CITY OF YAKIMA

JOINT PROBABILITY AND LEVEE INTERIOR DRAINAGE

Draft 2

October 2013

AKEL ENGINEERING GROUP, INC.

October 23, 2013

City of Yakima
2220 E. Viola
Yakima, WA 98901-9998

Attention: Shelley Willson
Project Manager

Subject: Levee Certification – Joint Probability and Levee Interior Drainage

Dear Shelley:

We are pleased to submit this letter report documenting the Joint Probability and Levee Interior Drainage analysis, as part of the recertification of the Yakima County Public Works levee system.

This report is intended to meet the Design Criteria for National Flood Insurance Protection Regulations 65.10(b) for the interior drainage of a levee. As part of these requirements, this report documents the development of the joint probability storm event, flood runoff hydrographs, and the findings of the interior flood analysis in areas that experience flood depths in excess of 1 foot. .

We are extending our thanks to you and other City staff whose courtesy and cooperation were valuable components in completing this study and producing this report.

Sincerely,

AKEL ENGINEERING GROUP, INC.

Tony Akel, P.E.
Principal

Enclosure: Report

City of Yakima

Joint Probability and Levee Interior Drainage

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JOINT PROBABILITY AND LEVEE INTERIOR DRAINAGE

1.0 BACKGROUND

The County of Yakima (County) maintains a levee system that protects portions of the City of Yakima, especially along the Yakima River (**Figure 1**). In July 2012, the County received a letter from the United States Army Corps of Engineers (USACE) stating that the County levees protecting the City of Yakima (City) would be decertified as of August 31, 2013.

Decertification was a result of changes to the Engineering Circular 1110-2-6067, USACE Process for the National Flood Insurance Program Levee System Evaluation. Prior to changes to the Engineering Circular, USACE assisted Federal Emergency Management Agency's (FEMA) in the evaluation of levees for design and construction issues. In some cases, USACE is documented with FEMA that a levee system is sufficient with only a letter or a letter with incomplete documentation. With changes to the Engineering Circular, USACE can no longer remain on record as certifying the levee system, which includes the Yakima County Public Works levee, which protects the City of Yakima.

The revisions to the Engineering Circular resulted with the County of Yakima proceeding with recertifying the levee system. The FEMA levee certification includes several design criteria that the County is addressing. The County requested the City of Yakima addresses the design criteria related to the interior drainage.

The City contracted with Akel Engineering Group to evaluate the interior drainage and joint probability analysis of the County's west levee system. Dr. Jack Humphrey, with Hydmet, assisted Akel Engineering Group in performing the analysis for joint probability and developing corresponding runoff hydrographs.

2.0 OBJECTIVE

The objective of this study is to address the design criteria related to the interior drainage of the County's west levee system. The NFIP Regulations section 65.10(b) includes a checklist for the design criteria related to the interior drainage. The checklist stipulates that "an analysis must be submitted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than 1 foot, the water-surface elevation(s) of the base flood. This analysis must be based on the joint probability of interior and exterior flooding and the capacity of facilities (such as drainage lines and pumps) for evacuating interior floodwaters."

3.0 SCOPE OF WORK

The scope of work for this project consisted of the following:

- Data collection and validation of assumptions to adequately evaluate the drainage areas.
- Development of flood runoff hydrographs to determine the volume of water that can potentially occur on the protected side of the levee.
- Evaluate the extent of flooding due to levee gate closure if the flooding exceeds 1 foot.
- Determine the joint probability 100-year storm volume during periods of critically high river flows.
- Determine the capacity of evacuation facilities.
- Map the areas that have flood depths exceeding 1 foot during the 100-year interior event.

4.0 DATA COLLECTION AND FIELD VERIFICATION

This task included collecting information associated with the County's west levee system floodgates. The task also included a field survey and inspection of each relevant floodgate, as identified in the mapping provided by the County (**Appendix A**). Each floodgate was field inspected, and field observations were reported on customized forms included in **Appendix B**.

The following floodgates were field verified: 2, 3, 4, 5, 6, 7A, 9, 10, and 11. Floodgate 1, 7, and 8 could not be located during this effort. The field verification also included the following water bodies: Sarge Hubbard Park pond and marsh, Buchanan, Bergland, and Rotary Lake (**Appendix B**). These water bodies were important to the interior flood analysis, as these are receiving waters located within the City.

5.0 JOINT PROBABILITY ANALYSIS

The purpose of the joint probability analysis is to determine the 100-year interior storm event that occurs with the rivers at a flood stage that prevents interior floodwater evacuation through the floodgates. Storm events were evaluated using the National Climatic Data Center rain gages at the Yakima Air Terminal, City of Moxee, City of Wapato, and 2 additional rain gages located in the City of Yakima. The Yakima Air Terminal served as the primary rain gage, as it maintained hourly and daily rain data from 1948 to 2013. The other rain gages maintain daily rainfall data of varying record between 1948 and 2013, and were used to evaluate areal coverage and snowfall versus rainfall.

This joint probability analysis included review and comparisons of over 17 significant and relevant historical rainfall events. Each comparison considered the timing of the rainfall event and the corresponding flood stage of the Yakima River, as extracted from the United States Geological Survey (USGS) data for river gages located along the Yakima River and Ahtanum Creek. These river gages covered varying periods of record between 1898 and 2013.

Based on the evaluation of the river gages, this study estimated that the floodgates along the Yakima County west levee system are no longer capable of opening when Yakima River flows exceed 12,000 cubic feet per second (cfs).

The Ahtanum Creek gage data was used in conjunction with hourly precipitation recorded at the Yakima Air Terminal to characterize the response of the Yakima River flooding. This characterization indicates that the historical peak intensity rainfall in the City occurs several hours prior to the Yakima River reaching the 12,000 cfs flood stage which may prevent the gates from opening. This lag time justified reducing the 100-year rainfall event's volume for the interior drainage analysis from 2.22 inches to 0.95 inches.

6.0 RUNOFF HYDROGRAPHS AND LEVEE GATES CAPACITY

Hydrographs were developed for each levee gate to determine the quantity of stormwater that may pond on the protected side of the Yakima County west levee system. Additionally, a floodgate capacity analysis of the west levee gates was completed.

6.1 Runoff Hydrographs

This analysis relied on models created as part of the 2013 Stormwater Collection System Master Plan to develop flood runoff hydrographs at the evacuation facilities along the levee system. These models were set up in the Army Corps of Engineers HEC-HMS model, and were evaluated using the joint probability interior storm event.

Flood hydrographs were used to determine the volume of floodwater that may be routed to the levee evacuation gates. Additionally, the system was evaluated for overland flow to determine if the stormwater collection system in the City of Yakima was capable of conveying excess stormwater to existing receiving water bodies, such as Buchanan Lake or the Sarge Hubbard Park pond.

6.2 Floodgate Capacity Analysis

This project included a capacity analysis to determine if the levee floodgates, surveyed by the City (**Appendix B**) are capable of routing the 100-year interior drainage event. The floodgates are considered automatic drainage gates, whereby the cover opens and allows drainage of water behind the gate. The gates operate under differential heads whereby the water evacuates through the floodgates when the interior water surface elevation is higher than the water surface elevation of the Yakima River. When the flood elevations in the Yakima River are higher than the water levels in the interior portion of the levee, the gates remain closed.

The County of Yakima provided the manufacturers manual for Floodgates 5 and 6, in addition to a 2006 model study of the floodgate performance conducted by the Bureau of Reclamation (Appendix C).

The Floodgate capacity analysis is documented on **Table 1**, which lists each floodgate and its estimated capacity in cubic feet per second (cfs). The table also lists the peak and average flows experienced during the interior event and documents the adequacy of these capacities.

It should be noted that the peak runoff of Floodgate 6 is limited by upstream pipe constraints. For this reason, it is recommended that future upgrades to the stormwater collection system should be preceded by upgrades to the retention facilities, as recommended in this report.

7.0 INTERIOR DRAINAGE SCENARIOS AND ANALYSIS

The interior drainage analysis included four scenarios to determine critical flood depths for areas protected by the Yakima County west levee system, and included mapping of the scenario that yielded critical flooding during the 100-year interior event.

7.1 Interior Drainage Scenarios and Analysis

The interior drainage analysis assumed automatic drainage floodgates that operate under differential heads, and included the following two scenarios to determine the critical flood depths:

- **Scenario 1.**
  Assumptions: This scenario assumes existing land use, and simulates the analysis using existing facilities with no improvements.

  Analysis: This joint probability and levee interior drainage analysis identified the 100-year levee interior storm flood event. Flooding in excess of 1 foot within the levee protected areas is cross hatched with an orange color on **Figure 1**. A detail of the flooded area is also included on **Figure 2.**

- **Scenario 2.**
  Assumptions: This scenario assumes existing land use, and simulates the analysis to include the proposed master plan improvements.

  Analysis: The master plan improvements recommended retaining stormwater runoff, and removing outfalls to the Yakima River. The retention facilities are sized to meet a storm volume of 1.80 inches, which exceeds the 100-year interior event of 0.95 inches. Stormwater is, therefore, retained before reaching the levee.

Scenario 2 includes improvements to the Fruitvale Canal as recommended in the 2013 Stormwater Collection System Master Plan. It should be noted that the master plan also recommends a sequence of construction that includes completing retention basin facilities prior to the construction of upstream conveyance improvements. Construction of the Fruitvale Canal improvements prior to either completion of the retention basin recommended in the master plan, or enhancing capacity of the levee gates, may result with flooding exceeding 1 foot near Floodgates 5 and 6.

7.2 Mapping of Critical Interior Flooding Scenario

This analysis indicates that Scenario 1 yielded critical flooding in the interior of the levee system (**Figure 1**). In this scenario, each floodgate was evaluated using the existing 2-foot contour maps obtained from the City and used to determine floodpaths and ponded areas due to closed floodgates. Each area receiving floodwater in this scenario is described below:

- **Area 1. Bergland Lake.** This lake receives minimal amounts of overland flood runoff generated near the interchange of State Route 12 and Interstate 82 (I-82). Floodgate 11 evacuates this area, and flooding does not exceed 1 foot. This area is not mapped on **Figure 1**.

- **Area 2. Rotary Lake / Boise-Cascade Mill Site.** This area receives stormwater runoff from two drainage basins located in the northeast of the City. The lake receives runoff from a 24-inch pipeline connected to the west edge of the lake, and the Boise-Cascade site receives stormwater from an unlined channel near the intersection of 4th Street and N Street.

  Floodgates 9 and 10 evacuate excess floodwater from the lake under normal conditions. During floodgate closure, excess water flows out of Rotary Lake to the south east, before crossing under I-82 and combining with runoff from the Boise-Cascade site. Floodwater from Rotary Lake and the Boise-Cascade site ponds at Floodgate 7A, and extends west of I-82 and to the south where it is bound by the railroad tracks.

  This area floods a maximum of 3.5 feet during the 100-year interior event to a water surface elevation of approximately 1,061.5 feet, as shown on **Figure 1**. The flooded area currently consists of open fields and is mapped on **Figure 2**.

- **Area 3. Fruitvale Canal / Yakima Avenue.** This area receives stormwater runoff from the Fruitvale Canal, and areas directly north of Yakima Avenue and west of Fair Avenue. The runoff that reaches the terminus of the Fruitvale Canal (Floodgate 6) is limited by the size of the 30-inch pipeline in H Street. As a result, flooding at the interior of the levee was largely limited by the capacity constraints imposed by this pipeline.

  The analysis indicates that the interior flood surface elevations at Floodgates 5 and 6 generally exceed the water surface elevations noted in the 100-year FEMA mapping of the Yakima River water surface elevation.

  The analysis also indicates that Yakima River water surface elevations near Floodgate 5 may approach the interior water surface elevations, and which may result with nuisance flooding that does not exceed one foot.

- **Area 4. Buchanan Lake.** Stormwater west of I-82, near the fairgrounds, is conveyed eastward and outfalls to Buchanan Lake via a 30-inch storm drain. Floodwater from the interior event does not exceed 1 foot in the lake, and the City survey noted no outflow from the lake. This area is not mapped on **Figure 1**.

- **Area 5. Sarge Hubbard Park / Arboretum.** Excess stormwater south of Yakima Avenue and west of I-82 is conveyed through a pipe and canal network to a pond and connected marsh at Sarge Hubbard Park. The pond and connected marsh are capable of storing some of the 100-year interior flood runoff before outflowing to an unlined channel that parallels the Yakima County Public Works levee. This unlined channel eventually is conveyed to Floodgate 4, where runoff combines and flows through the arboretum and southeast to Floodgates 2 and 3. While exceeding 1 foot and up to 3 feet, the flooded area is within the FEMA designated 100-year floodplain, and therefore requires no action. This area is not mapped on **Figure 1**.

8.0 SUMMARY

The Yakima County Public Works levee protects areas in the eastern most portion of the City, generally north of Nob Hill Boulevard, and east of 1st Street. The City surveyed 9 floodgates along the levee, as well as the major water bodies along the Yakima River and their outlets. The levee and floodgates are shown graphically on **Figure 1**. Additionally, a floodgate capacity analysis is documented on **Table 1**, which lists each floodgate and its estimated capacity in cubic feet per second (cfs). The table also lists the peak and average flows experienced during the interior event and documents the adequacy of these capacities.

Upon evaluation of the 100-year interior storm event, flood hydrographs were used to determine the volume of floodwater capable of being routed to the levee evacuation gates. Additionally, the system was evaluated for overland flow to determine if the stormwater collection system in the City of Yakima was capable of conveying excess stormwater to existing receiving water bodies, such as Buchanan Lake or the Sarge Hubbard Park pond.

The Ahtanum Creek gage data was used in conjunction with hourly precipitation recorded at the Yakima Air Terminal to characterize the response of the Yakima River flooding. This characterization indicates that the historical peak intensity rainfall in the City occurs several hours prior to the Yakima River reaching the 12,000 cfs flood stage which may prevent the gates from opening. This lag time justified reducing the 100-year rainfall event's volume for the interior drainage analysis from 2.22 inches to 0.95 inches.

The interior drainage analysis included two scenarios to determine critical flood depths for areas protected by the Yakima County west levee system:

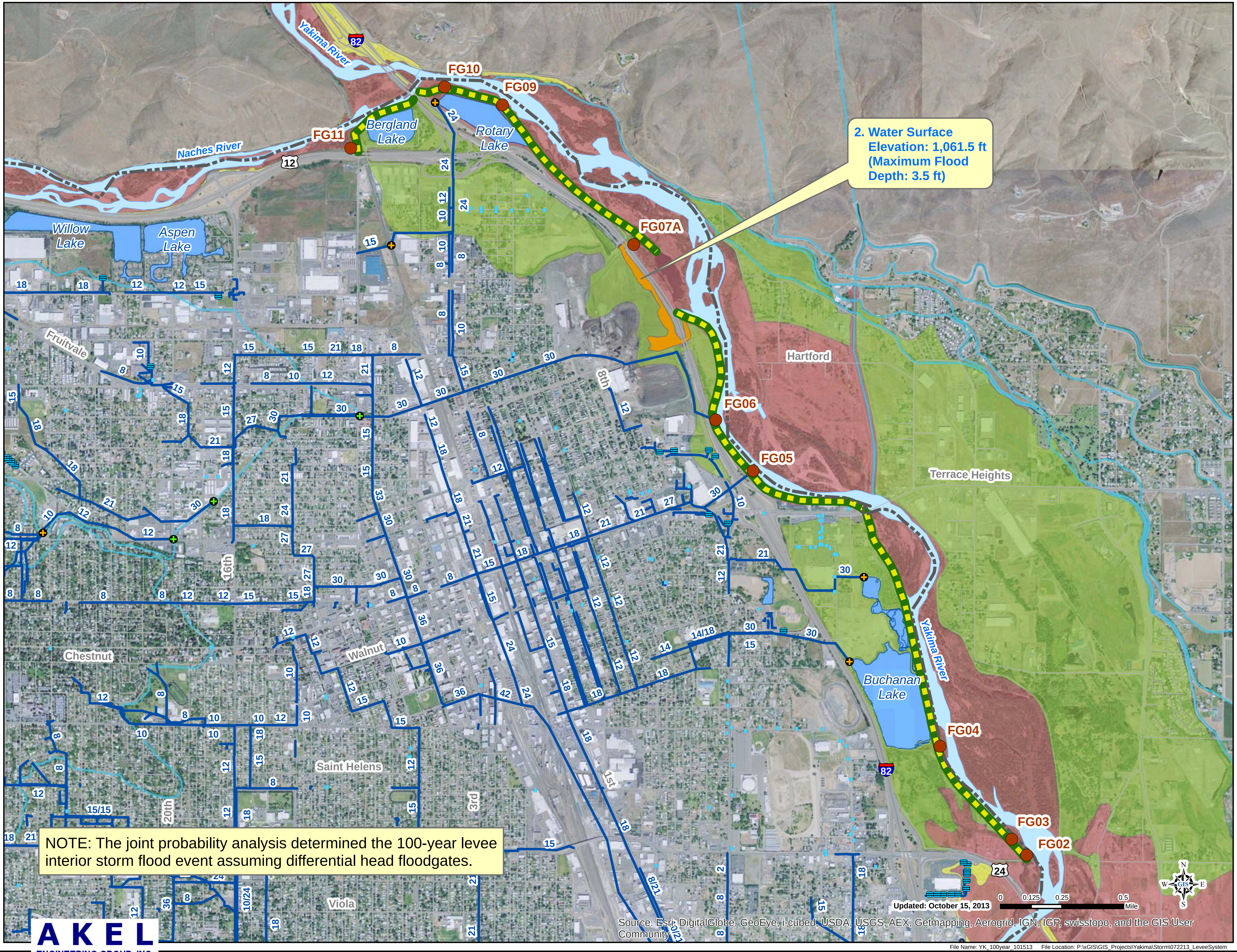
- Scenario 1 assumes existing land use, and simulates the analysis using existing facilities with no improvements. .

- Scenario 2 assumes existing land use, and simulates the analysis to include the proposed master plan improvements.

This analysis indicates that Scenario 1 yielded critical flooding in the interior of the levee system for Area 2. Floodwater from Rotary Lake and the Boise-Cascade site ponds at Floodgate 7A, and extends west of I-82 and to the south where it is bound by the railroad tracks. This area floods a maximum of 3.5 feet during the 100-year interior event to a water surface elevation of approximately 1,061.5 feet, as shown on **Figure 1**. The flooded area currently consists of open fields and is mapped on **Figure 2**.

It should be noted that the master plan also recommends a sequence of construction that includes completing retention basin facilities prior to the construction of upstream conveyance improvements. Construction of the Fruitvale Canal improvements prior to either completion of the retention basin recommended in the master plan, or enhancing capacity of the levee gates, may result with flooding exceeding 1 foot near Floodgates 5 and 6.

Figures



Legend

- Surveyed Levee Gate Locations
- Interior Flooding
- Levee

FEMA 100 Year Flood Zones

- 1% Annual Flood Chance
- 0.2% Annual Flood Chance
- Protected by Levee

Existing System

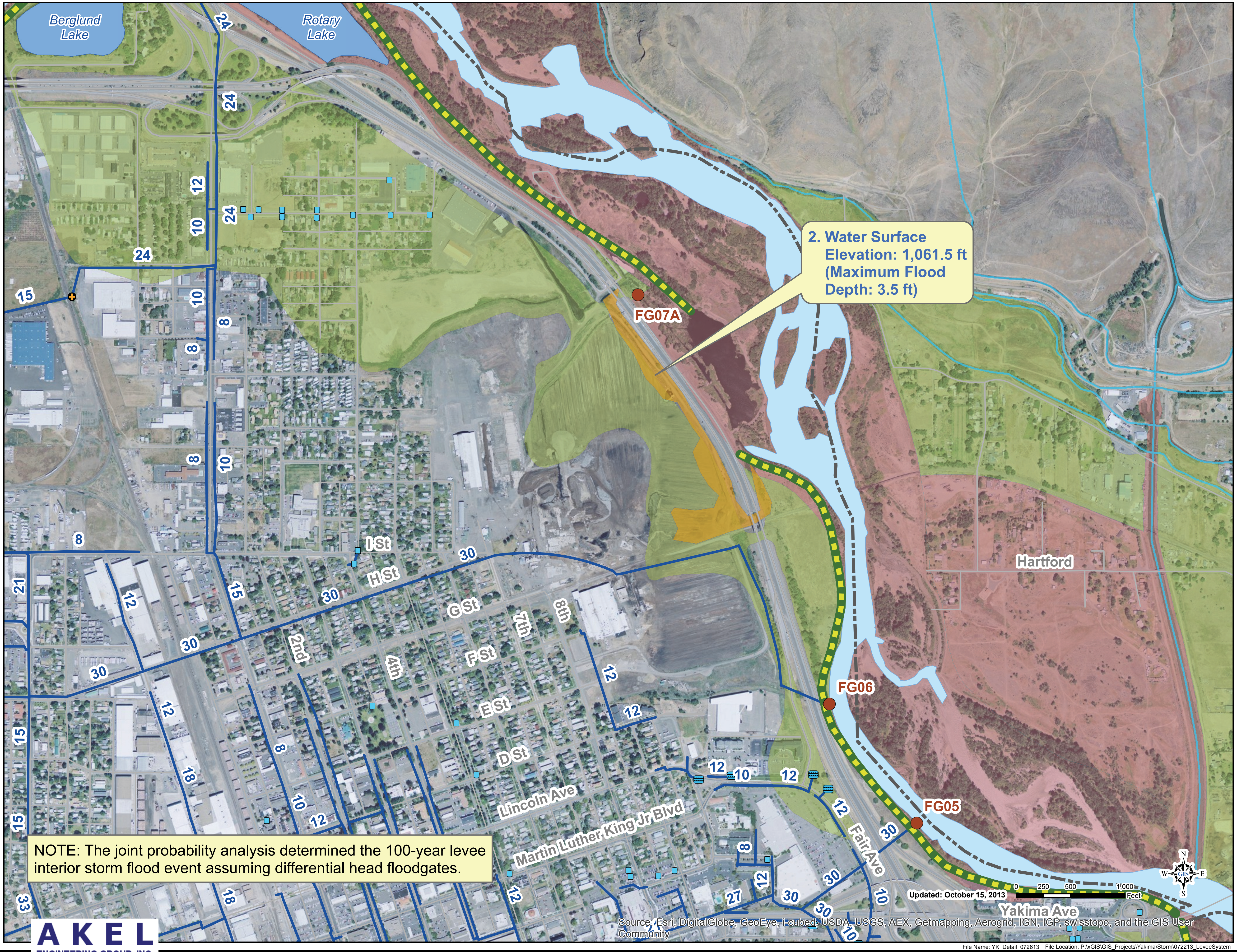
- City Drainage Outfall
- DID Drainage Outfall
- Drywell/UIC
- Swale
- Stormwater System
- Streets
- Highways
- City Limits
- Irrigation Canals
- Rivers
- Lakes

PRELIMINARY

Figure 1
100 Year Flood Depth Exceeding 1 Foot
Joint Probability and Levee Interior Drainage
City of Yakima

AKEL ENGINEERING GROUP, INC.

File Name: YK_100year_101513 File Location: P:\xGIS\GIS_Projects\Yakima\Storm\072213_LeveeSystem



AKEL ENGINEERING GROUP, INC.

File Name: YK_Detail_072613 File Location: P:\xGIS\GIS_Projects\Yakima\Storm\072213_LeveeSystem

Legend

- Surveyed Levee Gate Locations
- Interior Flooding
- Levee

FEMA 100 Year Flood Zones

- 1% Annual Flood Chance
- Protected by Levee

Existing System

- Drywell/UIC
- Swale
- Stormwater System
- Streets
- Highways
- City Limits
- Irrigation Canals
- Rivers

PRELIMINARY

Figure 2
100 Year Flood Depth Exceeding 1 Foot
-Detail-
Joint Probability and Levee Interior Drainage
City of Yakima

Tables

Table 1 Floodgate Capacity Analysis

Joint Probability and Levee Interior Drainage
City of Yakima

PRELIMINARY

Floodgate Information			Interior Flood Event Hydrograph (0.95 inches)		Capacity Adequacy	Comments / Controls
Floodgate No.	Size (in)	Capacity[3] (cfs)	Peak Flow (cfs)	Average Flow (cfs)		
2[1]	36	30	16	4	Adequate	Manual Lock
3[1]	36	30	16	4	Adequate	Manual Lock
4[1]	36	30	16	4	Adequate	Manual Lock
5[1]	30	18	12	2	Adequate	Manual Lock
6[1]	2 x 32	44[4]	23	18	Adequate	Manual Lock
7A[2]	48	64	21	4	Adequate	Manual Lock
9[1]	10 foot by 1.5 rectangular gate	92	37	9	Adequate	Operates in conjunction with Floodgate 10, Manual Lock
10[1]	21					Operates in conjunction with Floodgate 9, Manual Lock
11[1]	18	5	4	1	Adequate	Manual Lock

Notes:

7/26/2013

1. Source: Survey data received from City staff 6/26/2013.
2. Source: Survey data received from City staff 7/2/2013.
3. Pipe capacity based on slope of 0.002 and a Manning's n coefficient of 0.013.
4. Peak flow is reduced due to upstream pipe capacity restraints.

APPENDIX A

City of Yakima Levee Protection Map


Levee Interior Drainage
Legend
City of Yakima Stormwater
Swale
Outfall
Drywell\UIC
Private Swale
< 4"
4" - 10"
10" - 20"
20" - 30"
30" - 40"
> 40"
Yakima County Stormwater
Dry Well
Dry Well and Infiltration Trench
Infiltration Pond
Infiltration Swale
Infiltration Trench
Manhole
Outfall
Outfall (Ditch Culvert)
Outfall (Ditch)
Flow Deliniation
Deliniation
Flowline
Corps Levee Protection Area
DID Lines
DID Ditch
DID Pipe
Levees
City of Yakima
DID 1
Yakama Nation
PRIVATE
WDFG
WDOT
Yakima County Public Works
BOR
Other
Irrigation Canals
Floodgates
10 ft Contours
UnionGap_lines
Bergland Lake (Gordon Lake)
Rotary Lake
Boise Cascade Ponds
Open Ditch Section
Sandbag Closure
DID Outfall to Ditch
Area Drains to Floodgates 28 & 29
NC Machinery
Overflow Area from 28 & 29
Buchanan Lake Beach Street Pit
Sportsman Park
Area Drains to South of Yakima Project Levee
Area Drains to Blue Slough & then South of Yakima Project Levees
Blue Slough Drains Area

APPENDIX B

Levee Gate and Water Bodies Survey

Outflow Location:

outflow

Typical Lake Water Level: 1068.72

Wet Year Lake Water Level: 1069.72

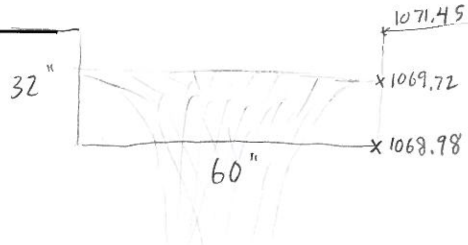
Highest Obeserved Lake Water Level: 1070.52

Outflow Elevation: 1068.98

If different from outflow, lowest lake elevation?:

Note: If lowest elevation differs from outflow point, please note the location on the map.

Outflow Size: Weir notch 60" wide × 32" high



Is a backflow preventer present? (Circle one)

Yes No

Notes:

Flood Gates 09 and 10 connect to NW end of Rotary Lake

Date Inspected: 6/4/13

Attachment B
Rotary Lake Information

Levee Interior Drainage
City of Yakima

Outflow Location: Sarge Hubbard Pond

Outflow into next pond

outflow into canal/ditch

Typical Lake Water Level:

1016.00

Wet Year Lake Water Level:

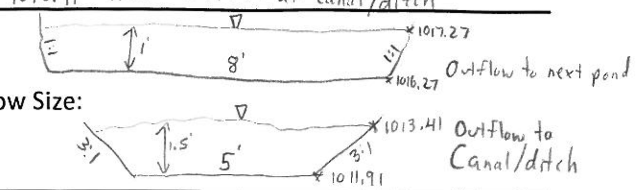
1017.27

Highest Obeserved Lake Water Level:

1017.52

Outflow Elevation:

1013.41 - 1.50 = 1011.91 at canal/ditch



Outflow Size:

If different from outflow, lowest lake elevation?:

Note: If lowest elevation differs from outflow point, please note the location on the map.

Is a backflow preventer present? (Circle one)

Yes No

Notes: Sarge Hubbard Pond + ponds + marsh to south are all connected. There is a 30' long channel connecting Sarge Hubbard Pond to the next pond. Water then runs from the pond to a series of small ponds + marshes until it outfalls into a canal/ditch. It does not flow into Buchanan Lake but rather flows thru an unlined canal between Buchanan Lake + Greenway path. Ditch is ≈ 5' wide @ bottom w/ 3:1 side slopes. Water depth was 1.5' deep. Outflow to next pond is 8' wide, 1:1 side slopes + 1' deep.

Date Inspected: 6/4/13

May 22, 2013

AKEL ENGINEERING GROUP, INC.

Attachment B
Wal-Mart Floodplain Information
Levee Interior Drainage
City of Yakima

Outflow Location:

outflow from Wal-mart into canal

Flood Gate 04 36" pipe i.e.

Typical Lake Water Level:

1010.91

Wet Year Lake Water Level:

1012.41

Highest Obeserved Lake Water Level:

1012.98

Outflow Elevation:

None Found

If different from outflow, lowest lake elevation?:

N/A

Note: If lowest elevation differs from outflow point, please note the location on the map.

Outflow Size:

N/A

Is a backflow preventer present? (Circle one) N/A

Yes

No

Notes: Flood gate 4 found by Greenway path - 36" pipe - i.e. east of path on River side → 1010.46 - 4.60 = 1005.86. Could not locate culvert west of path by canal/ditch/marsh.

Buchanan Lake is a former gravel pit.

Date Inspected: 6/4/13

May 22, 2013

Attachment B
Buchanan Lake Information
Levee Interior Drainage
City of Yakima

AKEL ENGINEERING GROUP, INC.

Outflow Location:

Typical Lake Water Level:

1074.96

Wet Year Lake Water Level:

1075.96

Highest Obeserved Lake Water Level:

1077.24

Outflow Elevation:

No out Flow

If different from outflow, lowest lake elevation?:

N/A

Note: If lowest elevation differs from outflow point, please note the location on the map.

Outflow Size:

N/A

Is a backflow preventer present? (Circle one) N/A

Yes No

Notes:

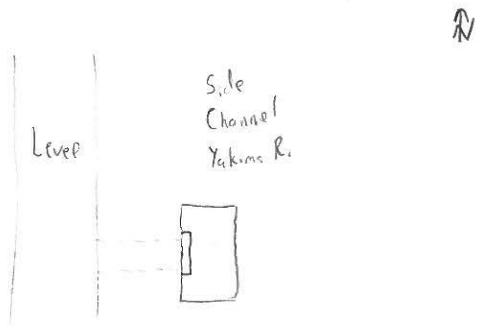
Date Inspected: 6/4/13

May 22, 2013

Attachment B
Bergland Lake Information
Levee Interior Drainage
City of Yakima

AKEL ENGINEERING GROUP, INC.

Schematic:



Size:

36" pipe

Control(s):

Manually Lock

Number:

Flood Gate 02

Elevation:

998.89 + 0.85 = 999.74"

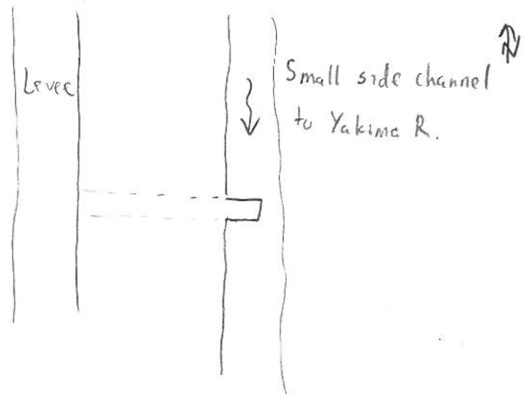
Image:

Notes:

Date Inspected: 6/10/13

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

Schematic:



Size:

36" pipe

Control(s):

Mannualy Lock

Number:

Flood Gate 03

Elevation:

1003.07 - 3.10 = 999.97

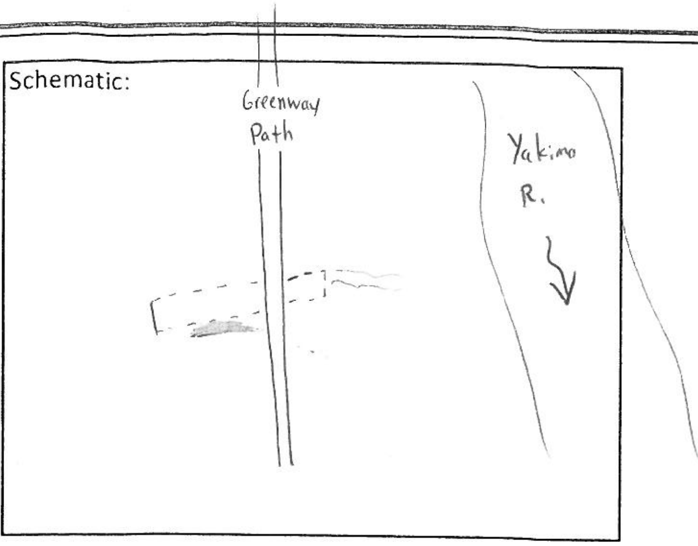
Image:

Notes:

Date Inspected: 6/10/13

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

Schematic:



Size:

36" pipe

Control(s):

Manual lock

Number:

Flood Gate 04

Elevation:

1010.46 - 4.60 = 1005.86

Image:

Notes:

Date Inspected: 6/4/13

May 22, 2013

Attachment A

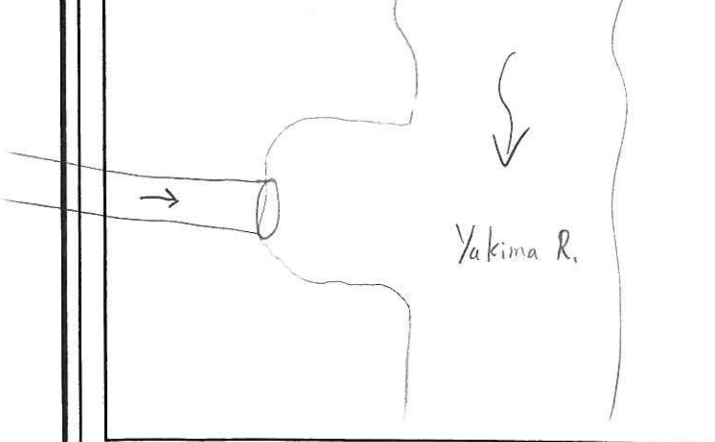
Evacuation Gate Information

Levee Interior Drainage

City of Yakima

AKEL ENGINEERING GROUP, INC.

Schematic:



Size:

30" pipe

Control(s):

Manually locks

Number:

Flood Gate 05

Elevation:

1030.50

Image:

Notes:

Flood Gate #05

AIMMS # 8151

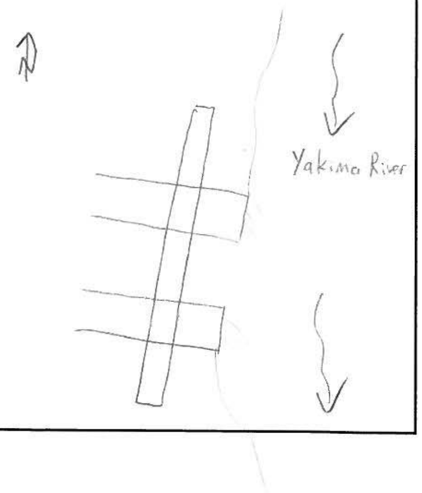
Date Inspected: 6/5/13

May 22, 2013

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

AKEL ENGINEERING GROUP, INC.

Schematic:



Size:

Two 32" CMP

Control(s):

Manually lock

Number:

Flood Gate 06

Elevation:

Top of wall
1042.62 - 3.65 = 1038.97

Image:

Notes:

Flood gate # 06

AIMMS # 8167 (north pipe)
AIMMS # 8146 (south pipe)

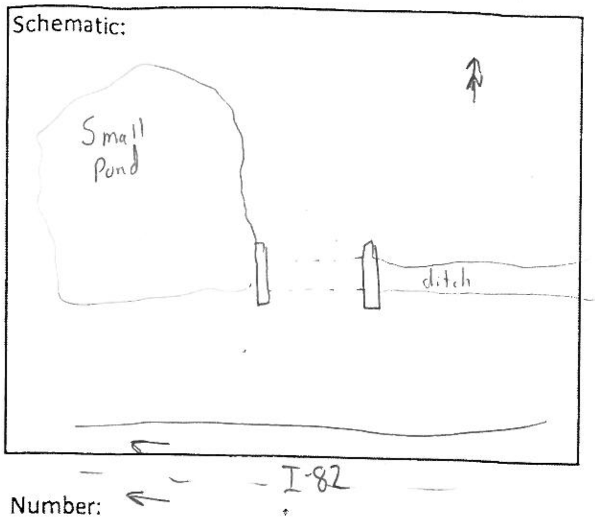
Date Inspected: 6/5/13

May 22, 2013

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

AKEL ENGINEERING GROUP, INC.

Schematic:



Size:

48" pipe

Number:

Flood Gate 7a

Control(s):

Manually Lock

Elevation:

1058.53 - 5.20' = 1053.33

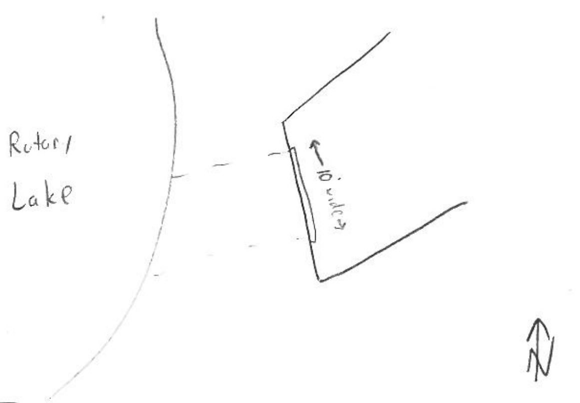
Image:

Notes:

Date Inspected: 6/28/13

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

Schematic:



Size:

10' wide × 18" high

Control(s):

Manual

Number:

Flood Gate 09

Elevation:

1081.48 − 13.15 = 1068'.33

Image:

Notes:

This is a big flood gate that connects the Yakima R. to Rotary Lake

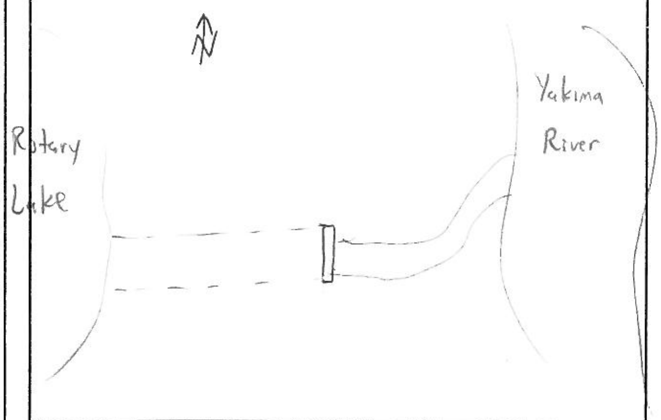
Date Inspected: 6/11/13

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

AKEL ENGINEERING GROUP, INC.

May 22, 2013

Schematic:



Size:

21" pipe

Control(s):

Manually lock

Number:

Flood Gate 10

Elevation:

1074.53 - 2.80 = 1071.73

Image:

Notes:

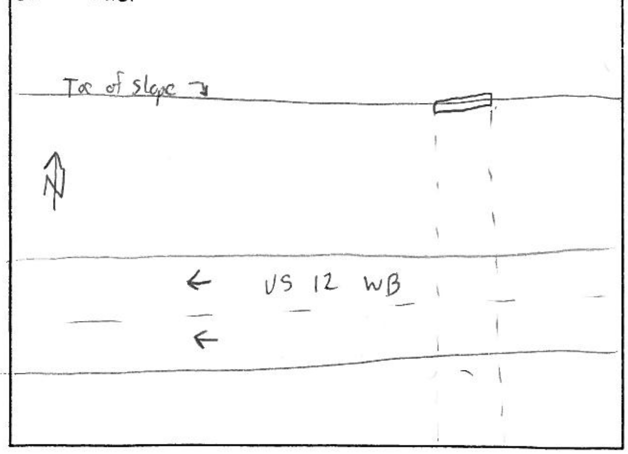
Flood gate 10 connects Rotary Lake to Yakima River

Date Inspected: 6/11/13

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

Naches R.

Schematic:



Size:

18"

Control(s):

Manually lock

Number:

Flood Gate 11

Elevation:

1084.50 + 1.35 = 1085.85

Image:

Notes:

Date Inspected: 6/11/13

May 22, 2013

Attachment A
Evacuation Gate Information
Levee Interior Drainage
City of Yakima

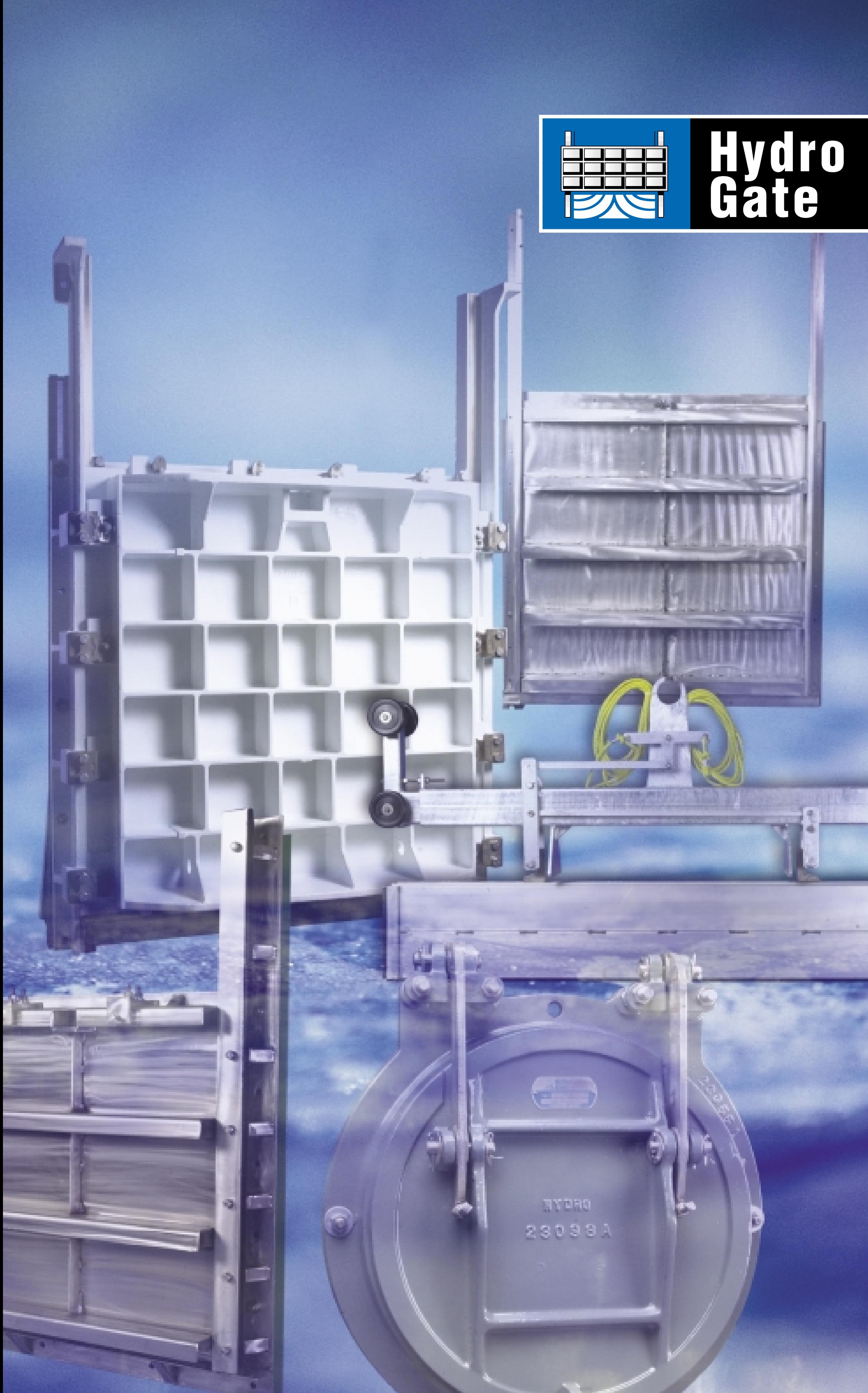
AKEL ENGINEERING GROUP, INC.

APPENDIX C

Floodgate Operation Manuals

Flap Gates

Hydro Gate



Pioneers in Gate Design

Hydro Gate

6101 Dexter Street
Commerce City, CO 80022

With more than 100 years of experience in gate design, Hydro Gate has built a long-standing reputation of providing superior quality water control gates for a variety of industries. Our manufacturing expertise revolves around making big, heavy-duty gates that are 100% custom-built to match specific applications.

Commitment to You… Our Customer

At Hydro Gate, customer satisfaction is our top priority. Bring your special requirements to our engineers who have years of experience in gate design. Our dedicated customer service staff is accustomed to custom requests, because that is what we do best. From your first contact through final delivery, our team of engineers and service experts are here to make sure you have the right gates to suit your needs.

Your Source for Water Control Gates

No matter what type of gates your project demands, chances are excellent Hydro Gate has the right gates for your specific application. Our product offering is vast and can suit applications for a wide variety of industries. Choose from cast iron slide or flap gates, fabricated slide or flap gates, rectangular butterfly gates, stop logs, wall thimbles, lifts and accessories.

Industries We Serve

Whether you need gates for flood control, wastewater treatment, environmental water treatment, irrigation, dam projects or hydroelectric plants, we can help. From standard configurations to custom designs, Hydro Gate offers a wide variety of water control gates as well as a full complement of actuators to meet your specific application.

Service Well Beyond Shipment

Our services extend beyond manufacturing. Hydro Gate's experienced field service technicians can help you with repair and refurbishment projects. If you have existing, yet serviceable gates, we can perform a retrofit that will extend their life and durability.

Focus on Quality

Hydro Gates expansive 90,000 square foot manufacturing facility utilizes precision equipment that allows us to merge time-tested gate design with cutting edge technology. We offer large scale manufacturing capabilities with the ability to produce cast iron gates up to 14' x 16' in size, and fabricated gates up to and over 20' in width or height.

Hydro Gate

Flap Gates

Table of Contents

Flap Gates

24" Heavy Duty Flap Gate

Applications

- Flood Control
- Municipal Projects
- Farm Levees
- Sewer Outfalls
- Industrial Waste Lines
- Water and Sewage Treatment Plants
- Tidal Drainage
- Irrigation Systems
- Pump Discharge Control

Description

Hydro Gate flap gates are made of cast iron or ductile iron, depending on the type of service. Ductile iron is recommended if moderate slamming of the gate can occur. Otherwise, grey cast iron is recommended. A small differential pressure on the back of the gate causes it to open automatically to allow discharge through levees, sewer lines or drainage conduits. When water on the face side of the gate rises above water on the back side, the gate closes automatically to prevent backflow.

Flap gates are equipped with flat-back or spigot-back seats for attaching to wall thimbles, new concrete headwalls or existing walls. The seat or frame of the flap gate is attached to a wall or pipe and forms the opening through which water passes. Since the gate opens or closes automatically, a mechanical lifting device is not necessary.

Automatic drainage gates must be kept clean if they are to function correctly. The hinged flap acts as a natural skimmer to cause timber, logs or trash to catch between the flap and the seat at low flow. Periodic inspection and cleaning should be scheduled when the water flowing through the flap gate carries floating material.

To make the gate more self-cleaning, it should be mounted 12 to 18 in. above the apron in front of the gate. This allows room at the bottom for floating material to work its way out and makes the gate flap somewhat self-cleaning.

Seat (Frames)

A seat (or frame) is a one-piece casting. The seating face is cast and machined at an angle off vertical so that the hinged cover has a horizontal force component to completely seat the gate by gravity.

Corrosion-resistant seating faces are pneumatically impacted into dovetail grooves for heavy-duty gates. All seating faces are machined flat and to a 63 micro-inch finish. Cast iron seating faces are available for all models of gates.

When rubber seats are specified, the gumdrop cross-section rubber seal is locked into a deep dovetail groove in the seat. Rubber seating face is available only with heavy-duty gates.

Flaps (Covers)

Flaps are iron castings of reinforced flat plate design. Reinforcing ribs (both horizontal and vertical) are cast integrally along with bosses for the hinges.

Corrosion-resistant seating faces are attached as described in the previous section for frames.

Double-Hinge Action

For proper seating of a flap gate, double-hinge action is necessary. The main hinge action on any flap gate is about its upper pivot points. However, flexibility is required at the bottom pivot points to allow seating of the flap against the seat. All Hydro Gate flap gates have this double action with bushings in all four pivot points.

It is necessary that bottom hinge action be limited. Otherwise, the flap can turn completely over on itself and wedge back in the opening of the gate seat, rendering the gate useless. Hydro Gate medium and heavy-duty circular opening flap gates are provided with hinge arms extending beyond the bottom pivot point. This limits the double-hinge action and prevents the flap from being rotated outward at the bottom. In addition, the bottom end of each hinge arm has a fine adjustment bolt to further limit the double- hinge action. Square or rectangular opening flap gates are also provided with extended links for fine adjustment even though the bottom of the flap cannot be turned into the gate opening as in the round gates.

Lubrication of Pivot Points

Lubrication of pivot points on flap gates is usually not necessary. The construction of the hinge assembly permits only a few degrees of rotation at the bottom pivot points. The gate cover rotates about the upper pivot points through an arc of 90° or less. With this limited rotation, lubrication of bushings is usually not needed nor is it normally recommended by Hydro Gate. When lubrication of flap gate pivot points is desired, two methods can be used:

1. A permanently lubricated bushing is installed at the factory; or
2. Links or hinge arms can be drilled for zerk-type grease fittings for use with ordinary grease guns.

Permanently Lubricated

If lubrication of pivot points is desired, Hydro Gate recommends the permanently lubricated bushing, usually made from bronze. (On rare occasions, other metals may be required, such as Monel for saltwater.) A familiar trade name is “Lubrite”. It is a one-piece bushing with a heavy wall thickness. Holes are drilled completely through the bushing wall toward its center and then filled with graphite. With this method, not only is the bushing lubricated for life, but it also has the same lubricating effect on the inside and outside.

Grease Fittings

Grease fittings can be used, but are not recommended by Hydro Gate because of two major drawbacks. First, they project from the hinge arm to the front and are easily broken off. Second, since most flap gates are inaccessible for maintenance, most grease fittings are never used after initial lubrication during installation.

Loss of Head Through Flap Gates

Tests conducted on flap gates show that the loss of head due to the flap riding on the water is very small compared with other losses in the hydraulic structure. Of these head losses, the entrance loss is usually considerably more critical than loss at the flap gate on the outlet end of the conduit.

The Hydraulic Laboratory of the State University of Iowa conducted a series of tests to determine the amount of head lost by water discharging through Model 10C flap gates (formerly Armco-Calco). The gates — 18, 24 and 30 in. in diameter — were supplied from commercial stock.

The following passage is excerpted from the report of Floyd A. Nagler, associate professor of mechanics and hydraulics, who supervised the tests.

“Based on these experiments the following empirical formula was derived to express the loss in head through Calco Gates of varying sizes and with different velocities of flow:

L = loss of head in feet
v = velocity of flow through gate in feet per second
d = diameter of outlet in feet
e = base of natural logarithms
g = acceleration of gravity, 32 ft/sec/sec

$$L = \left(\frac{4v^2}{g}\right) e^{\left(\frac{-1.15v}{\sqrt{d}}\right)}$$

“It may be concluded from these experiments that the Calco gate in its hydraulic characteristics is all that the manufacturers have claimed for it. The small loss in head obtained through these gates demonstrates that their installation has little effect on the discharged capacity of drainage outlets.”

Medium and heavy-duty flap gates have heavier flaps or covers than the gate model tested. As a result, head losses through these gates may be slightly more than those indicated by the tests.

Attachment to Concrete Wall or Pipe Flange

Since flap gates open when subjected to a back pressure, only a small unseating force is encountered. When a flap gate is under face or seating head, the force of the water pushes against the cover and only the weight of the gate itself is on the attaching bolts or anchors. For this reason, fasteners are needed only to hold the gate on the wall or flange. There is no hydrostatic force tending to separate the gate from the wall or flange.

In attaching a round heavy-duty flap gate to a pipe flange, the gate is partially drilled to match a 125 lb. ASME bolt circle with only a portion of the holes being used. The cost to full drill the gate seat, mate every hole in the flange, and furnish the additional corrosion-resistant bolts and install them is not justified.

Flanges must be installed perfectly flat. Any warpage of a flange is transferred to the gate seat, preventing the flap to seat properly, particularly at low differential head. (Perfectly flat is generally defined as within plus or minus 1/64 in. of a true theoretical flat plane.) Hydro Gate does not recommend flap gates mounting onto a wall thimble.

Adjustable Top Pivot Points

For the adjustable pivot point on Hydro Gate heavy-duty and medium-duty flap gates, four holes are drilled and tapped – two per side – in the flat ears at the top of the gate seat (see Figure 6-1). Threaded studs are screwed into these holes and are securely locked in position.

A double-eared adjustable pivot lug is then placed on these two studs, and hex nuts are placed on both sides of the bosses. Another double set of ears projects to the top of the pivot lug for mounting of the carbon steel, or bronze, hinge arms. A bushing in the hinge arm works on the body of the assembly pin. This arrangement allows the assembly pins through all pivot points to be in double shear for added strength and also provides for minimum lateral movement of the flap during gate operation.

With the double-nut arrangement on each stud, the top pivot lug can be moved in and out from the wall to vary the location of the top pivot point with respect to the seating face of the gate. All adjusting can be accomplished without removing the gate flap cover from the gate, as is necessary for other pivot arrangements.

The force required to open the gate increases as the pivot lug is moved back toward the wall. When the gate is in a tidal zone or when the gate is partially submerged, the pivot lug can be moved back as far as possible so that the weight of the flap keeps the gate closed. Where less pressure is needed to operate the gate, the pivot lugs are moved farther away from the wall.

Spring Bumper (Optional)

Gates mounted on a pipe (not mounted on a head wall) should be specified to have a spring bumper (swing) to prevent the cover from being thrown over center over top of gate thus preventing the gate from closing automatically. It also prevents personal injury caused by a flap that is balanced or teetering over center.

Leakage

Leakage through flap gates decreases as head increases. At very low heads, there may be insufficient force to fully effect a tight, intimate fit of the seats, and somewhat greater leakage is likely.

Opening Pressure

Any significant depth of water behind the gate will cause the cover to unseat a crack and allow drainage. The pivot lug can be adjusted for more or less sensitivity. When adjusted for less sensitivity, greater depth of water (back pressure) will be needed to crack the gate open. Generally, flap gates cannot hold more than a few inches of backwater for an extended length of time.

Safety Notice

Gates (particularly smaller gates) in public areas should be fenced since children playing on or around them can lift the covers and be injured at the cover's pinch points.

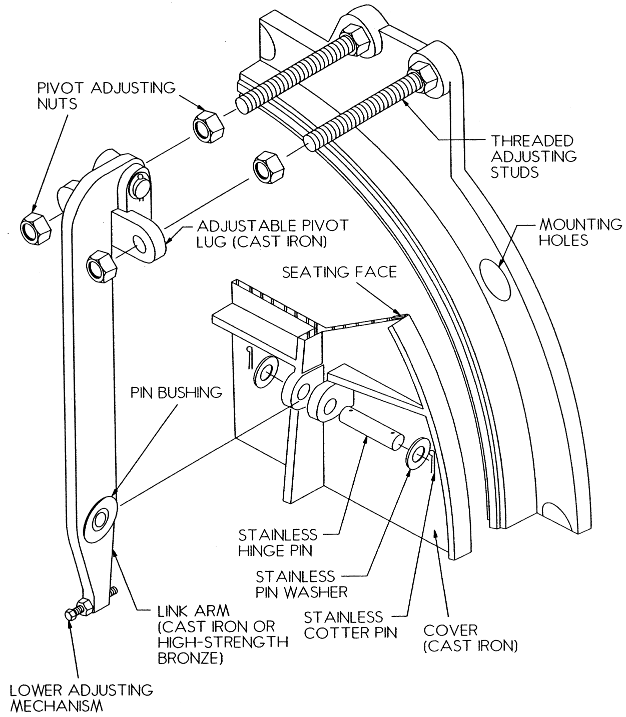


Figure 6-1
Adjustable Top Pivot and Link Assembly

Heavy-Duty Flap Gate

60″x36″ Rectangular flap gate installation

Heavy-duty flap gates have fully adjustable top pivot points. Through the use of two threaded studs, the top pivot point can be moved laterally from the wall to adjust the sensitivity of the gate or to compensate for slight misalignment in installation. The threaded studs with double-locking nuts allow adjustment to be accomplished without disassembly of the gate. By moving the top pivot point back, additional head is required to open the gate as the weight of the flap keeps the gate closed and reduces fluttering action caused by waves. Links or hinge arms are cast iron or bronze, and holes at pivot points are bronze bushed. Permanently lubricated bearings are available for gates requiring lubrication at the hinge points. The assembly bolts through the links are in double shear due to double-eared pivot lugs at the top of the link and double bosses on the flap at the bottom. All fasteners can be furnished in bronze, stainless steel, or Monel depending upon the environment in which they are installed.

A lifting eye is cast integrally with the flap cover to permit manual operation or to hold the gate open. A rubber seating face may be used in the gate seat if the gate is attached to the discharge end of a pump where moderate slamming action will occur. The seating face on the cover is bronze, stainless steel, or Monel as corrosive conditions require. This corrosion-resistant face is machined to a plane and makes contact with the rubber on the seat when the gate is closed. The rubber face on the seat is set in a machined dovetail groove that holds it firmly in position without the aid of bolts, pins or adhesive. The rubber face acts as a cushion for the flap as it closes under moderate slamming action. These gates are exceptionally watertight under higher face pressures because of slight deformation of the rubber faces. In cases where violent slamming action will occur as a result of the pump being turned off, a hydraulic cushion flap gate (see page 10) must be used to dampen the slamming action.

Features

- Model 50C (Circular)
- Model 50 (Square or Rectangular)
- Seating heads to 50 ft
- Round, square or rectangular opening
- Flat-back, corrosion-resistant fasteners
- Ductile iron, cast iron, bronze and stainless steel links

Description

Flat-back seats are for attaching the gate to a concrete wall or a pipe flange. The back of this gate seat is machined to a plane and drilled. Studs or anchor bolts should be of the same material as gate assembly bolts.

Fabricated Heavy Duty Flap Gates

Hydro Gate has the capability to provide a fabricated version of the Heavy Duty Flap Gate for special applications. This type of gate can accommodate odd size requirements or enhanced corrosion resistance than the cast iron line. Fabricated Flap Gates are offered in aluminum, stainless steel, or carbon steel and are designed with rubber seating faces. The fabricated version of the flap gate is designed to have the same functionality and performance as the cast iron version.

Dimensional Data

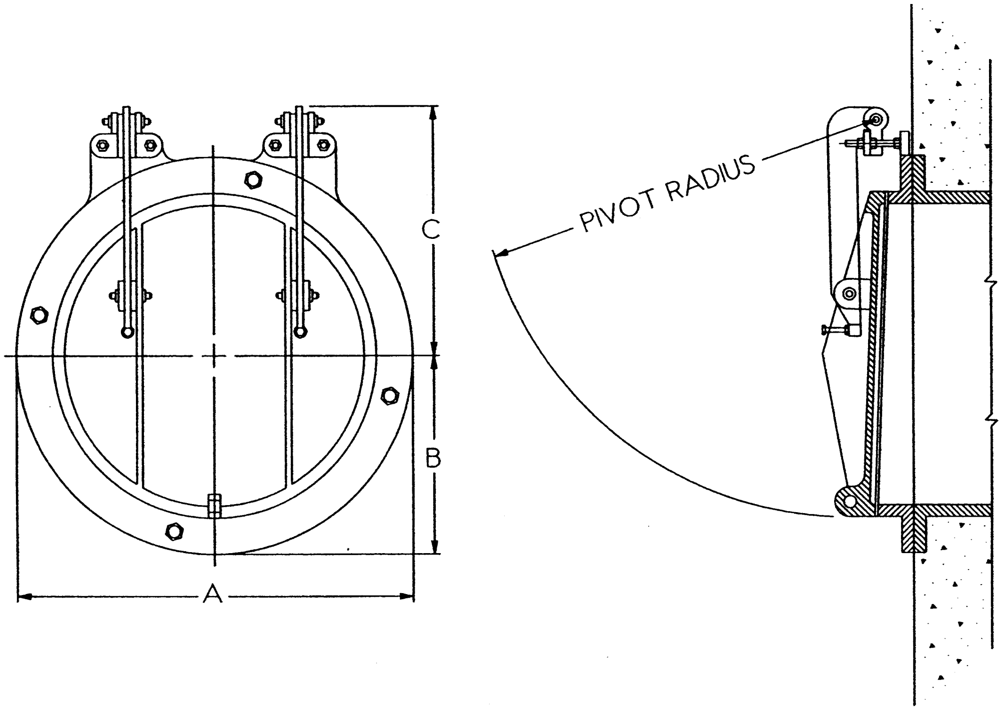


Figure 6-2
Heavy-Duty Flap Gate (Model 50C)

Model 50C Round Opening for Heads to 50 Ft

Opening Size Dia. (In.)	Dimensions (In.)			Pivot Radius (In.)
	A	B	C	
6	11.00	5.50	8.25	11.75
8	13.50	6.75	9.50	14.00
10	16.00	8.00	9.75	15.25
12	19.00	9.50	10.25	16.75
14	21.00	10.50	12.50	19.75
15	22.25	11.25	12.50	20.31
16	23.50	11.75	13.00	21.25
18	24.75	12.50	15.75	25.00
20	27.50	13.75	16.25	26.25
21	28.00	14.00	16.50	27.38
24	32.00	16.00	19.25	31.25
27	34.00	17.00	21.25	35.50

Opening Size Dia. (In.)	Dimensions (In.)			Pivot Radius (In.)
	A	B	C	
30	38.75	19.50	23.25	38.50
36	46.00	23.00	27.50	45.50
42	53.00	26.50	32.50	53.50
48	59.50	29.75	37.75	61.75
54	66.25	33.25	39.75	67.25
60	73.00	36.50	46.00	76.00
66	80.00	40.00	50.00	83.00
72	86.50	43.25	54.25	90.00
78	93.50	46.75	58.25	97.00
84	100.00	50.00	62.25	104.25
90	106.50	53.25	65.50	111.25
96	114.00	51.00	69.00	117.25

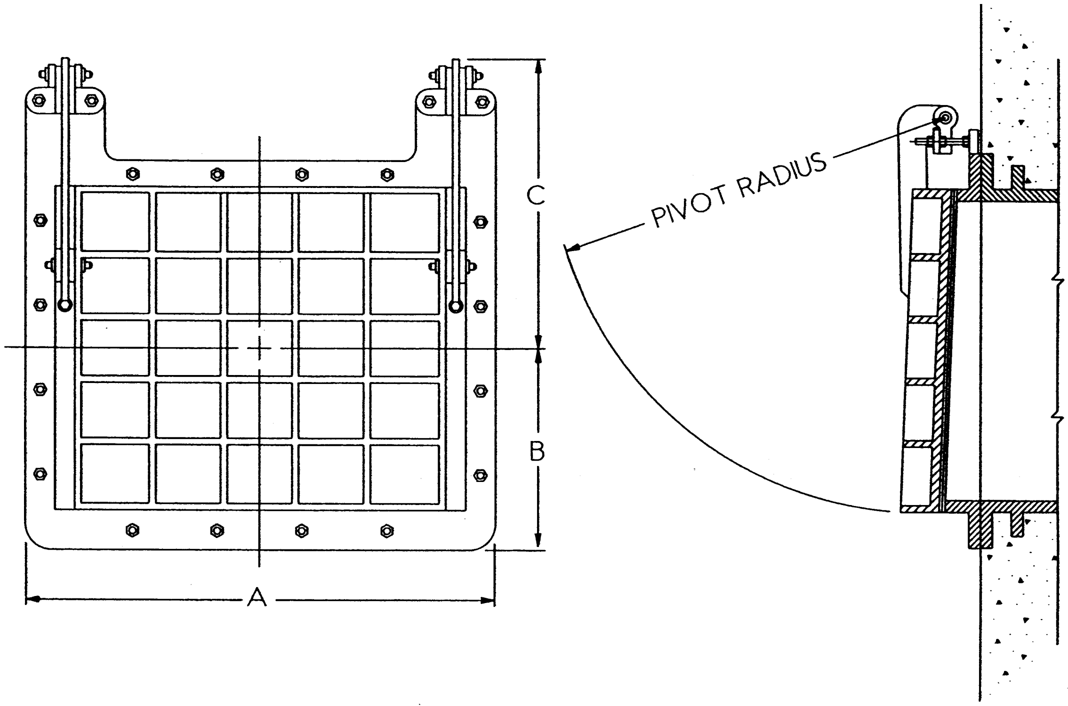


Figure 6-3
Heavy-Duty Flap Gate (Model 50)

Model 50 Square and Rectangular Openings for Heads to 50 Ft

Opening Dia. (In.)	Dimensions (In.)			Pivot Radius (In.)
	A	B	C	
12 x 12	18.00	9.00	11.25	18.25
18 x 18	25.00	12.50	15.75	25.00
24 x 24	32.00	15.00	19.25	31.25
30 x 18	37.00	12.50	15.75	25.00
30 x 30	40.50	18.75	25.75	40.25
36 x 24	44.00	16.00	21.00	31.25
36 x 36	44.00	22.00	27.50	45.25
42 x 30	52.00	19.25	23.25	38.25
42 x 42	52.00	25.00	32.50	53.25
48 x 24	56.00	16.00	19.00	29.25
48 x 36	56.00	22.00	27.50	46.50
48 x 48	58.00	29.00	37.75	61.75
54 x 36	63.00	22.50	27.50	47.50
54 x 54	64.00	32.00	39.75	66.75
60 x 30	68.00	19.00	24.25	39.75

Opening Dia. (In.)	Dimensions (In.)			Pivot Radius (In.)
	A	B	C	
60 x 36	70.00	23.00	29.00	48.75
60 x 48	70.00	29.00	37.75	61.75
60 x 60	70.00	35.00	45.75	75.75
66 x 42	76.00	26.00	32.75	53.50
66 x 66	76.00	38.00	52.00	85.00
72 x 48	82.00	29.00	37.75	61.75
72 x 60	82.00	35.00	45.75	75.75
72 x 72	82.00	41.00	54.75	90.50
84 x 60	94.00	35.00	46.00	75.75
84 x 84	94.00	47.00	62.25	104.00
96 x 60	108.00	36.00	46.00	76.00
96 x 84	108.00	48.00	62.50	104.00
96 x 96	108.00	54.00	69.00	117.00
108 x 108	120.00	60.00	76.00	138.00
120 x 120	132.00	60.00	81.00	149.00

Specifications for Heavy-Duty Flap Gates

General

Flap gates and accessories shall be of the size, material and construction shown on the drawings and specified herein. They shall be Hydro Gate heavy-duty flap gates or approved equal, with circular, square or rectangular openings. Similar installations shall have operated successfully for five years or more. All component parts shall be of the type material shown in the “Materials” section of this specification. The Material Combination Number applicable to each gate shall be shown in the “Gate Schedule.”

Seat

The seat shall be flat back and shall be cast in one piece with a raised section around the perimeter of the waterway opening to mount the seating faces. The raised section shall provide a seating plane diverging top to bottom from the plane of the mounting flange to assist in positive closure of the cover. The seat shall be shaped to provide two bosses extended above the top of the waterway opening for mounting the pivot lugs. Pivot lug bosses shall be drilled and tapped for mounting studs. The back of the seat shall be machined to a plane and drilled to mate the anchor or stud layout. Gates attached to concrete shall be mounted on anchor bolts and grouted in place.

Cover

The cover shall be cast in one piece with necessary reinforcing ribs, a lifting eye for manual operation, and with bosses to provide a pivot point connection with the links. Bosses shall be designed to place the hinge pins in double shear when the gate is assembled.

Seating Faces

A full-width, dovetail slot shall be machined around the perimeter of the cover and the seat. Corrosion-resistant dovetail seating faces shall be mounted in the slot and held securely without use of screws or other fasteners. The seating faces shall be machined to a plane with a minimum 63 micro-inch finish.

Flap gates subjected to mild slamming action shall have a rubber seating face on the seat. Rubber seating faces shall be mounted in a dovetail slot and held securely without use of pins or screws. The seating face on the cover shall be as specified in the previous section.

Pivot Lugs

Each pivot lug shall be cast in one piece. Lugs shall have double bosses to place the top hinge pins in double shear when they are assembled through the link. The lugs shall be adjustable in the horizontal plane without removal of the cover from the gate links. The adjustment shall allow the top pivot point to be moved toward the gate seat for reduced sensitivity of the cover, or moved away from the gate seat to provide opening with minimum differential head. Two corrosion-resistant studs shall be used to connect each pivot lug to the gate seat.

Links

The links connecting the cover and pivot lugs shall be heavy duty and cast in one piece. Each link shall be provided with commercial grade, corrosion-resistant bushings at each pivot point. The bottom of the links shall be provided with an adjusting screw to properly align seating faces on the cover with respect to the seat. The links shall be designed to limit the double hinge action, preventing the cover from rotating sufficiently to become wedged in the open position.

Fasteners

All anchor bolts, assembly bolts, screws, studs and nuts shall be of ample size to safely withstand the forces created by operation of the gate under the heads shown in the “Gate Schedule”. Quantity and size of the fasteners shall be recommended by the manufacturer. Anchor bolts shall be furnished with two nuts each to facilitate installation and alignment of the gates when attached to concrete.

Painting

Machined surfaces shall be coated with a water-resistant, rust-preventive compound. All cast iron parts shall be shop cleaned and painted in accordance with the manufacturer’s standard practice.

Drawings for Approval

Drawings showing the dimensions and details required to locate and install the component assemblies shall be submitted for the engineer’s approval prior to fabrication.

Installation

Installation of all parts shall be done by the contractor in a workmanlike manner and in accordance with the manufacturer’s instructions. It shall be the contractor’s responsibility to handle, store and install the gate in strict accord with the manufacturer’s drawings and recommendations.

Materials

The “Material Combination Number” included in the “Gate Schedule” and shown below defines the type of material for the component parts of the gates and accessories included in this specification. Materials shall conform to the requirements of the following ASTM standards. When more than one alloy, type or grade of material is shown, the exact alloy furnished must be at the manufacturer’s option.

Cast Iron
ASTM A126, Class B

Austenitic Gray Iron Casting
(Ni-Resist) ASTM A436, Type 2

Stainless Steel (Faces & Anchors)
ASTM A276, Type 302 or 304

Stainless Steel (Fasteners)
ASTM F593 (Bolts), Alloy Group 1

Monel (Seating Faces and Fasteners)
ASTM B164, Class A or B

Naval Bronze (Seating Faces)
ASTM B21, Alloy 482

Silicon Bronze (Seating Faces)
ASTM B98, Alloy 651

Rubber (Seating Faces)
ASTM D2000, Grade 1BE625

Bronze (Bushings)
ASTM B584, Alloy 932

Stainless Steel (Bushings and Pins)
ASTM A582, Type 303

Gate Part or Item of Assembly	Material Combination #1	Material Combination #2	Material Combination #3
GATE ASSEMBLY			
Seat and Cover	Cast Iron	Cast Iron	Cast Iron
Seating Faces (Seat)	Naval Bronze	Stainless Steel	Neoprene
Side Wedge Blocks (Cover)	Naval Bronze	Stainless Steel	Naval Bronze
Pivot Lugs and Links	Cast Iron	Cast Iron	Cast Iron
Bushings	Bronze	Stainless Steel	Bronze
Fasteners	Stainless Steel	Stainless Steel	Stainless Steel

Gate Part or Item of Assembly	Material Combination #4	Material Combination #5	Material Combination #6
GATE ASSEMBLY			
Seat and Cover	Cast Iron	Cast Iron	Ni-Resist
Seating Faces (Seat)	Neoprene	Phosphor Bronze	Monel
Side Wedge Blocks (Cover)	Stainless Steel	Phosphor Bronze	Monel
Pivot Lugs and Links	Cast Iron	Cast Iron	Ni-Resist
Bushings	Stainless Steel	Stainless Steel	Monel
Fasteners	Stainless Steel	Stainless Steel	Monel

Gate Schedule

Quantity Required	Size of Opening (In.)	Back Type	Seating Head (Ft)	Remarks

Hydraulic Cushion Flap Gate

18" Hydraulic Cushion Gate

Features

- For seating heads to 50 ft
- Round Opening
- Flat back

Description

The hydraulic cushion flap gate is manufactured exclusively by Hydro Gate and is recommended for installation on the end of pump discharge lines where violent slamming action will occur. The unique design of this gate uses water trapped between tapered seating faces to form a cushion that dampens slamming action caused when the pump is turned off or ceases to operate. The hydraulic cushion flap gate is used where violent slamming action of the cover can occur. Factors influencing slamming action include:

1. Maximum differential head (minimum water surface in the pump sump to maximum water surface elevation over the top of the gate).
2. The overall length of pipe including the pump column.
3. The velocity of discharge at the gate.
4. The diameter of the gate.

In those installations where the total pipe length is short and/or high unbalanced heads are present, violent slamming action will occur. For these installations, the only known flap gate that will give satisfactory service is the Hydro Gate hydraulic cushion. Contact Hydro Gate Engineering Department for selection criteria for hydraulic cushion gates.

This type of gate has two distinct movements that cushion slamming action. With the gate in closed position, the first movement of the cover, as water from the pump contacts it, is parallel to the centerline of the pipe. The domed cover attached to the large-diameter pin moves parallel to the centerline of the pipe through the bushed spider, connected to the gate hinge arms. A detent in this large horizontal pin permits the vertical, spring-loaded locking pin to be retracted from the bottom lip, which is cast as an integral part of the gate. The second movement is the pivoting of the operating portion of the gate about the upper pivot centers, similar to other flap gates.

When the flow through the gate suddenly ceases, the gate cover and linkage assembly pivot about the top points and, as the gate closes, is cushioned by the water around the perimeter. The final closing action is parallel to the centerline of the pipe. The cushion of water around the circumference of the gate continues to throttle the slamming action as the tapered seating surfaces move closer together. Final seating is metal-to-metal with the vertical spring-loaded pin making contact with the lip at the bottom of the gate opening. This forms a latch that prevents the cover assembly from bouncing back open after the gate is closed.

Pins and springs are stainless steel with sleeve bushings of self-lubricating bronze to ensure free operation of the gate. A heavy eyebolt is provided in the center of the face side of the gate for manual operation during maintenance or inspection.

The hydraulic cushion flap gate is designed to withstand 50 ft of seating head or withstand a combination of seating head and the vacuum that may develop when the gate is closed and the water flows away from the back side of the gate.

The seat of this model is made only in flat back, and is machined to a plane and digitally drilled for attaching to a pipe flange or concrete. Studs or anchors used for gate attachment should be stainless steel, the same material as other moving parts.

Dimensional Data

Opening Size Dia. (In.)	Dimensions (In.)				Pivot Radius (In.)	Bolt Circle (In.)
	A	B	C	D		
10	17.50	16.00	10.50	5.25	19.00	14.25
12	17.00	15.75	10.75	4.75	18.50	17.00
14	22.50	19.25	13.00	6.00	24.00	18.75
16	25.50	24.00	14.75	6.50	27.00	21.25
18	27.00	26.50	16.25	7.25	29.50	22.75
21	30.50	29.00	18.00	7.50	33.00	26.00
24	34.25	33.00	20.25	7.75	37.00	29.50
30	41.25	39.00	23.75	8.50	45.00	36.00
36	49.50	44.00	28.25	9.75	52.00	42.75
42	56.25	50.00	31.75	11.00	59.00	49.50
48	62.50	58.00	35.35	12.25	65.50	56.00
54	70.00	64.00	39.50	12.50	73.25	62.75
60	77.00	70.00	43.25	13.75	80.25	69.25

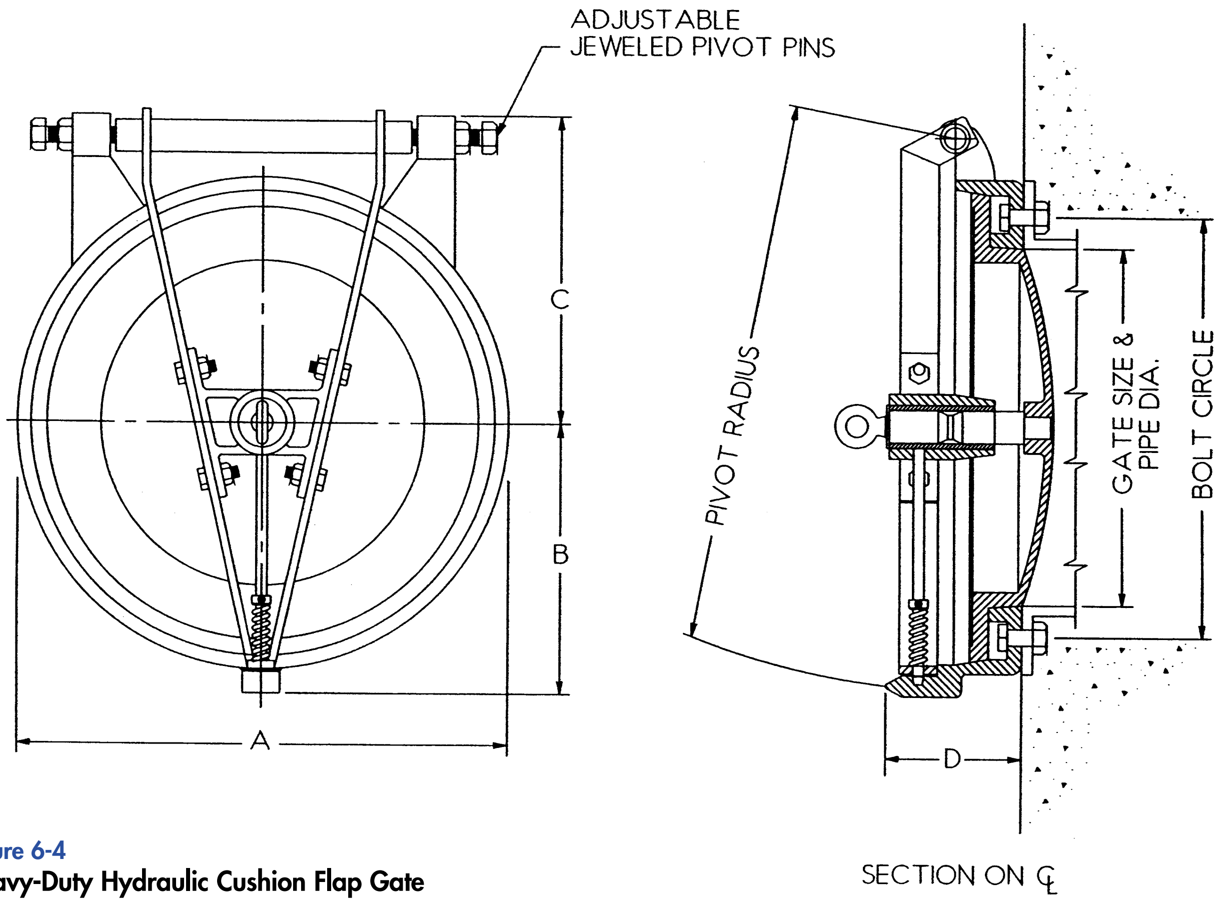


Figure 6-4
Heavy-Duty Hydraulic Cushion Flap Gate

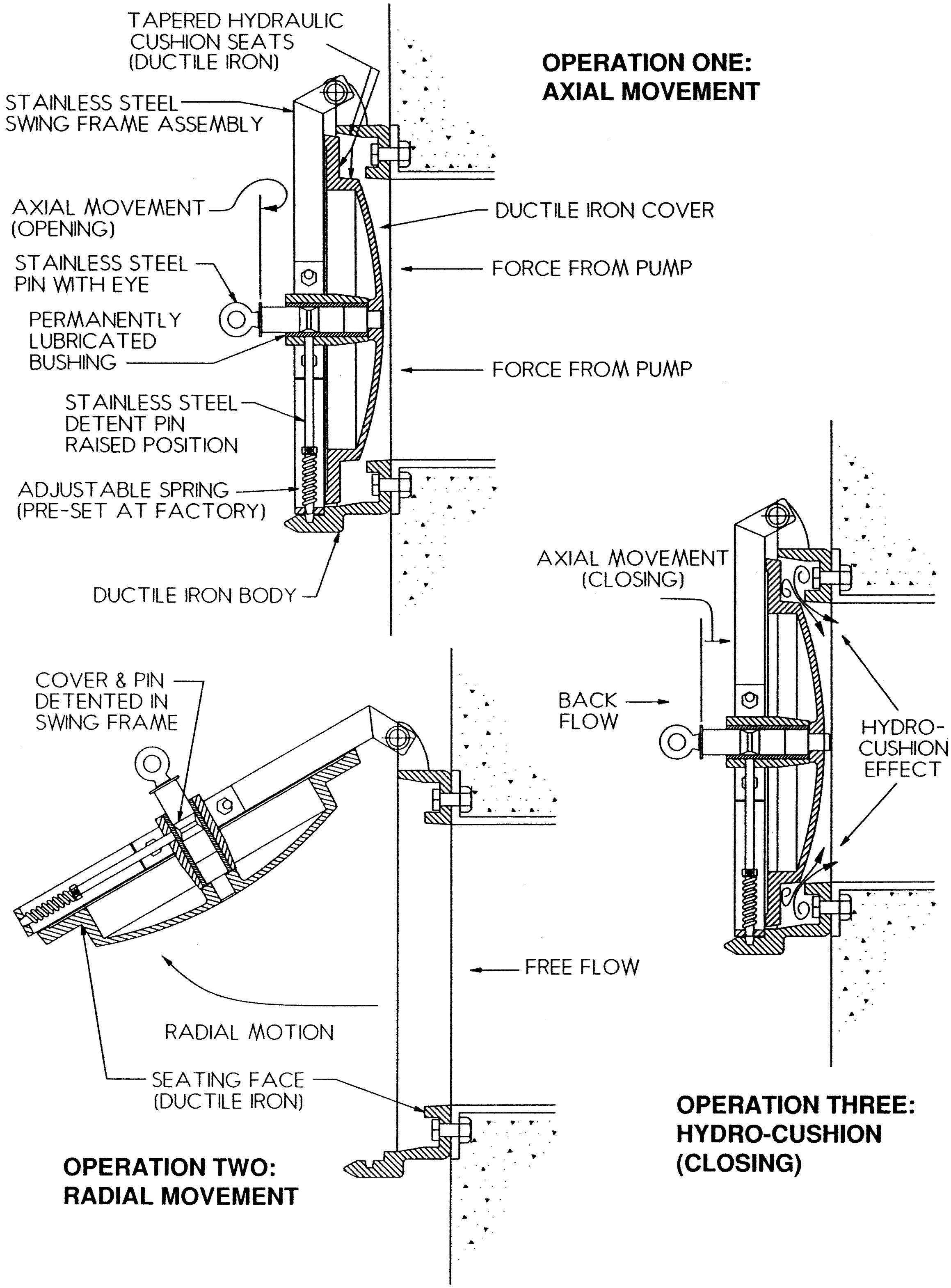


Figure 6-5
Hydraulic Cushion Gate Operation

Specifications For Hydraulic Cushion Flap Gates

General

Gates and accessories shall be of the size, type material and construction shown on the drawings and specified herein. Gates shall be circular opening Hydro Gate hydraulic cushion flap gates or approved equal. Similar installations shall have operated successfully for five years or more. All component parts shall be of the type material shown in the "Materials" section of this specification.

Design

The design shall provide for a hydraulic cushioning of closing forces and positive closure without rebounding of the cover. All gate parts shall be of ample section to safely withstand the combined forces created during closing.

Seat

The seat shall be a one-piece ductile-iron casting shaped to provide two pivot point bosses extended above the top of the waterway opening. The bosses shall be drilled and tapped for stainless steel pivot pins. Pivot pins shall be adjustable and provided with a positive means of locking. The back face of the seat shall be machined to a plane and drilled to match the pipe flange or anchor bolt layout. Stainless steel fasteners shall be provided for attaching to pipe flanges or concrete.

Cover

The cover shall be a dome-shaped, ductile iron casting with a heavy boss at the center. The boss shall be drilled and a heavy stainless steel pin shall be inserted and welded therein. The pin shall be machined to provide a recess for retraction of the spring-loaded locking pin and shall be provided with a heavy eyebolt for manual operation.

Seating Faces

The seat and the cover shall each be provided with two machined seating surfaces so arranged to be concentric and slightly conical with each other, creating the hydraulic cushion entrapment zone. Positive flat faced seats shall be provided for final close-off of the opening.

Linkage Assembly

The linkage assembly shall provide the connection between the adjustable pivot pins and the cover and shall house the spring-loaded retractable locking pin. Structural parts, springs, pins and fasteners shall be stainless steel. Self-lubricating bronze bushings shall be provided at the assembly pivot points.

Fasteners

All anchor bolts, assembly bolts, screws, nuts, etc. shall be of ample size to safely withstand the forces created by operation of the gate while subjected to the heads specified. Quantity and size of the fasteners shall be as recommended by the manufacturer. Anchor bolts shall be furnished with two nuts each to facilitate installation and alignment of the gates when attached to concrete. All other fasteners shall be double nutted or otherwise locked to prevent loosening.

Painting

Exposed machined or bearing surfaces shall be coated with a water-resistant, rust-preventive compound. All parts not made from corrosion-resistant steel shall be grit blasted and painted in accordance with the manufacturer's standard practice.

Drawings for Approval

Drawings showing the dimensions and details required to locate and install the component assemblies shall be submitted for the engineer's approval prior to fabrication.

Installation

Installation of all parts shall be done by the contractor in a workmanlike manner, and in accordance with the manufacturer's instructions. It shall be the contractor's responsibility to handle, store and install the gate in strict accord with the manufacturer's drawings and recommendations. Flanges shall be installed perfectly flat. Perfect flatness is generally defined as within + 1/64 in. of true perfect plane. The flange joint shall be sealed with mastic or a rubber gasket. Gates mounted on concrete shall be grouted with non-shrink high-strength grout.

Materials

Materials shall conform to the requirements of the following ASTM Standards.

Cast Ductile Iron
ASTM A536, Grade ip-55—06

Stainless Steel (Links)
ASTM A167, Type 304L, or ASTM A276, Type 304L

Stainless Steel (Fasteners)
ASTM F593 (Bolts), Alloy Group 1;
ASTM F594 (Nuts, Alloy Group 1
Section 6 – Page 14

Gate Schedule

Quantity Required	Size of Opening (In.)	Back Type	Seating Head (Ft)	Remarks

Flexible (Rubber) Flap Gates

Applications

- Very low unseating head requirements
- Pump discharge
- Coastal tide basin drainage
- Combined sewage overflow requirements

Description

Flexible Flap Gates are manufactured with a stainless steel frame and a reinforced neoprene cover. To aid in the sealing of the gate, a flexible neoprene seal is mounted to the stainless steel frame.

These gates are quiet operating and require very little maintenance. Should debris collect behind the cover it is easily removed or flushed out. These gates are ideally suited for pump discharge and wave action. There are no hinge pins to wear out and they never need painting. The Flexible Flap Gate can be mounted to a fabricated wall thimble or to a concrete wall with the incorporation of a grout pad.

These gates are available in a variety of sizes. The maximum width of each flap gate is limited to a 60" wide gate opening. For the minimum and maximum gate sizes available, please consult Hydro Gate's Engineering staff.

When specifying Hydro Gate's Flexible Flap Gate be sure to consider the characteristics of the water, the gate's function, the opening size and the maximum head requirements. Hydro Gate's Engineering staff is experienced in answering any of the questions you may have concerning the design and use of the Flexible Flap Gate.

Features

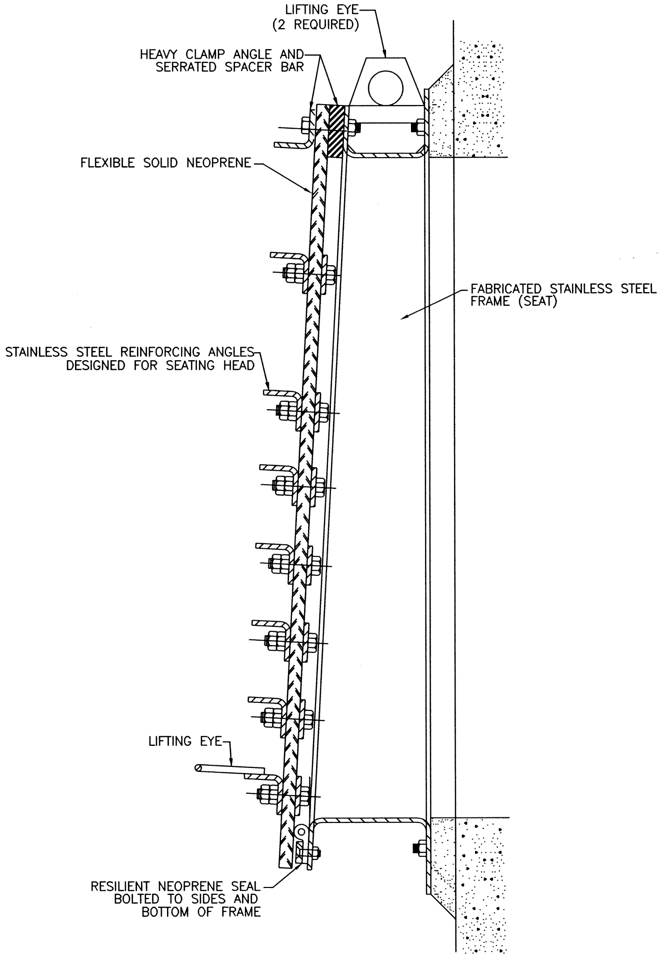
- Stainless steel frame (seat)
- Flexible neoprene cover (flap), one inch thick for most applications
- Stainless steel reinforcing angles bolted to cover with full width stainless steel backer bar
- Resilient neoprene hollow bulb seal bolted to frame for seating seal
- Flexible continuous hinge integral with neoprene cover

Design and application features:

- Simple rugged design
- Low head loss, low cracking pressure, self draining
- Quiet operation, no slamming metal to metal
- Withstands pump discharge and reverse flow slamming and wave action
- Tolerates debris, cover moulds around objects
- Corrosion resistant to most water born contaminates, resistant to algae and marine growth
- No painting, no lubrication, no broken hinges, links or worn pins
- Smooth design for easy flushing

Hydro Gate rubber flap gates are best suited for wall mounting on anchor bolts and grout pad. They can also be mounted on a fabricated or cast iron thimble; however, the back flange is un-machined which requires heavy layer of mastic or a thick soft gasket to seal the flange joint.

Gates larger (width or height) than 42 inches may require seaming and bonding of the rubber flap due to available rubber sheet width. Multiple gate openings or multiple gates may be used in lieu of a seamed rubber cover. Multiple gate openings prevent debris from catching in the frame members. Contact Hydro Gate Engineering Department for recommendation for your specific application.



Rubber Flap Gate — Section View

Specification for Flexible (Rubber) Flap Gate

Flexible flap gates shall be of size and material grades as specified herein and as shown on drawings and gate schedule. They shall be Hydro Gate Flexible Flap Gate or approved equal. They shall be square or rectangular or multiple opening style.

Frame

Frame shall be fabricated from stainless steel type 304. The frame shall have a diverging face top to bottom to assist in positive closure of the flap. The frame shall be provided with a rear attaching flange, holes to mount, and a concrete structure with a grout pad. Two lifting lugs shall be provided on the frame for handling and installation hanging.

Cover (Flap)

The cover shall be fabricated from fabric reinforced neoprene rubber and type 304 stainless steel reinforcing angles attached to the rubber sheet with stainless steel through bolts and backing bars. The bolts shall be caulked or sealed to prevent leakage through the boltholes. The size and quantity of reinforcing beams shall be designed to withstand the maximum hydrostatic force applied to the gate. The hinge end of the cover shall be securely bolted to the frame with heaving clamping bars and bolts.

The rubber cover sheet shall be one piece without seams. The rubber thickness shall be sufficient to prevent excessive "ballooning" under hydrostatic pressure. Gate widths greater than available rubber sheet shall be furnished with multiple (side by side) openings.

The flap cover shall have a lifting lug at its lower end to facilitate lifting for cleaning.

Hinge

The hinge shall be flexible type integral with the flexible rubber cover.

Seating Surfaces

Resilient hollow section or lip type rubber seals shall be attached to the divergent face of the gate frame with bolts and stainless steel retainer bars. The resilient seals shall provide a high degree of water tightness.

Limitations

Hydro Gate Corporation wants to be sure that flexible flap gates will meet the requirements of the project. Before specifying gates wider than 60" and head pressures more than twice the gate height, contact Hydro Gate Engineering Department for design and material limits. Provide information about the type of service, type of water, maximum seating heads and mounting information.

Gate Schedule

Quantity Required	Size of Opening (In.)	Back Type	Seating Head (Ft)	Remarks

Hydro Gate Representative Territories Listed by State

ALABAMA
Eco Tech, Inc.
Phone: 770-345-2118

ALASKA
Beaver Equipment
Phone: 425-451-3862

ARIZONA
C. R. Raleigh & Assoc.
Phone: 623-972-9238

ARKANSAS
H*E Engineered Equip.
Phone: 918-251-2121

CALIFORNIA
Southwest Valve & Equipment (Southern)
Phone: 714-832-1090

DC Frost Associates, Inc. (Northern)
Phone: 925-947-6733

COLORADO
Pipestone Industrial Co.
Phone: 303-771-2396

CONNECTICUT
Atlantic Fluid Tech. Assoc.
Phone: 508-755-0440

DELAWARE
John B. Atherholt, Inc.
Phone: 610-828-4140

DISTRICT OF COLUMBIA
John B. Atherholt, Inc.
Phone: 610-828-4140

FLORIDA
Eco Tech, Inc. (Panhandle)
Phone: 770-345-2118

TSC Jacobs
Phone: 813-888-5556

GEORGIA
Eco Tech, Inc.
Phone: 770-345-2118

HAWAII
CBC , Inc.
Phone: 808-263-8838

IDAHO
W-Cubed, Inc. (Eastern)
Phone: 801-466-3819

Beaver Equipment Specialty Co. (Western)
Phone: 425-451-3862

ILLINOIS
Norquip, Inc. (Northern)
Phone: 414-248-9445

Van Devanter Engineering Co. (Southern)
Phone: 314-343-8880

INDIANA
Colley & Associates
Phone: 317-254-1001

IOWA
Bert Gurney & Associates, Inc.
Phone: 402-551-7996

KANSAS
H*E Engineered Equip. Co., Inc.
Phone: 913-236-9494

KENTUCKY
BissNuss, Inc. (Eastern)
Phone: 513-860-1630

Van Devanter Engineering Co., Inc. (Western)
Phone: 314-343-8880

LOUISANA
Gulf States Engineering Co.
Phone: 504-243-5500

MAINE
Atlantic Fluid Technology Assoc.
Phone: 508-755-0440

MARYLAND
John B. Atherholt, Inc.
Phone: 610-828-4140

BissNuss, Inc. (Northwest)
Phone: 412-221-1200

MASSACHUSETTS
Atlantic Fluid Technology Associates
Phone: 508-755-0440

MICHIGAN
Norquip, Inc. (Upper Peninsula)
Phone: 414-248-9445

Kennedy Industries, Inc.
Phone: 248-684-1200

MINNESOTA
Plant & Flanged Equipment Co.
Phone: 763-792-3870

MISSISSIPPI
Gulf States Engineering Co.
Phone: 504-243-5500

MISSOURI
H*E Engineered Equipment Co. (Western)
Phone: 913-236-9494

Van Devanter Engineering Co. (Eastern)
Phone: 314-343-8880

NEBRASKA
Bert Gurney & Associates, Inc.
Phone: 402-551-7995

NEVADA
Southwest Valve & Equipment (Eastern)
Phone: 714-832-1090

D.C. Frost (Western)
Phone: 925-947-6733

NEW HAMPSHIRE
Atlantic Fluid Technology Associates
Phone: 508-755-0440

NEW JERSEY
Atlantic Fluid Technology Associates (Northern)
Phone: 508-755-0440

John B. Atherholt, Inc. (Southern)
Phone: 610-828-4140

NEW MEXICO
Pipestone Industrial Company
Phone: 303-771-2300

NEW YORK
Atlantic Fluid Technology Associates (Southeast)
Phone: 508-755-0440

J.L. Moore, Inc.
Phone: 716-655-3433

NORTH CAROLINA
EW2 Environmental
Phone: 704-542-2444

NORTH DAKOTA
Plant & Flanged Equipment Co.
Phone: 763-792-3870

OHIO
BissNuss, Inc. (Southeast)
Phone: 614-895-0911

BissNuss, Inc. (Southwest)
Phone: 513-860-1630

BissNuss, Inc. (East)
Phone: 412-221-1200

BissNuss, Inc. (North)
Phone: 440-871-8394

OKLAHOMA
H*E Engineered Equip. Co.
Phone: 918-251-2121

OREGON
Beaver Equipment
Phone: 503-692-8106

PENNSYLVANIA
BissNuss, Inc. (Western)
Phone: 412-221-1200

John B. Atherholt, Inc. (Eastern)
Phone: 610-828-4140

RHODE ISLAND
Atlantic Fluid Technology Assoc.
Phone: 508-755-0440

SOUTH CAROLINA
EW2 Environmental
Phone: 704-542-2444

SOUTH DAKOTA
Plant & Flanged Equipment Co.
Phone: 763-792-3870

TENNESSEE
Eco Tech, Inc.
Phone: 770-345-2118

TEXAS
Hartwell Environmental Corp. (Central)
Phone: 281-516-7102

Municipal Valve & Equipment Co. (North)
Phone: 214-934-1261

Pipestone Industrial Co., Inc. (Southeast)
Phone: 303-771-2300

UTAH
W-Cubed, Inc.
Phone: 801-466-3819

VERMONT
Atlantic Fluid Technology Assoc.
Phone: 508-755-0440

VIRGINIA
Engineered Systems & Products (Northern)
Phone: 804-271-7200

John B. Atherholt, Inc.
Phone: 610-828-4140

WASHINGTON
Beaver Equip. Specialty Co., Inc.
Phone: 425-451-3862

WEST VIRGINIA
BissNuss, Inc. (Southern)
Phone: 304-346-7532

BissNuss, Inc. (Northern)
Phone: 412-221-1200

WISCONSIN
Norquip, Inc.
Phone: 414-248-9445

Plant & Flanged Equipment Co. (Western)
Phone: 763-792-3870

WYOMING
Pipestone Industrial Co., Inc.
Phone: 303-771-2300

INTERNATIONAL
Stealth Valve & Controls, Ltd (Canada)
Phone: 905-845-4500

Construction Products Int'l (Middle East)
Phone 281-362-0155

CIVIL REPRESENTATIVE
States: AL, AZ, GA, KY, LA, TN
Hydro Con, Inc.
Phone: 901-755-8806

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RECLAMATION
Managing Water in the West

Hydraulic Laboratory Report HL-2006-04

CS-29 Black Bayou Culverts, Calcasieu Parish, Louisiana

1:4 Scale Model Study of Culvert Flap Gate

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Water Resources Research Laboratory
Denver, Colorado

June 2006

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14. ABSTRACT A 1:4 scale Froude-based hydraulic model of a single box culvert with flap gate was studied in Reclamation's Water Resources Research Laboratory. The main focus of the study was on verification of the operating characteristics and head loss associated with the light-weight aluminum flap gate that is being specified for the CS-29 Black Bayou culvert structure. The flap gates were found to operate with very low head loss within the range of operations expected at the Black Bayou Site. Data were compared to prior studies. The use of light-weight flap gates, while having low head loss characteristics, will likely require some onsite adjustments of gate buoyancy. In addition, since only a single barrel was modeled in the laboratory, the effects of having 10 side-by-side box culverts with flap gates may also require gate buoyancy to obtain expected performance of the structure.						
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1:4 Scale Model Study of Culvert Flap Gate

K. Warren Frizell

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Water Resources Research Laboratory
Denver, Colorado

June 2006

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgments

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Hydraulic Laboratory Reports

The Hydraulic Laboratory Report series is produced by the Bureau of Reclamation's Water Resources Research Laboratory (Mail Code 86-68560), PO Box 25007, Denver, Colorado 80225-0007. At the time of publication, this report was also made available online at **http://www.usbr.gov/pmts/hydraulics_lab/pubs/HL/HL-2006-04.pdf**

Disclaimer

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CONTENTS

FIGURES

GLOSSARY OF SYMBOLS

C	Constant
D	Diameter
F	Force
H	Head
H_L	Head loss
L	Characteristic length
M	Mass
Q	Volumetric discharge
W	Weight
g	gravitational constant
h_v	Velocity head
m	model (subscript)
p	prototype (subscript)
r	ratio (subscript)
ρ	Density
γ	Specific weight

Executive Summary

A 1:4 scale Froude-based model of a flap gate on the constructed CS-29 Black Bayou Culverts was tested in the hydraulic laboratory of the Bureau of Reclamation in Denver, Colorado. This project is to restore drainage at LA highway 384 and Black Bayou. A set of ten, 10 ft-by-10 ft cast-in-place box culverts is being constructed under highway 384 to allow continuous drainage out of the basin to the Calcasieu River. The culverts will have aluminum flat-back flap gates on the discharge side to prevent salt water intrusion from the Calcasieu River into the freshwater basin.

The laboratory model included one scaled 10 ft-by-10 ft culvert with flat-backed flap gate on the discharge side. The scale was chosen based on flow parameters and structure size, with the emphasis put on the need to be able to measure very small head differentials across the flap gate.

Very low heads were required to initiate flow through the culvert. With no additional buoyancy inserts installed and no submergence, only 0.042 ft of head was needed to initiate flow. With the gate submerged and all 4 Styrofoam inserts installed, the head required was reduced to 0.005 ft.

Gate angle during operation had mild correlation with the head drop across the culvert. This correlation broke down when all 4 buoyancy inserts were installed. Maximum prototype head loss measured during the study was 0.101 ft for loss across the entire culvert system. This prototype head drop includes entrance and exit losses from the culvert, friction within the culvert, and the loss added by the gate operation. When looking at the trend of gate loss only, it is inversely proportional to discharge for the case of the gates with added buoyancy; however for the gate without buoyancy inserts, the head loss imparted by the gate is basically constant. There is considerable scatter in the submerged head loss coefficients, which has been noted in previous studies in the literature.

Buoyancy inserts, allow the gate to rise essentially out of the flow for all flowrates when 4 inserts are installed, but becomes a problem when trying to get the gate to close and reseat. A balance between low head loss and good opening/closing performance was obtained with 2 foam inserts added to the gate. Fine tuning should be possible once the field installation is complete and engineers have observed the gates in operation.

Background

The Natural Resources Conservation Service (NRCS) in Alexandria, Louisiana and the Louisiana Department of Natural Resources (LA DNR) are currently constructing a Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) project (CS-29) to restore drainage under LA highway 384 at Black Bayou. When highway 384 was constructed, the road fill was placed continuously across Black Bayou/Black Bayou Cut without drainage features. Culverts will be constructed under the highway to allow continuous drainage out of the Mermentau River Basin to the Calcasieu River. The water will flow through ten, 10-ft by 10-ft cast-in-place concrete box culverts. For high tide events, the culverts will feature lightweight aluminum flat-back flap gates on the discharge side of the culverts to prevent salt water intrusion from the Calcasieu River into the fresh water basin of the Mermentau River. The flap gates must operate with very low head differentials, imparting very low head losses to the system.

The NRCS requested that Reclamation perform physical hydraulic model studies of the flap gate/culvert structure in order to prove the performance of the current design and allow for its future use and development in the region.

The design of the discharge structure and flap gates was developed on the basis of submerged flow calculations for the box culverts and an estimated 0.1 ft of head loss for the flap gate. The estimated head loss for the rectangular gate was based on a comparison with conventional circular gates and consideration of the weight of the gate and gravitational forces on the gate in a submerged (buoyant) condition. An observation was made that the weight of the proposed 10-ft by 10-ft flap gate fit in between the weights of the 54 in- and 60 in-diameter conventional circular gates. The head loss for these two gates with free outfall for opening was approximately 0.07 feet and head loss at design flow is approximately 0.05 feet. The gate area was also considered; the area of the 60 in-diameter gate is 19.6 ft^2 as compared to 100 ft^2 for the proposed gate, providing a water force column area five times greater to act on the rectangular gate of the same weight as that of the circular gate. For conservatism a chamber was added to the proposed gate for adding foam pads to increase buoyancy and further reduce the submerged weight of the gate. By installing the additional buoyancy the gate's submerged weight could be adjusted to a point of floating. Considering these factors, the estimated 0.1 feet of head loss for the proposed flap gate was believed to be conservative. The structural designer of the gates submitted calculations, indicating a required head differential of 0.02 feet for opening the gate in submerged conditions.

Considering the regional importance of utilizing a low head loss flap gate for CWPPRA hydrologic restoration projects in coastal Louisiana it was decided that it would be prudent to prove the design performance of the lightweight gate with and without the added buoyancy.

Reclamation's Water Resources Research Laboratory responded to the NRCS modeling request with a proposal to study a single barrel and flap gate from the proposed structure at a 1 to 4 Froude-based scale.

Modeling

To address specific questions regarding the flap gate operation, a relatively large model scale is required. This allows careful modeling of the gate properties of weight and submerged weight as these are extremely important in simulating the operation of the gate. Froude scaling is typically used for modeling flow problems that are dominated by gravitational forces, i.e. free surface turbulent flows. The model is designed and operated to equalize the Froude number of the model and the prototype:

$$\left[\frac{V}{\sqrt{gL}}\right]_m = \left[\frac{V}{\sqrt{gL}}\right]_p \tag{1}$$

To satisfy geometric similitude, all length properties must scale with the model scale. Kinematic properties such as velocity and discharge are also quite important and scale as follows:

$$V_r = \left[\frac{L_r \gamma_r}{\rho_r}\right]^{1/2} \text{ and } Q_r = \left[L_r^{5/2}\left(\frac{\gamma_r}{\rho_r}\right)^{1/2}\right]$$

where the r subscript indicates the ratio of the model and prototype values, e.g.

$$V_r = \frac{V_p}{V_m}.$$

Since water is the fluid used in both the model and the prototype, as is the case with most physical models, the ratios γ_r and ρ_r above are each equal to 1, so the velocity will scale with the square root of the length ratio and the discharge will scale with the length ratio to the 5/2 power.

Much of the information that we hope to learn from the model depends on the flap gate properties themselves. The dry weight and submerged weight affect the force required to open the gate, the angle the gate will open to, and the head loss imposed by the gate. Based on the size of the prototype gate and the flow expected, we chose to model a single culvert and gate at a 1 to 4 scale. The single barrel and gate were placed in a flume with water supplied through our laboratory system, figure 1 and 2.

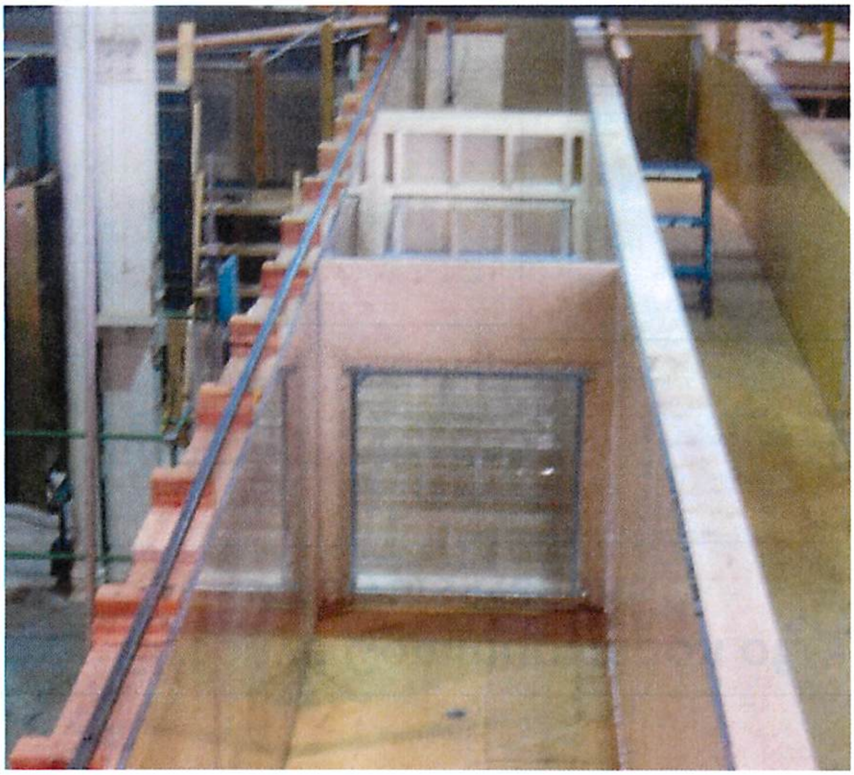

Figure 1: 1/4-scale sectional model of one - 10-ft by 10-ft box culvert.

a) entrance to culvert b) exit with flap gate in place

Figure 2: Entrance and exit of the 1:4 scale culvert model.

The sectional approach does present some difficulties in predicting the exact behavior of the full 10-barrel culvert structure. However, sectional modeling is a common practice and is especially valuable when the major interest is the very detailed performance of a small piece of the overall structure.

If we look at the dynamic properties, like mass and force, we quickly see that to simulate these properly we have a couple of options. The mass and force will scale as:

$$M_r = \left[L^3 \rho\right]_r \quad \text{and} \quad F_r = \left[L^3 \gamma\right]_r$$

Since water is the working fluid in the model and prototype, $\rho_r = 1$ and $\gamma_r = 1$, and the mass and forces associated with the water scale with $L_r^3 = 64$. To obtain appropriate model performance, the mass and force ratios for the gate should be the same as those of the water.

If you use the same material to construct the model and prototype gates, then the gate volume scale must be, L_r^3, or 64. For the Black Bayou flap gate, it is a lightweight aluminum structure – so each member would have to be reduced by 4 times in length, width, and thickness. This was found to be prohibitive from a model construction standpoint as many of the resulting gate members were only 1/16-in thick. The overall size of the gate needs to be geometrically scaled; however, to overcome the construction problem, the thickness of the members could be altered (thickened), thus changing the gate volume and weight. To compensate, a different (lighter) material could be used, resulting in a different density ratio, but maintaining the correct mass and force ratios.

To complicate matters, we would like to have identical mass and force ratios in both dry and submerged conditions, but this is impossible unless the working fluid for the model also is changed (i.e. has a different density). We could obtain a desired density ration in the dry that compensates for the overthickened members, but when submerged, the density ration would be different. We must make a choice. Since the majority of the testing of interest is concerned with the gate in submerged operation, we choose to adjust the submerged density ratio and the difference in volume caused by thicker members to produce the correctly scaled submerged weight of the gate.

We constructed the gate model from acrylic with increased member thicknesses, resulting in a greater volume of material in the gate (a reduction of only 14.95 times instead of 64). The dry density ratio between the prototype and model was 1.93 (ratio of aluminum to acrylic). This approach yielded a heavier scaled gate in dry conditions, but the submerged (buoyant) weight of the gate was less than 1 percent different from the expected scaled submerged weight. We verified submerged weight by submersing the model gate in a tank and weighing. The increased weight of the thickened members is spread uniformly so as not to affect the center-of-gravity of the model gate and the resulting forces required to reach equilibrium gate operation for a given flow condition. The Styrofoam inserts were reduced slightly in thickness, and no cover plates were used.

In addition, the operation of the flap gate is affected by the hinge mechanism and any possible friction associated with the opening or closing of the gate. We did not attempt to model this friction but used a nylon bushing/bearing in order to keep friction forces at a minimum.

Flows to the model were provided and measured by our laboratory system. The flow measurement is with calibrated venturi meters. Heads were measured upstream and downstream from the culvert entrance and exit using a piezometer tap and stilling well. A point gage was used to measure the stilling well elevation and could be read to the nearest 0.0005 ft (model). The point gages were referenced to the culvert invert using standard surveying equipment. Tailwater was controlled using an adjustable gate.

Results

Throughout the report, dimensions are given in prototype units unless specifically indicated. The test program for the Black Bayou Culvert model was designed, to determine:

- Head differential required to open the gate
- Head differential require to close and seat the gate
- Head loss imposed by the gate over the largest range of head conditions practical
- The angle of projection of the gate for the head conditions tested
- Discharge capacity over the entire head range
- Optimum gate buoyancy to allow the gate to barely close
- The differential in the items above for the gate with and without added buoyancy.

This basic list was followed within the constraints of the model.

The head required to open the gate to flow was extremely small. Even with no submergence (i.e. no reduced gate weight) a head of only 0.042 ft was required to permit flow through the culvert. With the gate completely submerged, this head requirement reduced to 0.012 ft. With the addition of 2 Styrofoam inserts (1 ft^3/insert) this reduced to 0.008 ft and with 4 Styrofoam inserts the head required was only 0.005 ft.

The head required to close and seat the gate was difficult to measure. Due to the design of the model, a consistent flow supply to the channel downstream from the flap gate was not available. We attempted to use portable means to pump water into the downstream channel but were unable to produce consistent and repeatable results for the seating head required. With no added buoyancy, it appeared that the seating head was similar to the head to initiate flow in the opposite direction. However with Styrofoam inserts added to the gate, especially with 4 inserts added, it was difficult to overcome the buoyancy to cause the gate to close. When totally submerged and with 4 inserts added, the gate essentially rises to 90-degrees, so even with substantial reverse flow through the conduit, we could not generate enough head to consistently close the flap gate.

Head loss imposed by the gate was not measured directly. The head loss through the entire culvert including the gate was measured and then the gate loss alone was computed by subtracting analytically estimated values of other losses in the system. We ran two basic cases, the culvert exit just submerged (elevation +1 ft) and with a head of 2.1 ft above the culvert crown (maximum condition). We ran a variety of flows for these head conditions and also tested with no additional buoyancy, 2 inserts, and 4 inserts added. Total head loss through the culvert system is shown on figure 3 for the case of just submerged, and figure 4 for the case of 2 ft of head over the culvert crown.

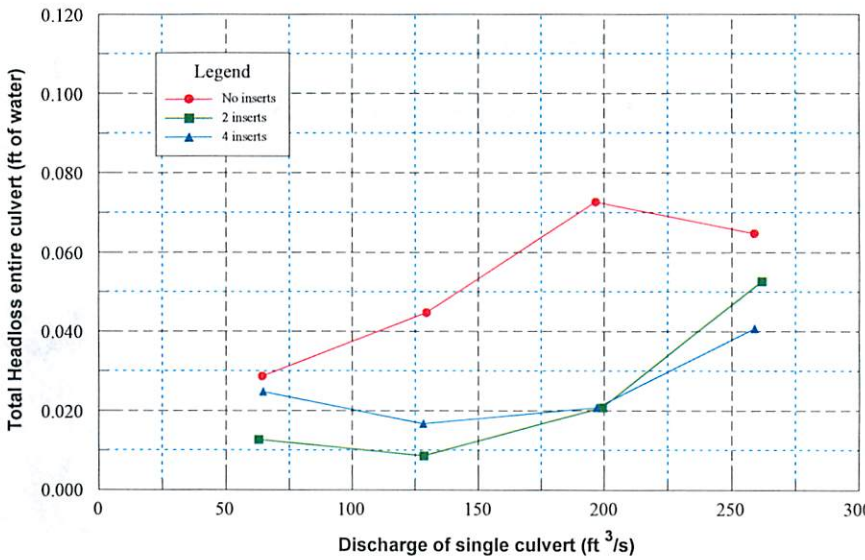

Figure 3: Total head loss through single barrel of culvert, exit of culvert just submerged.

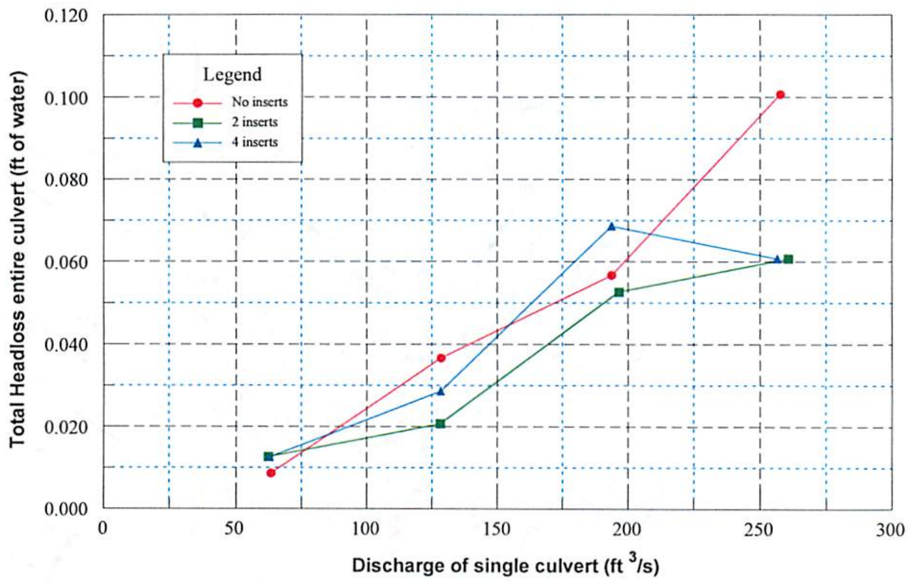

Figure 4: Total head loss through single barrel of culvert, 2 ft of head on culvert crown.

The projected angle of the gate was mechanically measured through the side window of the flume. The gate angle was very stable for a given condition and is shown on figure 5.

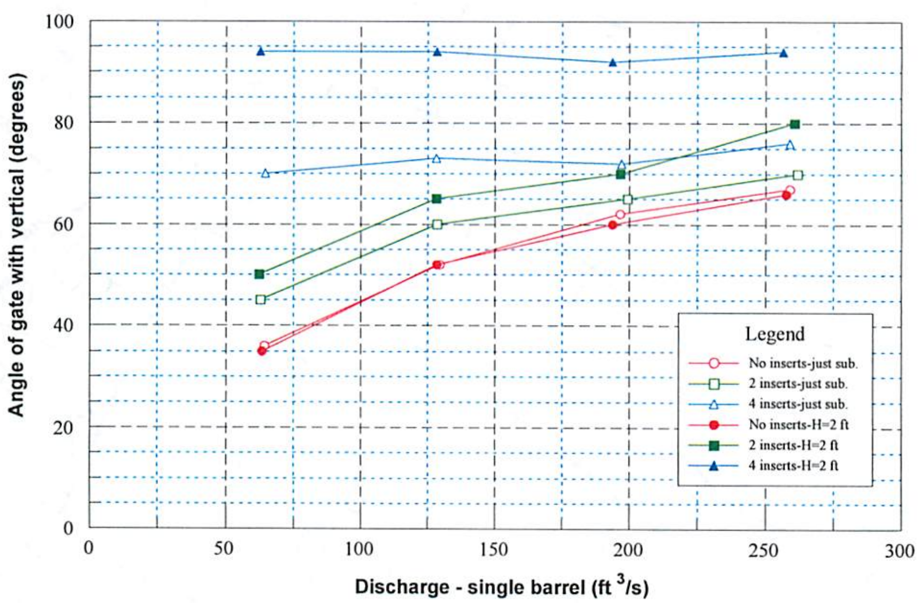

Figure 5: Angle of gate projection versus discharge for 2 different head conditions.

A true discharge capacity curve was not generated due to the lack of tailwater information. We ran each series of tests in a slightly different manner; with one we kept the tailwater elevation constant and varied the discharge, with the other we kept the upstream head constant and varied the discharge. The only data set that followed a typical form of $Q=CH^{1/2}$ is the maximum submergence case, with the gate having no added buoyancy, figure 6. The remaining data that were collected follow various trends, but do not correlate with the fit shown in figure 6.

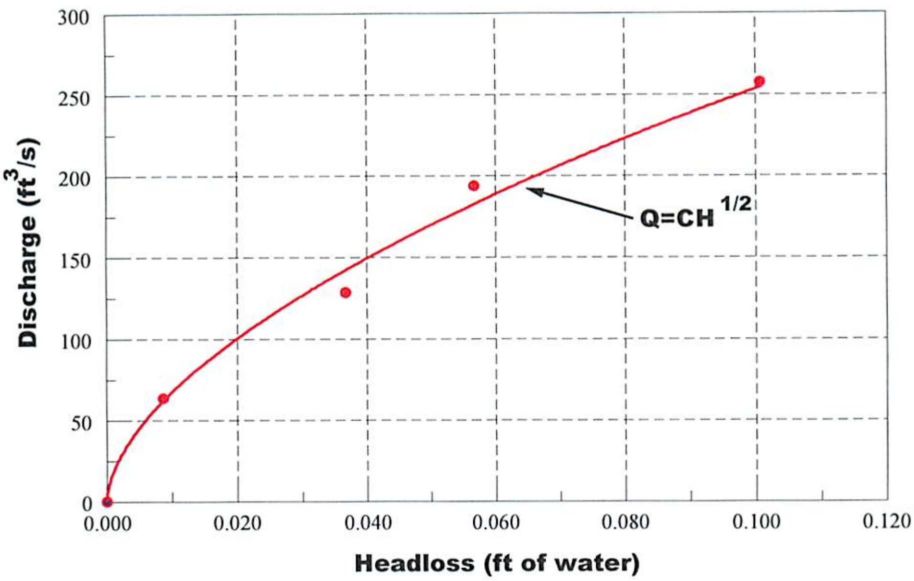

Figure 6: Discharge curve for no added buoyancy and maximum submergence.

Discussion

The modeling and analysis of the Black Bayou Culvert flap gates has offered a number of challenges including correctly modeling the geometric, kinematic and dynamic properties of the flow and associated gate performance. Ideally, the model should be constructed from the same material as the prototype and simply have the member sizes reduced by four times. This results in a volume reduction of 64 times. Unfortunately due to the lightweight construction of the prototype gate, a model following this plan would not be constructible by normal methods. This methodology would have provided a properly scaled dry weight, plus the correct submerged weight (dry weight – displaced weight of water). To overcome the construction challenge, we adjusted both the material density (using acrylic versus aluminum) and the thickness of several of the gate members. These adjustments resulted in a heavier model gate in the dry, but the submerged weight was within 1 percent of the desired submerged weight.

These differences had some effect on the gate performance for the cases where the gate was not entirely submerged. Depending on the downstream water level and the angle of the gate during operation, a model gate that was heavier than an ideally scaled model gate resulted, figure 7. The increase in gate weight with gate angle reflects that only a portion of the gate is submerged. Since the gate was heavier, this would tend to increase the head loss and head required to open the gate, and reduce the head needed to seal the gate.

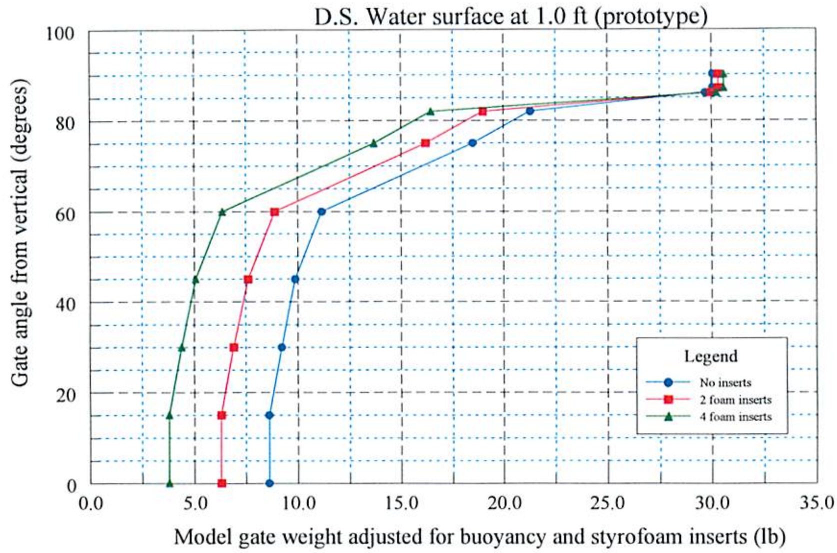

Figure 7: Effect of gate angle and resulting submergence on adjusted gate weight.

Figure 8 shows a photo of the model gate in operation with the end of the culvert submerged, but a portion of the gate itself is not submerged.

Figure 8: View showing part of gate above the water surface.

Figure 9 shows that when the water depths are great enough to totally submerge the gate through its entire range of movement, the adjusted weights remain constant and are correctly scaled.

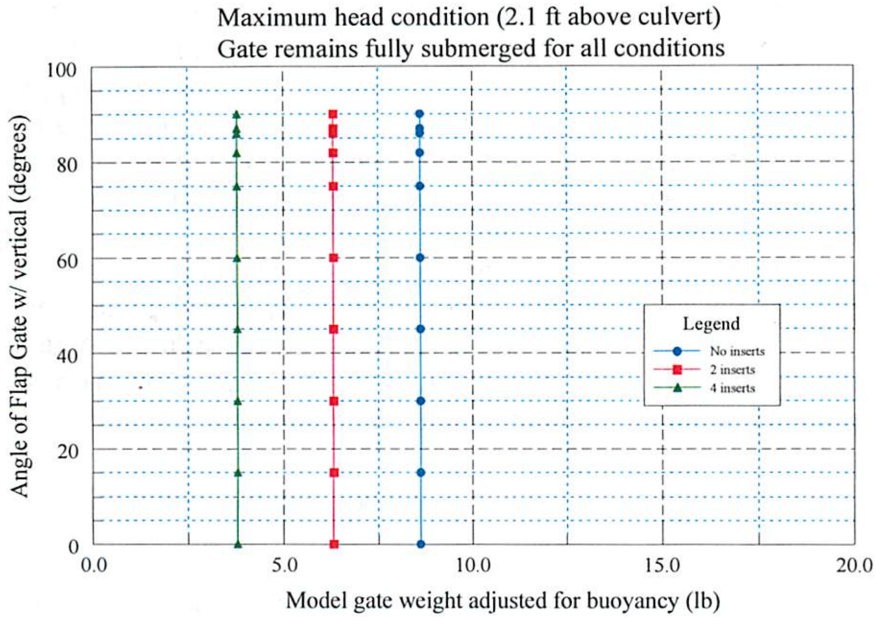

Figure 9: Effect of gate angle on adjusted weight when gate is totally submerged.

Figure 10 shows the gate operating fully submerged.

Figure 10: Model gate in operation, fully submerged.

A review of the literature on flap gate performance provided some insight into flap gate performance and design. Some of the first information was from studies performed at the State University of Iowa in 1936, where a series of tests determined the head loss through Armco-Calco flap gates (currently offered as model 10C gate by HydroGate). These gates were circular and all supplied through commercial stock. These values were extrapolated and interpolated by the Soil Conservation Service (now the Natural Resources Conservation Service) in one of their Engineering Handbook Series as design guidelines (SCS 1973). Qualitative head loss information was published by Armco (1978) for gates they manufactured, but was primarily based on the original Iowa studies.

Pethick and Harrison (1981) presented a theoretical treatment of rectangular flap gates. Burrows and Emmonds (1988) argued that the Iowa tests might be somewhat limited because they had been performed on "lightweight" gates and Armco suggested that "heavy" gates may cause more head loss than the values reported in the study. Unfortunately the distinction between "light" and "heavy" has never been definite.

Burrows et al. (1997) have recently reported on a study designed to estimate flow rates based on flap gate opening. Their most consistent data were for the free discharge case with no submergence. They did not detail the effects of submergence or how that affected head loss. Replogle and Wahlin (2003), while working to compare results of head loss for pinned hinges versus a flexible rubber hinge, provided updated design material for pin-hinged gates.

The submerged case for the flap gate is difficult to analyze theoretically, and there is very limited information in the literature for these conditions. Figure 11 shows the total system loss presented as the ratio of the loss compared to the velocity head. Looking at the dimensionless head loss ratio we can see that there is not strong correlation with gate angle for these light weight gates, especially with all four Styrofoam inserts in place. There is a weak indication that the heavier gate (no inserts) has higher head loss for the same gate angle than the gate with 2 inserts installed, figure 11.

We set up the model to measure head drop across the entire culvert section including the flap gate since we anticipated extremely small differentials in the prototype and measuring something 4 times smaller in the model could lead to measurement uncertainties as large as the head loss itself. When calculating the loss due to the gate alone, a trend of head loss being inversely proportional to discharge was revealed; however the losses associated with the conduit structure dominate the total head loss.

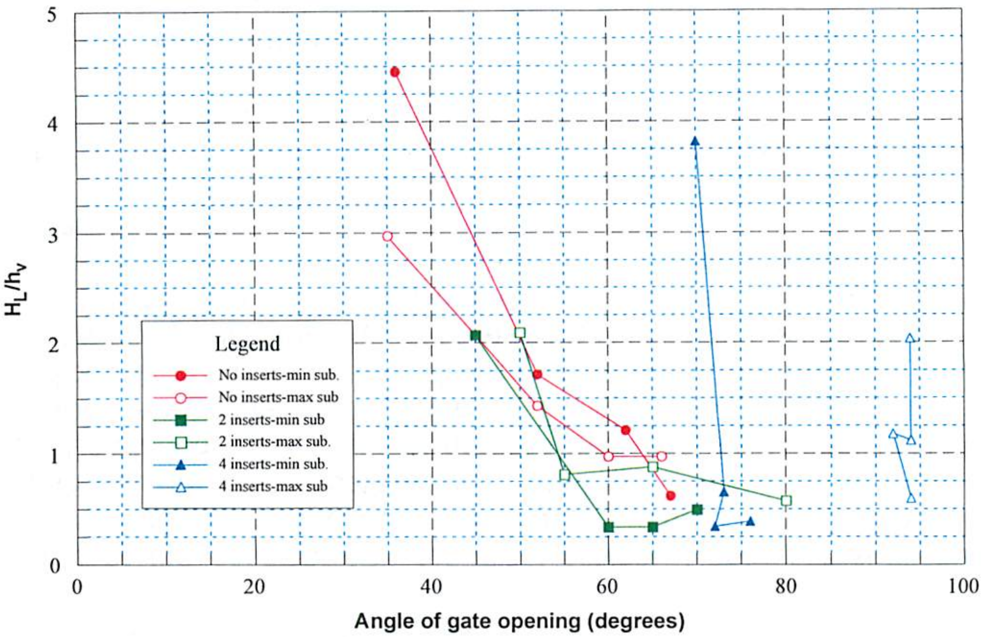

Figure 11: Dimensionless head loss versus projected angle of flap gate.

Analyzing the data in a similar manner to Burrows and Emmonds (1988), we can plot a dimensionless group made up of gate weight, diameter, fluid density and discharge versus angle of the gate opening, figure 12. We used an effective diameter in this ratio (i.e. $\pi D^2/4 = 100\,ft^2$). The data from the current study plots above data from previous studies as noted in the legend. There are many factors that appear to contribute to this; the amount of submergence, the submerged weight of the gate as the gate angle increses, and as Replogle and Wahlin (2003) showed, the relative length of the gate pivot arms. It appears that the gate modeled for Black Bayou is very large relative to its design discharge compared to the gates appearing in the previous literature.

Submergence of the Black Bayou flap gates will make them extremely light weight in the prototype. This is a good thing where head losses are concerned but can be a problem in closing the gate and reseating. Fortunately, we were able to close and seat the model gate, although now when all 4 buoyancy inserts were installed. Field adjustments will be needed, but the gate design that is being installed appears to offer all the flexibility that the site may need.

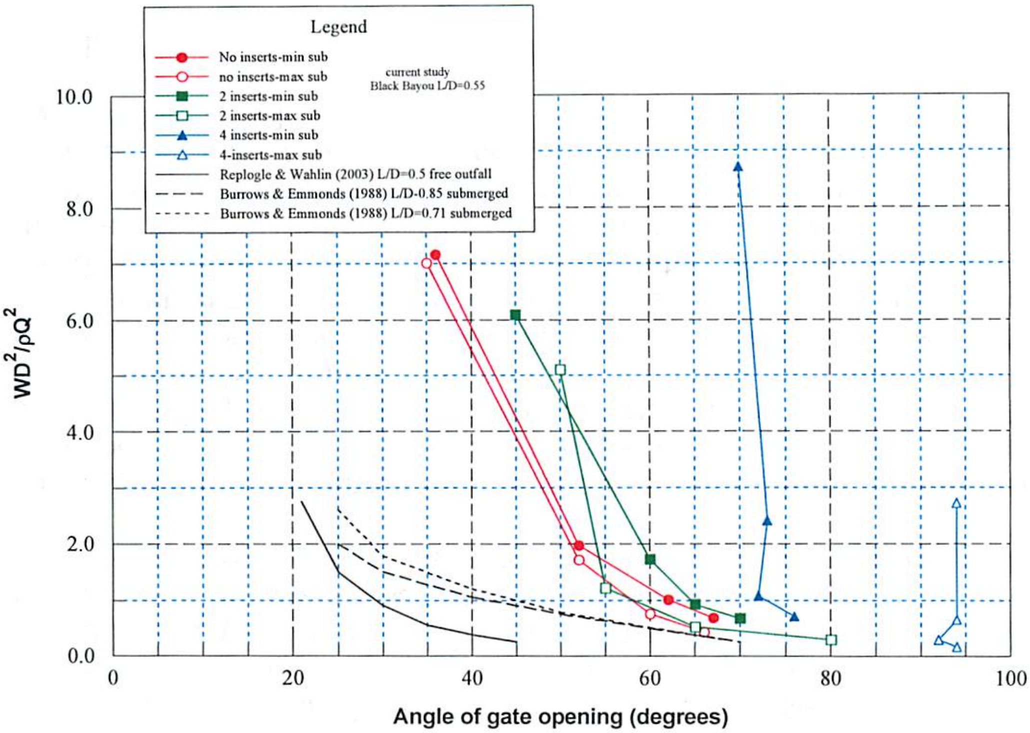

Figure 12: Gate weight (W), diameter (D), and discharge (Q), related to gate angle.

References

Armco. 1978. *Handbook of Drainage and Construction Products*. Armco Drainage & Metal Products, Inc. (Out of print, summary of Iowa results is available at: www.hydrogate.com).

Burrows, R., G.A. Ockleston, and K.H.M. Ali. 1997. Flow estimation from flap-gate monitoring. *J. Chartered Institution of Water and Environmental Management* (U.K.) 11(5): 346-356.

Burrows, R., and J. Emmonds. 1988. Energy head implications of the installation of circular flap gates on drainage outfalls. *J. Hydraulic Research* 26(2): 131-142.

Pethick, R.W., and A.J.M. Harrison. 1981. The theoretical treatment of the hydraulics of rectangular flap gates. Subject B(C), Paper No. 12 in *Proc. IAHR XIX Congress*, 247-254. Madrid, Spain: International Association of Hydraulic Research.

Replogle, J.A., and B.T. Wahlin. 2003. Head Loss Characteristics of Flap Gates at the Ends of Drain Pipes. *Transactions of the ASAE* 46(4): 1077-1084.

SCS. 1973. *Drainage of Agricultural Lands*. Published by Water Information Center, Inc. (Reformatted and reprinted from Section 16, Drainage of agricultural land, in the *National Engineering Handbook* issued in 1971 by the USDA Soil Conservation Service.)