File 1050.03. Design Technical Info.

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SOUTH PLATTE RIVER,
GLOBEVILLE
PHASE III DESIGN
DOCUMENTATION REPORT

Prepared By:
LOVE & ASSOCIATES, INC.
April, 1999

AND

"HYDRAULIC MODEL STUDY OF THE SOUTH PLATTE RIVER AT THE FRANKLIN STREET BRIDGE"

Prepared By:
COLORADO STATE UNIVERSITY
March, 1999

PREPARED FOR:

Urban Drainage and Flood Control District

City and County of Denver – Wastewater Division

and

Farmers Reservoir and Irrigation Company

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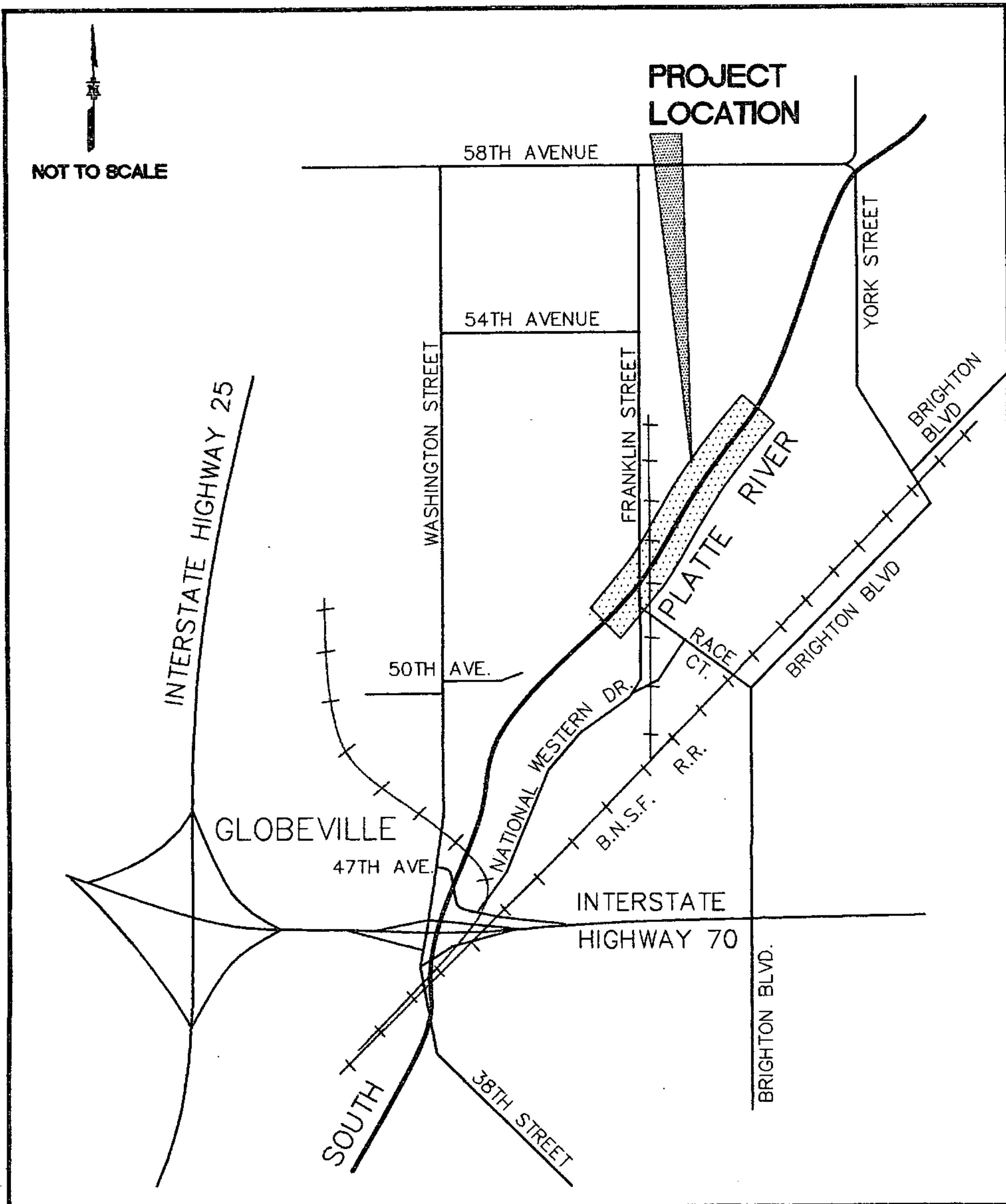
April 26, 1999

Mr. Ben Urbonas, P.E.
Chief, Master Planning and South Platte River Program
Urban Drainage & Flood Control District
2480 West 26th Avenue, Suite 156-B
Denver, CO 80211

REF: 9534F10 – South Platte River, Globeville
Phase III Design Documentation Report

Dear Ben:

The purpose of this report, prepared by Love & Associates, Inc. (Love), is to supplement the information contained in the CSU Physical Model Report entitled "Hydraulic Model Study of the South Platte River at the Franklin Street Bridge". The CSU report addresses the hydraulics, sediment transport, debris, scour potential and other important issues regarding the proposed project and is included following this report. Please refer to the Project Location Map, Figure 1 for approximate location of the project area. The primary purpose of this project is to remove approximately 300 acres of the Globeville neighborhood from the 100-year floodplain of the South Platte River. This project has been divided into three (3) separate final design and construction phases. Phase I, which was completed in May 1997, constructed 2,000 linear feet of channel improvements including flood levees, trails and revegetation of the banks. Phase II was completed in August, 1998 and included construction of an additional one mile of floodwalls and flood levees, revegetation, trails and aquatic and wildlife habitat. The Phase III portion of the project will include the removal of the Burlington Ditch and O'Brian diversion dam



SOUTH PLATTE RIVER
GLOBEVILLE AND NORTH AREAS

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LOCATION MAP

FIGURE 1

APRIL 26, 1999
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downstream of Franklin Street, the construction of a headgate approach channel (diversion approach channel) and a new diversion dam upstream of Franklin Street, the incorporation of a boat chute at the new diversion dam for safety purposes, the construction of grade control weirs within the boat chute, the construction of the Franklin Street trail underpass, the construction of a new pedestrian bridge, removal and replacement of the Union Pacific Railroad (UPRR) bridge downstream of Franklin Street, and removal and reconstruction of the 30-inch Denver Water Department water line below the channel invert. Also included is the construction of scour protection for the project including at the Franklin Street bridge and appurtenant facilities. Please note that the headgate approach channel is intended to be a part of the river system, not a part of the ditch system.

An hydraulic model for the project was developed by our firm utilizing the HEC-2 backwater computer program prior to the construction of the physical model at CSU. The HEC-2 model predicted the 100-year flood elevation at the Franklin Street bridge and at the proposed pedestrian bridge over the South Platte River to within 0.2 feet of actual 100-year water surface elevations measured in the physical model at CSU. This concurrence in the two models (computer and physical) reinforces the credibility for both models.

This cover report addresses several issues that are of primary importance to the Project Sponsors as well as the owners and users of the irrigation facilities that are proposed to be modified as a part of this project. The order by which issues are addressed in this report are by no means intended to be in the order of importance to the various affected parties concerned with this project. Each issue category has a discussion of our understanding of existing conditions and how the proposed project modifies or changes the issue factors. Following at the end of this report is a table which lists currently known issues expressed by the Farmers Reservoir and Irrigation Company (FRICO) and refers the reader to the page number(s) both in the CSU and/or Love reports where these specific issues of concern are addressed. Also at the end of this report is a second table which has been prepared and is a coded "score card" for a quick reference addressing project impacts to the floodplain, life safety, ditch facilities, and river facilities.

The issues discussed in this report prepared by Love & Associates, Inc. are:

1. Life Safety of the Public
2. Maintenance Access to Irrigation Facilities
3. Maintenance Requirements of Irrigation Facilities
4. Storm Sewer First Flush
5. Seepage from Headgate Approach Channel
6. 404 Permit
7. Diurnal Fluctuations in River

1. LIFE SAFETY OF THE PUBLIC

Existing Conditions

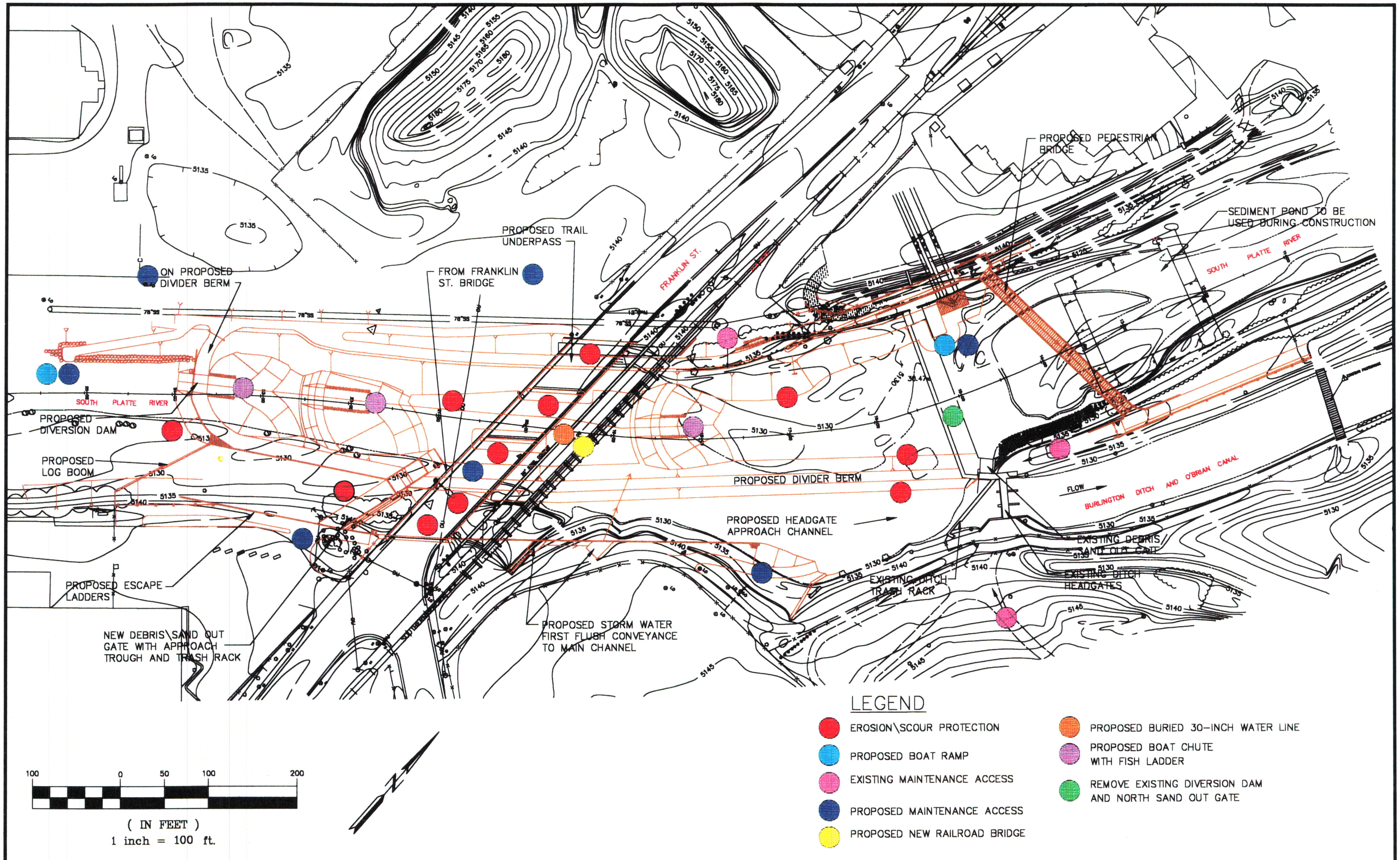
The existing irrigation ditch facilities are currently fenced on both sides of the river. The primary life safety concerns associated with the existing facilities are for persons who could be rafting, boating or swimming in the river itself in the vicinity of Franklin Street. These life safety concerns are:

- People who are transported over the existing diversion dam by river flows and are likely to be trapped in the "keeper" wave downstream. Keeper waves are also known as reverse flow or undertow.
- People trapped up against the existing trash rack at the diversion headgates.
- Boating hazards caused by the Franklin Street, water line and railroad bridge piers and the low chords of these bridges.

Proposed Conditions

Several levels of safety measures are proposed for this project. Please refer to Sheet 1 of 1 following. These measures include:

- Warning signage placed upstream and in the vicinity of the project.
- Removal and replacement of the railroad bridge. The new piers for the railroad bridge will be round and the span between the piers of the bridge will be three times as long as for the existing bridge.
- Removal of the waterline bridge by burying the pipeline below the river. This eliminates several piers in the river, which are potential boating hazards.
- Install floating log boom at the entrance to headgate approach channel to help keep boaters out of and to minimize inflow of debris into the headgate approach channel.
- Install escape ladders within headgate approach channel between floating log boom and new trash rack.
- Install a boat chute upstream of Franklin Street. Mark entrance to boat chute with signal rocks and upstream river signage. Please note that this project is not intended to promote boating at this location but instead it is intended to provide for boater safety. The boat chute would be passable for a relatively short time period each year, only when the flow in the river is sufficient to supply the irrigation diversions at this location and then have an excess for flows over the upstream dam.
- Install boat landings upstream and downstream of Franklin Street for portage purposes. These boat landings can also be used as maintenance access points.
- Remove the existing 8-foot high dam. This will eliminate a "keeper" wave downstream.



Love & Associates, Inc. water resource consultants 841 Front Street Louisville, Colorado 80027-1849 Phone: 303-673-9795 Fax: 303-673-9796	MARCH 1, 1999	URBAN DRAINAGE & FLOOD CONTROL DISTRICT CITY AND COUNTY OF DENVER	SOUTH PLATTE RIVER PHASE III	SHEET 1 OF 1

- Provide handrails, fencing or guardrails with proposed design as required for safety.
- The tops of all vertical walls not fitted with handrails or fencing are to have integrally poured 90° triangular concrete points at the top of the wall to prevent people from walking along the walls.
- The proposed project will remove approximately 300 acres of land within the Globeville neighborhood and north areas from the 100-year floodplain, which in itself is a very positive life safety issue.

In our professional opinion, the proposed project has definite and greatly enhanced life safety benefits, when compared to the existing facilities due to construction of the safety features described above and the decrease in the extent of the 100-year floodplain by approximately 300 acres.

2. MAINTENANCE ACCESS FOR IRRIGATION FACILITIES

Existing Conditions

Farmers Reservoir and Irrigation Company (FRICO) staff has advised us there are three maintenance access routes currently used on a regular basis by FRICO, who operate the Burlington Ditch and O'Brian Canal diversion works. These routes include:

- Access from the Riverside Cemetery to the south side of the existing canal headgates (regulating gates or takeoff gates) and trash rack;
- Access from York Street along South Platte River and Burlington Ditch and O'Brian Canal to north side of existing headgates, trash rack and debris/sandout gate;

- Access from Franklin Street east of railroad tracks to bottom of South Platte River

These access routes are adequate to perform routine maintenance to existing ditch facilities.

A secondary sandout gate currently exists on the northeast bank of the river. This sandout gate is operated periodically to flush out sediment trapped behind the dam. Access to this gate is afforded over private property owned by others east of Franklin Street along the north bank of the river. Under proposed conditions this facility will be removed and this access route will no longer be needed.

Proposed Conditions

The existing maintenance access routes will remain available for ditch company use under the proposed conditions with the exception of the access route to the secondary existing sandout gate. However, additional access routes are provided for in the proposed design. These include:

- Proposed maintenance access ramp to the headgate approach channel invert located between the existing canal headgates and Franklin Street.
- Proposed maintenance access from Franklin Street through the warehouse property southwest of Franklin Street to new trash rack and log boom from top of south bank of the river.
- Proposed maintenance access to new trash rack and new radial sluice gate from Franklin Street bridge deck.
- Proposed low flow maintenance access on proposed divider berm (separation weir) upstream of Franklin Street.

- Proposed maintenance access to headgate approach channel upstream of Franklin Street from existing pedestrian trail on the northwest bank of the South Platte River via the proposed boat landing.
- Proposed maintenance to main channel downstream of Franklin from proposed pedestrian trail via proposed boat landing.

In our professional opinion, the proposed project provides similar and slightly improved permanent maintenance access routes when compared to the existing facilities, since formal access locations are provided to all key existing and proposed facilities.

3. MAINTENANCE REQUIREMENTS FOR IRRIGATION FACILITIES

Existing Conditions

For existing conditions, the following maintenance is required:

- Existing diversion gates
- Existing sandout/trashout gates
- Existing concrete dam structure
- Existing trash rack
- Sediment accumulation removal upstream of existing dam by either gravity or mechanical methods
- Fences in vicinity of diversion facilities
- Existing riprap
- The existing diversion facilities have recently been overtopped by floodwaters (approximately 20-year flood event), causing flood waters to enter the canal in an uncontrolled manner. During an approximate 20-year flood event and greater, significant amounts of floodwaters

enter the canal, which can cause damage to the ditch system, and requires additional, non-scheduled ditch maintenance.

Although the existing facilities require regular operation and maintenance activities such as sandout periods to scour out sediment storage areas upstream of the diversion gates, these facilities do not appear to require an abnormal amount of maintenance activities to keep the system functioning.

Proposed Conditions

The existing northeast sandout (sluice) gate and a majority of the existing diversion dam will be removed as a part of the proposed project and will be replaced with a new sandout/debris (sluice) gate as well as a new diversion dam upstream of Franklin Street. The new dam will direct the water into the headgate approach channel where it can either be released to the river or taken into the Burlington Ditch. Since the proposed facilities will be new and the existing facilities are aged, the maintenance of some of the new facilities should not be more than existing facilities even though the location and the orientation of the facilities are different.

The new facilities which will require maintenance are as follows:

- New trash rack (maintenance at existing trash rack should lessen, however, total maintenance for existing plus new trash rack will increase slightly over existing conditions).
- New safety facilities (signage, floating log boom, escape ladders, handrails, fencing, w-rails, etc.). Periodic maintenance and maintenance after significant flood events will be required for these facilities.

- New headgate approach channel will require maintenance (primarily for sediment and debris removal). The total sediment storage volume available is similar for proposed and existing conditions. The total amount of "stored" sediment that can be removed by gravity flushing is increased by the geometry of the proposed facilities. If the proposed sluice gate at Franklin is operated to take advantage of diurnal flow fluctuations in the river (by either manual or automatic methods to keep a constant water level at the headgates), daily sand removal can be accomplished during much of the year with minimal effort. At higher river flows, this sluice gate can be operated for continuous sandout operations. These sluice gate operations will decrease the amount of mechanical sediment removal required upstream of the diversion headgates. Mechanical sediment removal for existing conditions is accessed from the northwest bank of the river. Two additional maintenance access points are provided for in the proposed design (headgate approach channel downstream of Franklin and headgate approach channel and main channel upstream of Franklin). Sediment removed by mechanical methods can be dumped into sides of boat chute with the proposed design.
- Riprap is currently failing at the existing sandout gate on the south bank of the river. This riprap will be repaired as a part of the proposed project.
- Buried scour protection will be provided for all proposed construction, as required.
- The CSU physical model did not include the proposed floating log boom because of space limitations in the river mechanics flume. However, the location and orientation of the log boom will cause small floating debris to be stored at the entrance to the boat chute where it can be periodically removed or be allowed to be stored and be washed

down the grade control weir into the river channel at higher river flows.

- For proposed conditions, the 100-year flood level is below the top of the concrete platform at the existing headgates. One-hundred-year flood flows can be excluded from entering the canal if the diversion headgates are closed. This cannot be accomplished under existing conditions since the 100-year flood under existing conditions is significantly higher than the aforementioned concrete platform and 100-year flood discharges flow uncontrolled into the canal. The canal is currently flooded by smaller events. Flooding at these lower flood levels will be eliminated by construction of these improvements.
- Additional information on sediment and trash can be found in the enclosed CSU report.

The proposed project will not increase and may reduce the net amount of operational maintenance required for irrigation related facilities if operated in accordance with design recommendations for the proposed sluice gate. Total trash and debris removal efforts will slightly increase because of the addition of a second trash racks. However, sediment removal should decrease because of new geometry of the headgate approach channel and the added sluicing ability provided by the proposed new sandout gate at Franklin Street.

At the same time, new additional river facilities such as the berm separating the approach channel and the river, boat chutes, trails, etc. will require maintenance activities heretofore not needed.

4. STORM SEWER FIRST FLUSH

Existing Conditions

Under existing conditions, two storm sewers discharge into the South Platte River immediately upstream of the existing irrigation diversion dam and headgates. The first flush water from these storm sewers mixes with the river water. Recognizing the ditch diverts all base flow in the river during much of the year, all or most of the first flush storm sewer water from these two storm sewers is currently diverted by the irrigation ditch under existing conditions.

Proposed Conditions

Vaults are proposed to be constructed on the two storm sewers located on the south bank (east of Franklin Street) immediately upstream of the existing canal's point of diversion. The vaults will be located in the river bank outside (south) of the headgate approach channel. A pipe will connect the upstream storm sewer vault to the downstream vault. Two encased 30-inch diameter RCP pipes will discharge from the downstream vault underneath the headgate approach channel to the main channel. When the capacity of the two 30-inch RCP pipes are exceeded, the vaults will overflow stormwater into the headgate approach channel.

The proposed project will reduce the amount of stormwater from these two pipes that enters the irrigation ditch.

5. SEEPAGE FROM HEADGATE APPROACH CHANNEL

Existing Conditions

Under existing conditions, there is no headgate approach channel. Based on our understanding of the existing dam's design, river water seeps below the existing dam and headgate structure, around the sides of the structure and into the banks, however, the amount of seepage under existing conditions was not quantified as a part of this study.

Proposed Conditions

For proposed conditions, the headgate approach channel is generally higher than the proposed parallel main channel. Since the South Platte River is a sand bottom channel, seepage from the headgate approach channel to the main channel could be expected unless mitigating efforts were undertaken. Sheet piling will be used as a mitigating effort to cut-off seepage along the headgate approach channel under the divider berm and at the entrance to the grade control weirs (boat chutes). The sheet piling will be driven to bedrock. Beneath the existing Franklin Street bridge, sheet piling cannot be installed due to limited headroom availability. At this location, the channel bed will be excavated to bedrock and a new concrete structure will be constructed from bedrock to tie to the existing concrete pier at the Franklin Street bridge to add continuity to the sheet pile cut-off system. Watertight connections will be made in the sheet pile wall at utility penetrations for the 30-inch waterline and the two 30-inch storm sewer first flush lines. As a result, the seepage from the proposed design is expected to be no more, but probably less, than what occurs under existing conditions.

6. 404 PERMIT

Existing Conditions

We recently discussed 404 permit requirements with Terry McKee of the Littleton office of the U.S. Army Corps of Engineers (February, 1999). Mr. McKee has personally observed FRICO performing instream mechanical sediment removal above the existing diversion dam in the recent past. Mr. McKee stated he has discussed this issue with other Corps staff in his office and that instream sediment removal and disposal of the material is allowed without a 404 Permit being required.

Proposed Conditions

This proposed project is currently permitted by the U.S. Army Corps of Engineers (Permit No. 199580557). The time limit for completing the work authorized currently ends on June 30, 2004. Terry McKee confirmed that regular mechanical sediment removal, if required for the proposed project, would still be allowed as a regular on-going ditch maintenance activity and would not require an individual 404 permit for these ongoing maintenance activities.

7. DIURNAL FLUCTUATIONS IN RIVER

Existing Conditions

During certain flow regimes in the river, the twice-daily fluctuations in the stage cause the need for the headgates to be adjusted to maintain allowed diversions into the canal.

Proposed Conditions

The proposed design effectively creates a longer crest length for the diversion dam weir. The longer crest length helps to maintain a more consistent driving head at the diversion headgates, thus minimizing the need for changing the setting on the opening of the headgates. The proposed sluice gate at Franklin Street could potentially be automated to keep a constant driving head at the diversion gates. This process would help insure that FRICO maximized the allowable water it could divert, while using excess water to clean sediment out of the system by flushing diurnal fluctuations through the sluice gate at Franklin Street or as an alternate operation when sanding out is not needed, the excess flows would then flow through the boat chute area, greatly enhancing the aquatic habitat conditions.

Please note that the CSU report recommends the sluice gate at Franklin Street be constructed at the originally proposed design/model location adjacent to the Franklin Street Bridge. The secondary alternate location, approximately 20 feet upstream, caused scour problems at one of the Franklin Street bridge piers and was therefore determined not to be a viable location for the sluice gate. We will proceed with the CSU recommendation on this issue and design the sluice gate adjacent to the existing bridge structure.

In the Appendix of this report, we have included a summary page of FRICO issues and where each issue is addressed in both our report and the attached CSU report. We have also included the "Score Card Summary of Impacts".

We thank you for the opportunity to submit this report and we stand ready to answer questions on this project.

Sincerely,

LOVE & ASSOCIATES, INC.

By ______________________
David J. Love, P.E.

Inclusions: FRICO Issues Table and "Scorecard of Improvements"
CSU Model Study Report

FRICO ISSUES
(NOT NECESSARILY IN ORDER OF IMPORTANCE TO FRICO)

ISSUE	LOVE REPORT PAGE NOS.	CSU REPORT PAGE NOS.
Project Impact on Diversion Capability		20, 36-38
Maintenance Access for Irrigation Facilities	7-9	
Maintenance Requirements for Irrigation Facilities	9-12	11-12, 20, 26-38
Life Safety	4-5, 7	
Storm Sewer First Flush	13	
Seepage from Headgate Approach Channel	14	
Low Flow Conditions		7-12, 19-20, 32
Ice/Cold Weather		26-27, 36
Railroad Structure	5	
Proposed Project Impacts on Floods	1	
Diurnal Fluctuations in River	15-16	
404 Permit Requirements	15	

SCORE CARD
SUMMARY OF IMPACTS
PROPOSED SOUTH PLATTE RIVER - GLOBEVILLE PHASE III
PREPARED BY
LOVE & ASSOCIATES, INC.

CATEGORY (NOT NECESSARILY IN ORDER OF IMPORTANCE)	SCORE
1. Flood Damage Reduction	[blue]
2. Life Safety Hazard Reduction	[blue]
3. Ditch System Facilities	
A. Project Impact on Diversion Capability	[yellow]
B. Maintenance Access to Irrigation Facilities	[green]
C. Maintenance Requirements for Irrigation Facilities	
• General	[yellow]
• Trash Rack Cleaning (2)	[light red]
• Sediment Removal	[green]
D. Storm Sewer First Flush	[blue]
E. Seepage From Headgate Approach Channel	[green]
F. Low Flow Conditions	[yellow]
G. Ice/Cold Weather	[yellow]
H. Railroad Structure	[blue]
I. Diurnal Fluctuations in River	[blue]
J. 404 Permit Requirements	[yellow]
4. River System Facilities	
A. Trail System	[blue]
B. Boat Passage	[blue]
C. Fish Passage	[blue]
D. Wildlife Habitat	[green]
E. Fish Habitat	[blue]
F. Maintenance Access	[blue]
G. Maintenance Requirements	[green]
H. Sediment Transport	[yellow]
I. Water Quality	[green]

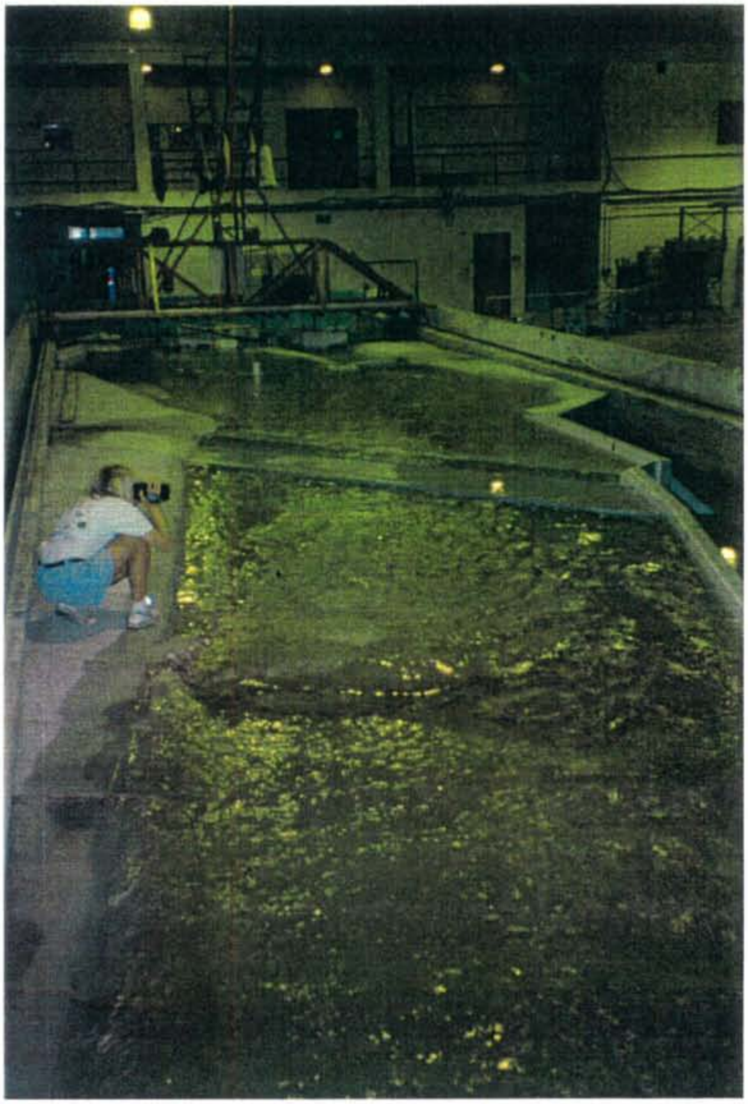
LEGEND

[red]	**Worse Condition**
[light red]	**Slightly Worse Condition**
[yellow]	**No Change**
[green]	**Slight Improvement**
[blue]	**Significant Improvement**

"HYDRAULIC MODEL STUDY OF THE SOUTH PLATTE RIVER AT THE FRANKLIN STREET BRIDGE"

Prepared By:
COLORADO STATE UNIVERSITY
March, 1999

HYDRAULIC MODEL STUDY OF THE SOUTH PLATTE RIVER AT THE FRANKLIN STREET BRIDGE



Steven R. Abt, Thomas E. Brisbane,
Kallie E. Sampish and Michelle L. Heintz

Engineering Research Center
Colorado State University
Fort Collins, CO 80523

March 1999

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The South Platte River runs generally south to north through the Denver metropolitan area and through the central region of the City and County of Denver, Colorado. Through the years, diversion dams and flow control structures have been constructed for irrigation canal takeoffs, cooling water and a multiplicity of other purposes. These structures have often adversely affected upstream areas by elevating the water surface and considerably expanding the extent of the floodplain. Also, with the increasing realization that the river provides a valuable resource for recreation, beautification and other aesthetic purposes, these structures create serious safety concerns. Boaters and water sport users are susceptible to the dangers associated with the structures and related flow conditions, particularly during minor floods. Flood conveyance, water delivery, recreation and aesthetics make the South Platte River a multi-use resource that impacts nearly every sector of the Denver region.

An ongoing project, sponsored by the Urban Drainage & Flood Control District (UDFCD) and the City and County of Denver, has been evaluating the impacts of, and in some cases, removing these large diversion structures in favor of more gradual structures that incorporate features that enhance boating safety, that reduce the floodplain impacts upstream of these structures thereby allowing free passage of the flood peaks, that continues the delivery of required flows to authorized diversions, and maintains/enhances the aesthetic value of the river valley.

Immediately downstream of the Franklin Street Bridge on the South Platte River is the Burlington Ditch and O'Brien Canal (Canal) diversion structure. The Canal provides agricultural and municipal waters for the region north of Denver near the City of Brighton in Adams County. The Canal diversion is a typical ditch takeoff consisting of a series of three regulating gates, as presented in Figure 1, on a large pool created by a diversion dam that spans the South Platte River. The head for the takeoff gates is derived from the diversion dam which creates the required pool elevation independent of river flow. Because of the seniority of the water right, the Canal has call on the river most times during the year.

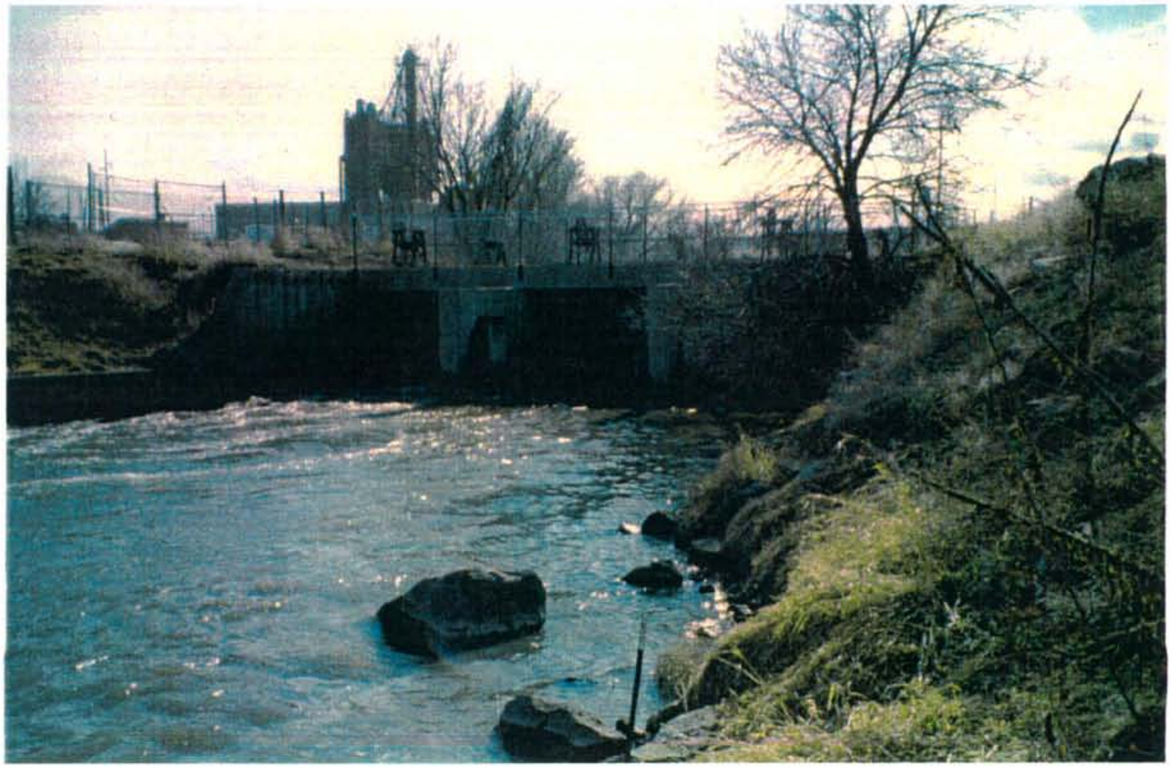


Figure 1. View of the existing head gates at the Burlington, O'Brien and Farmers Canal on the South Platte River.

The lowering of the floodplain upstream of the diversion dam adjacent to the Canal will require removal of the dam and construction of substitute features in the river to maintain the same water elevation at the Canal regulation head gates. The lowering of the flood plain will reduce the flooding potential of the Globeville neighborhood located upstream of the project site. At the same time, recreational boating must be maintained and safety enhanced at the Franklin Street Bridge and at the Union Pacific Railroad (UPRR) Bridge immediately downstream. These proposed modifications to the river must be accomplished while not infringing on the rights of the Canal to divert their allocated quantity or quality of water from the South Platte River.

Authorization

Love & Associates, Inc., water resource consultants located in Louisville, Colorado was contracted by the UDFCD to analyze and design a new series of structures and river features to replace the existing diversion dam and maintain the previously cited requirements. In cooperation with the UDFCD and the City and County of Denver (City), it was determined that a physical model study would be beneficial to visualize the proposed structures, to evaluate the performance of the many design options, and to refine and finalize the design of these structures/features. In addition, the model would assist in evaluating sediment, ice and debris impacts on the proposed structures/features.

Love & Associates, Inc. contracted with Colorado State University to construct and operate a 1:20 Froude scale model of the 1,400-foot river reach in the vicinity of the diversion dam. The model was constructed in the Hydraulics Laboratory of the Engineering Research Center at Colorado State University in Fort Collins, Colorado. The purpose of this study was to construct, operate and evaluate the proposed model incorporating the new design structures/features, provide suggestions for enhancements of these structures/features, and provide recommendations for the final design of these structures/features.

MODEL

General

A model study is used to predict prototype performance based on the observed conditions in a physical scale model. Flow patterns, velocities, pressures and water surface characteristics in the model are scaled to the prototype using the principles of similitude. Froude scaling is used for modeling when gravitational forces predominate. This is applicable to models that operate under free surface flow conditions and when flow rates are reasonably large. Froude modeling allows direct scaling of all physical length dimensions from model to prototype.

Selection of a Froude scale ratio, model to prototype, requires that numerous considerations be included such as the desire to keep the physical model relatively large within laboratory space constraints, meet required model flow capacities, assure that convenient sizes of standard pipe and fittings may be incorporated into model construction, and be economically feasible.

In this particular application, the proposed physical model must be capable of simulating river flows through the Franklin Street Bridge reach of the South Platte River incorporating the existing Canal regulation head gates, structures/features, and pertinent aspects of the river. Therefore, a Froude model scale of 1:20 (model to prototype) was selected for modeling the 1,400 foot South Plattle River reach and the structures/features around the Franklin Street Bridge, Union Pacific Railroad Bridge, and the Canal flow regulation gates. The river mechanics flume, a facility 20-feet wide by 100-feet long, was utilized for the construction and operation of the physical model. Water was supplied to the flume by two pumps through an existing pipe network that could deliver the required flow rate to the model. The flume has an existing carriage that can be moved to any location over the model and serve as a stable platform for measurements and observations. At a scale of 1:20, the entire study reach of river fit in the flume while allowing sufficient space upstream and downstream of the reach. The model was sufficient in size to allow observation and measurements of the appropriate physical parameters and document the behavior of the desired flow characteristics.

Model Construction and Instrumentation

The model was constructed as defined by drawings, cross sections, and associated supplemental information provided by Love & Associates, Inc. The model was constructed in the river mechanics flume by fabricating plywood templates across key cross sections throughout the length of the model. Well-graded sand was then placed and compacted to fill the space between the templates to an elevation within two inches of the top of the template as presented in Figure 2. A concrete cap was then placed to the top of the templates with the templates serving as guides for the concrete finishing to the desired contours as indicated in Figure 3. All features of the river bottom and banks, as well as roads and trails on the banks, were modeled with a hard boundary mortar. The templates were then coated with a waterproofing material.

The piers and deck of the Franklin Street Bridge were modeled with wood painted with an epoxy waterproof paint as shown in Figure 3. The bridge stringers and underside of the deck were modeled to provide the same flow restriction to flood waters as the prototype. The UPRR Bridge immediately downstream of the Franklin Street Bridge was modeled in a new design configuration, as directed by Love & Associates, Inc., to replace the old timber pilings presently in use. The UPRR Bridge will be removed and replaced as a part of the project. PVC pipe was used to simulate the circular cross section single pilings for the new bridge with a wooden bridge deck and supports. The elevated water pipeline located between the two bridges was not modeled as the pipeline is also scheduled for burial in the river bottom as part of this project.

Regulation head gates leading into the Canal and sluice gates between the diversion channel and the river were modeled as slide gates fabricated from galvanized sheet metal in metal guides. The gates were fabricated with adjustable openings to regulate flow. Trash racks were modeled with flat bar fabricated in the same grid pattern as the prototype.

At the upstream end of the model (inlet), a diffuser pipe received flow from the water supply network and distributed the flow across the width of the flume. Flow entry is through a diffuser baffle placed vertically across the upstream end of the model. The baffle consists of a 2-inch x 4-inch frame with wire fencing across both faces comprising

Figure 2. Model construction showing the cross section templates and sand fill before the concrete cap is applied.

Figure 3. View of the completed model looking downstream to the Franklin Street Bridge and the Union Pacific Railroad Bridge.

a basket; the basket frame was filled with 1-inch to 1.5-inch rock. The baffle serves to evenly disperse the flow and reduce turbulent flow as it enters the model through the rock voids.

Flow is regulated at the model outlet with adjustable gates, one in the main river channel and one in the Canal channel, to establish the desired backwater elevations and/or conditions associated with prescribed discharges. Downstream of the Canal regulation head gates, the Canal flow is confined to a rectangular channel containing a cutthroat flume (weir) for measuring the discharge separately from the main river. Both the river flow and the Canal flow return to the under floor sump for re-circulation. A schematic overview of the model is presented in Figure 4 and pictured as completed after construction in Figure 5.

Flow is conveyed to the model using two pumps connected to the flume through an existing pipe network. The pipe network is comprised of an 18-inch pipeline, with appropriate control valves, and contains a calibrated orifice plate accurate to ± 2%, used to measure the discharge. The delta pressure across the orifice plate was measured using a u-tube manometer filled with Meriam blue gauge oil. Prototype discharges ranged from 300 cubic feet per second (cfs) to 21,800 cfs and was simulated with model discharges ranging from 0.17 cfs to 12.19 cfs, respectively. Table 1 presents the river discharges with related hydrologic return periods, and corresponding model discharges used for this study.

Water surface profiles were measured using a point gauge (accurate to ± 0.001 feet) suspended from the movable carriage. Velocities were measured using a two dimensional Marsh-McBirney model 523 laboratory magnetic flow meter. The flow meter has a sensor calibrated for the lower velocities typically used for Froude scale modeling. Both x and y component velocities were obtained and resolved into a single velocity to obtain the velocity magnitude.

Velocity profile data were obtained for five cross sections selected in consultation with Love & Associates, Inc. Figure 6 indicates the location of the data collection cross sections on a schematic plan of the model. The first section was located 500 feet upstream of the Franklin Street Bridge and perpendicular to the flow. The second section

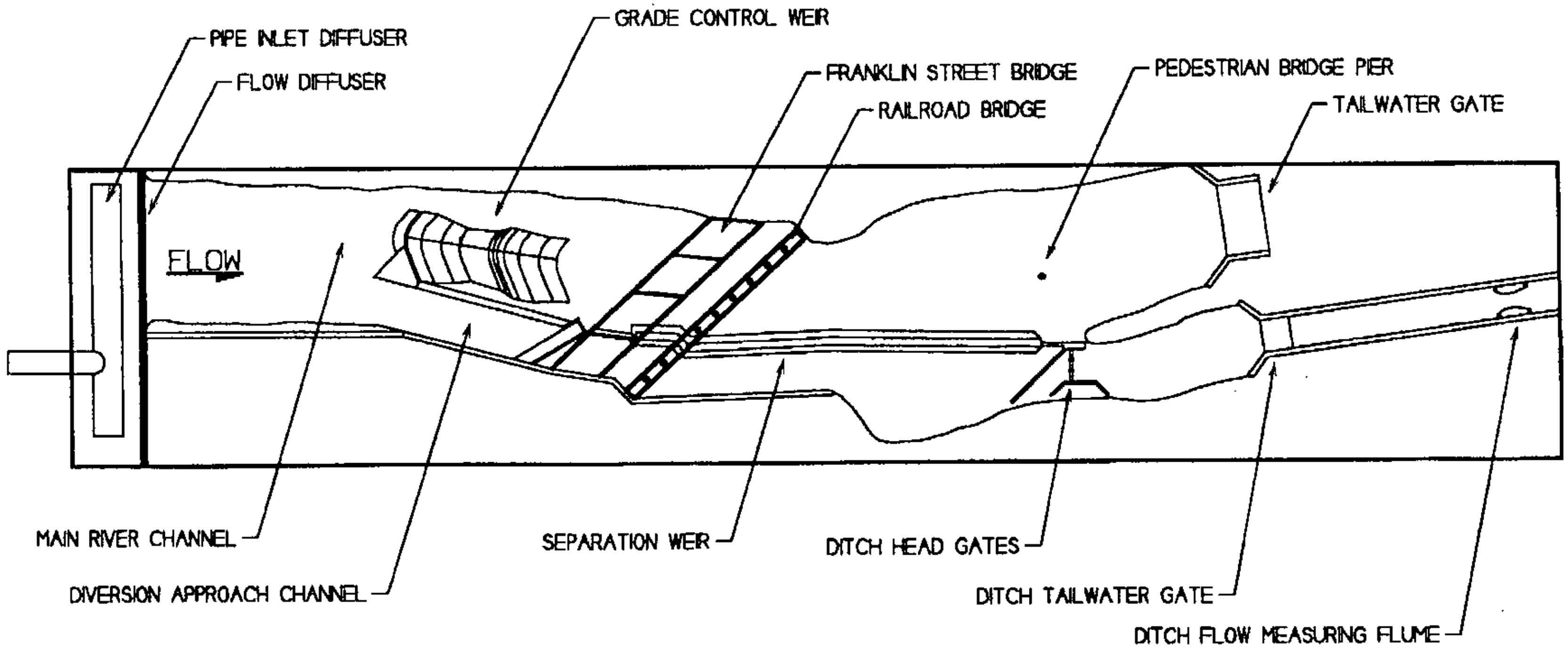


Figure 4. Drawing showing the reach of river as modeled in the river mechanics flume.

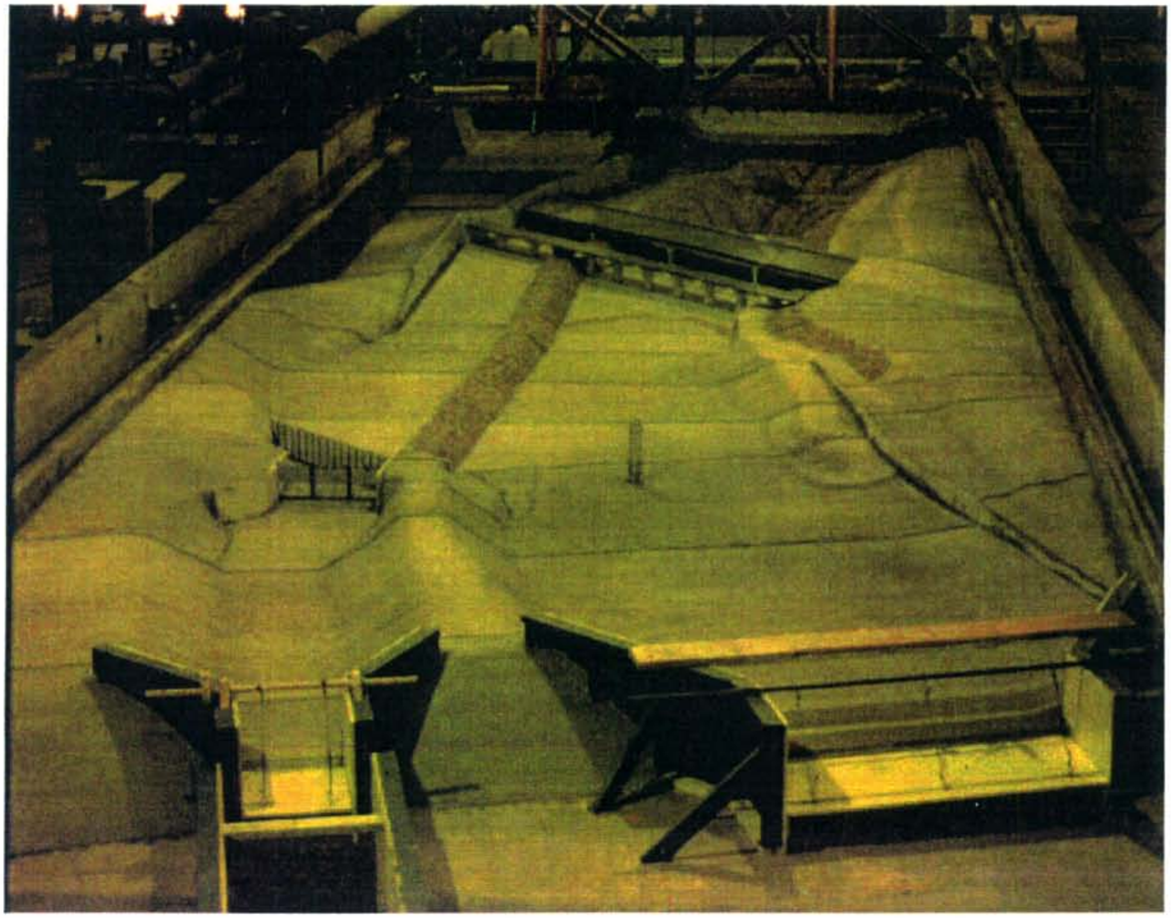


Figure 5. Overall view of the model looking upstream. The ditch is to the left and the main river channel is to the right.

Table 1. Prototype flows and elevations compared to model flows.

EVENT	TOTAL RIVER DISCHARGE (cfs)	WATER SURFACE ELEV. (ft)	TOTAL MODEL DISCHARGE	DITCH DISCHARGE (cfs)	WATER SURFACE ELEV.	MODEL DITCH DISCHARGE
	300		0.17	300	5,125.70	0.17
	1,000		0.56	300	5,125.70	0.17
2 year	3,600	5,127.98	2.01	50	5,124.40	0.03
10 year	8,600	5,131.15	4.81	500	5,126.60	0.28
50 year	17,300	5,135.08	9.67	1,000	5,128.00	0.56
100 year	21,800	5,136.64	12.19	2,000	5,130.20	1.12

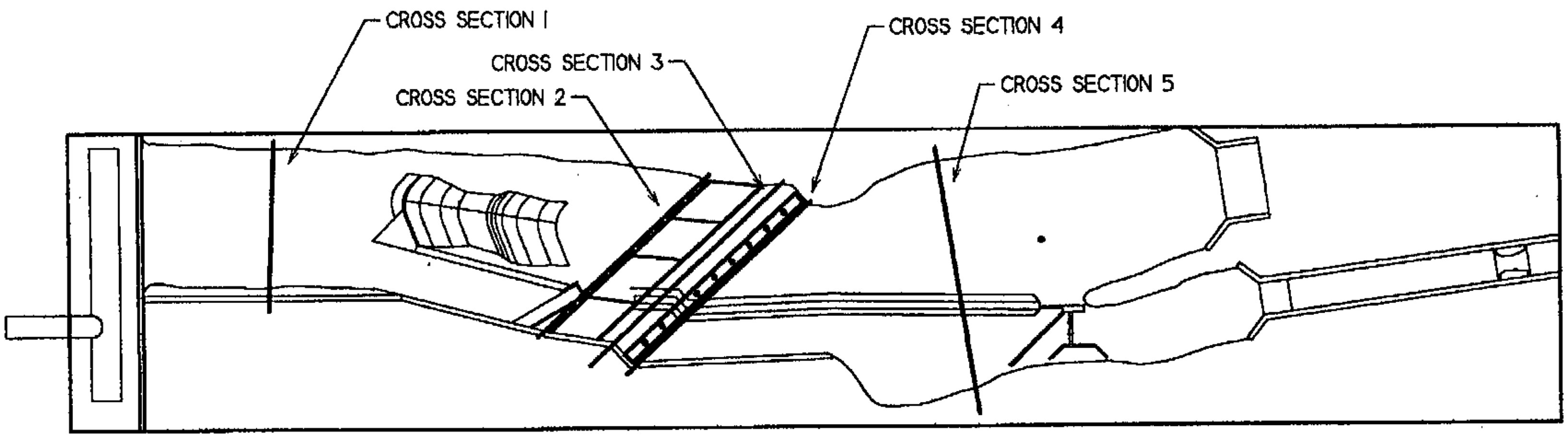


Figure 6. Location of cross sections for velocity and water surface measurements.

was located immediately upstream of the Franklin Street Bridge and aligned with the bridge. The third section was centered between the Franklin Street Bridge and the UPRR Bridge, and was aligned with the bridges. The fourth section was immediately downstream of the UPRR Bridge and also aligned with the bridges. The fifth section was located approximately 350 feet downstream of the Franklin Street Bridge and was oriented perpendicular to the river flow.

Sediment and Scour

Sediment is continually transported through the South Platte River system and affects every feature in and adjacent to the river channel. To assess the impacts of transported sediments throughout the modeled river reach, a sediment injector was installed on the model and operated at varying rates for several of the tests. Modeling of sediment transport and deposition in a scale model is a challenging task because the forces acting on the sediment do not scale in a manner similar to the hydraulic characteristics. The general areas of siltation may be determined, however direct physical measurements are not meaningful. Therefore, sediment transport, deposition, and localize scour must be qualitatively evaluated. The model was operated using two sediment sizes: one sediment size to simulate transport and deposition in the diversion approach channel and one sediment size to simulate localized scour at the numerous structures and features in the reach.

Fine sand, D_{50} of 0.35 mm, was used to evaluate sediment transport and depositional impacts in the diversion approach channel and on the structures, regulation gate and sluice gate, and other associated features modeled in the diversion approach channel. Fine sediments were injected into model flow over long, steady time periods to qualitatively demonstrate general zones of material deposition. It should be noted that sediment impacts could not be evaluated at flow rates of less than 1,000 cfs as the fine sand could not be transported through the model due to extremely low velocities (less than 3 feet per second).

In order to model scour potential at weir locations, pier locations, and separation zones and diversions, a coarser sand with D_{50} of 2 mm was utilized. The smaller sands were rapidly swept through the model at velocities that maximize scour potential. The larger sand materials allowed for a qualitative evaluation of scour potential because the particles were sufficiently small to be moved short distances but sufficiently large so as not to be transported out of the reach. The larger sand material was placed onto the river bed, not injected, and then the model was operated for several hours allowing the sediments to be scoured and/or repositioned until a steady state or equilibrium state was attained.

The qualitative analysis identified the locations and extent of deposition, range and extent of scour, and locations of scour in the vicinity of the Franklin Street Bridge. During the later stages of the testing program, a portion of the mortar cap was removed exposing the compacted sand base in the vacinity of the bridge piers. The scour potential near the bridge piers and adjacent to the Franklin Street Bridge sluice gate could then be evaluated.

Debris

Several tests were performed in which debris was injected and transported through the river reach and would be evaluated. Debris used for these tests consisted of small twigs, leaves and dry grass sized between 4 to 8 inches in length. These were used to simulate tree limbs, and other miscellaneous debris expected during flood events.

Testing Program

The testing program was comprised of 52 test runs as indicated in Table 2. The testing program was determined in consultation with Love & Associates, Inc., the UDFCD, and the City and County of Denver. The tests were oriented toward evaluating the numerous structures/features of the design over the stipulated range of hydrologic flows to include 300, 1,000, 3,600 (2-year), 8,600 (10-year), 17,300 (50-year) and 21,800 cfs (100-year). Specific tests were also conducted to determine the qualitative effects of sediment, ice, trash, and varying tailwater conditions on the performance of the proposed structures/features integrated into the physical model. Tests were also performed to evaluate the scour potential at the Franklin Street Bridge piers.

Table 2. Test matrix showing test runs performed on the Franklin Street Bridge South Platte River model.

RUN NO.	DATE	DISCHARGE			TEST	CONSTRUCTION CHANGES MADE
			MAIN	APPROACH		
1	5/15/99	DEMO	Ditch Personnel			
2	5/19/99	DEMO				
3	5/26/99	DEMO	Bureau of Reclamation Safety Inspectors			new diffuser box
4	6/1/98	2-year	2700	1000	velocity and WSEL	
5	6/1/98	10-year	7600	1000	velocity and WSEL	
6	6/2/98		varied		orifice check	base line
7	6/4/98		0	0-1000	flume check	
8	6/11/98	2-year	2760	946	velocity and WSEL	
9	6/11/98	10-year	7744	1027	velocity and WSEL	
10	6/15/98	2-year	2705	1073	sediment D_{50} = 0.32	
11	6/15/98	10-year	7440	1109	sediment D_{50} = 0.32	
12	6/15/98	50-year	16099	1127	sediment D_{50} = 0.32	
13	6/16/98	2-year	2769	1010	sediment with gates open to see how flushes	
14	6/16/98	10-year	8692	0	closed gates to see effect on sediment	
15	6/17/98	2-year	2632	1037	trash	
16	6/17/98	10-year	7665	948	trash	
17	6/17/98	2-year	2556	1037	sediment D_{50} = 0.6	
18	6/17/98	10-year	7470	1127	sediment D_{50} = 0.6	
19	6/23/98	100-year	20762	1000		
20	6/25/98	50-year	17500	0	WSEL	
21	6/25/98	100-year	21767	0	WSEL	
22	8/18/98	2-year	2529	1001	velocity and WSEL	lowered upstream weir took out point
23	8/18/98	10-year	7558	1073	velocity and WSEL	
24	8/19/98	2-year	2594	1038	sediment D_{50} = 0.32	
25	8/20/98	10-year	7486	1126	sediment D_{50} = 0.32	
26	8/25/98	2-year	2558	1073		
27	9/1/98	DEMO 2-year	3281	350		
28	10/13/98	1000 cfs	0	1073	velocity and WSEL	lower boat chute, raise trash rack elevation
29	10/13/98	2-year	2520	1073	velocity and WSEL	
30	10/15/98	2-year	2665	966	set tail water	
31	10/15/98	10-year	7606	1007	velocity and WSEL	
32	10/15/98	100-year	20817	1048	velocity and WSEL	
33	10/20/98	2-year	2720	987	trash	
34	10/20/98	10-year	7606	1007	trash	
35	10/20/98	100-year	20905	998	trash	
36	10/22/98	2-year	2645	986	sediment D_{50} = 0.32	
37	10/23/98	10-year	7607	1006	sediment D_{50} = 0.32	
38	10/27/98	100-year	20753	986	sediment D_{50} = 0.32	
39	10/27/98	2-year	2625	1006	no stop logs velocity and WSEL	
40	10/27/98	10-year	7586	1027	no stop logs velocity and WSEL	
41	10/29/99	285cfs	0	285	ice runs	
42	10/30/99	173 cfs-400 cfs	0		ice runs	
43	11/4/98	2-year	7893	752		
44	11/5/98	DEMO				
45	12/1/98	1000 cfs	0	1006		movable bed/scour
46		2-year	3281	350	scour	
47		10-year	8512	350	scour	
48	1/19/99	1000 cfs	719	367	scour	armored pool
49	1/20/99	2-year	3411	369	scour	
50	2/2/99	2-year	3262	369	trash and sediment	
51	2/4/99	10-year	8613	369	trash and sediment	
52	2/12/99	312 cfs	0	312	velocity in approach	

MODEL RESULTS

Once the physical model was constructed based on the original design documents, a series of tests were conducted to evaluate the performance of each of the structures, features and system components prescribed in the South Platte River reach upstream and downstream of the Franklin Street Bridge. After the baseline testing was performed, the model was modified through a series of alterations and refinements to enhance design of each of the structures, features and system components. The results section will briefly trace the evolution of the model, present basic hydraulic characteristics and information derived from the model, and present the general findings and recommendations resulting from the testing program.

The evaluation of the model focused on several structures and features of the river reach that included the following:

1. The weir height leading to the grade control structure and weir height leading to the diversion approach channel,
2. The shape of the weir transition entering the diversion approach channel and gates,
3. Grade control structure performance,
4. Placement and operation of the sluice gates placed between the diversion approach channel and the river,
5. Operation of the separation weir located between the diversion approach channel and the river,
6. Placement and operation of the trash racks,
7. Flow characteristics and channel capacity through the Franklin Street Bridge and the UPRR Bridge,
8. Flow delivery capability to the Canal,
9. Pier scour potential at the Franklin Street Bridge and the UPRR Bridge, and
10. Sediment, ice, and trash impacts on the operation of concerns 1 through 8.

Specific comments will be presented during the discussion of the baseline and modification tests pertaining to these areas of focus.

Baseline

The model was first tested with baseline conditions stipulated in the original design presented by Love & Associates, Inc. Test flows ranging from 300 to 21,800 cfs were routed through the model and revealed several operational concerns. At the upstream end of the grade control structure where the weir transitioned to the diversion approach channel entrance, severe flow separation was observed as portrayed in Figure 7, due to the angular or pointed boundary. At the 2-year (3,600 cfs) flow and above, the strong separation eddies created in the diversion approach channel immediately downstream of the point impacted into the right bank. The separation also created a standing wave in the diversion approach channel that migrated downstream toward the two bridges. The wake and separation turbulence also created a deep scour hole immediately downstream of the separation in the diversion approach channel.

Figure 7. The point at the upstream end of the diversion approach channel separating the grade control weir from the diversion approach channel.

In order to accommodate pier spacing at the UPRR Bridge, a bank offset was designed in the diversion approach channel under the UPRR Bridge. The offset, combined with two piers of the UPRR Bridge, created adverse flow conditions at discharges exceeding the 2-year return period. The velocities in the diversion approach channel negotiating the offset and encountering the two piers created an adverse flow condition resulting in a strong turbulence impacting the railroad piers. The potential for scour around the piers and along the diversion approach channel bank were determined to be excessive. The 10-year (8,600 cfs) flood flow yielded average velocities of 16.8 feet per second (fps) between the two bridges in the diversion approach channel as shown in Table 3.

Table 3. Average velocities and water surface elevations at test cross sections.

MAIN RIVER CHANNEL											
		CROSS SECTION									
		1		2		3		4		5	
		Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)
1000 cfs	Baseline										
	Modification #1										
	Modification #2	1.77	5132.0	0.00		0.00		0.00		0.00	
	Modification #3										
2 year 3600 cfs	Baseline	2.99	5134.8	2.27	5127.9	1.70	5126.7	1.98	5127.1	2.56	5126.7
	Modification #1	3.28	5132.7	2.25	5127.9	2.20	5128.0	2.36	5125.9	3.57	5127.9
	Modification #2	3.75	5134.8	2.98	5127.5	3.20	5126.5	3.46	5126.8	4.56	5126.4
	Modification #3	3.90	5134.5	3.29	5126.8	2.88	5126.8	3.24	5127.1	4.42	5126.6
10 year 8600 cfs	Baseline	5.92	5133.5	4.33	5131.2	5.02	5131.0	4.09	5131.2	5.39	5128.6
	Modification #1	5.29	5134.7	7.55	5130.6	5.30	5134.5	3.97	5123.5	3.48	5128.8
	Modification #2	6.92	5134.7	3.89	5130.7	3.75	5132.4	4.23	5130.9	4.98	5128.8
	Modification #3	6.44	5136.5	3.95	5131.9	3.86	5130.7	4.23	5131.0	6.80	5128.2

DIVERSION APPROACH CHANNEL											
		CROSS SECTION									
		1		2		3		4		5	
		Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)	Velocity (fps)	WSEL (ft)
300 cfs	Modification #3			2.28	5134.3	2.11	5127.8	2.53	5128.3	0.45	5125.6
1000 cfs	Baseline			0.00		0.00		0.00		0.00	
	Modification #1										
	Modification #2			4.49	5130.7	5.44	5130.0	3.53	5130.3	2.23	5127.5
	Modification #3										
2 year 3600 cfs	Baseline			7.43	5131.1	8.28	5130.6	6.47	5128.4	2.15	5128.1
	Modification #1			7.74	5131.1	9.21	5130.5	4.75		2.36	5128.2
	Modification #2			7.10	5131.2	9.12	5130.4	6.42	5130.8	2.74	5128.2
	Modification #3			7.86	5131.1	8.14	5130.7	5.55	5130.4	2.30	5128.0
10 year 8600 cfs	Baseline			14.47	5132.3	16.87	5130.6	8.47		3.49	5129.0
	Modification #1			13.92	5132.3	12.32	5134.2	6.83		3.26	5129.1
	Modification #2			11.47	5132.8	14.52	5133.0	6.64	5131.9	3.44	5129.0
	Modification #3			12.16	5132.2	13.83	5131.1	7.01	5131.4	3.25	5129.0

The initial grade control weir elevations tested diverted a significant volume of water to and through the diversion approach channel. At flows exceeding 1,000 cfs, debris was diverted to and remained in the diversion approach channel where it was trapped by the trash rack at the Franklin Street Bridge. When discharges approached or exceeded the 10-year return period level, debris was transported over the trash rack and downstream in the diversion approach channel to the trash rack located immediately upstream of the regulation head gates. Debris was also swept across the separation weir (between the diversion approach channel and the river channel) where it was detained or deposited on the riprap revetment at flows under the 10-year return period. Debris was returned to the river channel at flows exceeding the 10-year return period. The tests indicated that the grade control weir required modification and the separation weir elevation warranted modification to reduce the overflow at the lower flows (less than 1,000 cfs).

The baseline testing suggested the following modifications to the model:

1. Remove the triangular point at the transition of the diversion approach channel. Blend the curve of the grade control weir into the separating weir and remove the abrupt change of flow with a filler blending to the wall downstream.
2. Raise the top elevation of the trash rack at the Franklin Street Bridge to entrap debris at the higher flows (above the 10-year return period).
3. Remove the diversion approach channel offset at the UPRR Bridge and reduce the impact of the railroad bridge piers.
4. Lower the separation weir elevation and transition into the grade control weir upstream of the Franklin Street Bridge to redirect the flow to the river during flood events.

Modification 1

The model was modified as indicated from the results of baseline testing. The diversion approach channel - river separation weir was lowered 0.5 ft in elevation. The trash rack at the Franklin Street Bridge was sufficiently raised to exceed the 10-year flood water elevation. Also, the Franklin Street Bridge trash rack was re-oriented from approximately 35 degrees to approximately a 45 degree angle to the diversion approach channel to increase the flow capacity through the rack. The Franklin Street Bridge sluice gate (designed for sediment and trash disposal) was relocated perpendicular to the trash rack with an upstream wall extending into the river channel. The sluice gate was lowered 1 foot in elevation and a recess was added to the floor of the diversion approach channel 1 foot lower thereby extending across the entire channel width upstream of the trash rack for a 16-foot width. These modifications, in conjunction with the gate openings, were intended to enhance sediment flushing from the diversion approach channel.

The upstream grade control weir (including boat chute features, fish passage features, and boater safety features) was modified by lowering the river channel centerline by 2 feet. Stop logs were used to adjust the quantity of flow into the grade control structure. The grade control alteration simulated a self regulating weir crest at the grade control entrance thereby varying the rates of flow through the grade control entrance, depending on the flood stage.

The diversion approach channel offset located adjacent to the UPRR Bridge and the bridge piers were not altered because of the conditions in which the model was constructed. However, it was determined that the offset would not impact the evaluation nor design of the downstream structures and features, and therefore did not require further modification.

The modified model was assessed under 2-year and 10-year flood event conditions. The tests indicated that a major portion of flow entered the diversion approach channel. Also entrance conditions to the diversion approach channel were improved over the baseline condition. However, a separation zone remained evident downstream of the diversion approach channel entrance where the separation weir adjoins the grade control weir. Further modifications were deemed warranted at the diversion approach channel entrance. Average velocities between the two bridges in the diversion approach channel were reduced to approximately 12 fps for the 10-year flood event and to approximately 9 fps for the 2-year flood event.

Modification 2

The separation weir between the diversion approach channel and the river channel was again lowered to increase the overflow to the river channel upstream of the Franklin Street Bridge. The center of the grade control weir remained as indicated in Modification 1.

Modification 3

The separation weir between the diversion approach channel and the river channel was adjusted such that the grade control weir near the diversion approach channel entrance was slightly lowered while the separation weir elevation near the Franklin Street Bridge was slightly elevated. This adjustment was prescribed to enhance the overtopping of the weir further upstream and thereby flush diverted debris.

The hard boundary in the vicinity of the Franklin Street Bridge piers was removed and coarse sand was placed in this region to the elevation of the river bed hard boundary. This was performed to evaluate the potential for scour in the vicinity of the bridge piers as a result of flushing operations from the nearby sluice gate.

To simulate moving the Franklin Street Bridge sluicegate and trash rack upstream 20 feet from their original location, the bridge piers were shortened by 20 feet. While this was not a perfect simulation of the velocities in the region of the piers, it was believed that this would adequately demonstrate the scour potential when moving the sluice gate upstream.

Testing Program Results

The model of the South Platte River adjacent to the Franklin Street Bridge, UPRR Bridge, and the diversion approach channel as previously described through Modification 3 was extensively tested for flows of 300, 1,000, 3,600 (2-year), 8,600 (10-year), 17,300 (50-year), and 21,800 (100-year) cfs flows. The resulting average velocities and water surface elevations for both the diversion approach channel and the river channel are presented in Table 3. Additional information is presented in Appendices A and B.

The design of the new structures, features and system components divert the entire river flow, up to 1,000 cfs, into the diversion approach channel to insure that the Canal receives its authorized flow. Flows begin to overflow the separation weir and return to the river channel when exceeding 1,000 cfs. It was observed that the velocities in the diversion approach channel range from approximately 2.5 fps for a flow of 300 cfs to nearly 14 fps for a flow of 8,600 cfs (10-year). Average velocities in the river channel range from approximately 4 fps at a discharge of 3,600 cfs to nearly 7 fps at a discharge of 8,600 cfs.

Debris Observations

A series of tests was performed focusing on how debris will be transported through the study reach during 2-year and 10-year flood events. Figure 8 portrays a typical debris buildup on the trash rack resulting from a 2-year flood event. The tests indicated that of the total debris load entering the reach, approximately 80 percent of the debris entered the diversion approach channel with 20 percent remaining in the river channel. Of the debris transported down the diversion approach channel, approximately half was washed/flushed over the separation weir and returned to the main river channel upstream of the Franklin Street Bridge trash rack. Of the debris remaining in the diversion channel, 15 to 30 percent was trapped on the Franklin Street Bridge trash rack. The remaining debris was either trapped on the separation weir downstream of the Franklin Street Bridge or at the trash rack at the regulation head gates.

The model results indicate that the separation weir and Franklin Street Bridge trash rack are efficient in trapping debris and will significantly reduce the amount of debris approaching the regulation head gates. Further, the sluice gate adjacent to the Franklin Street Bridge will enhance returning the debris entrapped on the trash rack. However, the sluicing operation will not eliminate the need for periodic maintenance. It was observed that the Franklin Street Bridge trash rack will not trap all debris in the diversion approach channel. Based upon the model test results, the expected debris load at the regulation head gates should not exceed current (pre-construction) levels and, most probably, will be reduced in future operations.

Figure 8. Debris and trash trapped on trash rack and weir top, 2-year flood event.

Scour Tests

The placement of the Franklin Street Bridge trash rack in conjunction with the sluice gate used to return flow, flush sediment, and flush trash back to the main river channel created concern for scour potential near the piers of the Franklin Street Bridge. In the event that the sluice gate would be open during a flood event, high velocity flows from the sluice gate could potentially impact the upstream edge of the nearest bridge pier. To evaluate the potential for scour around the bridge pier, a section of the hard boundary in the vicinity of the bridge was removed and replaced with compacted coarse sand. A series of tests was performed to evaluate the pier scour potential of the Franklin Street Bridge with the sluice gate closed and then with the sluice gate operational. The scour holes resulting from these conditions could be compared to assess the scour impact from the sluice gate.

After extensive testing, is was determined that significant scour was observed during flows of 1,000 cfs and the 2-year flood event. Discharges greater than the 2-year flood event resulted in a high tailwater condition that reduced the elevation differential between the diversion approach channel and the main river channel. The higher tailwater conditions in the river at flows greater than 3,600 cfs tended to dissipate the energy of the jet derived from the sluice gate. Simultaneously, the reduced elevation differential substantially reduced the energy of the jet. Based on the results of the model tests, the 2-year flood events was considered the worse case condition for scour around the bridge piers.

Scour tests were run with the sluice gate between the diversion approach channel and the river channel placed completely open. The first test for scour resulted in a large hole created immediately downstream of the sluice gate. The scour hole was then replaced with large rocks mortared together to prevent the hole from further eroding. Additional testing indicated that the hole continued to erode outside of the perimeter of the hole's hard boundary. The hard boundary was then reformed to the dimensions of the larger hole, which equated to approximately a 40-feet radius extending from the sluice gate. The scour hole was then stabilized adjacent to the sluice gate outlet thereby preventing further scour.

Additional tests were performed to fully evaluate the scour potential at the Franklin Street Bridge piers. At a flow of 1,000 cfs, the scour was confined to the upstream end of the pier directly in front of the sluice gate outlet as portrayed in Figure 9. The scour hole was centered directly in front of the pier and was approximately 3.5 feet in length by 1.5-feet wide. The hole was only about 1-foot deep at the deepest point. Another hole formed at the edge of the hard boundary basin directly in line with the pier. This hole was larger in extent than the hole near the pier and was approximately 4-feet deep. Scour was also observed along the right side of the pier (looking downstream) extending downstream about 2 to 3 feet.

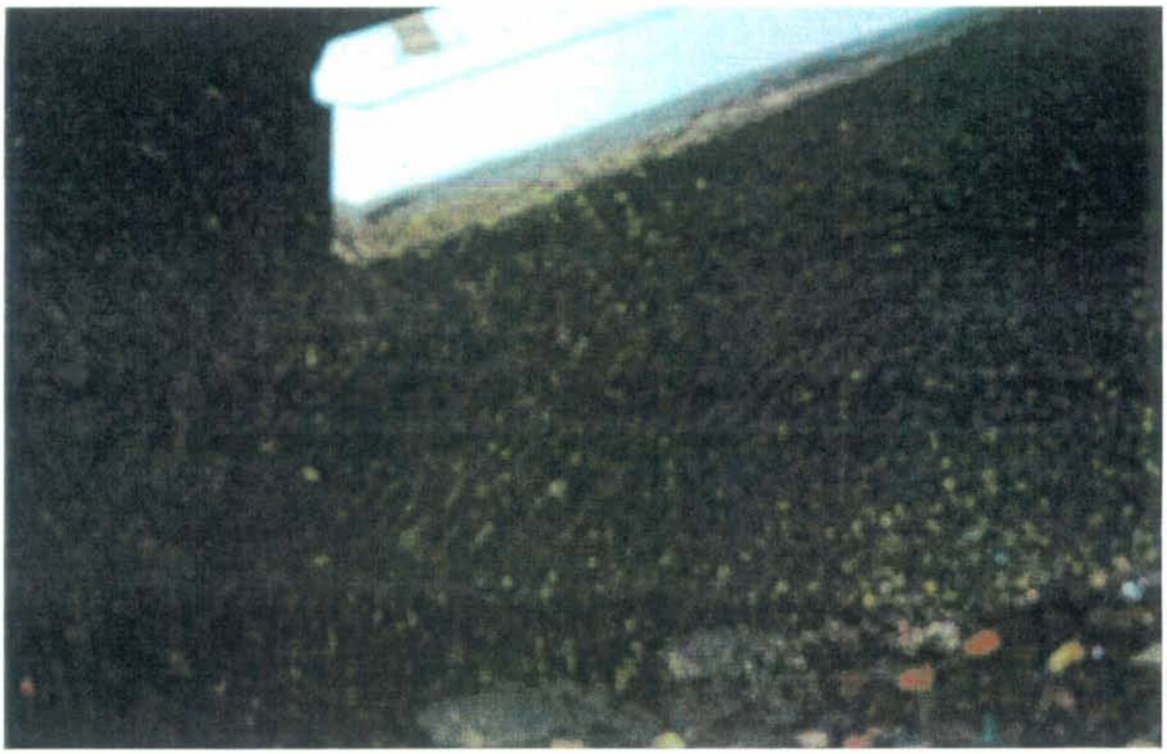


Figure 9. Scour at front of pier for 1,000 cfs flow rate, sluice gate at Franklin Street wide open, 300 cfs flow in canal.

The 2-year flood event created a scour hole that was considerably larger than observed after the 1,000 cfs event as observed in Figures 10 and 11. The scour hole extended from the edge of the hard boundary to the nose of the pier. This hole was 4- to 5-feet deep and approximately 20-feet wide extending to the nose of the pier. Scour

Figure 10. Pier scour with the 2-year flood event, sluice gate at Franklin Street wide open, 300 cfs flow in the canal. Piers are shortened by 20 feet.

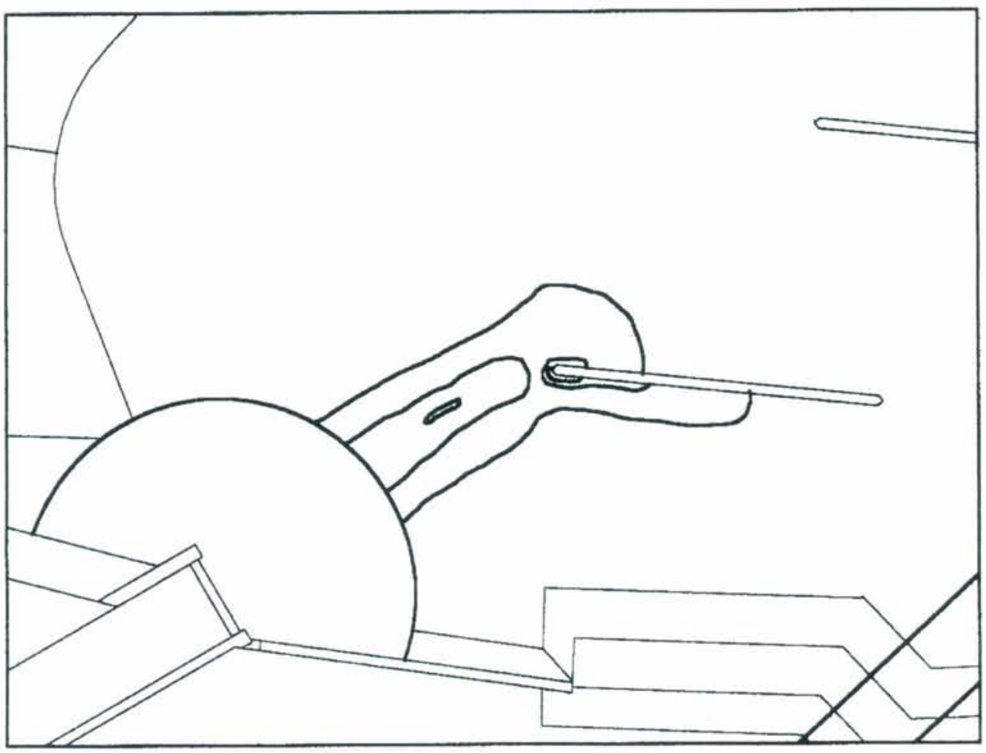


Figure 11. Scour pattern around the bridge pier, 2-year flood. Two foot contours.

extended along the right edge of the pier downstream approximately 20 feet and was measured to be approximately 5-feet deep at the upstream end. The left side of the pier (looking downstream) had only slight scour.

After the piers were shortened by 20 feet, the scour tests were re-run for the 1,000 cfs flow and for the 2-year flood. At 1,000 cfs, the scour around the bridge pier was substantially reduced. However, for the 2-year flood event the scour hole created was dramatically larger than for the previous tests, as shown in Figure 12. The scour hole extended down 10 feet in depth from the gate to a point upstream of the bridge pier. It appears that when the gate is located closer to the pier, a portion of the velocity energy is diverted downstream by the east face of the pier. With the gate located 20 feet upstream, the jet discharged uniformly from the gate and eroded a deeper hole.

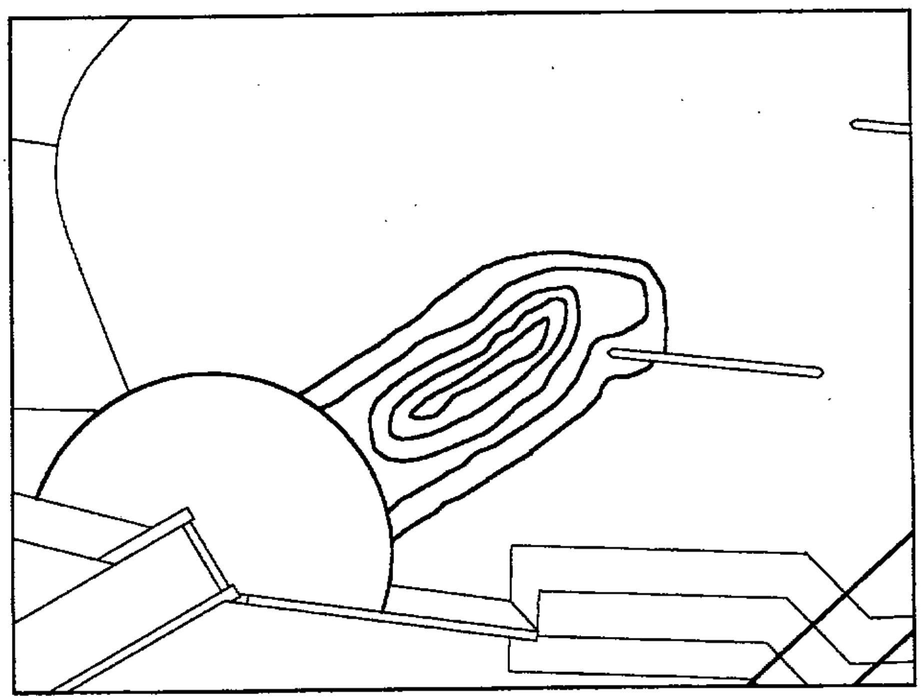


Figure 12. Scour pattern around the bridge pier after piers were shortened by 20 feet, 2-year flood. Two foot contours.

Scour tests were performed for the 10-year and 100-year flood events. However, the tailwater conditions were elevated to where the energy from the sluice gate jet was dissipated and the scour potential was reduced below the 2-year flood event level. In fact, the model tests indicated that the 2-year flood event scour hole was considerably larger than any other flood condition, particularly with the sluice gate in operation. The maximum scour hole observed was formed at the edge of the hard boundary pool to the upstream nose of the pier. The hole was approximately 10-feet deep along the entire length from the sluice gate outlet to the bridge pier. Scour extended around the left side of the pier at a 20-feet radius and to a 3-feet depth. Scour along the right side of the pier was moderate extending to a depth of 1.5 feet and continuing downstream approximately 5 feet.

The pier scour tests indicate that the placement of the Franklin Street Bridge sluice gate enhances the scour potential of the easterly pier of the Franklin Street Bridge. Therefore, a protective revetment is warranted at the outlet of the Franklin Street Bridge sluice gate and adjacent to the nose and right side (looking downstream) of the easterly bridge pier.

Ice Test Assessment

The approach and upstream pool adjacent to the regulation head gates controlling flow to the Canal channel are currently exposed to icing conditions during winter operation. It was assumed that the pool adjacent to the regulation head gates will not be altered from existing conditions. Therefore, an evaluation of icing impacts on the regulation head gates was not performed. However, a series of tests was conducted to assess how icing may impact flows and ice debris that enter the diversion approach channel, that are trapped at the Franklin Street Bridge trash rack and that are trapped at the trash rack adjacent to the regulation head gates. The tests focused on flows of 400 cfs or less.

To approximate icing conditions in the diversion approach channel and the trash racks, floating materials (plywood and block ice) and non-floating materials (masonite) were used to simulate channel blockage. Plywood, and in some cases both plywood and masonite materials were placed immediately upstream of each trash rack and the flow blockage was evaluated. For example, plywood and masonite were inserted in the flow at the regulation head gate trash rack as indicated in Figure 13. The head loss across the blockage was then recorded. Also, ice blocks were placed into the diversion approach channel both at the regulation head gate trash rack and the Franklin Street Bridge trash rack to assess ice blockage. Figure 14 illustrates the ice placed upstream of the Franklin Street Bridge trash rack.

Test results indicated that sufficient flow area was provided to allow the delivery of flow to the regulation head gate for every blockage condition simulated in the model for low flow conditions. The maximum prototype head differential at the Franklin Street Bridge trash rack due to the ice blockage was approximately 0.6 feet. This head loss is considered minimal considering the structure size and extended range of flows evaluated.

Flow will pool adjacent to the regulation head gates in both the pre-construction and post-construction conditions. Based upon the model results, any icing occurring during the post-construction condition should not exceed that of pre-construction since there is minimal modification to the pool area. Further, icing that may occur at the trash racks should not fully block the channel nor substantially hinder the delivery of flow beyond that currently experienced in the pre-construction condition.

There is the potential that floating ice debris from the South Platte River channel will be diverted into the diversion approach channel, particularly during low flow conditions. The model results indicate that once the Franklin Street Bridge trash rack ices, the floating ice debris will be trapped and not allowed to pass downstream toward the regulation head gate trash rack. Therefore, the impact of icing related to floating ice debris should be equal to or less than current icing conditions.

Sediment Impacts

Siltation in the diversion approach channel must be evaluated to assess the long-term operational maintenance requirements. Therefore, a series of tests was performed to qualitatively evaluate the potential siltation impacts at the diversion approach channel entrance, in the channel, and adjacent to the regulation head gates. Flows of 1,000 cfs, the 2-year flood event, and the 10-year flood event served as baseline events for the evaluation. Fine sediments were injected near the baffle as the flow entered the model for

Figure 13. Plywood sheets to simulate ice buildup against the canal head gates trash rack.

Figure 14. Using thin ice sheets to simulate ice buildup at the Franklin Street trash rack.

several hours during each test. Generally, transported sediments were observed to divide between the river channel and the diversion approach channel when the discharge was 1,000 cfs or greater. Sediment deposition was observed in areas where secondary circulation, flow separation, or low velocities (less than approximately 3 fps) routinely occurred.

During the 1,000 cfs flow with 1,000 cfs diversion at the regulation head gate, the entire sediment load was transported through the diversion approach channel. Deposits were observed near the entrance to the diversion approach channel, upstream of the Franklin Street Bridge trash rack and sluice gate, and in the pool area that forms upstream of the regulation head gates. Sediments were also observed adjacent to the separation weir in the diversion approach channel.

Sediments were injected into the model during the 2-year flood event in a manner similar to that described for the 1,000-cfs condition. Sediments were observed to be transported through both the river channel and the diversion approach channel. It is estimated that approximately 40 percent of the sediment migrated through the river channel while the remaining sediments were transported through the diversion approach channel. After several hours of operation, sediments were observed to deposit throughout the diversion approach channel as observed in Figure 15. Sediment deposits were observed adjacent to the Franklin Street Bridge trash rack and sluice gate, adjacent to the UPRR Bridge, and in the diversion approach channel upstream of the regulation head gates as portrayed in Figure 16.

The 10-year flood event was routed through the model while sediments were injected similar to the 1,000 cfs and 2-year flood events. Sediment deposition occurred in the same areas described for the 2-year flood condition. However, the sediment transport split between the river channel and the diversion approach channel was observed to be approximately 60 percent and 40 percent, respectively. The higher velocities and flow depths upstream of the diversion approach channel entrance tranported a greater portion of the sediment through the river channel, the river flow was not as strongly influenced by the diversion as observed at the lower flood events. Further, the relatively high velocities in the diversion approach channel overtopped the separation weir returning a portion of

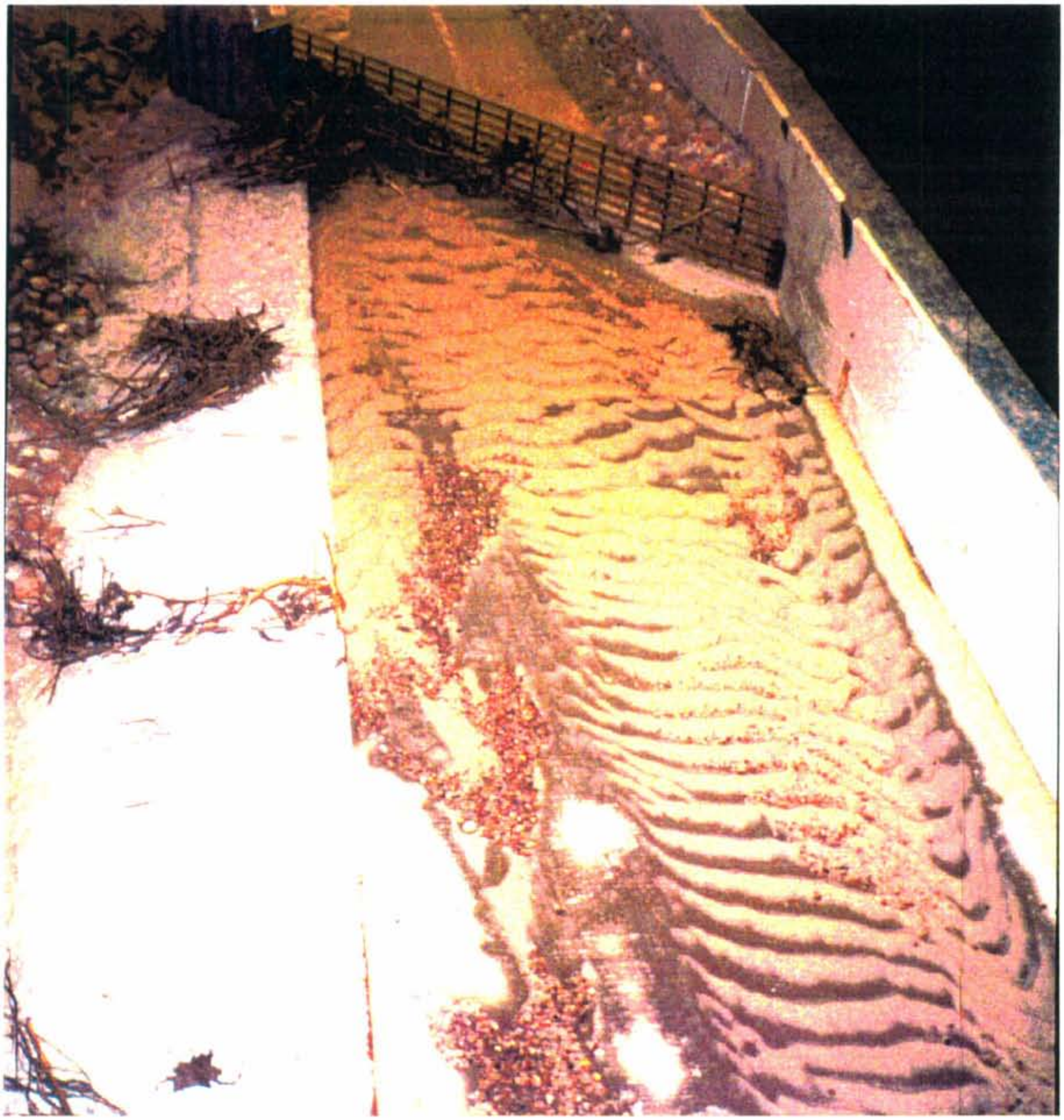


Figure 15. Sediment deposition in the diversion approach channel for the 2-year flood event.

Figure 16. Sediment deposition at canal regulation head gates for 2-year flood event.

the transported sediments to the river channel. Therefore, sediment deposits were significantly smaller than those observed for the 1,000 cfs and 2-year flood events as presented in Figures 17 and 18.

One test was conducted in which the discharge was approximately 300 cfs, and the entire flow was diverted into the diversion approach channel. Fine sediments were injected into the flow similar to the previously described tests. The vast majority of the sediments were deposited at the diversion approach channel entrance. The low average velocities (approximately 2 fps) were incapable of transporting the fine sand through the diversion approach channel. Sediment deposition was not observed in the diversion approach channel. It is recognized that fine silts and clays may be transported at these low velocities. However, sand particles and larger grain sizes will not be transported at extremely low flow rates of 300 cfs or lower.

At the conclusion of each of the sediment loading tests performed at the prescribed flood events, the sluice gates (sand out gates) were opened and operated to flush the sediments from the diversion approach channel back to the river channel. In every case, the sluice gates were observed to effectively flush sediments in the immediate gate area. Based on the testing program, it is recommended that the Franklin Street Bridge sluice gate be operated on a routine schedule, particularly during higher flows, to reduce the sediments transported downstream to the pooling area adjacent to the regulation head gates. The routine flushing of sands occur at the existing sluice gates (located adjacent to the regulation head gates) may be moved upstream to the Franklin Street Bridge sluice gates. The sluicing operations at the regulation head gate sluice should be significantly reduced.

These test results indicate that sediments will deposit in the diversion approach channel. However, with effective use of the sluice gates located at the Franklin Street Bridge and near the regulation head gates, sediments can be managed through periodic flushing and through flushing during high flows in the river. It should be recognized that the flushing maintenance will not eliminate the need for periodic dredging. But, sluice gate operations should help manage the sediment load to a level that will not exceed, and more likely, be lower than current levels at the regulation head gate sluice.

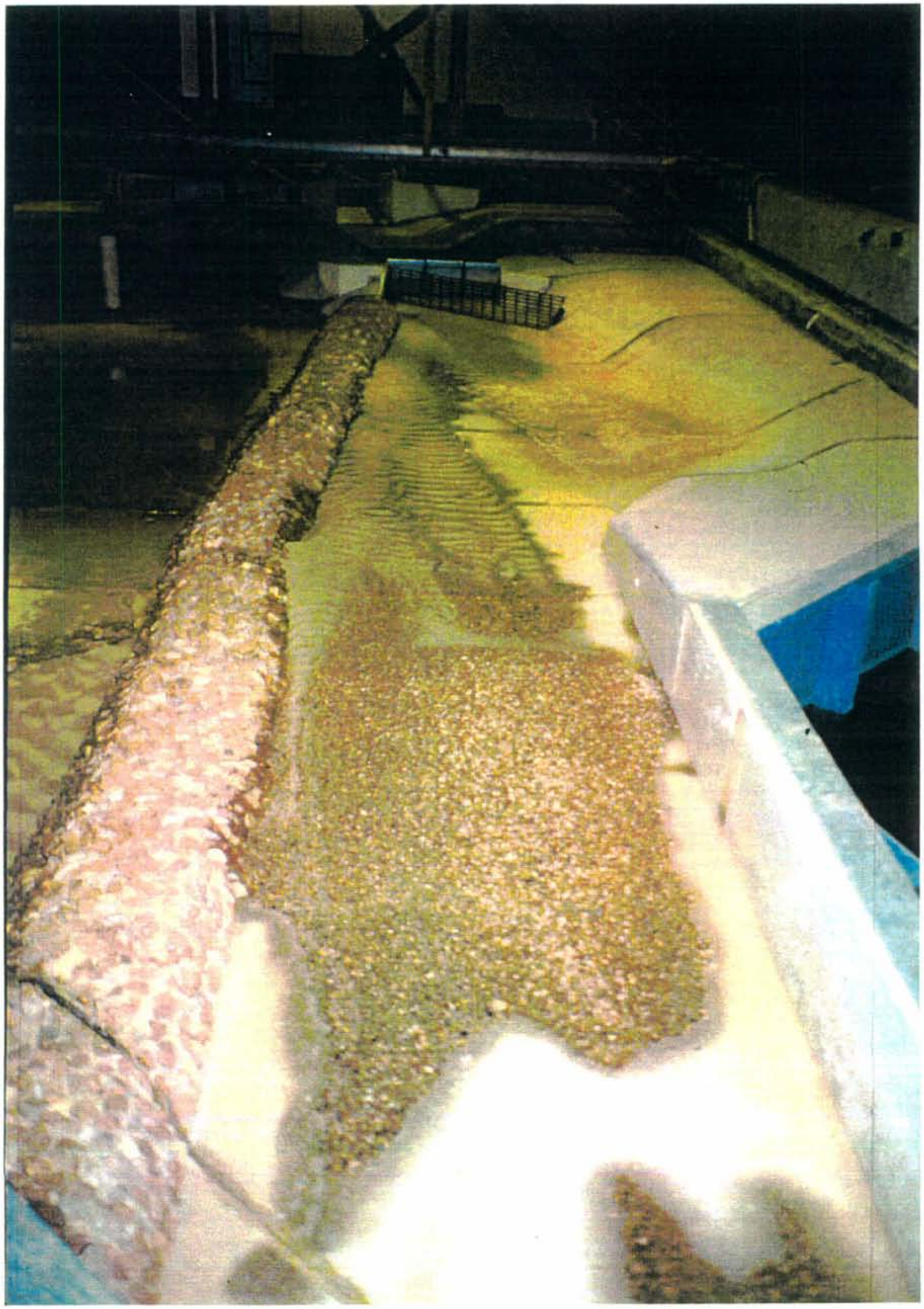


Figure 17. Siltation in the diversion approach channel with the 10-year flood event.

Figure 18. Siltation in the diversion approach channel with the 10-year flood event.

Sediment transport and deposition in the diversion approach channel will be a concern in the delivery of flow to the Canal. Transport and deposition of sediments will most significantly affect diversion approach channel operations during flow conditions of 1,000 cfs up to the 2-year flood event.. It is projected that the sediment load can be managed through effective use of the sluice gates located at the Franklin Street Bridge and adjacent to the pool area upstream of the regulation head gates.

The results of the test program indicate that the 2-year flood event was considered the worst case scenario for sediment deposition in the diversion approach channel. When the flow was 1,000 cfs or less, sand transport in the diversion approach channel was minimal, and in most cases not observed. When flow exceeded the 2-year event, a lower percentage of the sediment was diverted into the diversion approach channel. In most cases, sediments were transported from the diversion approach channel to the river channel as flow spilled over the separation weir.

CONCLUSIONS AND RECOMMENDATIONS

1. The separation weir between the grade control weir upstream face and the diversion approach channel should be smoothly blended so that the flow entering the diversion approach channel does not separate, nor create standing waves or eddies at this location.
2. The grade control weir entrance and the separation weir upstream of the Franklin Street Bridge should be lower than the downstream weir by approximately 0.5 feet. This will allow the 1,000 cfs flow to enter in the diversion approach channel. However, during flood events, a greater portion of the flow will remain in the main river channel or return to the main river channel. In addition, a greater portion of the debris will remain in the river channel when flows exceed 1,000 cfs.
3. A lower floor recess should be considered in the diversion approach channel upstream of the Franklin Street Bridge trash rack at approximately the same elevation as the gate opening invert. The floor recess will enhance the removal of sand from the diversion approach channel to the river during sluicing operations. If needed after project construction, additional investigation should be performed to determine the features that can be added to the floor recess to encourage sluicing of sand under the gate.
4. The right bank offset in the diversion approach channel in the vicinity of the UPRR Bridge creates unsatisfactory flow conditions in this segment of the diversion approach channel. It is recommended that the offset be removed. The present plan for pier spacing of the railroad bridge (different than modeled) will allow for removal of this offset.
5. Simulation of ice flows in the diversion approach channel during low flows indicated that sufficient flow reached the regulation head gates during icing at the trash racks. The diversion channel was capable of delivering sufficient flow to meet the required flow demands with minimal water surface increase. Model operations indicate that ice blockages in the diversion approach channel did not reduce the available head at the regulation head gates.

6. The pedestrian bridge pier created no adverse effects in the river flow.
7. The sluice gate located upstream of the Franklin Street Bridge significantly impacts the scour potential at and near the bridge piers. Moving the gate 20 feet upstream did not significantly reduce the scour potential and may potentially increase the extent of scour. Scour protection for the bridge piers will be required throughout the life of the bridge. It is recommended that the sluice gate be returned to its originally proposed location. Further, a basin of riprap or similar material should be placed in the river at the outlet of the Franklin Street Bridge sluice gate.
8. Siltation tests indicate that sediment will deposit along the entire length of the diversion approach channel and near the regulation head gates. The development of appropriate sluice gate flushing operations will reduce the long-term maintenance requirements.
9. The boat chute component of the grade control structure appeared to operate in a satisfactory manner during flood events. Large reverse rollers were not observed and the standing waves that developed at high flood events did not transition to reverse flows or undertow conditions. The structure provided for a safe boater environment and for fish passage when flows permitted.
10. Trash racks, located at the Franklin Street Bridge and upstream of the regulation head gates, were effective in trapping debris during flood events. The efficiency of the Franklin Street Bridge trash rack increased when raised to a height above the 10-year flood event surface water elevation. Little trash and debris was transported downstream of the Franklin Street Bridge trash rack. The debris that was not trapped by the Franklin Street Bridge trash rack either returned to the river channel over the separation weir or was trapped on the regulation head gate trash rack. The model results indicate that the debris accumulated upstream of the Franklin Street trash rack was effectively (approximately 40 to 60%) flushed to the river channel when the regulation head gates were closed and the upstream sluice gates were fully opened.
11. The diversion approach channel and the regulation head gates maintained sufficient flow to meet the Canal flow requirements under all conditions tested.

12. Model operations indicated that the proposed Globeville design modifications reduced the head variability at the Canal regulation head gates. The reduction in head variability was applicable for all river stages tested and resulted in an improved flow uniformity for specific gate openings. Also, the Canal did not flood during any flood event tested in the model.

APPENDIX A

CROSS SECTION VELOCITY DATA

Velocity Profiles 11 June 98
flow 3600

xsec 1

model feet	actual feet	velocity
4	80	0
6.5	130	3.595553
9	180	2.68561
11	220	2.692582

xsec1 avg 2.991248

xsec 2

	model feet		Velocity ft/s
	1.666667	33.33333	0
	3.083333	61.66667	2.54951
	4.083333	81.66667	3.106445
	5.75	115	2.408319
	7	140	1.30384
	8.083333	161.6667	0.316228
embank	9.75	195	2.529822
embank	10.83333	216.6667	3.687818
ditch	12.5	250	7.211103
ditch	14.16667	283.3333	7.641989

xsec2 avg 2.271712
ditch 7.426546

xsec3

	model feet		Velocity ft/s
	1.5	30	0
	2.583333	51.66667	2.280351
	3.333333	66.66667	1.5
	4.333333	86.66667	2.828427
	5.5	110	2
	6.833333	136.6667	0.921954
	8.166667	163.3333	1.360147
	9.583333	191.6667	1
ditch	12.25	245	7.924645
ditch	13.91667	278.3333	8.637129

xsec3 avg 1.698697
ditch 8.280887

xsec 4

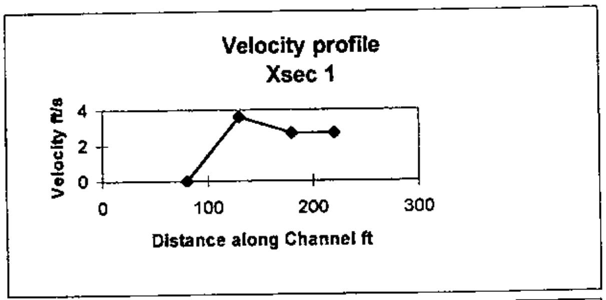
	model feet		Velocity ft/s
	1.75	35	
	3	60	3.605551
	4.416667	88.33333	2.607681
	5.916667	118.3333	1.843909
	7.5	150	1.360147
	9.25	185	0.5
ditch	11.75	235	9.219544
ditch	13	260	9.848858
ditch	13.75	275	5.813777
ditch	14.91667	298.3333	1

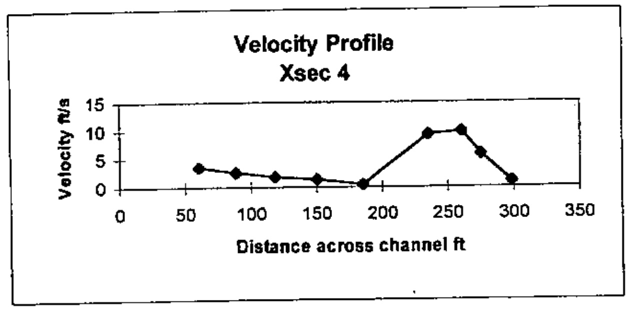
xsec4 avg 1.983458
ditch 6.470545

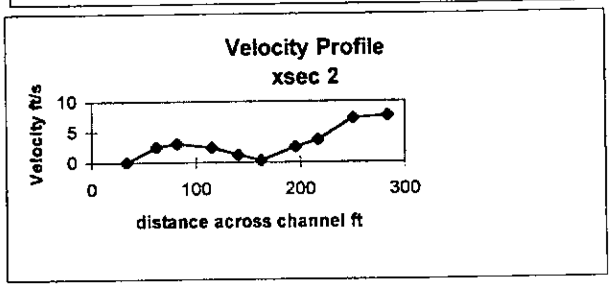
xsec 5

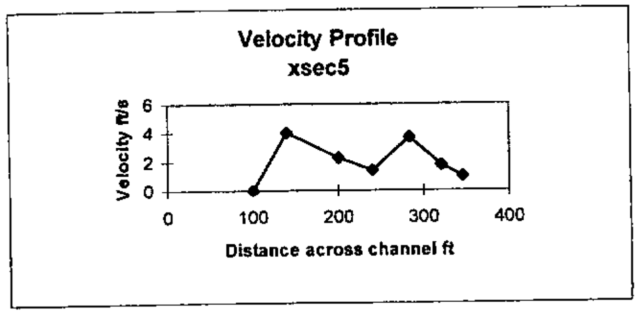
feet	prototype	Velocity
5	100	0
7	140	4.031129
10	200	2.247221
12	240	1.414214
14.16667	283.3333	3.695673
16	320	1.746425
17.25	345	1

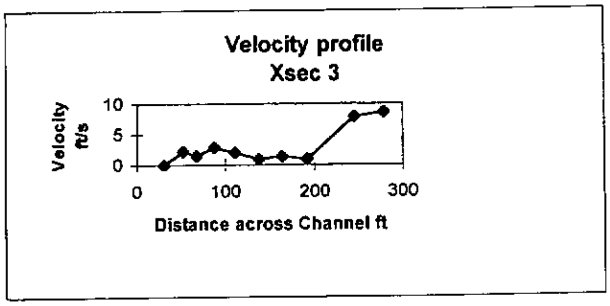
xsec5 avg 2.564188
ditch 2.147366











11 June 1998
2 year flood event

Velocity Profiles 11 June 1998
flow 8600

xsec 1

model feet	actual feet	velocity
4	80	5.656854
6.5	130	6.228965
9	180	5
11	220	6.811755

xsec 1 avg 5.924393

xsec 2

	model feet		Velocity ft/s
	1.666667	33.33333	0.5
	3.083333	61.66667	6.60303
	4.083333	81.66667	5.830952
	5.75	115	5.09902
	7	140	3
	8.083333	161.6667	3.847077
embank	9.75	195	4.219005
embank	10.83333	216.6667	5.531727
ditch	12.5	250	14.8054
ditch	14.16667	283.3333	14.14214

xsec2 avg 4.328851
ditch 14.47377

xsec3

	model feet		Velocity ft/s
	1.5	30	4.472136
	2.583333	51.66667	10.43072
	3.333333	66.66667	5.531727
	4.333333	86.66667	5
	5.5	110	3.820995
	6.833333	136.6667	3.605551
	8.166667	163.3333	4.669047
	9.583333	191.6667	2.607681
ditch	12.25	245	16.27882
ditch	13.91667	278.3333	17.46425

xsec3 avg 5.017233
ditch 16.87153

xsec 4

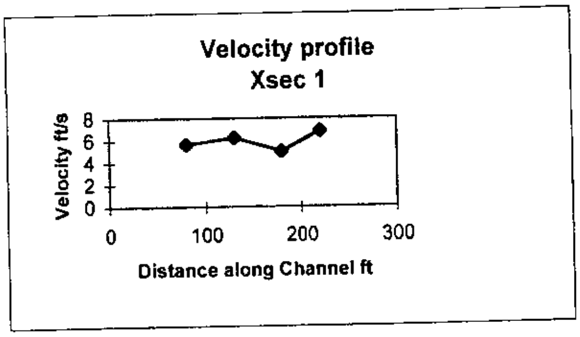
	model feet		Velocity ft/s
	1.75	35	6.276942
	3	60	5.440588
	4.416667	88.33333	4.669047
	5.916667	118.3333	3.162278
	7.5	150	2.720294
	9.25	185	2.247221
ditch	11.75	235	12.81405
ditch	13	260	13.42386
ditch	13.75	275	6.648308
ditch	14.91667	298.3333	1

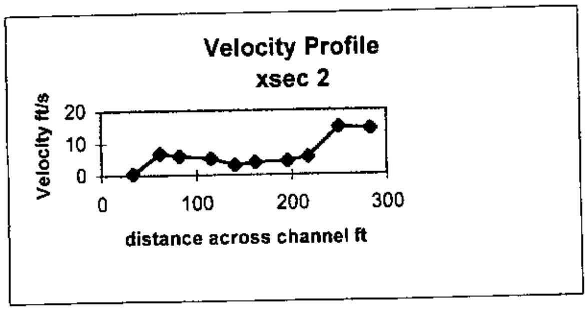
xsec4 avg 4.086062
ditch 8.471556

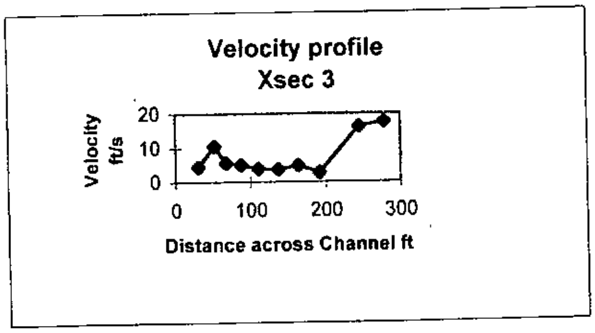
xsec 5

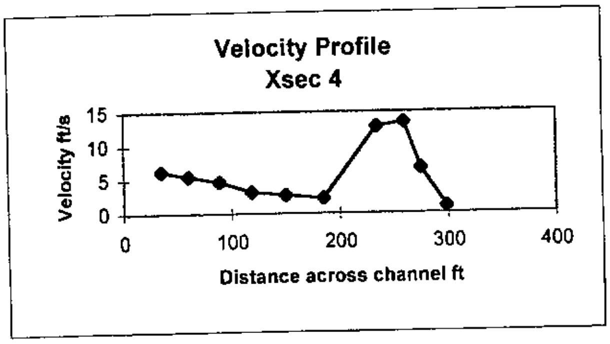
feet	prototype	Velocity
5	100	0
7	140	6.826419
10	200	5.215362
12	240	4.123106
14.16667	283.3333	7.224957
16	320	1.843909
17.25	345	1.414214

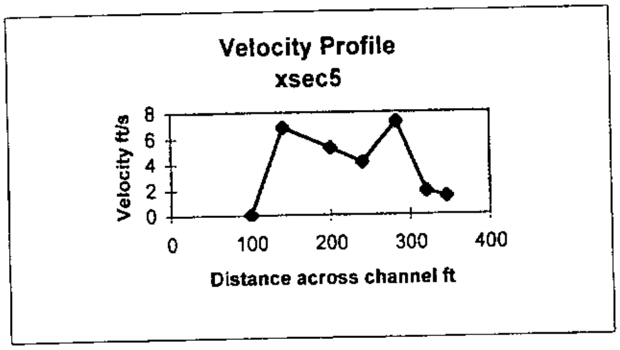
xsec5 avg 5.388296
ditch 3.49436











11 June 1998
10 year flood event

Velocity Profiles 18 August 1998
flow 3600

xsec 1

model feet	actual feet	velocity
4	80	3.69
6.5	130	4.12
9	180	4.12
11	220	1.20

xsec 1 avg 3.28

xsec 2

	model feet	actual feet	velocity
	1.67	33.33	0.00
	3.08	61.67	4.24
	4.08	81.67	4.40
	5.75	115.00	2.83
	7.00	140.00	2.41
	8.08	161.67	1.00
embank	9.75	195.00	0.45
embank	10.83	216.67	0.45
ditch	12.50	250.00	8.21
ditch	14.17	283.33	7.28

xsec 2 avg 2.25
ditch 7.74

xsec3

	model feet	actual feet	velocity
	1.50	30.00	0.00
	2.58	51.67	3.20
	3.33	66.67	3.16
	4.33	86.67	3.32
	5.50	110.00	2.24
	6.83	136.67	1.84
	8.17	163.33	1.00
	9.58	191.67	0.63
ditch	12.25	245.00	8.81
ditch	13.92	278.33	9.60

xsec 3 avg 2.20
ditch 9.21

xsec 4

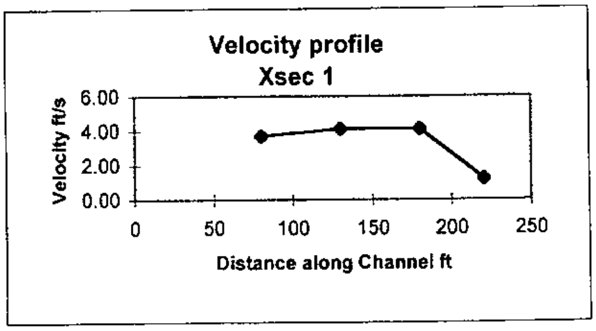
	model feet	actual feet	velocity
	1.75	35.00	0.00
	3.00	60.00	4.00
	4.42	88.33	3.69
	5.92	118.33	1.79
	7.50	150.00	1.34
	9.25	185.00	1.00
ditch	11.75	235.00	8.44
ditch	13.00	260.00	2.00
ditch	13.75	275.00	6.02
ditch	14.92	298.33	2.53

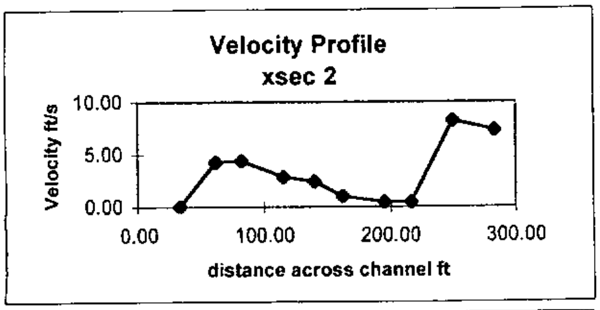
xsec 4 avg 2.36
ditch 4.75

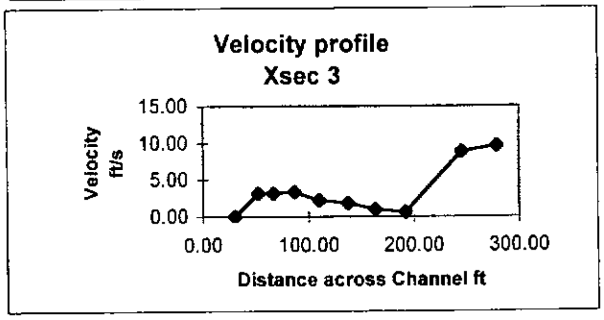
xsec 5

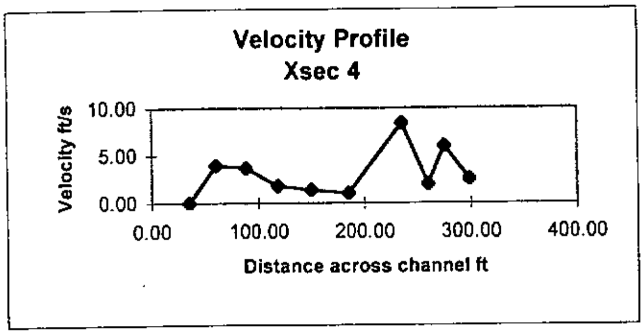
model feet	actual feet	velocity
5	100	0.00
7	140	5.69
10	200	2.41
12	240	2.61
14.17	283.33	4.30
16	320	1.84
17.25	345	0.92

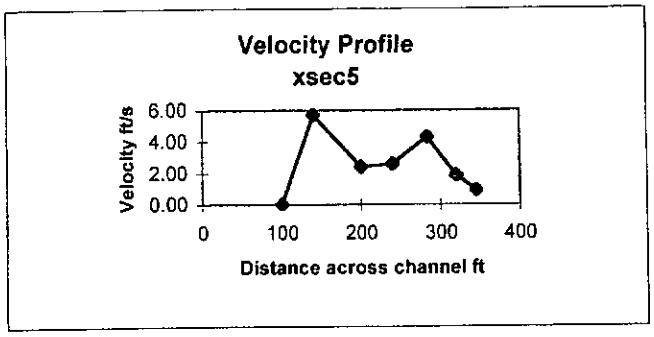
xsec 5 avg 3.57
ditch 2.36











18 August 1998
2 year flood event

Velocity Profiles 18 August 1998
flow 8600

xsec 1

model feet	actual feet	velocity
4	80	4.12
6.5	130	5.10
9	180	8.35
11	220	3.58

xsec 1 avg 5.29

xsec 2

	model feet		Velocity ft/s
	1.67	33.33	8.50
	3.08	61.67	9.63
	4.08	81.67	9.00
	5.75	115.00	4.03
	7.00	140.00	5.40
	8.08	161.67	6.60
embank	9.75	195.00	6.60
embank	10.83	216.67	10.60
ditch	12.50	250.00	16.38
ditch	14.17	283.33	11.45

xsec 2 avg 7.55
ditch 13.92

xsec3

	model feet		Velocity ft/s
	1.50	30.00	6.99
	2.58	51.67	1.84
	3.33	66.67	2.00
	4.33	86.67	5.39
	5.50	110.00	2.68
	6.83	136.67	5.73
	8.17	163.33	8.54
	9.58	191.67	9.21
ditch	12.25	245.00	13.60
ditch	13.92	278.33	11.05

xsec 3 avg 5.30
ditch 12.32

xsec 4

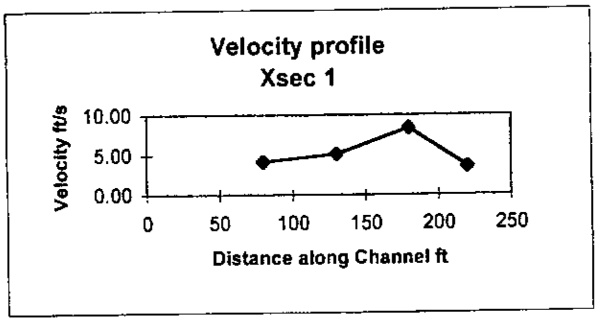
	model feet		Velocity ft/s
	1.75	35.00	0.00
	3.00	60.00	5.66
	4.42	88.33	4.82
	5.92	118.33	4.12
	7.50	150.00	3.41
	9.25	185.00	1.84
ditch	11.75	235.00	11.81
ditch	13.00	260.00	11.70
ditch	13.75	275.00	2.41
ditch	14.92	298.33	1.41

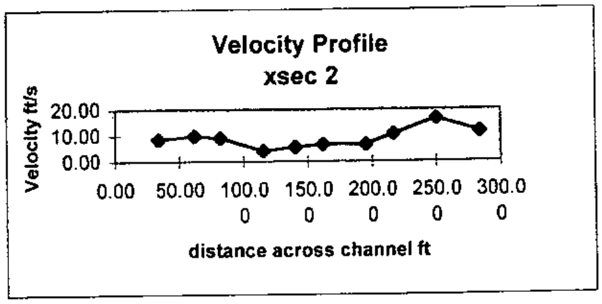
xsec 4 avg 3.97
ditch 6.83

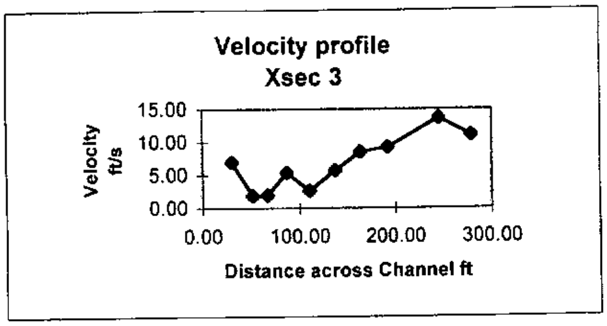
xsec 5

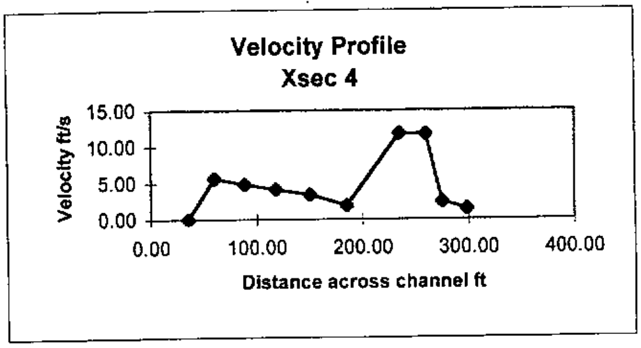
feet	prototype	Velocity
5	100	0.89
7	140	4.94
10	200	4.49
12	240	3.61
14.17	283.33	6.65
16	320	0.89
17.25	345	2.25

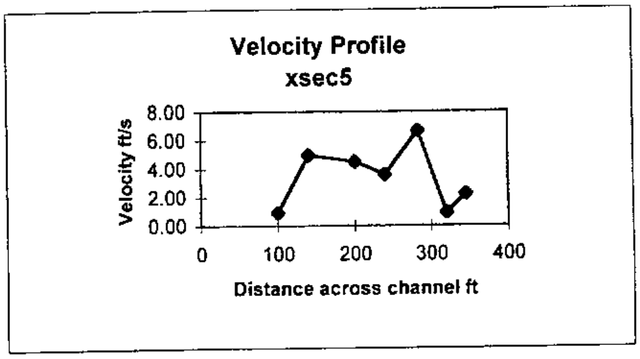
xsec 5 avg 3.48
ditch 3.26











18 August 1998
10 year flood event

Velocity Profiles 13 October 1998
flow 1000

xsec 1

model feet	actual feet	velocity
4	80	0.00
6.5	130	1.90
9	180	2.00
11	220	1.41

x sec1 avg 1.77

xsec 2

	model feet		Velocity ft/s
	1.67	33.33	0.00
	3.08	61.67	0.00
	4.08	81.67	0.00
	5.75	115.00	0.00
	7.00	140.00	0.00
	8.08	161.67	0.00
embank	9.75	195.00	0.00
embank	10.83	216.67	0.00
ditch	12.50	250.00	4.22
ditch	14.17	283.33	4.75

x sec2 avg ditch 4.49

xsec3

	model feet		Velocity ft/s
	1.50	30.00	0.00
	2.58	51.67	0.00
	3.33	66.67	0.00
	4.33	86.67	0.00
	5.50	110.00	0.00
	6.83	136.67	0.00
	8.17	163.33	0.00
	9.58	191.67	0.00
ditch	12.25	245.00	5.22
ditch	13.92	278.33	5.66

x sec3 avg ditch 5.44

xsec 4

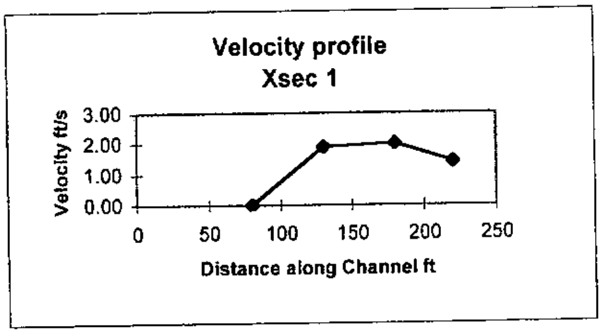
	model feet		Velocity ft/s
	1.75	35.00	0.00
	3.00	60.00	0.00
	4.42	88.33	0.00
	5.92	118.33	0.00
	7.50	150.00	0.00
	9.25	185.00	0.00
ditch	11.75	235.00	5.00
ditch	13.00	260.00	5.66
ditch	13.75	275.00	2.53
ditch	14.92	298.33	0.92

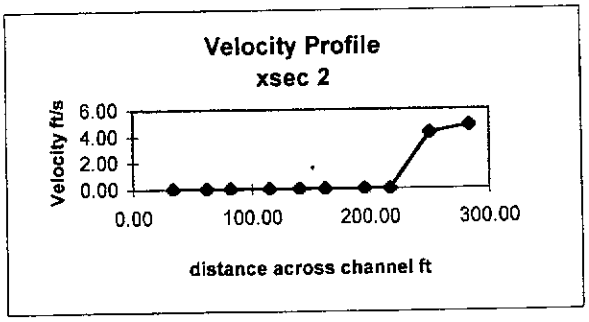
x sec4 avg ditch 3.53

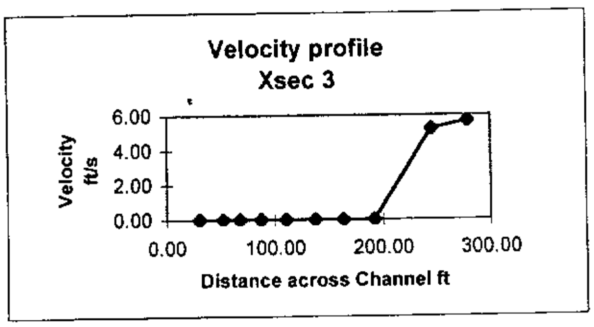
xsec 5

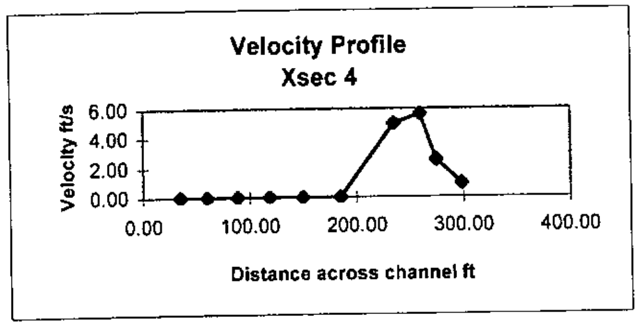
feet	prototype	Velocity
5	100	0.00
7	140	0.00
10	200	0.00
12	240	0.00
14.17	283.33	2.55
16	320	2.86
17.25	345	1.26

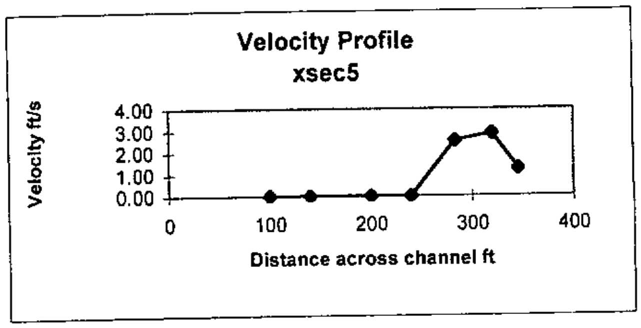
x sec2 avg ditch 2.23











13 October 1998
1,000 cfs flow rate

Velocity Profiles 13 October 1998
flow 3600

xsec 1

	model feet	actual feet	velocity
	4	80	0.00
	6.5	130	4.22
	9	180	4.79
	11	220	2.24
x sec1	**avg**		**3.75**

xsec 2

	model feet	actual feet	velocity
	1.67	33.33	0.00
	3.08	61.67	5.10
	4.08	81.67	5.40
	5.75	115.00	3.41
	7.00	140.00	2.72
	8.08	161.67	1.80
embank	9.75	195.00	1.00
embank	10.83	216.67	1.41
ditch	12.50	250.00	8.99
ditch	14.17	283.33	5.22
Xsec 2	**avg**		**2.98**
	ditch		**7.10**

xsec3

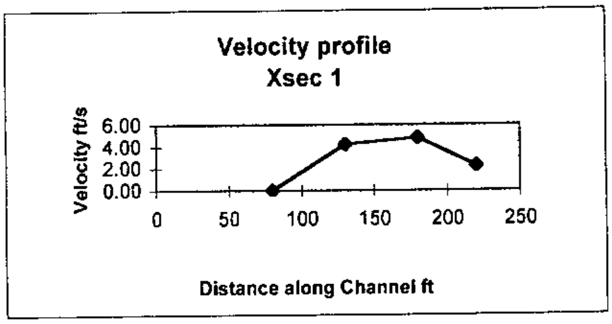
	model feet	actual feet	velocity
	1.50	30.00	0.00
	2.58	51.67	4.00
	3.33	66.67	4.40
	4.33	86.67	5.39
	5.50	110.00	3.61
	6.83	136.67	2.68
	8.17	163.33	1.34
	9.58	191.67	1.00
ditch	12.25	245.00	9.06
ditch	13.92	278.33	9.18
Xsec 3	**avg**		**3.20**
	ditch		**9.12**

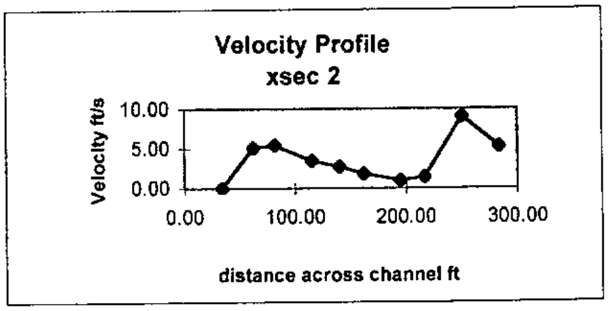
xsec 4

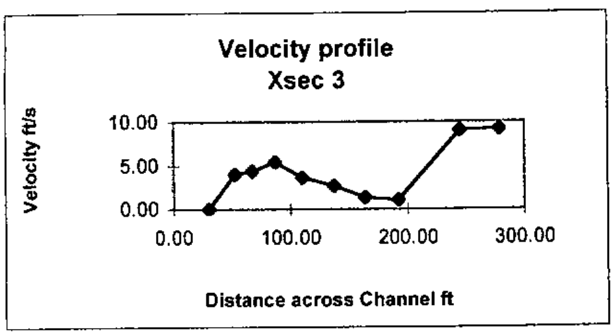
	model feet	actual feet	velocity
	1.75	35.00	0.00
	3.00	60.00	6.32
	4.42	88.33	5.39
	5.92	118.33	3.13
	7.50	150.00	1.84
	9.25	185.00	0.63
ditch	11.75	235.00	9.57
ditch	13.00	260.00	10.48
ditch	13.75	275.00	4.00
ditch	14.92	298.33	1.61
Xsec 4	**avg**		**3.46**
	ditch		**6.42**

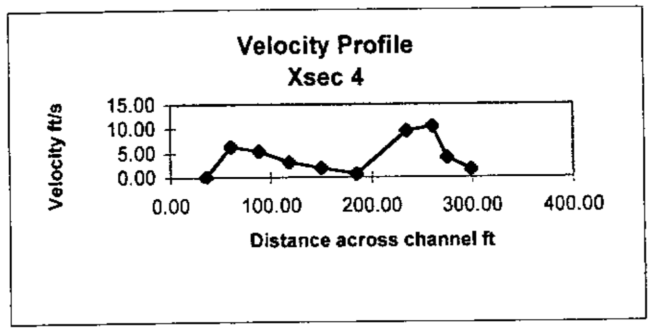
xsec 5

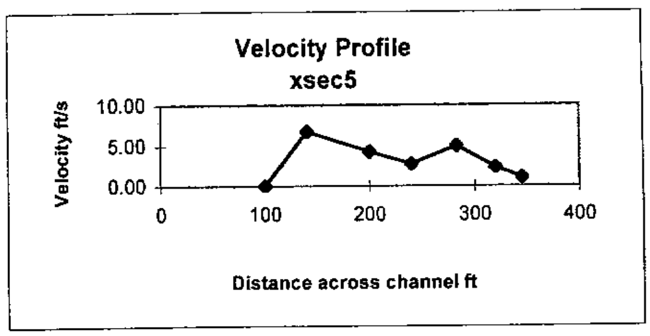
	model feet	actual feet	velocity
	5	100	0.00
	7	140	6.72
	10	200	4.24
	12	240	2.72
	14.17	283.33	4.94
	16	320	2.28
	17.25	345	1.00
Xsec 2	**avg**		**4.56**
	ditch		**2.74**











13 October 1998
2 year flood event

Velocity Profiles 15 October 1998
flow 8613

xsec 1

model feet	actual feet	velocity
4	80	0
6.5	130	6.26099
9	180	9.044335
11	220	5.440588

x sec1 avg 6.92

xsec 2

	model feet		Velocity ft/s
	1.666667	33.33333	0
	3.083333	61.66667	4.560702
	4.083333	81.66667	4.939636
	5.75	115	5.403702
	7	140	6.016644
	8.083333	161.6667	3.820995
embank	9.75	195	0.632456
embank	10.83333	216.6667	1.843909
ditch	12.5	250	12.16553
ditch	14.16667	283.3333	10.77033

x sec2 avg 3.89
ditch 11.47

xsec3

	model feet		Velocity ft/s
	1.5	30	2.906888
	2.583333	51.66667	4.5
	3.333333	66.66667	2.607681
	4.333333	86.66667	4.604346
	5.5	110	4.604346
	6.833333	136.6667	4.816638
	8.166667	163.3333	4.110961
	9.583333	191.6667	1.843909
ditch	12.25	245	15.42077
ditch	13.91667	278.3333	13.62351

x sec3 avg 3.75
ditch 14.52

xsec 4

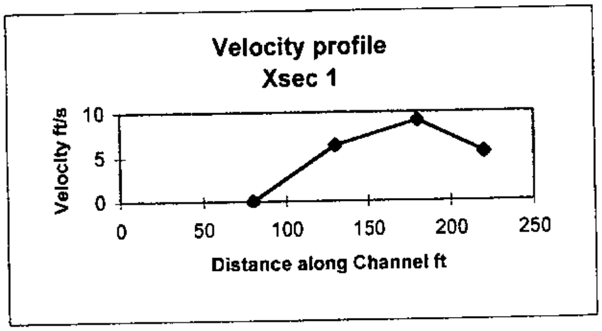
	model feet		Velocity ft/s
	1.75	35	0
	3	60	5.60357
	4.416667	88.33333	5.60357
	5.916667	118.3333	4.404543
	7.5	150	3
	9.25	185	2.529822
ditch	11.75	235	6.9857
ditch	13	260	13.29662
ditch	13.75	275	5.366563
ditch	14.91667	298.3333	0.894427

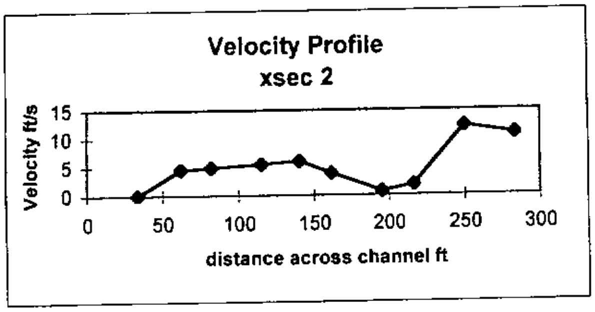
x sec2 avg 4.23
ditch 6.64

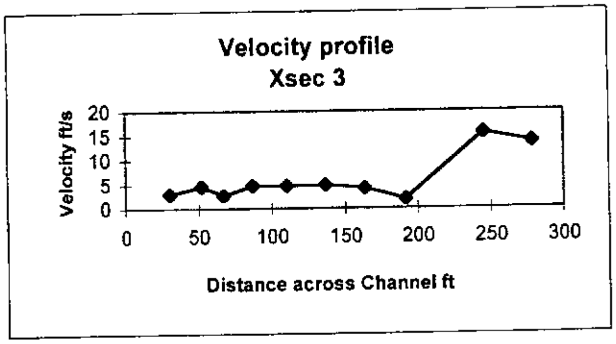
xsec 5

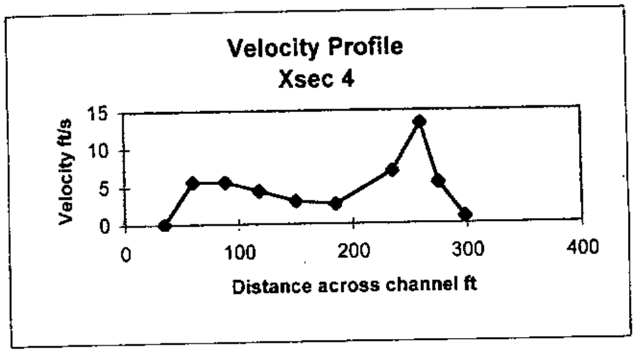
feet	prototype	Velocity
5	100	0
7	140	6.276942
10	200	4.964877
12	240	3.687818
14.16667	283.3333	6.723095
16	320	1.788854
17.25	345	1.81604

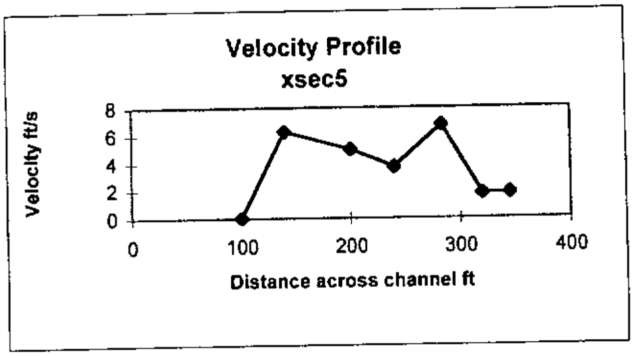
x sec5 avg 4.98
ditch 3.44











15 October 1998
10 year flood event

Velocity Profiles 15 October 1998
flow 21865

xsec 1

model feet	actual feet	velocity
4	80	0
6.5	130	0
9	180	0
11	220	0

xsec 2

	model feet		Velocity ft/s
	1.666667	33.33333	0
	3.083333	61.66667	0
	4.083333	81.66667	2.529822
	5.75	115	0
	7	140	6
	8.083333	161.6667	0
embank	9.75	195	8.809086
embank	10.83333	216.6667	0
ditch	12.5	250	0
ditch	14.16667	283.3333	4

xsec3

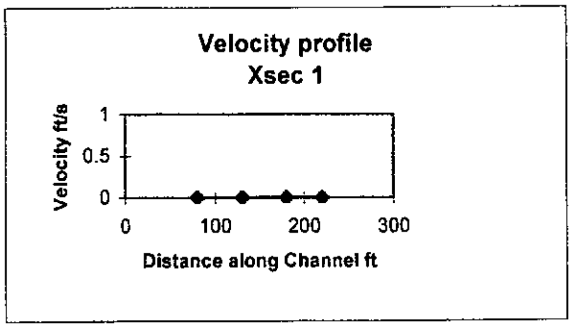
	model feet		Velocity ft/s
	1.5	30	0
	2.583333	51.66667	0
	3.333333	66.66667	0
	4.333333	86.66667	0
	5.5	110	0
	6.833333	136.6667	0
	8.166667	163.3333	0
	9.583333	191.6667	0
ditch	12.25	245	0
ditch	13.91667	278.3333	0

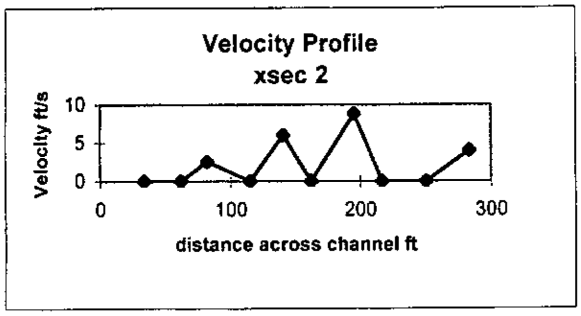
xsec 4

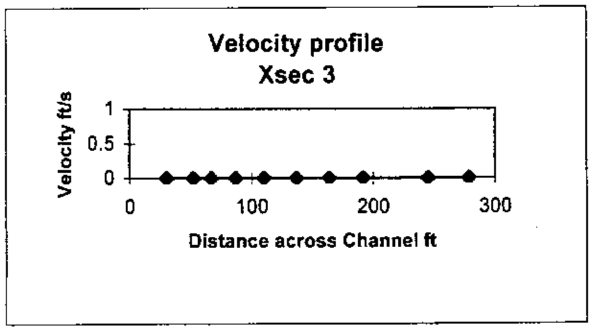
	model feet		Velocity ft/s
	1.75	35	0
	3	60	0
	4.416667	88.33333	0
	5.916667	118.3333	0
	7.5	150	0
	9.25	185	0
ditch	11.75	235	0
ditch	13	260	0
ditch	13.75	275	0
ditch	14.91667	298.3333	0

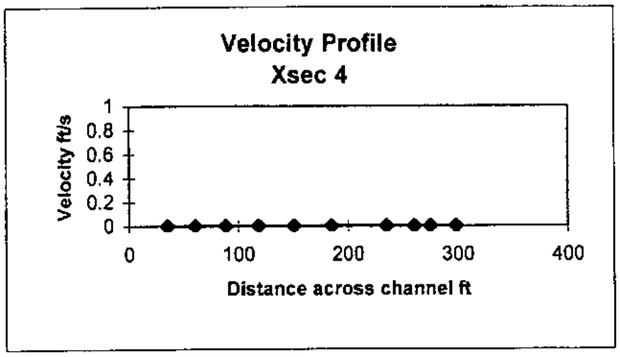
xsec 5

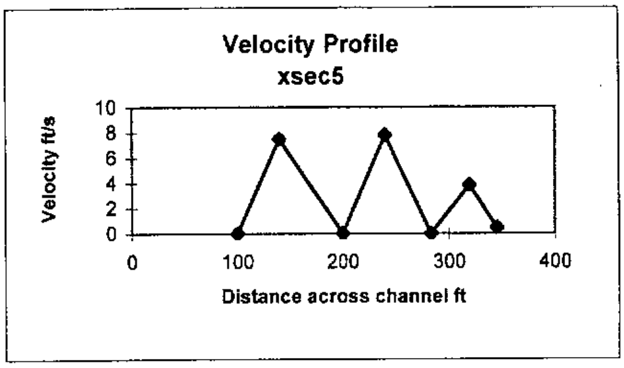
feet	prototype	Velocity
5	100	0
7	140	7.496666
10	200	0
12	240	7.81025
14.16667	283.3333	0
16	320	3.820995
17.25	345	0.447214











15 October 1998
100 year event

Data at selected locations only.

Velocity Profiles 27 October 1998
flow 3600
No stop logs

xsec 1

	model feet	actual feet	velocity
	4	80	0.00
	6.5	130	4.27
	9	180	3.75
	11	220	3.69
xsec1	**avg**		**3.90**

xsec 2

	model feet	actual feet	velocity
	1.67	33.33	0.00
	3.08	61.67	2.61
	4.08	81.67	4.30
	5.75	115.00	5.39
	7.00	140.00	3.00
	8.08	161.67	1.63
embank	9.75	195.00	6.08
embank	10.83	216.67	0.00
ditch	12.50	250.00	7.66
ditch	14.17	283.33	8.06
xsec2	**avg**		**3.29**
	ditch		**7.86**

xsec3

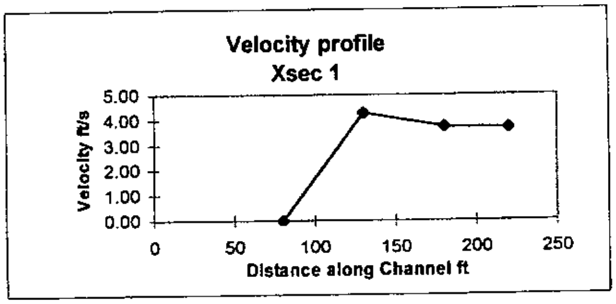
	model feet	actual feet	velocity
	1.50	30.00	0.00
	2.58	51.67	1.41
	3.33	66.67	1.61
	4.33	86.67	4.40
	5.50	110.00	3.61
	6.83	136.67	1.00
	8.17	163.33	5.83
	9.58	191.67	2.28
ditch	12.25	245.00	6.84
ditch	13.92	278.33	9.43
xsec3	**avg**		**2.88**
	ditch		**8.14**

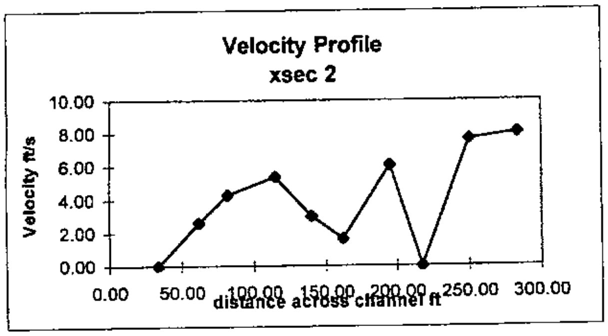
xsec 4

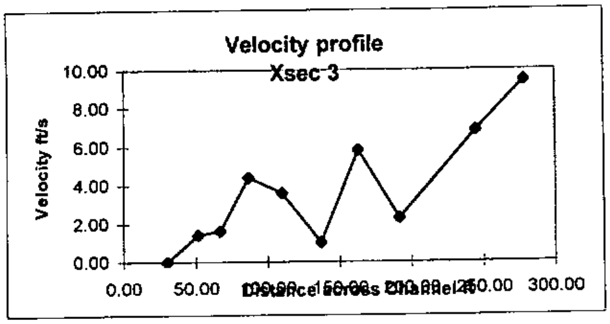
	model feet	actual feet	velocity
	1.75	35.00	0.00
	3.00	60.00	5.24
	4.42	88.33	4.43
	5.92	118.33	3.22
	7.50	150.00	2.86
	9.25	185.00	0.45
ditch	11.75	235.00	7.82
ditch	13.00	260.00	9.18
ditch	13.75	275.00	4.56
ditch	14.92	298.33	0.63
xsec4	**avg**		**3.24**
	ditch		**5.55**

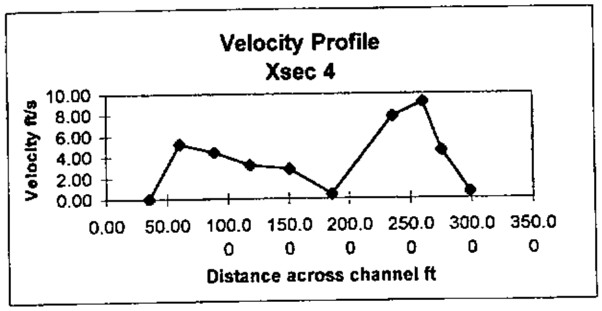
xsec 5

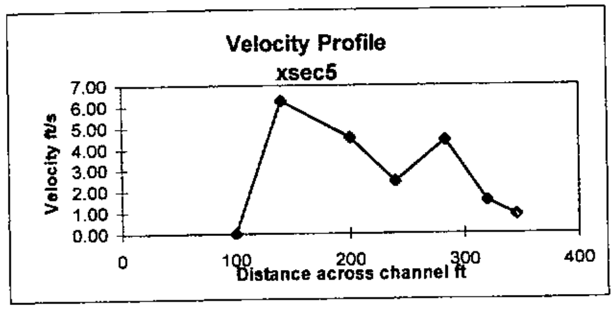
	model feet	actual feet	velocity
	5	100	0.00
	7	140	6.28
	10	200	4.53
	12	240	2.47
	14.17	283.33	4.43
	16	320	1.57
	17.25	345	0.89
xsec5	**avg**		**4.42**
	ditch		**2.30**











27 October 1998
2 year flood event
No stop logs boat chute

Velocity Profiles 27 October 1998
flow 8600
No stop logs

xsec 1

model feet	actual feet	velocity
4	80	0.00
6.5	130	6.45
9	180	6.21
11	220	6.65
xsec1	**avg**	**6.44**

xsec 2

	model feet		Velocity ft/s
	1.67	33.33	1.12
	3.08	61.67	6.08
	4.08	81.67	5.38
	5.75	115.00	5.10
	7.00	140.00	4.74
	8.08	161.67	4.32
embank	9.75	195.00	4.20
embank	10.83	216.67	0.63
ditch	12.50	250.00	13.43
ditch	14.17	283.33	10.88
xsec2	**avg**		**3.95**
	ditch		**12.16**

xsec3

	model feet		Velocity ft/s
	1.50	30.00	3.49
	2.58	51.67	5.10
	3.33	66.67	2.86
	4.33	86.67	5.28
	5.50	110.00	4.27
	6.83	136.67	3.64
	8.17	163.33	3.98
	9.58	191.67	2.24
ditch	12.25	245.00	13.77
ditch	13.92	278.33	13.89
xsec3	**avg**		**3.86**
	ditch		**13.83**

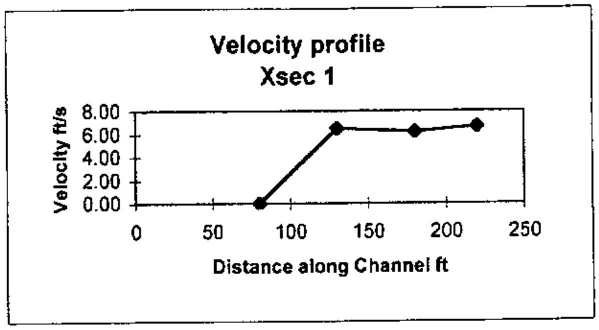
xsec 4

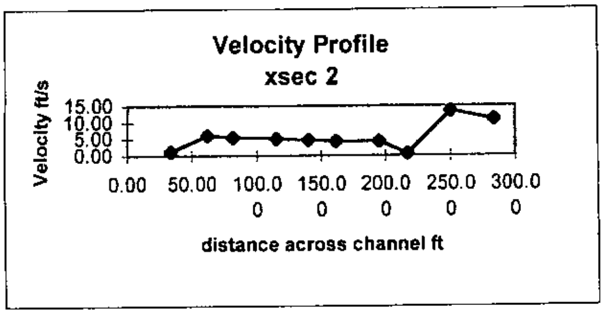
	model feet		Velocity ft/s
	1.75	35.00	0.00
	3.00	60.00	6.48
	4.42	88.33	5.54
	5.92	118.33	3.67
	7.50	150.00	3.41
	9.25	185.00	2.06
ditch	11.75	235.00	6.36
ditch	13.00	260.00	14.23
ditch	13.75	275.00	6.51
ditch	14.92	298.33	0.92
xsec4	**avg**		**4.23**
	ditch		**7.01**

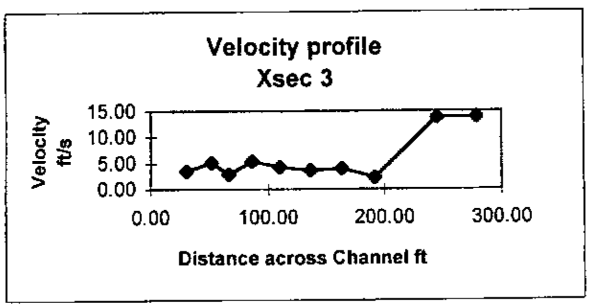
xsec 5

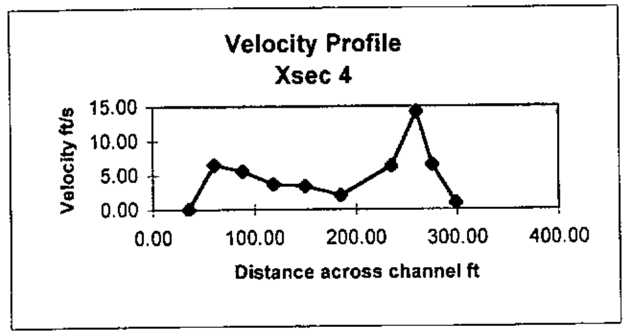
feet	prototype	Velocity
5	100	0.00
7	140	9.81
10	200	6.08
12	240	4.52
14.17	283.33	6.99
16	320	1.41
17.25	345	1.36
xsec5	**avg**	**6.80**
	ditch	**3.25**

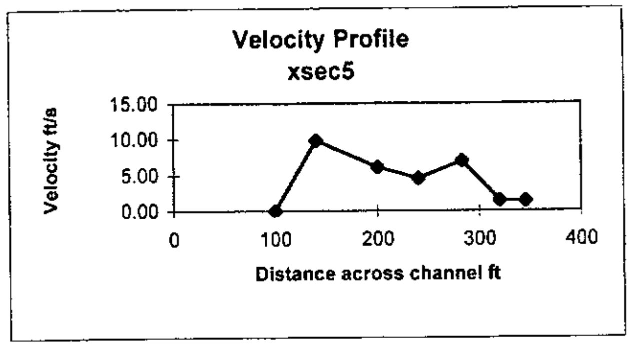
10 yr profile











27 October 1998
10 year flood event
No stop logs boat chute

APPENDIX B

CROSS SECTION WATER SURFACE ELEVATION DATA

South Platte River

Date:________ 6/11/98

Collected by:________

Flowrate:________ 3600

Time:_____

Tail water:_____

Xsec 1

	1	2	3	4
Elevation	5124.5	5125	5125	5130
Point Gauge 2 yr	0	1.752	1.739	1.745
Point Gauge bottom	1.635	1.311	1.319	1.341
diff		0.441	0.42	0.404
wsel		5133	5133	5138

0.422

5135

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121	5121	5121	5121	5121	5121	5128	5124	5124
Point Gauge	0	2.829	0	2.794	2.782	2.781	2.777	2.782	2.992	3.009
Point Gauge bottom	2.782	2.533	2.524	2.492	2.482	2.479	2.504	2.567	2.657	2.666
diff		0.296		0.302	0.3	0.302	0.273	0.215	0.335	0.343
wsel		5127		5127	5127	5127	5127	5132	5131	5131

0.281333 0.339

5127.892 5131.08

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126	5121	5121	5121	5121	5121	5121	5121	5124	5124
Point Gauge	0	2.816	0	0	2.785	0	2.776	2.785	2.997	2.994
Point Gauge bottom	2.822	2.514	2.526	2.514	2.496	2.488	2.497	2.485	2.673	2.685
diff		0.302			0.289		0.279	0.3	0.324	0.309
wsel		5127			5127		5126	5127	5131	5130

0.2925 0.3165

5126.65 5130.63

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5121	5121	5121	5121	5121	5124	5124	5124	5124
Point Gauge	0	0	2.918	0	2.903	2.909	0	3	0	0
Point Gauge bottom	2.967	2.602	2.602	2.59	2.589	2.596	2.813	2.793	2.793	2.796
diff			0.316		0.314	0.313		0.207		
wsel			5127		5127	5127		5128		

0.314333 0.207

5127.087 5128.44

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5121	5121	5121	5121	5121	5121
Point Gauge	0	1.405	1.415	1.424	1.677	1.688	0
Point Gauge bottom	1.522	1.119	1.118	1.123	1.325	1.314	1.307
diff		0.286	0.297	0.301	0.352	0.374	
wsel		5127	5127	5127	5128	5128	

0.295 0.363

5126.693 5128.06

South Platte River

Date:________ 6/11/99

Collected by:________

Flowrate:________ 8600

Time:_____

Tail water:____ 1.528
1.605

Xsec 1

	1	2	3	4
Elevation	5124.5	5125	5125	5130
Point Gauge 10yr	1.871	1.869	1.874	0
Point Gauge bottom	1.635	1.311	1.319	1.341
diff	0.236	0.558	0.555	
wsel	5129.2	5136	5136	

0.557
5133

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121	5121	5121	5121	5121	5121	5128	5124	5124
Point Gauge	3.057	0	3.025	0	2.997	0	2.993	0	3.057	0
Point Gauge bottom	2.782	2.533	2.524	2.492	2.482	2.479	2.504	2.567	2.657	2.666
diff	0.275		0.501		0.515		0.489		0.4	
wsel	5131.2		5131		5131		5131		5132	

0.445 0.4
5131.15 5132.3

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126	5121	5121	5121	5121	5121	5121	5121	5124	5124
Point Gauge	0	3.045	0	3.004	0	3	0	2.996	2.997	2.994
Point Gauge bottom	2.822	2.514	2.526	2.514	2.496	2.488	2.497	2.485	2.673	2.685
diff		0.531		0.49		0.512		0.511	0.324	0.309
wsel		5131		5131		5131		5131	5131	5130

0.511 0.3165
5131.02 5130.63

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5121	5121	5121	5121	5121	5124	5124	5124	5124
Point Gauge	3.1	0	0	0	3.094	0	0	0	0	0
Point Gauge bottom	2.967	2.602	2.602	2.59	2.589	2.596	2.813	2.793	2.793	2.796
diff	0.133				0.505					
wsel	5131.4				5131					

0.319 #DIV/0!
5131.155 #DIV/0!

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5121	5121	5121	5121	5121	5121
Point Gauge	1.588	1.606	1.617	1.626	1.735	0	0
Point Gauge bottom	1.522	1.119	1.118	1.123	1.325	1.314	1.307
diff	0.066	0.487	0.499	0.503	0.41		
wsel	5122.1	5131	5131	5131	5129		

0.389 0.41
5128.575 5129

South Platte River

Date:_________ 8/18/98

Collected by:_______ KES/BAS

Flowrate:_______ 3600

Time:_____

Tail water:_____ 1.479
1.505

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 2 yr	1.741	1.724	1.738	1.775
Point Gauge bottom	1.635	1.311	1.319	1.341
diff	0.106	0.413	0.419	0.434
wsel	5126.6	5132.8	5132.9	5138.7

avg ditchavg main

0.343

5132.7

avg davg main

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121.1	5121.1	5121.1	5121.1	5121.1	5121.1	5128.1	5124.3	5124.3
Point Gauge	2.893		2.862		2.832		2.836		2.997	
Point Gauge bottom	2.782		2.524		2.482		2.504		2.657	
diff	0.111		0.338		0.35		0.332		0.34	
wsel	5127.9		5127.9		5128.1		5127.7		5131.1	

0.28275 0.34

5127.905 5131.1

avg davg main

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126.0	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3
Point Gauge		2.885		2.871		2.846		2.843	2.94	3.04
Point Gauge bottom		2.514		2.514		2.488		2.485	2.673	2.685
diff		0.371		0.357		0.358		0.358	0.267	0.355
wsel		5128.2		5127.9		5128		5128	5129.6	5131.4

0.361 0.311

5128.02 5130.52

avg davg main

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3	5124.3	5124.3
Point Gauge	0	0		2.963						
Point Gauge bottom	2.967	2.602		2.59						
diff				0.373						
wsel	5128.8	5120.8		5128.3						

0.373 #DIV/0!

5125.937 #DIV/0!

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8
Point Gauge		1.465	1.476	1.483	1.677	1.69	1.688
Point Gauge bottom		1.119	1.118	1.123	1.325	1.314	1.307
diff		0.346	0.358	0.36	0.352	0.376	0.381
wsel		5127.7	5128	5128	5127.8	5128.3	5128.4

0.3547 0.3697

5127.893 5128.193

South Platte River

Date:________ 8/18/98
Collected by:_______ KES/BAS
Flowrate:_______ 8600

Time:_____

Tail water:_____ 1.605
1.525

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 10 yr	1.837	1.846	1.847	1.847
Point Gauge bottom	1.635	1.311	1.319	1.341
diff	0.202	0.535	0.528	0.506
wsel	5128.5	5135.2	5135.1	5140.1

avg ditchavg main

0.4428 5134.7

avg davg main

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121.1	5121.1	5121.1	5121.1	5121.1	5121.1	5128.1	5124.3	5124.3
Point Gauge	3.057	0	3.033	0	2.9	0	2.973	0	3.057	0
Point Gauge bottom	2.782		2.524		2.482		2.504		2.657	
diff	0.275		0.509		0.418		0.469		0.4	
wsel	5131.2		5131.3		5129.5		5130.5		5132.3	

0.41775 0.4
5130.605 5132.3

avg davg main

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126.0	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3
Point Gauge	3.45	3.46	0	3.25	0	3.02	2.995	2.99	3.17	0
Point Gauge bottom	2.822	2.514	2.526	2.514	2.496	2.488	2.497	2.485	2.673	2.685
diff	0.628	0.946		0.736		0.532	0.498	0.505	0.497	
wsel	5138.6	5139.7		5135.5		5131.4	5130.8	5130.9	5134.2	

0.640833 0.497
5134.483 5134.24

avg davg main

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3	5124.3	5124.3
Point Gauge	0	0	0	0	0	0	0	0	0	0
Point Gauge bottom	2.967	2.602		2.59						
diff										
wsel	5128.8	5120.8		5120.8						

#DIV/0! #DIV/0!
5123.45 #DIV/0!

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8
Point Gauge	1.609	1.621	1.624	1.632	1.718	1.736	1.74
Point Gauge bottom	1.522	1.119	1.118	1.123	1.325	1.314	1.307
diff	0.087	0.502	0.506	0.509	0.393	0.422	0.433
wsel	5122.5	5130.8	5130.9	5131	5128.7	5129.2	5129.5

0.401 0.416
5128.82 5129.12

South Platte River

Date:________ 10/13/98

Collected by:________ KES/MLH

Flowrate:________ 1073

Time:__ 1:00 10:30

Tail water:_____

ditch tailwater 1.507

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 1000 cfs	0	1.642	1.52	1.662
Point Gauge bottom		1.311	1.319	1.341
diff		0.331	0.201	0.321
wsel		5131.1	5128.5	5136.4

0.2843

5132.0

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121.1	5121.1	5121.1	5121.1	5121.1	5121.1	5128.1	5124.3	5124.3
Point Gauge	0	0	0	0	0	0	0	0	1.661	1.682
Point Gauge bottom									1.342	1.364
diff									0.319	0.318
wsel									5130.7	5130.7

avg ditch avg

#DIV/0! 0.3165

#DIV/0! 5130.67

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126.0	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3
Point Gauge									1.664	1.654
Point Gauge bottom									1.361	1.383
diff									0.303	0.271
wsel									5130.4	5129.7

avg ditch avg

#DIV/0! 0.287

#DIV/0! 5130.04

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3	5124.3	5124.3
Point Gauge						0	3.093	3.1	3.1	3.1
Point Gauge bottom							2.813	2.793	2.793	2.796
diff							0.28	0.307	0.307	0.304
wsel							5129.9	5130.4	5130.4	5130.4

avg ditch avg

#DIV/0! 0.2995

#DIV/0! 5130.29

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8
Point Gauge	0	1.207	1.215	1.228	1.645	1.65	1.65
Point Gauge bottom		1.119	1.118	1.123	1.325	1.314	1.307
diff		0.088	0.097	0.105	0.32	0.336	0.343
wsel		5122.6	5122.7	5122.9	5127.2	5127.5	5127.7

avg ditchavg

0.0967 0.333

5122.733 5127.46

South Platte River

Date:_________ 10/13/98
Collected by:________ KES/MLH
Flowrate:_______ 3600

Time:__ 1:00

Tail water:_____ 1.422
ditch tailwater 1.507
Franklin gate open 1 ft

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 2 yr	0	1.747	1.749	1.752
Point Gauge bottom		1.311	1.319	1.341
diff		0.436	0.43	0.411
wsel		5133.2	5133.1	5138.2

0.4257
5134.8

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121.1	5121.1	5121.1	5121.1	5121.1	5121.1	5128.1	5124.3	5124.3
Point Gauge	0	2.809	2.801	2.781	2.773	2.773	2.769	2.772	2.987	3.024
Point Gauge bottom		2.533	2.524	2.492	2.482	2.479	2.504	2.567	2.657	2.666
diff		0.276	0.277	0.289	0.291	0.294	0.265	0.205	0.33	0.358
wsel		5126.6	5126.6	5126.9	5126.9	5127	5126.4	5132.2	5130.9	5131.5

avg ditch avg
0.271 0.344
5127.519 5131.18

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126.0	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3
Point Gauge	0	2.808	0	0	2.781	2.779	0	2.76	2.983	2.983
Point Gauge bottom		2.514			2.496	2.488		2.485	2.673	2.685
diff		0.294			0.285	0.291		0.275	0.31	0.298
wsel		5126.7			5126.5	5126.6		5126.3	5130.5	5130.3

avg ditch avg
0.28625 0.304
5126.525 5130.38

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3	5124.3	5124.3
Point Gauge	0	0	2.9	2.899	0	2.896	3.13	0	3.13	0
Point Gauge bottom			2.602	2.59		2.596	2.813		2.793	
diff			0.298	0.309		0.3	0.317		0.337	
wsel			5126.8	5127		5126.8	5130.6		5131	

avg ditch avg
0.302333 0.327
5126.847 5130.84

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8
Point Gauge	0	1.392	1.393	1.408	1.681	1.687	1.69
Point Gauge bottom		1.119	1.118	1.123	1.325	1.314	1.307
diff		0.273	0.275	0.285	0.356	0.373	0.383
wsel		5126.3	5126.3	5126.5	5127.9	5128.3	5128.5

avg ditchavg
0.2777 0.3707
5126.353 5128.213

South Platte River

Date:__________ 10/15/98 Time:_____ 3:00

Collected by:________ kes

Flowrate:_______ 8600 Tail water:_____ 1.507

1.902

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 100 yr	1.841	1.842	1.839	1.845
Point Gauge bottom	1.635	1.311	1.319	1.341
diff	0.206	0.531	0.52	0.504
wsel	5128.62	5135.1	5134.9	5140.1

0.44

5135

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5126	5120.8	5120.8	5120.8	5121	5121	5121	5121	5124	5124
Point Gauge	0	1.694	1.695	1.691	0	0	1.661	0	0	1.789
Point Gauge bottom		1.197	1.191	1.179			1.196			1.364
diff		0.497	0.504	0.512			0.465			0.425
wsel		5130.7	5130.9	5131			5130			5133

avg ditch avg

0.4945 0.425

5130.69 5132.8

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126	5120.8	5120.8	5120.8	5121	5121	5121	5121	5124	5124
Point Gauge	3.053	3.04	0	3.22	0	3.14	3	3.07	3.19	3.035
Point Gauge bottom	2.822	2.556		2.554		2.488	2.497	2.485	2.673	2.685
diff		0.484		0.666		0.652	0.503	0.585	0.517	0.35
wsel		5130.5		5134.1		5134	5131	5133	5135	5131

avg ditch avg

0.578 0.4335

5132.36 5132.97

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.75	5120.8	5121	5121	5121	5121	5124	5124	5124	5124
Point Gauge	0	3.1	0	1.675	1.698	0	1.742	0	1.719	0
Point Gauge bottom		2.634		1.156	1.172		1.364		1.342	
diff	0	0.466	0	0.519	0.526	0	0.378	0	0.377	0
wsel		5130.1		5131.2	5131		5132		5132	

avg ditch

0.251833 0.18875

5130.873 5131.85

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5121	5121	5121	5121	5121
Point Gauge	1.608	1.617	1.628	1.638	1.729	1.716	1.725
Point Gauge bottom	1.522	1.119	1.118	1.123	1.325	1.314	1.307
diff	0.086	0.498	0.51	0.515	0.404	0.402	0.418
wsel	5122.52	5130.8	5131	5131.1	5129	5129	5129

avg ditchavg

0.402 0.408

5128.845 5128.96

South Platte River

Date:_________ 10/15/98

Collected by:________ kes

Flowrate:________ 21865

Time:_____ 3:00

Tail water:_____ 1.507

1.902

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 100 yr	0	2.062	2.049	2.04
Point Gauge bottom	1.635	1.311	1.319	1.341
diff		0.751	0.73	0.699
wsel		5139.5	5139.1	5144

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5126	5120.8	5120.8	5120.8	5121	5121	5121	5121	5124	5124
Point Gauge	0	0	2.033	0	2.019	0	2.011	0	0	2.08
Point Gauge bottom			1.19		1.192		1.209			1.365
diff			0.843		0.827	0	0.802	0	0	0.715
wsel			5137.7		5137		5137			5139

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation							5121		5124	
Point Gauge	0	0	0	0	0	0	1.997	0	1.99	0
Point Gauge bottom							1.173		1.365	
diff	0	0	0	0	0	0	0.824	0	0.625	0
wsel							5137		5137	

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.75	5120.8	5121	5121	5121	5121	5124	5124	5124	5124
Point Gauge	0	1.938	0	1.973	0	0	1.989	0	0	1.99
Point Gauge bottom		1.152		1.16			1.364			1.342
diff	0	0.786	0	0.813	0	0	0.625	0	0	0.648
wsel		5136.5		5137.1			5137			5137

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5121	5121	5121	5121	5121
Point Gauge	0	1.891	0	1.93	1.954	1.964	1.966
Point Gauge bottom		1.119		1.123	1.325	1.314	1.307
diff	0	0.772	0	0.807	0.629	0.65	0.659
wsel		5136.2		5136.9	5133	5134	5134

South Platte River

Date:_________ 10/27/98
Collected by:________ KES/MS
Flowrate:_______ 3631

Time:_____ 9:50

Tail water:_____ 1.403
ditch tailwater 1.507
Franklin gate open 1 ft
avg

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 2 yr	0	1.723	1.73	1.743
Point Gauge bottom		1.311	1.319	1.341
diff		0.412	0.411	0.402
wsel		5132.7	5132.7	5138.0

0.4083
5134.5

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121.1	5121.1	5121.1	5121.1	5121.1	5121.1	5128.1	5124.3	5124.3
Point Gauge	0	2.823	0	2.789	0	2.777	2.765	0	2.992	3.011
Point Gauge bottom		2.533		2.492		2.479	2.504		2.657	2.666
diff		0.29		0.297		0.298	0.261		0.335	0.345
wsel		5126.9		5127		5127.1	5126.3		5131	5131.2

avg ditch avg main ditch
0.2865 0.34
5126.83 5131.1

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126.0	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3
Point Gauge	0	2.814	0	0	2.796	2.791	0	2.786	2.995	2.998
Point Gauge bottom		2.514			2.496	2.488		2.485	2.673	2.685
diff		0.3			0.3	0.303		0.301	0.322	0.313
wsel		5126.8			5126.8	5126.9		5126.8	5130.7	5130.6

avg ditchavg ditch
0.301 0.3175
5126.82 5130.65

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3	5124.3	5124.3
Point Gauge	0	0	2.919	2.912	0	2.909	3.1	0	3.1	0
Point Gauge bottom			2.602	2.59		2.596	2.813		2.793	
diff			0.317	0.322		0.313	0.287		0.307	
wsel			5127.1	5127.2		5127.1	5130		5130.4	

avg ditchavg
0.317333 0.297
5127.147 5130.44

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8
Point Gauge	0	1.399	1.412	1.419	1.671	1.673	1.679
Point Gauge bottom		1.119	1.118	1.123	1.325	1.314	1.307
diff		0.28	0.294	0.296	0.346	0.359	0.372
wsel		5126.4	5126.7	5126.7	5127.7	5128	5128.2

avg ditchavg
0.29 0.359
5126.6 5127.98

South Platte River

Date: 10/27/98
Collected by: KES/MLH
Flowrate: 8600

Time: 1:00 10:30

Tail water:
ditch tailwater 1.507

Xsec 1

	1	2	3	4
Elevation	5124.5	5124.5	5124.5	5130.0
Point Gauge 10 yr	0	1.837	1.833	1.832
Point Gauge bottom		1.311	1.319	1.341
diff		0.526	0.514	0.491
wsel		5135.0	5134.8	5139.8

No stop logs
avg

0.5103
5136.5

Xsec 2

	5	6	7	8	9	10	11	12	13	14
Elevation	5125.7	5121.1	5121.1	5121.1	5121.1	5121.1	5121.1	5128.1	5124.3	5124.3
Point Gauge	3.03	3.024	0	2.994	0	0	2.983	2.976	3.026	3.084
Point Gauge bottom	2.782	2.533	2.524	2.492	2.482	2.479	2.504	2.567	2.657	2.666
diff	0.248	0.491		0.502			0.479	0.409	0.369	0.418
wsel	5130.7	5130.9		5131.1			5130.7	5136.3	5131.7	5132.7

avg ditch avg
0.4258 0.3935
5131.9 5132.2

Xsec 3

	15	16	17	18	19	20	21	22	23	24
Elevation	5126.0	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3
Point Gauge	3.029	3.024	0	3.009	0	2.992	2.988	2.988	3.018	3.023
Point Gauge bottom	2.822	2.514	2.526	2.514	2.496	2.488	2.497	2.485	2.673	2.685
diff	0.207	0.51		0.495		0.504	0.491	0.503	0.345	0.338
wsel	5130.1	5131.0		5130.7		5130.9	5130.6	5130.9	5131.2	5131.1

avg ditchavg
0.451667 0.3415
5130.7 5131.1

Xsec 4

	25	26	27	28	29	30	31	32	33	34
Elevation	5128.8	5120.8	5120.8	5120.8	5120.8	5120.8	5124.3	5124.3	5124.3	5124.3
Point Gauge	0	3.1	0	3.1	1.684	0	1.728	0	1.708	0
Point Gauge bottom		2.602		2.59	1.165		1.373		1.351	
diff		0.498		0.51	0.519	0	0.355	0	0.357	0
wsel		5130.8		5131	5131.2		5131.4		5131.4	

avg ditchavg
0.38175 0.178
5130.98 5131.42

Xsec 5

	35	36	37	38	39	40	41
Elevation	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8	5120.8
Point Gauge	1.578	1.587	1.6	1.602	1.719	1.728	1.729
Point Gauge bottom	1.522	1.119	1.118	1.123	1.325	1.314	1.307
diff	0.056	0.468	0.482	0.479	0.394	0.414	0.422
wsel	5121.9	5130.2	5130.4	5130.4	5128.7	5129.1	5129.2

avg ditchavg
0.3713 0.41
5128.225 5129