lodge WA delivery point collected by SonTek meter or Mace meters owned and installed by Reclamation
- Flow data at several reaches within Biggs-West Gridley WD collected in 2004, 2005, and 2006 by SonTek meters for the Measurement and Seepage Study
- DWR land use survey information
- Irrigation criteria developed in coordination with Biggs-West Gridley WD

For continuity, the reaches used for the 1999 design flow analysis were also used for the 2007 design flow update.

Updated Gray Lodge WA Delivery Requirements

First, monthly Gray Lodge WA flows were updated and formalized by the refuge managers in coordination with Reclamation in 2005. Refuge managers accounted for flows that would be feasible with existing on-refuge infrastructure and for how the refuge would be managed if full Level 4 deliveries were available. Table B-3 summarizes the peak flows likely to be requested with Level 4 deliveries, by month and by delivery point.

TABLE B-3
Projected Refuge Design Flows with Level 4 Deliveries—Developed in 2005

Month	Level 4 Needs (ac-ft)[a]	Level 4 Design Flows (peak flow, cfs)[b]	Allocation to Delivery Points (peak flow, cfs)[b]		
			Traynor	Cassady	Schwind
January	1,320	90	45	20	25
February[c]	1,320	0	0	0	0
March[c]	1,320	0	0	0	0
April	1,320	60	30	10	20
May	3,080	65	35	10	20
June	4,400	70	40	10	20
July	3,080	75	40	15	20
August	3,520	120	70	15	35
September	8,800	135	80	15	40
October	8,360	165	100	20	45
November	5,720	125	70	20	35
December	1,760	90	45	20	25

[a] Level 4 needs as defined in Reclamation, 1989. These volumes are approximations only.
[b] Forsberg (CDFG), 2005.
[c] On-refuge groundwater is expected to provide Level 4 water during February and March when the Biggs-West Gridley WD system is shut down.

Updated Biggs-West Gridley System Flows

Next, the peak average hourly flow for each reach was determined by day using the data collected in 2004, 2005, and 2006 for the Measurement and Seepage Study.[2] To determine flow in reaches where it was not measured directly, calculations (mass balances) were performed using data from SonTek meters in nearby canal reaches upstream and downstream of the unmetered reach. Where necessary, land use information (acreage and crop type) was incorporated into the calculation to best represent actual conditions and proportional water deliveries. The specific data source and equation used for each reach is shown in Attachment B-2 in the Attachments.

To determine the flow attributable to Biggs-West Gridley WD agricultural irrigators, the peak daily refuge flow was subtracted from the peak daily flow in each reach for every day of the study. This provided a baseline agricultural irrigation flow record to allow the effect of future peak refuge flows to be evaluated.

2007 Design Flow Calculation

Conceptually, to determine the maximum flow a reach must convey to District agricultural customers (irrigators) and Gray Lodge WA with Level 4 deliveries, the peak refuge flows shown in Table B-3 were added to the Biggs-West Gridley WD irrigator flows, and the maximum expected flow was identified for each reach.[3] Finally, these flows were rounded up to the nearest 5 or 10 cfs[4] to obtain a design flow for each reach that included peak Biggs-West Gridley WD operations and future peak Level 4 deliveries to Gray Lodge WA.

This calculation was performed on a daily basis using available flow data for the Biggs-West Gridley WD system and the Gray Lodge WA delivery points, and a peak was determined monthly. More specifically, for each canal reach for each month in the period of analysis, the average hourly flow delivered to Gray Lodge WA was subtracted from the average hourly flow observed in the canal at the same hour, and the maximum flow that Gray Lodge WA could have called on during the applicable month was added. The required design capacity was determined as the peak value of these calculations in a given month. Seepage losses are also accounted for within each reach by adding 1 percent of flow per mile, based on input from Biggs-West Gridley WD.

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[2] A rolling hourly average of every four 15-minute data points was computed, and the peak average value was selected as the peak average flow for a given day.

[3] The peak monthly refuge flows shown in Table 3 were applied daily throughout that month when added to the Biggs-West Gridley WD irrigator flow daily data set. Seepage of refuge flow was also accounted for within each reach.

[4] Flows greater than or equal to 100 cfs were rounded up to the nearest 10 cfs. Flows less than 100 cfs were rounded up to the nearest 5 cfs.

Figure B-2 graphically depicts a sample design flow calculation for Reach BEL5. First, data from applicable Gray Lodge WA deliveries[5] are combined with available flow data for Reach BEL5 to determine the actual flow attributable to Biggs-West Gridley WD irrigators, shown by the blue bars, and actual flow attributable to refuge deliveries, shown by the yellow bars. Next, when potential future peak flows (with full Level 4 refuge deliveries) are higher than actual Gray Lodge WA flows on a particular day, the additional increment is added on top of the existing flows, as shown by the green bars. Estimated seepage losses are included. The resulting plot shows that, if the reach was conveying peak District irrigator flow and peak flow to Gray Lodge WA at the same time, the flow in Reach BEL5 would have been approximately 265 cfs on May 26, 2006. Therefore, the design flow for Reach BEL5 is established at 270 cfs, indicated by the red line.

Table B-4 lists the design flows approved by the project team in 2008. These design flows were adjusted slightly from the design flows updated in 2007 in response to comments received during review by the project team. The design flows developed in 1999, based on land use information and irrigation criteria only, and the design flows updated in 2007 are presented for comparison. The set of 2008 design flows yields a high level of reliability for ensuring capacity is available for deliveries to Gray Lodge WA, even during peak District operations. Figure B-3 shows the design flow for each reach, given by the pink lines, and the maximum flow conveyed by each reach between 2004 and 2006 (where data are available). All design flows exceed the peak flow a reach has conveyed during these years.[6] The approved 2008 design flows will be used to determine where system improvements are necessary and as a basis for designing new facilities.

5 Flows to the Schwind delivery point are conveyed by Reach BEL5.

6 Design flows may be equal to the peak flow conveyed if a reach does not carry flows to Gray Lodge WA.

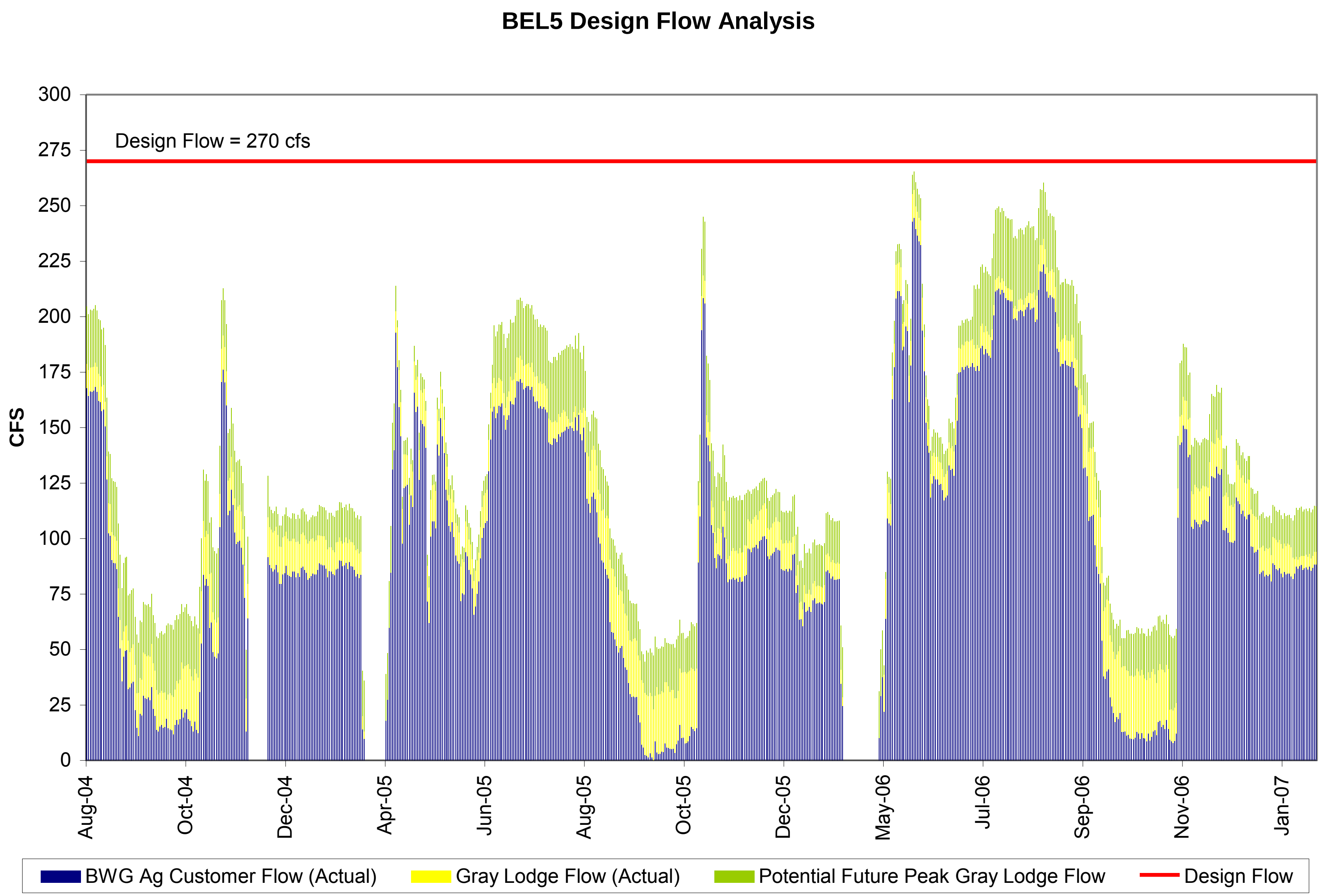

FIGURE B-2
Sample Design Flow Calculation for Reach BEL5

TABLE B-4
Peak Flows Expected with Level 4 Deliveries to Gray Lodge WA

Reach	1999 Design Flow (cfs)[a]	2007 Design Flow (cfs)[b]	2008 Approved Design Flow (cfs)[c]	Source
ASH1	130	130	140	Direct measurement
BEL1	790	820	850	Direct measurement
BEL2	650	720	750	Mass balance from direct measurements, distributed between reaches by land use ratio
BEL3	620	660	680	Mass balance from direct measurements, distributed between reaches by land use ratio
BEL4	600	650	670	Direct measurement
BEL5	230	270	270	Direct measurement plus additional 10 cfs to account for turnout upstream of measurement point
BEL6	200	220	220	Mass balance from direct measurements, distributed between reaches by land use ratio
CAS1	50	60	85	Land-use-based water demand estimate plus direct measurement
CAS2[d]	–	25	30	Direct measurement
GERST	80	85	95	Direct measurement
GREEN	100	110	110	Direct measurement
SCH1	90	100	100	Mass balance from direct measurements
SCH2	80	85	85	Direct measurement
SCH3	70	85	85	Mass balance from direct measurements, distributed between reaches by land use ratio
SPENCE	100	130	130	Mass balance from direct measurements, distributed between reaches by land use ratio
TRA1	340	380	380	Mass balance from direct measurements, distributed between reaches by land use ratio
TRA2	270	370	380	Direct measurement
TRA3	270	350	370	Direct measurement
TRA4	260	290	310	Mass balance from direct measurements
TRA5	160	200	220	Direct measurement
TRA6	100	110	120	Direct measurement
TRA7	100	100	110	Direct measurement

[a] Based on land use surveys, irrigation criteria, and peak Level 4 Gray Lodge WA deliveries estimated in 1998.
[b] Updated with empirical data, current operations, and peak Level 4 Gray Lodge WA deliveries estimated in 2005.
[c] Adjusted in 2008 in response to review comments from the project team. Approved by the project team in 2008.
[d] The Cassady Lateral was considered only one reach, CAS1, during the design flow analysis in 1999. It was decided to analyze two reaches within this lateral during the design flow analysis in 2005 to account for varying demands along the length of the lateral. (Source: Conference call with Reclamation, Biggs-West Gridley WD, and CH2M HILL consultant team, September 14, 2005.)

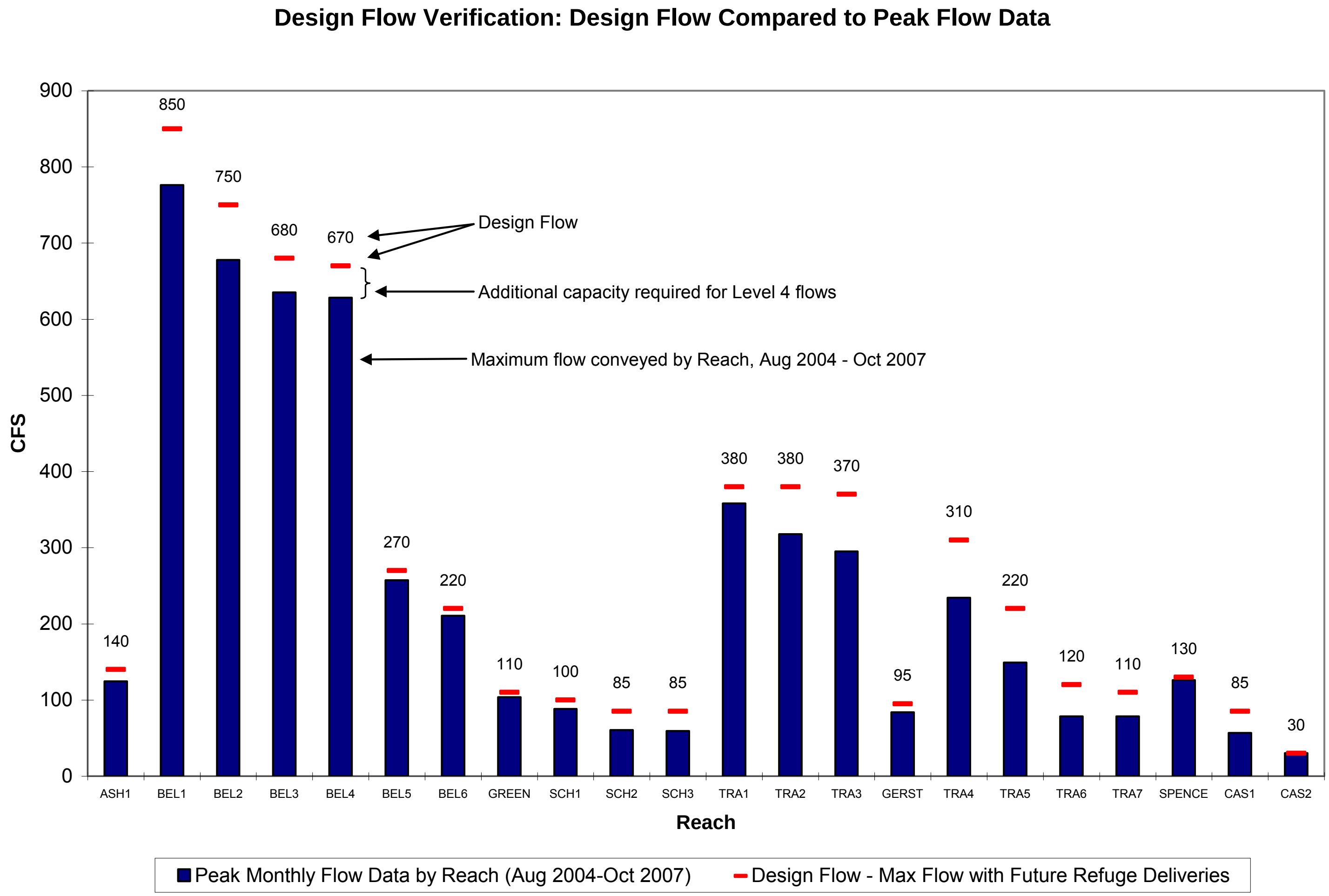

FIGURE B-3
Design Flow for Each Reach and Maximum Flow Conveyed by Each Reach between 2004 and 2006

System Design Guidelines

The design guidelines listed in Table B-5 were established for Biggs-West Gridley WD system improvements based on recognized design standards for canals and structures provided by Reclamation, and a review of standard earthen canal design and operations in Sacramento Valley irrigation districts based on recent designs in the Sacramento Valley and discussions with Sacramento Valley irrigation districts. Model results and system improvements will be evaluated with respect to the guidelines listed below. Recommended improvements will be consistent with local industry minimum standards and acceptable operating conditions within Sacramento Valley.

TABLE B-5
Design Guidelines for Biggs-West Gridley WD System Improvements

Parameter	Criteria
Earth Canal Guidelines	
Maximum average channel velocity	3 ft/sec (locally higher at structure inlets and outlets)
Freeboard, minimum permissible[a]	18 inches for canals > 200 cfs capacity 12 inches for canals ≤ 200 cfs capacity
Bottom width-to-depth ratio	2:1 for Q = 0 to 100 cfs 2.5:1 for Q = 500 to 1,000 cfs
Canal side slopes	1.5:1 for Q = 0 to 50 cfs 2:1 for Q > 50 cfs
Manning's roughness coefficient (n)	n = 0.025 to 0.06 (varies by season and reach—weed growth increases throughout the season and changes the n-value)
Service roads and levee widths	12 ft for Q = 0 to 100 cfs, one side of channel surfaced, one side unsurfaced 14 ft for Q > 100 cfs, one side of channel surfaced, one side unsurfaced
Structure Design Guidelines	
Sizing of canal control structures including gates and flashboard checks	Must maintain water surface elevation for upstream turnouts and convey peak flows. Sized for control at high, medium, and low flow profiles developed during hydraulic modeling.
Siphons and culverts	Major structures: velocity < 9 ft/sec inside the structure opening, and head loss does not impact upstream freeboard Minor structures: velocity < 5 ft/sec inside the structure opening, and head loss < 6 in.
Structure freeboard, minimum permissible[b]	18 inches for structures > 200 cfs capacity 12 inches for structures ≤ 200 cfs capacity
General configuration and design	Where appropriate, similar structure materials, designs, and configurations will be used throughout the system. Recommended structure types will be typical to standard irrigation practice. Poor approach and exit conditions will be minimized.

[a] Biggs-West Gridley WD Board issued a letter to Reclamation on July 24, 2007, to indicate freeboard requirements of 12 inches for canals up to and including 200 cfs capacity and 18 inches for canals with greater than 200 cfs capacity are acceptable.
[b] General guideline for structure freeboard. Structure function, operations, and site-specific conditions could require adjustments to freeboard during the design phase.

Design guidelines adapted from: Reclamation, 1990. Water Systems Operations and Maintenance Workshop, session notes and reference handouts. Bureau of Reclamation Engineering Division, Denver CO.

Notes:

ft/sec = feet per second
Q = flow rate (cfs)

Next Steps

The information contained in this memorandum will be used as the foundation for the analysis of system improvements, which will be documented in the Design Data Report. The next steps in the study are:

- Endorsement of the design flows and design criteria by project stakeholders
- Hydraulic modeling of Biggs-West Gridley WD system under future flow scenario with Level 4 water deliveries to Gray Lodge WA
- Development of system improvements required within Biggs-West Gridley WD to convey Level 4 flows to Gray Lodge WA

Attachment B-1
Summary of Biggs-West Gridley Facility Operations and Conditions

ATTACHMENT B-1
Summary of Biggs-West Gridley WD Facility Operations and Conditions

Reach or Structure	Function	Operations	Issues Noted by Biggs-West Gridley WD[a]	Changes Since 2000	Surveyed in 2005[b]	Improvements Proposed during Previous Technical Work (2000)
Biggs Extension Canal	Shared facility with Richvale ID, fed by the Sutter Butte Main.	Biggs-West Gridley WD has an operating contract for 64 percent of the capacity of the Biggs Extension Canal.	Deliveries to Richvale ID require water level elevation be kept as much as 4 inches above the bridge soffit. Bathtubbing occurs along this section.	None.	No	No canal improvements proposed. Note that Caltrans will be replacing the Highway 99 Bridge.
BEL1	Canal section of Belding conveys water from Belding Headgates to Railroad Culverts.	To determine flow down the Belding, a gauging station is maintained by the Joint Board just downstream of the Belding Headgates.	The canal has minimal freeboard just upstream of the Railroad Culverts, where it narrows. The canal makes a 90-degree turn downstream of the Railroad Culverts.	The siphon inlet and outlet were cleaned and scraped.	Yes	Improve canal[c] (downstream half of reach).
Razorback Siphon	A 60- by 140-inch submerged box culvert and an 84-inch CMP siphon convey water under a drain.		Typically overtops by 2 inches during peak flows.	None.	N/A	Demolish and construct a new 60-inch cross-drainage siphon.
Railroad Culverts	One 84-inch and one 90-inch culvert convey water under a railroad crossing.		Water rises above the canal banks just upstream of this siphon at peak flow conditions.	None.	N/A	Bore and jack to 48-inch-diameter pipe.
BEL2	Canal section of Belding conveys water from Railroad Culverts to Riceton Highway.	This reach is operated so the staff gauge on the Ashley Headgates structure reads 4.0 or 4.1.	It is challenging for the District to operate this reach of canal to convey peak flow through the Garcia Check and Garcia Siphon without breaching the canal banks.	The small check just downstream of the Belding-Ashley Split has been removed. Canal has been reshaped.	Yes	Improve canal.[c]
Garcia Check	Two 36-inch and four 42-inch bays with flashboards. Required to make upstream farm deliveries and to convey water to the Ashley Lateral.	Maintained fully open throughout the summer months. Checked up only during lower flows.	None.	None.	N/A	Demolish and replace below Belding-Ashley Split.
Garcia Siphon	A 68- by 140-inch submerged box culvert and a 72-inch CMP siphon convey water under a drain.		None.	The siphon inlet and outlet were cleaned and scraped.	N/A	Demolish and replace with box cross-drainage siphon.
BEL3 and BEL4	Canal section of Belding conveys water from Riceton Highway to Belding-Traynor Split.		The canal makes two quick turns immediately before the Fields Flume.	Reshaped, widened, dredged, and rocked from Banion Check to Farris Road. Dredged on the east side between the North Weir and Belding-Traynor Split.	Yes	Improve canal.[c]
Banion Check	Eight 38-inch bays, four center bays with slide gates and four outer bays have flashboards. Provides upstream water level control.	All boards are removed and the gates are operated fully open during the summer.	Backwater has been noted by the District upstream of the check.	None.	N/A	None.
Fields Flume	Conveys flows over a drain.		None.	None.	N/A	Demolish and reconstruct improved flume with new drain box culvert.
North Weir	Four 36-inch openings, two with slide gates and two with flashboards. Checks up water to serve upstream irrigators when not running at capacity. A 36-inch culvert with slide gate also passes flows downstream.	The 36-inch culvert generally remains fully open all summer. Water level is maintained at 1.1 on a staff gauge at the weir.	Although water levels are kept high, it is only possible to serve upstream irrigators with a small amount of water.	None.	N/A	Demolish and replace with radial gate control.
BEL5 and BEL6	Canal section of Belding conveys water from Belding-Traynor Split to Green-Schwind Headgates.		None.	None.	No	None.

ATTACHMENT B-1
Summary of Biggs-West Gridley WD Facility Operations and Conditions

Reach or Structure	Function	Operations	Issues Noted by Biggs-West Gridley WD[a]	Changes Since 2000	Surveyed in 2005[b]	Improvements Proposed during Previous Technical Work (2000)
Gates at Belding-Traynor Split (Start of Division 2)	Three 36-inch culverts check up water to service upstream turnouts. The outer two bays have slide gates and middle bay has flashboards.	Gates are maintained checked up to service upstream turnouts. These gates are never fully opened.	The structure has inadequate deck elevation to allow water to be checked up to serve upstream turnouts while conveying adequate flows through the gates.	None.	N/A	Demolish and replace with 10-foot by 6-foot structure and bridge with two 48-inch motor-operated slide gates.
Bonslett Bridge	Three 36-inch culverts that also function as check structures to make upstream deliveries.		None.	None.	N/A	Demolish and replace with box culvert with flashboard guides.
SCH1, SCH2, SCH3	Canal section of Schwind conveys water between the Schwind Headgates to West Liberty Road.		None.	Widened and banks raised from the Schwind Headgates to the flume north of Colusa Highway.	Yes, part of SCH1	None.
Farm Crossings	One farm crossing with a 42-inch culvert and two farm crossings with 48-inch pipes.		Water backs up behind these crossings during peak flows.	None.	N/A	Demolish and replace 42-inch pipe with box culvert.
Schwind West Liberty Road Crossing Structures	Two 36-inch culverts cross over a drain and under West Liberty Road.		If this area is improved, need to maintain ability to divert excess flows to prevent backing up at the Gray Lodge WA boundary.	None.	N/A	None.
TRA1	Canal section of Traynor conveys water from Traynor Headgates to 0.75 mile upstream of Colusa Highway.		None.	Dredged on both sides, top widened by 6 feet, rocked on east side.	Yes	None.
Traynor Headgates	Five 48-inch bays, four with slide gates and one with flashboards, for upstream level control and downstream flow control.	Maintained fully open during summer and peak flows. Flow capacity is approximately 300 cfs.	These headgates regularly overtop. The Division 2 Headgates also overtop, possibly because of backwater from the Traynor Headgates. Capacity is inadequate to meet downstream needs. The gates do not provide hydraulic control because they must be maintained fully open to pass desired flow. District is unable to accurately measure flow through the gates.	None.	N/A	None.
Nugent Flume	Conveys water from the Traynor Lateral over a drain.	As much flow as possible is conveyed through the flume.	Capacity is inadequate to pass necessary flows downstream. Flume has overtopped in the past.	To increase the capacity of the flume, the rim of the flume has been lined with concrete blocks.	N/A	Demolish and reconstruct improved flume and new drain box culvert.
TRA2	Canal section of Traynor conveys water from 0.75 mile upstream of Colusa Highway to Colusa Highway.		This section of canal had a major break 9 to 10 years ago because of rodent burrowing.	In 2001, the canal was dredged, widened on one side, and the banks raised by a few inches.	Yes	None.
TRA3 to TRA4	Canal section of Traynor conveys water from Colusa Highway to West Liberty Road.	Water levels are kept high in this reach to serve customers on the Gerst Lateral.	The canal has minimal freeboard in the reach above the Gerst Headgates because of backwater from the West Liberty Road gates.	Dredged on both sides.	Yes	None.
TRA5 to TRA6	Canal section of Traynor conveys water from West Liberty Road to Evans-Reimer Road.		None.	Dredged on both sides.	Yes	Canal improvements to TRA6.[d]
West Liberty Road Structures on Traynor Lateral	Includes the West Liberty Road Bridge, a three-bay check just downstream of the bridge on the Traynor Lateral, and a three-bay gate check on the Spence Lateral. Used for upstream and downstream hydraulic control.	To make deliveries to the Gerst Lateral, the staff gauge at West Liberty Road measures 8.6 to 9.0. To irrigate Onyett's field on the east side of the canal in reach TRA3, the staff gauge must read 8.7.	Because it is necessary to check water up at West Liberty Road to service the Gerst Lateral, flows are inadequate on the Traynor downstream of the bridge. Passing enough flow down the Spence also has been problematic for the District.	None.	N/A	None.

ATTACHMENT B-1
Summary of Biggs-West Gridley WD Facility Operations and Conditions

Reach or Structure	Function	Operations	Issues Noted by Biggs-West Gridley WD[a]	Changes Since 2000	Surveyed in 2005[b]	Improvements Proposed during Previous Technical Work (2000)
Gerst	Reach of canal conveys water to irrigators along the Gerst Lateral.	High water levels are maintained in the Gerst Lateral for irrigation deliveries.	No reliable measurement of flow down this reach is possible because only 3 inches of drop is typically seen at the Traynor-Gerst Split. Several high fields require a high water level to be maintained on the Gerst, which causes a backwater effect on the Traynor.	None.	No	None proposed for the canal. Stripping and excavation proposed for high fields along the Gerst.
CAS1	Reach of canal conveys water to irrigators along the Cassady Lateral.	Operators can move only 45 cfs through the upper reaches of the Cassady, but orders may be as much as 80 cfs.	Capacity may be inadequate in the upper Cassady. Several restrictions in the canal and inadequate hydraulic gradient may be causing backwater upstream. Disputes with landowners will need to be addressed before any alterations can be made.	Some sections reshaped.	No	None.
Cassady Headgates	48-inch pipe with slide gate conveys water under farm crossing.	Typically is operated fully open when conveying water down the Cassady.	None.	Replaced in March 2005.	N/A	Replace culvert.
Petersen's Flume/Check	8-foot-wide check with two 43-inch flashboard openings for upstream level control.	Typically is operated fully open in summer.	Water backs up upstream and downstream of this structure.	None.	N/A	None.
Private Crossing	48-inch culvert in private reach.	Private property not maintained or operated by Biggs-West Gridley WD.	Upper canal banks are overgrown with dense vegetation. Fallen trees upstream may affect higher flows. Landowner disputes may affect any future modifications.	None.	N/A	Remove and replace culvert.
Bonslett's Driveway and Weir	Check located downstream of the private reach of canal for upstream level control.	Operated to make deliveries to two upstream turnouts.	It is difficult for the District to keep the water checked up and convey adequate flow through this section to meet downstream deliveries.	None.	N/A	Replace weir and culvert with larger box culvert with flashboard guides.

[a] Hydraulic issues noted by Biggs-West Gridley WD staff will be verified with calibrated hydraulic model.
[b] Refers to canal sections only. All structure measurements were verified in 2005.
[c] Canal improvements include excavation, grading, hauling, compaction, and embankments.

Attachment B-2
Data Sources for Reach Flow Analysis

ATTACHMENT B-2
Design Flow Data Source and Equation

Reach	Design Flow Data Source and Equation
BEL1	(BELDING-BWG-FLOW) – [(RIS-RFG-FLOW)+(CAS-RFG-FLOW)+(SCH-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady) + (Peak Level 4 Schwind)]
ASH1	(ASH-FLOW-1)
BEL2	(BELDING-BWG-FLOW) – (ASH-FLOW-1) – [(RIS-RFG-FLOW)+(CAS-RFG-FLOW)+(SCH-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady) + (Peak Level 4 Schwind)]
BEL3	(BELDING-BWG-FLOW) – (ASH-FLOW-1) – [(BELDING-BWG-FLOW)–(ASH-FLOW-1) – (BEL-FLOW-1)] × (BEL2 land-use-based water ratio) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW)+(SCH-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady) + (Peak Level 4 Schwind)]
BEL4	(BEL-FLOW-1) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW) + (SCH-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady) + (Peak Level 4 Schwind)]
BEL5	(BEL-FLOW-2) + 10 cfs – (SCH-RFG-FLOW) + (Peak Level 4 Schwind)
BEL6	(BEL-FLOW-2) – [(BEL-FLOW-2) – (BEL-FLOW-1)] × (BEL5 land-use-based water ratio) – (SCH-RFG-FLOW) + (Peak Level 4 Schwind)
GREEN	(GRE-FLOW-1)
SCH1	(BEL-FLOW-3) – (GRE-FLOW-1) – (SCH-RFG-FLOW) + (Peak Level 4 Schwind)
SCH2	(SCH-FLOW-1) – (SCH-RFG-FLOW) + (Peak Level 4 Schwind)
SCH3	(SCH-FLOW-1) – [(SCH-FLOW-1)–(SCH-RFG-FLOW)] × (SCH2 land-use-based water ratio) – (SCH-RFG-FLOW) + (Peak Level 4 Schwind)
TRA1	(TRA-FLOW-3) + [(BEL-FLOW-1) – (BEL-FLOW-2) – (TRA-FLOW-3)] × (TRA1 land-use-based water ratio) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW)] + [(Peak Level 4 Rising River)+(Peak Level 4 Cassady)]
TRA2	(TRA-FLOW-3) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady)]
TRA3	(TRA-FLOW-2) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady)]
GERST	(GER-FLOW-1)
TRA4	(TRA-FLOW-2) – (GER-FLOW-1) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady)]
TRA5	(TRA-FLOW-1) – [(RIS-RFG-FLOW) + (CAS-RFG-FLOW)] + [(Peak Level 4 Rising River) + (Peak Level 4 Cassady)]
TRA6	(RIS-FLOW-1 data) – (RIS-RFG-FLOW) + (Peak Level 4 Rising River)
TRA7	(Peak Level 4 Rising River)

ATTACHMENT B-2
Design Flow Data Source and Equation

Reach	Design Flow Data Source and Equation
CAS1	(CAS1 land-use-based water demand) – (CAS-RFG-FLOW) + (Peak Level 4 Cassady)
CAS2	(Peak Level 4 Cassady)
SPENCE	(TRA-FLOW-2) – (TRA-FLOW-1) – (GER-FLOW-1) – [(TRA-FLOW-2) – (TRA-FLOW-1) – (GER-FLOW-1)] × (TRA4 land-use-based water ratio)

Notes:

1. “Peak Level 4 Rising River,” “Peak Level 4 Schwind,” and “Peak Level 4 Cassady” refer to the peak flow expected at the Rising River refuge delivery point, Schwind refuge delivery point, and Cassady refuge delivery point, respectively, with full Level 4 deliveries available. These flows vary by month according to Table B-3.
2. Seepage applicable from refuge delivery point to a given reach is added to all refuge flow data, Applicable seepage is also added to Peak Level 4 flows.
3. Land-use-based water ratios:
   BEL1 land-use-based water ratio = BEL1 / (BEL1 + BEL2 + BEL3)
   Where BEL1 = land-use-based water demand for BEL1, BEL2 = land-use-based water demand for BEL2, etc.
   BEL2 land-use-based water ratio = BEL2 / (BEL1 + BEL2 + BEL3)
   BEL5 land-use-based water ratio = BEL5 / (BEL5 + BEL6)
   TRA1 land-use-based water ratio = (0.5 × TRA1) / (0.5 × TRA1 + BEL4)
   TRA4 land-use-based water ratio = TRA4 / (SPENCE + TRA4)
4. Land-use-based water demand for CAS1 is determined monthly based on DWR land-use survey and irrigation guidelines listed in Table B-2.

Appendix C
Summary of Alternative Improvements

CH2MHILL

Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area
Biggs-West Gridley Water District
Composite Alternative Improvements: Belding Lateral

Reach	ID	Design Flow (cfs)	Low Flow (cfs)	High Flow (cfs)	Name/Description	Station	Existing Conditions	Alternative 1 Improvements	Alternative 2 Improvements	Composite Alternative Improvements	Composite Alternative Details/Notes
BEL1	–	850	200	680	Joint Board Gage Station	690+77	–	N/A	N/A	N/A	
BEL1	B-1	850	200	680	Razorback Siphon	644+44	6-ft diameter circular concrete siphon and 12-ft by 5-ft concrete box siphon	Remove existing siphon. Construct new siphon to take Dietzler Ditch flows under BWG main canal.	Remove existing siphon. Construct new siphon to take Dietzler Ditch flows under BWG main canal.	Remove existing siphon. Construct new siphon to take Dietzler Ditch flows under BWG main canal.	Remove existing siphon. Install 2 cross-drainage box siphons, each 50 ft long, 8 ft wide, 6 ft deep.
BEL1	B-2	850	200	680	Canal Section	607+73 to 603+89	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 384 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL1	B-3	850	200	680	Railroad Culverts	603+00	7-ft and 7.5-ft diameter circular concrete culvert	Improve canal capacity under railroad crossing by installing 2 additional 8-ft-diam culverts	Improve canal capacity under railroad crossing by installing 1 additional 8-ft-diam culverts	Improve canal capacity under railroad crossing by installing 2 additional culverts.	Bore and jack two 8-ft-diameter pipe culverts adjacent to existing culverts.
BEL1	B-4	850	200	680	Canal Section	596+65 to 591+50	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 515 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL2	B-5	750	189	591	Garcia Check	568+12	6-bay flashboard structure	N/A	N/A	Replace structure with long-crested weir.	Remove existing check and replace with 70-ft long-crested weir. Weir to be 7-ft high and Include three 3.3-ft wide overshot gates, max opening 6.5 ft.
BEL2	B-6	750	189	591	Garcia Siphon	558+64	6-ft diameter circular concrete siphon and 12-ft by 6-ft concrete box siphon	Remove existing siphon. Construct new siphon to take RD833 flow under BWG main canal.	Remove existing siphon. Construct new siphon to take RD833 flow under BWG main canal.	Remove existing canal siphon. Construct new siphon to take RD 833 flow under BWG main canal.	Remove existing canal siphon and replace with trapezoidal earthen canal section. Reconfigure RD 833 drainage by installing two cross-drainage box siphons, each 100 ft long by 8 ft wide by 6 ft deep.
BEL2	B-7	750	189	591	Canal Section	558+51 to 548+68.6	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 982 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL2	B-8	750	189	591	Biggs/Princeton (Afton) Bridge	548+70	Bridge with 5.2-ft circular concrete culvert and 12.4-ft by 6.4-ft concrete box culvert	N/A	N/A	Replace bridge with higher deck height and larger culvert opening.	Replace with 2-ft-thick flat slab bridge deck with at least 7-ft culvert opening. Assumes asphalt concrete (AC) driving surface will be applied.
BEL2	B-9	750	189	591	Canal Section	546+47 to 535+13	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 1,134 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL2	B-10	750	189	591	Banion Check	535+32	8-bay structure, 4 flashboard bays and 4 sluice gate bays, each 3.2-ft wide	N/A	N/A	Replace structure with long-crested weir.	Remove existing check and replace with 70-ft long-crested weir. Weir to be 6.4-ft high and Include three 4.5-ft wide overshot gates, max opening 6.25 ft.
BEL3	B-11	680	181	529	Canal Section	527+73 to 517+33	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 1,040 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL3	B-12	680	181	529	Canal Section	512+20 to 401+70	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 11,050 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL4	B-13	670	180	520	Fields Flume	483+94	Concrete flume 26-ft wide by 7-ft deep	Replace or modify structure with 26-ft width and 8.5 ft depth	Replace or modify structure with 26-ft width	Replace flume.	Replace with 26-ft-long flume with 8.5-ft-high embankment walls, each 6 inches thick. Install 2-ft-wide walkways. During final design, consider wasteway at this location to spill excess water
BEL4	–	670	180	520	N. Farris Rd Bridge	456+85	Bridge spanning canal with 1 1-ft wide center pier, 39-ft opening	N/A	N/A	N/A	County bridge is located in a canal reach recommended for modifications, however current structure dimensions are sufficient to convey flow. Canal will be widened in this area, cross section will neck down just upstream of bridge and widen just downstream of bridge.
BEL4	B-14	670	180	520	Canal Section	535+32 to 405+24	Canal dimensions 15-ft to 23-ft base width, 10-ft depth, less than a 1.5:1 side slopes.	Canal dimensions 30-ft base width, 10-ft depth, and 2:1 side slopes	N/A	Widen canal to improve hydraulics.	Widen 13,008 LF of canal to 30-ft bottom width, 10-ft depth, 2:1 side slopes. (Approximately 160 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks.
BEL4	B-15	670	180	520	North Weir	454+04	4 bay structure, 2 flashboard structure, each 3-ft wide, 2 sluice gates, each 3-ft wide by 9-ft deep, 1 2.7-ft diameter circular concrete culvert	4 bay sluice gate, each 4.5-ft wide by 8-ft in depth	4 bay sluice gate, each 4.5-ft wide by 8-ft in depth	Replace structure with long-crested weir.	Replace with 67-ft long-crested weir. Weir to be 6.7-ft high and include two 4-ft-wide overshot gates, max opening of 6.5 ft.

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Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area
Biggs-West Gridley Water District
Composite Alternative Improvements: Belding Lateral

Reach	ID	Design Flow (cfs)	Low Flow (cfs)	High Flow (cfs)	Name/Description	Station	Existing Conditions	Alternative 1 Improvements	Alternative 2 Improvements	Composite Alternative Improvements	Composite Alternative Details/Notes
BEL4	-	670	180	520	Farm Crossing #2010	436+00	Bridge spanning canal with 1 1-ft wide center pier, 27-ft opening	N/A	N/A	N/A	In final design, consider measures to prevent bed scouring due to increased velocities.
BEL5	B-16	270	80	190	Division 2 Head gate (Belding/Traynor Split)	400+03	3 3-ft circular concrete culverts with flashboards and farm crossing	3-bay sluice gate, each 4-ft wide by 7-ft depth, plus farm crossing bridge nearby, raise canal banks.	3-bay sluice gate, each 4-ft wide by 7-ft depth, plus farm crossing bridge nearby, raise canal banks.	Replace with 3-bay sluice gate and relocate farm crossing bridge nearby.	Replace farm crossing with 2-ft-thick flat slab deck and 7-ft opening to canal bottom. Replace existing headgate structure with 3-bay sluice gate, each 4-ft wide by 7-ft depth. Increase height of adjacent canal banks to achieve 18 inches of freeboard.
BEL5	B-17	270	80	190	Canal Section	381+70 to 346+70	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 3,500 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL5	B-18	270	80	190	Check #1889	357+22	3-bay flashboard structure, each 3.1-ft wide	3-bay sluice gate, each 5-ft wide by 8-ft in depth	N/A	Replace structure with long-crested weir.	Replace with 45-ft long-crested weir. Weir to be 5.3-ft high and Include one 4-ft wide overshot gate, max opening 5 ft.
BEL5	–	270	80	190	Farm Crossing #1867	343+15	Bridge spanning canal, 18-ft opening	N/A	N/A	N/A	
BEL5	B-19	270	80	190	Canal Section	343+10 to 309+72	–			Raise canal banks to meet freeboard requirements.	Increase height of 3,338 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL5	B-20	270	80	190	Check #1845	330+35	3-bay flashboard structure, each 3.7-ft wide	3-bay sluice gate, each 4-ft wide by 7-ft in depth	N/A	Replace structure with long-crested weir.	Replace with 83-ft long-crested weir. Weir to be 4.7-ft high and include 2 3.5-ft wide overshot gates, max opening 4.5 ft.
BEL6	–	220	40	150	Riley Rd Farm Crossing #1816	311+30	Bridge spanning canal, 20-ft opening	N/A	N/A	N/A	
BEL6	–	220	40	150	Check #1808	310+03	3-bay flashboard structure, each 3.7-ft wide	N/A	N/A	N/A	
BEL6	B-21	220	40	150	Canal Section	300+31.6 to 211+70	–			Raise canal banks to meet freeboard requirements.	Increase height of 8,861 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
BEL6	B-22	220	40	150	Farm Crossing # 1786	300+20	Bridge spanning canal, 21-ft opening	N/A	N/A	Replace farm crossing to improve capacity and meet freeboard requirement.	Replace farm crossing with 2-ft-thick flat slab bridge deck and 8-ft opening to canal bottom. Assume deck and soffit will be raised by 1 ft to improve freeboard. Assume aggregate base backfill for driving surface.
BEL6	–	220	40	150	Check #1757	284+51	3-bay flashboard structure	N/A	N/A	N/A	
BEL6	B-23	220	40	150	Farm Crossing #1719	264+20	Bridge spanning canal, 20.5-ft opening	N/A	N/A	Replace farm crossing to improve capacity and meet freeboard requirement.	Replace farm crossing with 2-ft-thick flat slab bridge deck and 8.5-ft opening to canal bottom. Assumes deck will be raised by 0.7 ft and soffit by 1 ft to improve freeboard. Assume AC driving surface.
BEL6	B-24	220	40	150	Farris Rd. Bridge	258+35	Bridge with 4 4-ft diameter circular concrete culverts	N/A	N/A	Replace farm crossing to improve capacity and meet freeboard requirement.	Replace bridge with open span, 1.7-ft thick slab deck with aggregate base backfill driving surface and 8.5-ft opening to canal bottom.
BEL6	–	220	40	150	Check #1695	257+02	3-bay flashboard structure, each 3.4-ft wide	N/A	N/A	N/A	
BEL6	B-25	220	40	150	Bonslett Bridge	230+40	3 3-ft diameter circular concrete culverts with flashboards and farm crossing.	3-bay sluice gate, each 3-ft wide by 8-ft in depth	replace with 12-ft by 4-ft box culvert with the ability to control water level.	Replace bridge and replace control structure with long-crested weir.	Replace bridge with bridge-box culvert structure, with 2-ft thick slab deck and 6-ft by 5-ft culvert. Install 50-ft long-crested weir. Weir to be 7-ft high and include one 4-ft wide overshot gate with max opening 6.5 ft.
BEL1 - BEL6	B-26	–	–	–	Seepage Drains	(where applicable)	Seepage drain parallel to canal along some reaches.	N/A	N/A	Replace seepage drains impacted by canal modifications.	Replace 84,400 LF of seepage drains.

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Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area
Biggs-West Gridley Water District
Composite Alternative Improvements: Schwind Lateral

Reach	ID	Design Flow (cfs)	Low Flow (cfs)	High Flow (cfs)	Name/Description	Station	Existing Conditions	Alternative 1 Improvements	Alternative 2 Improvements	Composite Alternative Improvements	Composite Alternative Details/Notes
SCH1	S-1	100	20	80	Canal Section	211+70 to 196+40	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 1,530 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
SCH1	–	100	20	80	Check #1609 Schwind Head gate	208+66	2-bay sluice gate, each 3.3-ft wide	N/A	N/A	N/A	
SCH1	–	100	20	80	Check # 1581	192+05		N/A	N/A	N/A	
SCH1	S-2	100	20	80	Canal Section	186+46 to 93+64	–			Raise canal banks to meet freeboard requirements.	Increase height of 9,282 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
SCH1	S-3	100	20	80	Farm Crossing #7137	165+30	4-ft diameter circular concrete culvert	Concrete box culvert, 7-ft wide by 4-ft deep	Concrete box culvert, 7-ft wide by 4-ft deep	Replace with concrete box culvert and farm crossing.	Replace with concrete box culvert, 24-ft long by 9-ft wide by 4-ft high, with integrated farm crossing.
SCH1	S-4	100	20	80	Schwind Flume	165+13	6.1-ft wide concrete flume	8-ft wide by 5-ft deep concrete flume	8-ft wide by 5-ft deep concrete flume	Replace flume, 8-ft wide by 5-ft deep.	Replace with 60-ft long by 8-ft wide by 5-ft deep flume. Install check bays on both sides of flume to allow for spill.
SCH1	S-5	100	20	80	Bridge #1522	161+03	3 3-ft diameter circular concrete culverts with flashboards and farm crossing	Concrete box culvert, 9-ft wide by 4-ft deep	Concrete box culvert, 9-ft wide by 4-ft deep	Replace with long-crested weir and farm crossing.	Replace with 37-ft ong crested weir. Weir to be 6.6-ft high and include one 3-ft-wide overshot gate, max opening 6.5 ft.
SCH2	–	85	17	68	Colusa Bridge	153+97	Bridge spanning canal, 12-ft opening	N/A	N/A	N/A	
SCH2	S-6	85	17	68	Farm Crossing #1491	148+27	4-ft diameter circular CMP culvert with farm crossing	Concrete box culvert, 9-ft wide by 4-ft deep	Concrete box culvert, 9-ft wide by 4-ft deep	Replace with concrete box culvert and farm crossing.	Replace with concrete box culvert, 20-ft long by 9-ft wide by 4-ft high, with integrated farm crossing.
SCH2	S-7	85	17	68	Canal Section	148+09 to 131+04	Canal dimensions 10-ft base width, 8-ft deep, and less than 1.5:1 side slopes.	Canal dimensions 14-ft base width, 8-ft depth, and 2:1 side slopes	N/A	Widen canal to improve hydraulics.	Widen 1,705 LF of canal to 14-ft bottom width, 8-ft depth, 2:1 side slopes. (Approximately 64 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks. Includes reconstruction or modifications of turnouts, as needed.
SCH2	–	85	17	68	Check #1462	131+17	2-bay flashboard structure, each 3.6-ft wide	N/A	N/A	N/A	
SCH3	S-8	85	17	68	Farm Crossing #1438	119+35	3.5-ft diameter circular concrete culvert	Concrete box culvert, 7-ft wide by 4-ft deep	Concrete box culvert, 7-ft wide by 4-ft deep	Replace with concrete box culvert.	Replace with concrete box culvert, 19-ft long by 7-ft wide by 4-ft high, with integrated farm crossing.
SCH3	–	85	17	68	Check #1423	115+77	1-bay sluice gate structure, 4.1-ft wide	N/A	N/A	N/A	
SCH3	S-9	85	17	68	Farm Crossing #5021	100+12	4-ft diameter circular CMP culvert with farm crossing	6-ft diameter circular siphon, 162-ft long	4-ft diameter circular siphon, 162-ft long	Replace existing structure with siphon.	Remove existing structure and install 162-ft-long by 6-ft-diam siphon. Single siphon will replace structures and accommodate flow between Farm Crossing #5021 and W. Liberty Road crossing.
SCH3	S-10	85	17	68	Culverts #5006	99+90	2 3-ft diameter circular CMP culverts over drain and under West Liberty Road	Removed	Removed	Remove existing structure.	Remove two 140-ft-long by 3-ft-diam CMP culverts.
SCH3	S-11	85	17	68	Culvert South of W. Liberty Rd.	99+00	4-ft diameter circular CMP culvert with farm crossing	Removed	Removed	Remove existing structure.	Remove 26-ft-long by 4-ft-diam CMP culvert.
SCH1 - SCH3	S-12	–	–	–	Seepage Drains	(where applicable)	Seepage drain parallel to canal along some reaches.	N/A	N/A	Replace seepage drains impacted by canal modifications.	Replace 5,970 LF of seepage drains.

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Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area
Biggs-West Gridley Water District
Composite Alternative Improvements: Traynor Lateral

Reach	ID	Design Flow (cfs)	Low Flow (cfs)	High Flow (cfs)	Name/Description	Station	Existing Conditions	Alternative 1 Improvements	Alternative 2 Improvements	Composite Alternative Improvements	Composite Alternative Details/Notes
TRA1	T-1	380	100	300	Canal Section: Head of Traynor to Nugent Flume	445+03 to 418+73.4	Canal dimensions 24.3-ft base width, 8-ft deep, and 1.5:1 side slopes.	Enlarge canal to 34-ft base width, 11-ft deep, and 2:1 side slopes.	Raise canal banks	Widen canal to improve hydraulics.	Widen 2,630 LF of canal to 30-ft bottom width, 11-ft depth, 2:1 side slopes. (Approximately 329 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks.
TRA1	T-2	380	100	300	Canal Section	445+03 to 415+72	Canal dimensions 24.3-ft base width, 8-ft deep, and 1.5:1 side slopes.	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 2,931 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA1	T-3	380	100	300	Traynor Headgates	444+75	5-bay structure, 4 4-ft wide gates, and 1 4-ft wide flashboard	N/A	Replace with 5-bay sluice gate, increase invert height to 90.1-ft elevation	Replace structure with long-crested weir.	Replace with 62-ft long-crested weir. Weir to be 7.4-ft high and include two 3-ft-wide overshot gates, max opening 6.5 ft.
TRA1	T-4	380	100	300	Nugent Flume	418+65.7 to 418+12.9	Concrete flume over drain, 17.5-ft wide, 7.25-ft deep, and 60-ft long	Concrete flume, 22-ft wide, 10.5-ft deep, and 60-ft long	Concrete flume, 22-ft wide, 11.5-ft deep, and 60-ft long	Replace flume to improve freeboard and capacity.	Replace with 60-ft long by 22-ft wide by 10.5-ft deep flume. Install 2 check bays, one on either side of flume, to allow for spill.
TRA1, TRA2	T-5	380	100	300	Canal Section: Nugent Flume to Farm Crossing	417+87.6 to 379+21.4	Canal dimensions 21-ft base width, 9.3-ft deep, and less than 1.5:1 side slopes.	Enlarge canal to 34-ft base width, 11-ft deep, and 2:1 side slopes.	Raise canal banks	Widen canal to improve hydraulics.	Widen 3,867 LF of canal to 34-ft bottom width, 11-ft depth, 2:1 side slopes. (Approximately 291 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks.
TRA1	T-6	380	100	300	Canal Section	405+80 to 373+25	Canal dimensions 21 ft BW, 9.3 ft D, <1.5:1 side slopes	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 3,255 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA2	T-7	380	100	300	Canal Section: Farm Crossing to Colusa Hwy Bridge	379+06 to 352+83.9	Canal dimensions 16-ft base width, 10.3-ft deep, and less than 1.5:1 side slopes	Enlarge canal to 25-ft BW, 10-ft depth, and 2:1 side slopes	Raise canal banks	Widen canal to improve hydraulics.	Widen 2,622 LF of canal to 16-ft bottom width, 10-ft depth, 2:1 side slopes. (Approximately 291 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks.
TRA2	T-8	380	100	300	Canal Section	368+55 to 357+95	Canal dimensions 16-ft base width, 10.3-ft depth, and less than 1.5:1 side slopes	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 1,060 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA2	T-9	380	100	300	Structure #2633: Farm Crossing	379+07	Bridge spanning canal, 29-ft opening, 1 1.5-ft wide pier	N/A	Replace bridge with higher roadway elevation	Replace farm crossing.	Replace with 2-ft-thick flat slab bridge deck. Assumes asphalt concrete (AC) driving surface will be applied.
TRA2	T-10	380	100	300	New Structure	354+00	–	N/A	N/A	Construct long-crested weir.	Construct 48-ft long-crested weir. Weir to be 8.7-ft high and include two 3-ft-wide overshot gates, max opening 7-ft.
TRA2	T-11	380	100	300	Canal Section	354+00 to 352+81.6	Canal dimensions 16-ft base width, 10.3-ft deep, and less than 1.5:1 side slopes.	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 118 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA2	T-12	370	100	300	Colusa Hwy Bridge	352+81.6	County bridge deck (5 ft thick) and piers form opening underneath bridge of approximately 13-ft wide by 5.5-ft deep	Replace bridge. Redesign to have same road height, 3-ft deck height with 2-ft wide center pier	Replace bridge with higher roadway elevation	Replace bridge with larger culvert opening.	Replace bridge with flat slab, 3-ft deck height and 2-ft wide center pier. Maintain existing road height. Consider siphon under bridge. Assume AC driving surface.
TRA3, TRA4	T-13	310	88	258	Canal Section: Colusa Hwy Bridge to West Liberty Rd Bridge	352+53.1 to 299+35.5	Canal dimensions 16-ft base width, 10-ft deep, and less than 1.5:1 side slopes	Enlarge canal to 16-ft base width, 10-ft deep, and 2:1 side slopes.	Raise canal banks	Widen canal to improve hydraulics.	Widen 5,317 LF of canal to 16-ft bottom width, 10-ft depth, 2:1 side slopes. (Approximately 50 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks.
TRA3	T-14	310	88	258	Canal Section	343+95 to 299+32.5	Canal dimensions 16-ft base width, 10-ft deep, and less than 1.5:1 side slopes	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 4,462 LF of canal banks to achieve 18 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA4	–	220	70	170	West Liberty Rd Bridge	299+32.5	County bridge deck (5 ft thick) and piers form opening underneath bridge of approximately 13-ft wide by 6.5-ft deep	N/A	Replace bridge with higher roadway elevation	N/A	Consider replacement during final design.
TRA5	–	220	70	170	Check	298+35.4	3-bay sluice gate structure, each 3.7-ft wide	N/A	N/A	N/A	
TRA5	–	220	70	170	#1366 - Farm Crossing	284+80	Bridge spanning canal, 17.8-ft wide opening	N/A	N/A	N/A	In final design, consider measures to prevent bed scouring due to increased velocities.
TRA5	T-15	220	70	170	Canal Section: Traynor Extension (West Liberty Rd Bridge to Rising River Headgates)	298+36.4 to 271+11	Canal dimensions 10-ft base width, 5.5-ft deep, and 1.5:1 side slopes.	Enlarge canal to 12-ft base width, 10-ft deep, and 1.5:1 side slopes (cut bottom channel slope linearly decreasing from u/s to d/s)	Raise canal banks	Widen canal to improve hydraulics.	Widen 2,725 LF of canal to 12-ft bottom width, 10-ft depth, 2:1 side slopes. (Approximately 170 sq ft of excavated dirt for every linear foot of canal.) Provide 14-ft minimum top width for canal banks. Cut bottom channel slope linearly decreasing from upstream to downstream.
TRA1 - TRA5	T-16	–	–	–	Seepage Drains	(where applicable)	Seepage drain parallel to canal along some reaches.	N/A	N/A	Replace seepage drains impacted by canal modifications.	Replace 29,300 LF of seepage drains.

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Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area

Biggs-West Gridley Water District

Composite Alternative Improvements: Rising River Lateral

Reach	ID	Design Flow (cfs)	Low Flow (cfs)	High Flow (cfs)	Name/Description	Station	Existing Conditions	Alternative 1 Improvements	Alternative 2 Improvements	Composite Alternative Improvements	Composite Alternative Details/Notes
TRA6	–	120	30	90	Canal Section: Downstream end of Traynor Extension to Rising River Headgates	271+11 to 270+78	Canal dimensions 10-ft base width, 9-ft deep, and much less than 1.5:1 side slopes. Traynor/Rising River joins to Cassady Lateral in this area	Enlarge canal to 10-ft base width, 9-ft depth, and 2:1 side slopes	N/A	N/A	
TRA6	–	120	30	90	#1344 - Rising River Headgates	270+77	3-bay structure, 1 sluice gate 3.2-ft wide, 6.1-ft high, 1-bay flashboard 3.2-ft wide	N/A	N/A	N/A	
TRA6	R-1	120	30	90	Canal Section	270+59 to 221+30	Canal dimensions 13-ft base width, 6 to 7-ft deep, and less than 2:1 side slopes			Raise canal banks to meet freeboard requirements.	Increase height of 4,929 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA6	–	120	30	90	Canal Section: Rising River (Rising River Headgates to Refuge	270+58 to 187+35	Canal dimensions 13-ft base width, 6 to 7-ft deep, and less than 2:1 side slopes.	Enlarge canal to 18-ft base width, 8 to 9-ft depth, and 2:1 side slopes	N/A	N/A	
TRA6	–	120	30	90	#2824 - Farm Crossing	234+20	Bridge spanning canal, 1.5-ft wide deck, 17-ft wide opening, 1 1-ft wide pier	N/A	N/A	N/A	
TRA6	R-2	120	30	90	#2808 - Flashboard Check	221+85.5	3-bay flashboard structures each 3-ft wide	N/A	N/A	Replace structure with long-crested weir.	Long-crested weir will be 19-ft long and 3.1-ft high. Include one 4-ft-wide gate, max opening 3-ft
TRA6	R-3	120	30	90	Canal Section	200+00 to 194+30	Canal dimensions 13-ft base width, 6 to 7-ft deep, and less than 2:1 side slopes.			Raise canal banks to meet freeboard requirements.	Increase height of 570 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
TRA6	–	120	30	90	Foot Bridge	199+94	1.5-ft wide deck	N/A	N/A	N/A	
TRA6	R-4	120	30	90	Evans Reimer Bridge	194+30	3.5-ft wide deck, 12-ft wide opening	N/A	N/A	Replace bridge	Replace with bridge having 1-ft-thick center pier, 2-ft-thick slab with 7-ft opening to canal base. Bridge deck should have 2-3/8-inch thick AC road surface.

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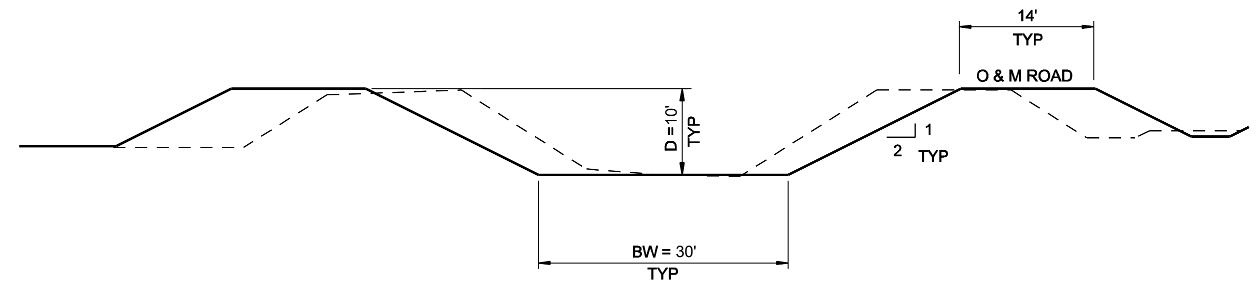
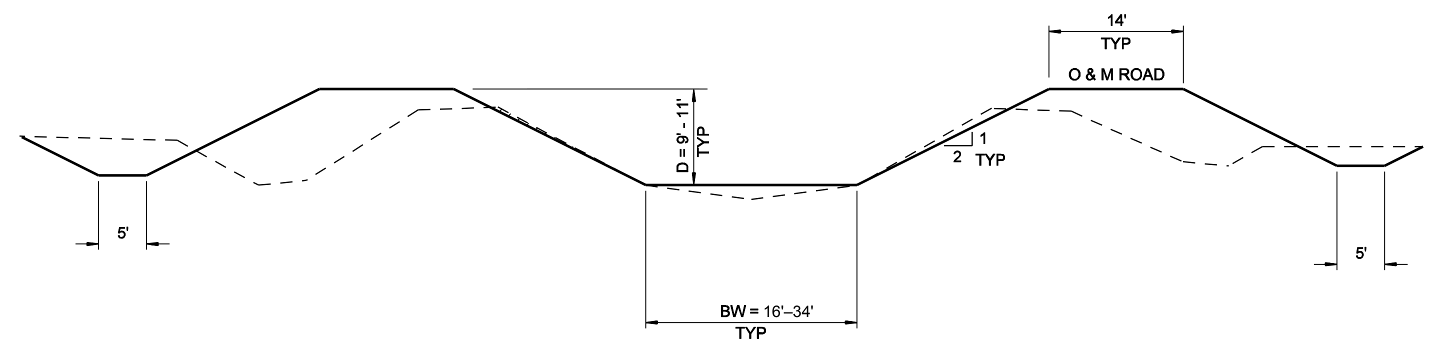
Conveyance of Refuge Water Supply to Gray Lodge Wildlife Area
Biggs-West Gridley Water District
Composite Alternative Improvements: Cassady Lateral

Reach	ID	Design Flow (cfs)	Low Flow (cfs)	High Flow (cfs)	Name/Description	Station	Existing Conditions	Alternative 1 Improvements	Alternative 2 Improvements	Composite Alternative Improvements	Composite Alternative Details/Notes
CAS1	C-1	85	43	71	Canal Section	450+63 to 364+56	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 8,607 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
CAS1	–	85	43	71	Structure #1292, Farm Crossing	428+89	–	N/A	N/A	N/A	
CAS1	–	85	43	71	Structure #1284	427+14	3-bay flashboard structure each 3.4-ft wide	N/A	N/A	N/A	
CAS1	–	85	43	71	Peterson's Check	400+09.55	2-bay flashboard structure each 3.6-ft wide	N/A	N/A	N/A	
CAS1	C-2	85	43	71	Structure #1226, Farm Crossing	394+00	4-ft diameter circular concrete culvert, 24-ft long	Concrete box culvert, 8-ft wide, 4-ft deep, and 24-ft long	Concrete box culvert, 8-ft wide, 4-ft deep, and 24-ft long	Replace box culvert/crossing.	Replace with concrete box culvert, 8-ft-wide by 4-ft-deep by 24-ft-long, with integrated farm crossing.
CAS1	C-3	85	43	71	Structure #1199, Bonslett's Driveway	384+78.48	3.5-ft circular concrete, 23.8-ft long	Concrete box culvert, 7-ft wide, 4-ft deep, and 24-ft long	Concrete box culvert, 7-ft wide, 4-ft deep, and 24-ft long	Replace box culvert/crossing.	Replace with concrete box culvert, 4-ft-wide by 6-ft-deep by 7-ft-long. Structure to have 6-ft-high sidewalls and wingwalls adjacent to driveway.
CAS1	C-4	85	43	71	Bonslett Weir	384+23.25	1-bay sluice gate structure, 6-ft wide by 3.3-ft deep	3-bay sluice gate, each 3-ft wide, and 3.5-ft deep	3-bay sluice gate, each 3-ft wide, and 3.5-ft in depth	Replace structure with long-crested weir.	Replace with 56-ft long-crested weir. Weir to be 2.7-ft high and include one 3-ft-wide overshot gate, max opening 2.5 ft .
CAS1	C-5	85	43	71	Structure #1163	364+56.7	3.5-ft diameter circular concrete culvert, 24-ft long	Replace with concrete box culvert, 5-ft wide, 4-ft deep, 35-ft long, and sluice gate, 5-ft wide, 4-ft in depth	Replace with concrete box culvert, 5-ft wide, 4-ft in depth, 35-ft long, and sluice gate, 5-ft wide, 4-ft in depth	Replace structure with long-crested weir.	Replace with 27-ft long-crested weir. Weir to be 6.3-ft high and include one 3-ft wide gate, max opening 3.5 ft.
CAS1	C-6	85	43	71	Canal Section	357+36 to 340+22	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 1,714 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
CAS2	–	30	24	25	Structure #1131	347+01.8	Concrete box culvert, 4-ft wide by 4.6-ft deep	N/A	N/A	N/A	
CAS2	–	30	24	25	Structure #1113	341+61.5	3.5-ft diameter circular concrete culvert	N/A	N/A	N/A	
CAS2	–	30	24	25	Structure #1090	339+92	1-bay flashboard structure, 4-ft wide	N/A	N/A	N/A	
CAS2	C-7	30	24	25	Canal Section	336+13 to 326+33	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 980 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
CAS2	–	30	24	25	Structure #1060	325+95	3-ft diameter circular concrete culvert	N/A	N/A	N/A	Consider replacement during final design to reduce head loss through culvert under high flow conditions
CAS2	C-8	30	24	25	Canal Section	319+82 to 300+00	–	N/A	N/A	Raise canal banks to meet freeboard requirements.	Increase height of 1,982 LF of canal banks to achieve 12 inches of freeboard and reshape to provide 14-ft minimum top width for canal banks.
CAS2	–	30	24	25	Evans Reimer Rd Culvert	295+15	3-ft diameter circular concrete culvert	N/A	N/A	N/A	

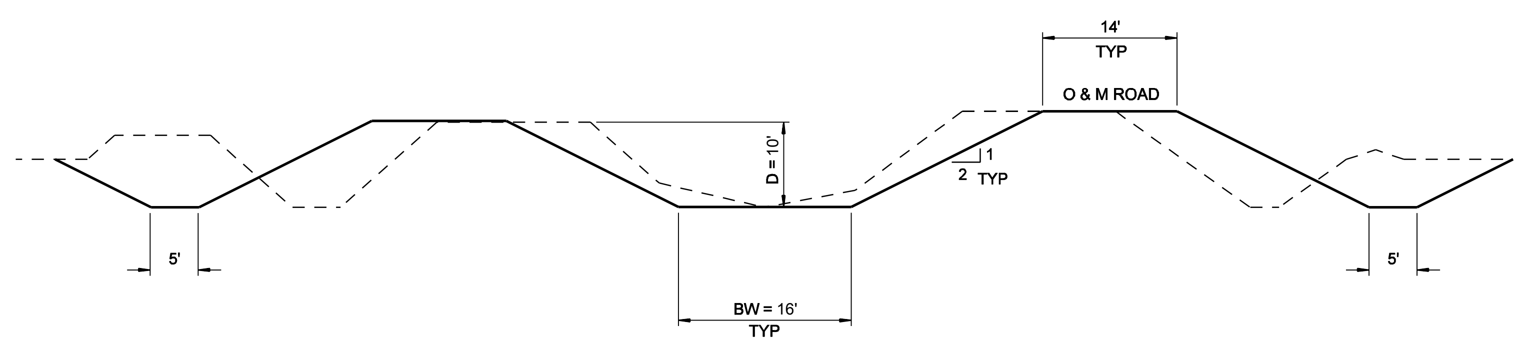
Appendix D
Appraisal-level Drawings



BELDING LATERAL, RICETON HWY TO FIELDS FLUME
1"=20'



TRAYNOR LATERAL, NUGENT FLUME
TO COLUSA HIGHWAY
1"=20'



TRAYNOR LATERAL, COLUSA HWY TO
WEST LIBERTY ROAD
1"=20'

LEGEND:

NEW CROSS SECTION

EXISTING CROSS SECTION

FIGURE D-1
TYPICAL CROSS-SECTIONS
FOR MAIN LATERAL IMPROVEMENTS
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

5993cp104.dlv 04-JAN-2006 14:43:19

175993.B8

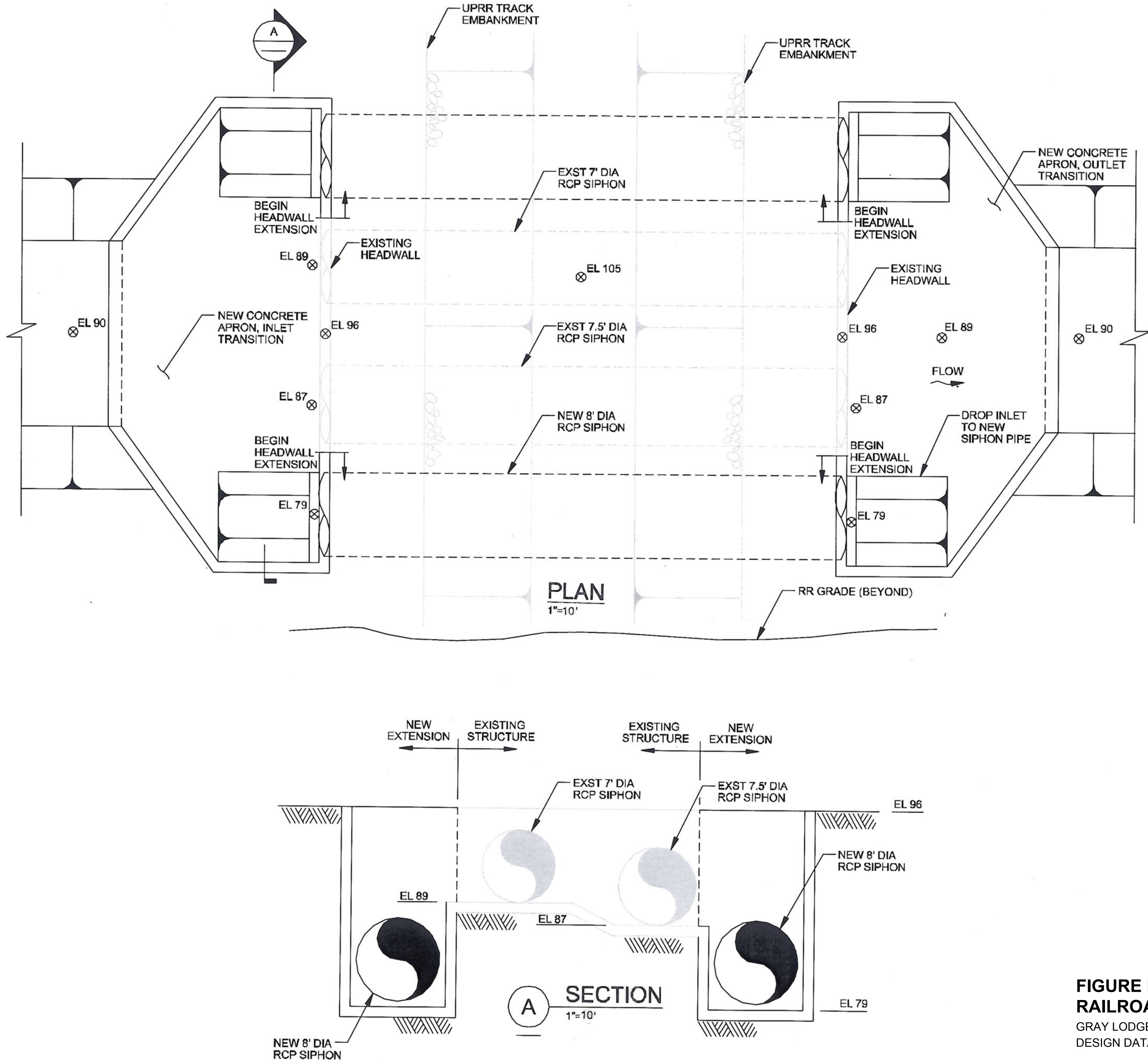


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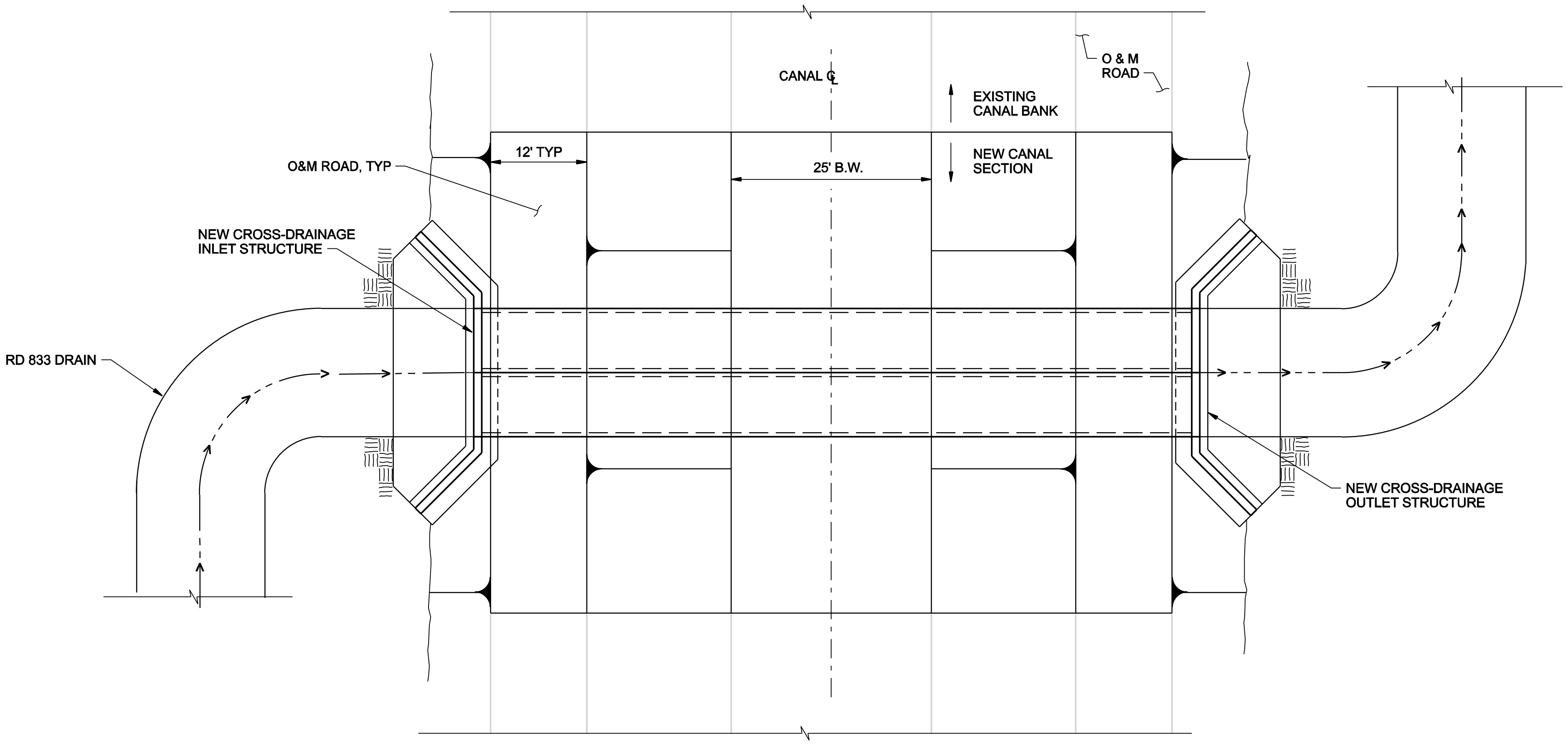
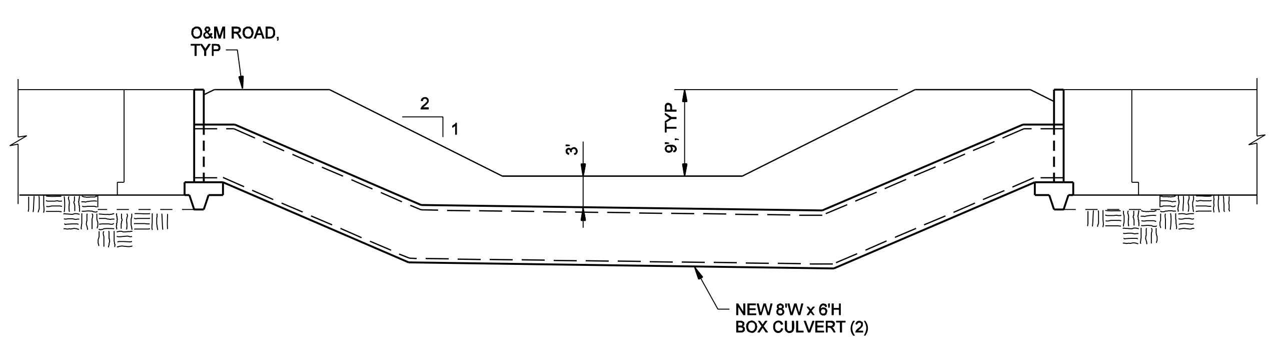
FIGURE D-2
RAILROAD CULVERTS
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL



PLAN
1"=20'



PROFILE
1"=20'

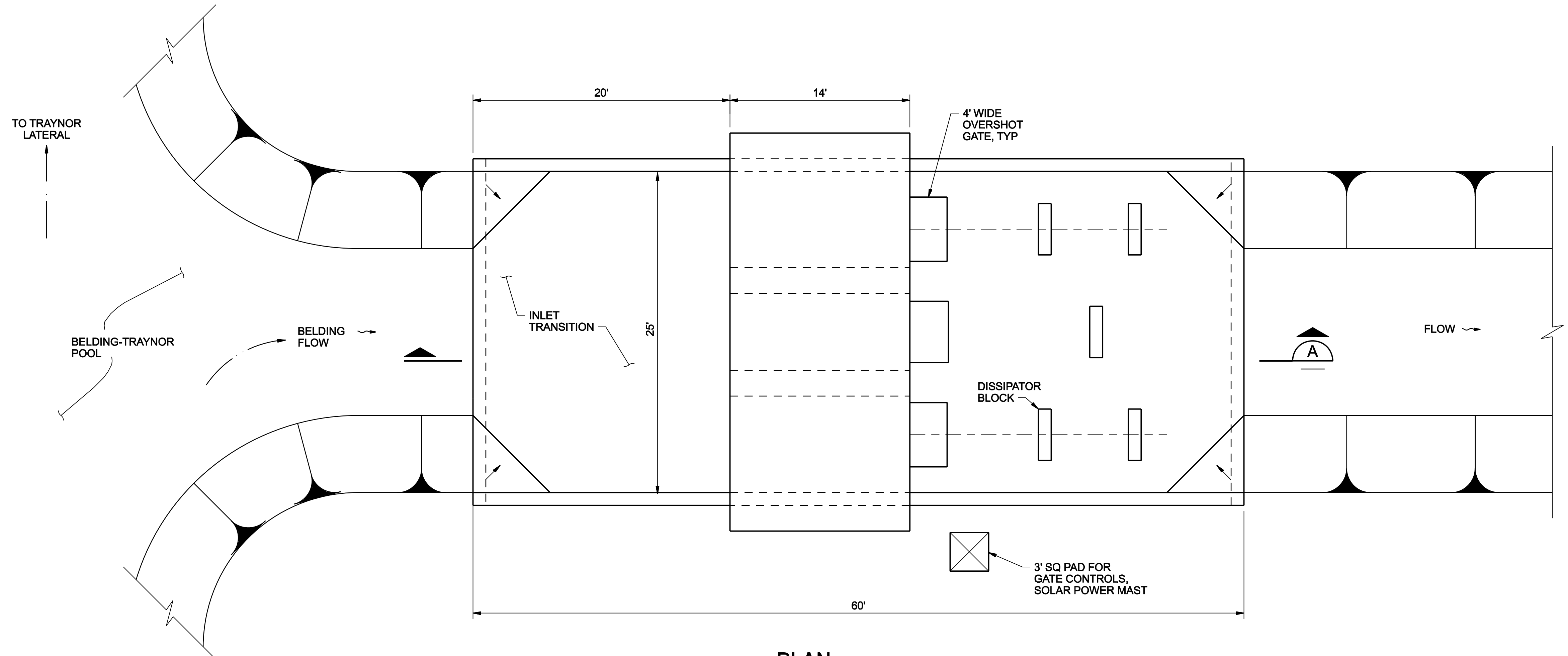
5993cp100.dlv 04-JAN-2006 15:44:14

175993.B8

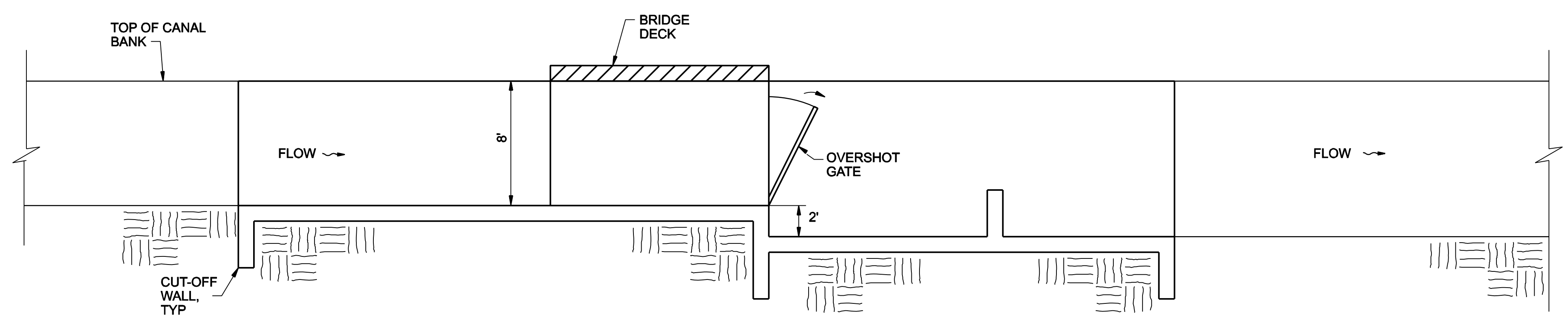
FIGURE D-3
NEW CROSS-DRAINAGE SIPHON STRUCTURE FOR RAZOR BACK AND GARCIA SIPHON REMOVAL PROJECTS

GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL



PLAN
1"=10'



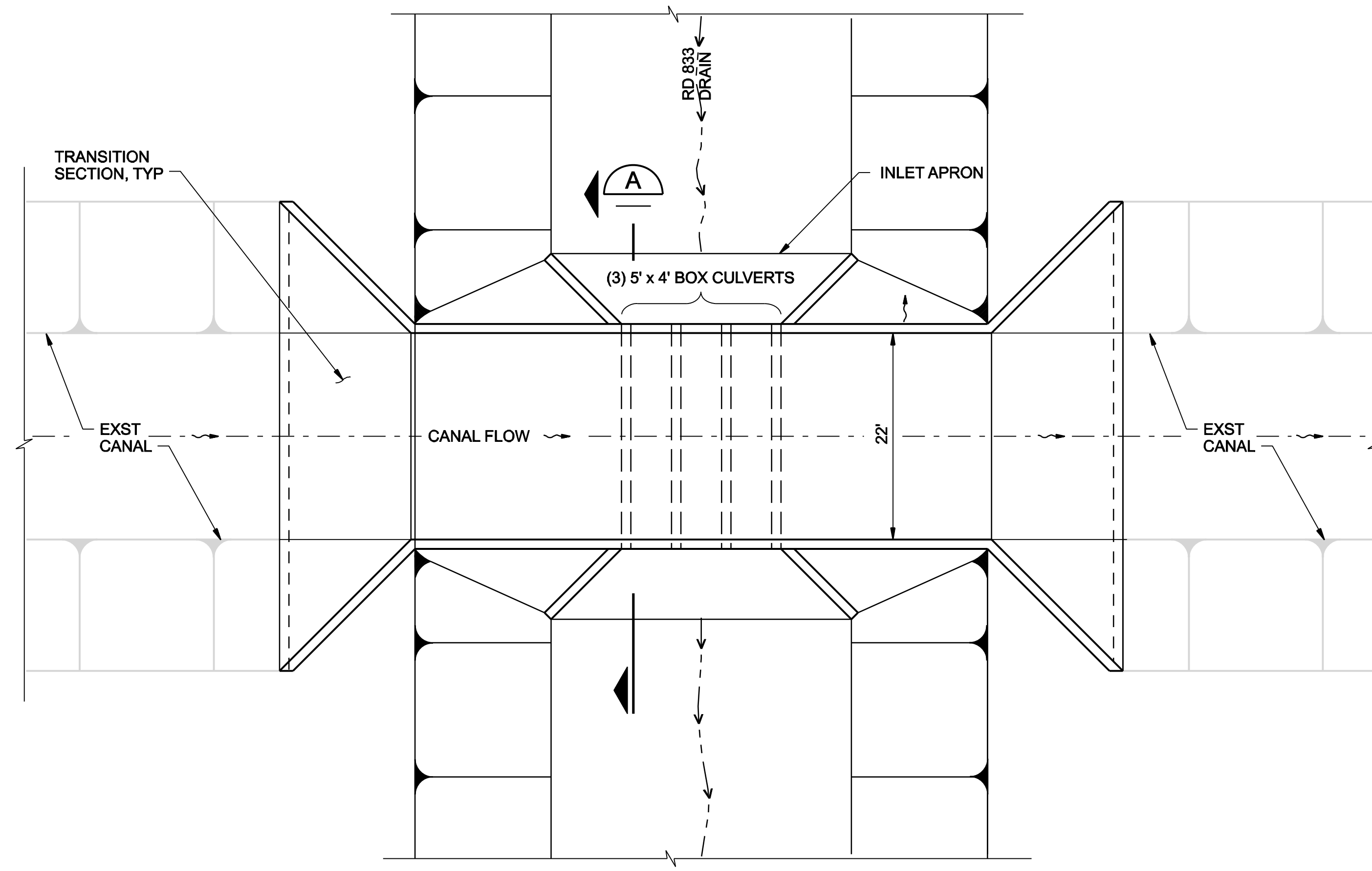
SECTION A
1"=10'

5993cp103.dlv 04-JAN-2006 14:42:49

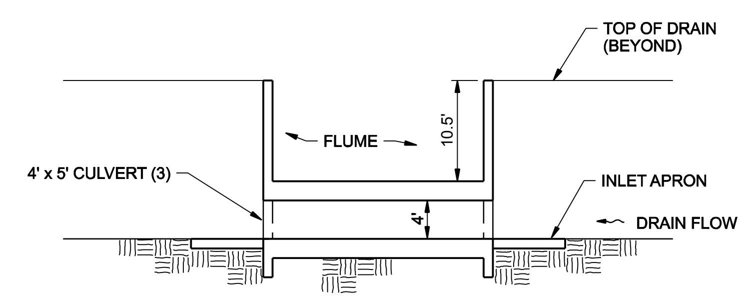
175993.B8

FIGURE D-4
DIVISION 2
HEADGATE AND ACCESS BRIDGE
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL



PLAN
1"=20'



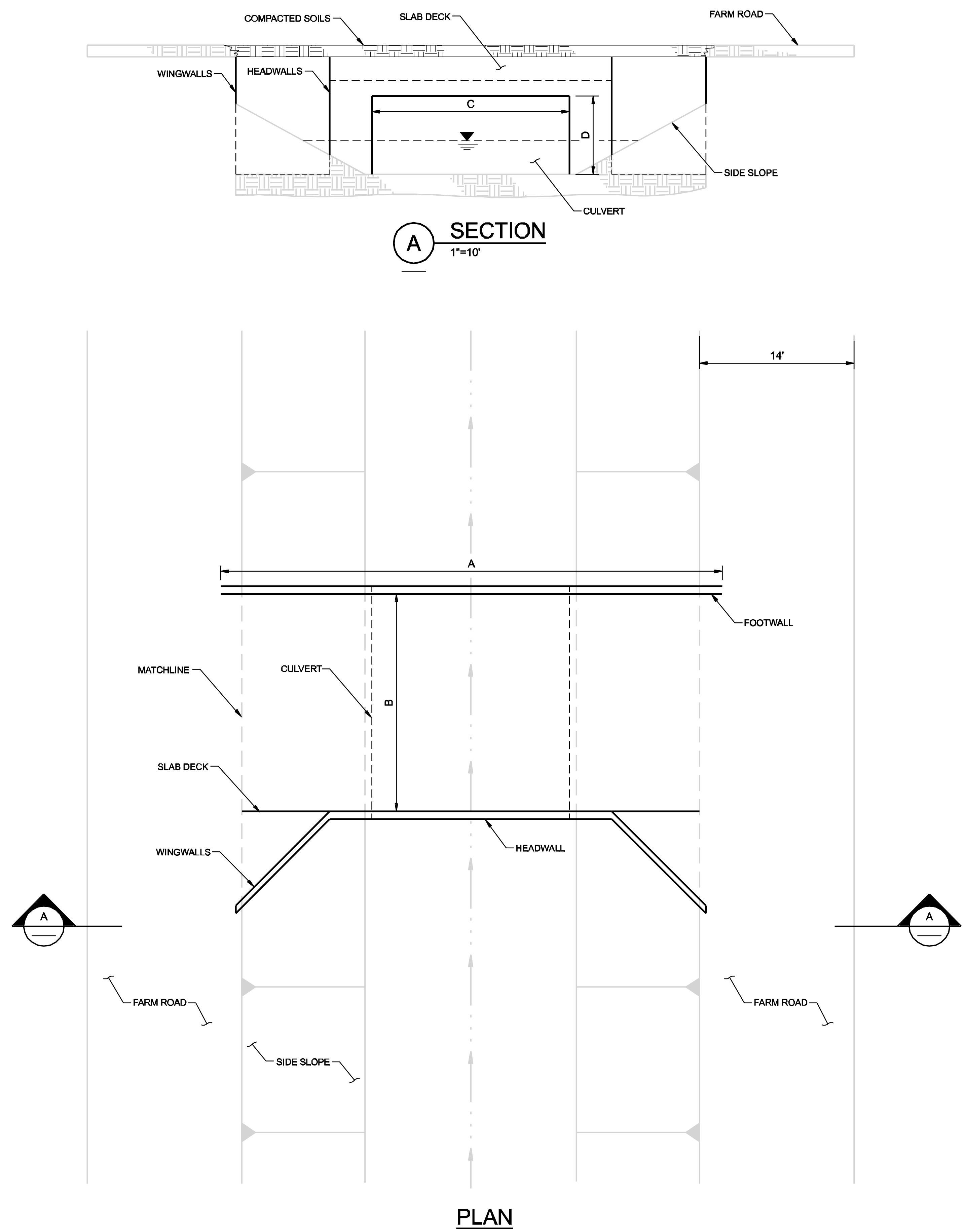
SECTION A
1"=20'

FIGURE D-5
NUGENT FLUME REPLACEMENT STRUCTURE
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL

175993.B8

5993cp101.dlv 04-JAN-2006 14:41:38



FARM CROSSING #7137 S-3

DIMENSION	DISTANCE
A	20.0
B	24.0
C	7.0
D	4.0

FARM CROSSING #1491 S-6

DIMENSION	DISTANCE
A	30.0
B	20.0
C	9.0
D	4.0

FARM CROSSING #1438 S-8

DIMENSION	DISTANCE
A	25.0
B	19.0
C	7.0
D	4.0

FARM CROSSING #1226 C-2

DIMENSION	DISTANCE
A	25.0
B	24.0
C	8.0
D	4.0

BONSLETT'S DRIVEWAY C-3

DIMENSION	DISTANCE
A	20.0
B	24.0
C	7.0
D	4.0

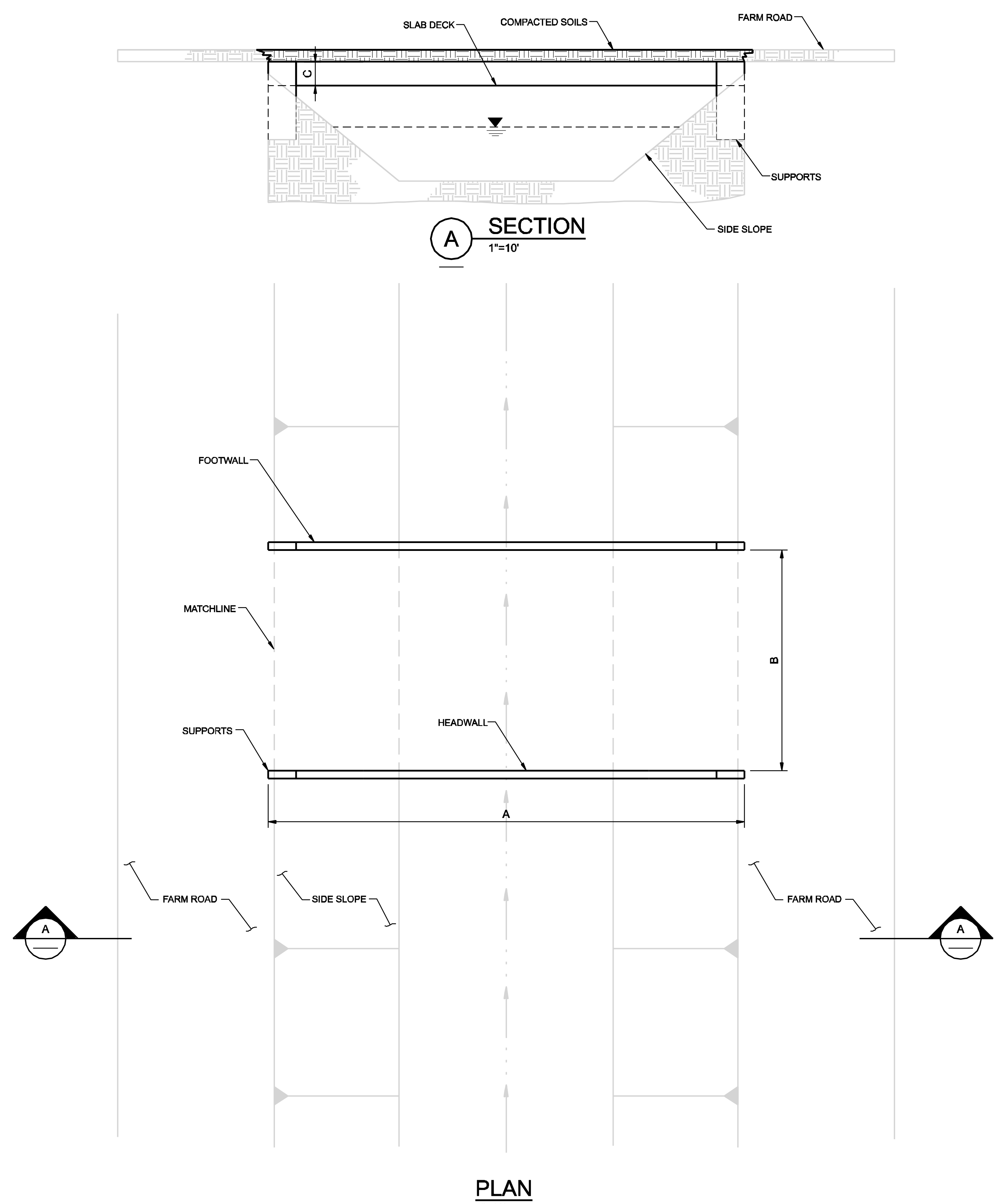
NOTE:

1. AREAS BETWEEN CULVERT AND SLAB ARE FILLED IN WITH SOILS.

FIGURE D-6
BRIDGE WITH CULVERT
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL

352069.RF.03.03.04



AFTON BRIDGE B-8

DIMENSION	DISTANCE
A	35.0
B	26.0
C	2.0

DIVISION 2 HEAD GATE B-16

DIMENSION	DISTANCE
A	35.0
B	12.0
C	2.0

FARM CROSSING #1786 B-22

DIMENSION	DISTANCE
A	24.0
B	18.5
C	2.0

FARM CROSSING #1719 B-23

DIMENSION	DISTANCE
A	24.0
B	18.5
C	2.0

FARRIS ROAD BRIDGE B-24

DIMENSION	DISTANCE
A	41.0
B	24.0
C	2.0

BONSLETT BRIDGE B-25

DIMENSION	DISTANCE
A	35.0
B	25.1
C	2.0

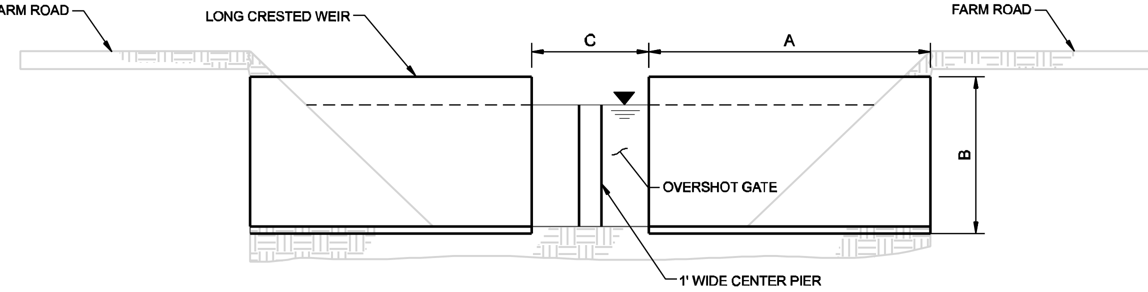
BRIDGE #1522 S-5

DIMENSION	DISTANCE
A	24.0
B	17.3
C	2.0

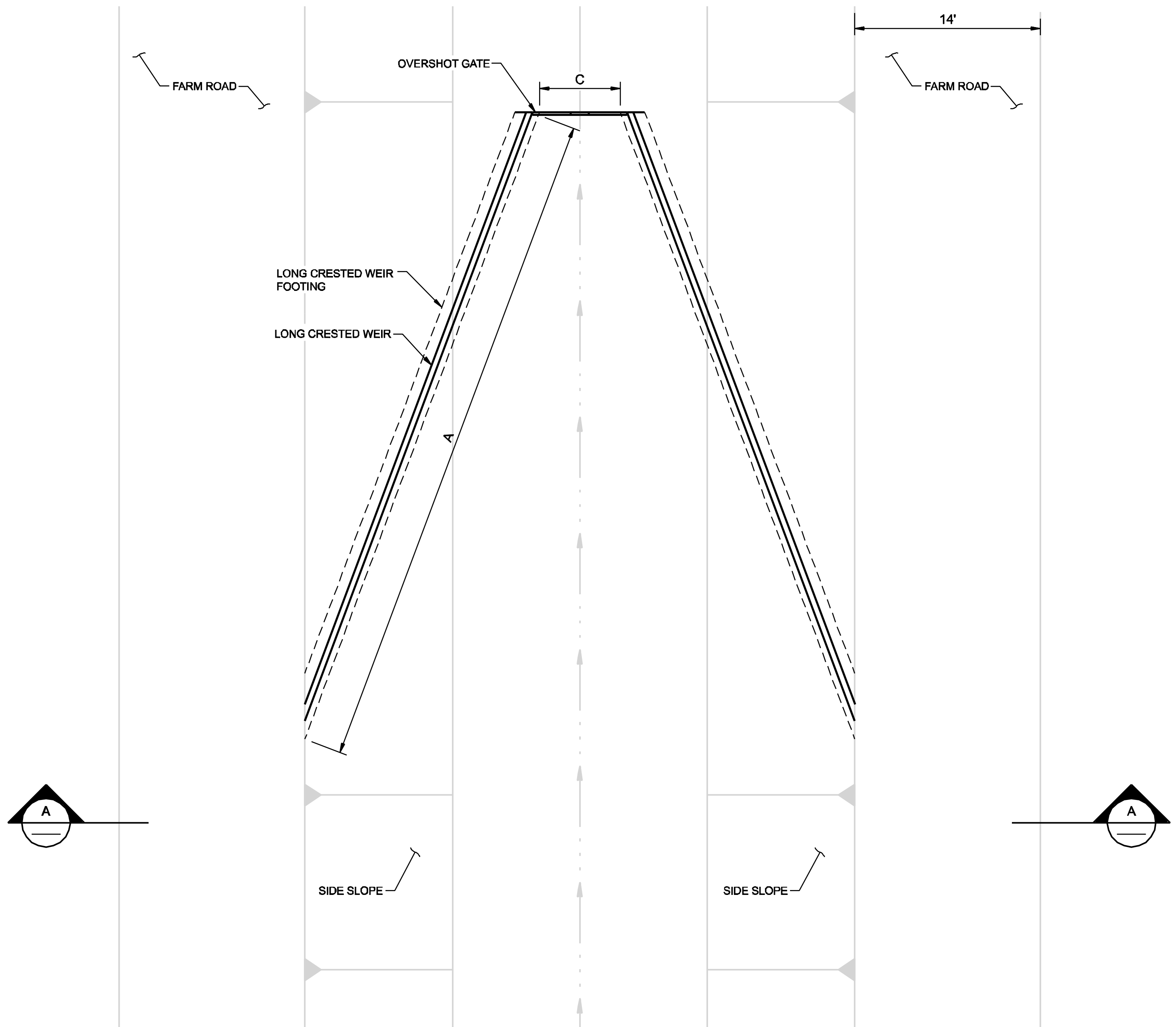
FIGURE D-7
FARM CROSSING
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL

352069.RF.03.03.04



A SECTION
1"=10'



PLAN
1"=10'

GARCIA CHECK B-5

DIMENSION	DISTANCE
A	35.0
B	7.0
C	12.0

BRIDGE #1522 S-5

DIMENSION	DISTANCE
A	18.5
B	6.6
C	3.0

BANION CHECK B-10

DIMENSION	DISTANCE
A	35.0
B	6.4
C	15.5

TRAYNOR HEADGATES T-3

DIMENSION	DISTANCE
A	31.0
B	7.4
C	7.0

NORTH WEIR B-15

DIMENSION	DISTANCE
A	50.0
B	6.6
C	10.0

NEW CONTROL STRUCTURE T-10

DIMENSION	DISTANCE
A	24.0
B	8.7
C	7.0

CHECK #1889 B-18

DIMENSION	DISTANCE
A	22.5
B	5.3
C	4.0

FLASHBOARD #2802 R-2

DIMENSION	DISTANCE
A	9.5
B	3.1
C	5.0

CHECK #1845 B-20

DIMENSION	DISTANCE
A	41.5
B	4.7
C	8.0

BONSLETT WEIR C-4

DIMENSION	DISTANCE
A	28.0
B	2.7
C	2.0

BONSLETT BRIDGE B-25

DIMENSION	DISTANCE
A	25.0
B	7.0
C	4.0

PIPE CULVERT #1163 C-5

DIMENSION	DISTANCE
A	13.5
B	6.3
C	2.0

NOTE:

1. NOT ALL OVERSHOT GATES WILL HAVE A CENTER PIER.

FIGURE D-8
LONG CRESTED WEIR OVERSHOT GATE
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

CH2MHILL

352069.RF.03.03.04

Appendix E
Appraisal-level Cost Estimates for Recommended Improvements

TABLE E-1
Belding Lateral Projects - Detailed Cost Table, June 2009
Gray Lodge Design Data Report

Location/Name	Cost List ID	Pay Item	Quantity	Units	Unit Cost	Item Subtotal
		Major Structures				
Razorback Siphon	B-1	Demolition	40	cubic yd	$ 230	$ 9,200
		Site excavation	350	cubic yd	$ 7	$ 2,450
		New headwalls	7	cubic yd	$ 1,950	$ 13,650
		New 8 ft x 6 ft culverts	100	linear ft	$ 1,000	$ 100,000
		New earthen canal section	950	cubic yd	$ 34	$ 32,300
		Diversion canal excavation	3,800	cubic yd	$ 7	$ 26,600
		Diversion canal importation	427	cubic yd	$ 34	$ 14,518
		Diversion canal compaction	586	cubic yd	$ 20	$ 11,720
		Diversion canal road compaction	284	cubic yd	$ 7	$ 1,988
		Mobilization @ 5%				$ 10,621
		Design Contingency @ 15% +/-				$ 26,953
					Contract Cost	**$ 250,000**
Railroad Culverts	B-3	Bore and jack 8 ft diameter (2)	140	linear ft	$ 5,750	$ 805,000
		Site excavation for additional width of canal	1,111	cubic yd	$ 7	$ 7,777
		Additional headwall width-both sides of RR(2)	11	cubic yd	$ 1,950	$ 21,450
		Mobilization @ 5%				$ 41,711
		Design Contingency @ 15% +/-				$ 124,062
					Contract Cost	**$ 1,000,000**
Garcia Check	B-5	Removal of check bays	6	each	$ 4,600	$ 27,600
		Removal of concrete headwalls	3.5	cubic yd	$ 230	$ 805
		Removal of concrete sidewalls	8	cubic yd	$ 230	$ 1,840
		Removal of concrete wingwalls	2.8	cubic yd	$ 230	$ 644
		Diversion canal excavation	3,800	cubic yd	$ 7	$ 26,600
		Diversion canal importation	427	cubic yd	$ 34	$ 14,518
		Diversion canal compaction	586	cubic yd	$ 20	$ 11,720
		Diversion canal road compaction	284	cubic yd	$ 7	$ 1,988
		Install concrete long crested weir	15	cubic yd	$ 1,950	$ 29,250
		Install overshot gate	8	linear ft	$ 8,600	$ 68,800
		Reinforced concrete structure above gate	1	each	$ 63,000	$ 63,000
		Mobilization @ 5%				$ 12,338
		Design Contingency @ 15% +/-				$ 40,897
					Contract Cost	**$ 300,000**
Garcia Siphon	B-6	Demolition	40	cubic yd	$ 230	$ 9,200
		Site excavation	350	cubic yd	$ 400	$ 140,000
		New headwalls	7	cubic yd	$ 1,950	$ 13,650
		New 8 ft x 6 ft culverts	200	linear ft	$ 1,000	$ 200,000
		New earthen canal section	950	cubic yd	$ 34	$ 32,300
		Diversion canal excavation	3,800	cubic yd	$ 7	$ 26,600
		Diversion canal importation	427	cubic yd	$ 34	$ 14,518
		Diversion canal compaction	586	cubic yd	$ 20	$ 11,720
		Diversion canal road compaction	284	cubic yd	$ 7	$ 1,988
		Mobilization @ 5%				$ 22,499
		Design Contingency @ 15% +/-				$ 67,525
					Contract Cost	**$ 540,000**
Afton Bridge	B-8	Removal of 4 ft diameter concrete culvert	32	linear ft	$ 72	$ 2,304
		Removal of headwalls	3	cubic yd	$ 230	$ 690
		Removal of wingwalls	4	cubic yd	$ 230	$ 920
		Removal of AC cement	9	cubic yd	$ 12	$ 108
		Removal of footwalls	9	cubic yd	$ 230	$ 2,070
		Removal of soils	198	cubic yd	$ 7	$ 1,386
		Installation of wingwalls	15.5	cubic yd	$ 1,700	$ 26,350
		Installation of slab crossing	67.5	cubic yd	$ 2,000	$ 135,000
		Installation of AC cement	144	cubic ft	$ 63	$ 9,072
		Diversion canal temporary bridge	1	each	$ 86,000	$ 86,000
		Diversion canal excavation	3,800	cubic yd	$ 7	$ 26,600
		Diversion canal importation	427	cubic yd	$ 34	$ 14,518
		Diversion canal compaction	586	cubic yd	$ 20	$ 11,720
		Diversion canal road compaction	284	cubic yd	$ 7	$ 1,988
		Mobilization @ 5%				$ 15,936
		Design Contingency @ 15% +/-				$ 45,338
					Contract Cost	**$ 380,000**
Banion Check	B-10	Removal of check bays	4	each	$ 4,600	$ 18,400
		Removal of sluice gates	4	each	$ 4,600	$ 18,400
		Removal of concrete headwalls	3.5	cubic yd	$ 230	$ 805
		Removal of concrete sidewalls	8	cubic yd	$ 230	$ 1,840
		Removal of concrete wingwalls	2.8	cubic yd	$ 230	$ 644
		Diversion canal excavation	3,800	cubic yd	$ 7	$ 26,600
		Diversion canal importation	427	cubic yd	$ 34	$ 14,518
		Diversion canal compaction	586	cubic yd	$ 20	$ 11,720
		Diversion canal road compaction	284	cubic yd	$ 7	$ 1,988
		Install concrete long crested weir	15	cubic yd	$ 1,950	$ 29,250
		Install overshot gate	8	linear ft	$ 8,600	$ 68,800
		Reinforced concrete structure above gate	1	each	$ 63,000	$ 63,000
		Mobilization @ 5%				$ 12,798
		Design Contingency @ 15% +/-				$ 41,237
					Contract Cost	**$ 310,000**

North Weir	B-15	Removal of sluice gates	2 each	$ 4,600	$ 9,200
		Removal of flashboard gates	2 each	$ 4,600	$ 9,200
		Removal of 2.7' diameter concrete culvert	16 linear ft	$ 45	$ 720
		Removal of concrete sidewalls	5 cubic yd	$ 230	$ 1,150
		Removal of concrete headwalls	1 cubic yd	$ 230	$ 230
		Removal of concrete wingwalls	1 cubic yd	$ 230	$ 230
		Installation of overshot gate	8 linear ft	$ 8,600	$ 68,800
		Reinforced concrete structure above gate	1 each	$ 63,000	$ 63,000
		Installation of concrete-long crested weir	18.5 cubic yd	$ 1,950	$ 36,075
		Diversion canal excavation	3,800 cubic yd	$ 7	$ 26,600
		Diversion canal importation	427 cubic yd	$ 34	$ 14,518
		Diversion canal compaction	586 cubic yd	$ 20	$ 11,720
		Diversion canal road compaction	284 cubic yd	$ 7	$ 1,988
		Mobilization @ 5%			$ 12,172
		Design Contingency @ 15% +/-			$ 34,397
				Contract Cost	**$ 290,000**
Division 2 Head Gate (Belding/Traynor Split)	B-16	RIGHT FORK			
		Removal of three, 3 ft diameter concrete culverts	39 linear ft	$ 49	$ 1,911
		Removal of sluice gates	2 each	$ 4,600	$ 9,200
		Removal of flash bays	1 each	$ 4,600	$ 4,600
		Removal of headwalls	5 cubic yd	$ 230	$ 1,150
		Removal of sidewalls	2 cubic yd	$ 230	$ 460
		Removal of earthen farm crossing	77 cubic yd	$ 7	$ 539
		Installation of sluice gates	3 each	$ 115	$ 345
		Installation of headwalls	2 cubic yd	$ 1,950	$ 3,900
		Installation of concrete slab farm crossing	85 cubic yd	$ 2,000	$ 170,000
		Compaction of farm crossing soils	16 cubic yd	$ 7	$ 112
		LEFT FORK			
		See Traynor spreadsheet, structure T-2			
		OTHER			
		Relocation of road along canal	74,574 square ft	$ 3	$ 223,722
		Compaction of road along canal	2,762 cubic yd	$ 7	$ 19,334
		Importation of soils for banks	4,142 cubic yd	$ 34	$ 140,828
		Mobilization @ 5%			$ 28,805
		Design Contingency @ 15% +/-			$ 85,094
				Contract Cost	**$ 690,000**
Check #1889	B-18	Removal of check bays	3 each	$ 4,600	$ 13,800
		Removal of concrete headwalls	3.5 cubic yd	$ 230	$ 805
		Removal of concrete sidewalls	8 cubic yd	$ 230	$ 1,840
		Removal of concrete wingwalls	2.8 cubic yd	$ 230	$ 644
		Install concrete long crested weir	11 cubic yd	$ 1,950	$ 21,450
		Install overshot gate	4 linear ft	$ 8,600	$ 34,400
		Reinforced concrete structure above gate	1 each	$ 57,500	$ 57,500
		Mobilization @ 5%			$ 6,522
		Design Contingency @ 15% +/-			$ 23,039
				Contract Cost	**$ 160,000**
Check #1845	B-20	Removal of check bays	3 each	$ 4,600	$ 13,800
		Removal of concrete sidewalls	2 cubic yd	$ 230	$ 460
		Removal of concrete headwalls	3.3 cubic yd	$ 230	$ 759
		Install concrete long crested weir	19 cubic yd	$ 1,950	$ 36,075
		Reinforced concrete structure above gate	1 each	$ 57,500	$ 57,500
		Install overshot gate	7.0 linear ft	$ 8,600	$ 60,200
		Mobilization @ 5%			$ 8,440
		Design Contingency @ 15% +/-			$ 22,766
				Contract Cost	**$ 200,000**
Farris Road Bridge	B-24	Removal of headwalls	13.5 cubic yd	$ 230	$ 3,105
		Removal of imprevious cement 2 lane road	4 cubic yd	$ 12	$ 48
		Removal of 3 ft dia concrete culverts	120 linear ft	$ 50	$ 6,000
		Removal of soils	125 cubic yd	$ 7	$ 875
		Installation of concrete slab crossing	73 cubic yd	$ 2,000	$ 146,000
		Compacation of farm crossing soils	27.5 cubic yd	$ 7	$ 193
		Installation of wingwalls	3.4 cubic yd	$ 1,700	$ 5,780
		Installation of impervious cement 2 lane road	5.5 cubic yd	$ 63	$ 347
		Mobilization @ 5%			$ 8,117
		Design Contingency @ 15% +/-			$ 19,536
				Contract Cost	**$ 190,000**
Bonslett Bridge	B-25	Removal of headwall and footwall	9 cubic yd	$ 230	$ 2,070
		Removal of three 3 ft dia concrete pipe culverts	75 linear ft	$ 50	$ 3,750
		Removal of earthen sections of farm crossing	161 cubic yd	$ 7	$ 1,127
		Removal of check bays	3 each	$ 4,600	$ 13,800
		Installation of farm crossing cement	65 cubic yd	$ 2,000	$ 130,000
		Compaction of soils on the farm crossing	32.5 cubic yd	$ 7	$ 228
		Install concrete long crested weir	14.5 cubic yd	$ 1,950	$ 28,275
		Reinforced concrete structure above gate	1 each	$ 57,500	$ 57,500
		Install overshot gate	4.0 linear ft	$ 8,600	$ 34,400
		Mobilization @ 5%			$ 13,557
		Design Contingency @ 15% +/-			$ 45,293
				Contract Cost	**$ 330,000**

		Minor Structures						
Fields Flume	B-13	Remove 6" wide, 7' high concrete embankement	26	cubic yd	$	230	$	5,980
		Removal of check bays	2	each	$	4,600	$	9,200
		Replace 2' wide walkway	1	each	$	11,500	$	11,500
		New 6" wide, 8.5' high embankement walls	32	cubic yd	$	1,700	$	54,400
		New check bays	2	each	$	6,900	$	13,800
		Diversion canal temporary flume	1	each	$	34,500	$	34,500
		Diversion canal excavation	3,800	cubic yd	$	7	$	26,600
		Diversion canal importation	427	cubic yd	$	34	$	14,518
		Diversion canal compaction	586	cubic yd	$	20	$	11,720
		Diversion canal road compaction	284	cubic yd	$	7	$	1,988
		Mobilization @ 5%					$	9,210
		Design Contingency @ 15% +/-					$	26,584
					Contract Cost		**$**	**220,000**
Farm Crossing #1786	B-22	Removal of farm crossing cement	33	cubic yd	$	230	$	7,590
		Removal of wing walls	2.7	cubic yd	$	230	$	621
		Removal of side walls	6.4	cubic yd	$	230	$	1,472
		Installation of farm crossing cement	33	cubic yd	$	2,000	$	66,000
		Installation of wingwalls	3.1	cubic yd	$	1,700	$	5,270
		Installation of sidewalls	7.3	cubic yd	$	1,700	$	12,410
		Compaction of farm crossing soils	16.5	cubic yd	$	7	$	116
		Installation of soils on the farm crossing	444	cubic yd	$	34	$	15,096
		Mobilization @ 5%					$	5,429
		Design Contingency @ 15% +/-					$	15,997
					Contract Cost		**$**	**130,000**
Farm Crossing #1719	B-23	Removal of farm crossing cement	33	cubic yd	$	230	$	7,590
		Removal of wing walls	2.8	cubic yd	$	230	$	644
		Removal of side walls	6.4	cubic yd	$	230	$	1,472
		Installation of farm crossing cement	33	cubic yd	$	2,000	$	66,000
		Installation of wingwalls	3.4	cubic yd	$	1,700	$	5,780
		Installation of sidewalls	7.8	cubic yd	$	1,700	$	13,260
		Compaction of farm crossing soils	16.5	cubic yd	$	7	$	116
		Compaction of soils on the farm crossing	444	cubic yd	$	34	$	15,096
		Mobilization @ 5%					$	5,498
		Design Contingency @ 15% +/-					$	14,545
					Contract Cost		**$**	**130,000**
		Canal Channel Improvements						
Canal Section 607+73 to 603+89	B-2	Importation of soils	427	cubic yd	$	34	$	14,518
		Compaction of soils	284	cubic yd	$	7	$	1,988
		Mobilization @ 5%					$	825
		Design Contingency @ 15% +/-						2669
					Contract Cost		**$**	**20,000**
Canal Section 596+65 to 591+50	B-4	Importation of soils	573	cubic yd	$	34	$	19,482
		Compaction of soils	381	cubic yd	$	7	$	2,667
		Mobilization @ 5%					$	1,107
		Design Contingency @ 15% +/-					$	6,744
					Contract Cost		**$**	**30,000**
Canal Section 558+51 to 548+68	B-7	Importation of soils	1,093	cubic yd	$	34	$	37,162
		Compaction of soils	728	cubic yd	$	7	$	5,096
		Mobilization @ 5%					$	2,113
		Design Contingency @ 15% +/-					$	5,629
					Contract Cost		**$**	**50,000**
Canal Section 546+47 to 535+13	B-9	Importation of soils	1,260	cubic yd	$	34	$	42,840
		Compaction of soils	840	cubic yd	$	7	$	5,880
		Mobilization @ 5%					$	2,436
		Design Contingency @ 15% +/-					$	8,844
					Contract Cost		**$**	**60,000**
Canal Section 527+73 to 517+33	B-11	Importation of soils	1,155	cubic yd	$	34	$	39,270
		Compaction of soils	770	cubic yd	$	7	$	5,390
		Mobilization @ 5%					$	2,233
		Design Contingency @ 15% +/-					$	3,107
					Contract Cost		**$**	**50,000**
Canal Section 512+20 to 401+70	B-12	Importation of soils	12,278	cubic yd	$	34	$	417,452
		Compaction of soils	8,185	cubic yd	$	7	$	57,295
		Mobilization @ 5%					$	23,737
		Design Contingency @ 15% +/-					$	71,516
					Contract Cost		**$**	**570,000**
Channel Modifications 535+32 to 405+24	B-14	Compaction of dirt soils	9,635	cubic yd	$	7	$	67,445
		Site Excavation	77,084	cubic yd	$	7	$	539,588
		Relocation of dirt road	260,160	square ft	$	3	$	780,480
		Mobilization @ 5%					$	69,376
		Design Contingency @ 15% +/-					$	213,111
					Contract Cost		**$**	**1,670,000**
Canal Section 381+70 to 346+70	B-17	Importation of soils	3,499	cubic yd	$	34	$	118,966
		Compaction of soils	3,499	cubic yd	$	7	$	24,493
		Mobilization @ 5%					$	7,173
		Design Contingency @ 15% +/-					$	19,368
					Contract Cost		**$**	**170,000**

Canal Section 343+10 to 309+72	B-19	Importation of soils	3,337	cubic yd	$	34	$	113,458
		Compaction of soils	3,337	cubic yd	$	7	$	23,359
		Mobilization @ 5%					$	6,841
		Design Contingency @ 15% +/-					$	16,342
					Contract Cost		**$**	**160,000**
Canal Section 300+31 to 211+70	B-21	Importation of soils	8,861	cubic yd	$	34	$	301,274
		Compaction of soils	8,861	cubic yd	$	7	$	62,027
		Mobilization @ 5%					$	18,165
		Design Contingency @ 15% +/-					$	58,534
					Contract Cost		**$**	**440,000**
Seepage Drain	B-26	Removal of soils	84404	linear ft	$	5	$	422,020
		Mobilization @ 5%					$	21,101
		Design Contingency @ 15% +/-					$	66,879
					Contract Cost		**$**	**510,000**
Belding Lateral Sub-Total							**$**	**8,850,000**
Right of Way								
Permanent Easement			10	acres	$	8,000	$	80,000
Temp. Construction Easement Allowance			1	lump sum	$	80,000	$	80,000
Sub-Total							**$**	**9,010,000**
Construction Contingency (25% approx)							$	2,250,000
Belding Lateral Field Cost (FC)							**$**	**11,260,000**

TABLE E-2
Schwind Lateral Projects - Detailed Cost Table, June 2009
Gray Lodge Design Data Report

Location/Name	Cost List ID	Pay Item	Quantity	Units	Unit Cost		Item Subtotal	
		Major Structures						
Bridge #1522	S-5	Remove the three, 3 ft dia concrete pipe culverts	52	linear ft	$	49	$	2,548
		Removal of check bays	3	each	$	4,600	$	13,800
		Removal of headwalls	7.6	cubic yd	$	230	$	1,748
		Removal of farm crossing soils	75	cubic yd	$	7	$	525
		Installation of concrete farm crossing	31	cubic yd	$	2,000	$	62,000
		Place and compaction soil for crossing	15.5	cubic yd	$	7	$	109
		Installation of reinforced concrete structure above gate	1	each	$	57,500	$	57,500
		Installation of overshot gate	3.0	linear ft	$	8,600	$	25,800
		Installation of concrete-long crested weir	282	cubic yd	$	1,950	$	549,900
		Mobilization @ 5%					$	35,696
		Design Contingency @ 15% +/-					$	110,374
					Contract Cost		**$**	**860,000**
Farm Crossing #1491	S-6	Removal of headwalls	5.6	cubic yd	$	230	$	1,288
		Removal of wingwalls	2.4	cubic yd	$	230	$	552
		Removal of 4 ft dia, CMP culvert	20	linear ft	$	59	$	1,180
		Removal of soils in farm crossing	125	cubic yd	$	7	$	875
		Installation of 9 ft W x 4 ft H concrete culvert	20	linear ft	$	970	$	19,400
		Installation of headwalls	229	cubic yd	$	1,950	$	446,550
		Installation of wingwalls	98	cubic yd	$	1,700	$	166,600
		Installation of soils for crossing	125	cubic yd	$	34	$	4,250
		Compaction of farm crossing soils	22	cubic yd	$	7	$	154
		Mobilization @ 5%					$	32,042
		Design Contingency @ 15% +/-					$	97,109
					Contract Cost		**$**	**770,000**
Farm Crossing #5021	S-9	Remove concrete headwalls	3.1	cubic yd	$	230	$	713
		Remove 4 ft dia CMP culvert	25	linear ft	$	58	$	1,450
		Remove farm crossing soils	117	cubic yd	$	7	$	819
		New headwalls	4	cubic yd	$	1,950	$	7,800
		Install 6 ft diameter concrete siphon	200	linear ft	$	774	$	154,800
		Removal of earthen sections for siphon	84	cubic yd	$	7	$	588
		Mobilization @ 5%					$	8,309
		Design Contingency @ 15% +/-					$	25,521
					Contract Cost		**$**	**200,000**
		Minor Structures						
Farm Crossing #7137	S-3	Removal of farm crossing soils	93	cubic yd	$	7	$	651
		Removal of headwalls	6.3	cubic yd	$	230	$	1,449
		Demolition of existing 4 ft dia concrete culvert	24	linear ft	$	70	$	1,680
		New RCB Culvert, 7 ft W x 4 ft H	24	linear ft	$	774	$	18,576
		Installation of headwalls	7	cubic yd	$	1,950	$	13,650
		Installation of soils	100	cubic yd	$	34	$	3,400
		Compaction of farm crossing soils	18	cubic yd	$	7	$	126
		Mobilization @ 5%					$	1,977
		Design Contingency @ 15% +/-					$	8,491
					Contract Cost		**$**	**50,000**
Schwind Flume	S-4	Removal of earthen section	21	cubic yd	$	7	$	147
		Removal of concrete sections	18	cubic yd	$	230	$	4,140
		Removal and replacement of cross-piers	1	each	$	11,500	$	11,500
		Removal of wingwalls	4	cubic yd	$	230	$	920
		Removal of check bays	2	each	$	4,600	$	9,200
		Install concrete flume	20	cubic yd	$	1,700	$	34,000
		Install wingwalls	4	cubic yd	$	1,700	$	6,800
		Install check bays	2	each	$	4,600	$	9,200
		Mobilization @ 5%					$	3,795
		Design Contingency @ 15% +/-					$	10,298
					Contract Cost		**$**	**90,000**
Farm Crossing #1438	S-8	Removal of headwalls	7	cubic yd	$	230	$	1,610
		Removal of wingwalls	2.4	cubic yd	$	230	$	552
		Removal of 3.5 ft dia concrete culvert	19	linear ft	$	61	$	1,159
		Removal of soils	92	cubic yd	$	7	$	644
		Installation of headwalls	7	cubic yd	$	1,950	$	13,650
		Installation of wingwalls	2.4	cubic yd	$	1,700	$	4,080
		Installation of 7 ft wide by 4 ft high culvert	19	linear ft	$	774	$	14,706
		Installation of farm crossing soils	92	cubic yd	$	34	$	3,128
		Compaction of farm crossing	17.6	cubic yd	$	7	$	123
		Mobilization @ 5%					$	1,983
		Design Contingency @ 15% +/-					$	8,365
					Contract Cost		**$**	**50,000**
Culverts #5006	S-10	Removal of CMP culverts, 3 ft diameter	140	linear ft	$	43	$	6,020
		Removal of concrete headwalls and supports	4.5	cubic yd	$	230	$	1,035
		Mobilization @ 5%					$	353
		Design Contingency @ 15% +/-					$	2,592
					Contract Cost		**$**	**10,000**

Culvert South West Liberty Road	S-11	Removal of 12" rip-rap	9.3	cubic yd	$	40	$	372
		Removal of 4 ft dia CMP culvert	26	linear ft	$	58	$	1,508
		Removal of earthen sections of farm crossing	157	cubic yd	$	7	$	1,099
		Mobilization @ 5%					$	149
		Design Contingency @ 15% +/-					$	1,872
					Contract Cost		**$**	**5,000**
		Canal Channel Improvements						
Canal Section 211+70 to 196+40	S-1	Importation of soils	1,133	cubic yd	$	34	$	38,522
		Compaction of soils	1,133	cubic yd	$	7	$	7,931
		Mobilization @ 5%					$	2,323
		Design Contingency @ 15% +/-					$	11,224
					Contract Cost		**$**	**60,000**
Canal Section 186+46 to 93+64	S-2	Importation of soils	6,875	cubic yd	$	34	$	233,750
		Compaction of soils	6,875	cubic yd	$	7	$	48,125
		Mobilization @ 5%					$	14,094
		Design Contingency @ 15% +/-					$	44,031
					Contract Cost		**$**	**340,000**
Channel Modifications 148+09 to 131+04	S-7	Site excavation	4,042	cubic yd	$	7	$	28,294
		Compaction of dirt soils	1,263	cubic yd	$	7	$	8,841
		Relocating dirt road away from canal	34,100	square ft	$	3	$	102,300
		Mobilization @ 5%					$	6,972
		Design Contingency @ 15% +/-					$	23,593
					Contract Cost		**$**	**170,000**
Seepage Drain	S-12	Removal of soils	5969	linear ft	$	5	$	29,845
		Mobilization @ 5%					$	1,492
		Design Contingency @ 15% +/-					$	3,663
					Contract Cost		**$**	**35,000**
Schwind Lateral Sub-Total							**$**	**2,640,000**
Right of Way								
Permanent Easement			2	acres	$	8,000	$	16,000
Temp. Construction Easement Allowance			1	lump sum	$	16,000	$	16,000
Sub-Total							**$**	**2,672,000**
Construction Contingency (25% approx)							$	668,000
Schwind Lateral Field Cost (FC)							**$**	**3,340,000**

TABLE E-3
Traynor Lateral Projects - Detailed Cost Table, June 2009
Gray Lodge Design Data Report

Location/Name	Cost List ID	Pay Item	Quantity	Units	Unit Cost	Item Subtotal
		Major Structures				
Colusa Hwy Bridge	T-12	Removal of wingwalls	2.4	cubic yd	$ 230	$ 552
		Removal of headwalls	6.6	cubic yd	$ 230	$ 1,518
		Removal of impermeable AC road	5.8	cubic yd	$ 12	$ 70
		Removal of soils in bridge	126	cubic yd	$ 7	$ 882
		Removal of bridge slab	64	cubic yd	$ 230	$ 14,720
		Installation of bridge crossing slab	115	cubic yd	$ 2,000	$ 230,000
		Compaction of bridge soils	57.4	cubic yd	$ 7	$ 402
		Installation of AC impermeable surface	11.4	cubic yd	$ 63	$ 718
		Installation of bridge center pier	8	cubic yd	$ 1,700	$ 13,600
		Installation of wingwalls	2.4	cubic yd	$ 1,700	$ 4,080
		Installation of headwalls	4.9	cubic yd	$ 1,950	$ 9,555
		Installation of sidewalls	5.3	cubic yd	$ 1,700	$ 9,010
		Mobilization @ 5%				$ 14,255
		Design Contingency @ 15% +/-				$ 40,638
					Contract Cost	**$ 340,000**
		Minor Structures				
Traynor Headgates	T-3	LEFT FORK				
		Removal of sluice gates	4	each	$ 4,600	$ 18,400
		Removal of check gates	1	each	$ 4,600	$ 4,600
		Removal of headwalls	3.8	cubic yd	$ 1,950	$ 7,410
		Installation of concrete-long crested weir	19	cubic yd	$ 1,950	$ 37,050
		Installation of concrete structure above gate	1	each	$ 57,500	$ 57,500
		Installation of overshot gate	6.0	linear ft	$ 8,600	$ 51,600
		RIGHT FORK				
		See Belding spreadsheet, structure B-12				
		Mobilization @ 5%				$ 8,828
		Design Contingency @ 15% +/-				$ 24,612
					Contract Cost	**$ 210,000**
Nugent Flume	T-4	Removal of earthen section	232	cubic yd	$ 7	$ 1,624
		Removal of concrete sections	32	cubic yd	$ 230	$ 7,360
		Removal and replacement of gates, cross-piers	1	each	$ 11,500	$ 11,500
		Removal of check bays	2	each	$ 4,600	$ 9,200
		Installation of concrete flume sections	48	cubic yd	$ 1,700	$ 81,600
		Installation of check bays	2	each	$ 4,600	$ 9,200
		Mobilization @ 5%				$ 6,024
		Design Contingency @ 15% +/-				$ 13,492
					Contract Cost	**$ 140,000**
Water Control Structure	T-10	Installation of concrete-long crested weir	16	cubic yd	$ 1,950	$ 31,200
		Installation of concrete structure above gate	1	each	$ 63,250	$ 63,250
		Installation of overshot gate	6.0	linear ft	$ 8,600	$ 51,600
		Mobilization @ 5%				$ 7,303
		Design Contingency @ 15% +/-				$ 26,647
					Contract Cost	**$ 180,000**
Farm Crossing #2633	T-9	Removal of farm crossing cement	33	cubic yd	$ 230	$ 7,590
		Removal of wing walls	2.8	cubic yd	$ 230	$ 644
		Removal of side walls	6.4	cubic yd	$ 230	$ 1,472
		Installation of farm crossing cement	33	cubic yd	$ 2,000	$ 66,000
		Installation of wingwalls	3.4	cubic yd	$ 1,700	$ 5,780
		Installation of sidewalls	7.8	cubic yd	$ 1,700	$ 13,260
		Compaction of farm crossing soils	16.5	cubic yd	$ 7	$ 116
		Compaction of soils on the farm crossing	444	cubic yd	$ 34	$ 15,096
		Mobilization @ 5%				$ 5,498
		Design Contingency @ 15% +/-				$ 14,545
					Contract Cost	**$ 130,000**
		Canal Channel Improvements				
Canal Section: Head of Traynor to Nugent Flume	T-1	Site excavation	32,008	cubic yd	$ 7	$ 224,056
		Compaction of dirt soils	1,948	cubic yd	$ 7	$ 13,636
		Relocating dirt road away from canal	52,600	square ft	$ 3	$ 157,800
		Mobilization @ 5%				$ 19,775
		Design Contingency @ 15% +/-				$ 54,733
					Contract Cost	**$ 470,000**
Canal Section 445+03 to 415+72	T-2	Importation of soils	4,341	cubic yd	$ 34	$ 147,594
		Compaction of soils	4,341	cubic yd	$ 7	$ 30,387
		Mobilization @ 5%				$ 8,899
		Design Contingency @ 15% +/-				$ 23,120
					Contract Cost	**$ 210,000**

Canal Section: Nugent Flume to Farm Crossing	T-5	Site excavation	41,670	cubic yd	$	7	$	291,690
		Compaction of dirt soils	2,864	cubic yd	$	7	$	20,048
		Relocating dirt road away from canal	77,320	square ft	$	3	$	231,960
		Mobilization @ 5%					$	27,185
		Design Contingency @ 15% +/-					$	79,117
					Contract Cost		**$**	**650,000**
Canal Section 405+80 to 373+25	T-6	Importation of soils	3,215	cubic yd	$	34	$	109,310
		Compaction of soils	3,215	cubic yd	$	7	$	22,505
		Mobilization @ 5%					$	6,591
		Design Contingency @ 15% +/-					$	21,594
					Contract Cost		**$**	**160,000**
Canal Section: Farm Crossing to Colusa Hwy Bridge	T-7	Site excavation	3,497	cubic yd	$	7	$	24,479
		Compaction of dirt soils	1,943	cubic yd	$	7	$	13,601
		Relocating dirt road away from canal	52,460	square ft	$	3	$	157,380
		Mobilization @ 5%					$	9,773
		Design Contingency @ 15% +/-					$	24,767
					Contract Cost		**$**	**230,000**
Canal Section 368+55 to 357+95	T-8	Importation of soils	10,923	cubic yd	$	34	$	371,382
		Compaction of soils	10,923	cubic yd	$	7	$	76,461
		Mobilization @ 5%					$	22,392
		Design Contingency @ 15% +/-					$	69,765
					Contract Cost		**$**	**540,000**
Canal Section 354+00 to 352+81	T-11	Importation of soils	117	cubic yd	$	34	$	3,978
		Compaction of soils	117	cubic yd	$	7	$	819
		Mobilization @ 5%					$	240
		Design Contingency @ 15% +/-					$	4,963
					Contract Cost		**$**	**10,000**
Canal Section: Colusa Hwy Bridge to West Liberty Rd Bridge	T-13	Site Excavation	9,848	cubic yd	$	7	$	68,936
		Compaction of dirt soils	3,939	cubic yd	$	7	$	27,573
		Relocating dirt road away from canal	106,360	square ft	$	3	$	319,080
		Mobilization @ 5%					$	20,779
		Design Contingency @ 15% +/-						63632
					Contract Cost		**$**	**500,000**
Canal Section 343+95 to 299+32	T-14	Importation of soils	4,406	cubic yd	$	34	$	149,804
		Compaction of soils	4,406	cubic yd	$	7	$	30,842
		Mobilization @ 5%					$	9,032
		Design Contingency @ 15% +/-						30322
					Contract Cost		**$**	**220,000**
Canal Section: Traynor Extension (West LIberty Rd Bridge to Rising River Headgates)	T-15	Site Excavation	17,117	cubic yd	$	7	$	119,819
		Compaction of dirt soils	2,018	cubic yd	$	7	$	14,126
		Relocating dirt road away from canal	54,500	square ft	$	3	$	163,500
		Mobilization @ 5%					$	14,872
		Design Contingency @ 15% +/-						47683
					Contract Cost		**$**	**360,000**
Seepage Drain	T-16	Removal of soils	29304	linear ft	$	5	$	146,520
		Mobilization @ 5%					$	7,326
		Design Contingency @ 15% +/-						26154
					Contract Cost		**$**	**180,000**
Traynor Lateral Sub-Total							**$**	**4,530,000**
Right of Way								
Permanent Easement			10	acres	$	8,000	$	80,000
Temp. Construction Easement Allowance			1	lump sum	$	80,000	$	80,000
Sub-Total							**$**	**4,690,000**
Construction Contingency (25% approx)							$	1,170,000
Traynor Lateral Field Cost (FC)							**$**	**5,860,000**

TABLE E-4
Rising River Lateral Projects - Detailed Cost Table, June 2009
Gray Lodge Design Data Report

Location/Name	Cost List ID	Pay Item	Quantity	Units	Unit Cost	Item Subtotal
		Major Structures				
Evans Reimer Bridge	R-4	Removal of wingwalls	2.4	cubic yd	$ 230	$ 552
		Removal of headwalls	5.9	cubic yd	$ 230	$ 1,357
		Removal of impermeable AC road	3.9	cubic yd	$ 12	$ 47
		Removal of 2 ft thick slab bridge.	47.0	cubic yd	$ 230	$ 10,810
		Removal of soils in bridge	126	cubic yd	$ 7	$ 882
		Installation of bridge crossing slab	115	cubic yd	$ 2,000	$ 230,000
		Compaction of bridge soils	57.0	cubic yd	$ 7	$ 399
		Installation of AC impermeable surface	12.0	cubic yd	$ 63	$ 756
		Installation of bridge center pier	8	cubic yd	$ 1,700	$ 13,600
		Installation of wingwalls	2.4	cubic yd	$ 1,700	$ 4,080
		Installation of headwalls	4.9	cubic yd	$ 1,950	$ 9,555
		Installation of sidewalls	10.7	cubic yd	$ 1,700	$ 18,190
		Mobilization @ 5%				$ 14,511
		Design Contingency @ 15% +/-				$ 45,261
					Contract Cost	**$ 350,000**
		Minor Structures				
Flashboard Check #2808	R-2	Removal of flashboard check	3	each	$ 4,600	$ 13,800
		Removal of headwalls	3.5	cubic yd	$ 230	$ 805
		Removal of sidewalls	2.4	cubic yd	$ 230	$ 552
		Removal of wingwalls	2.4	cubic yd	$ 230	$ 552
		Installation of concrete structure above gate	1	each	$ 57,500	$ 57,500
		Installation of overshot gate	4.0	linear ft	$ 8,600	$ 34,400
		Installation of concrete-long crested weir	4	cubic yd	$ 1,950	$ 7,800
		Mobilization @ 5%				$ 5,770
		Design Contingency @ 15% +/-				$ 18,821
					Contract Cost	**$ 140,000**
		Canal Channel Improvements				
Canal Section 270+59 to 221+30	R-1	Importation of soils	3,651	cubic yd	$ 34	$ 124,134
		Compaction of soils	3,651	cubic yd	$ 7	$ 25,557
		Mobilization @ 5%				$ 7,485
		Design Contingency @ 15% +/-				$ 22,824
					Contract Cost	**$ 180,000**
Canal Section 200+00 to 194+30	R-3	Importation of soils	423	cubic yd	$ 34	$ 14,382
		Compaction of soils	423	cubic yd	$ 7	$ 2,961
		Mobilization @ 5%				$ 867
		Design Contingency @ 15% +/-				$ 1,790
					Contract Cost	**$ 20,000**
Rising River Lateral Sub-Total						**$ 690,000**
Right of Way						
Permanent Easement			1	acres	$ 8,000	$ 8,000
Temp. Construction Easement Allowance			1	lump sum	$ 8,000	$ 8,000
Sub-Total						**$ 706,000**
Construction Contingency (25% approx)						$ 174,000
Rising River Lateral Field Cost (FC)						**$ 880,000**

TABLE E-5
Cassady Lateral Projects - Detailed Cost Table, June 2009
Gray Lodge Design Data Report

Location/Name	Cost List ID	Pay Item	Quantity	Units	Unit Cost	Item Subtotal
		Minor Structures				
Farm Crossing #1226	C-2	Demolition of existing 4 ft dia concrete culvert	24	linear ft	$ 71	$ 1,704
		Removal of soils from farm crossing	89	cubic yd	$ 7	$ 623
		Installation of concrete culvert, 8 ft W x 4 ft H	24	linear ft	$ 845	$ 20,280
		Installation of headwalls	3.7	cubic yd	$ 1,950	$ 7,215
		Placement of soils for farm crossing	133	cubic yd	$ 34	$ 4,522
		Compaction of soils for farm crossing	22	cubic yd	$ 7	$ 154
		Mobilization @ 5%				$ 1,725
		Design Contingency @ 15% +/-				$ 3,777
					Contract Cost	**$ 40,000**
Bonslett's Driveway	C-3	Demolition of existing 3.5 ft dia concrete	24	linear ft	$ 61	$ 1,464
		Removal of headwalls	1.5	cubic yd	$ 230	$ 345
		Removal of wingwalls	3.5	cubic yd	$ 230	$ 805
		Removal of footwalls	1.5	cubic yd	$ 230	$ 345
		Removal of sidewalls	3.7	cubic yd	$ 230	$ 851
		Removal of miscellaneous concrete downstream	5.0	cubic yd	$ 230	$ 1,150
		Removal of soils from driveway	89	cubic yd	$ 7	$ 623
		Installation of concrete culvert, 7 ft W x 4 ft H	24	linear ft	$ 774	$ 18,576
		Installation of headwalls	5.9	cubic yd	$ 1,950	$ 11,505
		Installation of wingwalls	2.0	cubic yd	$ 1,700	$ 3,400
		Installation of sidewalls	5.9	cubic yd	$ 1,700	$ 10,030
		Placement of soils for driveway	106	cubic yd	$ 34	$ 3,604
		Compaction of soils	18	cubic yd	$ 7	$ 126
		Mobilization @ 5%				$ 2,641
		Design Contingency @ 15% +/-				$ 4,535
						$ 60,000
Bonslett Weir	C-4	Removal of check bays	1	each	$ 4,600	$ 4,600
		Removal of 3 ft diameter concrete culvert	20	linear ft	$ 50	$ 1,000
		Removal of farm crossing soils	111	cubic yd	$ 7	$ 777
		Removal of headwalls	2	cubic yd	$ 230	$ 460
		Installation of concrete structure above gate	1	each	$ 57,500	$ 57,500
		Installation of overshot gate	2.0	linear ft	$ 8,600	$ 17,200
		Installation of concrete-long crested weir	10	cubic yd	$ 1,950	$ 19,500
		Mobilization @ 5%				$ 5,052
		Design Contingency @ 15% +/-				$ 13,911
					Contract Cost	**$ 120,000**
Concrete Pipe Culvert #1163	C-5	Demolition of existing 3.5 ft dia concrete culvert	24	linear ft	$ 61	$ 1,464
		Removal of headwalls	1	cubic yd	$ 230	$ 230
		Removal of wingwalls	1.7	cubic yd	$ 230	$ 391
		Removal of soils	10.7	cubic yd	$ 7	$ 75
		Removal of fence over culvert	1	each	$ 575	$ 575
		Installation of concrete-long crested weir	8	cubic yd	$ 1,950	$ 15,600
		Installation of concrete structure above gate	1	each	$ 57,500	$ 57,500
		Installation of overshot gate	2.0	linear ft	$ 8,600	$ 17,200
		Mobilization @ 5%				$ 4,652
		Design Contingency @ 15% +/-				$ 12,313
					Contract Cost	**$ 110,000**
		Canal Channel Improvements				
Canal Section 450+63 to 364+56	C-1	Importation of soils	6,376	cubic yd	$ 34	$ 216,784
		Compaction of soils	6,376	cubic yd	$ 7	$ 44,632
		Mobilization @ 5%				$ 13,071
		Design Contingency @ 15% +/-				$ 45,513
					Contract Cost	**$ 320,000**
Canal Section 357+36 to 340+22	C-6	Importation of soils	1,270	cubic yd	$ 34	$ 43,180
		Compaction of soils	1,270	cubic yd	$ 7	$ 8,890
		Mobilization @ 5%				$ 2,604
		Design Contingency @ 15% +/-				$ 5,326
					Contract Cost	**$ 60,000**
Canal Section 336+13 to 326+33	C-7	Importation of soils	726	cubic yd	$ 34	$ 24,684
		Compaction of soils	726	cubic yd	$ 7	$ 5,082
		Mobilization @ 5%				$ 1,488
		Design Contingency @ 15% +/-				$ 8,746
					Contract Cost	**$ 40,000**
Canal Section 319+82 to 300+00	C-8	Importation of soils	1,468	cubic yd	$ 34	$ 49,912
		Compaction of soils	1,468	cubic yd	$ 7	$ 10,276
		Mobilization @ 5%				$ 3,009
		Design Contingency @ 15% +/-				$ 6,803
					Contract Cost	**$ 70,000**
Cassady Lateral Sub-Total			Cassady Lateral Sub-Total			**$ 820,000**
Right of Way						
Permanent Easement			2	acres	$ 8,000	$ 16,000
Temp. Construction Easement Allowance			1	lump sum	$ 16,000	$ 16,000
Sub-Total						**$ 852,000**
Construction Contingency (25% approx)						$ 218,000
Cassady Lateral Field Cost (FC)						**$ 1,070,000**

Appendix F
Maps

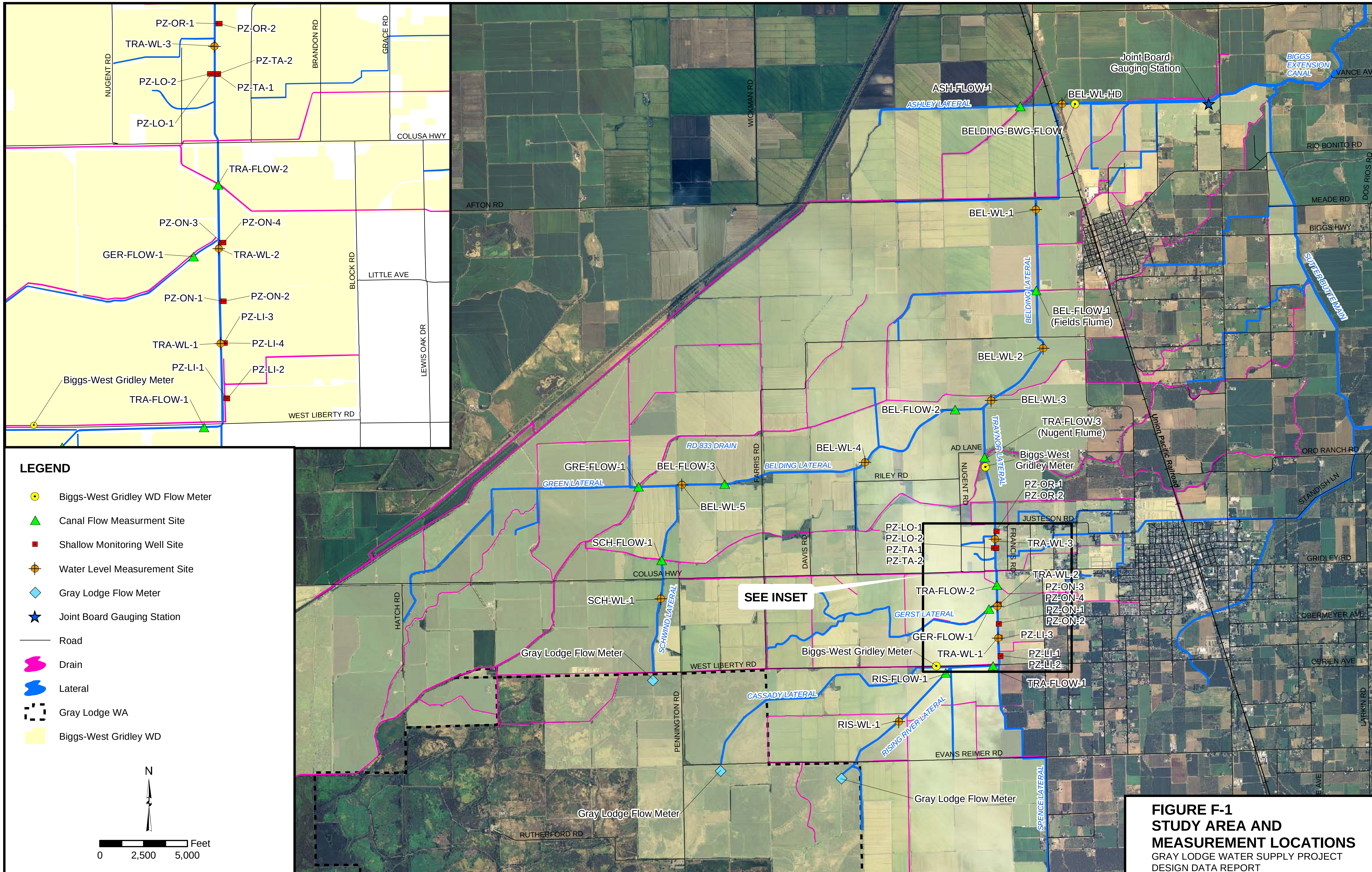


FIGURE F-1
STUDY AREA AND MEASUREMENT LOCATIONS
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

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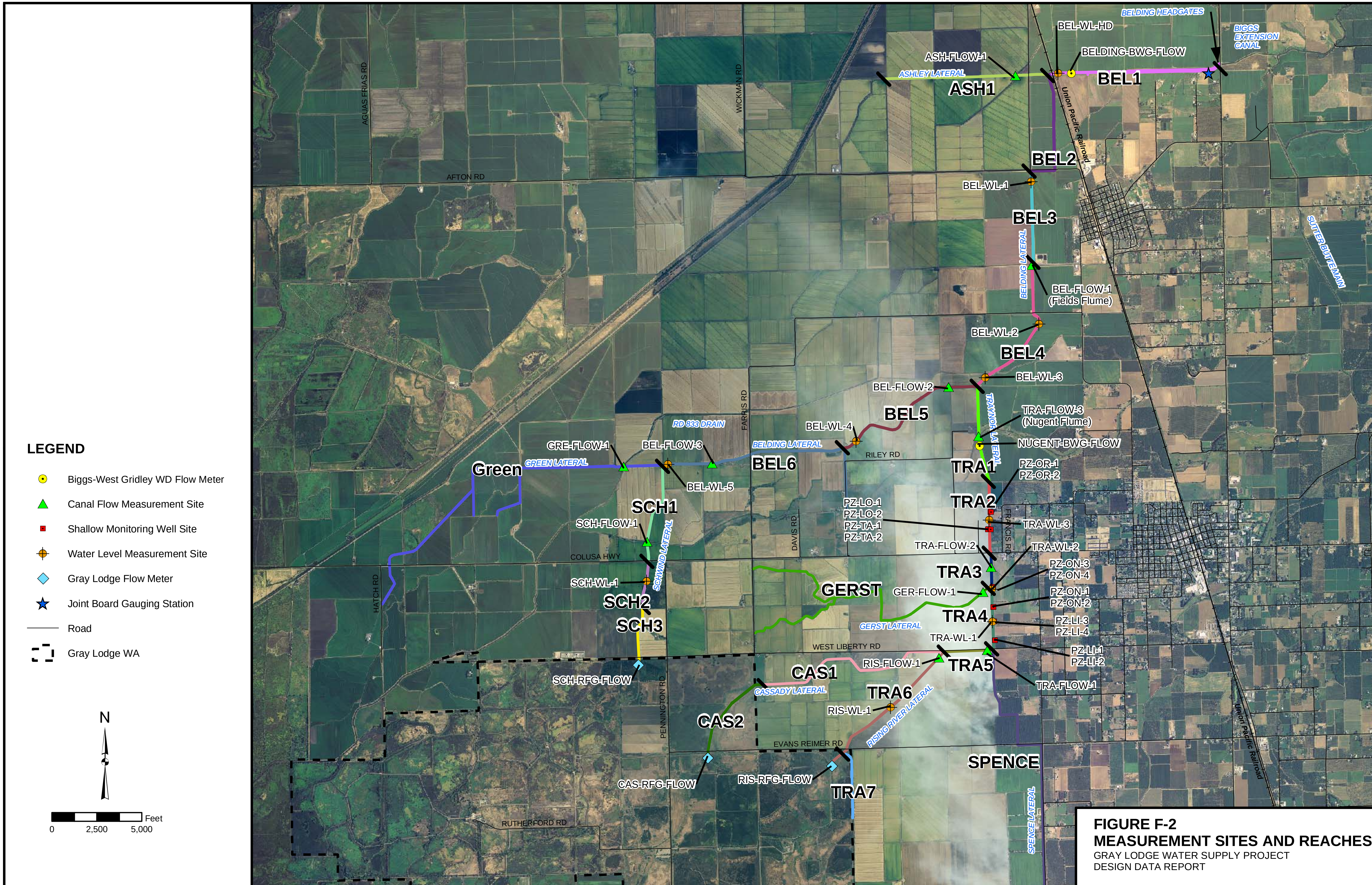

FIGURE F-2
MEASUREMENT SITES AND REACHES
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

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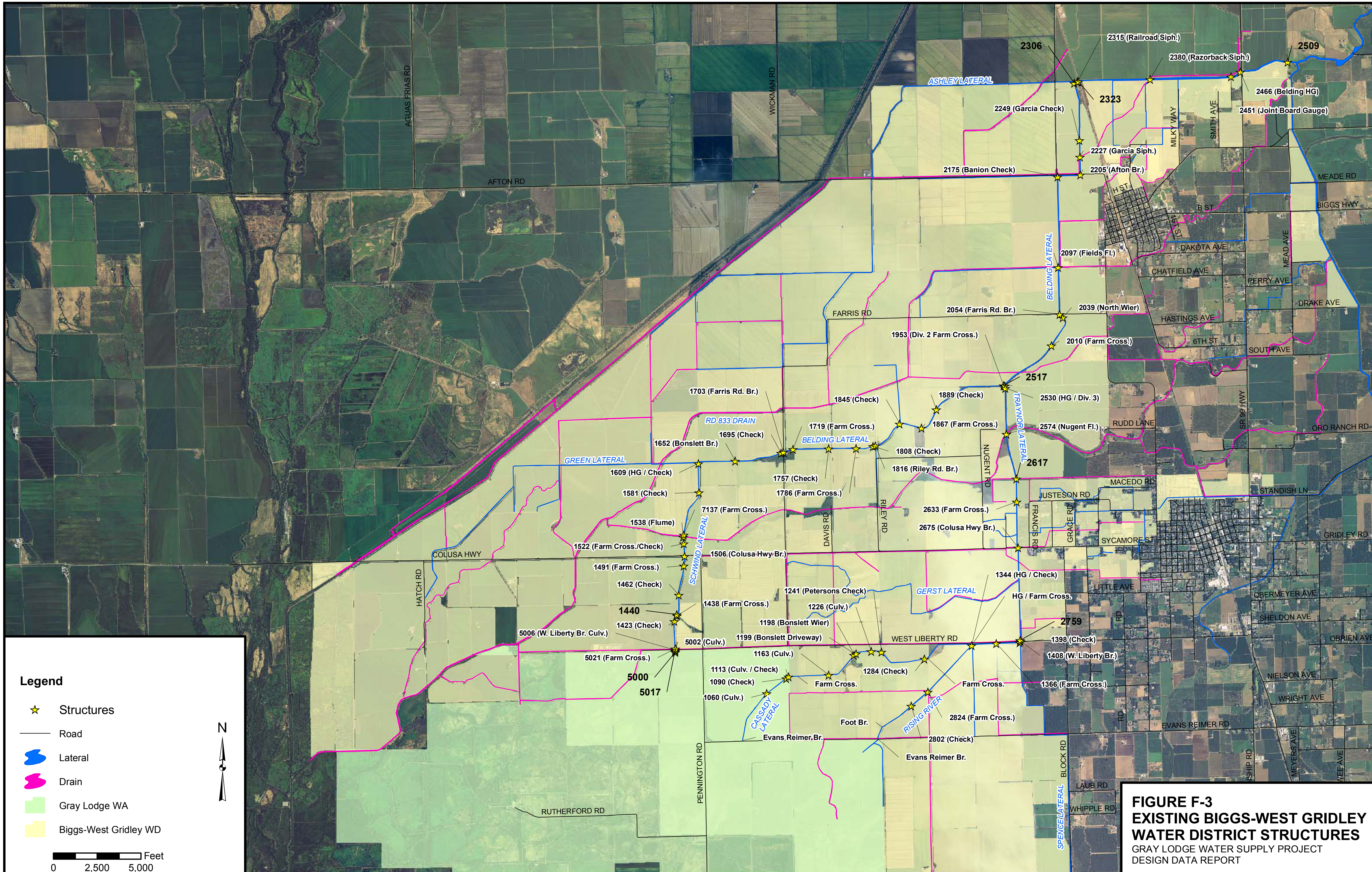

FIGURE F-3
EXISTING BIGGS-WEST GRIDLEY WATER DISTRICT STRUCTURES
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

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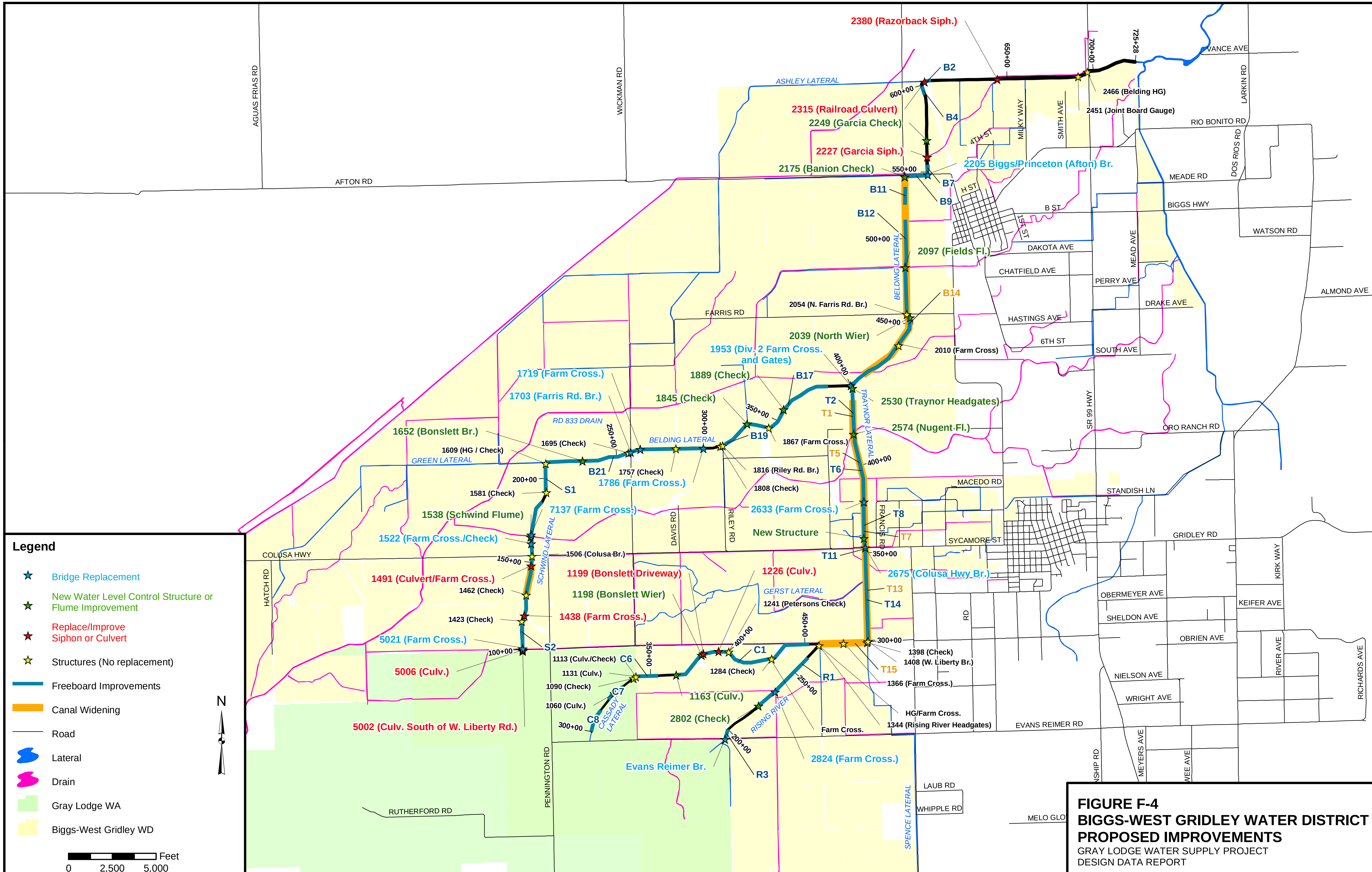

FIGURE F-4
BIGGS-WEST GRIDLEY WATER DISTRICT PROPOSED IMPROVEMENTS
GRAY LODGE WATER SUPPLY PROJECT
DESIGN DATA REPORT

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Appendix G
Additional Engineering Design Data for Composite Alternative

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Gray Lodge WA Water Supply Project
Design Data Report
Additional Engineering Design Data - Belding Lateral

					Water Level Control Structure										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Invert Elevation (ft)**	**Top of Structure Elevation (ft)**	**Weir Length (ft)**	**Weir Crest Elevation (ft)**	**Weir Coeff**	**Modeled Weir Coeff**	**Number of Gates**	**Gate Invert Elevation (ft)**	**Gate Width (ft)**	**Gate Height (ft)**	**Gate Discharge Coeff**
BEL2	750	Garcia Check	568+12	Replace structure with long crested weir.	88.3	97.7	70	95.3	2.7	3.5	3	88.8	3.3	6.5	0.6
BEL2	750	Banion Check	535+32	Replace structure with long crested weir.	86.8	95.6	70	93.2	2.7	3.6	3	87.0	4.5	6.25	0.6
BEL4	670	North Weir	454+04	Replace structure with long crested weir.	83.4	92.5	67	90.1	2.7	3.02	2	83.4	4	6.5	0.6
BEL5	270	Division 2 Head gate (Belding/Traynor Split)	400+03	Replace with 3-bay sluice gate and relocate farm crossing bridge nearby.	81	88.1	-	-	-	-	3	91	4	7	0.6
BEL5	270	Canal Section	381+70 to 346+70	Raise canal banks to meet freeboard requirements.											
BEL5	270	Check #1889	357+22	Replace structure with long crested weir.	77.9	86	45	83.2	2.7	3.47	1	77.9	4	5	0.6
BEL5	270	Canal Section	343+10 to 309+72	Raise canal banks to meet freeboard requirements.	77.4	86	83	82.1	2.7	5.09	2	77.4	3.5	4.5	0.6
BEL6	220	Bonslett Bridge	230+40	Replace structure with long crested weir.	69.7	78	50	76.7	2.7	3.65	1	69.7	4	6.5	0.6

					Culvert										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Number of New Culverts**	**Material**	**Shape**	**Diam (ft)**	**Dimensions (ft)**	**Length (ft)**	**Entrance Loss Coeff**	**Exit Loss Coeff**	**Manning's n**	**Up-stream Invert Elevation (ft)**	**Down-stream Invert Elevation (ft)**
BEL1	850	Railroad Culverts	603+00	Improve canal capacity under railroad crossing by installing 2 additional culverts.	2	Concrete	Circular	8	-	50.5	1	1	0.014	87.2	85.7

					Bridge				
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Deck Elevation (ft)**	**Deck Thickness (ft)**	**Bridge Opening (ft)**	**Number of Piers**	**Pier Thickness (ft)**
BEL2	750	Biggs/Princeton Bridge	548+70	Replace bridge with higher deck height and larger culvert opening.	95	1.5	28	-	-
BEL6	220	Farm Crossing # 1786	300+20	Replace farm crossing to improve capacity and meet freeboard requirement.	81.9	2	24.1	-	-
BEL6	220	Farm Crossing #1719	264+20	Replace farm crossing to improve capacity and meet freeboard requirement.	80	1.7	20.5	-	-
BEL6	220	Farris Rd. Bridge	258+35	Replace farm crossing to improve capacity and meet freeboard requirement.	80	1.7	24.6	-	-

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Gray Lodge WA Water Supply Project
Design Data Report
Additional Engineering Design Data - Schwind Lateral

					Water Level Control Structure										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Invert Elevation (ft)**	**Top of Structure Elevation (ft)**	**Weir Length (ft)**	**Weir Crest Elevation (ft)**	**Weir Coeff**	**Modeled Weir Coeff**	**Number of Gates**	**Gate Invert Elevation (ft)**	**Gate Width (ft)**	**Gate Height (ft)**	**Gate Discharge Coeff**
SCH1	100	Bridge #1522	161+03	Replace structure with long crested weir.	67.9	76	37	74.5	2.7	2.7	1	67.9	2	6.5	0.6

					Culvert										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Number of New Culverts**	**Material**	**Shape**	**Diam (ft)**	**Dimensions (ft)**	**Length (ft)**	**Entrance Loss Coeff**	**Exit Loss Coeff**	**Manning's n**	**Up-stream Invert Elevation (ft)**	**Down-stream Invert Elevation (ft)**
SCH1	100	Farm Crossing #7137	165+30	Replace with concrete box culvert and farm crossing.	1	Concrete	Rectangular	-	9 by 4	24	0.2	1	0.014	69.7	69.7
SCH2	85	Farm Crossing #1491	148+27	Replace with concrete box culvert and farm crossing.	1	Concrete	Rectangular	-	9 by 4	20	0.2	1	0.024	68	67.5
SCH3	85	Farm Crossing #1438	119+35	Replace with concrete box culvert and farm crossing.	1	Concrete	Rectangular	-	7 by 4	18.4	0.5	1	0.014	66.5	66.5
SCH3	85	Farm Crossing #5021	100+12	Replace existing structure with siphon.	1	Concrete	Circular	6	-	162	0.9	1	0.021	58	57.5

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Gray Lodge WA Water Supply Project

Design Data Report

Additional Engineering Design Data - Traynor Lateral

					Water Level Control Structure										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Invert Elevation (ft)**	**Top of Structure Elevation (ft)**	**Weir Length (ft)**	**Weir Crest Elevation (ft)**	**Weir Coeff**	**Modeled Weir Coeff**	**Number of Gates**	**Gate Invert Elevation (ft)**	**Gate Width (ft)**	**Gate Height (ft)**	**Gate Discharge Coeff**
TRA1	380	Traynor Headgates	444+75	Replace structure with long crested weir.	80.8	90	62	88.2	2.7	2.79	2	80.8	3	6.5	0.6
TRA2	380	New Structure	354+00	Construct long crested weir.	77.4	88	48	86.1	2.7	7.85	2	77.4	3	7	0.6

					Bridge				
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Deck Elevation (ft)**	**Deck Thickness (ft)**	**Bridge Opening (ft)**	**Number of Piers**	**Pier Thickness (ft)**
TRA2	370	Colusa Hwy Bridge	352+81.6	Replace bridge with larger culvert opening.	88.8	3	51	1	2

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Gray Lodge WA Water Supply Project
Design Data Report
Additional Engineering Design Data - Rising River Lateral

					Water Level Control Structure											
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Invert Elevation (ft)**	**Top of Structure Elevation (ft)**	**Weir Length (ft)**	**Weir Crest Elevation (ft)**	**Weir Coeff**	**Modeled Weir Coeff**	**Number of Gates**	**Gate Invert Elevation (ft)**	**Gate Width (ft)**	**Gate Height (ft)**	**Gate Discharge Coeff**
TRA6	120	#2802 - Flashboard Check	221+85.5	Replace structure with long crested weir.	76.4	82.5	19	79.5	2.7	3.95	2	76.4	2	3	0.6

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Gray Lodge WA Water Supply Project
Design Data Report
Additional Engineering Design Data - Cassady Lateral

					Water Level Control Structure										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Invert Elevation (ft)**	**Top of Structure Elevation (ft)**	**Weir Length (ft)**	**Weir Crest Elevation (ft)**	**Weir Coeff**	**Modeled Weir Coeff**	**Number of Gates**	**Gate Invert Elevation (ft)**	**Gate Width (ft)**	**Gate Height (ft)**	**Gate Discharge Coeff**
CAS1	85	Bonslett Weir	384+23.25	Replace structure with long crested weir.	78.6	81.9	56	81.3	2.7	15.12	1	78.6	2	2.5	0.6
CAS1	85	Structure #1163	364+56.7	Replace structure with long crested weir.	74.2	82.2	27	80.5	2.7	8.01	1	74.2	2	3.5	0.6

					Culvert										
Reach	**Approved Design Flow (cfs)**	**Name/Description**	**Station**	**Composite Alternative Improvements**	**Number of New Culverts**	**Material**	**Shape**	**Diam (ft)**	**Dimensions (ft)**	**Length (ft)**	**Entrance Loss Coeff**	**Exit Loss Coeff**	**Manning's n**	**Up-stream Invert Elevation (ft)**	**Down-stream Invert Elevation (ft)**
CAS1	85	Structure #1226, Farm Crossing	394+00	Replace box culvert/crossing.	1	Concrete	Rectangular	-	8 by 4	24	0.5	1	0.014	76.7	76
CAS1	85	Structure #1199, Bonslett's Driveway	384+78.48	Replace box culvert/crossing.	1	Concrete	Rectangular	-	7 by 4	23.8	0.5	1	0.014	77.9	77.6

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Gray Lodge WA Water Supply Project
Design Data Report
Manning's n-values Assumed for Hydraulic Model

Belding Lateral

HEC-RAS Cross-Section Station	n-value
694+62.0	0.025
693+03.0	0.025
692+73.0	0.025
691+08.0	0.025
690+85.0	0.025
690+79.6	0.025
690+76.6	0.025
690+47.0	0.025
687+73.0	0.025
686+00.0	0.025
682+73.0	0.025
677+73.0	0.025
672+73.0	0.025
667+73.0	0.025
662+73.0	0.025
657+73.0	0.025
652+73.0	0.025
647+73.0	0.025
645+06.0	0.025
644+77.0	0.025
644+31.0	0.025
644+14.0	0.025
644+03.0	0.025
642+73.0	0.025
637+73.0	0.025
632+73.0	0.025
627+73.0	0.025
622+73.0	0.025
617+73.0	0.025
612+73.0	0.025
607+73.0	0.025
603+89.0	0.025
603+46.5	0.025
602+95.0	0.025
602+73.0	0.025
602+20.0	0.025
600+55.0	0.025
596+65.0	0.025
591+50.0	0.025
586+30.0	0.025
581+20.0	0.025
576+00.0	0.025
570+70.0	0.025
568+33.0	0.025
568+14.0	0.025
568+11.7	0.02
567+86.0	0.02
567+85.0	0.025
567+60.0	0.025
565+80.0	0.025
559+75.0	0.025
559+26.0	0.025
558+96.0	0.025
558+51.0	0.025
558+21.0	0.025
554+80.0	0.025
549+70.0	0.025
549+24.0	0.025
548+95.9	0.025
548+68.6	0.025
548+29.0	0.025

HEC-RAS Cross-Section Station	n-value
547+89.0	0.025
546+47.0	0.025
541+00.0	0.025
536+10.0	0.025
535+43.0	0.025
535+34.0	0.025
535+31.0	0.03
535+14.0	0.03
535+13.0	0.025
534+93.0	0.025
533+07.0	0.025
527+73.0	0.025
522+48.0	0.025
517+33.0	0.025
512+20.0	0.025
507+00.0	0.025
501+60.0	0.025
496+33.0	0.025
491+29.0	0.025
485+60.0	0.025
484+16.0	0.025
483+95.0	0.025
483+94.0	0.02
483+37.7	0.02
483+24.0	0.025
482+99.0	0.025
478+32.0	0.025
472+77.0	0.025
467+57.0	0.025
462+57.0	0.025
457+70.0	0.025
457+13.0	0.025
457+04.2	0.025
456+75.4	0.025
456+65.0	0.025
455+28.5	0.025
454+15.0	0.025
454+06.0	0.025
454+03.0	0.02
453+89.0	0.02
453+88.0	0.025
453+66.0	0.025
451+91.0	0.025
447+12.0	0.025
441+80.0	0.025
436+90.0	0.025
436+40.0	0.025
436+14.6	0.025
435+95.4	0.025
435+62.0	0.025
431+65.0	0.025
426+20.0	0.025
420+75.0	0.025
415+50.0	0.025
410+05.0	0.025
405+24.0	0.025
401+70.0	0.025

Belding Lateral, Downstream of Division 2 Headgates

HEC-RAS Cross-Section Station	n-value
400+44.0	0.025
400+14.0	0.025
400+04.0	0.025
400+01.0	0.035
399+56.0	0.035
396+70.0	0.035
391+70.0	0.035
386+70.0	0.035
384+50.0	0.035
381+70.0	0.035
376+70.0	0.035
371+70.0	0.035
366+70.0	0.035
361+70.0	0.035
357+35.0	0.035
357+24.0	0.035
357+08.0	0.035
356+81.0	0.035
356+70.0	0.035
351+70.0	0.035
346+70.0	0.035
343+61.0	0.035
343+31.4	0.035
343+10.9	0.035
342+76.0	0.035
341+70.0	0.035
336+70.0	0.035
331+70.0	0.035
330+48.0	0.035
330+37.0	0.035
330+22.0	0.035
330+05.0	0.035
326+70.0	0.035
321+70.0	0.035
316+70.0	0.035
311+70.0	0.035
311+41.4	0.035
311+21.4	0.035
310+61.0	0.035
310+16.0	0.035
310+05.0	0.035
310+02.0	0.02
309+87.0	0.02
309+86.0	0.035
309+72.0	0.035
309+65.0	0.035
306+70.0	0.035
301+70.0	0.035
300+58.0	0.035
300+31.6	0.035
300+12.1	0.035
299+83.0	0.035
296+70.0	0.035
291+70.0	0.035
286+70.0	0.035
284+64.0	0.035
284+53.0	0.035
284+50.0	0.02
284+35.0	0.02
284+34.0	0.035
284+17.0	0.035
281+70.0	0.035
276+70.0	0.035
271+70.0	0.035
266+70.0	0.035

HEC-RAS Cross-Section Station	n-value
264+63.0	0.035
264+31.1	0.035
264+11.6	0.04
263+78.0	0.04
261+70.0	0.04
259+03.0	0.04
258+63.2	0.04
258+32.0	0.04
257+68.0	0.04
257+15.0	0.04
257+04.0	0.04
257+01.0	0.02
256+88.0	0.02
256+87.0	0.045
256+60.0	0.045
251+70.0	0.045
246+70.0	0.045
241+70.0	0.045
236+45.0	0.045
231+70.0	0.045
230+81.0	0.045
230+57.0	0.045
230+46.0	0.045
230+43.0	0.045
230+19.9	0.05
229+88.0	0.05
226+70.0	0.05
221+70.0	0.05
216+70.0	0.05
211+70.0	0.05
209+44.0	0.05
208+84.0	0.05
208+68.0	0.05

Schwind Lateral

HEC-RAS Cross-Section Station	n-value
208+65.0	0.02
208+55.0	0.02
208+54.0	0.05
208+29.0	0.05
208+09.0	0.05
206+48.0	0.05
201+50.0	0.05
196+40.0	0.05
192+21.0	0.05
192+07.0	0.05
192+04.0	0.02
191+96.0	0.02
191+95.0	0.05
191+70.0	0.05
191+29.0	0.05
186+46.0	0.05
181+44.0	0.05
176+13.0	0.05
171+05.0	0.05
166+10.0	0.05
165+75.0	0.05
165+44.7	0.05
165+19.7	0.02
165+14.0	0.02
165+13.1	0.02
164+51.1	0.02
164+47.0	0.02
164+46.0	0.05
164+21.0	0.05
163+93.0	0.05
161+70.0	0.05
161+34.0	0.05
161+13.0	0.05
161+04.3	0.05
161+01.3	0.05
160+86.0	0.05
160+71.0	0.05
160+54.0	0.05
156+70.0	0.05
154+31.0	0.05
154+12.0	0.05
153+98.6	0.05
153+70.3	0.055
153+42.0	0.055
153+28.0	0.055
151+70.0	0.055
148+58.0	0.055
148+30.0	0.055
148+09.0	0.055
147+94.0	0.055
147+74.0	0.055
146+70.0	0.055
141+70.0	0.055
136+70.0	0.055
131+70.0	0.055
131+47.0	0.055
131+33.0	0.055
131+19.0	0.055
131+16.0	0.02
131+05.0	0.02
131+04.0	0.06
130+79.0	0.06
130+63.0	0.06
126+70.0	0.06
121+70.0	0.06

Traynor Lateral

HEC-RAS Cross-Section Station	n-value
119+73.0	0.06
119+60.0	0.06
119+45.9	0.06
119+26.5	0.06
118+91.0	0.06
116+70.0	0.06
116+13.0	0.06
115+95.0	0.06
115+79.0	0.06
115+76.0	0.02
115+65.0	0.02
115+64.0	0.06
115+25.0	0.06
111+70.0	0.06
106+70.0	0.06
101+70.0	0.06
100+53.0	0.06
100+34.7	0.06
98+72.0	0.06
98+52.0	0.06
93+64.0	0.06
86+70.0	0.06

HEC-RAS Cross-Section Station	n-value
445+03.0	0.06
444+88.0	0.06
444+58.0	0.06
444+56.0	0.06
444+36.0	0.06
443+95.0	0.06
439+40.0	0.06
434+08.0	0.06
428+97.0	0.06
424+00.0	0.06
419+17.0	0.06
419+00.0	0.06
418+75.0	0.06
418+73.4	0.06
418+66.7	0.06
418+65.7	0.04
418+12.9	0.04
418+11.9	0.06
417+87.6	0.06
417+85.0	0.06
417+55.0	0.06
417+29.0	0.06
415+72.0	0.06
410+85.0	0.06
405+80.0	0.06
400+20.0	0.06
395+10.0	0.06
390+00.0	0.06
384+34.0	0.06
379+93.0	0.06
379+25.4	0.06
379+21.4	0.06
379+06.0	0.06
378+96.0	0.06
378+35.0	0.06
373+25.0	0.06
368+55.0	0.06
363+34.0	0.06
357+95.0	0.06
354+31.0	0.06
354+01.0	0.06
353+99.0	0.06
353+95.6	0.06
353+92.3	0.06
353+89.0	0.06
353+85.6	0.06
353+82.3	0.06
353+79.0	0.06
353+69.5	0.06
353+60.0	0.06
353+50.5	0.06
353+41.0	0.06
353+31.5	0.06
353+22.0	0.06
353+17.0	0.06
353+12.1	0.06
353+07.2	0.06
353+02.2	0.06
352+97.3	0.06
352+92.4	0.06
352+88.1	0.06
352+83.9	0.06
352+53.1	0.06
352+30.7	0.06
351+84.0	0.06

Rising River Lateral

HEC-RAS Cross-Section Station	n-value
349+03.0	0.06
343+95.0	0.06
339+11.0	0.06
334+33.0	0.06
328+04.0	0.06
323+03.0	0.06
317+92.0	0.06
313+28.0	0.06
307+70.0	0.06
302+78.0	0.06
299+47.5	0.06
299+35.5	0.06
299+10.5	0.04
299+08.5	0.04
298+36.4	0.04
298+33.4	0.06
298+23.4	0.06
295+92.0	0.06
291+04.0	0.06
285+65.0	0.06
285+04.0	0.06
284+79.5	0.06
284+72.0	0.06
281+00.0	0.06
275+90.0	0.06

HEC-RAS Cross-Section Station	n-value
271+11.0	0.06
270+82.0	0.06
270+78.0	0.06
270+76.0	0.02
270+64.2	0.035
270+59.0	0.035
270+58.0	0.06
269+53.0	0.06
264+29.0	0.06
259+10.0	0.06
253+89.0	0.06
248+82.0	0.06
243+68.0	0.06
238+69.0	0.06
234+34.4	0.06
234+26.4	0.06
234+07.9	0.06
233+93.5	0.06
231+82.0	0.06
226+90.0	0.06
221+97.0	0.06
221+86.5	0.06
221+68.2	0.06
221+53.2	0.06
221+30.0	0.06
214+90.0	0.06
209+88.0	0.06
204+95.0	0.06
200+00.0	0.06
199+97.0	0.06
199+96.0	0.06
199+90.6	0.06
199+88.6	0.06
194+70.0	0.06
194+45.1	0.06
194+35.1	0.06
194+13.0	0.06
193+90.6	0.06
190+52.0	0.06
187+35.0	0.06

Cassady Lateral

HEC-RAS Cross-Section Station	n-value
458+01.0	0.03
455+52.0	0.03
450+63.0	0.03
445+52.0	0.03
440+68.0	0.03
438+61.0	0.03
433+65.0	0.03
428+99.8	0.03
428+78.3	0.03
427+51.0	0.03
427+15.0	0.03
427+09.0	0.03
426+80.0	0.035
420+54.0	0.035
415+47.0	0.035
410+39.0	0.035
405+67.0	0.035
400+46.0	0.035
400+17.6	0.035
400+16.6	0.02
399+95.6	0.035
399+55.0	0.035
394+52.0	0.035
394+25.2	0.03
393+99.2	0.03
393+66.0	0.035
390+35.0	0.035
385+25.0	0.035
384+79.5	0.03
384+53.7	0.03
384+27.3	0.03
384+19.3	0.03
383+95.0	0.03
379+58.0	0.03
374+58.0	0.03
369+84.0	0.04
364+89.0	0.04
364+59.7	0.04
364+57.7	0.04
364+20.7	0.04
363+98.0	0.04
357+36.0	0.04
352+33.0	0.04
347+32.0	0.04
347+06.8	0.02
347+00.8	0.02
346+79.5	0.03
346+55.0	0.04
341+95.0	0.04
341+70.5	0.03
341+30.5	0.03
340+91.0	0.04
340+22.0	0.04
339+94.0	0.03
339+88.0	0.03
339+62.0	0.04
336+13.0	0.04
331+29.0	0.04
326+33.0	0.04
325+96.0	0.03
325+42.0	0.03
325+13.0	0.04
324+60.0	0.04
319+82.0	0.04
315+04.0	0.04

HEC-RAS Cross-Section Station	n-value
310+09.0	0.04
305+00.0	0.04
300+00.0	0.04
295+16.0	0.04
294+08.0	0.04
293+50.0	0.04