

**ANALYSIS OF FLAP GATE DESIGN AND IMPLEMENTATIONS FOR WATER
DELIVERY SYSTEMS IN CALIFORNIA AND NEVADA**

by

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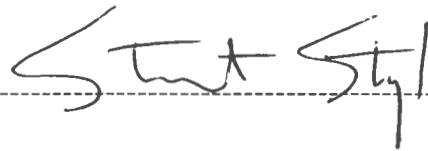
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ABSTRACT

This project was conducted to analyze, compile and summarize the modifications and adjustments on the ITRC Flap Gate over the past 15 years of implementations in California and Nevada. Over these years, the ITRC has made several developments, along with improvements implemented by water and irrigation districts. For this project, the ITRC Flap Gate was evaluated by the following districts: Alta Irrigation District, Chowchilla Water District, Fresno Irrigation District, and Walker River Irrigation District. Additionally, the typical foundation of the ITRC Flap Gate was briefly analyzed in the FLOW-3D computation fluid dynamics software program. During this analysis process, the author also designed and helped construct an ITRC Flap Gate for Walker River Irrigation District, Yerington, NV. From the research, some of the main beneficial findings were ease of design, construction and implementation, galvanizing, variable heights and chain stops.

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INTRODUCTION

Background

The idea of a gate to control upstream water level hydraulically originated in the Netherlands in the 1940's by Vlugter. From then on the flap gate design has been modified and developed into a cost-effective, straightforward hydraulic gate for automatic upstream water level control.

Although there are several variations of flap gate design, as discussed in the literature review, all flap gates also consist of a steel plate pivoting about some horizontal axis. The majority of the concepts for flap gate type design use a counterweight on the top of the gate plate which counteracts with the pressure that the water exerts on the gate. Water level increases in the water body causing the pressure on the gate to increase and a moment is created about the gate that tends to open it (gate-opening couple). Conversely, when the water level decreases due to outflow, the pressure decreases and the counterweight creates an opposite moment about the gate which tends to close it (gate-closing couple). The flap gate must be designed and operated so that the gate-closing couple about the pivot point is precisely balanced with the gate-opening couple about the same point. If these two couples, shown in **Figure 1**, are balanced, the flap gate is able to maintain the same upstream water level for varying flow rates. When the gate is correctly designed, the upstream water level will be controlled within a few centimeters (Burt et al., 2001).

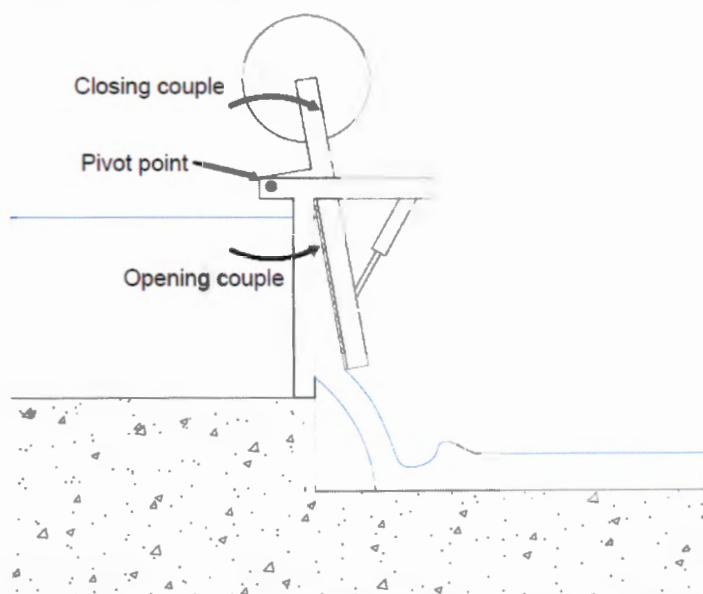


Figure 1. Opening and closing couple for the flap gate design (Burt et al., 2001)

Its design is appealing to water and irrigation districts with a need for accurate deliveries at the lowest possible cost. The Cal Poly Irrigation Training and Research Center (ITRC) designed and developed the ITRC Flap Gate, see **Figure 2**.



Figure 2. ITRC Flap Gate Installation at Walker River Irrigation District (ITRC, 2012)

Along with the gate design, an EXCEL design program was created, which increases the ease of use, feasibility of design and installation. Today, there are over two hundred flap gate installations in California and Nevada. Water and irrigation districts in both California and Nevada are modifying and updating their water delivery structures. However, they must simultaneously limit grower's costs, especially in dry years where water is scarce. The ITRC Flap Gate is a simple, economic solution to accomplish these goals.

Project Justification

Water delivery in California and Nevada needs to be as efficient as possible due to increasing demand. For irrigation districts in this region, it is crucial to be able to deliver water through a canal or pipeline accurately. Especially for years when end users only receive a percentage of their allotment, the quantity that the end users receive must be as accurate as possible. For agricultural deliveries, having improved control of deliveries enables growers to efficiently use water. When selecting a method for upstream water level control, (which in turn controls the flow rate) one of the deciding factors is cost. If upstream water level control is expensive, the cost of water will also be expensive. In

order to satisfy the customer with accuracy, control and cost demands, many irrigations districts choose flap gates as a solution to the problem. Flap gates are able to maintain a water level elevation within ± 0.5 inches, are able to operate steadily at varying flow conditions and are inexpensive.

Objectives

This project will analyze previously installed flap gates in California and Nevada considering accuracy, cost, and durability. Additionally, this project aims to consolidate and update the ITRC Flap Gate Design for the water industry. This report details flap gate installations and development within several irrigation districts including: Alta Irrigation District, Walker River Irrigation District and Chowchilla Water District, with a focus on Walker River Irrigation District. An evaluation of these gates is necessary for consolidation of conclusions drawn from field installations of the ITRC's Flap Gate. In addition, this project will also discuss the ITRC Flap Gate for Walker River Irrigation District in Yerington, Nevada that the author designed and helped construct, along with Justin McBride, ITRC. This project will also include an evaluation of the ITRC Flap Gate using computational fluid dynamics software called FLOW 3D. FLOW 3D analysis will aid in viewing how the flap gate operates and how to explain events that have occurred in the ITRC's experience with flap gate installation. This project is supported by the Irrigation Training and Research Center (ITRC), Cal Poly.

LITERATURE REVIEW

Water Level Control Structures

In a water delivery canal, delivery accuracy is extremely important. It might be assumed that the accuracy might be controlled through flow rate control. On the contrary, it is much easier and much more accurate for the canal operators to control the water level in the canal. "Furthermore, constraints of feeding gravity turnouts, stability of canal banks, efforts to reduce weed growth, constitution of intermediate water storage volumes, risks of overflow, are expressed in terms of water levels" (Malaterre, 1995). The water level can be controlled by upstream or downstream water level control. **Figure 3** shows a diagram of water level control in an upstream pool (y_{up}) and **Figure 4** shows a diagram of water level control in a downstream pool (y_{dn}).

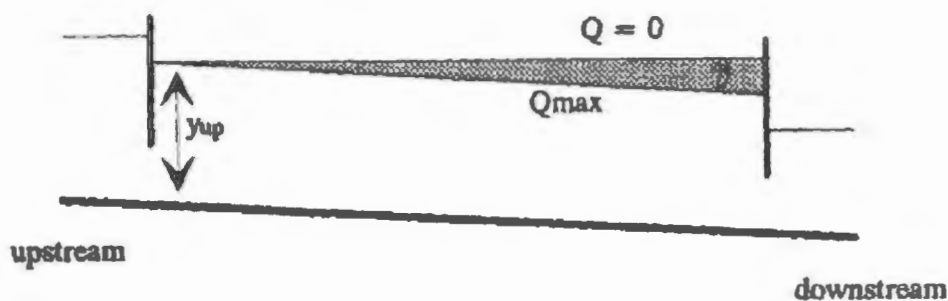


Figure 3. Upstream pool water level control diagram (Malaterre, 1995)

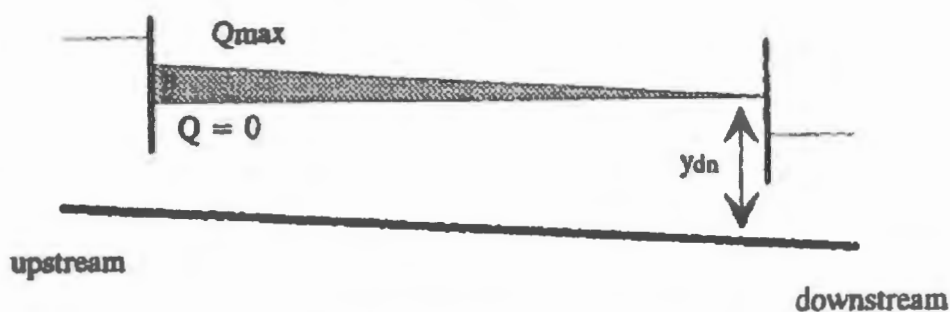


Figure 4. Downstream pool water level control diagram (Malaterre, 1995)

Out of the above options of water level control, upstream water level control is the most commonly used method. The reasoning behind the choice of upstream water level control is likely due to the manual operation with no automatic or remote controls. Upstream water level control is easier for water delivery personnel to operate since it is supplier oriented (Clemmens et al., 1989). When an irrigation district (or other water

delivery agency) has a rigid delivery schedule, upstream water level control is the better choice (Replogle et al., 1980). However, if a flexible schedule is necessary, upstream water level control is less practical. In upstream water level control system, prior notice of one to five days is needed for changes in the delivery schedule. This lead time can be more flexible only if there is storage along in the delivery canal or if there is excess water that is returned to the river through a spillway (Clemmens et al., 1989).

There are several methods of upstream water level control including manual, remote, or automatic gates, weirs, flumes and combinations of these. The common types of gates used are radial, vertical lift and flap gates (Seghal, 1996). Several considerations are made when selecting methods for upstream water level control. These considerations include cost of implementation and maintenance, ease of installation and maintenance, accuracy level needed, water delivery schedule and flexibility. For most districts, the most heavily weighted factor out of these is the cost of implementation and maintenance. Along with the ease of installation and maintenance, cost-effectiveness is the reason why the flap gate makes an intelligent decision for upstream water level control in a canal or other open water delivery system. "Depending on the size and design of the gate, water level control <1 in. (2.5 cm) has been obtained. For this reason, and due to the low maintenance and initial costs, the flap gate is a prime candidate..." (Burt et al. 2001).

Variations of Flap Gate Control Structures and Applications.

There are several variations on flap gate concept of using the hydraulic differential to operate a control structure. This design idea has been implemented across the world, originating in the Netherlands, then moving to the United States, China and other countries. The following are some of the variations on the flap gate design.

The Xiangtan Q-type automatic hydraulic flap gate uses two curvilinear bearings that guide the gate to slide back and forth. According to Jiong, the advantages of the gate include safety of function, wide range of use, high reliability in operation, simplicity in structure, no necessity for skillful maintenance, lower cost of work and maintenance, larger flow capacity, and better capacity to remove flood debris. This gate has a maximum opening angle of 80 degrees (Jiong, 1988). Jiong states that there are "Since 1980, at least 35 Q-type gates have been installed on 10 gate weirs near Xiangtan City, in Hunan China. They have operated safely for 5-8 years without any damage". Although, there was no discussion of how accurate the gate is for maintaining upstream water level control.

Several different sizes of flap gates have been used. Seghal (1996) discusses a flap gate that has great widths, up to 100 m wide. It is also mentioned that due to cost the flap gates are normally only 4 m high.

Another variation on the flap gate was reported by Chinh et al (2008). A simplified version of the flap gate was used on the downstream end of a canal in a rice paddy, see **Figure 5**. In this case, an equation was developed to find the flow rate through the gate for optimizing the operation of the gates in the drainage canal (Chinh et al., 2008). There was no discussion of the accuracy of the flap gate as a flow rate measurement tool. In

this application, the flap gate was not used for upstream water level control, as in the other variations on the gate.

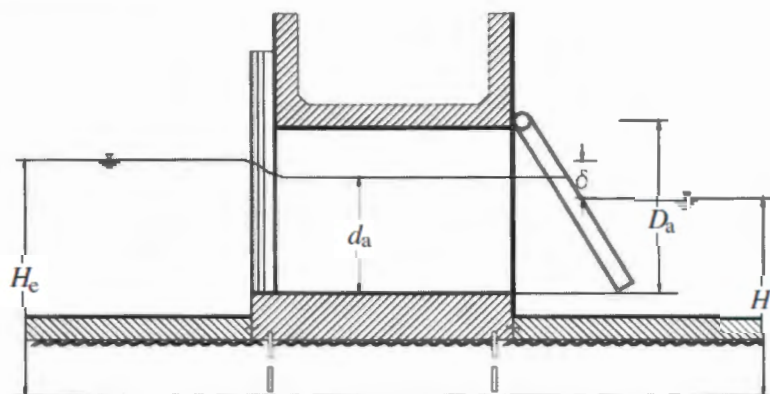


Figure 5. Cross-section of Flap Gate Variation (Chinh, 2008)

Raemy and Hager (1998) discuss a design similar to the ITRC Flap Gate. However, the channel does not have a weir and the design presented is for a suppressed sidewall condition, unlike the ITRC Flap Gate. In an evaluation of these designs, Burt (2002) states, "None of the 100+ installations that I am aware of in California have suppressed conditions". Additionally, Raemy and Hager (1998) confirm "since the analysis does not give the pressure distribution, the moment on the gate cannot be determined". For this gate, an empirically derived equation for the opening moment to find the equilibrium model (Litrico et al., 2005).

Begemann Gate. The closest flap gate design to that of the ITRC Flap Gate is the Begemann gate. Litrico et al. (2005) describes the Begemann gate as "a weir equipped with a steel plate rotating around a horizontal axis located above the upstream water level". With the Begemann Gate, the water is able to freely flow on both sides of the opened gate, see **Figure 6**. When there is no influence from downstream, this gate is able to maintain upstream levels fairly accurately. The Vlugter Gate is a variation of the Begemann Gate and has a round back, intended to operate in submerged conditions (Litrico et al., 2005).



Figure 6. Ten Begemann gates in the Hadejia Valley Irrigation Project North Main Canal (Litrico et al., 2005)

ITRC Flap Gate. The ITRC Flap Gate is the gate that will be discussed in this report. The gate is a result of the findings of several different research projects. Burt (2001) states that:

Vlugter (1940) investigated various configurations such as the Begemann and Doell. Brouwer (1987) summarizes important design principles, including key dimension ratios. Raemy and Hager (1997) examined the opening and closing moments at various angles of opening, and Brants (1995) documented the use of such gates in Indonesia. Burt and Styles (1999) observed poorly maintained flap gates in an irrigation project in the Dominican Republic. Medrano and Pitter (1997) and Sweigard and Dudley (1995) worked on prototype flap gates (commonly known as Begemann gates) at the Water Delivery Facility of the Irrigation Training and Research Center (ITRC) at Cal Poly.

The ITRC, along with the support of the Mid-Pacific Region of the U. S. Bureau of Reclamation, has constructed and installed over 105 flap gates in the Chowchilla Water District (CWD). The testing for developing the ITRC Flap Gate in part occurred within the CWD. Even though many of the gates met the expectations, some design refinement was needed (Burt et al., 2001). Burt (2001) discusses in detail the refined ITRC Flap Gate design and states that the updated design has been installed in the Turlock Irrigation District (ID), Alta ID, and Broadview Water District (WD). According to Dr. Stuart Styles, the ITRC Flap Gates have also been installed in Walker River ID, Truckee Carson ID, Glen-Colusa ID, Merced ID, Banta-Carbona ID, Fresno ID, James ID, Oakdale ID, Pixley ID, San Luis Canal Company, Solano ID, South San Joaquin ID, and Tulare ID.

Alternative Flap Gate Application. Another application of flap gates other than upstream water level control is the use at the end of pipe drains and pump outlets in order to avoid water backflow or small animal entry. However, the gate does impose a restriction on the upstream head of the water system. Replogle and Wahlin (2003)

discuss the head loss characteristics of the flap gate application at drain pipe ends. They concluded that the “flap gates of either the pinned-hinge or the flexure style add small head losses that amount to about 1-2 percent of the pipe diameter”. This research helps the implementer to decide whether the flap gate application is correct for their situation.

FLOW 3D Computational Fluid Dynamics Software and Applications

In the past, numerical simulations have required extensive analyzing and critical physical tests to prove accurate. FLOW 3D is a computational fluid dynamics (CFD) software that allows for flow simulation in up to three dimensions in a varying range of applications. For hydraulics engineers, the program is a powerful tool to simulate situations, ranging from “large hydroelectric power project to small municipal wastewater treatment systems” (FLOW 3D, 2014a). This program allows hydraulic engineers to test various situations and variations of applications before investing in physical models.

Comparisons between physical and FLOW 3D models. Several studies have been conducted to evaluate the accuracy of FLOW 3D in correlation to physical models. Afshar and Hoseini (2013) compared the experimental and 3D numerical simulation of flow over a rectangular broad-crested weir. Their goal was to produce a free-surface profile of a rectangular broad-crested weir. The paper details all of the parameters used in the FLOW 3D CFD simulation (grid types and boundary conditions) and the physical model. Several different turbulence models were created in order to anticipate the water surface and streamlines. According to Afshar and Hoseini, “The computational results showed a good agreement with experimental values” (Afshar et al, 2013). Another validation project was conducted by Riddette and Ho (2013) evaluating flow-induced vibrations in radial gates during an extreme flood, shown in **Figure 7**. A radial gate is an undershot gate that has an orifice flow with variable areas (USBR, 2001). In this study, both a scale physical (1:80) and CFD model were built to represent the spillway radial gates on the Wyangala spillway, see **Figure 7**. Riddette and Ho discuss the results of 15 different validation analyses cases for the study. They conclude that the FLOW 3D CFD program is able to “model vortex shedding frequency under flow conditions similar to those occurring at Wyangala Dam spillway during extreme outflows. This has been shown to be possible for simple 2D and 3D cases...” (Riddette et al., 2013). According to their detailed study, FLOW 3D has proved accurate for this type of application.

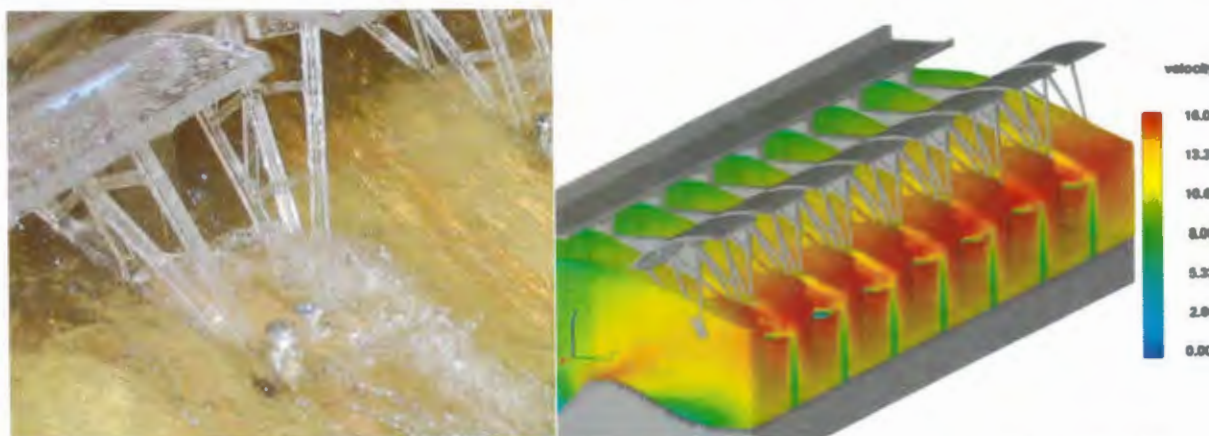


Figure 7. Comparison of scale physical model (SMEC 2006) to FLOW 3D Model (WorleyParsons, 2008)

PROCEDURE AND METHODS

Flap Gate Design Procedure

The following is the design procedure for the ITRC flap gate, see **Figure 8** for drawing:

1. Site investigation with sketches of the key features of the site and organization of information about flow conditions, available construction sites, etc.
2. Surveying of the site at high and low flow rates. The specific survey data required can be summarized so a 3rd party firm can collect the information.
3. Decide on the maximum flow that the flap gate has to pass
4. Input hydraulic information and channel geometry into the design spreadsheet
5. Evaluate designs and select one based on a thorough assessment of surveying data
6. Output dimensioned construction drawings
7. Build the ITRC Flap Gate



Figure 8. SolidWorks rendering of ITRC Flap Gate for Walker River Irrigation District

Design Procedure

The ITRC Flap Gate is designed using an EXCEL spreadsheet design program. The opening and closing couples of the gate are estimated with a specified upstream water level and for various angles. Using statics equations to find the gate-closing couple, the centroid of the mass is determinable if the mass and relative locations of all the steel members in the gate are known (Burt et al., 2001). Through hydraulic evaluations on flap gates, Raemy and Hager (1997) found that a linear pressure distribution only occurs when there is no flow. Actual force on the gate decreased as the gate opened due to the water flowing through the gate was only subjected to atmospheric pressure.

The ITRC built a prototype flap gate to develop and further analyze the design. From the prototype, the total dynamic pressure heads are varying flow rates, upstream depths, and angles of opening. The average pressure distribution curves, with a parabolic curve fit, were developed for additional analysis (Burt et al., 2001)

Force Calculations. As stated above, the force decreases as the opening angle of the flap gate increases. For every angle, the hydraulic force and the location of the centroid of that force on the faceplate varies. These two values must be determined in order calculate the opening moment. From the ITRC prototype flap gate parabolic pressure distribution curves, the area under the curve was found. Then the hydraulic forces were found by multiplying the area by the width of the gate, the density of water, and gravitational acceleration. For this gate, the relationship between the adjusted force and the angle of gate opening was found, see **Figure 9**.

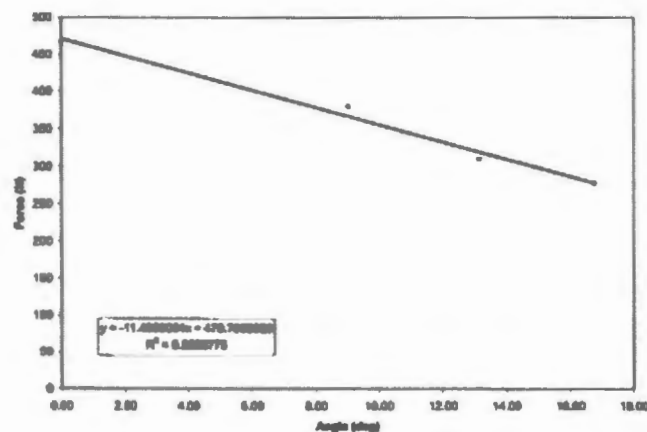


Figure 9. Relationship between the adjusted force versus the angle of opening for the ITRC Prototype Flap Gate (Burt et al., 2001)

The graph shown in **Figure 9** will be similar for similar gates; however the y-intercept (the force when closed) will vary with the gate specifications. A force ratio was developed to create a universal equation (1) for all gates:

$$\text{Force ratio} = \frac{\text{slope}}{\text{ITRC gate force at zero flow}} \quad (\text{Burt et al., 2001}) \quad (1)$$

The actual force on the gate can be determined at any angle knowing the static force on the gate using the following equation(2, 3):

$$Force (N) = (force \text{ at zero flow rate})(1 + (force \text{ ratio}) - \theta) \quad (2)$$

$$Force (N) = \left(\gamma \frac{h_s}{2} A\right) (1 - 0.024 - \theta) \quad (3)$$

Where:

γ = specific weight of water (9.807 N/m²)

h_s = upstream water depth, measured from the bottom of the faceplate (m)

A = area of faceplate (m²)

θ = angle of gate opening (degrees)

These calculations have been verified by empirical testing conducted at the ITRC.

Centroid Calculations. The vertical location of the centroid of the forces is calculated using the following equation (4):

$$h_c = \left(\frac{h_s}{3}\right) (1 + 0.009 * \theta) \quad (4)$$

Where:

h_c =upstream static water level (m)

θ = angle of gate opening (degrees)

Opening and Closing Moments

The ITRC created an EXCEL spreadsheet that estimates the closing and opening couples of the gate at various angles with a determined upstream water level control. The pressure distribution with and without flow is discussed in this paper. In addition, the force calculations are done to find the opening and closing moments of the gate. "It is impossible to obtain a design that provides an exact match of moments (couples) at all angles of opening, but they can be very similar." **Table 1** shown below shows an example of this(Burt et al., 2001).

Table 1. Opening and Closing Moments for an Example Design (Burt, 2001)

Angle (degrees) (1)	Opening moment (ft-lb) (2)	Closing moment (ft-lb) (3)	Change in moment (ft-lb) (4)	Change in water level (5)
0	1731	1731	1	0.0
2	1619	1640	-22	-0.1
4	1509	1543	-39	-0.5
6	1402	1453	-51	-0.6
8	1296	1357	-59	-0.5
10	1197	1259	-62	-0.9
12	1100	1160	-60	-1.0
14	1005	1059	-54	-1.0
16	913	957	-44	-0.9
18	824	854	-30	-0.6
20	736	750	-11	-0.3

EXCEL Design of the ITRC Flap Gate

The ITRC developed an EXCEL spreadsheet design program to design the flap gate with given inputs from the designer. As with any design, the program has guidelines for creating ideal gates for flow rates between 0-100 CFS.

EXCEL Program Inputs. For the EXCEL design program, the designer will need to have the following inputs, shown in **Figure 10**:

- Desired upstream water height above the bottom of the static frame of the flap gate, inches (b)
- Width of the structure opening, inches (c)
- Pivot point height above the bottom of the static frame (d)
- Pivot arm length, inches (p)
- Face plate overlap, inches
- Face plate thickness, inches
- Weight per foot of steel tubing used to make the dynamic frame, pounds per foot
- Tubing dimensions, inches

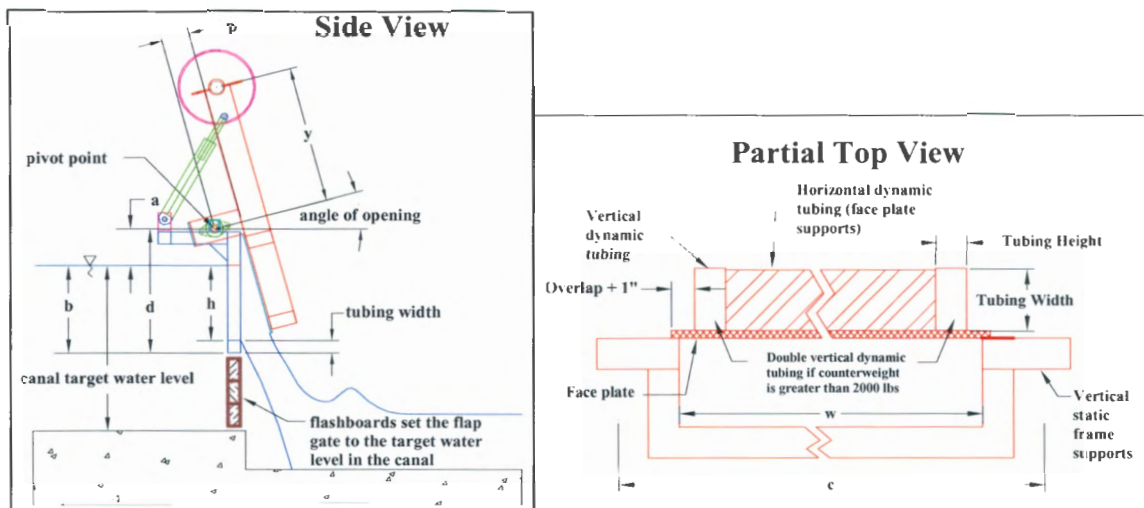


Figure 10. AutoCAD Sketches of Flap Gate EXCEL Inputs, (L) Side View, (R) Partial Top View (ITRC, 2003)

The EXCEL spreadsheet prompts the designer to keep the angle from the pivot point to the center of gravity of the flap gate between 48 and 53 degrees. Additionally, the ratio of the distance from the pivot point to the water surface to the upstream water depth (a/h)

should be 0.5 or less. The ratio of the lever arm length to pivot point height should be 0.25 or less.

Appendix B shows the EXCEL design for the Walker River Irrigation District's (WRID) River Simpson 1 flap gate design edited by the author of this report. This specific flap gate was designed for an estimated maximum flow rate of 25 CFS and a maximum angle opening of 31 degrees from the static frame.

ITRC Flap Gate Construction Method

After the design in the EXCEL program is completed, construction begins. There are two main components to the ITRC Flap Gate, the dynamic frame and the static frame, see **Figure 11**. The static frame will be set in the canal, or other structures, and the dynamic frame will pivot around the static frame via a fixed shaft and bearings mounted to the dynamic frame. This portion of the report is based off of the author's experience, along with the help of Justin McBride of the ITRC, in building an ITRC Flap Gate for WRID River Simpson 1 site, as discussed above and shown in **Appendices B and C**.

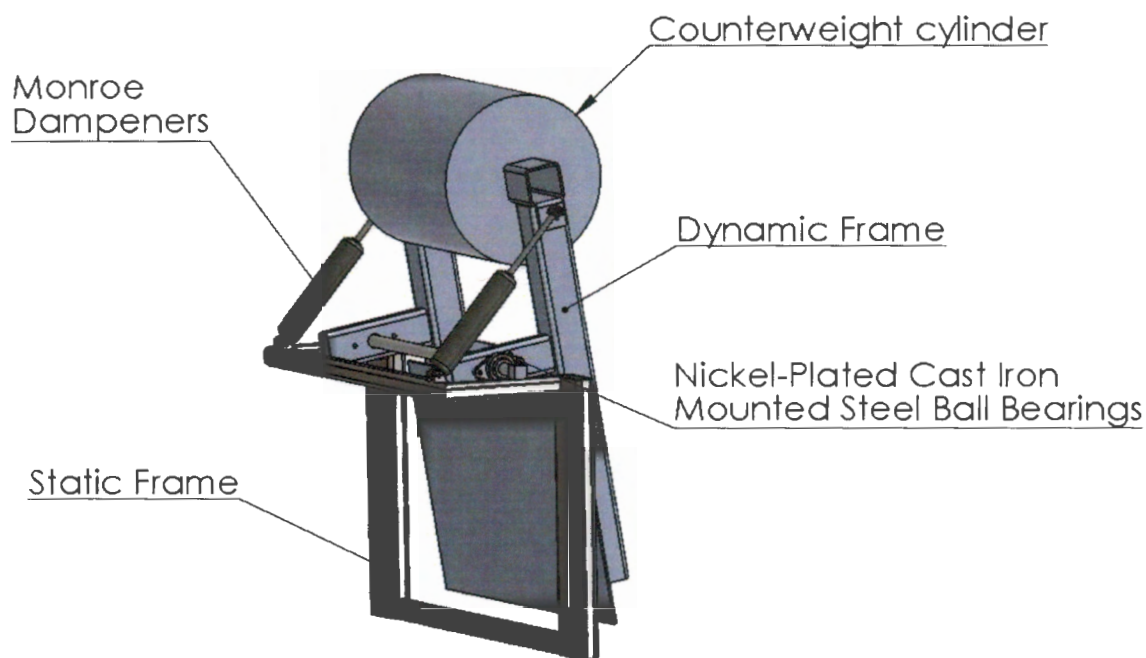


Figure 11. Main assembly parts of the ITRC Flap Gate designed and built for WRID

First, the materials, shown in **Table 2**, must be ordered for the flap gate construction. **Table 2** shows the specific materials for the ITRC Flap Gate built for WRID; however the materials do not change per flap gate, just the quantities. It must be specified that the table discusses the specific part numbers used for the flap gate for WRID and the ITRC does not necessarily endorse any of these product, any equivalent model to these items can be used.

Table 2. Materials List for ITRC Flap Gate built for WRID

Item	Quantity	Length (ft)	Part No.
B&B Steel Order			
2"x2" tubing (1/4" thick)	1	20	
2"x4" tubing (1/4" thick)	1	20	
2"x6" tubing (1/4" thick)	1	20	
4"x4" tubing (1/4" thick)	1	20	
#4 rebar	6	20	
4'x8'x0.25" Steel sheet	1		
Mcmaster Order			
1 1/4" diameter	1	4	Mcmaster #1346K47
1 1/4" bearings	2	n/a	Mcmaster #6494K45
Counterweight Cylinder			
18" nominal outside diameter pipe	1	3	
Napa Order			
Monroe steering damper	2		Napa: NS SC2916
Other Items			
Hinge	1		
Padlock Hinge	1		
Padlock	1		
Latch	1		
bag of concrete	1		
9/16"x2.5" bolts	4		

Once the materials arrive, a CNC Plasma cutter is used to cut out the caps for the steel tubing and for the counterweight cylinder. **Figure 12** shows the cutout that was created for the ITRC Flap Gate for WRID by the author. These files must be made in AutoCAD then saved in ".dxf" format to be able to communicate with the BobCAD program for the plasma cutter. Since these pieces are made out of sheet metal, the goal is to optimize the space on the sheet.

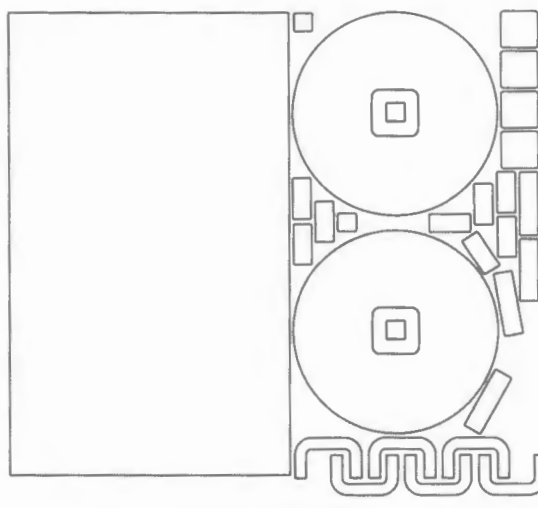


Figure 12. CNC plasma cutter layout for the ITRC Flap Gate for WRID

After the pieces are cut out, the next step is to cut the steel tubing and rebar to the lengths specified in the spreadsheet. Once all the materials are cut, they are assembled according to the construction drawings and welded together. Holes for the bearings are drilled according to the bearings purchased. The cylinder for the counterweight must be cut to size also. Once the cylinder is cut to size, a flap, with handles welded on, must be cut in the cylinder to allow for the insertion of concrete. If galvanizing the gate, small holes must be drilled in the tubing and in the counterweight cylinder for the hot dip galvanized process.

ITRC Flap Gate Installation Method

Since flap gates are typically installed by the districts, specifying the installation method is particularly important. **Figure 13** shows an ITRC Flap Gate installation in a flashboard structure setting. Although there are various installation configurations possible, the most popular configuration is installing the flap gate in a new or existing flashboard structure. The reason for the multiple gates is due to the high flow rate capacity needed in the canal.



Figure 13. Installation of ITRC Flap Gate in a flashboard structure (ITRC, 2013)

The installation method for retrofitting an ITRC Flap Gate into a flashboard structure, **Figure 13**, per Irrigation Support Engineer, Mr. Kyle Feist, is outlined in the following steps:

1. Before installation can begin, the distance between the top of the flashboard section and the upstream pool's target water level needs to be compared to the value for "b" off of the EXCEL spreadsheet. See **Figure 14** for the dimension "b", in this example "b" is 26 inches.

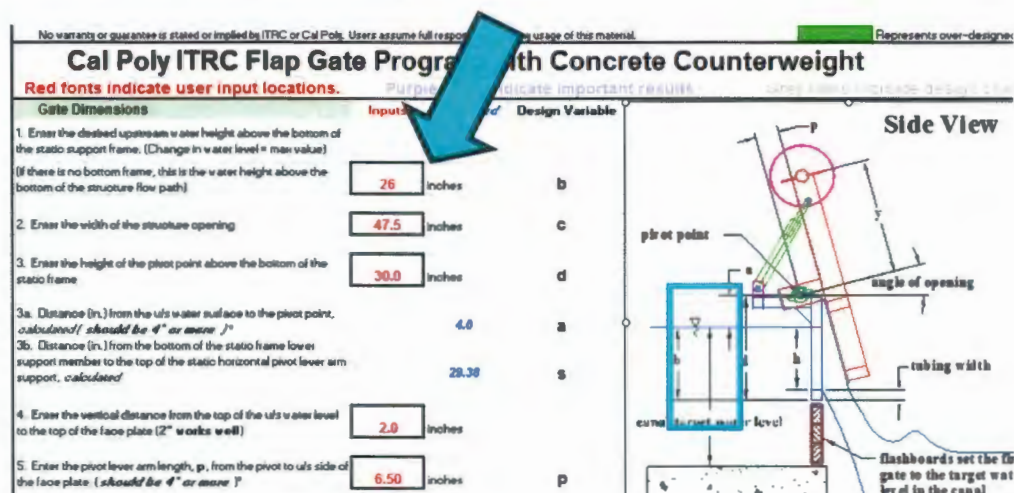


Figure 14. EXCEL flap gate design spreadsheet with critical dimension "b"

2. Once the dimension “b” is confirmed, the static frame can be inserted into the previously determined location in the steel or concrete channels. The static and dynamic frames are shown in **Figure 15**.

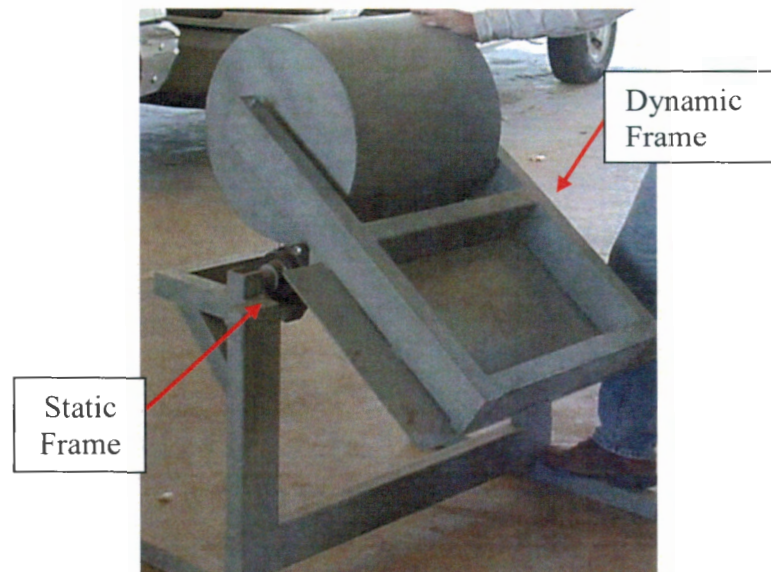


Figure 15. The ITRC Flap Gate static and dynamic frames

3. The bearings are to be loosely bolted to the inside of the dynamic frame, through the holes shown in **Figure 16**. Insure that the bolt heads are on the outside of the frame. Place the mechanical lock washer on the inside of the frame, on the nut side, of the bolts.

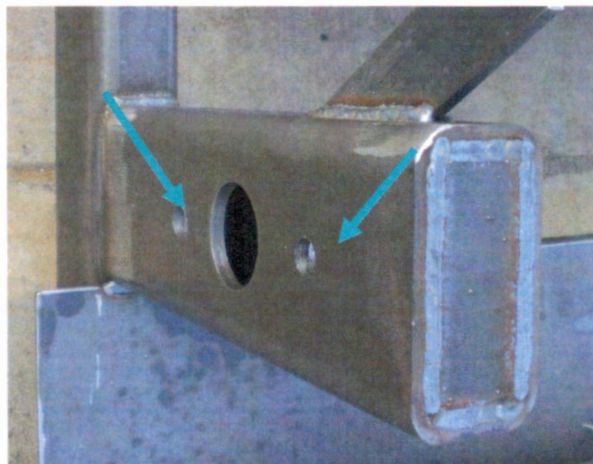


Figure 16. Outside face of the dynamic frame bearing holes

4. A lubricant, for example WD40, must be applied to the pivot shaft to reduce friction. Working from the outside face of the dynamic frame, slide the pivot shaft through the bearings. If necessary, use a soft-faced dead blow hammer.

Insure that the amount of exposed shaft is the same dimension of both sides of the frame and that the shaft is centered in between the bearings.

5. After the pivot shaft is inserted into the dynamic frame, place the dynamic frame onto the static frame by setting the ends of the pivot shaft in both saddles, shown in **Figure 17**.

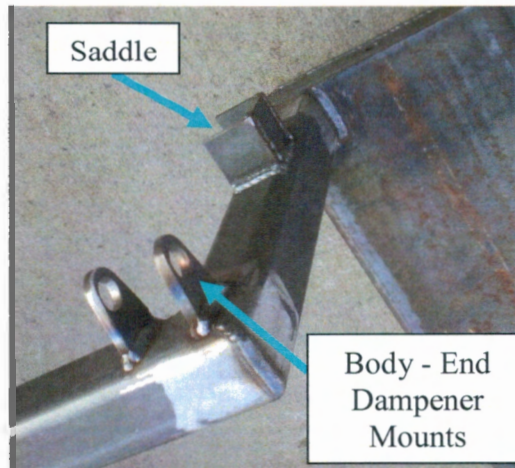


Figure 17. ITRC Flap Gate shaft saddle on the static frame (step 5) and the body-end dampener mounts (step 8)

6. Adjust the dynamic frame assembly to make sure that the dynamic frame has equally distributed loads on the static frame. After this is done, tighten the bolts which attach the bearing to the dynamic frame.
7. Slide the shaft end of the shock dampeners onto each of the threaded studs on the sides of the dynamic frame. Install the fastening hardware in the following order: Dampener eyelet, Spacer/Washer, Mechanical locking washer, Nut. See **Figure 18** for a detailed photo.

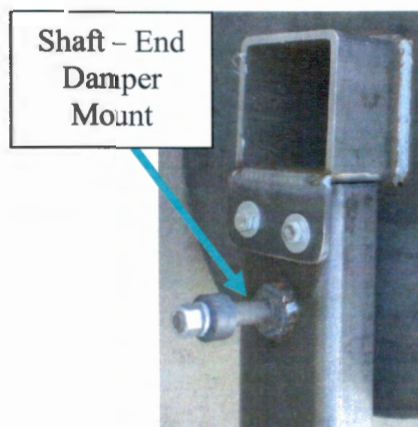


Figure 18. ITRC Flap Gate steering damper mount on the dynamic frame

8. Using an appropriately sized bolt, fasten the opposite end (body end) of the dampener to the welded tabs on the static frame, see **Figure 17**. The orientation of the bolt is not critical, however the use of a mechanical locking washer on the nut side is recommended.
9. Unbolt the counterweight lid, shown in **Figure 19**, and completely fill with concrete. Once the concrete has been set for approximately two hours, fasten the lid onto the frame with the supplied fasteners.



Figure 19. ITRC Flap Gate counterweight lid

10. Operate the canal at the specified flow rate and examine the water level upstream of the flap gate. If more closing moment is needed (raised upstream water level), insert the rebar into the center of the counterweight to match the desired upstream water level. Until the moment limit is reached, adding weight (rebar) will raise the operational water level. Conversely, subtracting weight (rebar) will lower the operational water level.

FLOW-3D

Introduction to FLOW-3D. For the purposes of this project and ease, FLOW-3D, computational fluid dynamic (CFD) software was selected. According to their website, “FLOW-3D is a powerful and highly-accurate CFD software that gives engineers valuable insight into many physical flow processes” (FLOW-3D, 2014b). This software was selected due to its optimized capability to predict free-surface flow in a wide range of applications. FLOW-3D is often referred to as a general purpose 3D solver due to its basis on the fundamental laws of energy conservation, mass and momentum, through the Navier-Stokes equation (Griffith, A, et. al., 2007). The software is even able to simulate transitions between subcritical and supercritical flow in one model setup (Woolgar et al., 2006). FLOW-3D can play a huge role in the design and testing phase of hydraulic engineering projects. In addition, FLOW-3D can aid in evaluating a current design, as

used in this report. FLOW-3D utilizes stereo lithographic files to develop a mesh, and then the analysis is conducted. In the program, the physics of the situation to be solved must be determined and entered into the program. Additionally, the position of the object in 3D space must be defined. One must have a deep understanding of the physics behind the situation to be able to properly analyze an item using the FLOW-3D CFD software.

Navier-Stokes equation. The Navier-Stokes equation, shown below (5-7), is able to describe time-dependent motion in one, two and three dimensions. For the application of the irrigation canal structures in FLOW-3D, the flow is assumed to be incompressible and constant viscosity is assumed over the control volume.

$$\rho \left(\frac{\partial V_x}{\partial t} + \sum_j V_j \frac{\partial V_x}{\partial x_j} \right) = \rho F_{vol_x} - \frac{\partial P}{\partial x} + F_{visc_x} \quad (5)$$

$$\rho \left(\frac{\partial V_y}{\partial t} + \sum_j V_j \frac{\partial V_y}{\partial x_j} \right) = \rho F_{vol_y} - \frac{\partial P}{\partial y} + F_{visc_y} \quad (6)$$

$$\rho \left(\frac{\partial V_z}{\partial t} + \sum_j V_j \frac{\partial V_z}{\partial x_j} \right) = \rho F_{vol_z} - \frac{\partial P}{\partial z} + F_{visc_z} \quad (7)$$

Where ρ is the fluid density of the liquid analyzed, which is assumed to be constant in time and space (Chanson, 2004).

TruVOF Volume-of-Fluid (VOF) method for fluid interfaces. The Volume of Fluid technique is composed of three different parts: "...a scheme to locate the surface, an algorithm to track the surface as a sharp interface moving through a computational grid, and a means of applying boundary conditions at the surface" (Griffith, A, et. al., 2007). FLOW-3D v10.1 comes with the improved VOF scheme, referred to as the Split Lagrangian method. See **Figure 20** for a free surface flow example. When dealing with open channel flow, the behavior of the fluid volume becomes essential. According to studies done by FLOW-3D, the volume error was normally small over one time period (one wave). However, when several wave periods are modeled, there is much greater room for error and percent errors greater than 1% can be seen (FLOW-3D, 2013). For our purposes, this should not be a substantial issue.

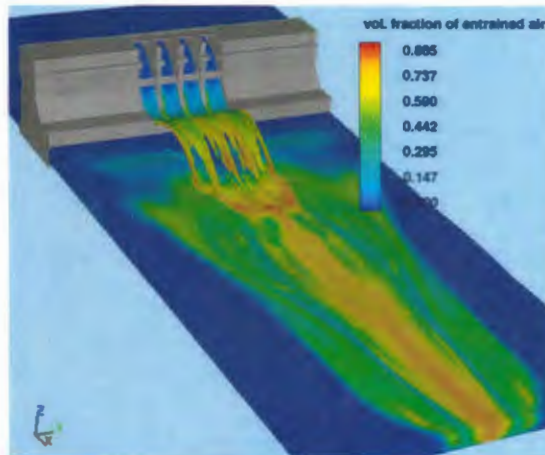


Figure 20. Free surface flow example using the TruVOF method in FLOW-3D

Methodology for FLOW-3D. When conducting an evaluation in FLOW-3D, the user must have knowledge of the physics of the situation and the boundary conditions. The surrounding elements can be drawn in a computer aided drafting program (AutoCAD or SolidWorks) and imported to FLOW-3D via stereo lithograph file (".stl"). The ".stl" format is a universal format to represent closed, watertight, solid objects. For the boundary conditions, many considerations must be taken, such as flow rates upstream, the upstream and downstream elevations, dynamic flooding conditions, fluid sources, downstream conditions and obstructions, time-dependent boundary conditions and/or fluid sources. The methodology for using FLOW-3D is simplified in the following steps:

1. Import topography and other relevant geological components, in ".stl" file format
2. Turn on the relevant physics according to the specific situation
3. Define the fluid properties, i.e. water, oil, etc.
4. If there are moving objects in the FLOW-3D evaluation, define the solid mass properties
5. Create a free mesh on the object
6. Define the boundary conditions of the system
7. Define the initial conditions for the evaluation
8. Fine-tune the numerical inputs to the application
9. Select the outputs desired by the user
10. Run the coarse grid on the item, check, then run the fine grids
11. Run the evaluation and obtain desired outputs

If great attention to all the details of the evaluation is taken, the evaluation can produce very accurate results. However, the user must have a prediction as to what will happen in the program's evaluation. Since there is so much room for error, the user must be aware of the expected results (FLOW-3D, 2012).

RESULTS

Results Overview

For this report, the Alta Irrigation District, Chowchilla Water District and the Walker River Irrigation District were concentrated on for this report. Doug Welch, general manager of Chowchilla Water District, and Javier Cavazos, Alta Irrigation District, interviewed for this report. The author of this report designed a flap gate for Walker River Irrigation District. Below is a discussion and summary of the developments, progressions and guidelines that have been developed for the flap gate over the years since it was first designed.

Benefits of Using Flap Gates

The benefits of using a flap gate include: operating steadily at various flow conditions, water elevation can be maintained within ± 0.5 inches, water travel time consistency, less mechanical parts than other options, can be designed and installed within one week and increases water delivery flexibility (Styles, 2001).

Javier Cavazos, Alta Irrigation District, stated that the greatest benefit of the ITRC Flap Gate was that it does not require man power to operate. For Alta Irrigation District, this a huge advantage for controlling the sections of canal without power (Cavazos, 2014).

According to Doug Welch, Chowchilla Water District, the ITRC Flap Gates are beneficial for maintaining upstream water level, providing a non-fluctuating water level for either another canal or turnout with a greater need for steady flow. Additionally, Mr. Welch stated that the flap gate keeps the vegetation around the dirt canals at a minimum. He also mentioned that since the flap gate maintains a constant water level and keeps rodents from burrowing in the dirt canals (Welch, 2014).

Site Requirements

From previous studies conducted by the ITRC, the following specifications for the site are used. The site must be in a relatively small canal, below 60 CFS, with continuous upstream water level. If the flap gate is to maintain the upstream water level, there are two requirements:

1. Substantial change in pressure (30-36 inches of head drop across the check structure). This is to prevent the flap gate from becoming submerged.
2. The flap gate cannot be installed adjacent to an operation weir due to the fact that they tend to hydraulically oppose each other.

Flap Gate Design and Construction Ease

From the author's experience, the ITRC Flap Gate is straightforward to design and build. The EXCEL design spreadsheet is clear on what is required and the construction only took two days to construct. Also, from communicating with other employees at the ITRC, it was concluded that the flap gate was effective, but simplistic in design and construction, making it the perfect upstream water level tool for districts.

Alta Irrigation District Specifics

The Alta Irrigation District (AID) has five flap gate installations in their district. They have had flap gates over the past ten years and have not needed to conduct any maintenance on the flap gates. Mr. Cavazos stated that their flap gates are installed in pipelines under pressure and serve the purpose of letting water out and not letting water in. AID does not have a ceiling flow rate that they operate their flap gates under (Cavazos, 2014).

Walker River Irrigation District Specifics

The Walker River Irrigation District (WRID) in Yerington, Nevada has three flap gate installations and plans to implement at least three more ITRC Flap Gates. In most of the cases in WRID, the existing spill structures have been or are recommended to be upgraded with an ITRC Flap Gate. Since several of these cases involve a drop of many feet, the flap gate is installed to maintain an upstream water level within ± 0.05 ft and be a continuous spill for the canal.

The reason for modifying the existing flashboard spill structures with an ITRC Flap Gate, of the same width, is to be able to pass through significantly greater amounts of flow and maintain the upstream water level in the canal to a greater degree of accuracy. For example, a 4-ft wide flashboard spill can pass approximately 10 CFS with 1 foot of pressure exerted by the water on the weir, and can pass approximately 30 CFS with an additional foot of pressure (in other words, changing the upstream water level) and no changes to the boards. In contrast, a 4-ft wide ITRC Flap Gate can pass through flows ranging from 0 CFS to about 50 CFS with only slight changes in the upstream water level.

There are important operational justifications for having continuous spills upstream of the automated flow control gates. The automated flow control gates will not have to move as frequently if operators can always divert more water than is required for irrigation demands. It has no effect on the overall amount of water diverted from the river because the 'excess' water is immediately returned to the same reach of river. In addition, the continuous spills provide an inherent safety feature in the event there are any problems with the gate automation.

The ITRC has completed designing and manufacturing three flap gates for WRID. Shown below in **Figure 21** and **Figure 22** are two of the completed installations in the district.



Figure 21. ITRC Flap Gate Installation on WRID Saroni Canal Headworks (ITRC, 2013)



Figure 22. ITRC Flap Gate Installation on WRID Plymouth Canal Headworks (ITRC, 2013)

At WRID, the flap gates are reported to operate smoothly and produce optimized conditions for the flow measurement sites that are directly downstream of them in the canal.

Chowchilla Water District Specifics

Doug Welch, General Manager of the Chowchilla Water District in Chowchilla, CA, provided that the district has 105 flap gate installations, ranging from 0-90 CFS flow rates. The district has been operating ITRC Flap Gates since 1995 and even did the initial testing and calibration of the ITRC Flap Gate design in their district. For the maintenance on the gates, they used to paint them, now the gates are sand blasted and galvanized. The gates are also greased every few years. The gates that are further downstream in the canal are flushed by pushing the gate open with a foot to insure that no mass is blocking the gate open or closed. Mr. Welch stated that only 10% of the time the flow is disturbed by something getting caught in the flap gate.

When asked about modifications, Mr. Welch explained that the district has made several varying modifications to the gates. One of the most significant developments was that they created variable heights for the counter balance, from 12-14 inches from the pivot point. This is done to vary the height of the counterweight above the pivot arm and therefore vary the closing couple on the gate. Another development was to have variable links on the pivot arm to change the opening of the gate (Welch, 2014).

CWD were the innovators of the chain stop, shown in **Figure 23**. This mechanism is to prevent the flap gates from being subjected to unequal moment couples, surpassing their center of gravity and being stuck open in the channel. The simplicity and low-cost of this implement makes it the ideal solution to the problem.



Figure 23. Chowchilla Water District chain stops (ITRC, 2013)

Fresno Irrigation District Specifics

Felix Vaquilar provided the information for Fresno Irrigation District. He stated that FID currently has 15 flap gate installations and their first flap gate installation was on FID's Gould No. 97 Canal in September 2006. The main purpose of the flap gate installations at FID is to provide level control at a constant level without continually making adjustments to compensate for fluctuations in a particular section of canal. The secondary purpose of FID's flap gate installations is to reduce the encroachment of burrowing rodents in the canal due to fluctuation in the level of the canal. FID is very pleased with the low maintenance of the flap gate. Mr. Vaquilar stated that galvanizing the gates has greatly helped with the maintenance of the gate and it is well worth the upfront cost of the gate. As far as the maintenance they have done, they grease the steering dampeners once a year and replace them when needed.

For the modifications that the district has made to the flap gate, Mr. Vaquilar said that the district has used a second set of dampeners on one flap gate. This gate was installed at the end of culvert that was doubled up as a check structure. Also, it was in a turbulent area, causing the gate to bob up and down. To compensate, the district extended the check structure so that the flap gate would be placed further downstream and they added a second set of dampeners to better counteract the wave action that was occurring (Vaquilar, 2014).

Glenn Colusa Irrigation District Specifics

Zac Dickens, the GCID Lead Engineer, provided the information for GCID. GCID currently has 15 flap gate installations and have had flap gates in the district for 5 years. The purpose of their flap gates is to maintain upstream water level, which in turn, facilitates the check operations by replacing flash boards and lift gates. He stated that the ideal site conditions for a flap gate were "uniform approach flow and free form lateral curves". Instead of galvanizing their gates, they paint them with a corrosion resistive paint (Dickens, 2014).

FLOW-3D Results

The FLOW-3D program was used to analyze a weir and a flap gate installation. The weir installation was very straightforward and two situation were considered, see **Figure** and **Figure 25**.

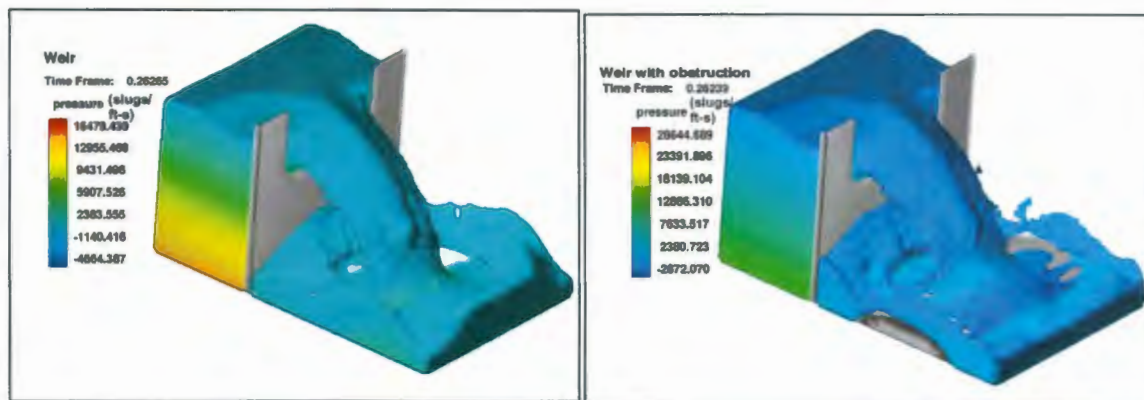


Figure 24. Flow-3D Comparison of Weir Simulations, Velocity Model

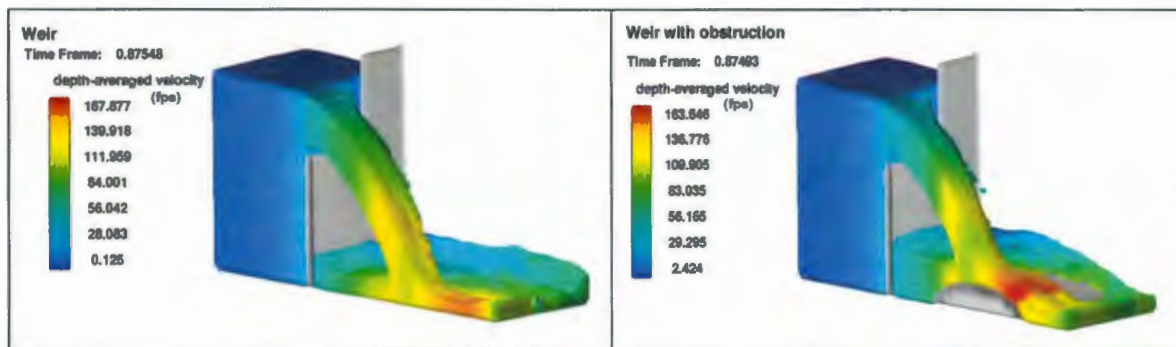


Figure 25. FLOW-3D Comparison of Weir Situations

The simulations show both the pressure and the velocity of the water over the flume. By observation, one can see how the water pressure varies across the surface. In the condition on the right in both **Figure** and **Figure**, the weir has an obstruction directly downstream from it. This showed that the water pressure decreased slightly in the weir. This did not seem correct to the author. Therefore, the FLOW-3D portion of this project needs to be analyzed further.

DISCUSSION

Over the past 20 years since it was developed, the ITRC Flap Gate has developed into a straightforward solution to upstream water level control. Although there are several advantages of the ITRC Flap Gate, the most impactful advantages were ease of design, construction and implementation, galvanizing, variable heights and chain stops. Due to the design and construction done by the author, the design and construction process was determined to be simplistic and easy to interpret. It must also be mentioned that an error was made in the construction of the flap gate. To clarify from the spreadsheet, the length of the counterweight cylinder specified in the spreadsheet is the actual length of the tube and does not include the thickness of the steel plate caps that go on the counterweight cylinder. The problem was very easy to fix, however it could have been avoided if more attention was paid during the construction phase.

Due to the installations of hundreds of flap gates across California and Nevada, the ITRC Flap Gate design provides results that can be replicated continuously. However, attention must be drawn to the fact that the spreadsheet needs to be interpreted with a logical thinking process and not just the “plug-and-chug” process. Overall, the ITRC flap gate is the ultimate solution to cost-effective, efficient, and accurate upstream water level control without much investment in the product. The main benefit to districts is the cost of the gate and the ease of construction; most districts have adopted the gate design process and fabricated the gate internally. This cost allows the district to have more sites where the upstream water level is maintained.

The FLOW-3D program proved to be a practical tool for analyzing situations when the user has knowledge of the outcome and can provide a prediction for the outcome. While the computational fluid dynamics program is accurate, it cannot be stressed enough that attention must be paid to the end result of the program and interpretation is necessary to avoid mistakes and anomalies in the program. The author plans to further her research in FLOW-3D with the evaluation of other installations in canals.

RECOMMENDATIONS

Flap Gate Design Spreadsheet

If this project were done over, several recommendations would be made. The flap gate design spreadsheet needs to be interpreted and discussed with someone who is versed in the spreadsheet, especially for someone like the author who does not have significant manufacturing experience. The recommendations that the author would make are to pay attention to the outside dimensions of the gate. For example, the length of the counterweight cylinder specified in spreadsheet is the actual length of the tube and does not include the thickness of the steel plate caps that go on the counterweight cylinder. For the plasma cutter outline in the management site, it is editable and should be used. The user must insure that the layout is saved in a “.dxf” format. The SolidWorks model of the flap gate definitely helps the user understand the end goal of their product. Construction drawings made from the spreadsheet are very useful to visualize the end product of the gate. Looking towards the future, having an EXCEL spreadsheet that updated a SolidWorks drawing would be very helpful in explaining and marketing the ITRC Flap Gate.

FLOW-3D Implementation

For the FLOW-3D implementation, it must be noted that this is not a week-long process. However rapid it may seem, running a simulation in FLOW-3D is time consuming, takes great attention to detail, and knowledge of the end result. It would be recommended to start the FLOW-3D model as early on in the project as possible.

District Surveys

When trying to get information from districts, give them a timeline. Do not hesitate to ask for something by certain date. Also, when creating the survey think about if the questions will cover the topic clearly and broadly enough for your expectations. Districts are very busy, so one must also be careful to distribute the surveys with plenty of time.

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APPENDIX A
HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

This project meets the requirements for the BRAE major since it is a design, construction and analysis project. Although the analysis was the majority of the project, the design and construction process of the ITRC Flap Gate was incorporated.

- Major Design Experience:

The objectives and criteria of the design project were specified and established by Walker River Irrigation District. The whole project synergistically allowed the author to experience a full design and build process, all while analyzing others' design, build and use processes.

The testing and evaluations that occurred in this project were done by districts and the information was collected by the ITRC.

Due to the reputation of the ITRC Flap Gate, the design and construction had to be within the engineering standards that were established when the gate was first designed.

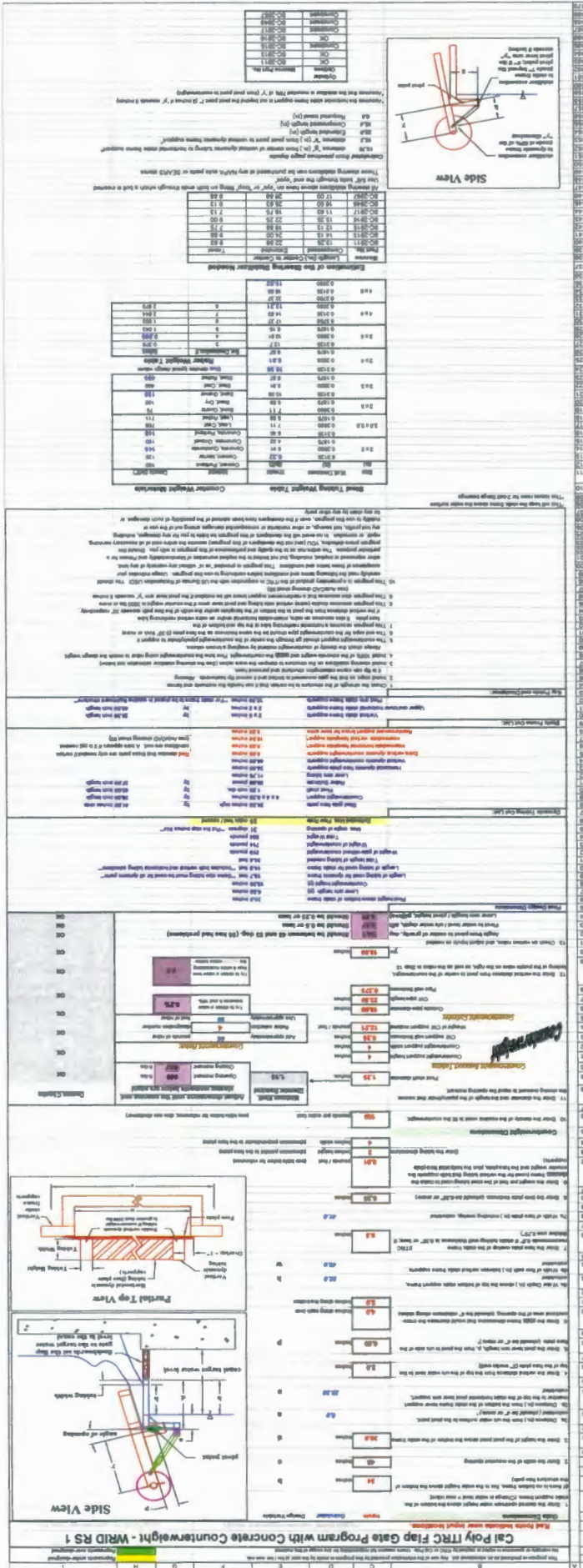
- Capstone Design Experience

This project incorporated knowledge from ME 211, ME 212, BRAE 236, BRAE 312, BRAE 421 and BRAE 422.

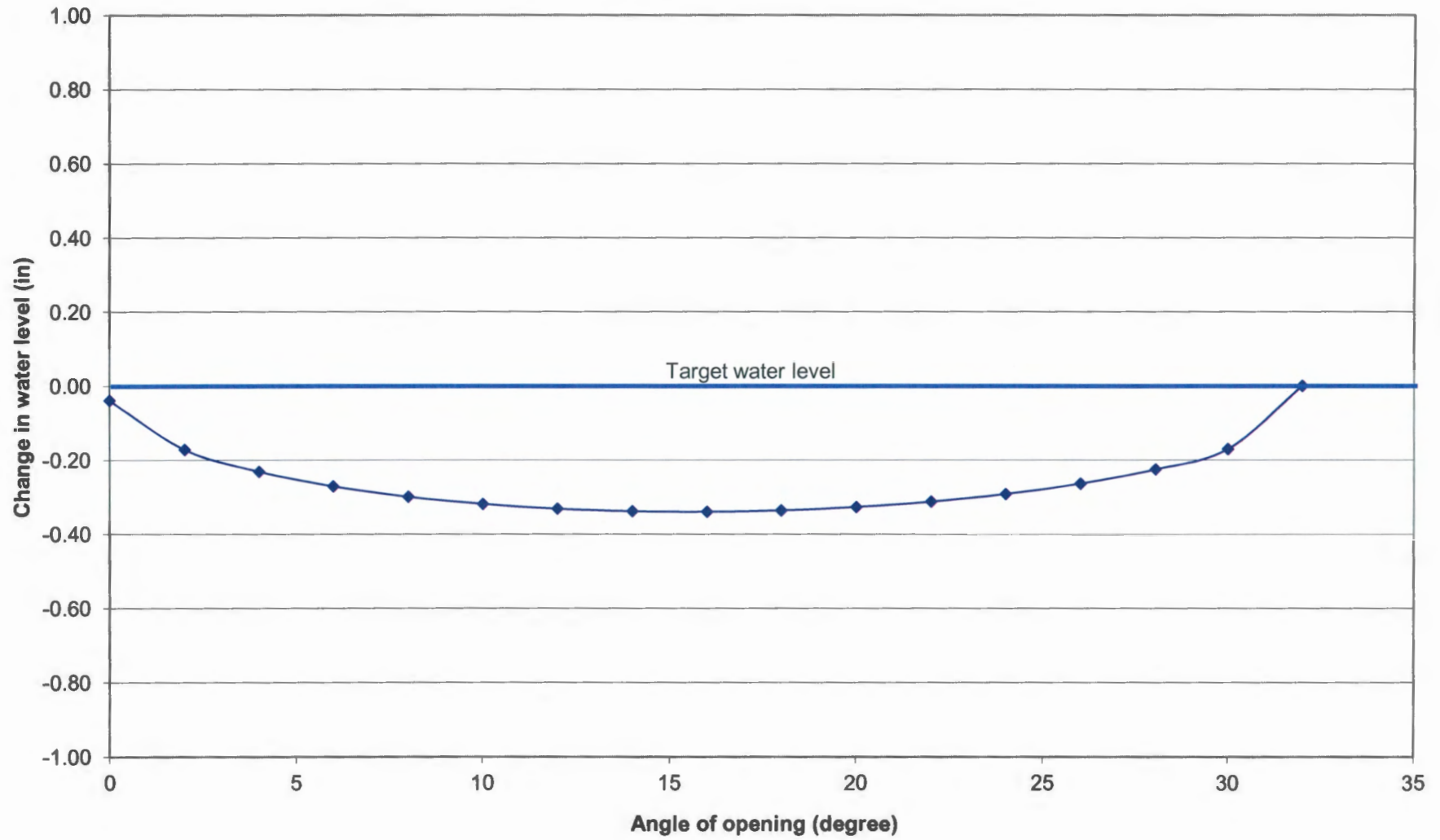
- Design Parameters and Constraints. The flap gate was designed for a 30 CFS maximum flow rate.

The physical constraint is that it could not have a reaction with the water or other surroundings. The economic constraint was that it had to be cost-effective for the district.

APPENDIX B
FLAP GATE DESIGN SPREADSHEET



Accuracy of Design
(Water level vs. Angle of opening)

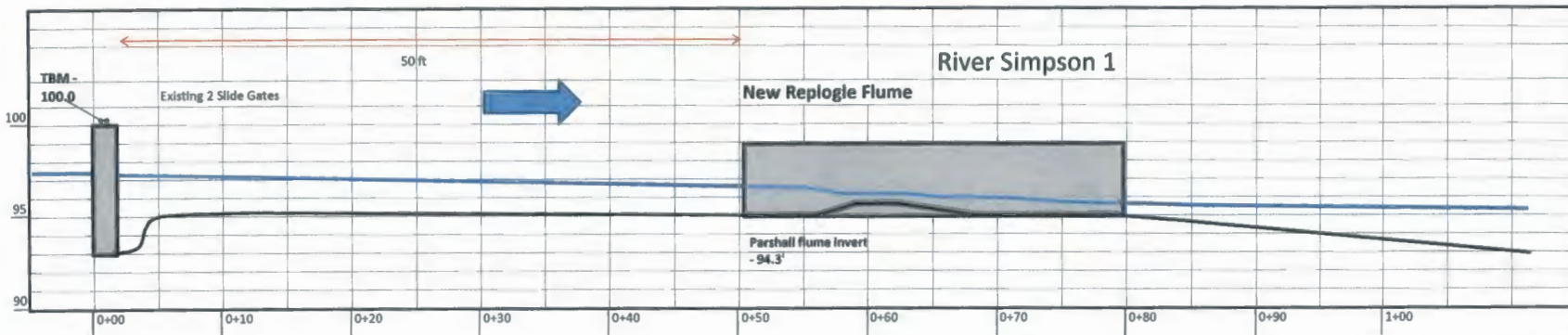


APPENDIX C
WRID IMPLEMENTATION DRAWINGS

River Simpson 1 Canal Survey - 60 CFS Max, 34 CFS AVG



Survey	BS	HI	FS	Elev (ft)
TBM (10. W. Side North)			6.24	100.00
Upstream of Head wall				
1. Invert	14.15			92.09
2. Invert	10.83			95.41
3. HWM	8.85			97.39
4. Water Level	8.91			97.33
Headwall				
5. Invert	14.23			92.01
6. E. Headwall	6.20			100.04
7. E. Headwall	6.21			100.03
8. W. Headwall	6.25			99.99
9. W. Headwall	6.28			99.96
10. W. Side North	6.24			100.00
11. W. Side South	6.24			100.00
12. E. Side	6.27			99.97
STA 0+53 Parshall Flume				
13. Invert	11.83			94.41
14. Invert	12.11			94.13
15. Invert	12.14			94.10
16. Invert	11.93			94.31
17. Staff gauge	10.84			95.40
STA 1+25:				
18. TOC Lining	10.18			96.06
19. HWM	10.95			95.29
20. Invert	13.27			92.97



River Simpson 1
Modifications
10 Oct 2013

River Simpson 1 Canal - Plan View NTS



Walker River



Spill to Walker River



ITRC Flap Gate to be installed

TBM - 100.0

Replogle Flume
Invert Elev - 94.3'

River Simpson Canal

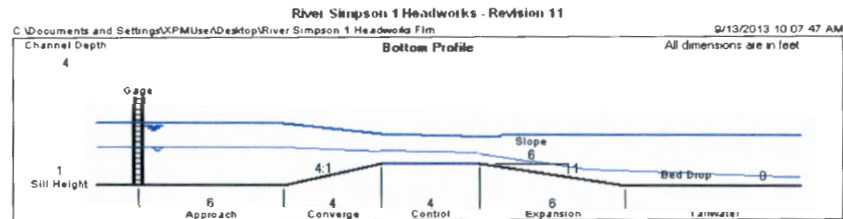
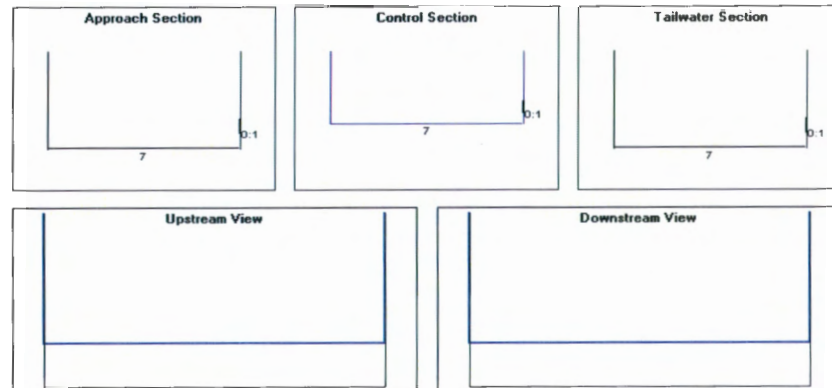
Two (2) new 60" x 48" slide gates to be installed

6-in stilling well intake pipe
12-in stilling well



River Simpson 1
Modifications
10 Oct 2013

River Simpson 1 Headworks - WinFlume Output: 60 CFS MAX, 34 CFS AVG



Tailwater Calculations		
Discharge (CFS)	Tailwater Level (ft)	
Flow Condition 1	30	1
Flow Condition 2	60	2.32

High Flow Calculations	
	Height (feet)
Invert Elevation	94.3
Sill Height	1
+ Head at Gage	1.85
HWM u/s of Flume	97.15
HWM u/s of check:	97.39

User: unknown WinFlume32 Version 1.05.0020
C:\XPMUser\Desktop\River Simpson 1 Headworks Flm - Revision 11
River Simpson 1 Headworks
Standard Rating Table, Printed: 9/13/2013 10:06:29 AM

Discharge cu ft/s	Head at Gage, h1 ft	Froude Number	Required Head Loss ft	H1/L Ratio	Submerge Ratio	Errors
10	0.59784	0.1247	0.08304	0.15269	0	
12	0.67145	0.13986	0.08815	0.17211	0	
14	0.74053	0.15356	0.09255	0.19047	0	
16	0.80596	0.16604	0.09641	0.20796	0	
18	0.86835	0.17752	0.09985	0.22474	0	
20	0.92814	0.18814	0.10294	0.24091	0	
22	0.98568	0.19803	0.10576	0.25654	0	
24	1.04124	0.20727	0.10834	0.27171	0	
26	1.09503	0.21595	0.11073	0.28646	0	
28	1.14725	0.22413	0.11294	0.30083	0	
30	1.19811	0.23185	0.11501	0.31487	0	
32	1.24759	0.23919	0.11696	0.3286	0.06201	
34	1.29589	0.24616	0.11879	0.34204	0.11995	
36	1.34308	0.2528	0.12052	0.35523	0.17438	
38	1.38927	0.25915	0.12217	0.36817	0.22573	
40	1.43451	0.26522	0.12373	0.38088	0.2744	
42	1.47887	0.27104	0.12522	0.39339	0.32067	
44	1.52242	0.27662	0.12666	0.4057	0.36482	
46.00001	1.5652	0.28199	0.12802	0.41782	0.40705	
48.00001	1.60725	0.28716	0.12934	0.42977	0.44757	
50.00001	1.64862	0.29215	0.1306	0.44155	0.6164	
52.00001	1.68934	0.29696	0.13182	0.45318	0.6485	
54.00001	1.72946	0.30161	0.13299	0.46465	0.67973	
56.00001	1.76899	0.3061	0.13413	0.47599	0.71014	
58.00001	1.80798	0.31046	0.13523	0.48719	0.73979	
60	1.84662	0.31464	0.13629	0.49827	0.76873	

Error Summary

No errors.

User: unknown WinFlume32 - Version 1.05.0020
River Simpson 1 Headworks

Head at Gage, h1 feet	Discharge cu ft/s	Equation Discharge cu ft/s	Equation Error cu ft/s	Equation Error ft	Hydraulic Errors
0.741	14	14	0.002	0.02	
0.806	16	16	0.001	0.01	
0.868	18	18	-0.003	0.02	
0.928	20	20	-0.004	0.02	
0.986	22	22	-0.003	-0.02	
1.041	24	24	-0.003	0.01	
1.095	26	26	0.002	-0.01	
1.147	28	28	0	0	
1.198	30	30	0.004	0.01	
1.248	32	32	0.005	0.02	
1.296	34	34.01	0.006	0.02	
1.343	36	36.01	0.006	0.02	
1.389	38	38.01	0.006	0.02	
1.435	40	40.01	0.006	0.02	
1.479	42	42.01	0.006	0.01	
1.522	44	44	0.005	0.01	
1.565	46	46	0.004	0.01	
1.607	48	48	0.002	0	
1.649	50	50	0	0	
1.689	52	52	-0.003	-0.01	
1.729	54	53.99	-0.006	0.01	
1.769	56	55.99	0.01	0.02	
1.808	58	57.99	-0.014	0.02	
1.847	60	59.99	-0.008	0.01	

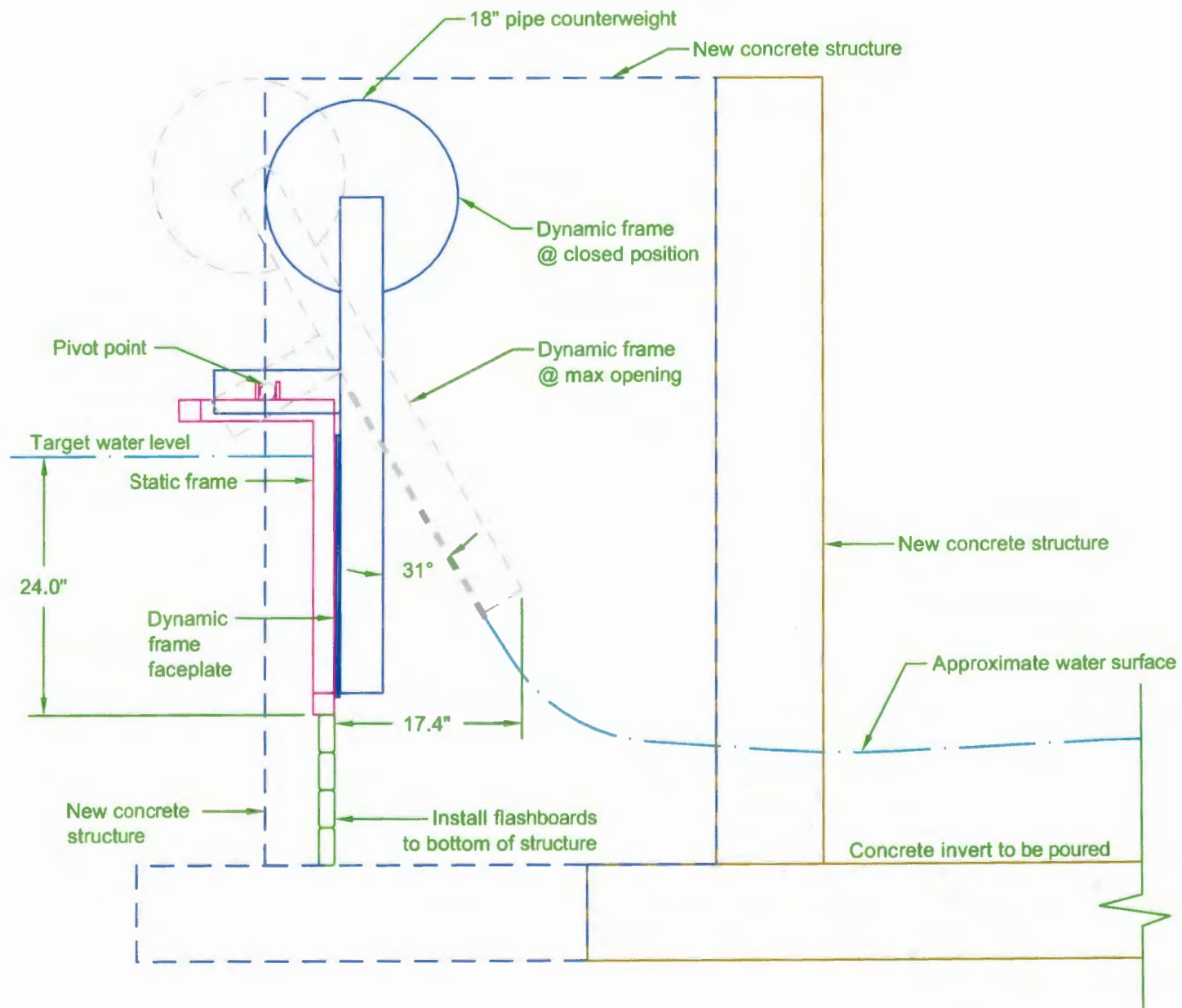
Equation: $Q = K1 * (h1 + K2) ^ u$
Parameters: K1 = 21.49

K2 = 0.02882
u = 1.633
Coefficient of determination: 0.99999989

Error Summary

No errors

River Simpson 1
Modifications
10 Oct 2013



APPENDIX D
ITRC FLAP GATE SURVEYS

ITRC
moving water in new directions
Flap Gate Survey

Question:	Response	Comments:
1 How many flap gate installations does your entity have?	105	
2 How long have you had flap gates in the district?	1995	
3 What is the purpose of your flap gate?	Upstream water level control	one that quasi controls d/s water level
4 What is the typical maintenance done on the flap gate?		Originally painting, now sand blasting and galvanizing. Grease every few years, if in further downstream, more often flush. Flush by using gate open with foot. Only 10% of time have something caught that disturbs flow
5 Have you made any modifications/improvements to your flap gates?		All kinds. Variable heights to put counter balance. Variable links on pivot arm. Vary height that weight is above the pivot point. Have vary from 12-14 inches from pivot point.
6 What are the optimum site conditions to operate a flap gate?		Optimum straight clear channel. No optimum to be d/s side of siphon and box and having more water pressure hitting one gate than another gate. They have road siphon, check structure makes 90 degree turn, flap gate on outside radius of turn -> open a lot; one more flap gate on inside. 5 bay structure -> outside gates don't see as much velocity. 6 bays - one of outside bays is an undershot gate, get more capacity. 36-inch high 42-inches wide flap gate. Sluice gate on one side to get more capacity. 5 ITRC FG 1 Sluice gate each one cap=60-65 CFS (control water level within 2.5 inches at high flow) Use chains to stop gate. Acts like an orifice at high flow. Extra inch of head. Have several locations with orifices inside FG. 2 bay structure,
7 Do you have a ceiling flow rate for flap gates?		0 - 90 CFS, height of flap itself 12-48 inches, width 24-72 inches. 90 CFS works good.
8 Have you used a galvanized gate? Thoughts?		Makes them last longer. In some locations, don't include static frame (5%). Went without frame to not take up room in canal, didn't want to lose inches on each.
9 What are your benefits of using the flap gate?		1. Maintain constant u/s water level, provides non-fluctuating water level for either another canal or turnout with a more steady flow 2. In an earth canal (99% of CWD) provides for not having as many weeds growing, can run the canal constant level. 3. If lower level, rodents will burrow, when bring WL back up cause holes in canal. With flap gate, allows to send changes in flow down the canal and not have to follow and pull stop locks in order to maintain WL. Provides with a known amt of time to transfer water, consistently. Before, you would have to pull boards to change flow rate from 50 to 60 CFS. Canal travel 1 hr/mile or 0.5 hr.mile, flow is CONSISTENT. Key for operating canal and the flap gate allow. Only changing volume in canal in upper portion in beginning. Reduces amount of labor and miles driven, reduce wear and tear on pickups, reduce dust and emissions.
10 What are three things you would like to see in the flap gate?		1. They have some locations where in order to maintain WL u/s of siphon, with check structure on d/s side of siphon. Turnout is 1/4 miles upstream of check structure. When at low Q head loss at siphon is 0. At High Q the head loss is 7 inches. Trying to maintain WL, not at chk structure, but at the turnout that is a 1/4 mile upstream. On d/s side of siphon vary WL by 6 inches, depending of Hi Q or Lo Q. Needs ITRC flap gate to maintain variable level. Probably going to be done by moving the whole flap gate up and down, actual static stand cranks up and down. Slide with 5/16 galvanized sheet metal about 1 ft high. Use 2x6 static member at bottom slide up or down on metal. CWD did all the data testing. Built ITRC flap gates for 5ft x 2ft high, \$2000-2500. Very cost effective. The ITRC flap gate. Along with SCADA and LCW, radically changed the way we operate the district. Can sit in SCADA room and send water pretty much anywhere in district. SCADA controls at headings of canals. They have locations where monitoring



Question:	Response	Comments:
1 How many flap gate installations does your entity have?	5	
2 How long have you had flap gates in the district?		Within the last 10 years
3 What is the purpose of your flap gate?		Allows water out not in
4 What is the typical maintenance done on the flap gate?		No maintenance to date
5 Have you made any modifications/improvements to your flap gates?		NO
6 What are the optimum site conditions to operate a flap gate?		A pipeline under pressure
7 Do you have a ceiling flow rate for flap gates?		NO
8 Have you used a galvanized gate? Thoughts?		NO
9 What are your benefits of using the flap gate?		Does not require man power to operate
10 What are 2-3 things you would like to see in the flap gate?		The gate serves it's purpose, no recommendations



Question:	Response	Comments:
1 How many flap gate installations does your entity have?	15	
2 How long have you had flap gates in the district?	5 years	
3 What is the purpose of your flap gate?	Automatic upstream water level maintenance control	Facilitate check operations by generally eliminating the need for boards and lift gates.
4 What is the typical maintenance done on the flap gate?	Shock replacement	After a few years the shock have a tendency to fail.
5 Have you made any modifications/improvements to your flap gates?	Added pivot arm stops	Two steel tongues are welded to the pivot arm and postioned to allow the gate to fully open, but contact the static horizontal frame support arm if opened much further.
6 What are the optimum site conditions to operate a flap gate?	Please see comments	Uniform approach flow, free from lateral curves
7 Do you have a ceiling flow rate for flap gates?	Yes	Utilizing the ITRC design program's estimated max flow rate (weir vs. orifice)
8 Have you used a galvininzed gate? Thoughts?	No	Gates are painted with a corrosion resistant paint.
9 What are your benefits of using the flap gate?	Please see comments	1) Upstream water level maintenance. 2) Minimizes water operator time spent manipulating gates and boards. 3) Automatic and strictly mechanical
10 What are 2-3 things you would like to see in the flap gate?	Please see comments	1) Inclinator which would correlate opening with a flow rate. 2) More robust shock alternatives.



Flap Gate Survey

Question:	Response	Comments:
1 How many flap gate installations does your entity have?	FID has 15 flap gate installations.	
2 How long have you had flap gates in the district?	FID installed its first flap gate in September 2006 on FID's Gould No. 97 Canal (S/E Ashlan & Chestnut) and have been utilizing them since.	
3 What is the purpose of your flap gate?	The purpose of FID's flap gates is primarily to provide level control for a particular section of canal such that water is maintained at a constant level without the need of an operator to continually make adjustments at a regulating structure (check weir) due to fluctuations in a canal. Also, to minimize the encroachment of rodents burrowing into the canal bank below the typical operating water level of the canal.	
4 What is the typical maintenance done on the flap gate?	FID's flap gates have been virtually maintenance free. Approximately once a year, the dampeners are greased. On a few occasions, the dampeners needed to be replaced. Eventually, the dampeners of all the flap gate will need to be replaced due to wear but to date, this hasn't been a frequent occurrence.	
5 Have you made any modifications/improvements to your flap gates?	In general, FID has hot-dip galvanized all its flap gates to protect it from corrosion and increase its longevity/durability. Earlier FID gates had modified counterbalance weights to better operate the gates and on one occasion, FID added a second set of dampeners to better counteract wave action effects at one particular location.	How did you modify the counterbalance weights? Added sand. How did the second set of dampeners work out for you? Location: pretty turbulent, flap gate bobbing up and down. Did a couple. Placed at the end of a culvert that was doubled up as check structure extend check structure walls so that the flap gate would be pace further downstream. Also added second set of dampeners so far it has worked.
6 What are the optimum site conditions to operate a flap gate?	The ideal site locations to install a flap gate is at a check structure that have sufficient head difference between the upstream and downstream water levels. On a separate note, FID's preference is to install flap gates at the beginning or middle reaches of our canals where there is a consistent flow rate. We've installed flap gates at spill locations (end of a canal run) with limited success. FID's operators are not comfortable utilizing flap gates at these locations due to the large flow rate differences experienced at these locations (no flow to max flow) and the breaching issues that occur from rodents burrowing holes into the canal bank at a time when there is no flow.	
7 Do you have a cutting flow rate for flap gates?	FID utilizes flap gates on our small to medium size canals. The largest canal flow rate that FID has designed/fabricated (1) one flap gate is approximately 40 CFS. The largest canal flow rate that FID has designed/fabricated a series of flap gates (i.e. 3 gates) is 55 CFS.	
8 Have you used a galvanized gate? Thoughts?	Yes, FID typically hot-dip galvanizes its flap gates. FID feels the benefit of galvanizing flap gates including reduced maintenance cost and increased longevity of each gate outweighs the extra cost of not doing so. Since FID first started using flap gates in 2006, the flap gates have been virtually maintenance free.	Biggest thing for them is hot dip galvanized. In doing so really decreased the maintenance on the gates. Be added.
9 What are your benefits of using the flap gate?	More efficient use of an operator's time with the elimination of making constant adjustments. Reduction in canal breaches due to rodents burrowing into the canal bank.	
10 What are 2-3 things you would like to see in the flap gate?	A restraining mechanism such that a flap gate doesn't open up beyond a particular opening angle and overtop; This has been an issue at some locations during times of high winds and when a large amount of debris has collected at a particular site such that the flap gate "bounces" in the open/close position.	