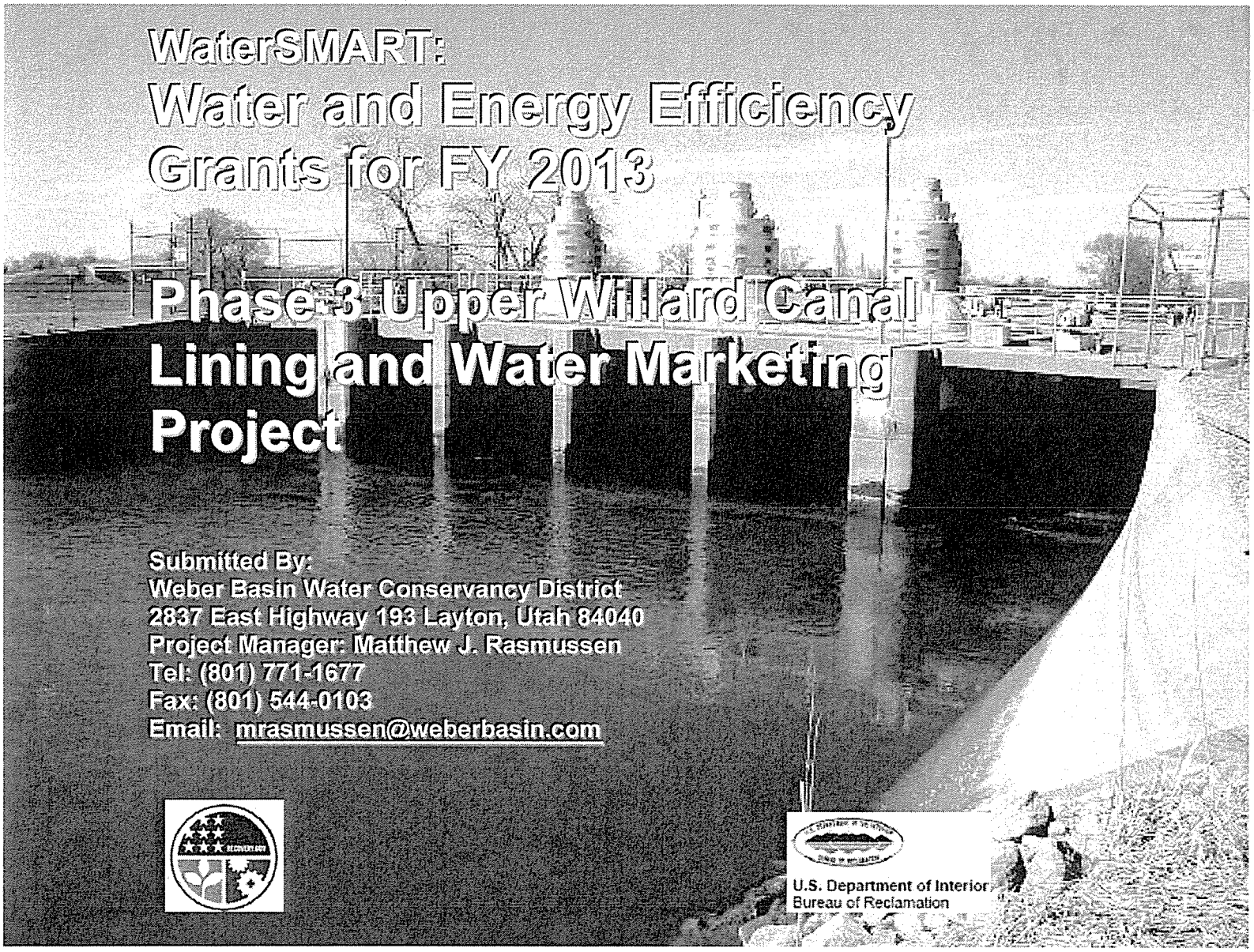
RECLAMATION

Managing Water in the West

Funding Opportunity No. R13SF80003



WaterSMART: Water and Energy Efficiency Grants for FY 2013

Phase 3 Upper Willard Canal Lining and Water Marketing Project

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U.S. Department of Interior
Bureau of Reclamation

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1.0 TECHNICAL PROPSAL AND EVALUATION CRITERIA

1.A Executive Summary

FOA:	R13SF80003: WaterSMART – Water and Energy Efficiency Grants
Date:	January 17, 2013
Applicant:	Weber Basin Water Conservancy District 2837 East Highway 193 Layton, UT 84040
Project Location:	A portion of the Willard Canal located in Marriott-Slaterville, in Weber County, UT

The Weber Basin Project (Project), which was aimed at developing and effectively utilizing the available water resources within the Weber River Basin Drainage, was constructed by the United States Bureau of Reclamation (Reclamation), and is currently administered, operated, and maintained by the Weber Basin Water Conservancy District. Through collaborative efforts in conducting a System Optimization Review (SOR) of all Project Facilities, the District and Reclamation recently identified the Willard Canal as a source of potential significant water loss due to canal seepage. Because the District serves one of the fastest growing regions in the Western United States, conservation efforts that will extend the capacity of existing supplies are a key to the District's success in managing the water resources within the region and avoiding water related conflicts. With the canal seepage losses in the upper 5,000 to 7,000 linear-feet (LF) of the Willard Canal estimated to be as high as 15,600 acre-feet (AF) per year, mitigating these losses is now a top priority. Accordingly, the District is pleased to submit this application for the ***Phase 3 Upper Willard Canal Lining and Water Marketing Project*** to Reclamation in response to *Fiscal Year 2013 Funding Opportunity Announcement (FOA) No. R13SF80003: WaterSMART – Water and Energy Efficiency Grants*. The proposed *Phase 3 Upper Willard Canal Lining and Water Marketing Project*, which will result in 2,900 LF of the Willard Canal being lined with reinforced concrete, addresses three of the four eligible FOA Project Tasks, specifically; **Water Conservation, Energy-Water Nexus**, and **Water Markets**. With an estimated total cost of $3,182,665 for environmental compliance, design, and construction, and a projected **water savings of 4,425** AF per year, the cost effectiveness of the proposed *Phase 3 Upper Willard Canal Lining and Water Marketing Project* equates to $14.38/AF/yr, which is more than 94% less costly than current District rates for irrigation water. If successful, the District will complete the project, which generally consists of six tasks, including; **Environment Compliance, Flow Measurement and Performance Measures, Engineering Design, Bidding and Contractor Selection, Construction of the Concrete Liner,** and **Creation of Water Marketing Mechanism,** within the three year time frame prescribed in the FOA for projects seeking Group II Funding.

The pages that follow describe the specific details of the proposed *Phase 3 Upper Willard Canal Lining and Water Marketing Project.*

1.B Background Data

1.B.1 History: In 1949, the Unites States Congress authorized the Weber Basin Project (Project), which was a U.S. Bureau of Reclamation (Reclamation) project aimed at developing and effectively utilizing the available water resources within the Weber River Basin Drainage. The Weber Basin Water Conservancy District (District) was subsequently created in June of 1950 by a decree of the Second District Court of Utah and under the guidelines of the Utah Water Conservancy Act. The District was established as the legal agency representing the people of the five-county area within the Weber River Basin Drainage, including Davis, Morgan, Summit, Weber, and (a portion of) Box Elder counties. The District entered into a repayment contract with the United States in 1952 to repay all Weber Basin Project costs, and also to administer the sale and delivery of Project water and to operate and maintain Project facilities, which it continues to do today.

The Project was planned to conserve and utilize available flows from the natural drainage of the Weber River, including those from the Ogden River, its principal tributary. Although Reclamation-owned Project water rights also include both groundwater rights and surface water rights on many of the smaller streams along the Wasatch Front, the vast majority of water made available through Project water rights and facilities is from excess flows on the Weber and Ogden Rivers, and the subsequent storage of those flows in storage reservoirs. A map depicting the extent of the District's service area and Weber Basin Drainage can be seen in **Figure 1.**

In October of 2008, the District received partial funding through collaboration with Reclamation to perform a System Optimization Review (SOR). The scope of the SOR entailed examining the District's entire water distribution system for the purpose of identifying water distribution efficiency and water marketing opportunities. As a result of conducting this SOR, the Willard Canal was identified as a high priority project due to the estimated amount of water being lost through seepage in the canal each year.

The estimated water loss was calculated by performing field investigations, sampling, and laboratory testing of the Willard Canal to determine the type and condition of the existing clay liner, material permeability rates, stratigraphic data, etc., to ultimately determine seepage rates. Empirical data from several published sources, including Reclamation reports, were then used to estimate water losses based on the observed findings of the field investigations. A summary of these analyses is given in **Attachment A.**

Through these analyses, it was determined that "...a disproportionate 54-62% of the total (water) volume lost is lost within the first 10-14% (5,000-7,000 feet) of the canal length". Based on these findings, the District has successfully submitted two (2) previous applications for funding assistance from Reclamation through the WaterSMART Grant Program for the (2011) Phase 1 and (2012) Phase 2 Upper

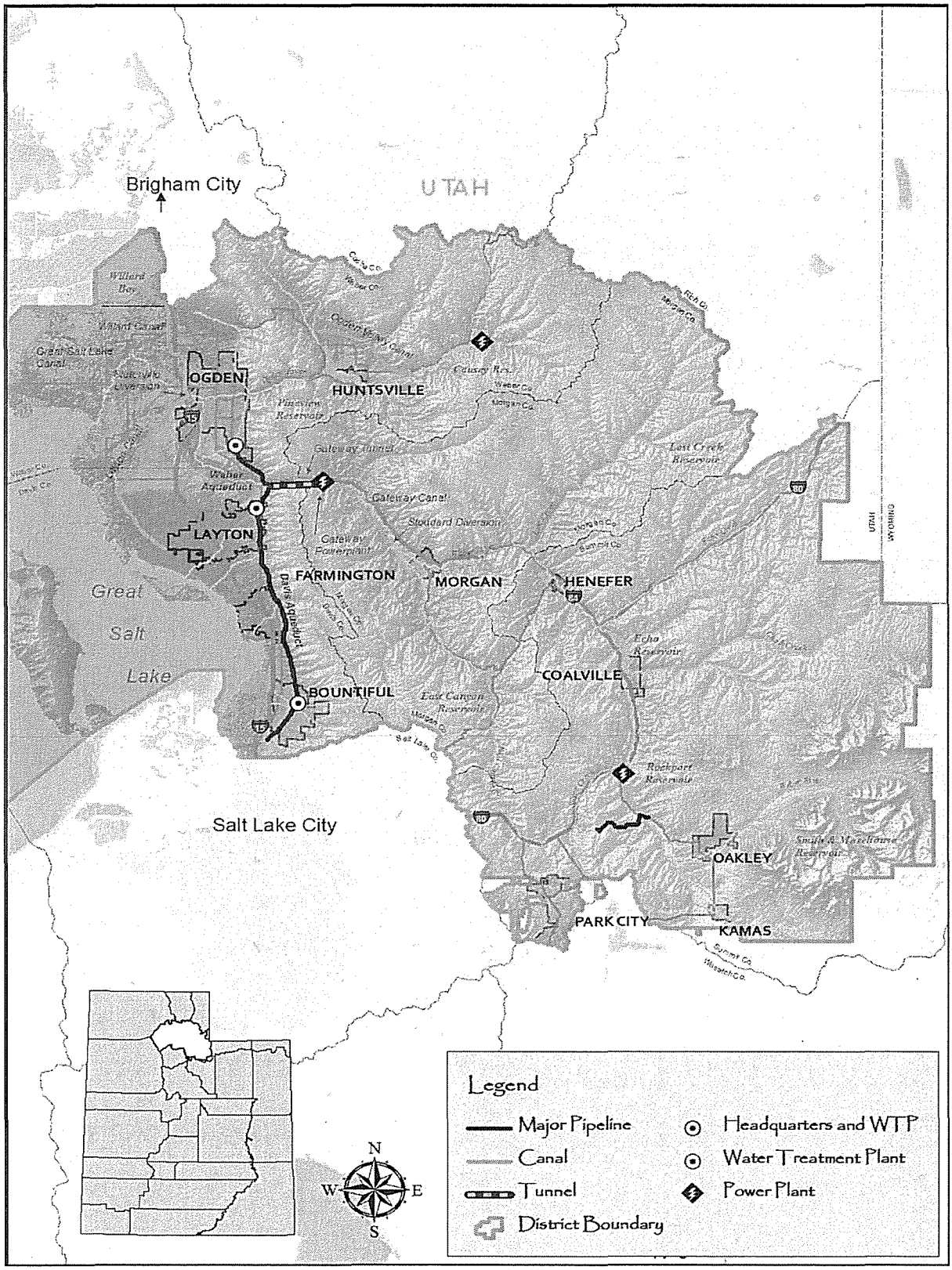


Figure 1: Overview of Geographic Extent of the Weber Basin Water Conservancy District

Willard Canal Lining and Water Marketing Projects. Phase 1, which will result in the uppermost 3,000 LF of the Willard Canal being lined, is scheduled to be complete by March 1, 2013. Phase 2, which will result in an additional 2,500 LF being lined, is currently in design, and will be completed by early March, 2014. With these two phases already under way, the District is pleased to submit this proposal for the *Phase 3 Upper Willard Canal Lining and Water Marketing Project.*

1.B.2 Summary of Weber Basin Project Facilities:

Project facilities include storage reservoirs, diversion dams, canals, tunnels, pipelines, power plants, pumping plants, deep groundwater wells, and various other facilities. The location of many of the principal Project works can be seen in **Figure 1**, and a brief summary description of these facilities and others, including the dates of construction, capacity, types, location, etc., can be found in **Figure 2**.

Of the principal Project works, the approximately 10-mile long Willard Canal is one of the most important. Using the Weber and Ogden Rivers as conveyance facilities, excess river flows and/or stored Project water from upstream reservoirs can be diverted from the lower Weber River into the Willard Canal at the Slaterville Diversion, located in Weber County, Utah. The bi-directional Willard Canal is designed to convey excess river flows or water from upstream storage via gravity toward Willard Bay Reservoir, where it can be either delivered directly or through other Project and/or privately-owned conveyance facilities for irrigation of lands adjacent to the Great Salt Lake in northwestern Weber and southwestern Box Elder Counties, or it can continue to Willard Bay Reservoir where it can be stored. When river flows subside, operation of the Willard Canal can be reversed, and it then serves as a conveyance facility to deliver stored water from Willard Bay Reservoir back toward the Slaterville Diversion via the Willard No. 1 and No. 2 Pumping Plants, continuing deliveries of irrigation water to adjacent lands, continuing down the Weber River to other downstream users, or being diverted into the Layton Canal, where it serves other irrigation suppliers and users in southwestern Weber County. In these ways, the Willard Canal provides the District with a great amount of operational flexibility for delivering storage and irrigation water throughout the western portion of the District's service area.

The Willard and Layton Canal System will soon take on an additional role for the District; that of providing for the conveyance of raw water to a new Water Treatment Plant (WTP) facility that is currently in the planning stages. Since its inception, the District has continuously been adding new facilities to supplement existing supply and extending service into areas that previously had none. Due to the rapid development (and the subsequent demand for water) within western Weber County, which is one of the last primarily undeveloped areas within the District's service area along the Wasatch Front, the District is anticipating building the need for an additional water treatment plant in western Weber County with an initial treatment capacity of up to 60 million gallons per day (MGD), and a future build-out capacity of up to 165 MGD.

Weber Basin Project • PRINCIPAL PROJECT WORKS

RESERVOIRS

Name	Type of Dam	Height (Feet)	Total Capacity	Usable District Capacity	Construction Dates
Causey	Earth & Rock	200	7,870	6,870	1962-1964
East Canyon	Concrete Arch	245	51,200	20,100	1965-1967
Lost Creek	Earth & Rock	220	22,500	20,010	1964-1966
Pineview	Earth & Rock	91	110,150	66,228	1955-1957
Smith & Morehouse	Earth & Rock	82	8,350	6,560	1984-1988
Wanship	Earth & Rock	156	62,120	60,860	1954-1957
Willard	Earth	36	215,000	198,200	1957-1963

DIVERSION DAMS

Name	Location	Pass-Through Capacity	Construction Dates
Ogden Valley	South Fork of Ogden River	2,000 C.F.S.	1962-1964
Slaterville	Weber River west of Ogden	9,000 C.F.S.	1956-1957
Stoddard	Weber River west of Morgan	6,000 C.F.S.	1955-1956

CANALS, TUNNELS & PIPELINES

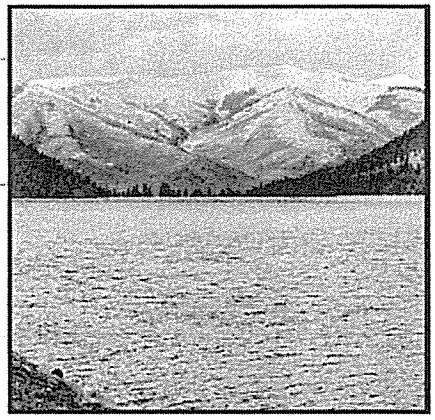
Name	Type	Length (Miles)	Capacity (CFS)	Construction Dates
Davis Aqueduct	Concrete pipe	23.0	355	1954-1957
Gateway Canal	Concrete-lined	8.5	700	1954-1956
Gateway Tunnel	Concrete-lined	3.3	435	1952-1954
Layton Canal	Earth-lined/pipe	18.0	260	1962-1964
Ogden Valley Canal	Part Earth-lined	9.2	35	1962-1964
Weber Aqueduct	Concrete pipe	5.0	80	1954-1956
Willard Canal	Earth-lined	11.0	1,150	1961-1963
M&I pipelines	Varies 6" – 48"	76.5	–	1955-2002

POWER PLANTS

Name	Type	Capacity (Kilowatts)	Construction Dates
Causey	2-unit	2,100	1999-2000
Gateway	2-unit	4,275	1957-1958
Wanship	1-unit	1,950	1957-1958

PUMPING PLANTS

Name	Location	Capacity (CFS)	Height of Lift (Ft.)
East Bountiful	Davis Aqueduct	18	475
East Layton	Davis Aqueduct	6	165
Gateway	Gateway Canal	150	150
Layton	Layton Canal	260	23
Roy Drought Relief	Layton Canal	150	340
Sand Ridge East	Davis Aqueduct	8	92
Sand Ridge West	Davis Aqueduct	15	138
South Davis	Davis Aqueduct	18	580
Uintah Bench	Weber Aqueduct	18	365
Val Verda	Davis Aqueduct	6	240
Willard No. 1	Willard Canal	500	45
Willard No. 2	Willard Canal	250	20
Antelope Booster	Layton	22	50
Old Post Road Booster	Ogden	6	200



UNDERGROUND WATER

Well	Capacity (CFS)
Ben Lomond	2.0
Bountiful	5.2
Clearfield 1	5.0
Clearfield 2	5.0
Davis Boulevard	2.2
District Well 2	11.0
District Well 3	10.0
Laytona	5.0
North Ogden	1.6
Orchard Drive	1.0
Riverdale	6.6
South Weber 1	10.0
South Weber 2	10.0
Fairfield	10.0
Irrigation Wells	
Farmington #1	5.0
Farmington #2	5.0
West Bountiful Golf	2.0
5th South	3.5

WATER TREATMENT PLANT CAPACITIES

Plant	Capacity
Davis North	70 CFS (46 MGD)
Davis South	25 CFS (16 MGD)
Weber South	40 CFS (26 MGD)

Various Uses of Water Supplied by the Weber Basin Water Conservancy District

INDUSTRIAL WATER: Several industries in Davis and Weber Counties rely on water supplied by the District for their manufacturing and other uses.

IRRIGATION WATER: The Project is a source of economical irrigation water for many farmers in Box Elder, Davis, Morgan, Summit and Weber Counties. Water is delivered either directly to individual farmers or is conveyed by an irrigation company.

REPLACEMENT WATER: Many residents of the District do not have access to a municipal or community water system and must depend on alternative sources for their domestic water. The District owns storage rights in Morgan County, Summit County and Weber County. Individuals may contract with the District for a water right which, along with an approved exchange application from the State Engineer, permits drilling of a well to meet the needs of these individuals.

SECONDARY WATER: Many residents of Davis and Weber Counties enjoy the use of Weber Basin water to sprinkle their lawns and gardens. The District supplies water to a number of secondary water companies along the Wasatch Front. These organizations then transport water to customers in their respective service areas. Weber Basin also provides secondary water directly to many residents from Ogden to Bountiful.

CULINARY WATER: Weber Basin Water Conservancy District wholesales culinary water to almost every city and water improvement district in Davis and Weber Counties. They provide either all or a portion of this supply to their customers. Future culinary water supplies are anticipated in Morgan and Summit Counties.

CFS=Cubic Feet per Second • MGD=Millions Gallons Per Day

Figure 2: Weber Basin Water Conservancy District System Summary

Water savings realized through *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will result directly in additional water storage, capacity, and/or available water supply for the new WTP.

1.B.3 District Supply and Demand: Overall, Project works and the subsequent expansion of those works by the District serve a geographic area over 2,500 square miles, with five principle water uses:

- **Wholesale Irrigation:** The District supplies wholesale water to a number of irrigation suppliers along the Wasatch Front. These organizations then retail water to customers in their respective service areas. This use accounts for approximately 35% of the District's water contracts.
- **Groundwater Replacement:** The District supplies various drinking water purveyors and individuals (either residential or agricultural) with a water contract, which is then used in an exchange application to obtain approval from the State Engineer to drill a groundwater well to meet water supply needs. This use accounts for nearly 11% of District contracts currently. By banking water, a potential source of conflict related to ground water rights can be mitigated.
- **Retail Secondary Irrigation:** The District delivers economical irrigation water to many irrigators and farmers in Box Elder, Davis, Morgan, Summit and Weber Counties. The District also provides residential customers with irrigation water in Davis and Weber counties via 211 miles of pipelines. This use accounts for roughly 26% of water contracts.
- **Treated Municipal Water:** The District wholesales culinary water to nearly 50 cities and water improvement districts in Davis and Weber Counties via 69 miles of transmission lines. This use accounts for approximately 22% of the District's contracts.
- **Untreated Industrial Water:** This use accounts for about 5% of the District's Contracts.As noted previously, the District receives its water from the Weber and Ogden Rivers and from various deep groundwater wells. Table 2 illustrates a breakdown of the District's existing water resources, which include that made available through Project facilities as well as additional water that the District has acquired and developed over time.

In 2011, District-administered water contracts totaled 225,449 acre-feet (AF), with 87,036 AF categorized as municipal and industrial (M&I) water, and the remaining 138,413 AF categorized as irrigation.

Available Project and District supply used to meet the above demands consists of stored water, deep groundwater wells, water shares acquired from other independent water suppliers, and decreed water rights that are above and beyond Project water rights. The total and reliable yields of all available supplies are summarized in **Table 1**. It is worth noting that in 2011, existing water contracts obligate nearly 84% of all reliable yield supply available to the District.

Table 1: Source and Annual Yield of Supplies

Source	Maximum Yield (AF)	Reliable Yield (AF)
Project Stored Water	377,278	206,914
District Stored Water	7,848	7,848
Wells (both District and Project)	70,990	35,495
Stock Water	20,601	16,481
Decreed Water Rights	3,960	3,168
Totals:	**480,677**	**269,906**

1.B.4 Past Projects with Reclamation: The District has collaborated with Reclamation on a number of recently completed and ongoing cooperative projects, including:

- **Phase 2 Upper Willard Canal Lining and Water Marketing Project:** This project, which received partial funding through the 2012 WaterSMART program, is currently underway and is in design. Construction will commence in approximately October 2013.
- **Phase 1 Upper Willard Canal Lining and Water Marketing Project:** This project, which received partial funding through the 2011 WaterSMART program, is currently underway and is being constructed. Construction is anticipated to be completed by February 1, 2013.
- **The Layton Canal Lining and Water Marketing Project:** This project, which received partial funding through the 2010 WaterSMART program, has been completed.
- **The Uintah Bench Retail Secondary Water Meter Project:** This project, which received partial funding through the 2010 WaterSMART program, has been completed.
- **System Optimization Review (SOR):** Completed in 2008, this project evaluated the efficiencies of the District's entire water storage and distribution system.
- **Weber River Basin Aquifer Recharge Water Bank:** This project, which was completed in 2009, received partial funding through the 2007 Water 2025 program.
- **Gateway Canal Landslide Stabilization Projects:** This is an ongoing collaboration.

1.C Technical Project Description

The proposed Weber Basin Water Conservancy District *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will include the following six (6) integrated Project Tasks:

1.C.1 Environment Compliance Review:

- **Schedule:** October 2013 to March 2014
- **Scope:** An environmental compliance review will be conducted as required by Federal Statute. This will include a Class I Inventory (File Search) and a Class III cultural resource inventory of the entire project Area of Potential Effects (APE), which will be prepared in accordance with Utah State Historic Preservation Office (SHPO). SHPO concurrence with the findings of the cultural resources survey will be provided to Reclamation for completion of remaining NEPA requirements.

1.C.2 Flow Measurement and Performance Measures:

- **Schedule:** April 2014 to April 2015
- **Scope:** Flow measurements will be collected and recorded by the District at each end of the proposed project, both before and after installation of the concrete liner. This will be accomplished using a portable Acoustic Doppler Current Profile (ADCP) meter as manufactured by Teledyne Instruments for their StreamPro Meter (which the District has already acquired for the Phase 1 and Phase 2 Upper Willard Canal Lining and Water Marketing Projects). The data collected with also include metered flow data collected from the permanent ADCP meter installation at the termination of the Phase 2 project. Although the use of the permanent meter will not be necessary to accurately measure seepage loss, this will provide additional data that will help to validate the accuracy of measurement. When complete, the resulting data will allow the District to accurately document actual canal leakage for both the current condition and the post-lining condition. Flow measurements will also allow a comparison to, and if necessary, refinement of the canal leakage estimates (which were based upon geotechnical testing of the canal lining and empirical data). In this way, accurate measures of water savings will be determined and documented. Actual measured water savings will then be available for water marketing.

1.C.3 Engineering Design:

- **Schedule:** March 2014 to August 2014
- **Scope:** The District will retain a professional engineering consulting firm to assist the District in preparing the final design and construction documents for the construction portion of the project.

1.C.4 Bidding and Contractor Selection:

- **Schedule:** August 2014 to September 2014
- **Scope:** The District, with assistance from the Consulting Engineer, will prequalify General Contractors, provide only those Contractors that are approved to perform the work with bid documents, and solicit bids from them for all construction services associated with installation of the concrete liner and ancillary equipment.

1.C.5 Construction of Concrete Liner:

- **Schedule:** September 2014 to April 2015 (this schedule includes liner construction through January 2015, with two additional months for project closeout).
- **Scope:** This task will include installation of a new steel reinforced 6" thick concrete liner on the Willard Canal from the termination of the Phase 2 Project at 700 South Street, to 200 South Street in Marriott Slaterville. This segment comprises approximately 2,900 LF, or approximately 5% of the entire Willard Canal.

1.C.6 Creation of Water Marketing Mechanism:

- **Schedule:** Will commence in April 2015, and will be ongoing
- **Scope:** This will be a continuation of the ongoing effort underway for the Phases 1 and 2 Upper Willard Canal Lining and Water Marketing Projects. The *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will improve sustainable water supplies by directly allowing the District to conserve an average of 4,425 AF per year, over the 50 year life of the project. This water can be stored in the existing upstream reservoirs operated by the District, or in Willard Bay Reservoir. Existing petition and water transfer agreement mechanisms will be used to market saved water, and thus avoid issues created by using a new water allocation method.

A map depicting the upper Willard Canal can be seen in **Figure 3**. Relevant Reclamation As-Built Drawings of the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* extent can be found in **Attachment B**.

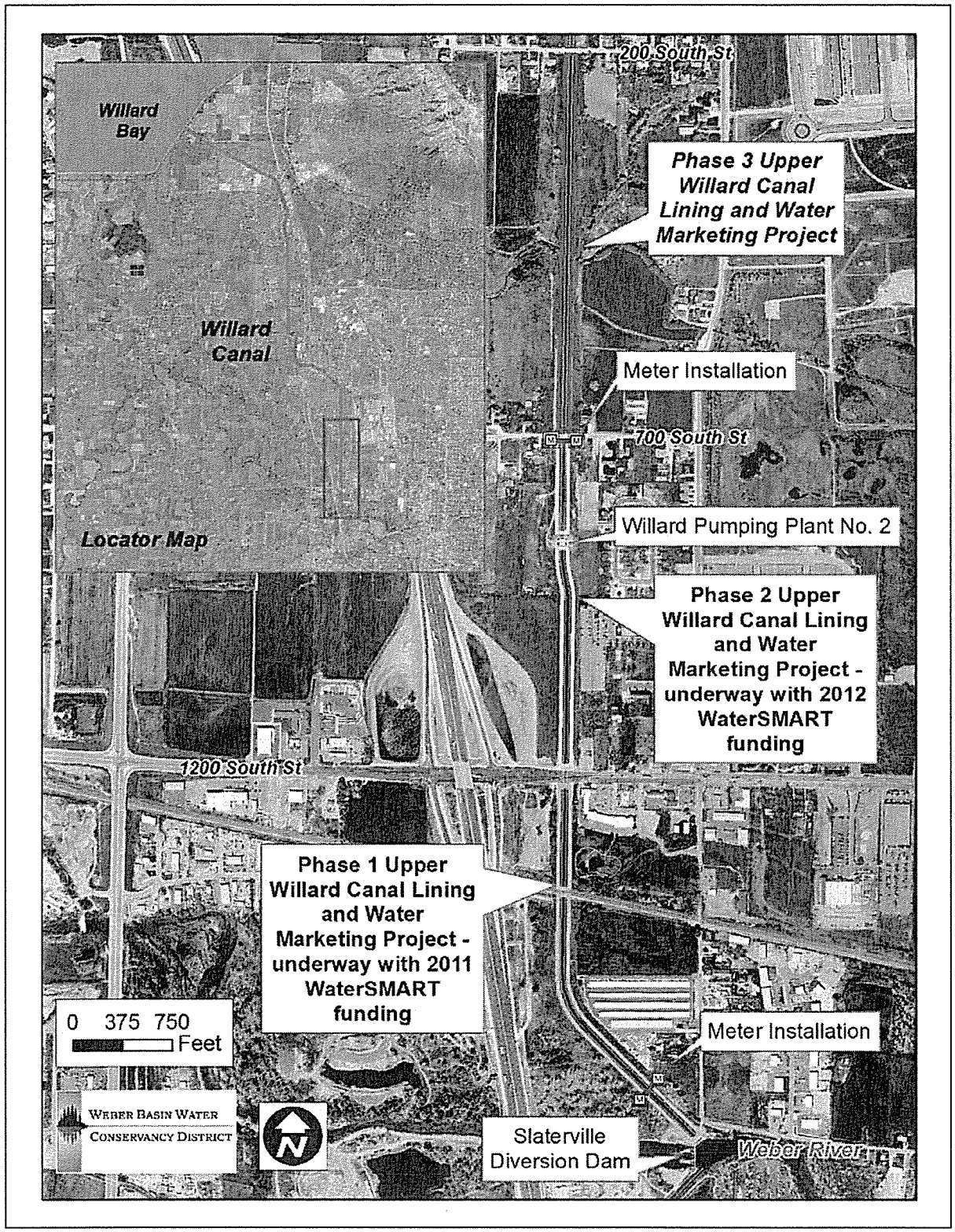


Figure 3: Map of Willard Canal and Extent of Upper Willard Canal Lining Projects

1.D Evaluation Criteria

As was the case with previous phases, the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* directly addresses three of the four eligible project tasks; specifically Task A – Water Conservation, Task B – Energy-Water Nexus, and Task D – Water Markets. These tasks and their respective evaluation criteria as listed in the FOA are addressed in the following sub-sections:

1.D.1 Evaluation Criterion A: Water Conservation

- **Subcriterion No. A.1(a) – Quantifiable Water Savings:** Based on the results of a seepage analysis, up to 15,600 AF of water is lost through seepage in the uppermost 5,000 to 7,000 LF of the Willard Canal. Through installation of a 6" thick steel reinforced concrete liner, the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will result in a water savings of 4,425 AF/yr.

FOA Questions for Canal Lining Projects and subsequent District Responses are given below:

– *How has the estimated average annual water savings that will result from the Project been determined? Please provide all relevant calculations, assumptions, and supporting data.*

It has been assumed that the average annual water savings resulting from the proposed project will be equal to the current canal seepage losses of 2.0 AF/LF of canal, (refer to calculation in the District's response to the FOA question pertaining to how seepage losses are determined below, and supporting **Attachment A**), multiplied by the effectiveness of the newly installed concrete liner. The proposed project will comprise a total of 2,900 LF. Therefore, the water loss for this stretch of the canal can be calculated to be 2,900 LF x 2.0 AF/LF = 5,900 AF per year. Conservatively assuming a liner effectiveness of only 75% (refer to the District's response to the FOA question pertaining to post–project seepage losses below, and supporting **Attachment C**), the estimated average annual water savings resulting from the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will be:

5,900 AF/year x 75% liner effectiveness = 4,425 AF per year

– *How have average annual canal seepage losses been determined? Have ponding and/or inflow/outflow tests been conducted to determine seepage rates under varying conditions? If so, please provide detailed descriptions of testing methods and all results. If not, please provide an explanation of the method(s) used to calculate seepage losses. All estimates should be supported with multiple sets of data/measurements from representative sections of canals.*

The District has conducted a detailed seepage analysis of the Willard Canal, which can be found in the District's SOR and is enclosed in **Attachment A.** The methods used to estimate canal water losses were as follows:

i.) Research was conducted to ascertain canal lining techniques used by other Districts in the Western United States;
ii.) Canal system design and maintenance information was reviewed and analyzed by a Geotechnical firm with experience in canal design;
iii.) Borings were placed along the entire alignment of the Willard Canal;
iv.) Piezometers were installed at aforementioned boring locations to determine water table levels and fluctuations with respect to canal water levels;
v.) Samples of canal lining materials were taken along the entire alignment of the canal;
vi.) Data collected were analyzed and compared to published reports; and
vii.) Operational measurements from existing system operations records were considered.

From this analysis, it is estimated that anywhere from 12,880 AF to 15,600 AF per year is lost to seepage through the southernmost 5,000-7,000 LF of the Willard Canal. Using an average value of 14,240 AF per year through 7,000 LF of canal, it can be inferred that

Seepage Loss = 14,240 AF/7,000 LF = 2.0 AF/LF of canal

– *What are the expected post-project seepage/leakage losses and how were these estimates determined? (e.g., can data specific to the type of material being used in the project be provided)?*

The District has utilized the results of Reclamation Project "R-00-01: CANAL LINING DEMONSTRATION PROJECT 2000 SUPPLEMENTAL REPORT" to derive post project leakage estimates. A portion of this report up to and including the Executive Summary and relative conclucsions, can be found in **Attachment C**.

This report states for the project area studied that a complete prism concrete lining method should be 70% to 85% effective. A conservative value of 75% effectiveness is used to reduce the water savings estimates in the seepage analysis contained in **Attachment A.**

– *What are the anticipated annual transit loss reductions in terms of acre-feet per mile for the overall project and for each section of canal included in the project?*

Transit losses generally consist of seepage, spillage, and evaporation. Seepage losses have already been estimated as described above, using a conservative 75% effectiveness rating for the new concrete liner. Spillage and evaporation will not be greatly impacted by the project, as the original geometry of the existing

unlined canal will be utilized. Although the canal may operate at a reduced depth due to increased hydraulic efficiency, and the area of atmospheric exposure will therefore be reduced slightly, evaporation will not be reduced significantly from what it has historically been. Additionally, there are no turnouts or other diversions in the stretch proposed to be lined that would be improved substantially which would contribute to reduce spillage. Therefore, with the exception of afore mentioned reduction in seepage, there will be no significant change in transit losses that would translate into additional water loss (or savings).

- *How will actual canal loss seepage reductions be verified?*

Actual losses will be measured as outlined in the **Technical Project Description** (Section 1.C, paragraph 2). Specifically, flow measurements will be collected and recorded by the District at each end of the proposed project, both before and after installation of the concrete liner. This will be accomplished using a portable ADCP meter as manufactured by Teledyne Instruments for their StreamPro Meter (which the District has already acquired for the Phase 1 and Phase 2 Upper Willard Canal Lining and Water Marketing Projects). The resulting data will allow the District to accurately document actual canal leakage for both the current condition and the post-lining condition. In this way, accurate measures of water savings will be determined and documented. Actual measured water savings will then be available for water marketing.

- *Include a detailed description of the materials being used.*

The project will use materials consistent with previous canal lining projects that the District has already completed or are underway, which were partially funded through previously received WaterSMART Grants. Specifically:

i.) The Willard Canal will be thoroughly cleaned and restored to a trapezoidal geometry using mostly in-situ material, with some infill possibly needed in selected areas;

ii.) Granular 6" minus material may be used for subgrade stabilization as required. Free draining 1" minus drain rock, non-woven filter fabric, and perforated HDPE pipe will be used to augment underdrains and prevent pore water pressures resulting from natural fluctuations in the groundwater table, or resulting ice, from heaving concrete liner; and

iii.) The canal liner will consist of reinforced concrete, with a thickness of 6" along the cross section of the canal prism. Freeboard will be as per Reclamation Standards for the design flow. Construction and expansion joints will include water stops. Construction cost estimate data can be found in **Attachment D**. Please note that the District used the *average* of construction bids received for the Phase 1 Upper Willard Canal Lining and Water Marketing Project, and the most recent cost for Consulting Engineering design and construction services, which was received for the Phase 2 Upper Willard Canal Lining and Water Marketing Project (2012).

- **Subcriterion No. A.2 – Percentage of Total Supply:** Using the formula found in the FOA:

$$\textit{Percentage of Total Supply} = \frac{\textit{4,425 AF/yr saved}}{\textit{269,906 AF/yr available}} = \textit{1.6\%}$$

The water savings achieved by the proposed *Phase 3 Upper Willard Canal Lining and Water Marketing Project* amount to savings of approximately 1.6% of the total water supply across the entire five-county area served by the District. However, it should also be noted that the water savings is a much greater percentage of the total amount of water conveyed by the Willard Canal in an average year.

- **Subcriteria No. A.3 – Reasonableness of Costs:** Using the formula found in the FOA:

$$\textit{Cost Reasonableness} = \frac{\textit{\$3,182,665}}{\textit{4,425 AF/yr x 50 years}} = \textit{\$14.38/AF/year}$$

Compared to the District's current retail rate for untreated water of $248.11/acre foot/year; the proposed *Phase 3 Upper Willard Canal Lining and Water Marketing Project* is extremely cost effective.

1.D.2 Evaluation Criterion B: Energy-Water Nexus

- **Subcriterion No. B.2 – Increased Energy Efficiency in Water Management:** Analyses performed as a part of the District's SOR allows for projection of potential savings in pumping costs as a function of AF of water delivered. The proposed *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will result in power savings of up to 40,315 Kilowatt hours (kWh) due to saved pumping costs of otherwise lost water. This estimate is based on a canal seepage rate of 4,425 AF per year, or approximately 2,741 gpm. Willard Pumping Plant No. 2 requires 15.66 ft of head (lift), and Willard Canal Pumping Plant No. 1 requires 20.48 ft of head (lift), for a total head of 36.14 ft. The horsepower required to pump (lift) 2,741 gpm 36.14 ft is calculated to be 25 horsepower, or 18.7 kW (conservatively neglecting motor and pump efficiencies). Since the pumping plants are only operated over approximately half the irrigation season based on historical records, this equates to approximately 90 days, or 2,160 hrs, thus requiring 37.3 kW x 2,160 hrs, or 40,315 kWh.

1.D.3 Evaluation Criterion C: Benefits to Endangered Species (Not Used)

1.D.4 Evaluation Criterion D: Water Marketing

- **Estimated Amount of Water to be Marketed:** Existing petition and water transfer agreement mechanisms will be used to market saved water. The District is therefore able to market the entire amount of water saved through the *Phase 3 Upper Willard Canal Lining and Water Marketing Project*, which is estimated to be 4,425 AF/year.
- **Detailed Description of Water Marketing Mechanism:** The District will create a flexible water marketing legal structure which will allow this conserved water to be marketed. All of the water saved by constructing the proposed project can be marketed. In this regard, water marketing planning work to be done as a part of the currently underway Phase 1 and Phase 2 Upper Willard Canal Lining and Water Marketing Projects will be directly applicable to this current 2013 WaterSMART application.
- **Number and Types of Users:** The proposed approach of storing the saved water at any of the District's upstream storage reservoirs (refer to **Figure 1**) will allow the District considerable flexibility in the number and types of users for the marketed water. As the demand for water is increasing, with few other sources of new water available, the District will have no difficulty in marketing water saved through this project.
- **Description of Legal Issues:** Based on the results of water marketing investigations conducted thus far, as a component of the District's SOR, no limitations exist with regard to which types of users the water may be marketed to. Water saved as a result of this project will most likely be marketed using the existing legal structure in place for many of the District's secondary water customers, via water lease petitions. Other mechanisms, such as transfer agreements, will also be considered to identify the best approach to achieve water conservation objectives in the District's Water Conservation Plan.
- **Estimated Duration of Water Market:** The specific duration of transfer agreements will need to be determined during the course of the project. If a water transfer agreement (or agreements) is the best approach for water conservation and water management, then the District will negotiate these agreements. Interested parties will likely consist of the District's larger wholesale customers (other canal companies and cities).

1.D.5 Evaluation Criterion E: Other Contributions to Water Supply Sustainability

Utah is the second driest state in the United States. As such, drought relief planning is an essential component of the Weber Basin Water Conservancy District's planning efforts.

All of the water saved through this project may be used to meet rapidly increasing demands for water, particularly in western Weber County. This has never been more apparent than in 2012, when following one of the driest winters and then the hottest summer on record, decreed water rights on the Weber River system were cut to 1862 and earlier priority in July of 2012. This was the second time cuts of this magnitude

have been made in the last 10 years, indicating an over-allocation of existing water within the basin and/or increased climate variability leading to drought conditions.

The *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will address several water sustainability issues that have been identified as a high priority in the District's Master Plan. Through development of a water marketing mechanism for the additional 4,425 AF/yr or water to be saved, the District will be able to provide more water to wholesale customers in its five-county service area. Many of these customers are municipalities that have limited or no ability to develop new water sources themselves.

In addition, the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will also reduce the potential for water related conflict. The District serves one of the fastest growing regions in the Western United States, with the population of the region (and thereby the demand for water) expected to increase by 20-30% by 2025. Due to this rapid growth, there is an increasingly volatile balance between the demand for irrigation water, and the rapidly increasing demand for additional municipal and industrial (M&I) water; particularly in years of drought. By conserving an additional 4,425 AF per year, the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will contribute substantially to the District's conservation efforts and will help to alleviate potential future conflicts.

1.D.6 Evaluation Criterion F: Implementation and Results

- **Subcriterion F.1 – Project Planning:**
  - i.) **District Wide Planning that Supports the Project:** The District has recently completed a District Wide System Optimization Review. This SOR has identified canal lining and metering projects as the top two priorities. This application addresses the canal lining priority. The approach used in the SOR that was used to identify the need for the Upper Willard Canal Lining and Water Marketing Projects is shown in **Figure 4**.
  - ii.) **Engineering or Design work Performed Specifically in Support of the Proposed Project:** The District has performed thorough evaluations of the condition of the liner in the Willard Canal and used this information to estimate canal seepage rates. This information can be found in **Attachment A**.
  - iii.) **How Project Conforms to and Meets Goals of State or Regional Water Plans:** The proposed project will assist the District in meeting its conservation goal of a 25% reduction by 2050 by saving 4,425 AF of the water currently being lost due to canal seepage in the subject portion of the Willard Canal.
- **Subcriterion F.2 – Readiness to Proceed:** The District is prepared to proceed with the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* immediately upon funding by Reclamation. The work plan as presented above in the **Technical Project Description,** Section 1.C, paragraphs 1 through 6 will be implemented.

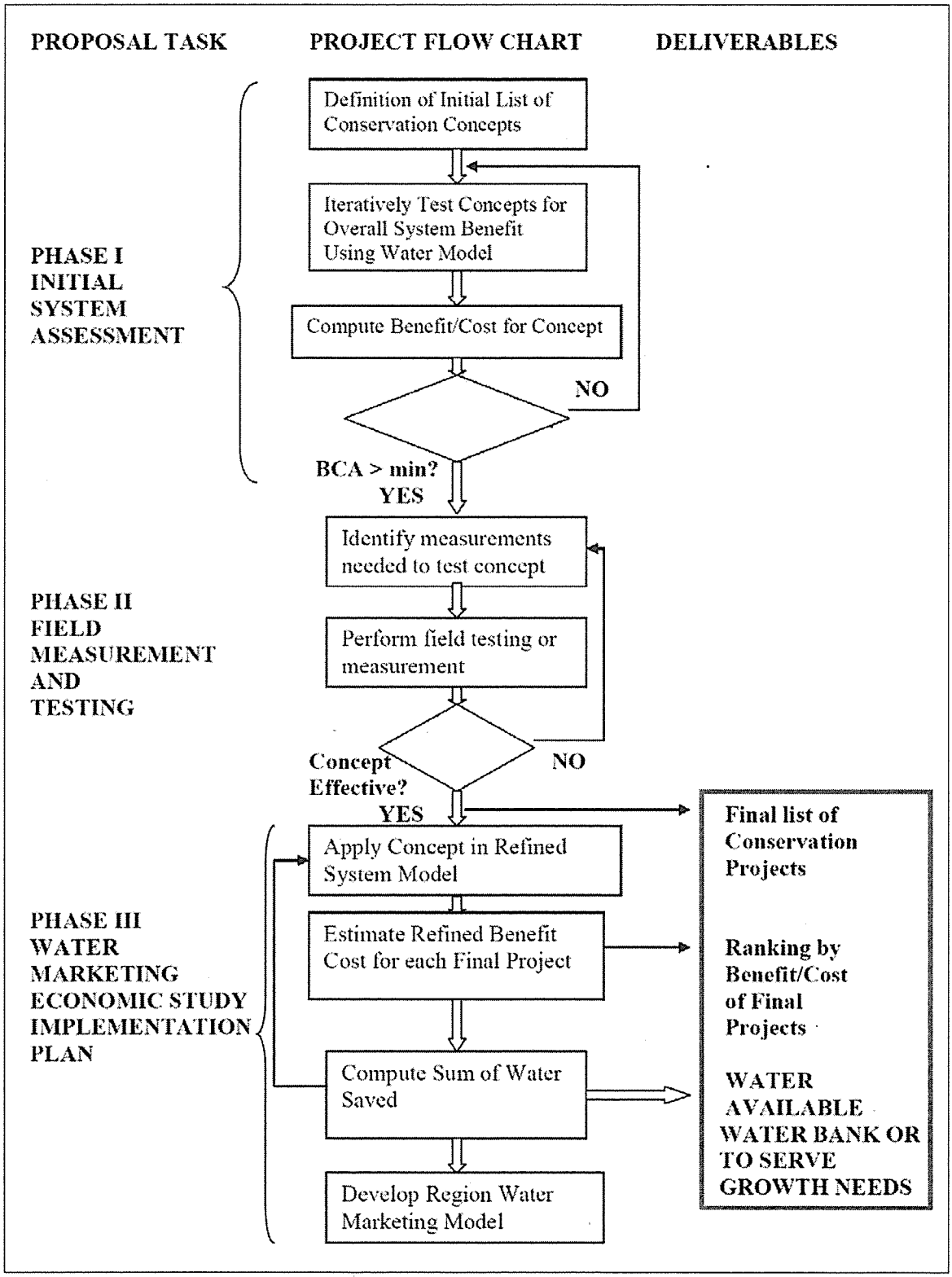


Figure 4: Decision Process Used in the Weber Basin Water Conservancy District's SOR to Identify High Priority Water Conservation and Water Banking Project

- **Subcriterion F.3 – Performance Measures:** Actual losses will be measured as outlined in the **Technical Project Description** (Section 1.C, paragraph 2). Specifically, flow measurements will be collected and recorded by the District at each end of the proposed project, both before and after installation of the concrete liner. This will be accomplished using a portable ADCP meter, which the District has already acquired for previous projects. The resulting data will allow the District to accurately document actual canal leakage for both the current condition and the post-lining condition. In this way, accurate measures of water savings will be determined and documented. Actual measured water savings will then be available for water marketing.

1.D.7 Evaluation Criterion G: Additional Non-Federal Funding

Using the formula found in the FOA, the total project cost, as itemized in Table 2 of the budget proposal is:

$$\textit{Total Non-Federal Funding} = \frac{\$1,682,665.00}{\$3,182,665.00} = 52.9\%$$

Of the total amount, the District is requesting a Federal share of $1,500,000.00 (47.1%).

1.D.8 Evaluation Criterion F: Connection to Reclamation Project Activities

The project is directly connected to Reclamation activities, since the Willard Canal is a Reclamation-owned Weber Basin Project facility, and is located entirely upon land owned in fee-simple title by Reclamation. All of the water saved as a result of the project will serve to augment water supplies in the Weber Basin area, thus reducing future conflicts as per Reclamation objectives.

The *Phase 3 Upper Willard Canal Lining and Water Marketing Project* will also serve to support Reclamation objectives in its desire to raise the height of the A.V. Watkins Dam, as the Willard Canal is the sole conveyance facility for supplying water to Willard Bay.

2.0 ENVIRONMENTAL AND CULTURAL RESOURCES COMPLIANCE

The District understands that in order to allow Reclamation to assess the probable environmental impacts and costs associated with each application, all applicants must respond to the following list of questions focusing on the requirements of the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and the National Historic Preservation Act (NHPA). The District therefore submits the following responses to the questions contained in the FOA, to the best of the District's knowledge:

- *Will the project impact the surrounding environment (i.e., soil [dust], air, water [quality and quantity], animal habitat, etc.)? Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the project area. Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.*

  The project will require a moderate level of earth work. However, this entire earthwork is within the existing canal right of way. Animal habitats will not be negatively impacted.

- *Are you aware of any endangered or threatened species in the project area? If so, would they be affected by any activities associated with the proposed project?*

  No endangered species are impacted by this project.

- *Are there wetlands inside the project boundaries? If so, please estimate how many acres of wetlands there are and describe any impact the project will have on the wetlands.*

  No wetlands are in the project boundaries.

- *When was the water delivery system constructed?*

  The original canal was constructed over a several year period in the early 1960's.

- *Will the project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)?*

  Yes, the primary modifications will be canal lining. No other modifications or effects thereof are anticipated.

- *Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places?*

  No.

- *Are there any know archeological sites in the proposed project area?*

  No.

- *Will the project limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands?*

  No.

- *Will the project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?*

  No.

3.0 REQUIRED PERMITS OR APPROVALS

The project will be constructed entirely upon property that is owned in fee-simple title by Reclamation, and all improvements will remain in United States ownership. For this reason, there are no permits or approvals needed.

4.0 LETTER OF PROJECT SUPPORT (NOT USED)

5.0 OFFICIAL RESOLUTION

An official resolution will be submitted to Reclamation within 30 days of this application submittal, as required by the FOA. This resolution will be approved by the District's Board of Trustees.

6.0 PROJECT BUDGET

6.A Funding Plan and Letters of Commitment

Information in this section describes how the non-Reclamation share of project costs will be obtained.

The District will fund all non-Federal contributions entirely with Weber Basin Water Conservancy District funds. The District provides the following responses to questions in the FOA:

- *How you will make your contribution to the cost-share requirement, such as monetary and/or in-kind contributions and source funds contributed by the applicant (e.g., reserve account, tax revenue, and/or assessments).*

  The District will fund the project through a combination of proceeds from bonds and current operating revenues.

- *Describe any in-kind costs incurred before the anticipated project start date that you seek to include as project costs. Include:*
  i.) What project expenses have been incurred

ii.) How they benefited the project
iii.) The amount of the expense
iv.) The date of cost incurrence

The District does not wish to include any in-kind costs incurred prior to the project start date as project costs.

- *Provide the identity and amount of funding to be provided by funding partners, as well as the required letters of commitment.*

  The District has no other funding partners.

- *Describe any funding requested or received from other Federal partners.*

  None.

- *Describe any pending funding requests that have not yet been approved, and explain how the project will be affected if such funding is denied.*

  None.

- *Please include the following chart to summarize your non-Federal and other Federal funding sources.*

  The requested chart is included below. Please refer to **Table 2.**

- *Please include the following chart to summarize your Federal funding request by year.*

  The requested chart is included below. Please refer to **Table 3.**

Table 2: Breakdowns of Funding by Source

Funding Sources	Funding Amount (%)	Funding Amount ($)
Weber Basin Water Conservancy District	52.9%	$1,682,665.00
Other Federal Entities	0%	$0.00
Bureau of Reclamation	47.1%	$1,500,000.00
Total Project Funding:	**100%**	**$3,182,665.00**

Please note that although all costs will be incurred by the end of Year 2 (FY 2014), the maximum reimbursement limitations of $750,000 per year as set forth in the NOA necessitates that the District carry all remaining costs through Year 2 and request reimbursement of the final costs in Year 3. This carryover is based on the assumption that the District will be successful in its application for Group 1 Funding under a separate application.

6.B Budget Proposal

6.B.1 Budget Narrative: The following budget narrative is provided for the specific items listed in the FOA. These items, and subsequent District responses, are as follows:

- **Salaries and Wages:** The District is not requesting reimbursement for District personnel costs.
- **Fringe Benefits:** The District's fringe benefit rate is 42%. However, the District is not asking for reimbursement of internal project costs.
- **Travel:** The District is not requesting any reimbursement of travel.
- **Equipment:** There will be no new equipment purchased for the proposed project. The District already has acquired or will acquire the necessary equipment through previous projects. As such, this equipment is not reimbursable under the currently proposed project.
- **Materials and Supplies:** Itemizations of construction by major category, unit price, quantity, and purpose, such as whether the items are needed for office use, research, or construction is provided in **Attachment D**. The District is not asking for reimbursement of any office supplies.
- **Contractual:** The total project design and construction budget is $3,151,153.
- **Environmental and Regulatory Compliance Costs:** Environmental costs are expected to be very minimal, as all work is done in the existing canal right of way in the immediate vicinity and/or directly in the location of the existing canal. However, as instructed in Paragraph IV.D.4 of the FOA, a cost of no less than 1% of the total project budget is allocated for environmental and regulatory compliance costs.
  Although this is the amount that will be budgeted for in the financial assistance agreement between Reclamation and the District, it is anticipated that if any portion of the funds budgeted for environmental and regulatory compliance are not required for compliance activities, such funds may be reallocated to the project, if appropriate.

Table 3: Breakdown of Funding by Year

Funding Group II Request			
	Year 1 (FY 2013)	**Year 2 (FY 2014)**	**Year 3 (FY 2015)**
Yearly Funding Requested:	$450,000.00	$750,000	$300,000

- **Reporting:** The District is not requesting reimbursement for any reporting fee costs.
- **Other Expenses:** The District is not asking for reimbursement of any other costs.
- **Indirect Costs:** The District is not asking for reimbursement of any indirect costs.
- **Total Costs:** The total project cost is $3,182,665.00. The proposed District cost share is $1,682,665.00 (52.9%); and the proposed federal share is $1,500,000 (47.1%). All costs associated with the *Phase 3 Upper Willard Canal Lining and Water Marketing Project* are itemized in Table 4 below, and are also given in form 424C- Construction programs.

Table 4: Breakdown of Funding by Year

Budget Item Description	Computation		Quantity Type	Total Cost
	$/Unit	Quantity		
Salaries and Wages	Reimbursement of District salaries and wages is not requested			
Fringe Benefits	Reimbursement of District fringe benefits is not requested			
Travel	Reimbursement of District travel is not requested			
Equipment	$0	$0	N/A	$0
Supplies and Materials	Reimbursement of District supplies and materials is not requested			
Contractual/Construction				
Engineering Services	$68,754	1	LS	$68,754
Construction Services	$3,082,399	1	LS	$3,082,399
Other				
Environmental and Regulatory Compliance (1% of total)	$31,512	1	LS	$31,512
Establishing Water Bank	Reimbursement of District contributions in establishing water bank is not requested			
Total Direct Costs				**$3,182,665**
Indirect Costs – 0%	-	-	-	-
			Total Project Costs:	**$3,182,665**

7.0 ATTACHMENTS

Attachment A: Willard Canal Leakage Analysis

Attachment B: Selected Original Reclamation Drawings

Attachment C: Basis for Post-Project Seepage Loss Estimates

Attachment D: Canal Lining Cost Estimate Basis

Attachment A: Willard Canal Leakage Analysis

IGES®

February 15, 2011

Mr. John Masek
Weber Basin Water Conservatory District
2837 East Highway 193
Layton, UT 84040

Phase 2 Canal Seepage Assessment
Willard Canal
Weber and Box Elder Counties, Utah

Mr. Masek:

Intermountain GeoEnvironmental Services, Inc. (IGES) has performed additional field investigation, sampling, laboratory testing and seepage assessment for the 10 mile stretch of the Willard Canal maintained and operated by the Weber Basin Water Conservancy District (District). This work was intended to supplement the findings of our 2009 subsurface investigation and liner sampling of the canal in order to better quantify the performance of the canal liner. Our liner sampling was performed at an additional 12 locations within the partially empty canal (see Figure A-1). Sample locations were selected to fill in gaps between the 10 locations sampled in 2009. The locations were spaced along the entire length of open canal starting at the Slaterville Diversion Dam and ending near Willard Bay in Box Elder County. Our field services and analysis were performed in accordance with our proposal dated January 27, 2010. This letter provides a summation of field work, laboratory testing, and seepage modeling.

CANAL OBSERVATIONS

Sampling and observation of the canal liner in 2009 was complicated by the presence of approximately 7-8 feet of water in the canal during our field investigation. Under the circumstances sample quality was relatively good, but an accurate representation of the existing channel cross section was not available or easily obtainable.

For a period of time in early February 2010 flow was not actively diverted into the Willard Canal from either the Weber River or Willard Bay. Our field investigation was scheduled and performed between February 3rd and 5th, 2010. Due to the relatively flat bottom slope of the canal, ponded water (up to 3 feet deep) and some ice (up to 1.5 feet thick) was encountered at sampling locations throughout the canal. These conditions limited measurement/documentation of canal bottom conditions. For most of the northern portions of the canal (10-6 through 10-12) snow was also present (up to 0.5 feet deep) on top of ice and on the canal side slopes limiting observation of liner conditions on the side slopes of the channel as well.

CROSS-SECTION SURVEY

In order to document the existing ground surface profile, IGES retained the services of a professional land surveyor. A surveyed cross section (ground surface or top of ice) was obtained at seven of the twelve sampling locations. The remaining five were not surveyed because of a scheduling conflict which prevented the surveyors from returning to the site prior to the canal being charged on February 5th. This survey data was combined with field measurements of ice thickness, water depth, liner thickness, laboratory measured permeability rates and previously obtained subsurface stratigraphic data (IGES, 2009) to create seepage models for each canal cross section. The estimated water level (7-8 feet) for the canal cross section(s) carrying 1,150 cfs corresponded with the liner deformation (sidewall sloughing) observed and measured by the surveyors.

LINER SAMPLING

Attempts were made to obtain at least one undisturbed sample of liner material at each of the 12 locations explored in this investigation; additional disturbed samples were collected for correlation of permeability testing results based on index testing of both sample types. The existing liner thickness was probed in the vicinity of collected samples using rebar. For simplicity in identifying sample locations at each cross section they have been identified as Left Bank, Center, and Right Bank. The following tables provide a summary of the estimated liner thickness encountered at each section; additional detail and observations about the sections are included in Appendix B.

10-1

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,565,630	415,209	1.17	1.17	1.17

10-2

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center Bank.	Right Bank
4,567,655	415,177	1.0	1.0	1.0

10-3

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,569,170	415,118	1.0	1.17-1.5	1.0

10-4

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,570,134	414,751	0.67	1.5 - 2.0	0.67

10-5

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,570,431	414,302	1.0	2.0	1.0

10-6

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,571,011	413,637	0.5	2.0	0.67

10-7

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,569,170	415,118	0.5	2.0	1.0

10-8

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,573,337	413,427	0.5 - 0.67	2.0	0.5 - 0.67

10-9

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
		Left Bank	Center	Right Bank
4,574,664	413,385	0.5 - 0.67	2.0 - 2.5	0.67

10-10

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
4,575,306	413,325	Left Bank	Center	Right Bank
		No Sample	2.5	3.0

10-11

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
4,576,184	413,275	Left Bank	Center	Right Bank
		Rip Rap*	2.0**	Rip Rap*

* unable able to probe through gravel/cobbles (rip-rap) or excavate through frozen soils with hand tools, did not reach top of liner.
** pushed through 2' of soft material, but could not keep in Shelby tube.

10-12

Sampling Location				
Northing (m)	Easting (m)	Approximate Liner Thickness (ft)		
4,577,228	412,331	Left Bank	Center	Right Bank
		1.0	2.0	1.0

Photographs of sampling locations and the conditions encountered are contained in Appendix B.

The photographs show that during our 2010 investigation, while the canal was not under normal operational water levels, it was also not completely drained. Water, ice and snow obscured the canal/liner surface at the majority of our investigation locations. At the two southernmost locations (10-1 & 10-2) most of the canal cross section was visible and showed that liner soils were not uniformly distributed through the canal in these areas. Samples were collected and liner thickness measured from visible liner soils; however, streams flowing around liner "islands" indicated that little or no liner soils were present in portions of the southern reaches of the canal. This corresponds with our 2009 sampling in the southern reaches of the canal (locations 09-1 and 09-2) where respective liner thickness of 0 and 3 inches were measured.

LABORATORY TEST RESULTS

As mentioned previously general index and soil permeability tests were performed on samples collected during our field investigation. The following table provides a summary of the laboratory testing performed.

SAMPLE LOCATION	NATURAL DRY DENSITY (pcf)	NATURAL MOISTURE CONTENT %	GRADATION (%)			ATTERBERG LIMITS		PERMEABILITY	
Point No			Gravel >#4	Sand	Silt and Clay <#200	Liquid Limit	Plasticity Index	(cm/s)	(ft/yr)
10-1 C		32.3	0	85.8	14.2	48	18	2.30E-05	2.38E+01
10-1 R									
10-1 L			0.6	45.1	54.3	34	7		
10-2 C			17.9	31.5	50.6	NP	NP	5.60E-04	5.79E+02
10-2 R					34.3	20	5		
10-2 L									
10-3 C		17.7							
10-3 R									
10-3 L			40.6	32.2	27.2	NP	NP		
10-4 C	91.7	23.9			1	NP	NP		
10-4 R					46.4	25	8		
10-4 L									
10-5 C		23.7	0.6	93.8	5.6	24	7	1.30E-04	1.35E+02
10-5 R									
10-5 L			20.2	38.3	41.5	19	3		
10-6 C	89.9	30.6			33.6	NP	NP		
10-6 R			13.1	38.6	48.3	21	5		
10-6 L									
10-7 C									
10-7 R									
10-7 L		20.1			40.8	21	7		
10-8 C	86	32.7			33.8	NP	NP		
10-8 R			7	50.9	42.1	18	3		
10-8 L									
10-9 C		29.5	-	81.2	18.8	NP	NP	1.20E-04	1.24E+02
10-9 R									
10-9 L					59.7	23	8		
10-10 C	88.4	32.6			32.1	NP	NP		
10-10 R					37.5	NP	NP		
10-10 L									
10-11 C	No sample								
10-11 R			88	10.5	1.5	NP	NP		
10-11 L	No sample								
10-12 C		49.8	-	36.4	63.6	34	12	1.00E-04	1.03E+02
10-12 R									
10-12 L		25.4			54.6	22	6		

Detailed results of the individual tests performed are included in Appendix C.

SEEPAGE LOSSES

A simplistic model was created previously to approximate seepage losses based largely on the design cross section, utilizing an average head (water level in the canal) and average distance to groundwater (arbitrarily set 2.5 feet below the liner). Because the survey performed in February 2010 provided actual surface topography for most of the cross sections, and more accurate measurements of the liner thickness were obtained seepage losses were approximated using the Finite Element Modeling (FEM) capabilities of SLIDE 5.0 by RocScience instead of the simplistic evaluation performed using Darcy's Law in our previous canal assessment (IGES, 2009). Using the FEM method allowed us to accurately account for the variation in driving head along sloped sidewalls of the trapezoidal canal, it also allowed us to more easily model the impacts of groundwater fluctuation on seepage losses. Our 2009 assessment set groundwater 2.5 feet below the bottom of the constructed liner (average distance between bottom/side slopes and the natural groundwater surface); however, piezometer data indicated the water levels within the embankments were above this level. Our revised analysis attempts to quantify the impacts of groundwater fluctuation while also accounting for the variable distance to the water surface on the side slopes of the canal. Assumed values of embankment and native soil permeability were still required to complete the modeling. The same permeability value was assigned to the entire liner thickness at each cross section even though it is possible for the permeability to vary within the liner at that location. Because the canal runs near capacity for the entirety of the irrigation season, a constant water surface elevation (corresponding to 1,150 cfs) was used at each cross section.

As previously discussed, uneven distribution of liner soils was observed in the southern reaches of the canal (locations 10-1, 09-1, 10-2 and 09-2). This was particularly noted in the ~5,000 feet of canal located between the Slaterville Diversion Dam and Willard Pump Station No. 2 where low level flows meandered around liner "islands" on the bottom of the canal (see Figure B-2). We do not know exactly the causes or extent of liner degradation, but have attempted to account for the observed uneven liner distribution in our seepage modeling by removing the liner from 50% of the canal length between the two structures. Combining the removal of liner material with the granular nature of native soils in this area results in a seepage loss rate 33-37 times higher than the same section where a liner is present.

The following table provides a summary of the total annual seepage losses modeled for the entire length of the canal.

Scenario		Total Seepage Loss (acre-ft)
1,150 cfs	GW 2.5 feet below bottom of Liner	
	Simplistic (2009)	28,182
	FEM (2010)	29,126
	GW at levels measured in May 2009	
	FEM (2010)	20,903

With the groundwater modeled below the bottom of the liner for the entire length of the irrigation season (200 days) our modeling showed a 3.3% increase in approximated seepage losses by using the FEM method. Modeling the seepage losses using the May 2009 groundwater levels shows a 25% reduction in losses as compared to our previous modeling. Our modeling results approximate a 4.5-6.5% loss of water to seepage during the irrigation season. Further details of seepage modeling are included with this document in Appendix D.

CONCLUSIONS AND RECOMMENDATIONS

Based on construction drawings provided by WBWCD the canal liner was designed/constructed to be at least 2-feet thick (floor and side slopes) for the majority of the canal alignment, and 3 feet thick in the northernmost reach as it approaches Willard Bay. The liner thickness measured by IGES typically showed a reduced thickness on the side slopes, and sloughing of sidewalls was observed near the normal canal water surface and measured in most surveyed cross sections. Some of the soft material encountered/sampled may be comprised of liner material eroded from other areas of the canal or sediment transported by the Weber River. This hydraulically deposited material may be subject to additional movement during canal operation; altering the seepage rates as it changes location. Liner thickness on side slopes was typically measured to be less than that encountered on the canal "floor." Gravel (rip-rap) and frozen soils limited probing/measurement and sampling of liner material in some locations. It is also possible that the gravel encountered is part of the originally installed "liner" material, depending on the material source. Based on our field/laboratory measurements and computer modeling the canal loses between 4.5 and 6.5 percent of its total annual flow by seepage from the canal. Actual seepage rates will vary depending on surrounding groundwater levels and the depth of water in the canal; the canal may also receive water from surrounding groundwater during other times of the year. Our approximation of seepage from the canal does not include water lost during the initial charging of the canal and filling of voids in the "dry" liner or other surrounding soils. It is possible that some areas of the canal have less liner soils and more free-draining sands and gravels than encountered at the points explored. Our seepage modeling has not attempted to account for every variation in liner/native soil conditions between and beyond the points explored during our investigations. Substantial losses may result from a small area of the canal that

has a more free-draining liner/native soil profile. Other losses such as evaporation, or gains from precipitation should also be taken in to account when evaluating the overall canal performance.

Groundwater fluctuation is one key variable in accurately estimating the seepage losses from the canal. Piezometers have been installed to track the seasonal/operational fluctuations but have not been monitored since shortly after their installation in May 2009. Without data we cannot be certain, but because the canal had been full for a time prior to piezometer installation we assume that groundwater levels measured at that time closely reflect "normal" conditions; the stabilized level of groundwater through the majority of the irrigation season. We recommend that periodic readings be taken over the course of the calendar year in order to better understand the fluctuations.

From the differences seen when varying the groundwater levels, it can be inferred that loss rates will be highest during initial charging of the canal (spring) when surrounding groundwater levels are likely at or near their seasonal lows. The more rapid rate of seepage losses associated with low groundwater could be experienced for a larger portion of the season depending on weather. In a drought cycle where snowpack/runoff and rainfall recharge of groundwater is low, a greater percentage of the total canal flow could be lost. These losses become increasingly problematic because of increased demand during dry weather cycles.

By using a soil liner system in the canal some seepage is inevitable; however, based on our observations and measurements of liner variability we conclude the highest rate of seepage losses occur in the southernmost reaches of the canal where liner distribution was observed to be least uniform. Depending on groundwater levels we estimate the losses in this southern portion to be between 12,880 and 15,600 acre-ft per year. This means that a disproportionate 54-62% of the total volume lost is lost within the first 10-14% (5,000-7,000 feet) of the canal length. Considering the District's proposed Phase I lining project, we recommend that rehabilitation efforts be initially focused on the ~5,000 feet between the Slaterville Diversion Dam and Willard Pump Station No. 2. The next priority area should include the 2,000 feet immediately downstream (north) of Pump Station No 2.

We appreciate the opportunity to provide you with our services on this project. If you have any questions, please contact us at your convenience (801-270-9400.

Respectfully Submitted,
IGES, Inc.

Jared Hawes, P.E.
Project Engineer

Brett Mickelson, P.E.
Principal

Attachments

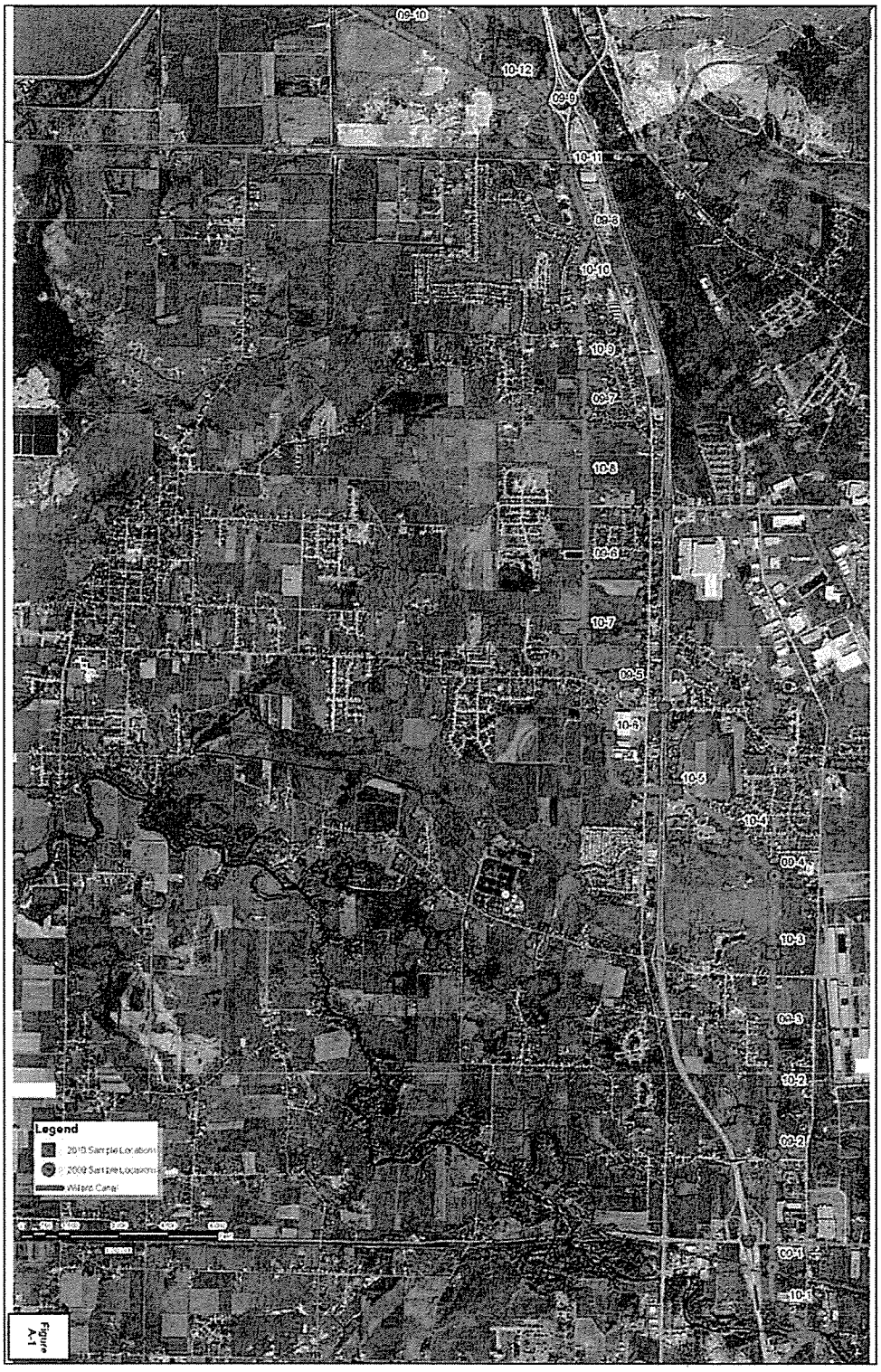
Appendix A
Figure A-1 Site Investigation Location Map

Appendix B
Figures B-1 through B-24 Field Investigation Notes and Photographs

Appendix C
Laboratory Test Results

Appendix D
Seepage Modeling Results

APPENDIX A


09-10
10-12
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10-3
09-3
10-2
09-2
09-1
10-1
Legend
Figure A-1

APPENDIX B

2010 Willard Canal Assessment

Project #:	00578-011			
Date:	2/2/2010			
Staff:	C. Ege, D. Siebach			
Location ID	WC2010 - 1			
	Proposed	Actual		
UTM Coordinates:	415,191.0 m E	415,209.0 m E	Install and Label T-post	☐
	4,565,797.7 m N	4,565,630.0 m N		

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 18 soft for 14", unable to probe beyond 14", no visual indication of seepage, bucket sample collected

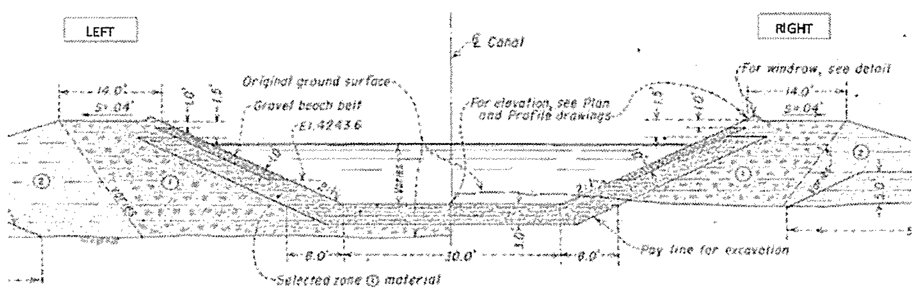
Center/Bottom

Photo: 19 1" ice, some water, soft for 14" then stiff to 3' (~3' of fine-grained soils) shelby tube sample

Left Bank

Photo: 20 soft for 14", unable to probe beyond 14", no visual indication of seepage, bucket sample collected

Sketch any observed differences from design cross section shown below



Additional Comments:

Photo 12: Sample Location

Figure B-1

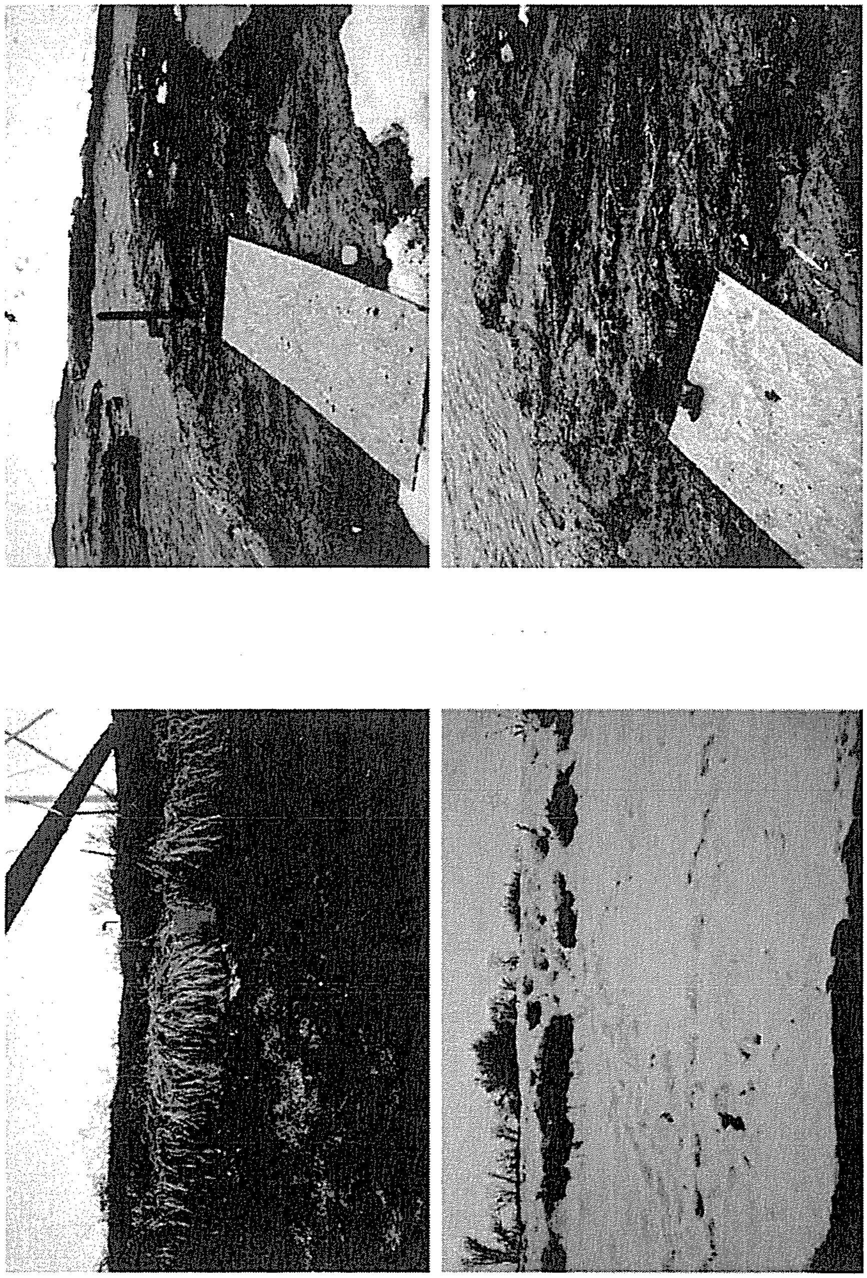


Figure B-2

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/2/2010
Staff: C. Ege, D. Siebach
Location ID: WC2010 - 2

	Proposed	Actual	
UTM Coordinates:	415,122.3 m E	415,177.0 m E	Install and Label T-post ☐
	4,567,808.8 m N	4,657,655.0 m N	

Canal Description: Include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 22 Rounded gravel rip-rap on surface ~ 6" thick, silty sand - black, organic, liner ~1' thick (bucket sample)

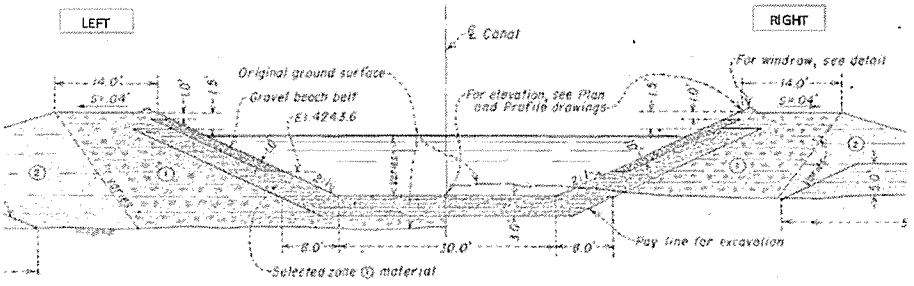
Center/Bottom

Photo: 23 12" of liner (shelby sample)

Left Bank

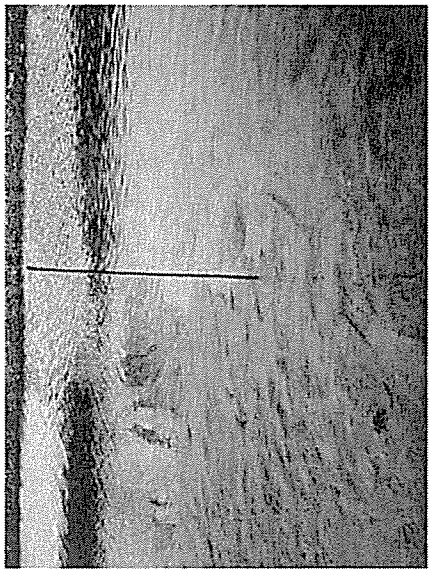
Photo: 24 Rounded gravel rip-rap on surface ~ 6" thick, silty sand - black, organic, liner ~1' thick (bucket sample)

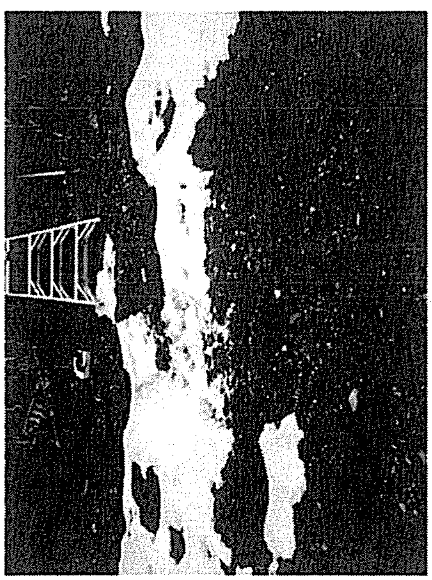
Sketch any observed differences from design cross section shown below

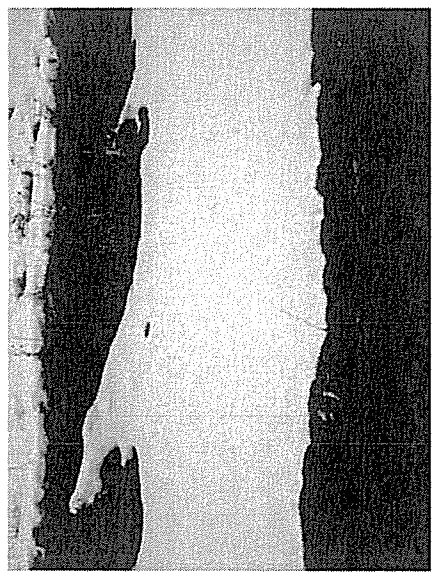


Additional Comments:

Figure B-3







Site Photos
Section 2
Project Number: 00578-011

Figure
B-4

IGES

2010 Willard Canal Assessment

Project #:	00578-011			
Date:	2/3/2010			
Staff:	C. Ege, D. Siebach			
Location ID	WC2010-3			
	Proposed	Actual		
UTM Coordinates:	415,113.1 m E	415,118.0 m E	Install and Label T-post	☐
	4,569,131.9 m N	4,569,197.0 m N		

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 25 6" gravel over 1' of liner

[illegible]

Center/Bottom

Photo: 26 14-18" of liner (shelby sample)

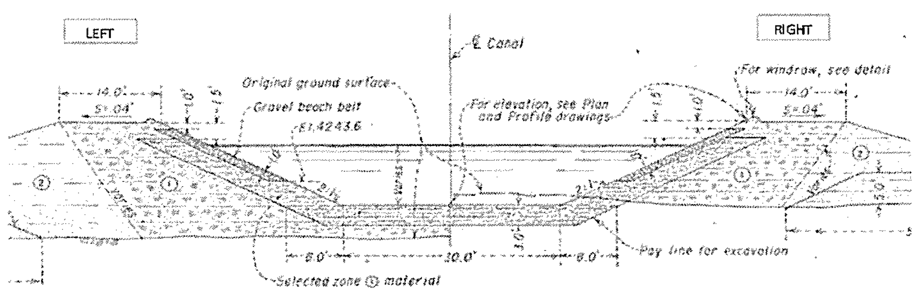
[illegible]

Left Bank

Photo: 27 6" gravel over 1' of liner

[illegible]

Sketch any observed differences from design cross section shown below



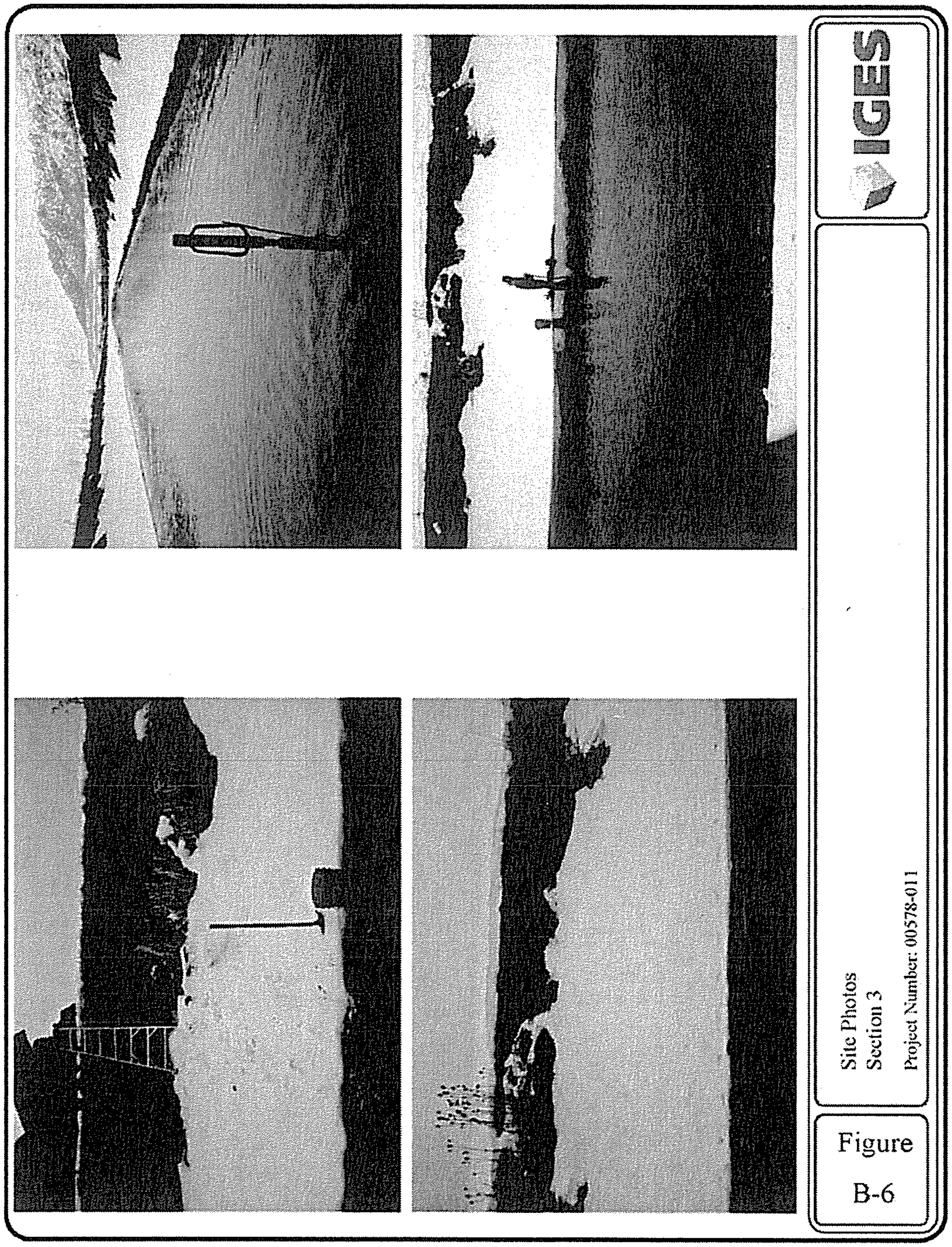
Additional Comments:

Photos 30-31:

Figure B-5

[illegible]

[illegible]


IGES
Site Photos
Section 3
Project Number: 00578-011
Figure
B-6

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/3/2010
Staff: C. Ege, D. Siebach
Location ID: WC2010 - 4

	Proposed	Actual		
UTM Coordinates:	414,770.7 m E	414,751.0 m E	Install and Label T-post	☐
	4,570,242.3 m N	4,570,134.0 m N		

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 32 3" gravel rip-rap over 8" liner (bucket sample)

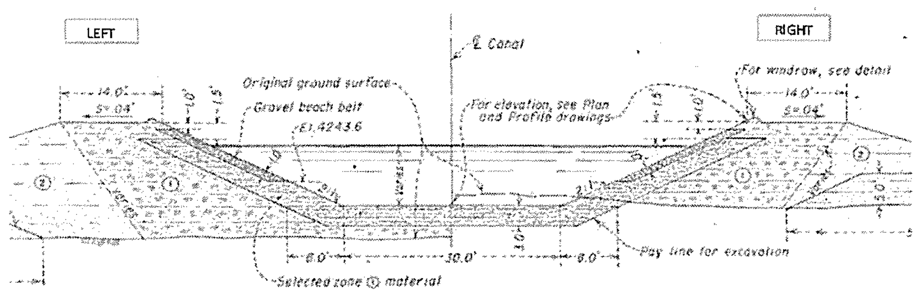
Center/Bottom

Photo: 33 18-24" of liner (shelby sample)

Left Bank

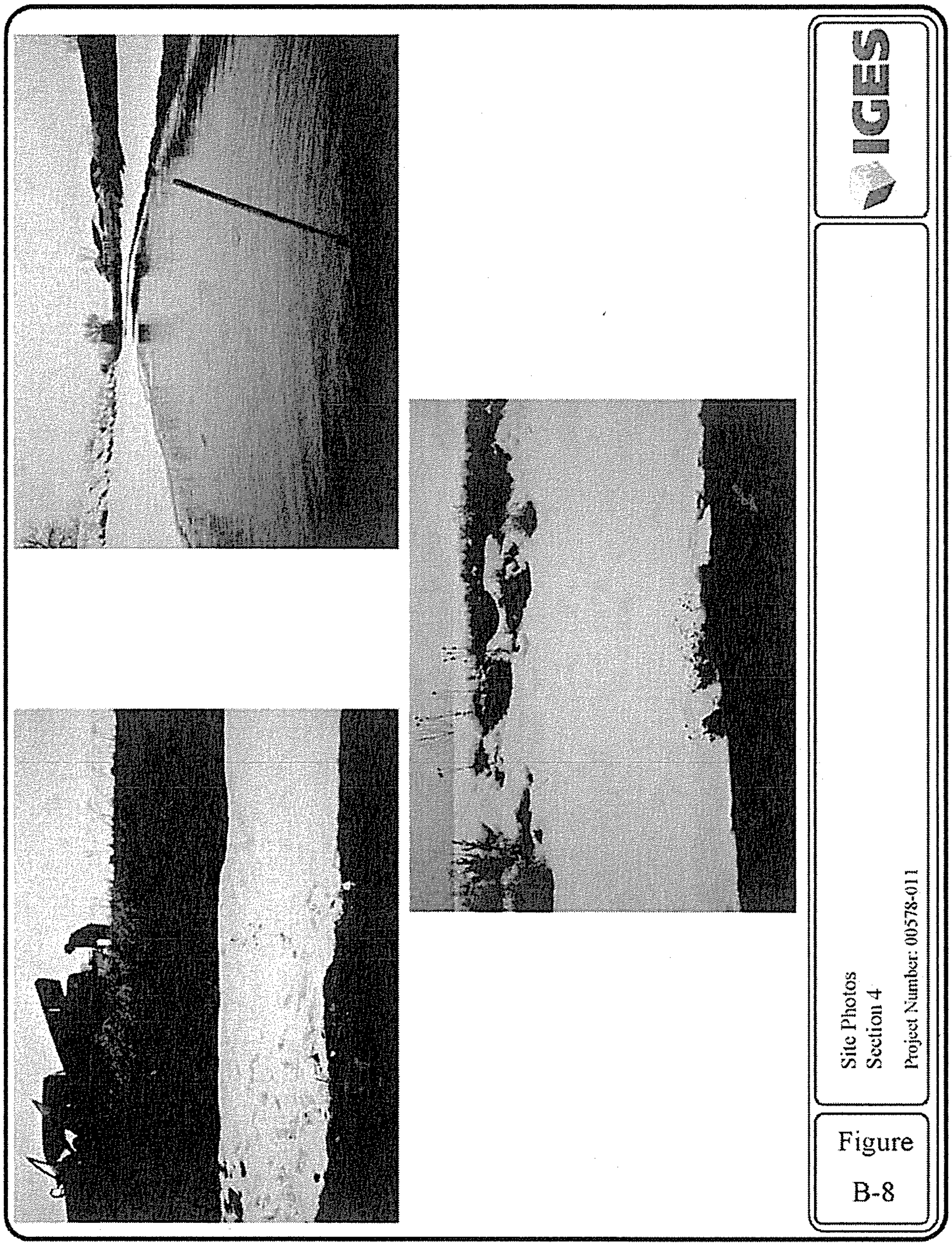
Photo: 34 3" gravel rip-rap over 8" liner (bucket sample)

Sketch any observed differences from design cross section shown below



Additional Comments:

Figure B-7


IGES
Site Photos
Section 4
Project Number: 00578-011
Figure
B-8

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/3/2010
Staff: C. Ege, D. Siebach
Location ID: WC2010-5

	Proposed	Actual	
UTM Coordinates:	414,196.3 m E	414,302.0 m E	Install and Label T-post ☐
	4,570,641.8 m N	4,570,431.0 m N	

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 35 — 3" rip-rap, 12" liner (bucket)

\\Shares\projects\PROJECTS\9

Center/Bottom

Photo: 36 — 24" soft (shelby sample)

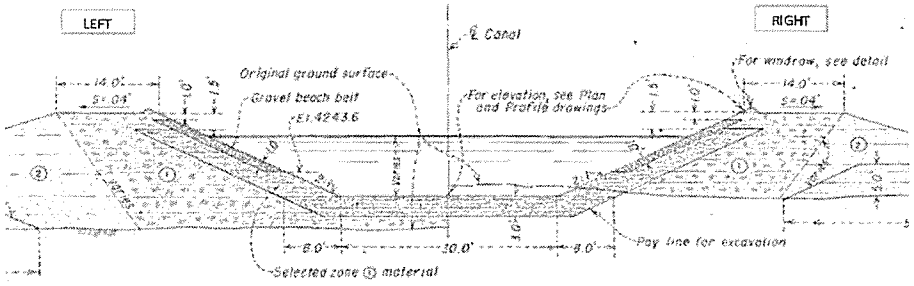
\\Shares\projects\PROJECTS\9

Left Bank

Photo: 37 — 8" ice

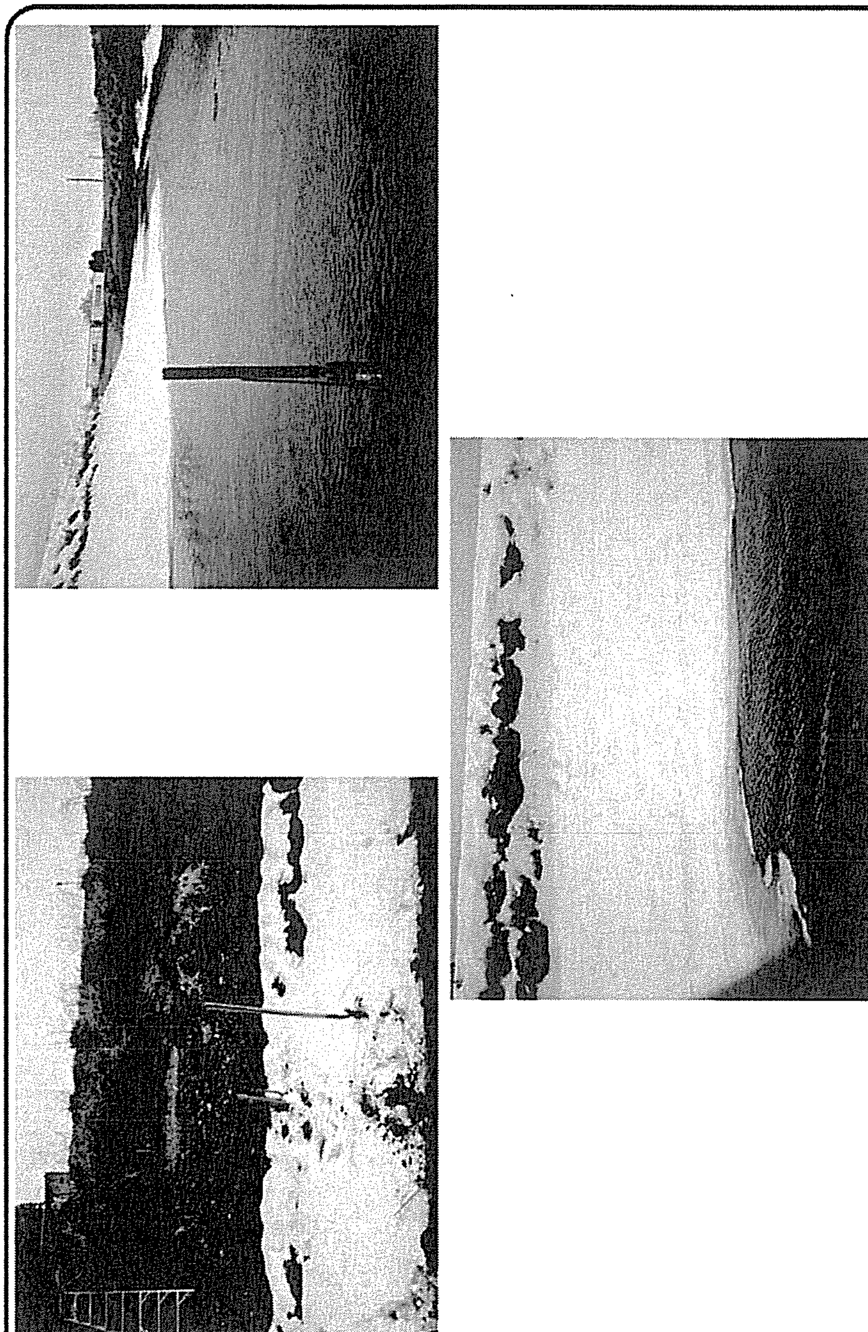
\\Shares\projects\PROJECTS\9 — 3" rip rap, 1' liner (bucket sample)

Sketch any observed differences from design cross section shown below



Additional Comments:

Figure B-9



Site Photos
Section 5
Project Number: 00578-011

IGES

Figure B-10

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/3/2010
Staff: C. Ege, D. Siebach
Location ID: WC2010 - 6

	Proposed	Actual		
UTM Coordinates:	413,577.5 m E	413,637.0 m E	Install and Label T-post	☐
	4,571,139.9 m N	4,571,011.0 m N		

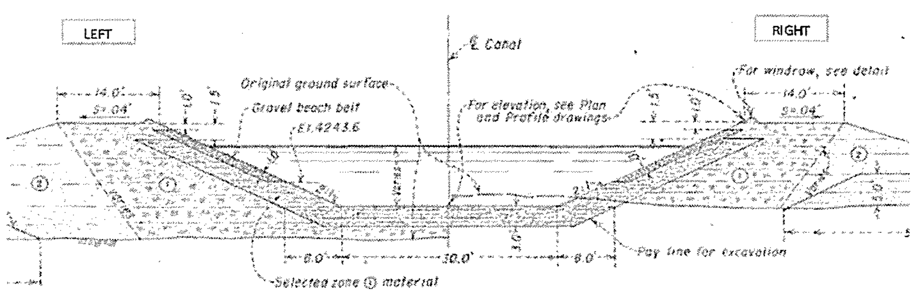
Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank
Photo: 38 — Ice/snow 12-18" thick, 3" rip-rap, 8" liner- soft (bucket sample)

Center/Bottom
Photo: 39 — 8-10" ice, 3" rip-rap, 2' soft clay (shelby sample)

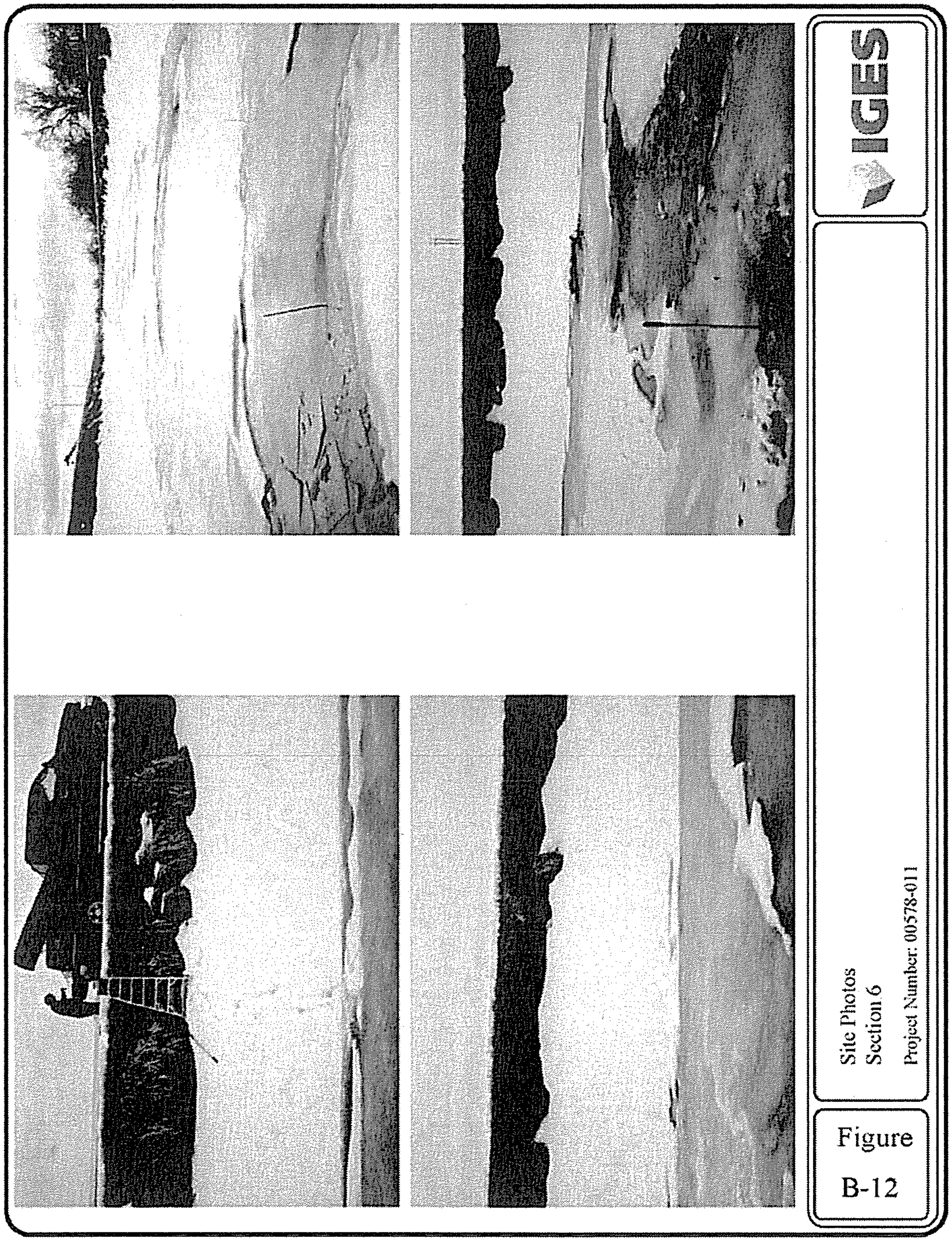
Left Bank
Photo: 40 — 6" ice, 3" rip-rap, 6" soft, hard below (bucket sample)

Sketch any observed differences from design cross section shown below



Additional Comments:

Figure B-11


Site Photos
Section 6
Project Number: 00578-011
Figure
B-12
IGES

2010 Willard Canal Assessment

Project #:	00578-011		
Date:	2/3/2010		
Staff:	C. Ege, D. Siebach		
Location ID	**WC2010 - 7**		
	Proposed	Actual	
UTM Coordinates:	413,348.1 m E	413,373.0 m E	Install and Label T-post ☐
	4,572,102.5 m N	4,572,361.0 m N	

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 42 Ice ~6" thick, soft to 12" unable to probe/sample below (bucket sample)

[illegible]

Center/Bottom

Photo: 43 Ice 8-10" thick, 3" gravel rip-rap, soft for 2' below (shelby sample)

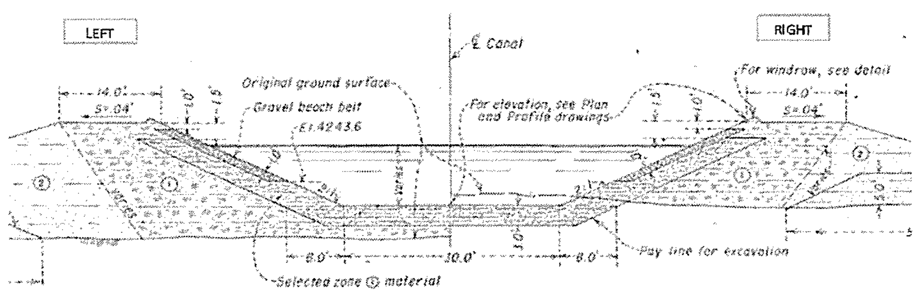
[illegible]

Left Bank

Photo: 44 Ice ~6" thick, 3' rip-rap, soft for 6" unable to probe/sample deeper (bucket sample)

[illegible]

Sketch any observed differences from design cross section shown below

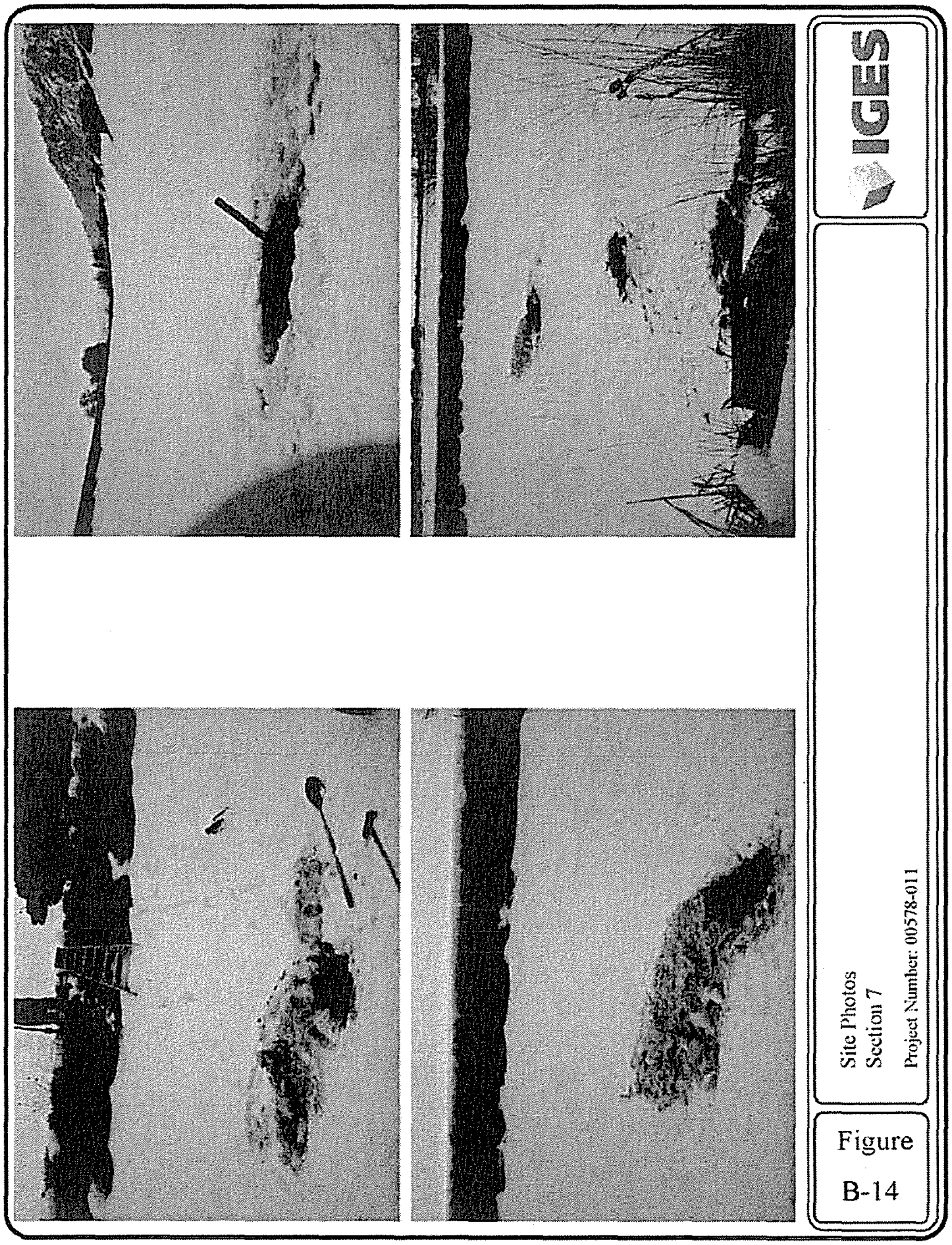


Additional Comments:

[illegible]

Photo 45

Figure B-13


IGES
Site Photos
Section 7
Project Number: 00578-011
Figure
B-14

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/3/2010
Staff: C. Ege, D. Siebach
Location ID WC2010 - 8

	Proposed	Actual	
UTM Coordinates:	413,365.5 m E	413,427.0 m E	Install and Label T-post ☐
	4,573,550.5 m N	4,573,337.0 m N	

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 46 Ice ~ 2" thick, 2 inches of gravel rip-rap over 6-8" soft clay (bucket sample)

\\[redacted]

Center/Bottom

Photo: 47 ice 12-15" thick, soft clay liner ~2' thick unable to probe/sample beyond 2' deep (shelby sample)

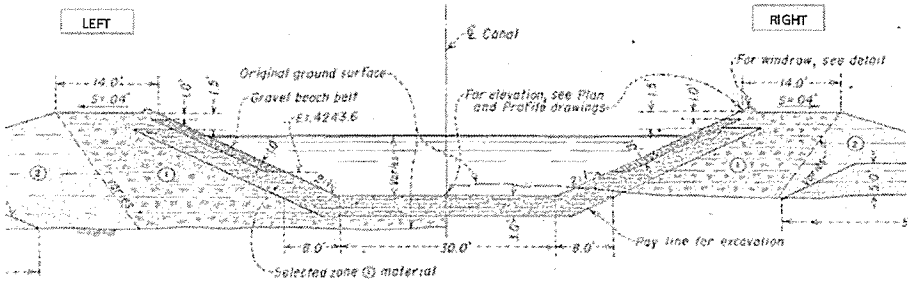
\\[redacted]

Left Bank

Photo: 48 Ice ~ 2" thick, 2 inches of gravel rip-rap over 6-8" soft clay (bucket sample)

\\[redacted]

Sketch any observed differences from design cross section shown below

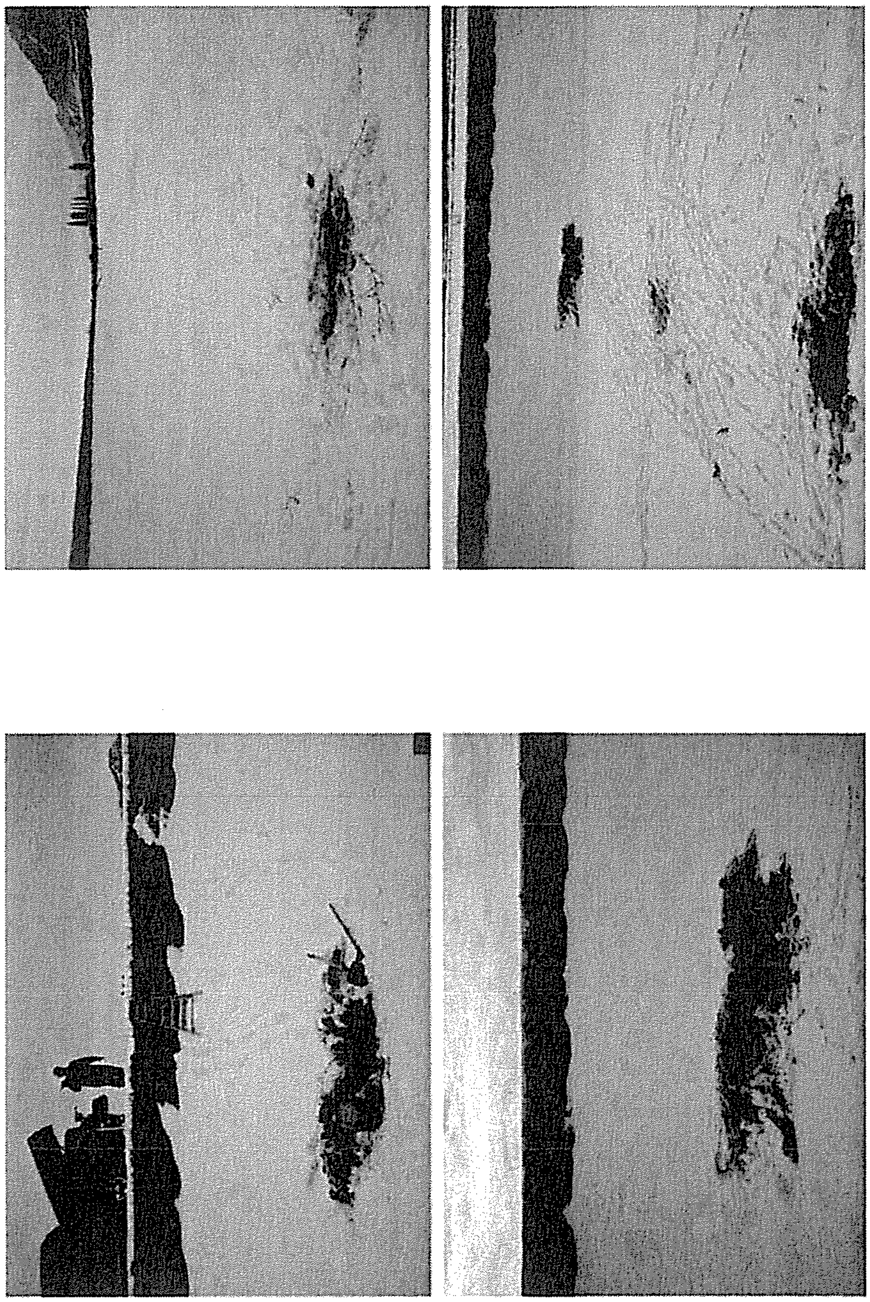


Additional Comments:

Photo #49

\\[redacted]

Figure B-15



Site Photos
Section 8
Project Number: 00578-011

Figure B-16

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/4/2010
Staff: C. Ege, D. Siebach
Location ID: WC2010 - 9

	Proposed	Actual	
UTM Coordinates:	413,342.8 m E	413,385.0 m E	Install and Label T-post ☐
	4,574,664.6 m N	4,574,664.0 m N	

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 50 — 6" subrounded gravel (rip-rap) 8" soft clay - bucket sample

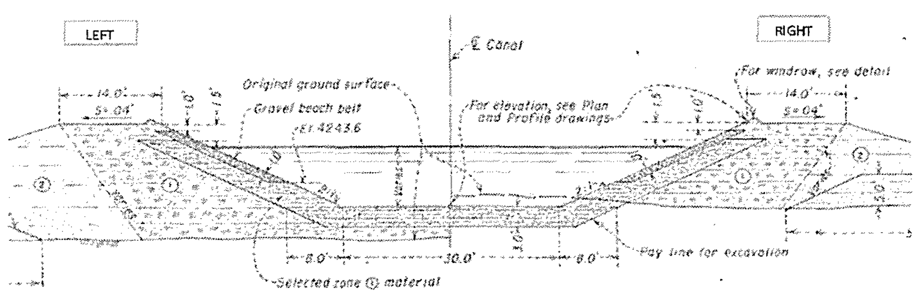
Center/Bottom

Photo: 51 — 2-2.5' of soft clay, ~4-6" organics on top (shelby sample)

Left Bank

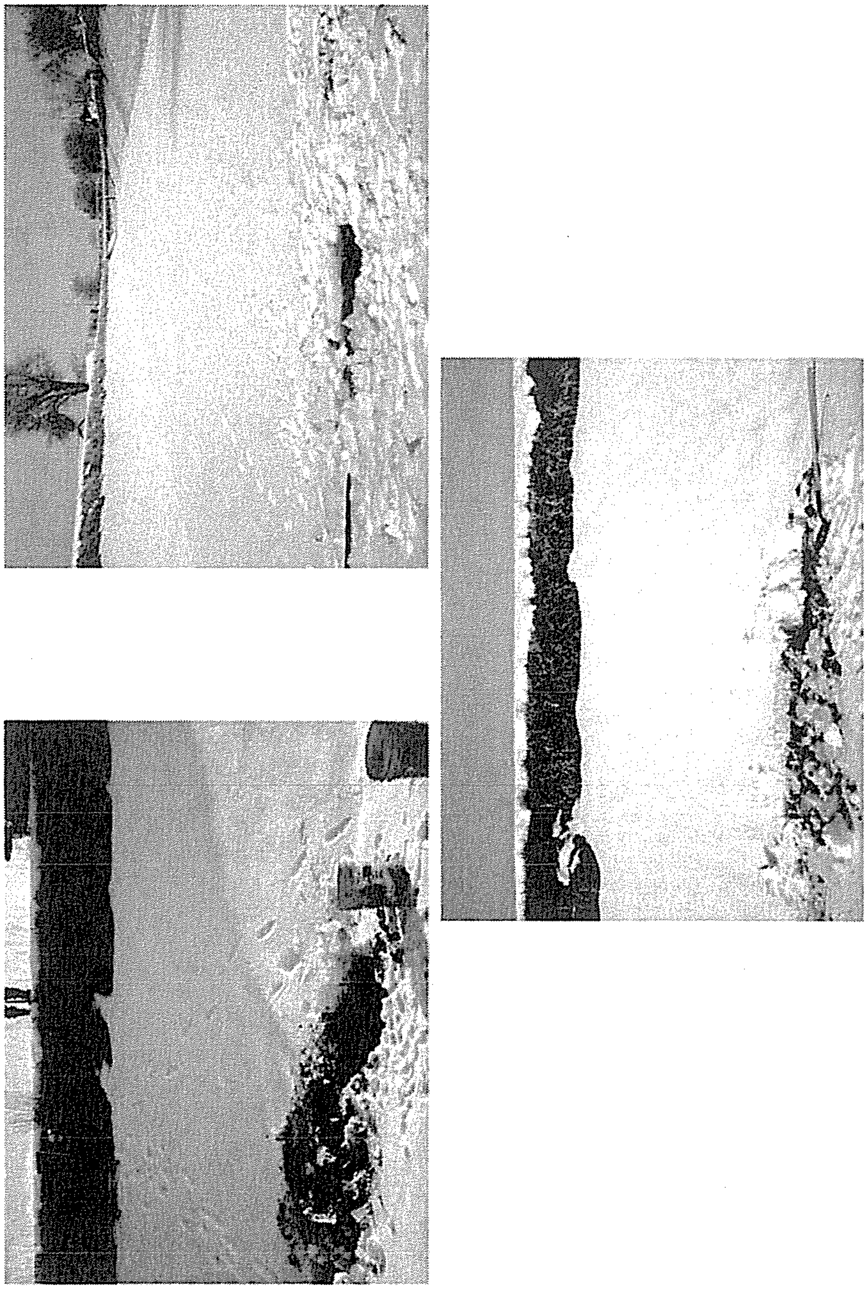
Photo: 52 — 3 to 6" subrounded gravel rip-rap over 6-8" clay (bucket sample)

Sketch any observed differences from design cross section shown below



Additional Comments:

Figure B-17



Site Photos
Section 9
Project Number: 00578-011

Figure B-18

2010 Willard Canal Assessment

Project #:	00578-011			
Date:	2/4/2010			
Staff:	C. Ege, D. Siebach			
Location ID	**WC2010 - 10**			
	Proposed	Actual		
UTM Coordinates:	413,244.6 m E	413,325.0 m E	Install and Label T-post	☐
	4,575,411.0 m N	4,575,306.0 m N		

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 53 Ice ~3" thick, no gravel, very soft, organic smell in upper 3', grass on slope, no apparent slumping

(bucket sample)

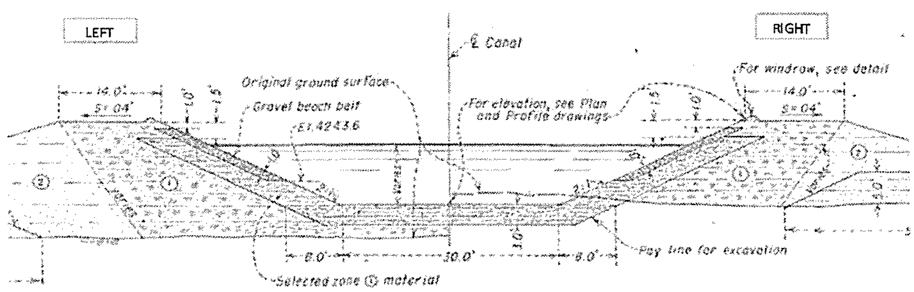
Center/Bottom

Photo: 54 Ice ~12" thick, some water, very soft to 24-30" below water (shelby sample)

Left Bank

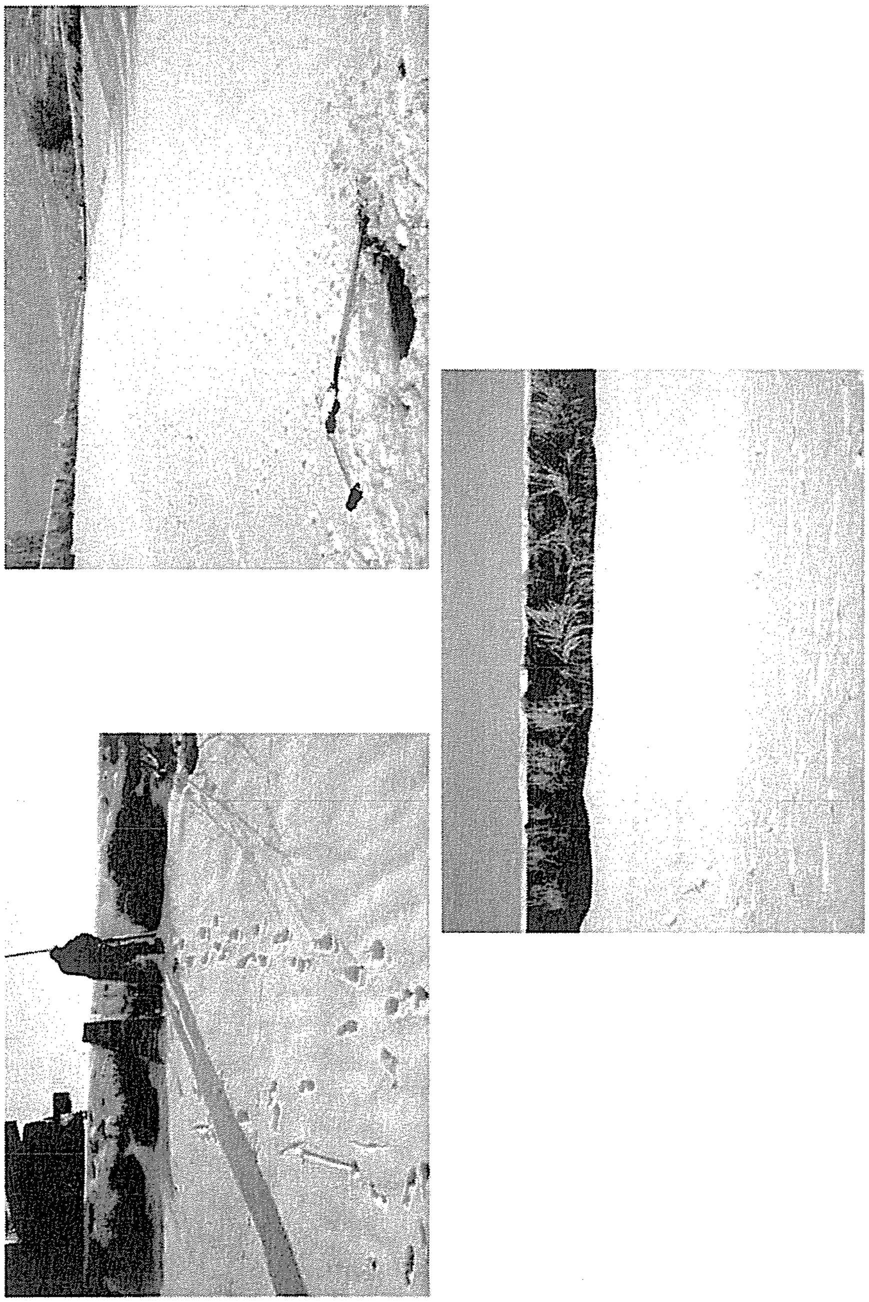
Photo: 55 Upper 3' exposed grass, no apparent slumping, no seeps (did not collect sample)

Sketch any observed differences from design cross section shown below



Additional Comments:

Figure B-19



Site Photos
Section 10
Project Number: 00578-011

Figure
B-20

2010 Willard Canal Assessment

Project #:	00578-011			
Date:	2/4/2010			
Staff:	C. Ege, D. Siebach			
Location ID	WC2010 - 11			
	Proposed	Actual		
UTM Coordinates:	413,187.4 m E	413,275.0 m E	Install and Label T-post	
	4,576,460.6 m N	4,576,184.0 m N		

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 56 — 6" of ice, gravel (subrounded to rounded) at least 12" thick, unable to locate liner (bucket sample)

\\Mcsgrove\company\PROJECTS\0

Center/Bottom

Photo: 57 — Ice up to 18" thick, soft for 2' below, could not keep sample in shelby tube

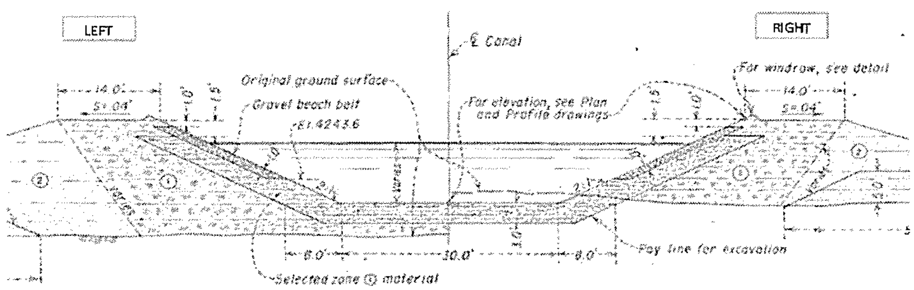
\\Mcsgrove\company\PROJECTS\0

Left Bank

Photo: 58 — upper 2'3 feet of slope exposed grass, snow 3-6" thick, ice ~6" thick (no sample)

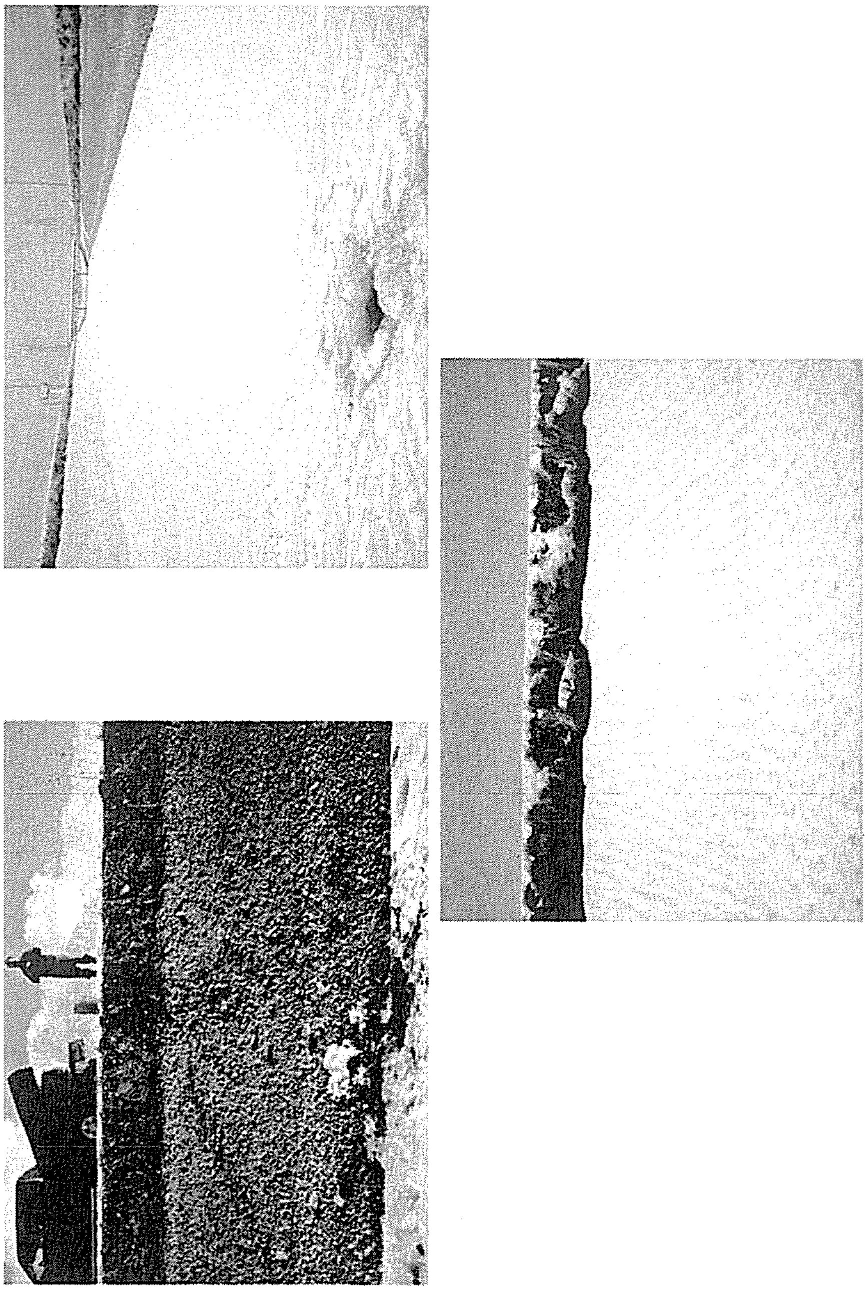
\\Mcsgrove\company\PROJECTS\0

Sketch any observed differences from design cross section shown below



Additional Comments:

Figure B-21



Site Photos
Section 11
Project Number: 00578-011

Figure
B-22

IGES

2010 Willard Canal Assessment

Project #: 00578-011
Date: 2/4/2010
Staff: C. Ege, D. Siebach
Location ID: **WC2010 - 12**

	Proposed	Actual	
UTM Coordinates:	412,513.6 m E	412,331.0 m E	Install and Label T-post ☐
	4,577,275.5 m N	4,577,228.0 m N	

Canal Description: include water/snow depth and ice thickness, probe liner thickness (describe location and resistance) Describe type and location of samples; describe vegetation (any indication of seepage)

Right Bank

Photo: 59 Exposed face (gravel and cobbles) gravel ~3" thick, soft for 1' below (liner - bucket sample)

\\Sharepoint\common\PROJECTS\0

Center/Bottom

Photo: 60 ice 12-18" thick, water ~3' deep, liner ~2' thick (soft) shelby sample

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Left Bank

Photo: 61 Covered with snow and ice, soft (liner) is ~1' thick (liner - bucket sample)

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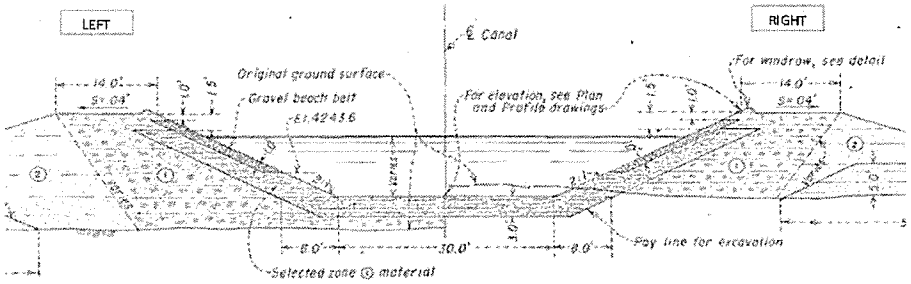
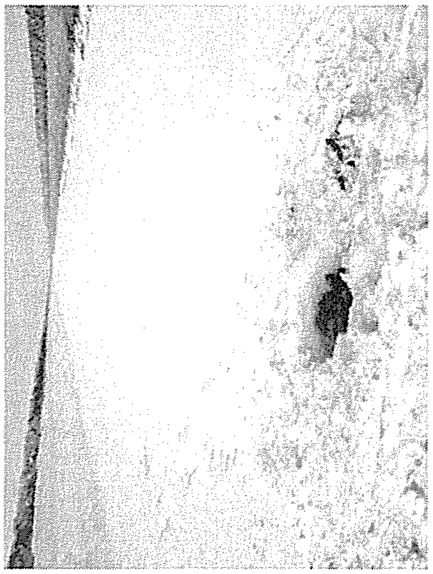
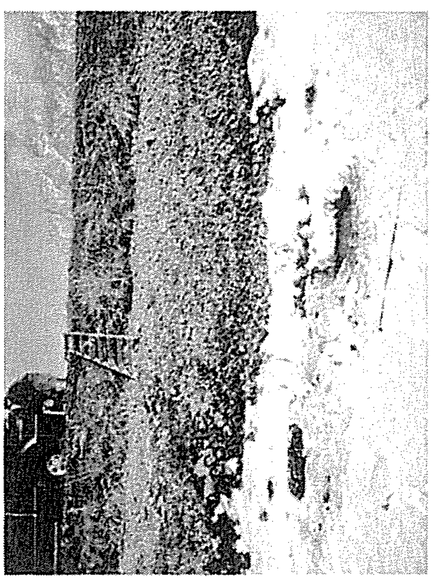
Sketch any observed differences from design cross section shown below

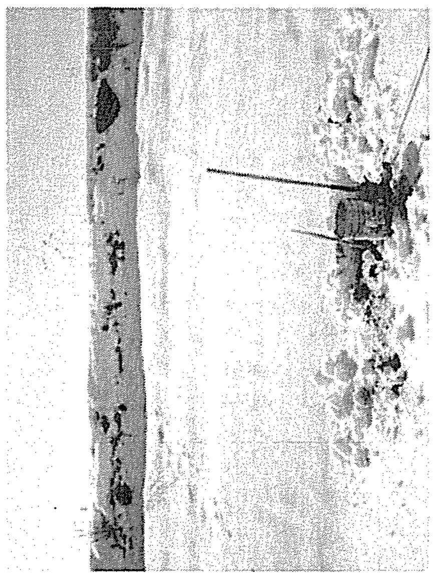


Additional Comments:

Figure B-23



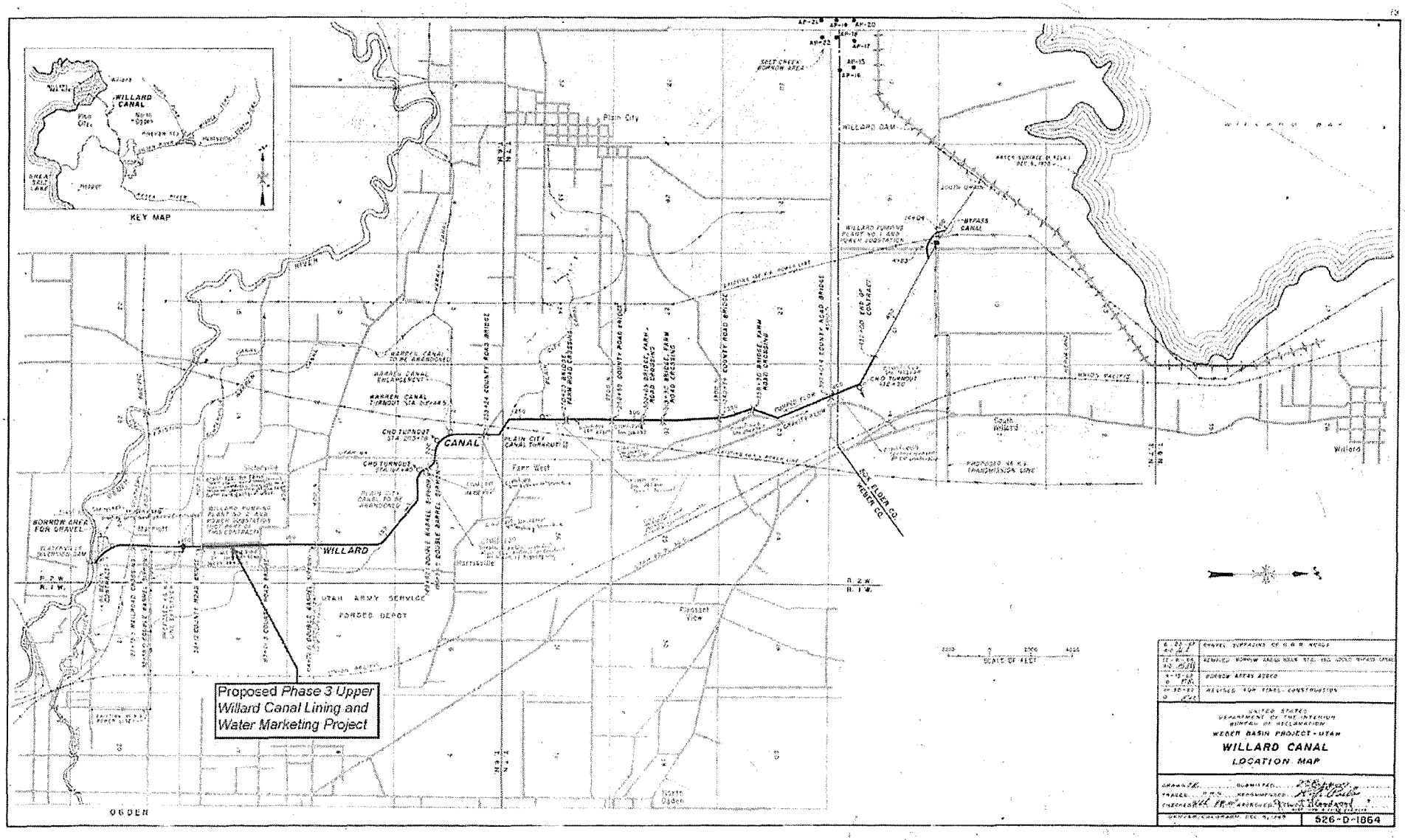




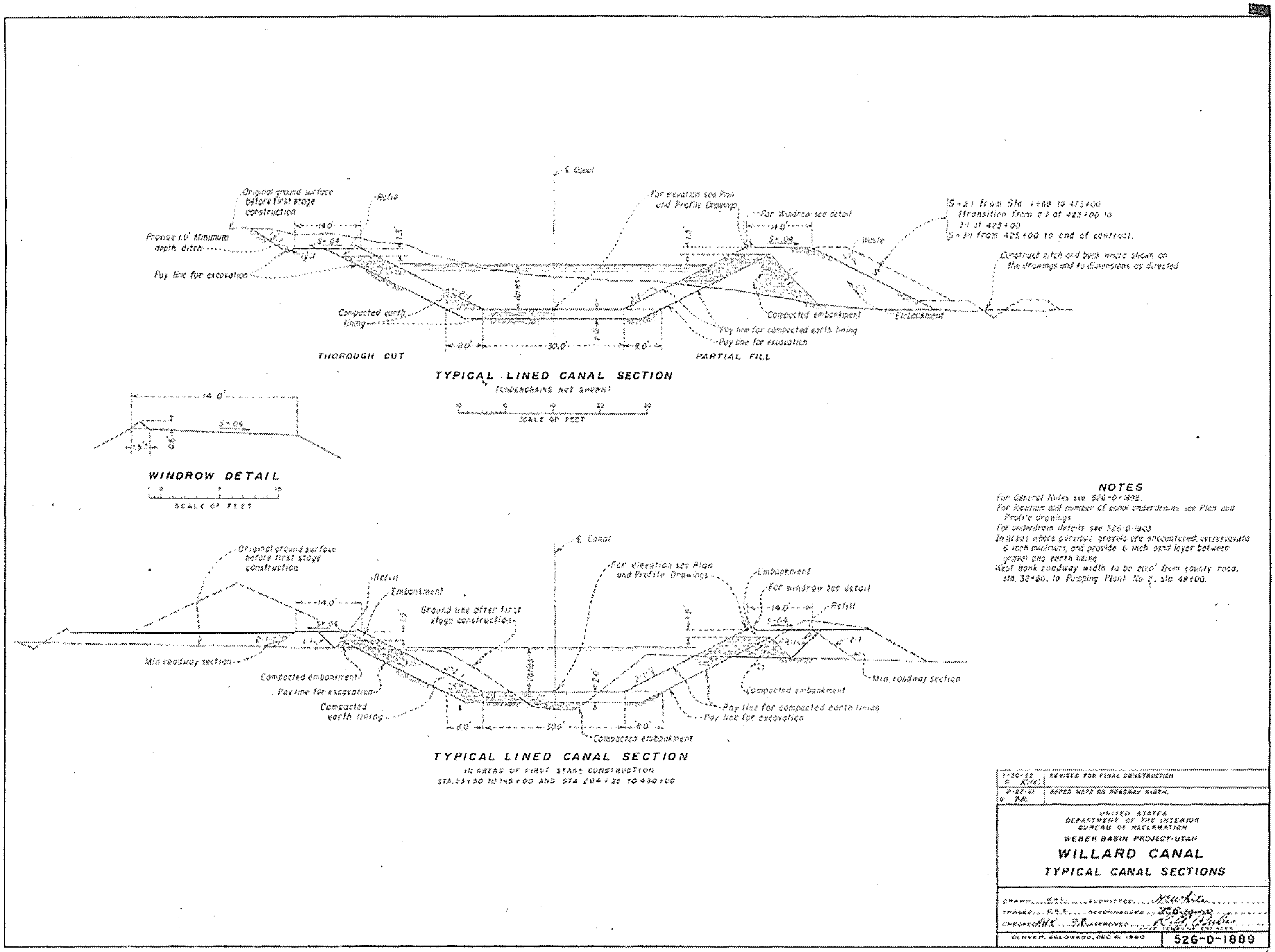
Site Photos
Section 12
Project Number: 00578-011

Figure
B-24

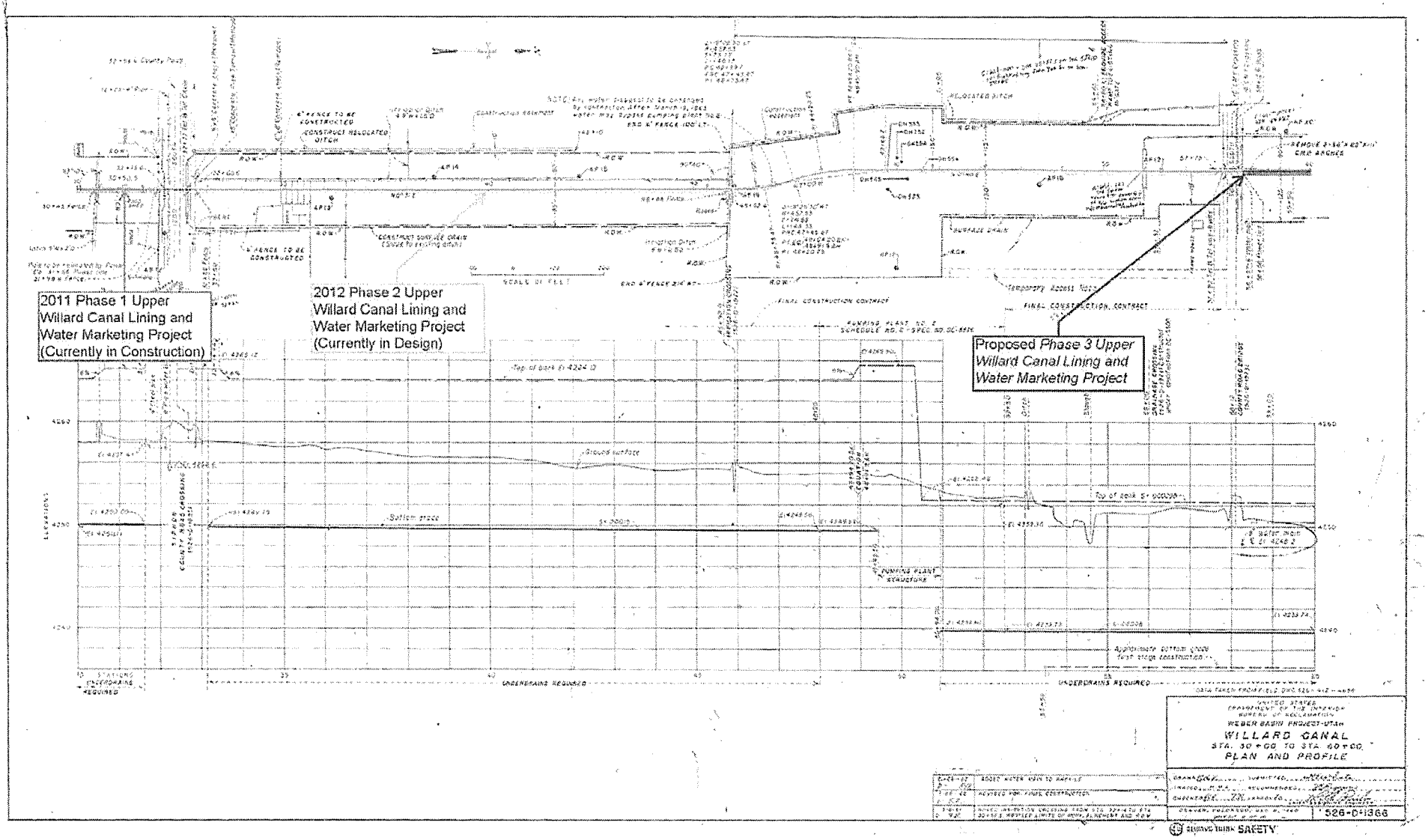
Attachment B: Selected Original Reclamation Drawings

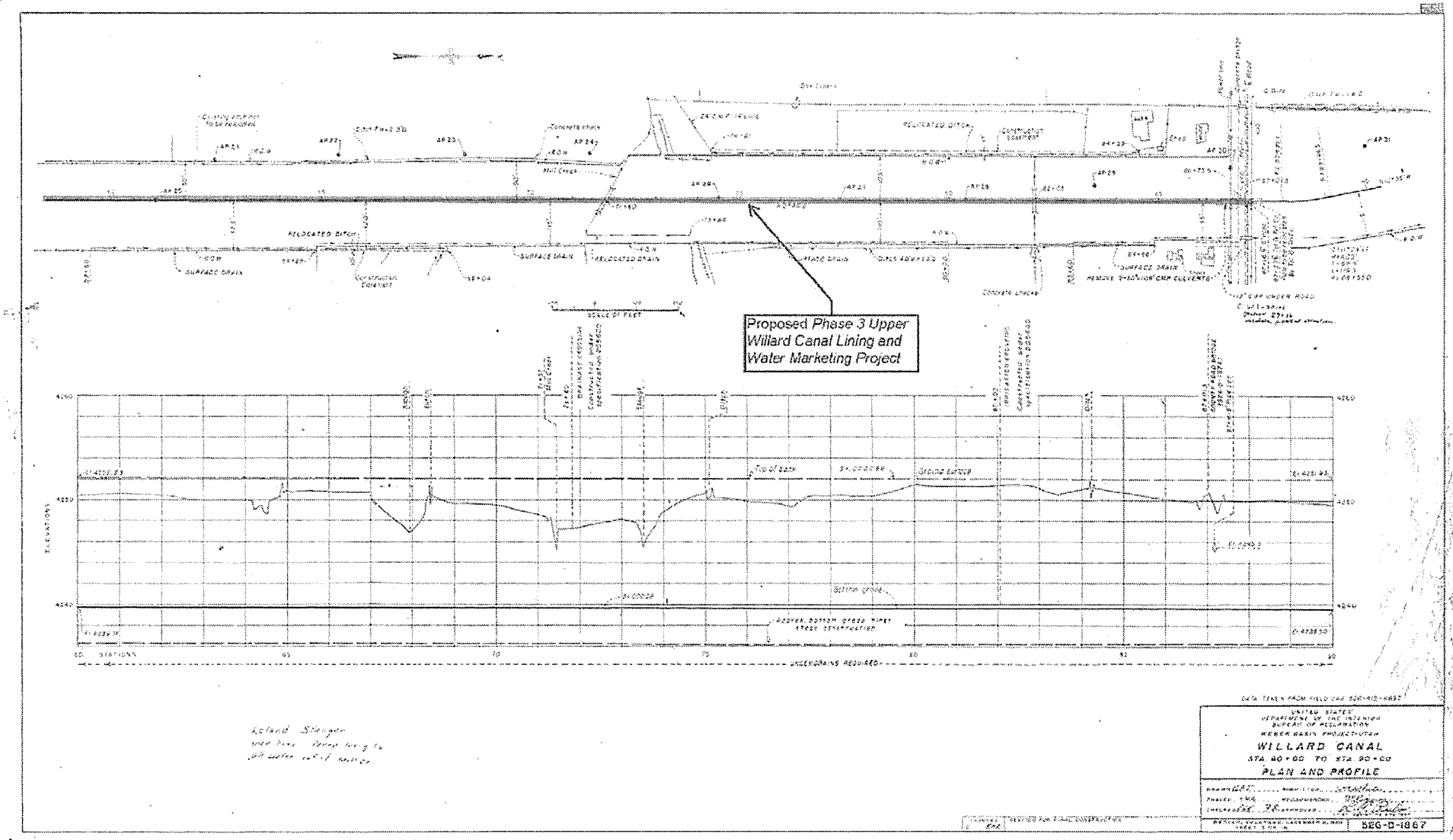


Funding Opportunity No. R13SF80003
Phase 3 Upper Willard Canal Lining
and Water Marketing Project

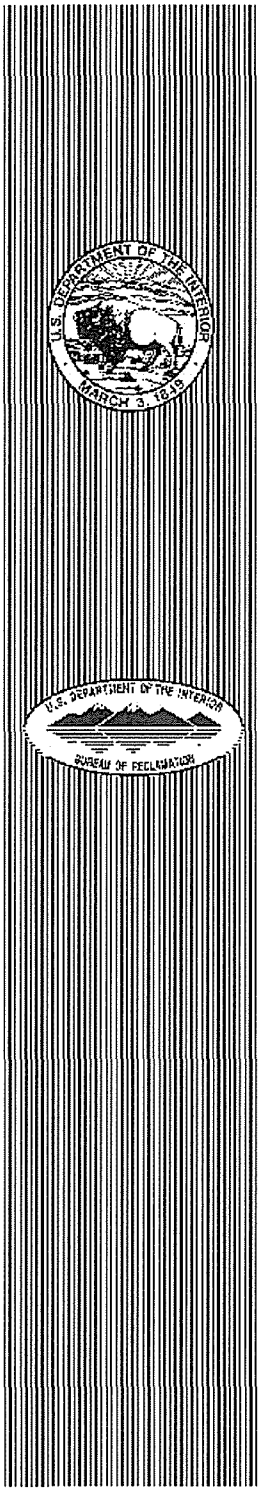


TYPICAL LINED CANAL SECTION
THOROUGH CUT
PARTIAL FILL
SCALE OF FEET
Compacted earth lining
Pay line for excavation
Pay line for compacted earth lining
Compacted embankment
Embankment
Waste
Refill
WINDROW DETAIL
SCALE OF FEET
NOTES
TYPICAL LINED CANAL SECTION
Original ground surface before first stage construction
Ground line after first stage construction
For elevation see Plan and Profile Drawings
For windrow see detail
Min roadway section
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
WEBER BASIN PROJECT-UTAH
WILLARD CANAL
TYPICAL CANAL SECTIONS
526-D-1889


2011 Phase 1 Upper Willard Canal Lining and Water Marketing Project (Currently in Construction)
2012 Phase 2 Upper Willard Canal Lining and Water Marketing Project (Currently in Design)
Proposed Phase 3 Upper Willard Canal Lining and Water Marketing Project
WILLARD CANAL
STA. 30+00 TO STA. 60+00
PLAN AND PROFILE
526-D-1366


Proposed Phase 3 Upper Willard Canal Lining and Water Marketing Project
WILLARD CANAL
STA. 80+00 TO STA. 90+00
PLAN AND PROFILE
SEG-D-1867

Attachment C: Basis for Post-Project Seepage Loss Estimates



R-00-01

CANAL-LINING DEMONSTRATION PROJECT
2000 SUPPLEMENTAL REPORT

January 2000

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

Pacific Northwest Region
Water Conservation Center

Technical Service Center
Civil Engineering Services
Materials Engineering Research Laboratory

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13. ABSTRACT ***(Maximum 200 words)***

The Deschutes Canal-Lining Demonstration Project is a cooperative effort among the Bureau of Reclamation, several irrigation districts, and several geosynthetic lining manufacturers. The purpose of the study is to develop low-cost canal-lining technologies to reduce seepage over severe rocky subgrade conditions. Over the first 7 years, Reclamation constructed 27 alternative canal-lining test sections using combinations of geosynthetics, shotcrete, roller compacted concrete (RCC), grout mattresses, soil, elastomeric coatings, and sprayed-in-place foam. This report documents the construction of two additional test sections using an exposed 45-mil EPDM rubber geomembrane and an exposed 30-mil Linear Low Density Polyethylene (LLDPE) geomembrane. Unit construction costs range from $0.78 to $0.87 per square foot. The test sections will be monitored for maintenance requirements, durability, and effectiveness to calculate Benefit-Cost ratios.

This report also documents seepage studies performed on a RCC-Shotcrete test section. The seepage studies include both full-scale short-term ponding tests and long-term inflow-outflow measurements taken over a 3-year period. The two methods yield similar results, and show that the RCC-Shotcrete lining is 75 to 85 percent effective which agrees well with previous estimates.

14. SUBJECT TERMS
geosynthetic/water conservation/geotextile/geocomposite/geomembrane/ponding tests/Benefit-Cost Analysis/life-cycle costs

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CANAL-LINING DEMONSTRATION PROJECT
2000 SUPPLEMENTAL REPORT

by

Jay Swihart
Jack Haynes

Denver Technical Service Center
Civil Engineering Services
Materials Engineering Research Laboratory
Denver, Colorado

Pacific Northwest Region
Water Conservation Center
Boise, Idaho

January 2000

UNITED STATES DEPARTMENT OF THE INTERIOR • BUREAU OF RECLAMATION

ACKNOWLEDGMENTS

The authors wish to thank the irrigation districts whose support was essential to the planning and implementation of this project. The Bureau of Reclamation particularly appreciates the support from the boards of directors of the Arnold, North Unit, Tumalo, Ochoco, Juniper Flat, Frenchtown, and Lugert-Altus Irrigation Districts. Water user support consisted of both a financial commitment and the acceptance of the risks involved with using unfamiliar technologies.

The authors wish to acknowledge the various material suppliers and contractors who were willing to participate in the project. In addition to making financial contributions, the participating companies provided invaluable technical support. These companies have also assumed risks by placing their products adjacent to those of their competitors under adverse conditions and often in new applications.

U.S. Department of the Interior
Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

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Tables

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Photographs

EXECUTIVE SUMMARY

The Deschutes Canal-Lining Demonstration Project is a cooperative effort among the Bureau of Reclamation, several irrigation districts, and several geosynthetic lining manufacturers. The purpose of the study is to develop low-cost canal-lining technologies to reduce seepage over severe rocky subgrade conditions.

Over the first 7 years, Reclamation constructed 27 alternative canal-lining test sections using combinations of geosynthetics, shotcrete, roller compacted concrete (RCC), grout-filled mattresses, elastomeric coatings, and sprayed-in-place foam. This report documents the construction of two additional test sections in November 1999, and additional seepage studies performed in December 1999.

The two new test sections include exposed 45-mil EPDM rubber, and exposed 30-mil EPDM rubber. Construction costs ranged from $0.78 to $0.87 per square foot. These construction costs are at the low end of all the test sections built to date.

The seepage studies were performed on the RCC-Shotcrete test section in the North Unit Main Canal. The seepage studies include both short-term full-scale ponding tests performed over a 1,400-ft reach of canal, and long-term inflow-outflow measurements taken over a 25-mile reach of canal over a 3-year period. The 3 years of inflow-outflow measurements include 1996 (unlined canal), 1998 (canal invert lined with RCC), and 1999 (canal invert lined with RCC, sideslopes lined with shotcrete). The inflow-outflow measurements show:

1. The unlined seepage rate for the North Unit Canal averages 1.1 ft/day which agrees well with our earlier estimate of 1 ft/day *(Year 7 Report)*. The first 12½ miles of canal has a higher unlined seepage rate (1.5 ft/day), with some isolated areas as high as 20 ft/day.

2. The effectiveness of RCC lining of the invert only is about 30 percent, which agrees well with our earlier estimate of 40 percent effectiveness *(Year 7 Report)*.

3. The fully-lined seepage rate is 0.38 ft/day, which agrees reasonably well with the 1999 ponding test result of 0.6 ft/day.

4. The effectiveness of RCC lining of the invert and shotcrete lining of the sideslopes is about 75 percent, which agrees well with our earlier estimate of 70 percent *(Year 7 Report)*. This effectiveness also agrees well with the 1999 ponding test which shows effectiveness of 80 to 85 percent.

All 29 of the test sections will continue to be monitored for maintenance requirements, durability (life expectancy), and effectiveness (seepage reduction) to calculate Benefit-Cost ratios.

Attachment D: Canal Lining Cost Estimate Basis

PHASE 1 UPPER WILLARD CANAL LINING AND WATER MARKETING PROJECT
CONSTRUCTION BID SCHEDULE SUMMARY
WEBER BASIN WATER CONSERVANCY DISTRICT
August 28, 2012

BID SCHEDULE				Alder Construction		Bowen Construction		Gerber Construction		Whitaker Construction		WW Clyde		Summary
Item No.	Description	Quantity	Unit	Unit Price	Amount	Unit Price	Amount	Unit Price	Amount	Unit Price	Amount	Unit Price	Amount	Average Bid Price
1	Mobilization, demobilization, temporary facilities, and administrative items (not to exceed 10% of Total Base Bid)	1	LS	$ 300,000	$ 300,000	$ 85,000	$ 85,000	$ 127,000	$ 127,000	$ 150,000	$ 150,000	$ 283,000	$ 283,000	$ 189,000
2	Construction Dewatering	1	LS	$ 360,000	$ 360,000	$ 75,000	$ 75,000	$ 110,000	$ 110,000	$ 100,000	$ 100,000	$ 63,000	$ 63,000	$ 141,600
3	Subgrade Preparation: Includes construction surveys; excavation and grading; spreading and grading of excess materials within the Owner's right-of-way; and all other work necessary to prepare native subgrade prior to installation of geotextile fabric, drain rock base layer and underdrain system; does not include additional over excavation for foundation stabilization material as directed by the Engineer; and installation of underdrain system, both of which are covered under seperate bid items.	14,500	CY	$ 11	$ 159,500	$ 12	$ 171,970	$ 10	$ 145,000	$ 10	$ 141,375	$ 7	$ 104,400	$ 144,449
4	Foundation Stabilization (only as directed by Engineer): Includes overexcavation and installation of foundation stabilization material in areas required for proper subgrade preparation due to wet and unstable soils.	1,500	CY	$ 53	$ 79,500	$ 44	$ 66,600	$ 46	$ 69,000	$ 43	$ 64,500	$ 42	$ 62,700	$ 68,460
5	Underdrain System and Drain Rock Base Layer: Includes installation of geotextile fabric, drain rock layer, installation of underdrain piping, valves, and manholes, complete.	1	LS	$ 583,000	$ 583,000	$ 574,000	$ 574,000	$ 521,000	$ 521,000	$ 495,000	$ 495,000	$ 600,500	$ 600,500	$ 554,700
6	Concrete Canal Liner: Includes all transitions and access ramps, complete as shown on plans	1	LS	$ 1,560,000	$ 1,560,000	$ 1,371,000	$ 1,371,000	$ 2,041,000	$ 2,041,000	$ 2,750,000	$ 2,750,000	$ 1,625,400	$ 1,625,400	$ 1,869,480
~~7~~	~~Canal Flow Meter: Includes all work associated with installation of Owner provided flow metering equipment: electrical panels, gear and connections, trenching and conduit, foundation pedestal, and protective pipe bollards, complete~~	~~1~~	~~LS~~	~~$ 80,000~~	~~$ 80,000~~			~~$ 35,000~~	~~$ 35,000~~	~~$ 32,000~~	~~$ 32,000~~	~~$ 50,000~~	~~$ 50,000~~	N/A
8	Balance of Work, including but not limited to modifications to existing underdrain system, canal safety cables, miscellaneous construction survey, site grading and clean up, traffic control, permitting, miscellaneous site, concrete, mechanical, and electrical work, and all other Work necessary to complete the project as described in the plans and specifications.	1	LS	$ 83,000	$ 83,000	$ 34,550	$ 34,550	$ 93,000	$ 93,000	$ 145,000	$ 145,000	$ 93,000	$ 93,000	$ 89,710
9	Materials Testing Services Allowance	1	LS	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000
	Bid Total:				**$ 3,230,000**		**$ 2,403,120**		**$ 3,166,000**		**$ 3,902,875**		**$ 2,907,000**	$ 3,082,399

Weber Basin Water Conservancy District
Phase 2 Willard Canal Lining Project

Engineering Fee Estimate
Updated 11-27-13

		Office Staff		Engineering Technicians											Subtotal	Subtotal
Task	Labor	Office	Editor	Tech 3	Tech 3	Tech 4	EN 1	EN 2	EN 4	Structural	I & C	Electrical	Tech Adv/QC	PM/PIC	Hours	Cost
		M. Skousen	A. Hansen	B. Abel	R. Garcia	L. Williams	D. Stoker	M. Stayner	K. Larson	R. Davis	D. Winger	D. Stewart	W. Dahl	J. Luettinger		
	Hourly Rate	$64.00	$64.00	$87.00	$106.00	$68.00	$87.00	$93.00	$106.00	$120.00	$101.00	$106.00	$203.00	$127.00		
1	Design Period Services															
1-1	Design Progress Meetings						4	4				4	2	12	26	$3,068
1-2	Preliminary Hycraulic Analysis						20	4	4					8	36	$3,552
1-3	Utility Identification						4							2	6	$602
1-4	Geotechnical Investigation													4	4	$508
1-5	Field Surveys													2	2	$254
1-6	Canal Liner Evaluation						8						8	16	32	$4,328
1-7	Final Design			20			20			20	10	20	4	20	114	$12,350
1-8	Permits						4							1	5	$475
1-9	Contract Documents	4	12	60	16		20			4	4	4		8	132	$12,004
1-10	Contractor Prequalification													4	4	$508
	Subtotal	4	12	80	16	0	80	8	4	24	14	28	14	77	391	$37,649
2	Services During Construction															
2-1	Bid Period Services					4								8	12	$1,408
2-2	Pre-Construction Meeting					4								4	8	$900
2-3	Services During Construction					100				8		8		32	148	$15,672
2-4	Record Drawings			8		4									12	$1,068
	Subtotal	0	0	8	0	112	0	0	0	8	0	8	0	44	180	$19,068
	TOTAL HOURS	4	12	88	16	112	80	8	4	32	14	36	14	121	541	$56,717
	TOTAL LABOR	$256	$768	$7,656	$1,696	$10,976	$6,960	$744	$424	$3,840	$1,414	$3,816	$2,900	$15,367	$56,717	

Expenses	Unit	Rate	Cost
Item			
COMMUNICATION/COMPUTER/MISC EXPENSES	Per hr	$7.00	$3,437
PRINTING /GRAPHICS			$100
AUTO MILEAGE	Per mi	$0.75	$1,500
SURVEY			$0
GEOTECHNICAL			$7,000
TOTAL EXPENSES			$12,037

Budget Assumptions

1. WBWCD will provide CM and daily inspections during construction. Assumed 8 hours per week for meetings, submittal review, and construction administration over a four month construction period.

TOTAL LABOR COST	$56,717
EXPENSES	$12,037
TOTAL COST	**$68,754**