PAP-730

Recommended Corrective Measures, Mirdan Canal Section 1, North Loup Division, Pick-Sloan Missouri Basin Program, Nebraska

by

David C. Rogers

May 1996

	PEER REVIEWER(S)	CODE
5/3	Arthur Glickman Signature	8140
	Arthur Glickman Printed Name	
	Signature	
	Printed Name	
Author initials	PEER REVIEW NOT REQUIRED	

D-8560
RES-3.50

MAY 3 1996

MEMORANDUM

To: Manager, Grand Island NE
Attention: NK-MDK (Kube)

From: David C. Rogers
Hydraulic Engineer

Subject: Recommended Corrective Measures, Mirdan Canal Section 1, North Loup Division, Pick-Sloan Missouri Basin Program, Nebraska

The attached report addresses wasteway design, remote data monitoring, and canal operation recommendations for Mirdan Canal, as requested in your work request dated March 25, 1996.

David C. Rogers

Attachment

cc: Manager, Billings MT, Attention: GP-2200 (Armer)
(w/att)

bc: D-8140 (Glickman)
D-8560 (Rogers)
(w/att to each)

WBR:DCRogers:rlc:5/2/96:6-2000,x445
h:\home\rcasey\wpfiles\rogers\op&wwrec.ltr

MIRDAN CANAL OPERATION, CONTROL AND WASTEWAY RECOMMENDATIONS

1.0 INTRODUCTION

This report summarizes studies performed in Reclamation's Technical Service Center (TSC) and presents recommended improvements for Mirdan Canal Section 1. The Twin Loups District and the Nebraska-Kansas Area Office seek to improve operation capabilities and accuracy in Mirdan Canal. Operating problems are caused by fluctuating flows entering Mirdan Canal from Taylor-Ord Canal and by large storm inflows. Three methods to address these problems are proposed:

1. Construction of an emergency wasteway
2. A remote monitoring and control system
3. Enhanced canal operating techniques

2.0 EMERGENCY WASTEWAY AT STA 601+50 -- DESIGN RECOMMENDATIONS

2.1 Purpose - Storm runoff into Taylor-Ord Canal can increase the inflow to Mirdan Canal Section 1 through the Taylor-Ord Inlet structure and, thus, increase flow in Mirdan Canal above capacity. The wasteway at station 1026+45 is too far downstream to protect Mirdan Canal from this condition. An additional emergency wasteway is planned at Mirdan Canal station 601+50. Studies have been conducted to determine design recommendations for this new wasteway.

2.2 Assumptions - The wasteway design recommendations in this report are based on the following assumptions:

1. A 25-year frequency storm event was used. Based on the North Loup drainage discharge curves, this storm could produce a maximum additional flow of 280 ft^3/s entering Mirdan Canal through the Taylor-Ord inlet.

2. Mirdan Canal is assumed to be operating at maximum (design) flow capacity during the storm event. Flow rate is 720 ft^3/s from the headworks to station 438 and below station 715, with 870 ft^3/s in Mirdan Canal between the Taylor-Ord inlet and outlet structures (Taylor-Ord inflow and outflow = 150 ft^3/s). Storm inflow raises maximum flow in Mirdan Canal below the Taylor-Ord inlet to 1150 ft^3/s.

3. Wasteway design should prevent canal water levels from overtopping the concrete canal lining during the above combination of flows.

4. The new wasteway should be designed to minimize operational waste flows (designed for emergency conditions only, not for normal operations).

2.3 Hydraulic Analysis - Steady state hydraulics were analyzed for the reach of Mirdan Canal Section 1 from the Taylor-Ord inlet (station 438+24) to the South Turtle Creek Siphon (station 1027+15). The analysis computed canal water levels from the 25-year flood based on hydraulic properties of the canal and in-line structures such as checks and siphons. At the two wasteway locations (sta. 601 and 1026), flow was distributed realistically between the siphons and the overflow wasteways. Rather than assuming a prescribed wasteway flow, actual flows were computed based on water levels in the canal. At these locations, a portion of any flow increase will continue downstream through the siphons as canal water levels rise.

The hydraulic analysis computed an appropriate head loss at in-line structures that would accompany the increased canal flow. It was assumed that check gates would not be operated during the flood, but would remain at a gate position to pass the normal design flow. At each check structure and siphon, hydraulic loss across the structure will increase in proportion to the square of the flow increase. Therefore, upstream depth must exceed downstream depth at each of these structures to pass the higher flood flows, and the water tends to "stack up" at siphons and checks.

Table 1 shows canal water levels in the section of Mirdan Canal from the Taylor-Ord Inlet to the South Turtle Creek Wasteway at station 1026, based on gradually-varied flow computations for the 25-year flood.

LOCATION	CANAL STATION	FLOW (ft^3/s)	DEPTH (ft)
Taylor-Ord Inlet	438+24	1150	11.4
	511+70	1150	11.4
Check 511			
	512+29	1150	11.2
601 Wasteway	601+69	1150	11.1
601 Siphon			
	605+59	970	10.8
Taylor-Ord Outlet	717+00	970	11.0
Check 711			
	717+65	820	10.0
	816+34	820	10.0
816 Siphon			
	822+15	820	9.8
1026 Wasteway	1026+65	820	9.9

Table 1 - Canal water levels during 25-year flood (with 601 Wasteway)

The maximum canal water depth will occur between the Taylor-Ord Inlet and Check 511. In order to keep this water level below the top of the canal lining (11.5 ft), maximum water depth at the 601 Wasteway cannot exceed 11.1 ft. Of the 280 ft^3/s additional inflow (flood flow) coming from Taylor-Ord Canal, approximately 180 ft^3/s will go over the 601 Wasteway crest and the remaining 100 ft^3/s will go downstream through the 601 Siphon because of the increased water level (11.1 ft) at the siphon inlet. (Increased flow through the siphon cannot be prevented because the siphon inlet is uncontrolled.) Some or all of this 100 ft^3/s could be wasted at the 1026 Wasteway, depending on operation of the Check 1027 gate. Water levels should remain at least 6 inches below the top of lining in all canal segments below the 601 Siphon.

Determining the wasteway crest height and length is a trade-off between spill frequency and cost. A higher crest will need to be longer but will decrease unwanted operational spills. Table 2 compares wasteway options:

Crest height (ft)	Height above NWS (ft)	Required crest length (ft)	Maximum canal flow before spill occurs (ft^3/s)	Excess flow before spill occurs (ft^3/sec)
10.2	0.2	70	885	15
10.4	0.4	100	900	30
10.5	0.5	120	910	40

Table 2 - Design options for 601 Wasteway crest height and length

To prevent spills during non-emergency conditions, a crest height of 10.5 ft (6" above NWS) is recommended. With this crest height, required crest length is 120 ft and up to 40 ft^3/s excess flow can be passed down the canal without causing a spill. For discussion purposes, this wasteway crest (L = 120 ft, H = 10.5 ft) would pass 280 ft^3/s with a canal depth of 11.3 ft, and 400 ft^3/s with a canal depth of 11.5 ft.

The wasteway should include a vertical slide gate (sluice gate) to permit emergency spills when the canal water level is below the wasteway crest. Maximum flow would be approximately 40 ft^3/sec through a 24" x 24" gate and 140 ft^3/sec through a 48" x 48" gate. These flow capacities are estimates because gate flow will depend on downstream conditions in the wasteway structure. The larger gate (48-inch square) is recommended because it will increase evacuation capacity for a small additional cost.

2.4 Recommendations -

1. The new wasteway near Mirdan Canal station 601 + 50 should have a crest height of 10.5 ft above canal invert and a crest length of 120 ft.

2. Wasteway pipe, drop, and open channel sections should be designed to pass at least 180 ft^3/s without creating downstream submergence of the wasteway crest. Designers should evaluate the cost of sizing these structures for the full 280 ft^3/s capacity. (Although actual wasteway flow rate should be only about 180 ft^3/s during the 25-year

flood event studied, sizing the wasteway for the full 280 ft^3/s capacity will help ensure against abnormal canal operations, larger storm events, and power failure at Geranium Pumping Plant during a storm event.)

3. The general design of the 601 Wasteway may be essentially the same as the South Turtle Creek Wasteway (sta 1026+45), with structural design and dimension changes as appropriate.

4. The wasteway structure should include a 48" x 48" sluice gate.

3.0 DATA COLLECTION AND REMOTE MONITORING -- PRELIMINARY DESIGN CONCEPT

3.1 Purpose - Operations on the Taylor-Ord Canal create large flow fluctuations in Mirdan Canal Section 1. These flow fluctuations cause undesirable water level fluctuations in Mirdan Canal, unsteady turnout flows, and frequent "operational" spills through the "emergency" wasteway at Mirdan Canal station 1026+45. Additionally, storm runoff entering Mirdan Canal through the Taylor-Ord Canal Inlet can increase Mirdan Canal flow above capacity and threaten system integrity.

A remote monitoring system is proposed to help manage Mirdan Canal operations. Centralized data monitoring of water level and flow at key locations will help canal operators to control fluctuating flows and storm flows. Additional remote control and automatic control capabilities could be added in the future. These proposed monitoring and control system enhancements can be implemented in phases to avoid a large initial cost; however, long-term plans should be considered in the initial system design.

3.2 General Capabilities -

Phase 1: Flood inflow monitoring

As an minimum level of data collection and remote monitoring, flow should be measured at the Taylor-Ord Inlet and telemetered to the headquarters office in Scotia. A water level sensing device, such as a pressure transducer or bubbler system, could be installed in the existing well at the Parshall flume. Water level data can be telemetered by radio the Twin Loups Headquarters Office, where operators could observe present water level and computed flow on a computer display. The system can be set up to trigger an alarm when Taylor-Ord Inlet flow exceeds a prescribed limit, and an auto-dial function could alert the Calamus Dam tender of this alarm.

An example water level recording and reporting system is shown in Appendix A. The block diagram itemizes components for a complete system using a bubbler level transmitter. Some of the components (e.g. uninterruptable power supply, Wonderware man-machine interface software package) are optional, but they will improve reliability and performance (and add cost) beyond a basic system. The communication system supplied as part of the Phase 1 equipment should be expandable to accommodate the additional monitoring and control sites projected for subsequent phases.

Phase 2: Supervisory monitoring for other important sites.

Key water level and flow information from additional locations in Mirdan Canal Section 1 should be collected, telemetered, and displayed at the headquarters office. This will allow canal operators to monitor conditions in Mirdan Canal between the Taylor-Ord Canal Inlet and the wasteway at station 1026+45. The following data should be included:

1. Water level upstream from check 511
2. Water level upstream from 601 siphon (plus 601 wasteway flow, computed from this level)
3. Water level upstream from check 717
4. Water level upstream from 1027 siphon (plus 1026 wasteway flow, computed from this level)

A bubbler or submerged pressure transducer are recommended to measure the water level at these sites. These devices could be installed using a small pipe attached to the concrete structure, because these check structures do not have stilling wells. Essentially, Phase 2 involves adding four more data collection sites to the Phase 1 system. If this expansion is anticipated during Phase 1, additional requirements at the master station (headquarters office) would be limited to software modifications.

Phase 3: Expanded monitoring plus supervisory manual control.

Supervisory data monitoring could be expanded to include the following sites:

1. Mirdan Canal headworks flow (computed from water level at Parshall flume at station 44+50)
2. Water level upstream from check 263
3. Taylor-Ord Canal Outlet flow (computed from water level at Parshall flume)
4. Geranium Canal flow

In addition to the supervisory monitoring discussed above, remote control capabilities could be added to allow canal operators to adjust check gates and monitor gate positions from the headquarters office (supervisory manual control). This would apply to all check structures in Mirdan Canal Section 1:

1. Mirdan Canal headworks
2. Check 263
3. Check 511
4. Check 717
5. Check 1027

On-site equipment would need to include relays, limit switches, alarms, gate position sensors, and additional software to enable dependable remote control of gate motors. The master station would also need software modifications for remote manual control.

Phase 4: Additional control system expansion

Future control system expansion could include supervisory monitoring and control of additional sites, such as Geranium Pumping Plant, Taylor-Ord Canal Outlet, and the check structures further downstream in Mirdan Canal.

3.4 Equipment requirements and cost estimate -

Phase 1: Flood inflow monitoring

Item	Est. cost	Number	Total cost
On-site:		1	
RTU (remote terminal unit), including microprocessor, software, radio, RF modem, lightning protection, and enclosure	$ 2300		
Water level sensor and associated hardware	$ 600		
Solar power supply, solar panel, battery, charger, and associated hardware	$ 500		
Antenna and mast	$ 350		
Installation labor	$ 1500		
Contingencies	$ 500		
TOTAL ON-SITE	$ 5750	1	$ 5750
Master station:		1	
MCU (master control unit), including computer, master station software, radio, RF modem, and work station.	$ 5000		
Antenna and mast	$ 150		
Installation labor	$ 1500		
Contingencies	$ 700		
TOTAL MASTER STATION	$ 7350	1	$ 7350
Additional: **			
Radio repeater	$ 5000	1	$ 5000
GRAND TOTAL			$ 18,100

** Exact communication system requirements are dependent on design. Additional investigation is needed to determine these requirements.

Phase 2: Supervisory monitoring for other important sites.

Item	Est. cost	Number	Total cost
On-site: RTU (remote terminal unit), including microprocessor, software, radio, RF modem, lightning protection, and enclosure	$ 2300	4	
Water level sensor and associated hardware	$ 600		
Solar power supply, solar panel, battery, charger, and associated hardware	$ 500		
Antenna and mast	$ 350		
Installation labor	$ 1500		
Contingencies	$ 500		
TOTAL ON-SITE	$ 5750	4	$ 23,000
Master station: Software modifications to collect and display data from additional remote sites	$ 2000		$2000
GRAND TOTAL			$ 25,000

** Exact communication system requirements are dependent on design. Additional investigation is needed to determine these requirements.

Phase 3: Expanded monitoring plus supervisory manual control.

Item	Est. cost	Number	Total cost
Expanded supervisory data monitoring: Four additional sites, with same capabilities and equipment as Phase 1 sites.	$ 5750	4	$ 23,000
Remote control of Mirdan Canal Section 1 check gates: Gate position indicators, relays, relay drivers, limit switches, and alarms.	$ 500	5	
Control and interface software	$ 500		
Installation labor	$ 1000		
Contingencies	$ 200		
TOTAL	$ 2200	5	$ 11,000
Added control capabilities at master station: Control, interface, and alarm software	$ 500	1	
Installation labor	$ 1000		
Contingencies	$ 200		
TOTAL	$ 1700	1	$ 1700
GRAND TOTAL			$ 35,700

4.0 CANAL OPERATING TECHNIQUES

As data collection and remote monitoring capabilities are added, canal operators will be better able to manage canal flows and water levels. Initially, improvements will be restricted by the limitations of local manual control and by the limited number of data collection sites. Operations personnel will still need to travel to check sites to make adjustments, and operating decisions will not have the benefit of system-wide conditions. As control system capabilities grow, substantial improvements in canal operations are possible.

The basic concept for operating Mirdan Canal should be demand oriented. To the extent possible, the amount of water supplied from the canal headworks should match the amount of downstream demand by water users. Whenever there is too much or too little water at a point in the canal, adjustments should be made upstream from that point. This concept is difficult to implement in a conventional canal system, but it becomes more feasible with the addition of modern control equipment. The following sections suggest techniques that operators might use to manage canal flow changes.

4.1 Phase 1, using Taylor-Ord Inlet monitoring - Canal operators can use the knowledge of actual inflow from Taylor-Ord Canal to adjust Mirdan Canal headworks flow. The headworks flow should be changed to compensate for any major changes in Taylor-Ord Inlet flow. The initial effect of a flow change at the headworks will take about an hour to reach the Taylor-Ord Inlet, and the full flow change may take several hours, depending on the amount of flow change and the operation of Check 263.

For example, if an additional flood flow of 280 ft^3/s begins to enter Mirdan Canal through the Taylor-Ord Inlet, headworks flow could be immediately reduced by the same amount (280 ft^3/s). If the canal were flowing full before this change and if no other structures were adjusted, the lag time required to rebalance flows would be almost four hours. If Check 263 was also adjusted, so as to reduce flow and maintain the upstream water level, the lag time would be reduced to less than three hours. Therefore, spills over the wasteways downstream could be limited to a few hours. Additionally, if the flood flow increases gradually instead of all at once, headworks flow reduction could "keep up" better.

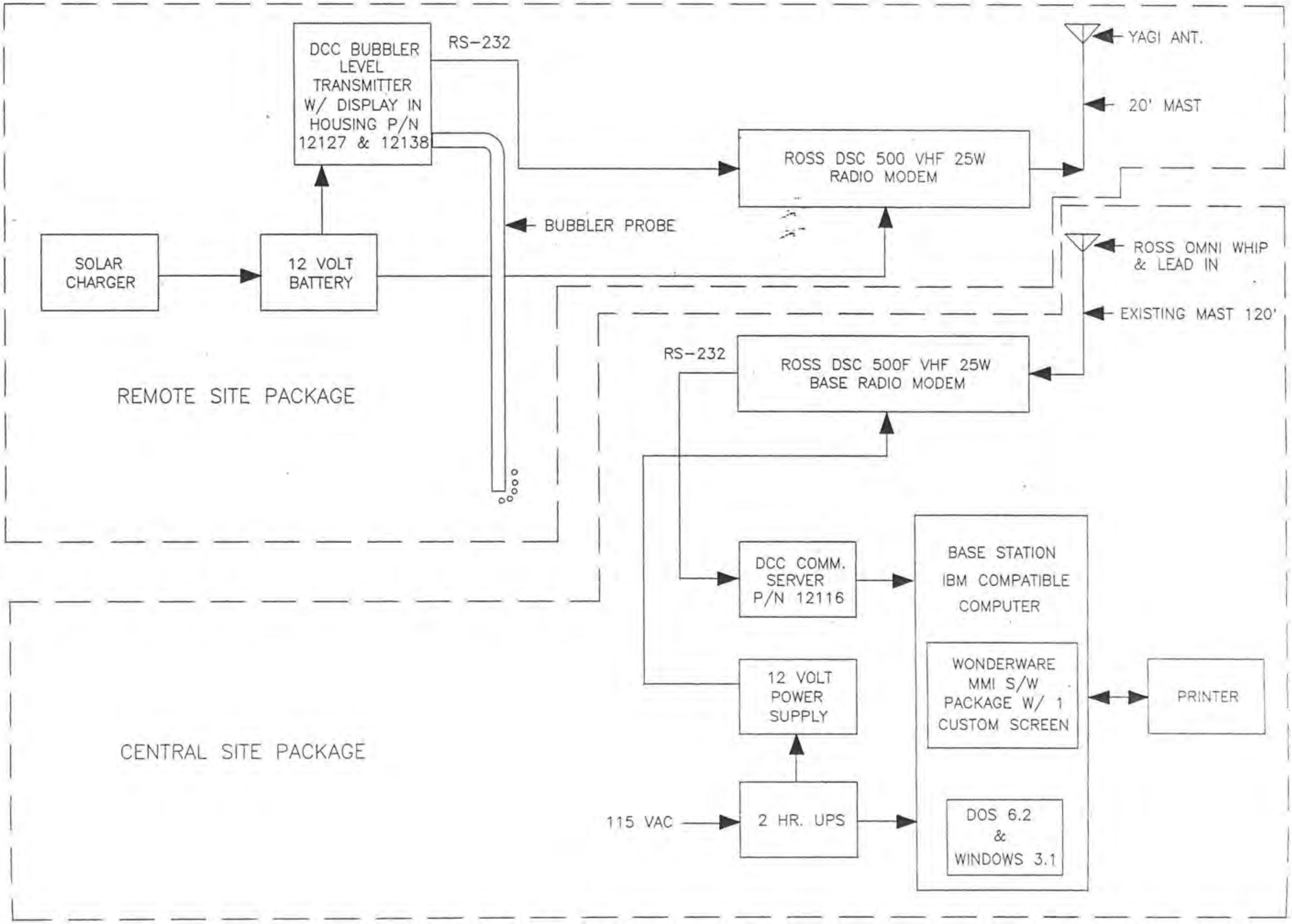
Smaller flow changes from Taylor-Ord canal could be handled in a similar fashion. Lag times would be reduced because the volume of water to be filled or drained from Mirdan Canal would be smaller. As with present operations, local manual control of check gates will help to manage the remaining flow mismatches as they propagate downstream.

4.2 Phase 2, with supervisory monitoring for other important sites - The concept of Phase 1 can be expanded and implemented more effectively when the watermaster has more information on current conditions in the canal. By monitoring the water level in each canal pool from the Taylor-Ord Inlet to the South Turtle Creek Siphon, headworks flow adjustments can be coordinated with check structures downstream. Minor flow fluctuations from Taylor-Ord Canal may not necessitate a headworks adjustment if conditions in Mirdan Canal remain manageable with check gate adjustments. With better information, operators will be able to make better decisions.

4.3 Phase 3, with expanded monitoring plus supervisory manual control - Control of all Section 1 check structures from the headquarters office will virtually eliminate the lengthy response time of local manual control. When conditions warrant, all structures can be adjusted simultaneously. When the simultaneous gate operating technique is used, canal pool volumes don't have to change in order to change the flow rate. (When pool inflow and outflow changes are equal, the volume of water in the pool remains constant.) After a flow change, pool water levels recover quickly to a new steady state.

Simultaneous gate operation is an excellent technique during emergencies. For example, when flood flows from Taylor-Ord Canal are detected, all Mirdan check structures can be adjusted immediately. Flow can be reduced at the headworks and at Check 263 to offset the flow increase at the Taylor-Ord Inlet. Checks 511, 717, and 1027 can be adjusted as appropriate to manage excess runoff in the canal until the headworks flow decrease migrates downstream. Additionally, these lower checks can be used to manage wasteway flows versus the flow into Section 2.

{Report prepared by D.C.Rogers, D-8560, 4/26/96}



BUBBLER WATER LEVEL RECORDING AND REPORTING SYSTEM

(APPENDIX 1)

DIGITAL CONTROL CORP.
10871 75th Street North
LARGO, FL. 34647 PH. (813) 547-1622

BUREAU OF RECLAMATION WATER BUBBLER LEVEL RECORDING & REPORTING SYSTEM

REV	DESCRIPTION	DATE					
	INITIAL RELEASE	4/26/96	CAD OPER	HOLTZMAN	TEH	SCALE N/A	DRAWING NO.
			DEV ENGR	BRITTIAN		SHEET 1 of 1	