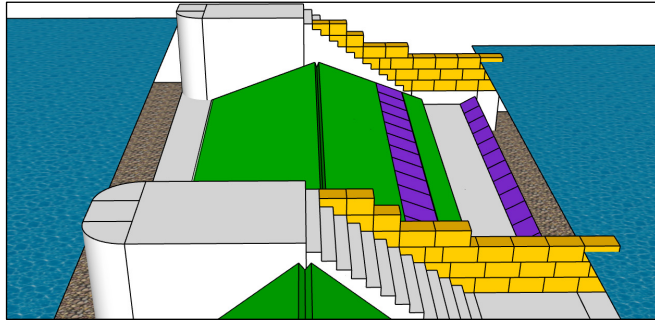
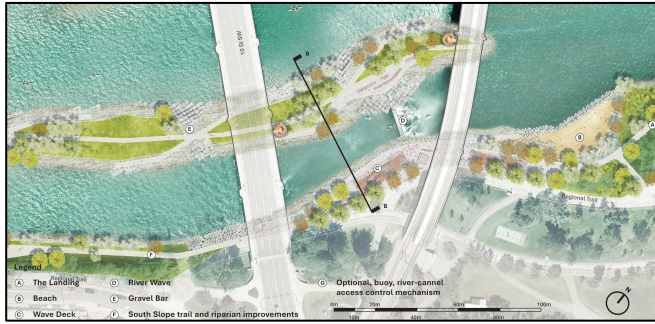




Additional details for adjustable wave design – Calgary River Wave Park

**Calgary
Alberta**

Sep 4, 2024

**Updated
August 17, 2025**

Presented by

SURF 
A N Y W H E R E

This document provides additional details regarding the recommended design and construction costs for the adjustable river wave in the Calgary River Wave Park. This document is in addition to the “Preliminary Wave Design for the 10th Street Gravel Management Project” report and the “10th Street Recreational Wave Viability Report”.

This design will allow a 6 to 10 year economic return on investment for the entire 10th Street Gravel Bar project and conservatively generate \$2M to \$4M in new economic activity. Please contact Neil Egsgard of Surf Anywhere with questions.

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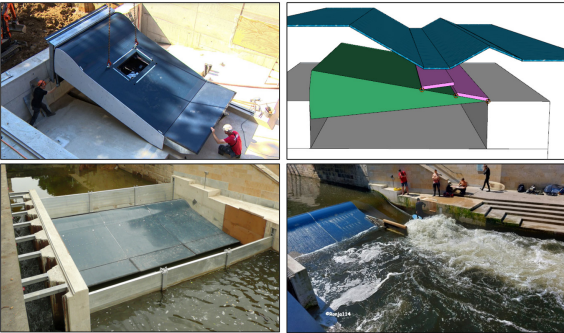
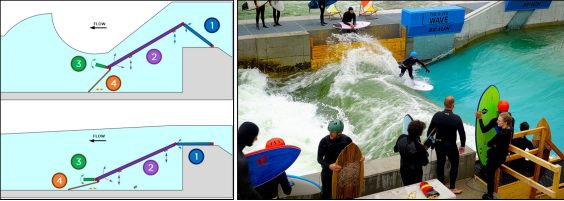
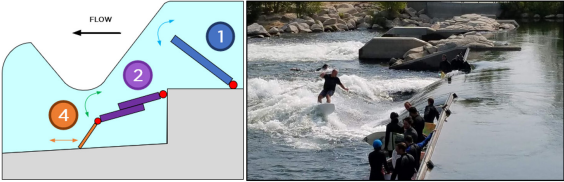
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1 Wave structure selection

The recommended adjustable wave structure solution is a flap gate with downstream slope modified to have kickers on the downslope and foundation and adjustable side walls. The City of Calgary required the adjustable wave to be based on a proven solution and must be able to lower to be flat against the riverbed. Over 30+ manufactured and adjustable river waves were reviewed. Four existing designs were considered that met the City of Calgary requirements. All adjustable wave structures are custom builds due to the unique nature of every river wave location.

Wave type	Existing solution	Reasons for selection or rejection
Flap gate with downstream slope	Ex. Boise, USA, and Epinal, France Will be modified to have pneumatic kickers on downslope and foundation, and adjustable walls as per top left. 	- Proven technology in wild rivers with sediment transport over many years. - Structure movement is by Obermeyer gates which have been approved for SR-1 Springbank Offstream Reservoir. - Makes very good river waves which will drive spectacle and project returns. - Able to raise and repair gates in case of failure of lifting mechanism. - Pneumatic bladder fills most of void understructure making sediment removal easier. - Simple design.
Rotating Ramp	Ex. Leinewelle, Hanover, Deutschland 	- Never used in wild rivers, only in concrete canals. - Higher cost due to hydraulic cylinders. - Higher cost due to fabrication in Europe and transport to Canada. - Sediment removal is currently challenging.
Lifting ramp	Ex. The.RiverWave, Ebensee, Austria 	- Higher cost due to hydraulic cylinders. - Need to lift the entire structure. - Sediment removal is challenging due to large void under structure.
Flap gate with no slope	Ex. Boise Phase I, Idaho, USA 	Lowest quality of wave reducing value of spectacle and value of project returns.

1.1 Waves reviewed for the design

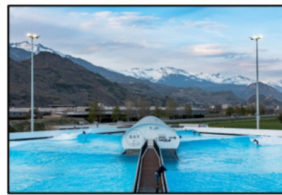
Below are some of the 30+ manufactured and adjustable waves reviewed.



Dauerwelle, DE (2022)



Nottingham, UK (2022)



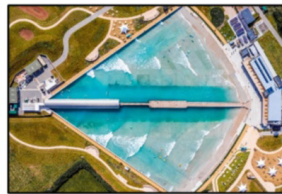
Alaia Bay, CH (2021)



Lake Chelan, US (2022)



Ebensee, AU (2020)



Wavegarden, UK (2021)



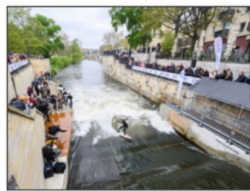
Kananaskis, CA (2019)



Columbus, US (2020)



Vail, US (2022)



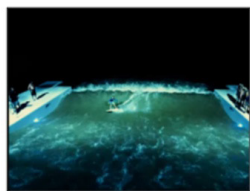
Leinewelle, DE (2023)



Scout wave, US (2023)



The LineUp, US (2023)



Southern Shores, US (2023)



Dauerwelle, DE (2022)



Vlny Stvanice, CZ (2022)



Lake Chelan, US (2021)



Annecy wave, FR (2021)



Donsurf, RU (2020)



The River.Wave, AT (2020)



Boise Phase 2, US (2020)



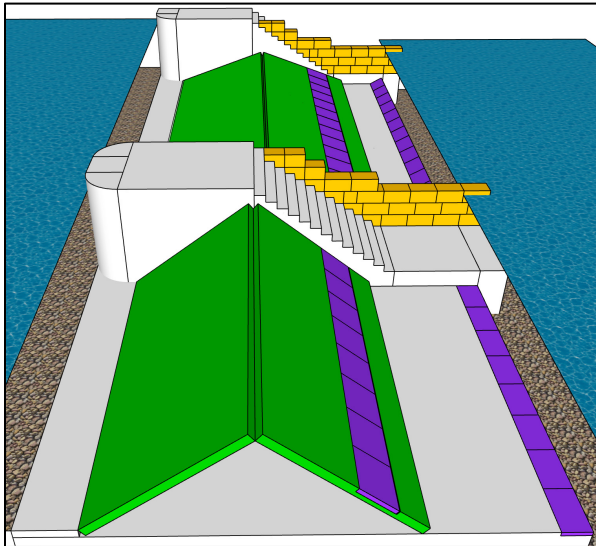
Unit Surf Pool, DE (2018)

2 Recommended design: Flap gate with downstream slope

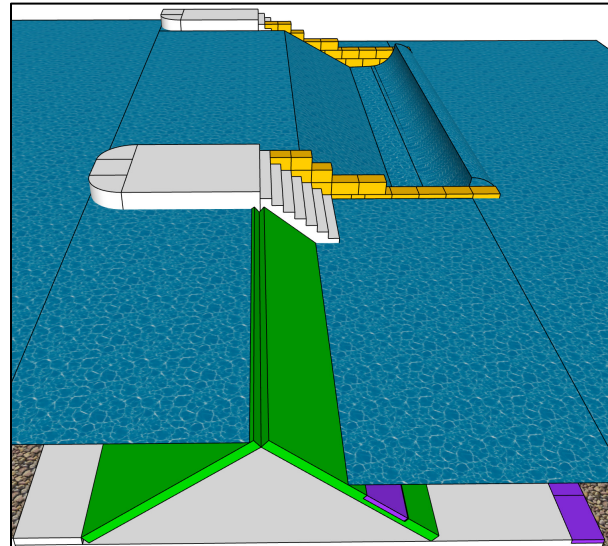
This design is a combination of existing waves technologies. The key design components are:

- Wave berm with adjustable wave channels
 - A concrete berm with two concrete adjustable wave channels.
 - The berm is 30m wide and spans the south channel.
 - The adjustable wave channels are 8m wide and 14m wide.
 - Each adjustable wave channel contains an adjustable wave structure.
- Adjustable headwater gate and slope in green with pneumatic adjustment.
 - Controls headwater elevation, creates drop, and sets slope angle.
 - Prevents flow over part of channel to keep wave quality in low flow conditions and to make maintenance easier.
 - Continuous across channel.
- Adjustable kickers in purple with pneumatic adjustment.
 - Redirects the flow to form a wave. Allows for waves to form at widely different tailwater elevations. Prevents retentive hydraulic formation.
 - Multiple sections across slope. Allows different wave types.
- Adjustable walls in yellow with manual adjustment.
 - Allow control of wave shape and control of access to the wave over the 1.5m range of tailwater elevations.
- Tailwater control
 - Maintains tailwater levels necessary for good wave formation.
 - Boulders imbedded in the riverbed downstream of the wave berm.

Regular flow surf configuration – 142 m³/s
14m gate active, 8m gate closed. Lower tailwater so foundation kickers are active. Structure shown.

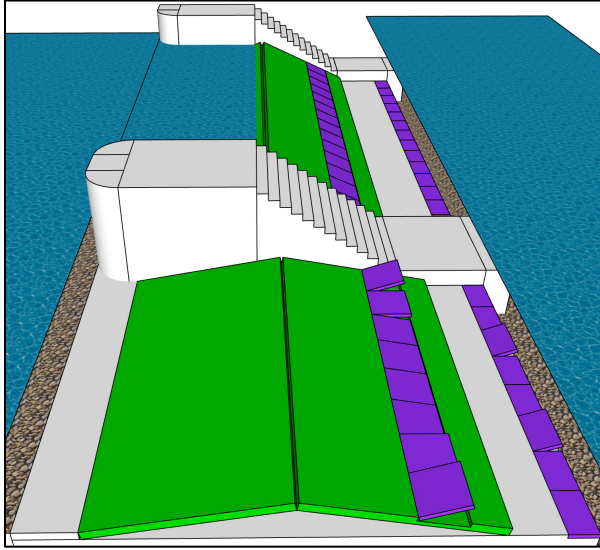


Regular flow surf configuration – 142 m³/s
14m gate active, 8m gate closed. Lower tailwater so foundation kickers are active. Water shown.



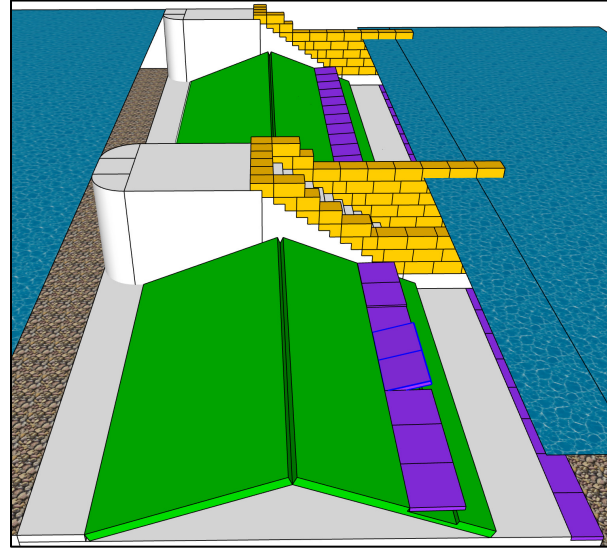
Low flow kayak configuration – 33 m³/s

8m gate open, 14m gate closed. Lower tailwater so foundation kickers are active.



High flow surf & kayak configuration – 280 m³/s

14m gate and 8m gate active. Lower tailwater so slope kickers are active.



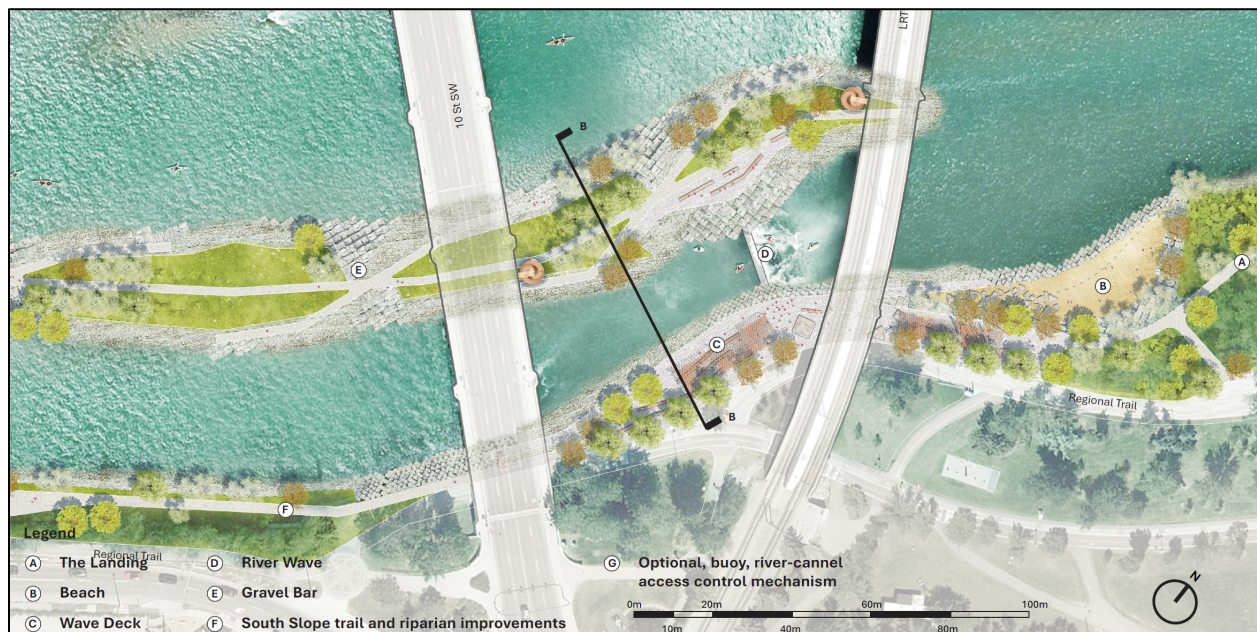
3 Increasing River Safety

The adjustable wave design increases river safety and minimizes safety risks through several mechanisms.

- Increased number of onsite skilled river users due to good waves. As shown at Harvie Passage, onsite skilled river users respond to incidents in seconds preventing accidents and reducing the severity.
- Wave disappears during undesired times like night and during high flows. The wave structure can flatten to the riverbed. In case of pneumatic system failure, the gates will lower flat preventing flood risk.
- Removing flow in case of in-river emergency. The wave structures can be fully raised to block flow through either or both channels.
- Reduction in impact risk by having deeper water over the wave structure. Blocking a single channel puts more flow through the open channel which deepens the water over the structure and reduces impacts risks.
- Prevention of retentive hydraulics at high tailwater elevations. Using the higher elevation row of kickers prevents the formation of retentive hydraulics at higher tailwater levels.
- Elimination of entrapments risks by using rubber seals at the intersection of a moving surface with another surface.

4 Project site

The concept images below are from the Preliminary Design project and show the project location.



5 Channel configuration

The adjustable wave structure consists of two channels, one 14m wide and one 8m wide, and a 3m wide pier between the channels. These adjustable wave structures channel dimensions were included in the physical and computer flood modelling. This configuration has the following benefits:

- Increased water velocities which helps prevent deposition on the structure during high flow events.
- Lower water elevations during a 1:100 year flood.
- Ideal flow intensities for high value wave formation across all design flows.

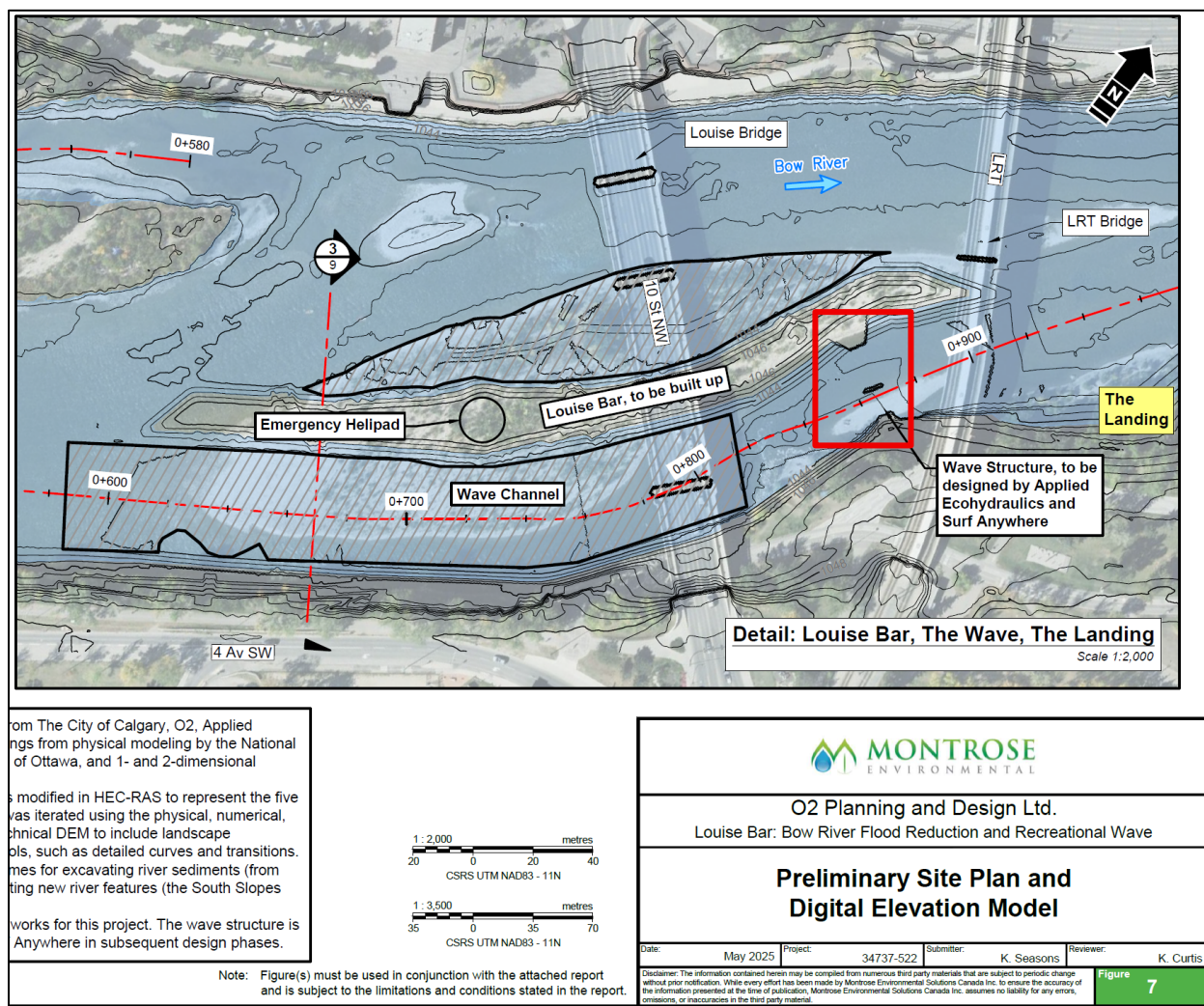


Figure 1: Adjustable wave structure channels and pier in the Site Plan and Digital Elevation Model.¹

¹ (Preliminary Hydrotechnical Design Report Bow River Louise Bar: Flood Reduction and Recreational Wave, 2025)

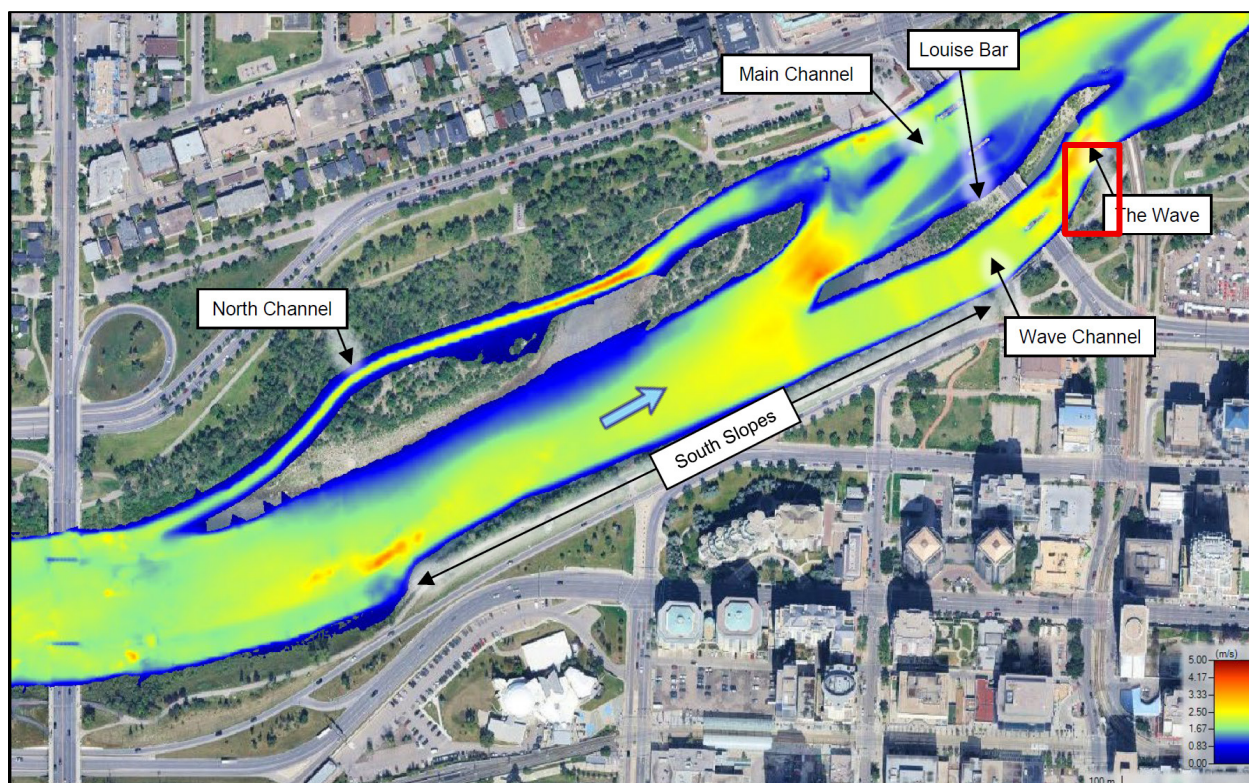


Figure 2: Modelled Velocities at Safe Boating Advisory Flow ($280 \text{ m}^3/\text{s}$).²

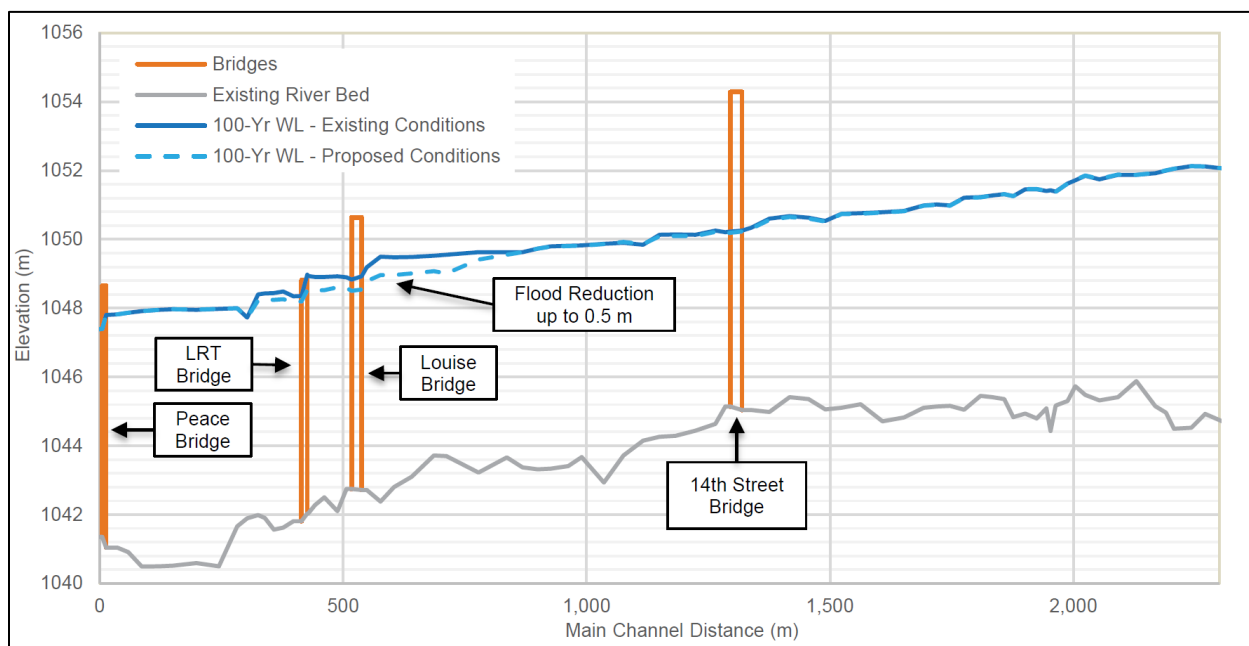


Figure 3: Reduced water level at wave structure during 1:100 year flood.³

² (Preliminary Hydrotechnical Design Report Bow River Louise Bar: Flood Reduction and Recreational Wave, 2025)

³ (Preliminary Hydrotechnical Design Report Bow River Louise Bar: Flood Reduction and Recreational Wave, 2025)

6 Flow split between channels

The adjusted gravel bar will result in about a 30-70 flow split between the south and north channel. The wave in the south channel will receive between 35% to 45% of the flow from 50 m³/s to 280 m³/s.⁴ The reasons for this split are:

6.1 Similar to existing and historical conditions

The 30-70 split is similar to existing conditions and historical conditions.



Figure 4: Louise Bridge 1926.



Figure 5: Louise Bridge 2019.

6.2 Stability of new configuration

Physical and computer modelling with the National Hydrology Research Center showed the split would be stable through major flood events.

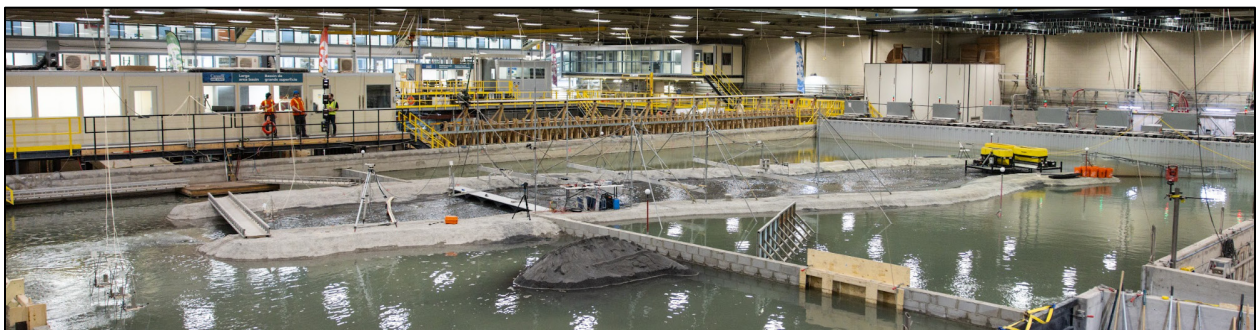


Figure 6: National Hydrology Research Center physical model.

6.3 Ideal flow intensity over the wave

The 30% flow split through the wave channel allows the wave to function over the entire operating flow range. The flow intensity breakdown is detailed in the next section.

6.4 Boat and fish passage

Maintains 70% flow through unobstructed passage of the river for people and fish moving up and down the river.

⁴ (Preliminary Hydrotechnical Design Report Bow River Louise Bar: Flood Reduction and Recreational Wave, 2025)

7 Flow intensity

Flow intensity is the volume of water per second per meter of width that goes through the adjustable wave channels. The ideal flow intensity for a river wave is between 2 to 7 m³/s per meter of width based on observations of 30+ manufactured river waves around the world.

7.1 Examples of flow intensity and wave quality

The below images are from the Scout Wave in Salida, Colorado, in 2024⁵. The pictures show the impact of flow intensity on wave quality. As flow intensity increases, the wave quality increases. Scout wave is static so no part of the structure moves and only one type of wave is possible at any flow. The Calgary wave will be adjustable to allow for a variety of waves at any flow. The flow intensities are based on the full river flow. The Salida wave has a fish passage and berms are designed to have water flowing over them. Since flow is able to bypass the wave at higher flows, flow intensities on the wave are lower then shown at the higher full river flow levels.

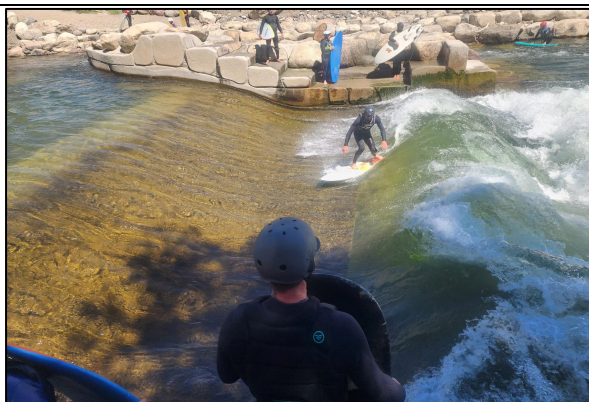


Figure 7: 10m wave at 1.2 m³/s per m. 12 m³/s total flow. Salida on Sep 2, 2024.



Figure 8: 10m at 2.1 m³/s per m. 21 m³/s. total flow. Salida on Aug 10, 2024.



Figure 9: 10m at 3.6 m³/s per m. 36 m³/s total flow. Salida on Jul 7, 2024.



Figure 10: 10m wave at 7 m³/s per m. 70 m³/s total flow. Salida on Jun 25, 2024.

⁵ (Colorado River Surfers, 2025)

7.2 Flow intensity and adjustable wave quality

The image below shows the adjustable wave channel layout and the table shows the flow intensities and wave qualities at different total river flows.



Figure 11: Adjustable wave structure channel and pier layout.

Green is excellent wave quality and yellow indicates good wave quality. Flow split data from preliminary design HEC-RAS modelling.

% of time flow exceeded from April to Oct	Total River Flow (m ³ /s)	Gate Crest Elev (m)	Surf channel flow (m ³ /s)	Wave width (m)	Channel 1	Channel 2	Channel 1 + 2
					8	14	22
				% of flow in surf channel	Flow intensity (m ³ /s)/m	Flow intensity (m ³ /s)/m	Flow intensity (m ³ /s)/m
100%	33	1043.75	16.9	51%	2.1	1.2	0.8
95%	50	1043.75	22.4	45%	2.8	1.6	1.0
80%	60 ⁶	1043.75	21.6	36%	2.7	1.5	1.0
70%	70 ¹	1043.75	25.2	36%	3.2	1.8	1.1
60%	75 ¹	1043.75	27	36%	3.4	1.9	1.2
40%	100 ¹	1043.75	36	36%	4.5	2.6	1.6
38%	115	1043.75	41	36%	5.1	2.9	1.9
23%	142	1043.75	48.4	34%	6.1	3.5	2.2
12%	180	1043.75	57.6	32%	7.2	4.1	2.6
7%	230 ¹	1043.75	71.3	31%	8.9	5.1	3.2
4%	280	1043.75	82.6	30%	10.3	5.9	3.8

Figure 12: Flow intensity and wave quality.

⁶ Extrapolated total river flow.

8 Actuation technology

The slope gate and the kickers are actuated by pneumatic bladders. This technology is proven to work in rivers with high sediment load like the Bow. Pneumatic flap gates are being used on the Springbank Off-stream Reservoir (SR-1) to divert Elbow River flood waters into the reservoir during 1:100 year flood events. If the pneumatic system fails, the gates collapse to flat.

8.1 Pneumatic gates in Springbank Off Stream Reservoir

Pneumatic gates are part of the Springbank Off Stream Reservoir and used to divert flood waters into the Off Stream Reservoir. Each gate is 5m high and 24m wide.



Figure 13: 5m high pneumatic flap gates as part of the Springbank Off Stream Reservoir.⁷

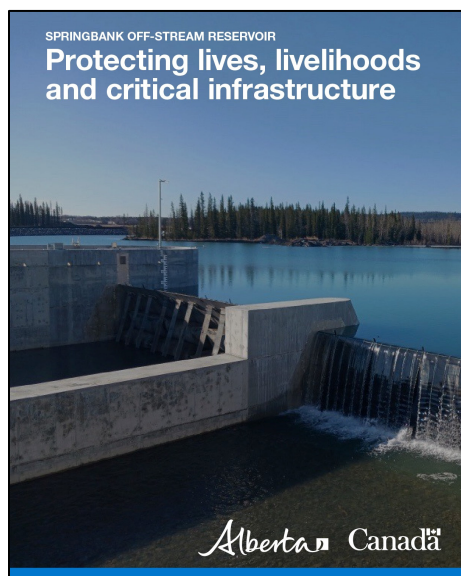


Figure 14: Alberta Government release about SR-1. 2025.



Figure 15: [NRCC: Physical Model Study of the Springbank Off-Stream Reservoir.](#)

⁷ (Springbank off-stream reservoir now in operation, 2025)

⁹ (Springbank Dam Project Tender, 2021)

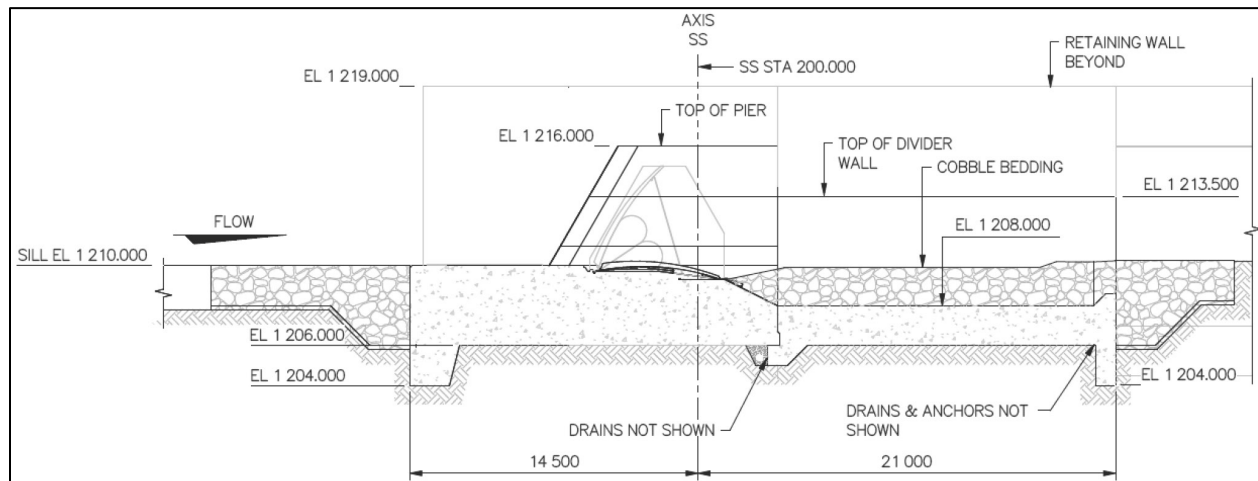


Figure 16: Profile of 5m high pneumatic gates.⁸

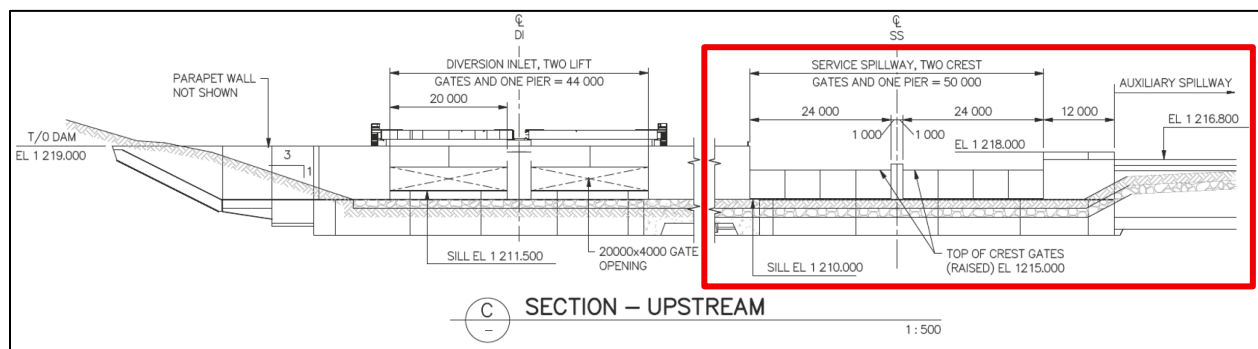


Figure 17: Cross section of the 5m high and 24m wide pneumatic gates from public Springbank Off-stream Reservoir drawings.⁹

8.2 Pneumatic kickers in Bend, USA

The river wave in Bend, Oregon, USA, uses pneumatic kickers to shape the river wave.



Figure 18: Pneumatic kickers creating a good river wave in Bend, Oregon, USA.



Figure 19: Installation of the pneumatic kickers in Bend, USA.

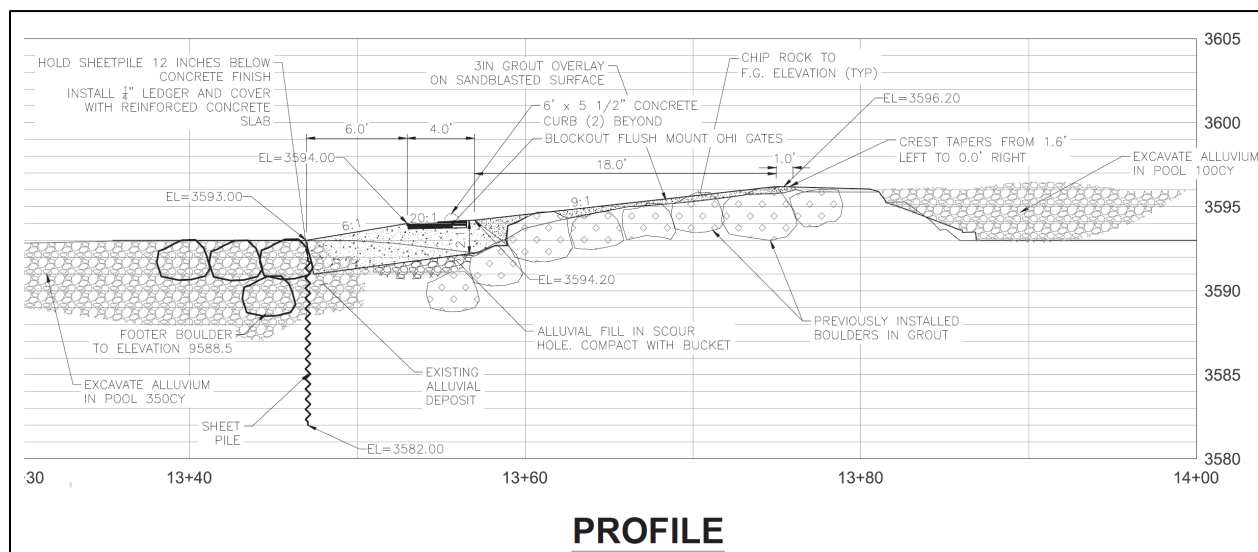
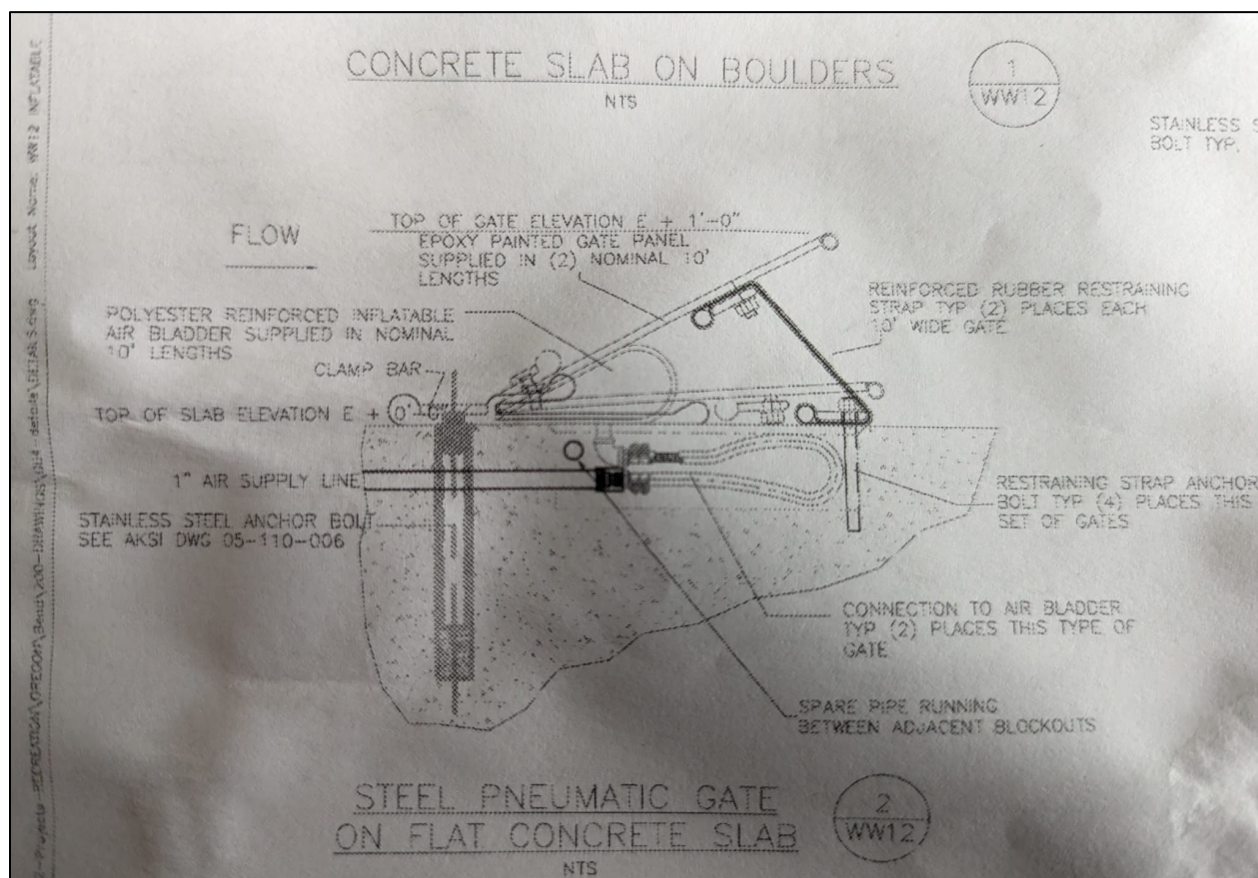


Figure 20: Profiles of the Bend, Oregon, adjustable wave from public drawings.¹⁰

¹⁰ (Bend Parks & Recreation District, 2016)

8.3 Examples of pneumatic gates

The images below show different installations and examples of pneumatic flap gates.



Figure 21: Example Obermeyer pneumatic gate not installed.



Figure 22: 1.5m high Obermeyer pneumatic gate installed.

9 Headwater flap gate with slope

The adjustable wave structure uses headwater flap gates with a downstream slope. These gates can close either wave channel at flows up to $280 \text{ m}^3/\text{s}$ and will collapse into the foundation so there is no increase in flood risk during high flow events. To close the channels at $280 \text{ m}^3/\text{s}$, the adjustable wave structures need to have a peak elevation of 3.1m above the foundation. The Springbank Offstream Reservoir uses similar gates with a peak elevation of 5m above the foundation¹¹. If the pneumatic system fails, the gates collapse to flat.



Figure 23: Boise, USA, flap gate with downslope blocking flow and making wave



Figure 24: Epinal, France, flap gate with downslope lowered.



Figure 25: Epinal, France, raised flap gate with downslope making a wave.

¹¹ 8.1 Pneumatic gates in Springbank Off Stream Reservoir

9.1 Examples of existing wave technologies for flap gate slope

Boise, Idaho, USA. Phase 2 surf wave.

Consists of:

- Concrete channel walls and floor.
- Continuous 10m flap gate with downstream slope that is raised by one Obermeyer bladder.
- Bolt on side walls to extend the channel walls.
- Bolt on kickers to shape the wave.

Key points:

- Continuous flap gate with down slope generates water velocity and conditions needed for surf wave.



Figure 26: Boise Phase 2 flap gate with downslope forming a wave.

Epinal, France

Consists of:

- Adjustable flap gate with downslope
- Concave concrete transition to sharp drop
- Concrete side walls
- Tailwater elevation control via manually adjustable constriction downstream

Key points:

- Flap gate upstream end slides forwards and backwards, downstream end it fixed.
- Concave transition to sharp drop forms a good wave but very sensitive to any changes in the slope angle or tailwater elevation.



Figure 27: Flap gate with downslope wave in Epinal, France.

9.2 Headwater flap gate elevations

The adjustable wave needs to:

1. Collapse to the river bottom for high flows and ice.
2. Close either the 8m or 14m wide channel up to 280 m³/s full Bow flow as per the flow split above.

At any flow level, the wave structure needs the maximum possible headwater elevation to have the largest drop possible and to create the best waves. The maximum possible headwater elevation at the wave is less than the water surface elevation at the flow split at the top of the island. This means that required gate heights can be approximated by the water surface elevation at the flow split at the top of the island.

All elevation data comes from the preliminary engineering physical and computer modelling and Surf Anywhere calculations on that data.

9.2.1 Comparison of elevation options and impacts

Description	Recommended structure elevation	Alternate structure
	Data or comments	Data or comments
Structure overview	Wave structures in both channels.	Wave structure in one channel. Standard Obermeyer gate for flow intensity control in one channel.
Vertical range of motion	3.08m for both gates	0.95m for wave gate. Up to 2.83m for flow control gate.
Max wave structure elevation	1045.44m for both gates	1044.06m for wave gate. 1045.44m for flow control gate.
Min wave structure elevation	1042.36m for both gates. 1m below tailwater at 33 m ³ /s.	1043.11m for both gates. 0.25m below tailwater at 33 m ³ /s.
Min structure crest elevation when making waves	1043.16m for wave structure. 0.8m above foundation or min wave structure elevation.	1043.91m for wave structure. 0.8m above foundation or min wave structure elevation.
# of parallel waves	2	1
Quality of waves	Very high	High
Range of wave operation	Full operational flow range. 33 m ³ /s to 280 m ³ /s	Less than full operational flow range.
Return on investment	Very high	Good
Best river wave in the world	Yes	No
Cost	Higher cost	Lower cost

9.2.2 Water surface elevations

Elevation locations from preliminary engineering HEC-RAS 2D modelling.



Water surface elevation table

Total Bow Flow	Inlet of surf wave channel elevation	End of surf wave channel elevation	Drop	Comment relating to wave structure max elevation
	Maximum wave headwater elevation	Minimum wave tailwater elevation	Headwater - Tailwater	
m ³ /s	m	m	m	
33	1044.13	1043.36	0.77	
60	1044.42	1043.51	0.91	
92	1044.69	1043.66	1.03	
115	1044.84	1043.77	1.07	
142	1044.97	1043.92	1.05	1044.97 is the min max wave structure elevation for the 14m channel. Will block the 14m channel at 142 m ³ /s total Bow flow.
190	1045.14	1044.15	0.99	
240	1045.31	1044.38	0.93	
280	1045.44	1044.56	0.88	1045.44 is the min max wave structure elevation for the 8m channel. Will block the 8m channel at 280 m ³ /s total Bow flow.

9.2.3 Gate lowered elevation

- **Min gate lowered elevation = 1042.36 (Recommended)**
 - Tailwater elevation downstream of wave at $33 \text{ m}^3/\text{s} = 1043.36\text{m}$
 - 1m less is an elevation for the wave foundation that would create a good wave at $33 \text{ m}^3/\text{s}$.
 - Recommended lowered elevation to allow for waves at all flows.
- **Max gate lowered elevation = 1043.11**
 - 0.25m lower than tailwater elevation downstream of wave at $33 \text{ m}^3/\text{s}$
 - $1043.36\text{m} - 0.25\text{m} = 1043.11\text{m}$
 - This would not create a good wave at low flow but would allow safe passage at low flow conditions.

9.2.4 Gate raised elevation

- **Gate raised elevation = 1045.44m (Recommended)**
 - Elevation of water at flow split at top of island at $280 \text{ m}^3/\text{s} = 1045.44\text{m}$
 - Water can back up to this level and then go down the north channel.
 - Blocks flow at $280 \text{ m}^3/\text{s}$.
 - Allows closure of either channel at high flows to allow ideal flow intensity as per table above.
- **Min gate raised elevation = 1044.06m**
 - 0.7m higher than tailwater elevation at $33 \text{ m}^3/\text{s}$
 - $1043.36\text{m} + 0.7\text{m} = 1044.06\text{m}$
 - This wave structure elevation is used at multiple locations to create waves at our desired wave channel flow intensity including Salida, Bend, and Pueblo.
 - Elevation of water at flow split at top of island at $33 \text{ m}^3/\text{s} = 1044.13\text{m}$
 - Blocks flow at $33 \text{ m}^3/\text{s}$.

9.2.5 Gate range of motion

- **Max range of vertical movement for wave structure = 3.1m (Recommended)**
 - Max gate raised elevation – Min gate lowered elevation
 - $1045.44\text{m} - 1042.36\text{m} = 3.1\text{m}$
 - Best waves and returns at all flows
 - Can block off channel at high operating flows
 - Allows for two wave channels
- **Minimum range of vertical movement for wave structure = 0.95m**
 - Min gate raised elevation – Max gate lowered elevation
 - $1044.06\text{m} - 1043.11\text{m} = 0.95\text{m}$
 - Lower quality wave and smaller returns
 - Only works for part of flow range
 - Requires a single wave channel and a standard Obermeyer gate for flow intensity control

9.2.6 Min wave structure crest elevation for wave formation

The minimum wave structure crest elevation for wave formations is 0.7m above the foundation. This value is based on the actual crest elevation to foundation elevation differences at Bend and Salida. Both Bend and Salida make good waves.

Bend profile

Crest to transition is $0.7\text{m} = 2.0' = 3596.2' - 3594.0'$

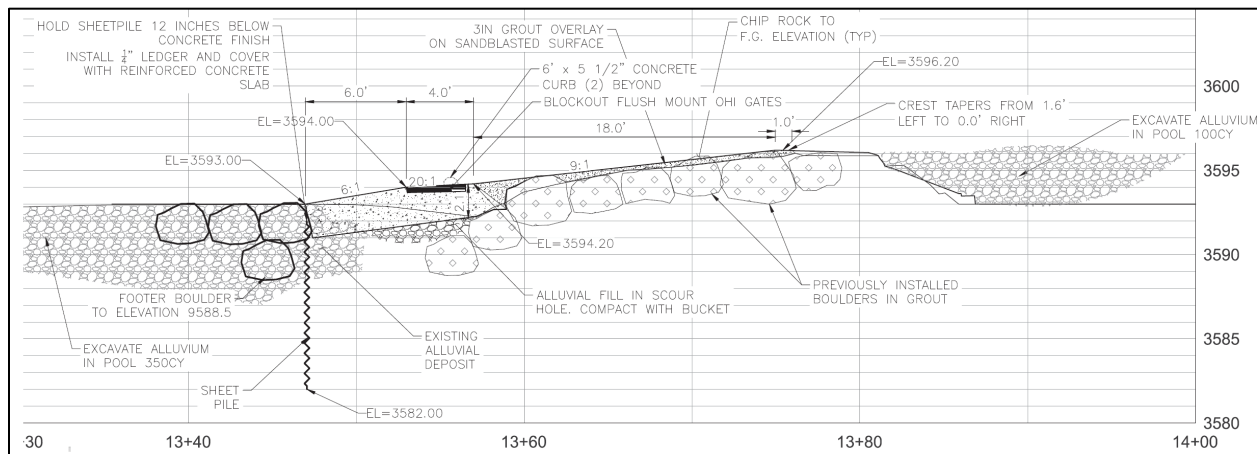


Figure 28: Profiles of the Bend, Oregon, adjustable wave from public drawings.¹²



¹² (Bend Parks & Recreation District, 2016)

Salida profile

Crest to transition is $0.8\text{m} = 2.5' = 7027.0' - 7024.5'$

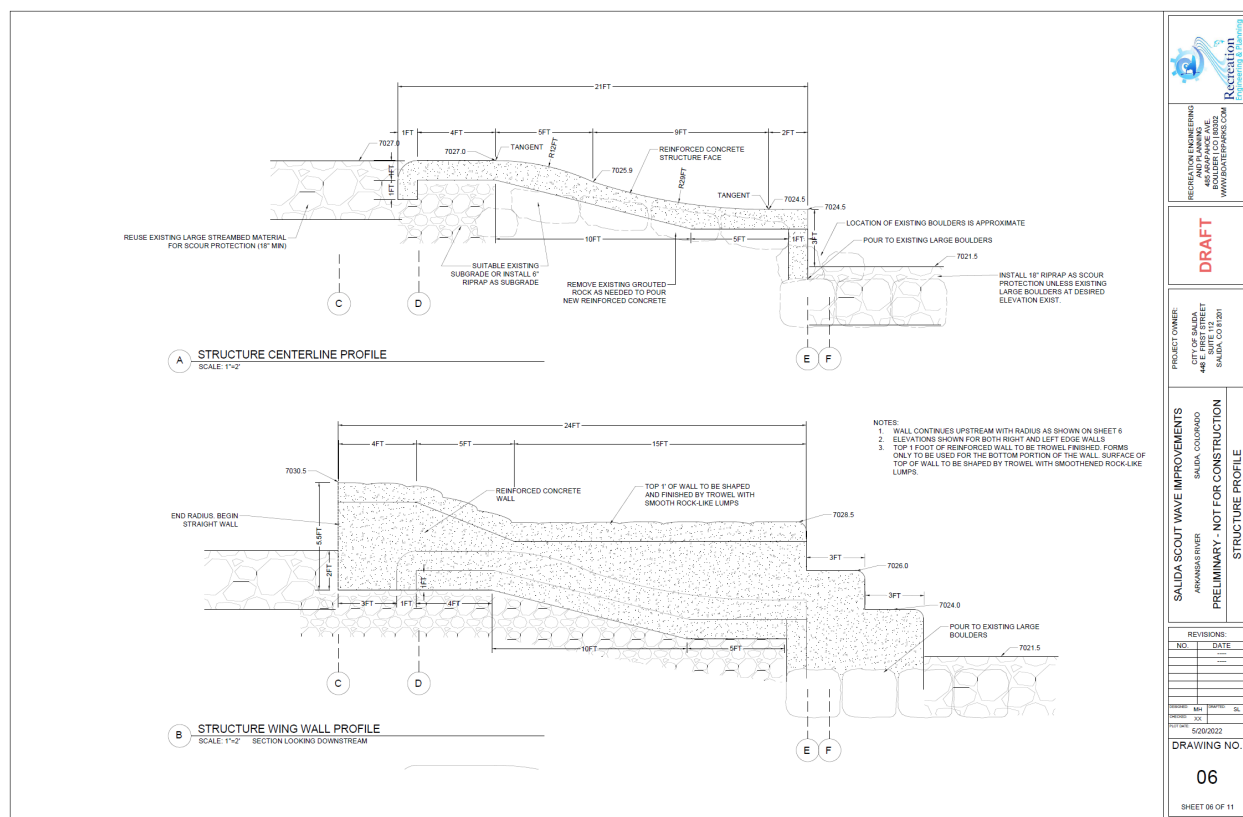


Figure 29: Profile of Salida wave from public City of Salida document.¹³



Figure 30: Salida wave at $22\text{ m}^3/\text{s}$ in May 2023.

¹³ (City of Salida, 2022)

10 Kicker elevation

The adjustable wave design includes two parallel rows of kickers ensure the kicker depth below tailwater can always create high quality waves by having the kicker elevation between close to 1m and 1.5m below tailwater.

10.1 Ideal kicker elevation

Kickers need to be between 0.25m and 1.5m below tailwater elevation to create good waves. These depths are based on observations of existing waves, physical & [Flow3D modelling by Surf Anywhere, the University of Ottawa, the Alberta River Surfing Association, and the Alberta Whitewater Association](#). Depth of kickers below the tailwater is based on water velocity balancing force of tailwater to make a wave. The deeper the kickers, the better the wave until the kickers are too deep and a wave cannot form.

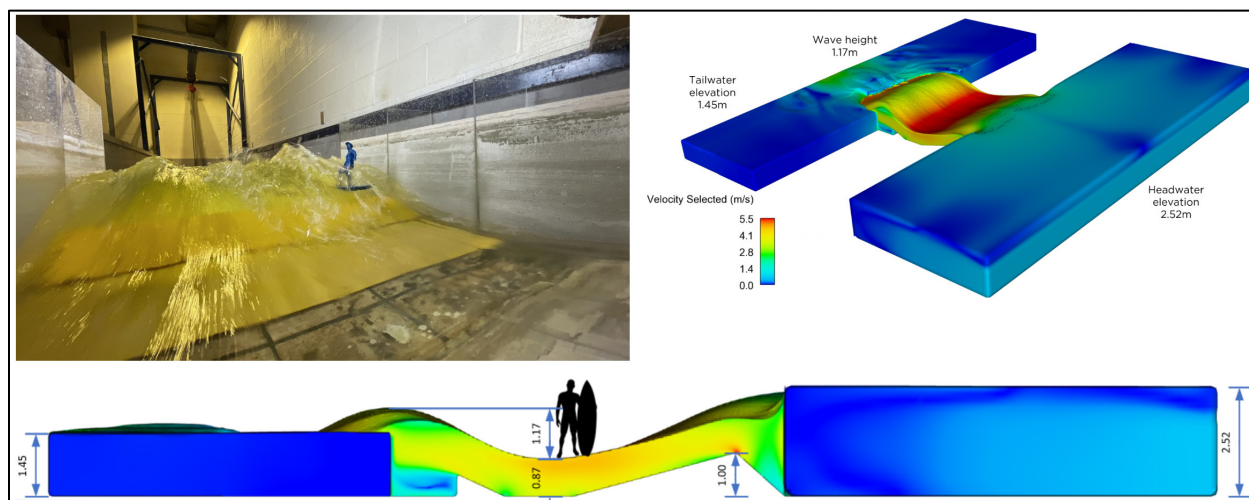


Figure 31: 1.45m tailwater above kicker validated with computer and physical modelling.

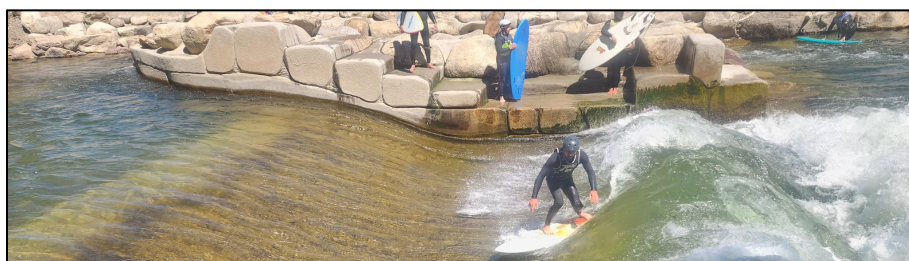


Figure 32: Tailwater at transition elevation forming wave. Salida, USA.



Figure 33: Tailwater above transition forming a taller wave. Salida, USA.

10.2 Kicker elevation physical modelling

This physical model shows that good waves form at different tailwater positions by moving the kickers up the ramp. There is a 1.5m change in tailwater at the Calgary Project. This model is an example of why two parallel rows of kickers are recommended to manage the different tailwater elevations. Modelling was by Surf Anywhere, the University of Ottawa, the Alberta River Surfing Association, and the Alberta Whitewater Association.¹⁴



Figure 34: Wave forming with kicker at lower positions and with lower tailwater.

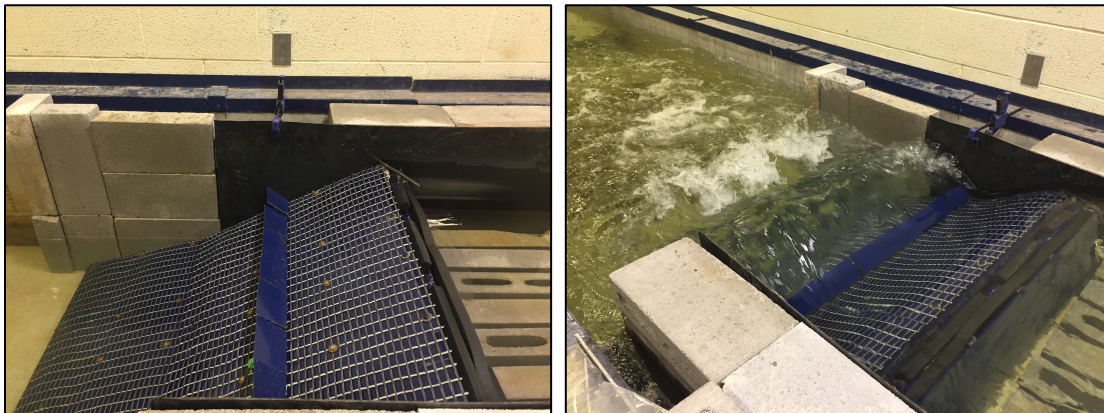


Figure 35: Wave forming with kicker at higher position and with higher tailwater.

¹⁴ (Egsgard, Kayak wave research report, 2021)

The diagrams below show the change in max wave height and max tailwater elevation as the kicker moves along the ramp. The key points are:

- In each graph of a modelling series the flow is constant, and the headwater elevation is constant. Tailwater and kicker elevation are changed to make tallest wave.
- Kicker elevation for the max wave height is well below the tailwater elevation.
- High flow intensities create larger waves.
- Low flow intensities can result in no wave.
- Wave height decreases as kickers and tailwater elevations increase.

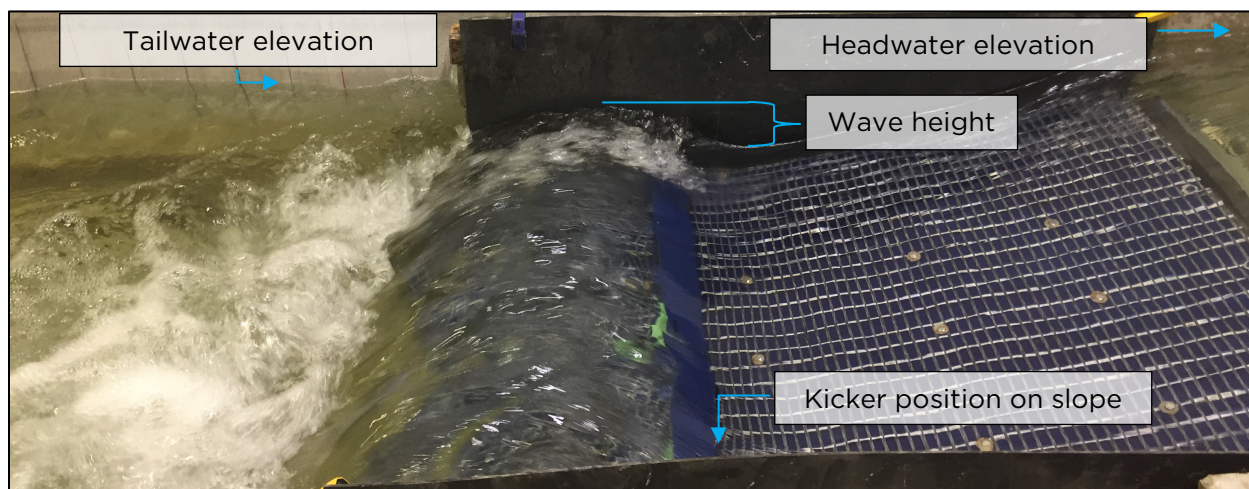


Figure 36: Measurement points on wave model image for the wave height and tailwater elevation charts.

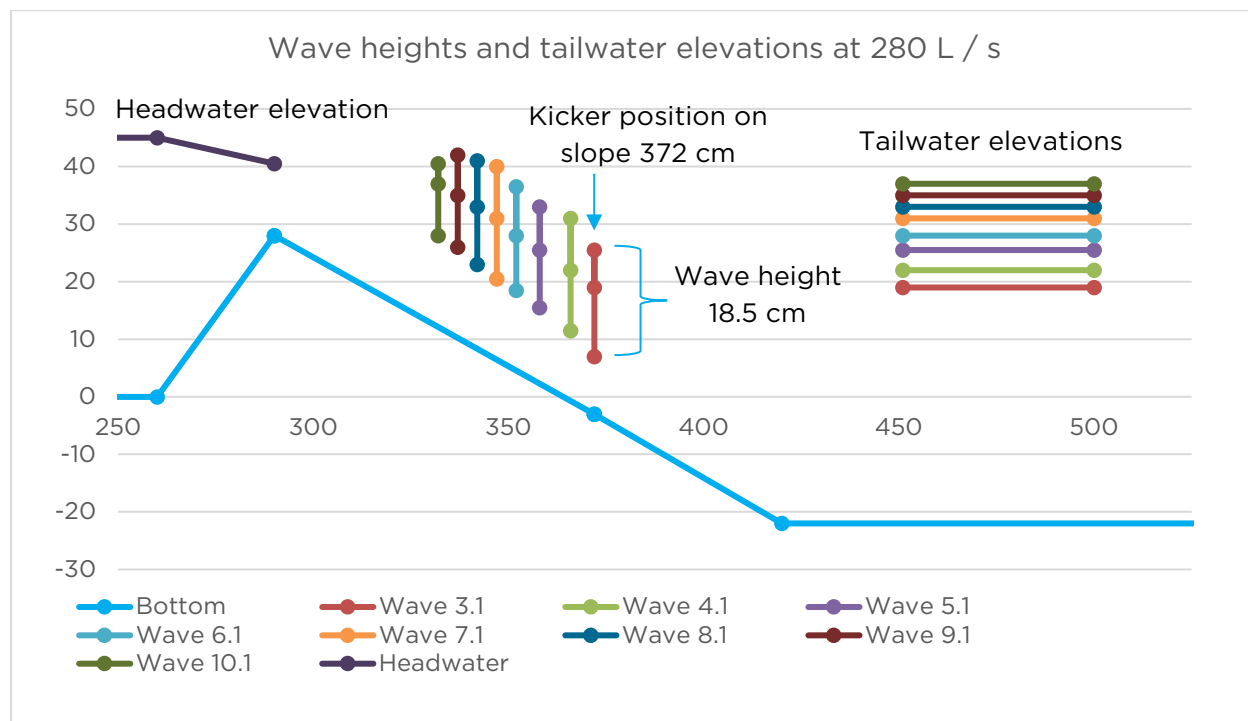


Figure 37: Slope wave heights and tailwater elevations at 280 L / s.

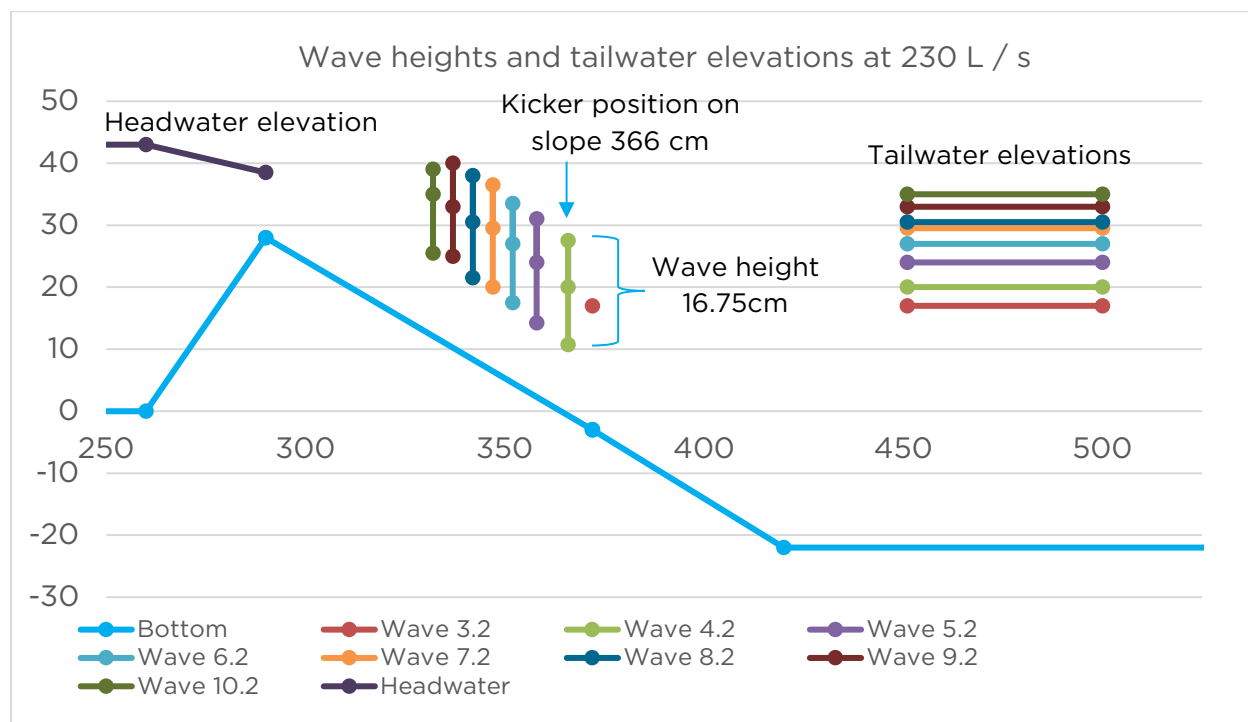


Figure 38: Slope wave heights and tailwater elevations at 230 L / s.

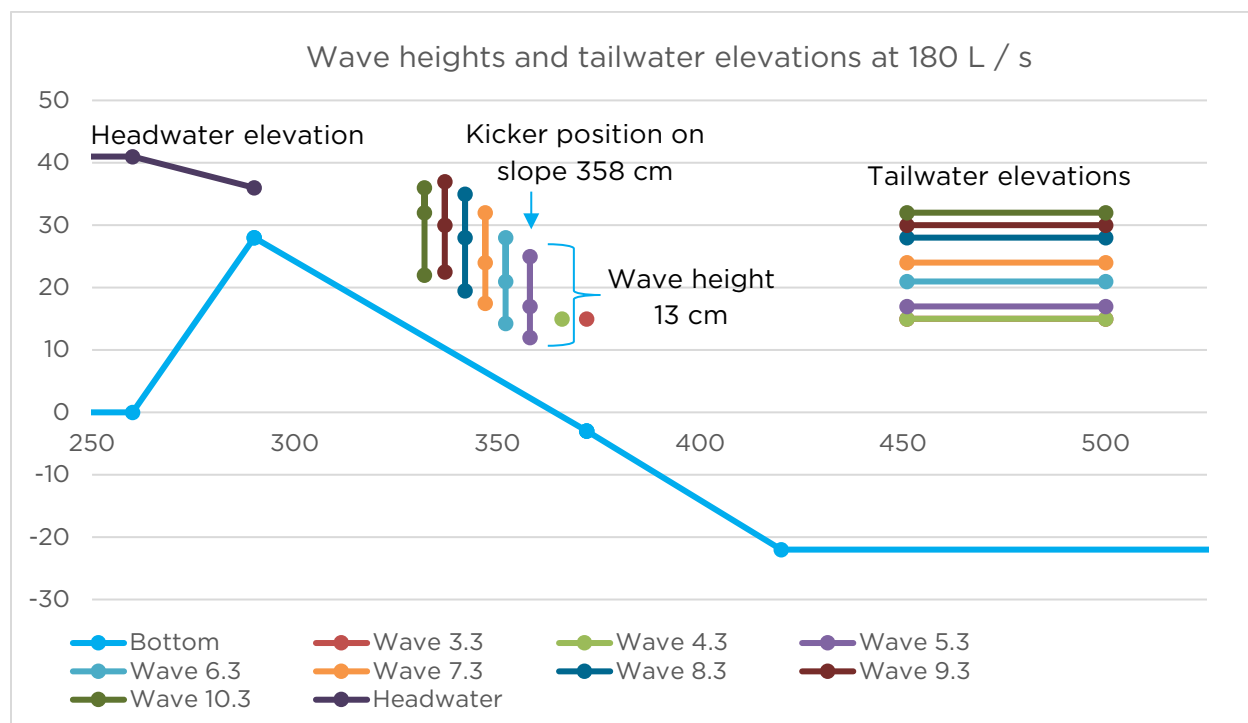


Figure 39: Slope wave heights and tailwater elevations at 180 L / s.

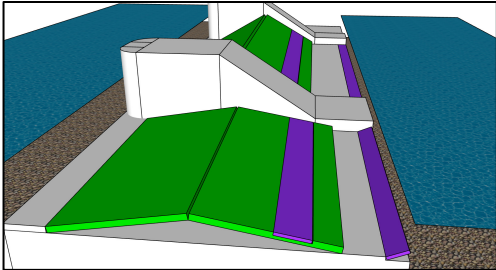
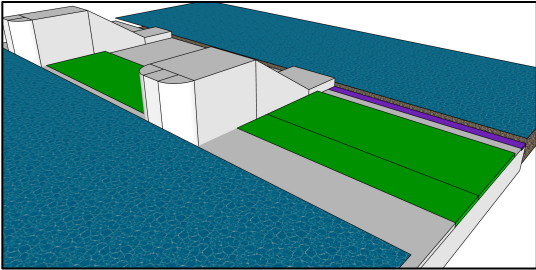
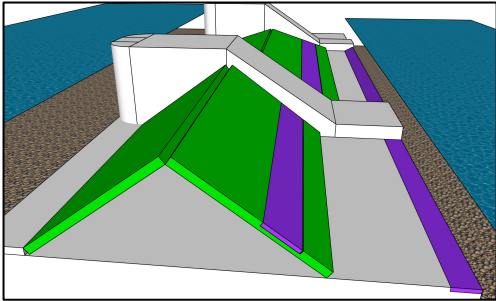
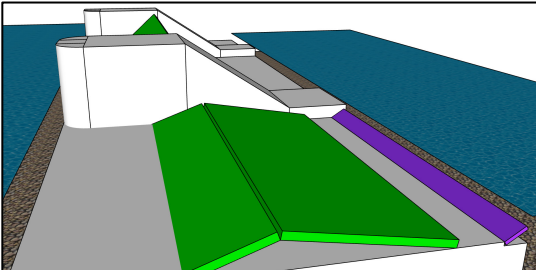
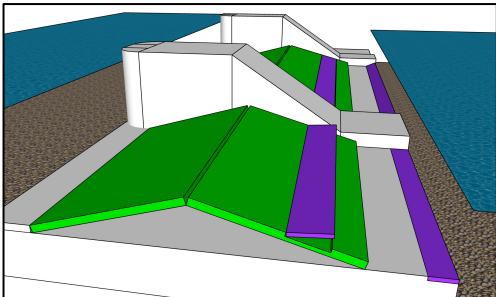
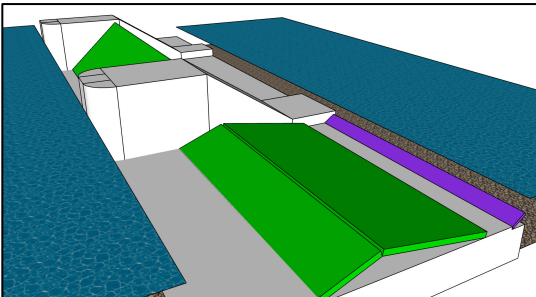
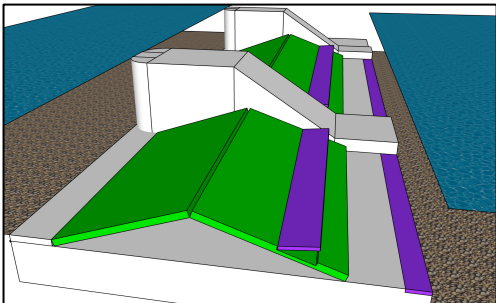
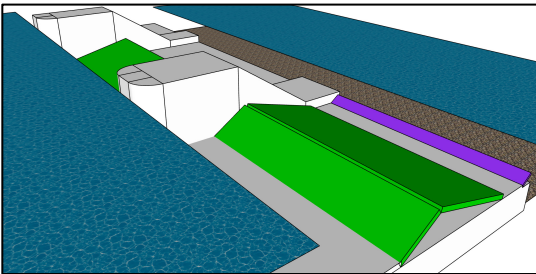
10.3 Benefits of parallel kicker rows

Parallel kickers allow for higher value waves across the full range of tailwater elevations.

Description	Recommended kicker configuration	Alternate kicker configuration
Kicker overview	Multiple rows of kickers at different elevations.	Single row of kickers on foundation.
Quality of waves	Very high at all flows.	Moderate at low flows and increasing as flows rise. High at higher flows
Types of waves	Many wave types	Limited wave types
Return on investment	Very high	Good
Best river wave in the world	Yes	No
Cost	Higher cost	Lower cost
Adjustability for tailwater changes due to natural processes	Yes - wave can be formed if tailwater lowers or raises.	No - Potential for the wave not to work at some flows if the tailwater elevation permanently raises or lowers.

The table below shows how the parallel rows of kickers allow the kicker depth to remain between 1m and 1.5m allowing for high quality waves at all flows.

Total Bow Flow	Surf channel Flow	Inlet of surf wave channel elevation	End of surf wave channel elevation	Drop	Parallel rows of kickers			Single row of kickers		
					Foundation elevation	Foundation to kicker	Kicker to TW	Foundation elevation	Foundation to kicker	Kicker to TW
		Max wave headwater Elevation (HW)	Tailwater elevation (TW)	HW - TW	1m less than TW	Kickers on foundation and on slope		0.25m less than TW	Kickers only on foundation	
m ³ /s	m ³ /s	m	m	m	m	m	m	m	m	m
33	16.9	1044.13	1043.36	0.77	1042.36	0	1	1043.11	0	0.25
60	21.6	1044.42	1043.51	0.91	1042.36	0	1.15	1043.11	0	0.4
92	33.1	1044.69	1043.66	1.03	1042.36	0	1.3	1043.11	0	0.55
115	41	1044.84	1043.77	1.07	1042.36	0	1.41	1043.11	0	0.66
142	48.4	1044.97	1043.92	1.05	1042.36	0	1.56	1043.11	0	0.81
190	60.8	1045.14	1044.15	0.99	1042.36	0.7	1.09	1043.11	0	1.04
240	74.4	1045.31	1044.38	0.93	1042.36	0.7	1.32	1043.11	0	1.27
280	84	1045.44	1044.56	0.88	1042.36	0.7	1.5	1043.11	0	1.45

Flow	Parallel kicker rows	Single kicker row
33 m ³ /s	8m gate open, 14m gate closed, foundation kicker active. 	12m gate open, 10m gate open, no waves because cannot create a high enough tailwater elevation. 
92 m ³ /s	8m gate closed, 14m gate open, foundation kicker active. 	12m gate closed, 10m gate open, foundation kicker active. 
142 m ³ /s	8m gate open, slope kicker active. 14m gate open, foundation kicker active. 	12m gate closed, 10m gate open, foundation kicker active. 
280 m ³ /s	8m gate open, slope kicker active. 14m gate open, slope kicker active. 	12m gate partially closed, 10m gate open, foundation kicker active. 

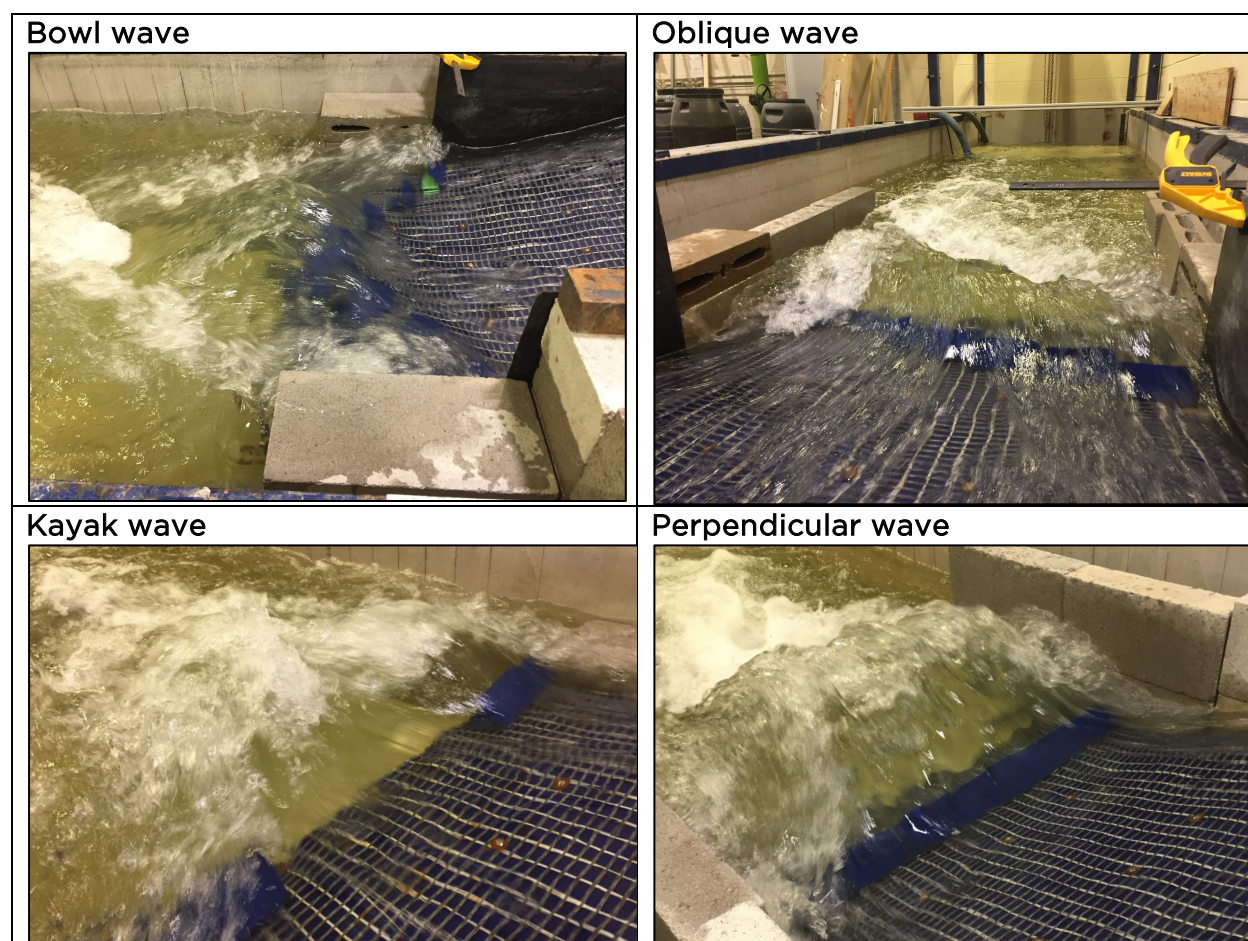
11 Multiple independent kickers vs continuous kicker

Multiple independent kickers in allow for more wave shapes, higher wave quality, and better returns than a continuous kicker. The recommendation are to have 1m wide kickers that can move independently and that cover the full width of each of the adjustable wave channels.

Images are from Surf Anywhere, Alberta River Surfing Association, and Alberta Whitewater Association wave design research with the University of Ottawa.¹⁵

11.1 Waves available from independent kickers

Many different wave types are available when there are independently moving kickers. Some possible wave types are shown below.



11.2 Waves available from a continuous kicker

Only the perpendicular wave can be made from a continuous kicker.

¹⁵ (Egsgard, River Wave Research, 2021)

11.3 Example configurations with multiple independent kickers

These are a couple of configurations that allow the formation of better waves for kayaking using multiple independent kickers.

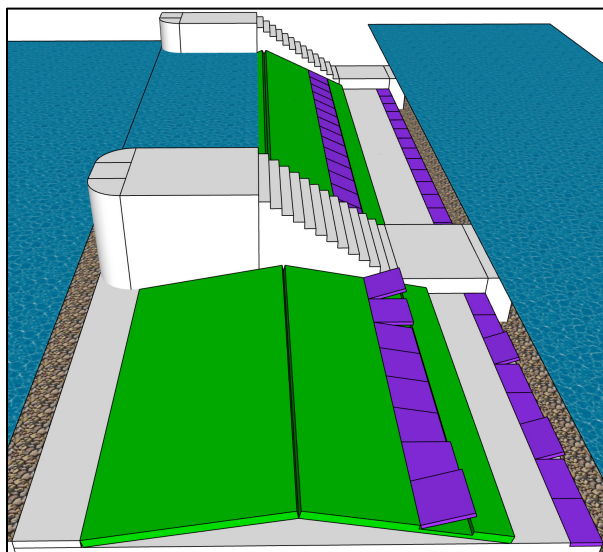


Figure 40: Low flow kayak setup – 33 m³/s
8m gate open, 14m gate closed. Lower tailwater so foundation kickers are active.

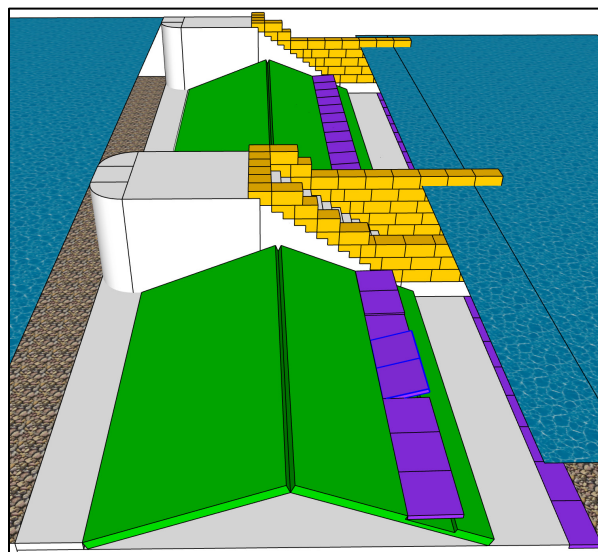


Figure 41: High flow surf & kayak setup – 280 m³/s
14m gate and 8m gate active. Lower tailwater so slope kickers are active.

12 Adjustable channel walls

Adjustable walls allow for wave access and wave type to be changed based on the tailwater elevation. The tailwater elevation at the adjustable wave has a 1.5m range. Full channel walls allow for a higher wave and a cleaner wave. The walls allow the tailwater to be higher which allows for the wave to be higher. As the walls lower, water enters the wave from the side making the wave break at lower tailwater levels.

For ideal surf waves, the sidewalls need to be at or above the tailwater elevation. For kayak waves, the sidewalls need to be at least 0.2m below tailwater. Only the part of the wall below the water level matters for wave formation. The kayak wave requirements are detailed in the [Surf Anywhere Kayak Research Report](#) by Surf Anywhere, Alberta Whitewater Association, Alberta River Surfing Association, and the University of Ottawa.¹⁶



Figure 42: Physical modelling of sidewall impacts on wave formation. Left image shows walls above tailwater. Middle and right images show wall below tailwater.¹⁷

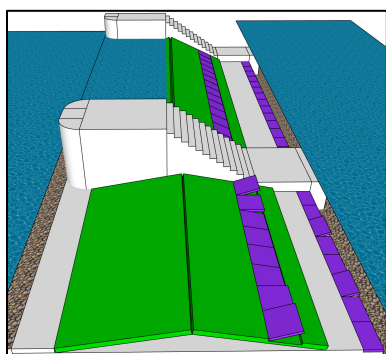


Figure 43: 33 m³/s walls. Kayak focus.

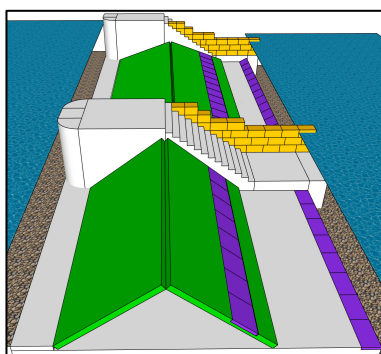


Figure 44: 142 m³/s walls. Kayak focus.

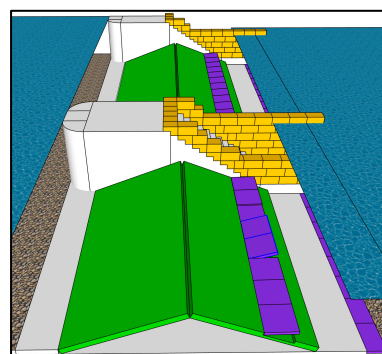


Figure 45: 280 m³/s walls. Surf and kayak focus.

¹⁶ (Egsgard, Kayak wave research report, 2021)

¹⁷ (Egsgard, Effect of channel walls on waves, 2021)



Figure 46: Adjustable wall in Boise, USA.



Figure 47: Adjustable walls in a whitewater park in Epinal, France.

13 Foundation

Based on similar existing adjustable waves, the foundation under the adjustable wave structure should consist of:

- 1.3m thick foundation slab under the structure
- Sheet pile under the foundation on the upstream end and downstream ends of the slab

13.1 Springbank Off-stream Reservoir foundation

The Springbank Off-stream Reservoir project uses a 6m reinforced concrete foundation tied to bedrock under their 5m tall pneumatic crest gates. These gates are 2m taller than the proposed project adjustable wave gates and are designed to be operated under major flood conditions. The 6m depth of foundation is probably not required for the Calgary River Wave Park because of the forces on adjustable wave gates will be much smaller due to smaller gate size and gate being fully lowered during flood event.

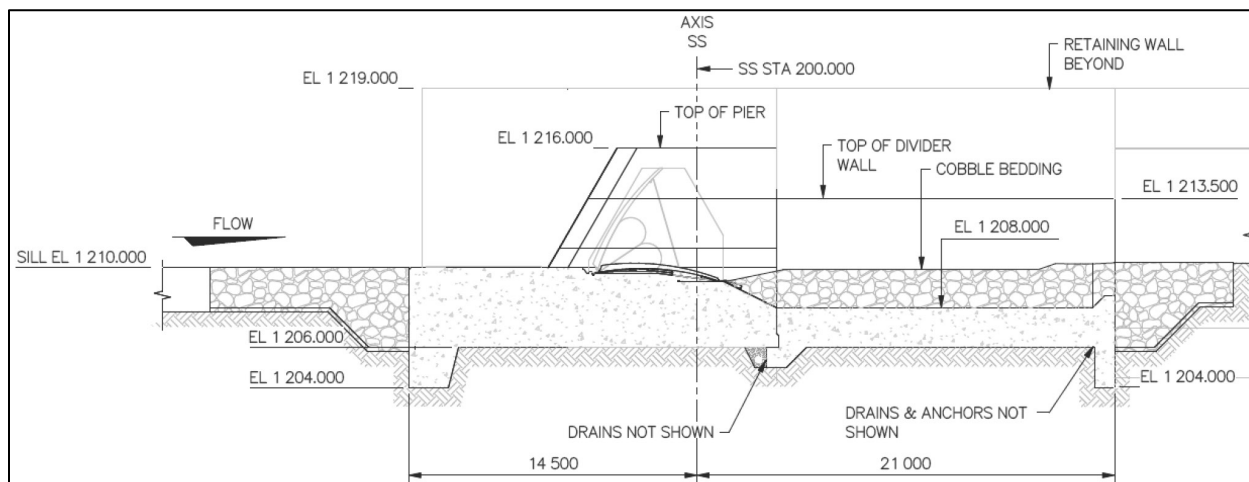


Figure 48: Profile of pneumatic gates from public Springbank Off-stream Reservoir drawings.¹⁸

¹⁸ (Springbank Dam Project Tender, 2021)

13.2 Harvie Passage foundation

The Harvie Passage foundations consist of large boulders grouted together. The foundations that were grouted boulders survived the 2013 flood. The section of the foundations between the north and south channel that failed did not have concrete on the north side. The river bounced off the north bank, cut through the unprotected north side of the foundation and broke the foundation.

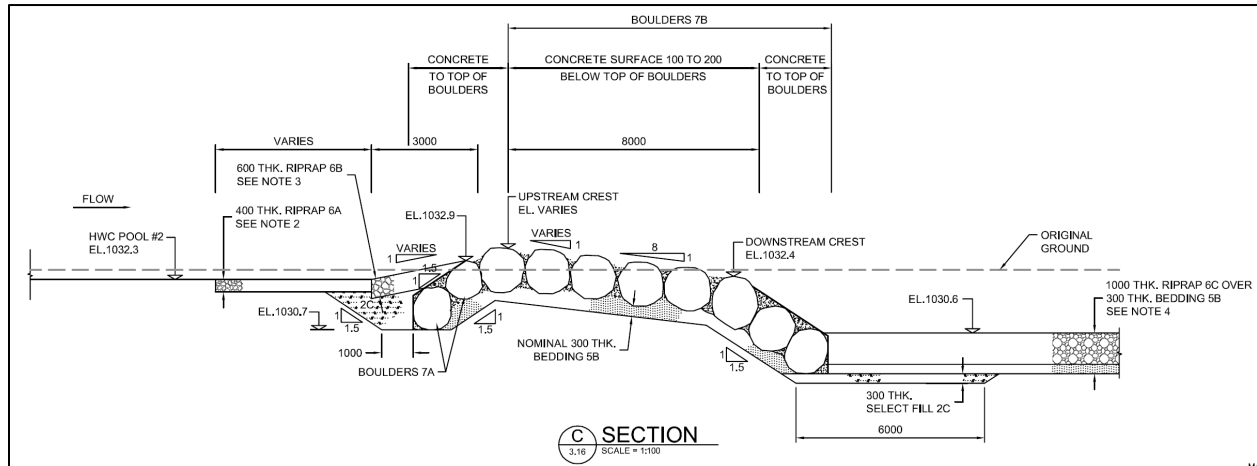


Figure 49: Profile of Harvie Passage foundation from public project drawings.

13.3 Boise foundation

Drawings of Boise Whitewater Park publicly released by City in meeting notes.

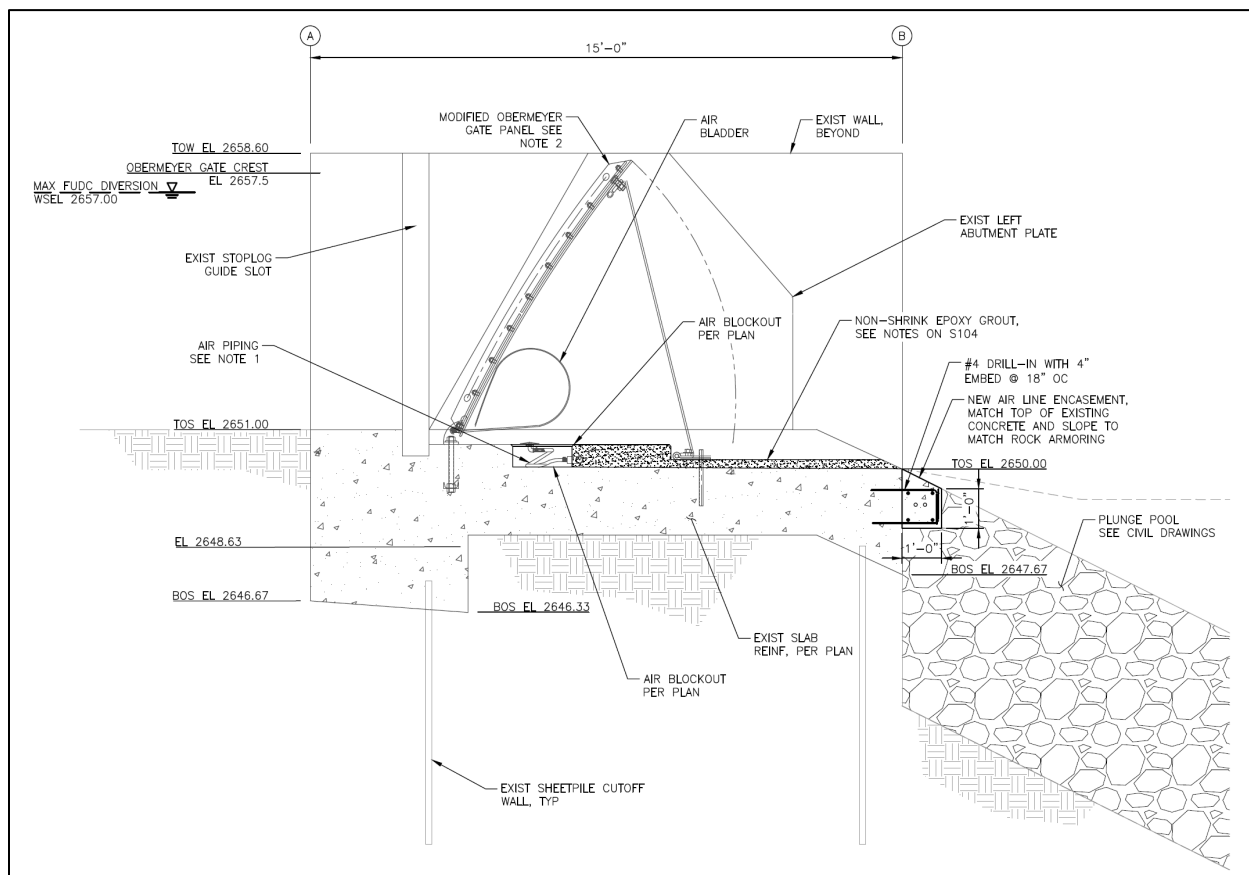


Figure 50: Profile of foundation from public drawings of Boise Whitewater Park Phase 2, USA.¹⁹

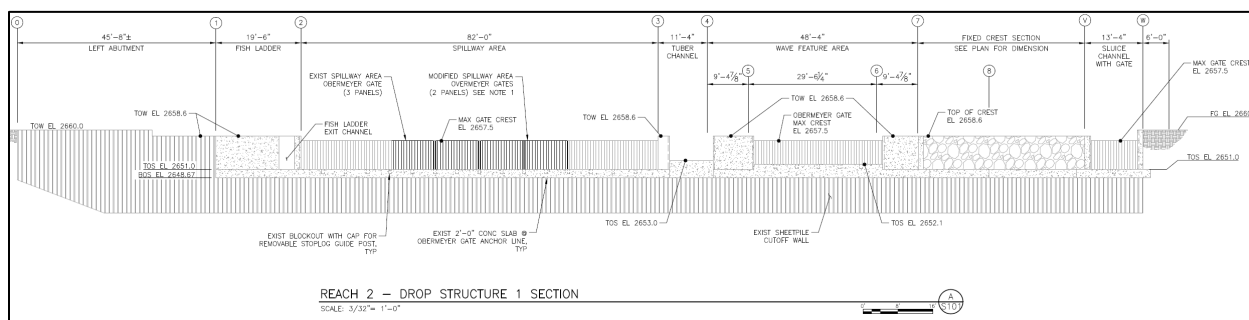


Figure 51: Cross section of foundation from public drawings of Boise Whitewater Park Phase 2, USA.²⁰

¹⁹ (City of Boise, 2023)

²⁰ (City of Boise, 2023)

Boise Phase 1 foundation of sheet pile and concrete Drawings were publicly released by City in meeting notes.

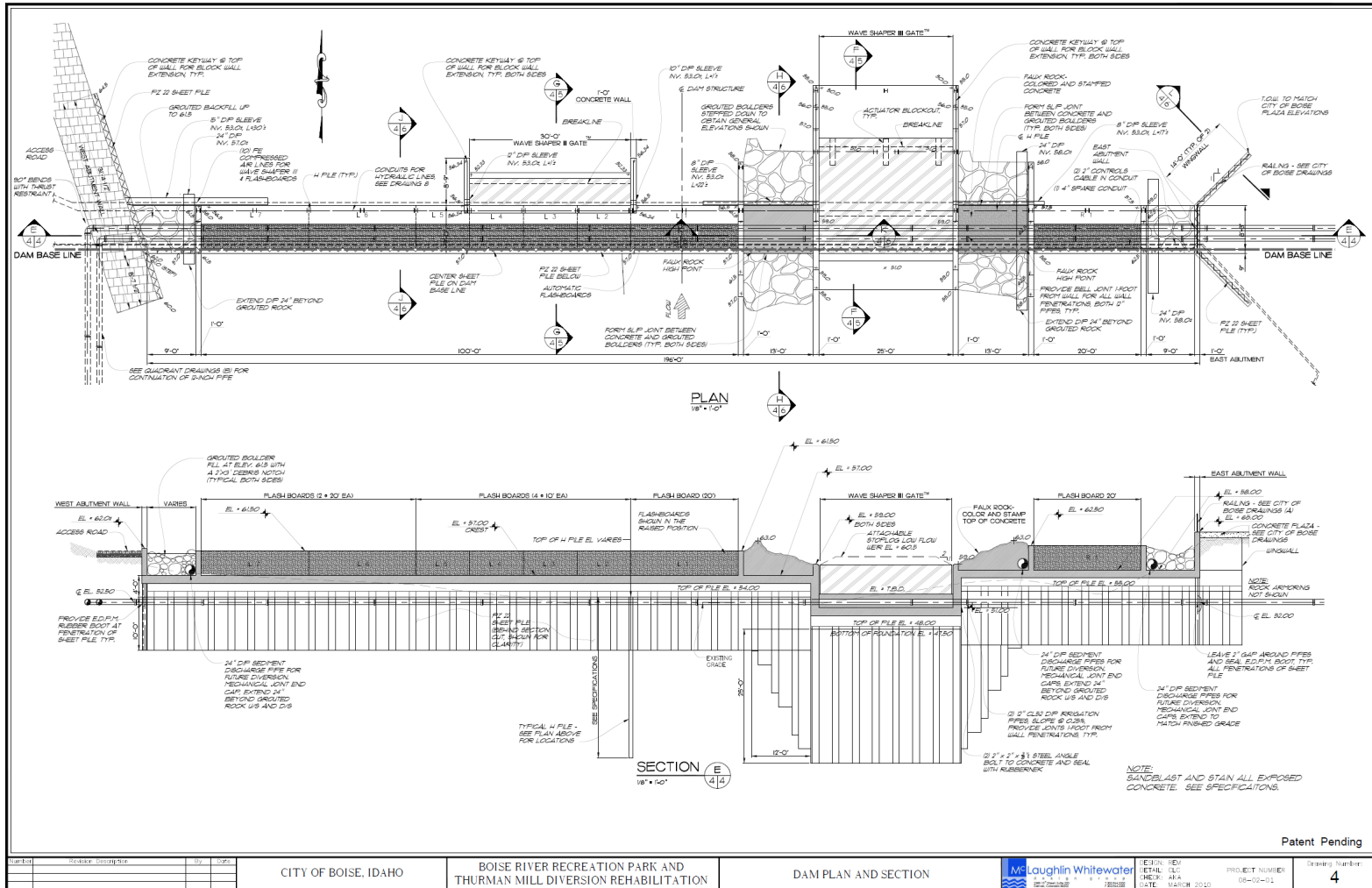


Figure 52: Cross section of foundation from public drawings of Boise Whitewater Park Phase, USA.

14 Tailwater

Tailwater elevation relative to the kicker elevation is a critical factor in the quality of the wave. Tailwater can be significantly lowered through scour downstream of the wave structure especially during high water events. Tailwater can be significantly raised through deposition downstream of the wave structure during high water events.

14.1 Preventing tailwater elevation loss

To prevent tailwater elevation drops, a minimum tailwater level needs to be set using boulders in the riverbed. The boulders prevent the bed elevation from reducing below the level of the boulders.

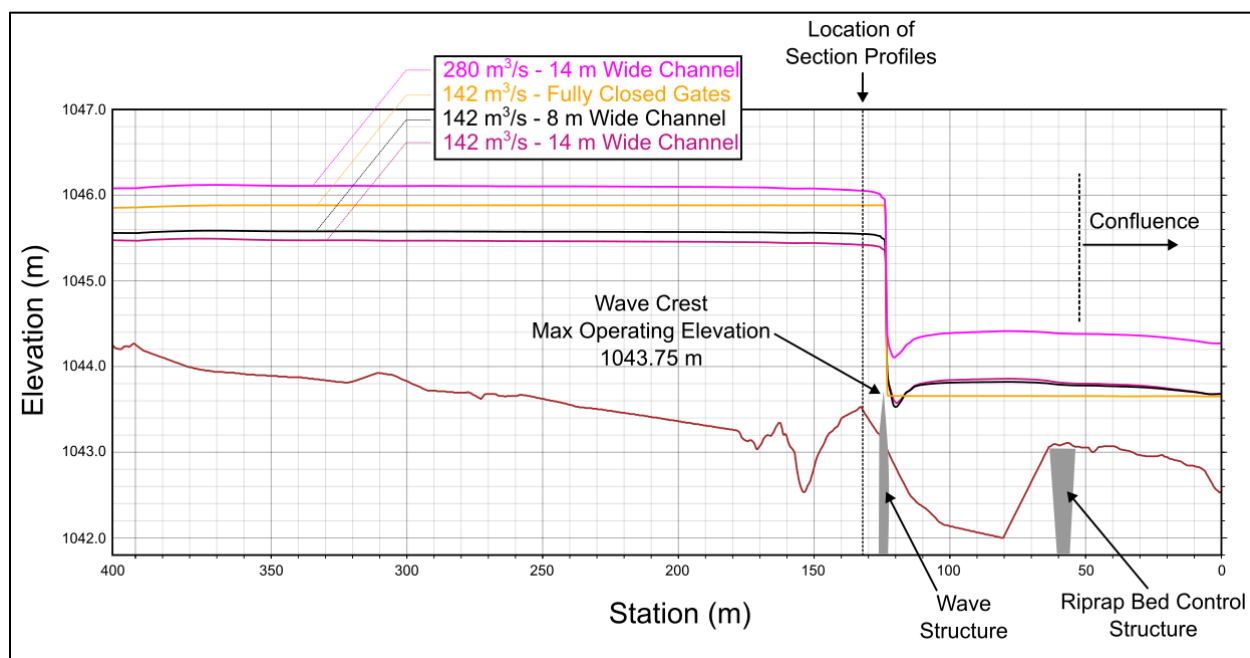


Figure 53: Tailwater elevation control using a riprap bed control structure.²²

14.2 Managing tailwater elevation increase

Tailwater elevation increase can be managed by:

- Opening one channel at a time to send higher velocity water over the depositions to move them downstream.
- Having kickers at different elevations on the wave structure to allow for good wave formation at higher tailwater levels.
- Setting a higher elevation to the structure foundation. This will reduce the wave quality at lower flows.

²² (Preliminary Wave Design for the 10th Street Gravel Management Project, 2025)

15 Structural, electrical, and mechanical requirements

The design of the adjustable wave structure needs structural, electrical, and mechanical engineering. Engineering drawings from existing adjustable waves are included in “Section 21 Drawings from other projects”.

In general, the adjustable wave structures will need:

- Control room containing:
 - Control equipment
 - Compressors for the bladders
 - Internet connection
 - Power
- Air lines between the control room and the bladder
 - Air lines connections and lines need to be high quality to prevent air leaks.
- Control room needs to be flood proof or above high water line
- Lifting points on the wave structures gates in case external lifting is necessary.
- 2 meter flat concrete apron upstream of the wave structure gates for water diversion in case upstream access is needed

16 Maintenance and inspection

Gate and structure maintenance and inspection techniques require raising the gates and dewatering. When operating properly the flap gate can be raised to eliminate flow in one or both wave structure channels. When dewatering is needed, stopped logs or meter bags, and pumps can be used.

16.1 How to fix failed pneumatic flap gates

Pneumatic flap gates are lifted by a pneumatic bladder on the downstream side of the gate. If the bladder fails then the gate lays flat. According to Obermeyer, this is how to fix a failed bladder.

1. Do work in low flow conditions.
2. Raise the gates on either side of the failed gate
 - a. This directs water away from the gate area and provides a sheltered space to work behind the gates.
3. To lift the failed gate, do one of:
 - a. Over inflate the broken bladder
 - b. Mechanically lift the gate using jacks, a crane, or a winch anchored upstream.
4. Once the gate is raised, install support struts and do the repairs.

16.2 Dewatering

If the adjustable structure needs to be dewatered, stop logs and / or meter bags can be used with pumps to eliminate water around the wave structure during low flow conditions. A crane or excavator would be required to install the diversion equipment.

16.2.1 Stop logs

Stop logs can be used upstream and downstream of the adjustable structure to isolate the structure from the river.



Figure 54: Example of stop logs in a channel blocking water.

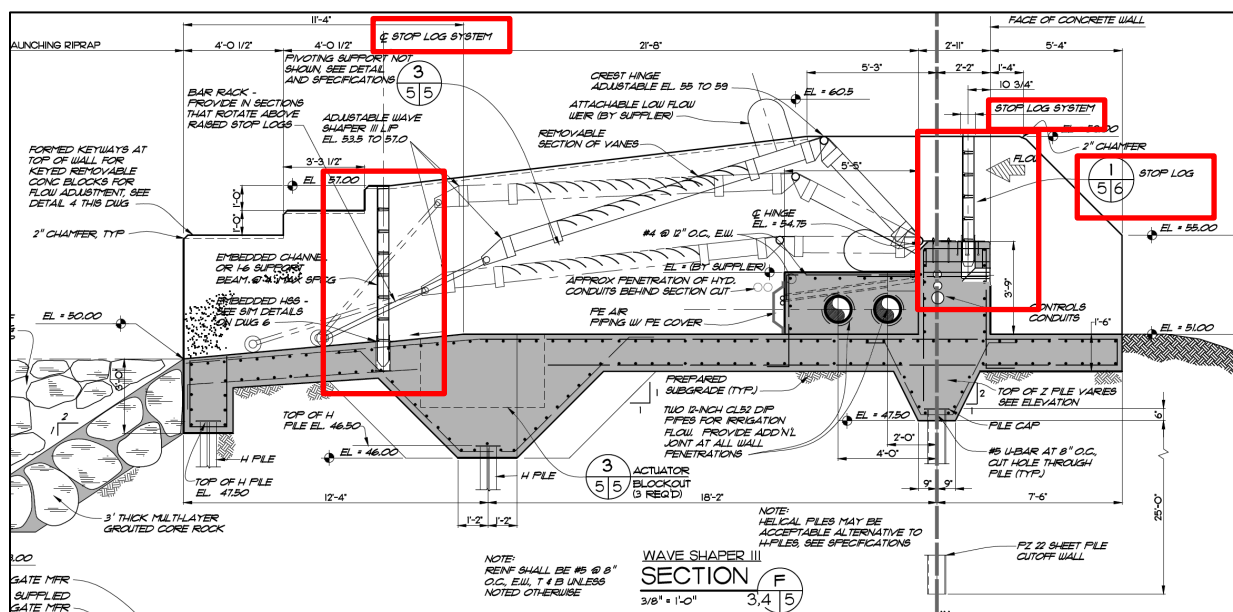


Figure 55: Stop logs from public drawings of Boise Whitewater Park, USA.²³

²³ (City of Boise Planning & Zoning Commission, 2011)

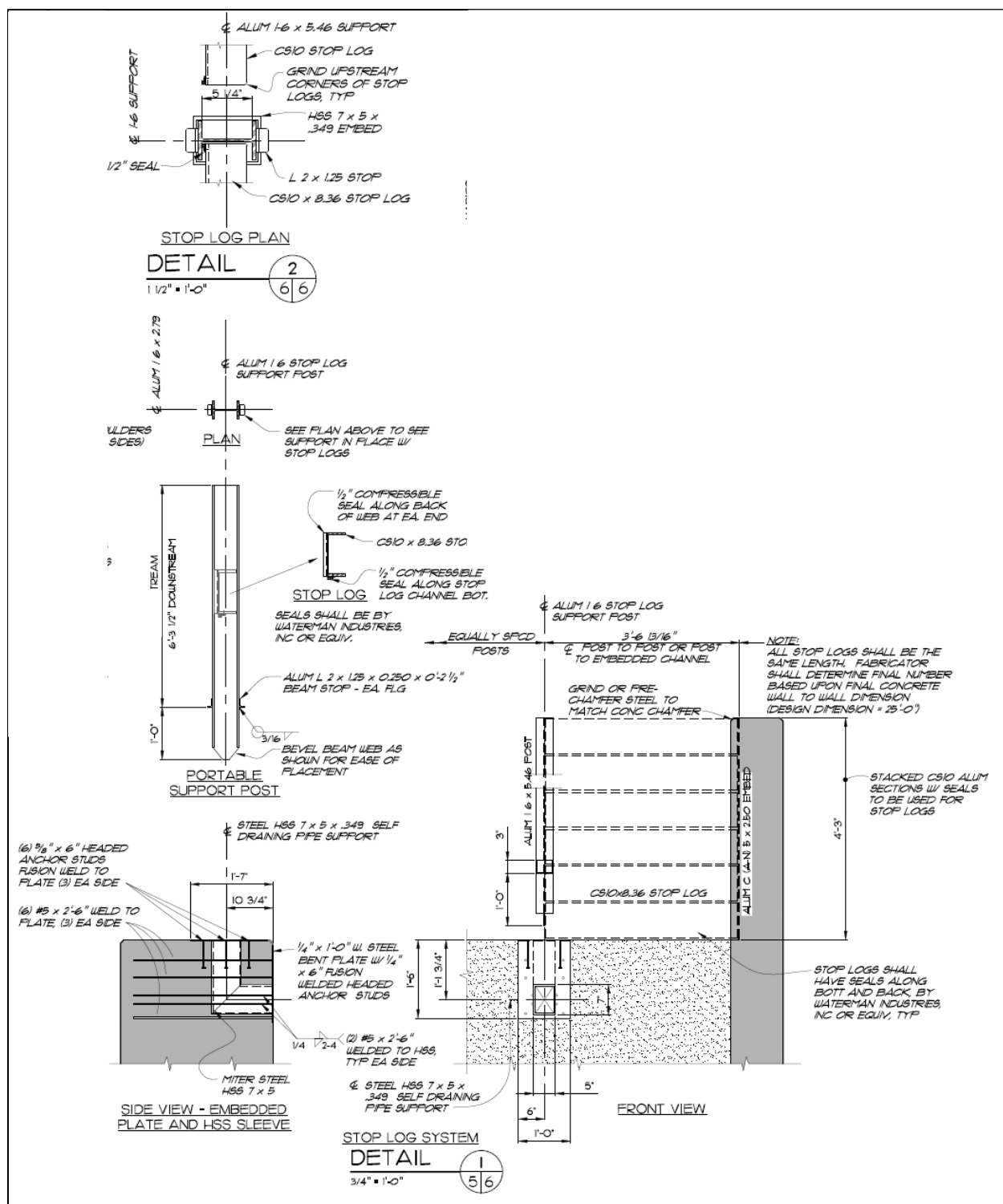


Figure 56: Stop logs details from public drawings of Boise Whitewater Park, USA.²⁴

²⁴ (City of Boise Planning & Zoning Commission, 2011)

16.2.2 Meter bags

To divert water from the adjustable structure, meter bags can be installed on the flat concrete section upstream of the flap gate



Figure 57: Meter bags at the Bend Whitewater Park, USA.

17 Costs of adjustable river waves

This sections details construction and maintenance costs of pneumatic flap gates. Maintenance costs for well constructed river waves are minimal. Costs will be refined when structural, mechanical, and electrical engineering start in the Adjustable Wave Detail Design phase. No structural, mechanical, or electrical engineering has been completed yet for the adjustable wave.

Costs in this table are from the following sections.

Cost source	Year	Cost (CAD)	Comment
Pneumatic gate cost from supplier based on gate area.	2017	\$1,995,840	Includes adjustable wave structure supply and engineering. Does not include install or foundation or other project costs. Converted from USD at 1 USD : 1.4 CAD. The Calgary River Wave Park adjustable waves will have a higher cost because not all project costs are included.
Surf Anywhere “Initial Design Report for Calgary River Wave Park”.	2019	\$9,586,933	Includes all costs as a stand-alone project. The adjustable wave structure shares costs with the rest of the project which means the cost for the Calgary project would be lower. The Calgary Wave Park adjustable waves will have a lower cost than a stand-alone project because it shares costs with the rest of the project.
Maximum cost based on unit width cost from similar projects.	2020	\$7,095,890	Includes all costs as a stand-alone project. Converted from USD at 1 USD : 1.4 CAD. The Calgary Wave Park adjustable waves will have a lower cost than a stand-alone project because it shares costs with the rest of the project.

17.1 Wave structure supply cost

Based on discussions with a pneumatic gate supplier in 2017, pneumatic gate supply with all components and engineering costs are \$5,400 per cubic meter. Based on this unit cost, the supply of the adjustable wave structure would cost \$1,425,600 USD or \$1,995,840 CAD at 1 USD: 1.4 CAD.

The calculation for the Calgary River Wave Park is based on three parallel pneumatic gates. The south channel width is 30m. The total adjustable wave channel width is 22m and this width is used for the slope and kickers. The cost for the Calgary adjustable wave is based on:

= (Slope gate cost) + (Slope kicker gate cost) + (Foundation kicker gate cost)
 = (Unit area X area of slope and foundation) + 2 X (Unit area cost X area of kickers for the kicker gates)

Item	Height (m)	Length (m)	Area (m ²)	Unit cost (USD)	Unit cost unit	Cost (USD)	Cost (CAD)	Year of costs
Slope which folds in half. Allows 3.1m raised height with downslope.	8	22	176	\$5,400	Square meter	\$950,400	\$1,330,560	2017
Kicker 1	2	22	44	\$5,400	Square meter	\$237,600	\$332,640	2017
Kicker 2	2	22	44	\$5,400	Square meter	\$237,600	\$332,640	2017
Concrete foundation not included								
Total						\$1,425,600	\$1,995,840	2017

17.2 Cost from 2019 initial design report

The Surf Anywhere “Initial Design Report for Calgary River Wave Park (SA-2018-009-R1)” (2019) in “Section 20.1 Capital Budget” provides a total stand-alone project cost for the Calgary River Wave Park adjustable waves of **\$9,586,933 CAD**.

SA-2018-009-R1: Initial Design Report for the Calgary River Wave Park					
Dec 15 2019					
20 Budget					
20.1 Capital Budget					
The rough pricing below is based on other river projects and input from local Southern Alberta river engineering firms. Only pricing for Louise Bridge location has been included.					
Description	Unit	Quantity	Unit Cost	Cost	Notes
Design and permitting					
Engineering: Preliminary design and design development	Lump Sum	1	\$268,972	\$268,972	Based on quotes from Calgary engineering firms and APEGA guidelines on costs
Engineering: Construction drawings	Lump Sum	1	\$537,944	\$537,944	Based on quotes from Calgary engineering firms and APEGA guidelines on costs
Engineering: Contract administration, post construction service and other engineering services	Lump Sum	1	\$268,972	\$268,972	Based on quotes from Calgary engineering firms and APEGA guidelines on costs
Permitting	Lump Sum	1	\$150,000	\$150,000	Based on quotes from Calgary engineering firms and previous permitting work.
Design and permitting subtotal				\$1,225,889	
Construction					
Access roads	Lump Sum	1	\$200,000	\$200,000	Based on comparing costs from other Calgary river construction projects
Excavation of banks, island and riverbed for boulder & concrete placement	m³	1,347	\$30	\$40,410	Based on comparing costs from other Calgary river construction projects
Placement of excavated materials	m³	1,347	\$80	\$107,760	Based on comparing costs from other Calgary river construction projects
Boulder supply and placement	Tonne	3,985	\$240	\$956,400	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Boulder concrete supply and placement	m³	1,003	\$500	\$501,500	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Mobilization (20% of other construction costs)	Lump Sum	1	\$896,574	\$896,574	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Wave structure	m²	330	\$5,000	\$1,650,000	Based on comparing pricing from water control structure manufacturers with costs for Alberta supplied materials
Care of water	Lump Sum	1	\$750,000	\$750,000	Based on comparing costs from other Calgary and area river construction projects
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SA-2018-009-R1: Initial Design Report for the Calgary River Wave Park					
Dec 15 2019					
Description	Unit	Quantity	Unit Cost	Cost	Notes
Downstream riparian habitat enhancement	m	240	\$320	\$76,800	Based on comparing costs from other Calgary and area river construction projects
Signage and riverbank amenities	Lump Sum	1	\$200,000	\$200,000	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Construction Subtotal				\$5,379,444	
Design & Construction Subtotal				\$6,605,333	
Contingency (30%)				\$1,981,600	
Flood recovery fund				\$1,000,000	Funds for river adjustments to ensure high quality waves following a major flood (ex. 1:100 year)
Total				\$9,586,933	
Notes Completion of preliminary engineering with provide substantially more accurate cost estimates.					
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17.3 Costs from similar projects

Reviewing existing and proposed projects using pneumatic gates provides a cost per unit width for each project. Using the highest per meter of width cost from these projects provides a Calgary adjustable waves cost of **\$5,068,493 USD** in 2020 dollars or **\$7,095,890 CAD** at 1 USD: 1.4 CAD. Source of costs are detailed in the following subsections.

The calculation for the Calgary River Wave Park is based on three parallel pneumatic gates. The reviewed projects have a single pneumatic gate for the length. The Calgary slope gate is taller and the kicker gates are shorter than the gates in the review projects. A provide higher values, the same cost per unit width is used for all three Calgary parallel gates. The south channel width is 30m and the total adjustable wave channel width is 22m. The cost for the Calgary adjustable wave is based on:

$$= (\text{Slope gate cost}) + (\text{Slope kicker gate cost}) + (\text{Foundation kicker gate cost})$$

$$= (\text{Unit width cost} \times 30\text{m for the slope and foundation}) + 2 \times (\text{Unit width cost} \times 24\text{m for the kicker gates})$$

Cost Type	Project	Year of cost	Length across river	Gate height	Cost (USD)	Cost per meter of width (USD)	Cost for Calgary River Wave Park adjustable wave structures (USD)	Comments
Actual	Boise phase 1 whitewater park	2010	178 ft 54 m	10 ft 3 m	\$3,000,000	\$55,556	\$4,111,111	Includes all project costs. Includes patented waves system. Includes flap gates for headwater elevation and two adjustable wave structures. In Boise Phase 1, the gates cost \$750,000 USD.
Actual	Bend whitewater park	2016	80 ft 24 m	2-4 ft 0.6-1.2 m	\$1,500,000	\$62,500	\$4,625,000	Includes centre channel only with adjustable waves. Engineering and other costs not included.
Actual	Boise phase 2 whitewater park	2020	480 ft 146 m	10 ft 3 m	\$10,000,000	\$68,493	\$5,068,493	Includes all project costs. Includes patented wave system.
Projected	Puddingstone Diversion Dam Structural Concept	2015	175 ft 53 m	6 ft 1.8 m	\$1,197,000	\$22,585	\$1,671,283	Includes gates, PLC, concrete spillway. Does not include engineering or other costs.
Projected	Devils Gate Dam Structural Concept	2015	171 ft 52 m	5 ft 1.5 m	\$877,230	\$16,870	\$1,248,366	Includes gates, PLC, concrete spillway. Does not include engineering or other costs.

Additional details for adjustable wave design – Calgary River Wave Park Aug 17, 2025

Cost Type	Project	Year of cost	Length across river	Gate height	Cost (USD)	Cost per meter of width (USD)	Cost for Calgary River Wave Park adjustable wave structures (USD)	Comments
Projected	Eaton Wash Dam Structural Concept	2015	270 ft 82 m	10 ft 3 m	\$4,309,200	\$52,551	\$3,888,790	Includes gates, PLC, concrete spillway. Does not include engineering or other costs.
Projected	Willow Lake Enhancement Project	2010	144 ft 44 m	9 ft 2.75 m	\$2,465,857	\$56,042	\$4,147,123	Includes all project costs.

Figure 58: Summary of adjustable wave costs from similar projects.

17.3.1 Projected construction cost details

17.4 These costs are used in the preceding “Section 17.1 Wave structure supply cost

Based on discussions with a pneumatic gate supplier in 2017, pneumatic gate supply with all components and engineering costs are \$5,400 per cubic meter. Based on this unit cost, the supply of the adjustable wave structure would cost \$1,425,600 USD or \$1,995,840 CAD at 1 USD: 1.4 CAD.

The calculation for the Calgary River Wave Park is based on three parallel pneumatic gates. The south channel width is 30m. The total adjustable wave channel width is 22m and this width is used for the slope and kickers. The cost for the Calgary adjustable wave is based on:

$$= (\text{Slope gate cost}) + (\text{Slope kicker gate cost}) + (\text{Foundation kicker gate cost})$$

$$= (\text{Unit area} \times \text{area of slope and foundation}) + 2 \times (\text{Unit area cost} \times \text{area of kickers for the kicker gates})$$

Item	Height (m)	Length (m)	Area (m ²)	Unit cost (USD)	Unit cost unit	Cost (USD)	Cost (CAD)	Year of costs
Slope which folds in half. Allows 3.1m raised height with downslope.	8	22	176	\$5,400	Square meter	\$950,400	\$1,330,560	2017
Kicker 1	2	22	44	\$5,400	Square meter	\$237,600	\$332,640	2017
Kicker 2	2	22	44	\$5,400	Square meter	\$237,600	\$332,640	2017
Concrete foundation not included								
Total						\$1,425,600	\$1,995,840	2017

17.5 Cost from 2019 initial design report

The Surf Anywhere “Initial Design Report for Calgary River Wave Park (SA-2018-009-R1)” (2019) in “Section 20.1 Capital Budget” provides a total stand-alone project cost for the Calgary River Wave Park adjustable waves of **\$9,586,933 CAD**.

SA-2018-009-R1: Initial Design Report for the Calgary River Wave Park					
Dec 15 2019					
20 Budget					
20.1 Capital Budget					
The rough pricing below is based on other river projects and input from local Southern Alberta river engineering firms. Only pricing for Louise Bridge location has been included.					
Description	Unit	Quantity	Unit Cost	Cost	Notes
Design and permitting					
Engineering: Preliminary design and design development	Lump Sum	1	\$268,972	\$268,972	Based on quotes from Calgary engineering firms and APEGA guidelines on costs
Engineering: Construction drawings	Lump Sum	1	\$537,944	\$537,944	Based on quotes from Calgary engineering firms and APEGA guidelines on costs
Engineering: Contract administration, post construction service and other engineering services	Lump Sum	1	\$268,972	\$268,972	Based on quotes from Calgary engineering firms and APEGA guidelines on costs
Permitting	Lump Sum	1	\$150,000	\$150,000	Based on quotes from Calgary engineering firms and previous permitting work.
Design and permitting subtotal				\$1,225,889	
Construction					
Access roads	Lump Sum	1	\$200,000	\$200,000	Based on comparing costs from other Calgary river construction projects
Excavation of banks, island and riverbed for boulder & concrete placement	m³	1,347	\$30	\$40,410	Based on comparing costs from other Calgary river construction projects
Placement of excavated materials	m³	1,347	\$80	\$107,760	Based on comparing costs from other Calgary river construction projects
Boulder supply and placement	Tonne	3,985	\$240	\$956,400	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Boulder concrete supply and placement	m³	1,003	\$500	\$501,500	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Mobilization (20% of other construction costs)	Lump Sum	1	\$896,574	\$896,574	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Wave structure	m²	330	\$5,000	\$1,650,000	Based on comparing pricing from water control structure manufacturers with costs for Alberta supplied materials
Care of water	Lump Sum	1	\$750,000	\$750,000	Based on comparing costs from other Calgary and area river construction projects
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SA-2018-009-R1: Initial Design Report for the Calgary River Wave Park					
Dec 15 2019					
Description	Unit	Quantity	Unit Cost	Cost	Notes
Downstream riparian habitat enhancement	m	240	\$320	\$76,800	Based on comparing costs from other Calgary and area river construction projects
Signage and riverbank amenities	Lump Sum	1	\$200,000	\$200,000	Based on comparing costs from other Calgary and area river construction projects and from past Alberta RSA projects.
Construction Subtotal				\$5,379,444	
Design & Construction Subtotal				\$6,605,333	
Contingency (30%)				\$1,981,600	
Flood recovery fund				\$1,000,000	Funds for river adjustments to ensure high quality waves following a major flood (ex. 1:100 year)
Total				\$9,586,933	
Notes Completion of preliminary engineering with provide substantially more accurate cost estimates.					
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Additional details for adjustable wave design – Calgary River Wave Park Aug 17, 2025

Costs from similar projects”. Costs are pulled from the following documents:

- [Los Angeles Basin Study. Appendix E: LACFCD Dam Hydrology and Cost Estimates. 2015.](#)
- [Big Butte Feasibility Study. 2010.](#)

Project	Item	%	Height (ft)	Height (m)	Length (ft)	Length (m)	Unit cost unit	Unit cost (USD)	Cost (USD)	Year of costs	Source
Puddingstone Diversion Dam Structural Concept	6 foot tall pneumatically actuated gate		6	1.83	175	53.34	Linear ft	\$3,000	\$525,000	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Puddingstone Diversion Dam Structural Concept	Programmable logic controller (% of gate cost)	8%						\$525,000	\$42,000	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Puddingstone Diversion Dam Structural Concept	Installation cost of 6 foot tall raised spillway		6	1.83	175	53.34	Linear ft	\$3,600	\$630,000	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Puddingstone Diversion Dam Structural Concept	Total								\$1,197,000	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Devils Gate Dam Structural Concept	5 foot tall pneumatically actuated gate		5	1.52	171	52.12	Linear ft	\$2,250	\$384,750	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Devils Gate Dam Structural Concept	Programmable logic controller (% of gate cost)	8%						\$384,750	\$30,780	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Devils Gate Dam Structural Concept	Installation cost of 5 foot tall raised spillway		5	1.52	171	52.12	Linear ft	\$2,700	\$461,700	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Devils Gate Dam Structural Concept	Total								\$877,230	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Eaton Wash Dam Structural Concept	10 foot tall pneumatically actuated gate		10	3.048	270	82.30	Linear ft	\$7,000	\$1,890,000	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Eaton Wash Dam Structural Concept	Programmable logic controller (% of gate cost)	8%						\$1,890,000	\$151,200	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Eaton Wash Dam Structural Concept	Installation cost of 5 foot tall raised spillway		10	3.048	270	82.30	Linear ft	\$8,400	\$2,268,000	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Eaton Wash Dam Structural Concept	Total								\$4,209,200	2015	Appendix E: LACFCD Dam Hydrology and Cost Estimates
Willow Lake Enhancement Project	9 foot tall Obermeyer weir materials		9	2.74	144	43.89	Linear ft	\$6,527.78	\$940,000	2010	Big Butte Feasibility Study

Additional details for adjustable wave design – Calgary River Wave Park Aug 17, 2025

Project	Item	%	Height (ft)	Height (m)	Length (ft)	Length (m)	Unit cost unit	Unit cost (USD)	Cost (USD)	Year of costs	Source
Willow Lake Enhancement Project	Labour and materials to install Obermeyer weir							\$17,350.70	\$17,350.70	2010	Big Butte Feasibility Study
	Concrete foundation not included										Big Butte Feasibility Study
Willow Lake Enhancement Project	Subtotal								\$957,350.70	2010	Big Butte Feasibility Study
Willow Lake Enhancement Project	Total from document including all costs								\$2,265,857	2010	Big Butte Feasibility Study

17.5.1 Actual construction costs

These costs are from people involved with the construction of the Bend, Oregon, and Boise, Idaho, whitewater parks.

17.5.1.1 Boise Phase 1 cost - 2010



Figure 59: Boise - Phase 1

- Built in 2010
- Total cost of the project: \$3M USD
- Cost of gates: \$735,000 USD
- Costs include Obermeyer flap gates and two large adjustable wave structures
- One drop with total channel width: 178 ft or 54m
- Cost per width: \$16,850 / ft or \$55,295 / m
- Cost for Calgary River Wave Park drop at 98' or 30m = \$1,685,000
- Adjustable gates
 - Four 20' x 10' gates
 - Four 10' x 10' gates
 - One pneumatic crest gate with hydraulic actuator
 - One 30' McLaughlin hydraulic wave shaper

17.5.1.1.1 Cost of gates from sole source contract

The cost of the Waveshaper was \$750,000 USD. The projected cost of the project at the time of that cost was \$2.8M USD.

CITY OF BOISE SOLE SOURCE DEPARTMENT RECOMMENDATION	
TO:	Denis Ryall, Purchasing Agent and/or Mayor and City Council
FROM:	Wendy Larimore
DEPT:	Parks and Recreation
DATE:	October 11, 2010
SUBJECT:	Sole Source Declaration for Obermeyer Hydro Inc, to prepare shop drawings and fabricate a new, automated, inflatable gate system with a boatable, hinged gate, spillway system to be installed in the Boise River at the Thurman Mill diversion. 5511-039
BACKGROUND: By agreements approved by the City Council, the City of Boise is working with the Thurman Mill Ditch Company and the Friends of the Park (FOP) foundation to replace the existing Thurman Mill irrigation diversion structure to make it safer for river floaters and to provide a recreational amenity which will be the first phase of the Ray Neef Whitewater Park. A major part of this project will be the fabrication of the automated inflatable flash boards and an automated, boatable, hinged, spillway gate system commonly referred to as a waveshaper. As part of the agreement with FOP, the City of Boise will purchase the materials using City funds and the FOP will contract for the associated infrastructure construction and installation of the flashboards and waveshaper using donated funds. Thurman Mill Ditch Company will own the facility once completed. The total project is estimated at \$2.8M with the diversion materials are estimated to cost \$0.74M. Staff has conducted research as to the availability of firms to purchase the waveshaper from. This research included the following: - Discussions with Mr. Rick McLaughlin of the McLaughlin Whitewater Group, a nationally recognized firm in Whitewater Park design and also Boise's design consultant for the project. - Internet research for comparable products. Based upon this research, staff has concluded that Obermeyer Hydro, Inc. is the only known company which can fabricate and supply the inflatable gate system and waveshaper equipment. Obermeyer Hydro, Inc. has provided equipment for all other similar Whitewater Parks developed in the United States and they own patents specific to this equipment making them uniquely qualified to provide the equipment. Therefore staff is requesting the City Council declare Obermeyer Hydro, Inc. as the sole source provider of the inflatable gate system and the waveshapers for the Thurman Mill Ditch Company diversion structure replacement as there is no other known firms that can provide a functional equivalent. As a first phase, Boise will contract for the preparation of the shop drawings. This is estimated to cost \$44,000. Upon approval of the shop drawing and FOP (Friends of Park) securing the necessary funding for the installation costs, Boise will contract for the fabrication of the waveshaper. 9/7/2010	

FISCAL IMPACTS: The estimated cost for the waveshaper is \$735,000. The FY 11 budget includes \$750,000 for the Whitewater Park. City appropriation for this expenditure is in the following account.

RECOMMENDATION: Parks and Recreation Department requests that City Council declare Obermeyer Hydro, Inc. as the sole source provider of the automated inflatable flash boards and waveshaper systems for the Thurman Mill Ditch Company diversion structure replacement as there is no other known firms that can provide a functional equivalent.

ACTION REQUIRED: Purchasing Agent and Mayor and City Council approval.

17.5.1.1.2 Adjustable wave 2 engineering drawing and photos from construction

Photos are from the [Boise Whitewater Park Construction.MP4](#) by Kayak Idaho.

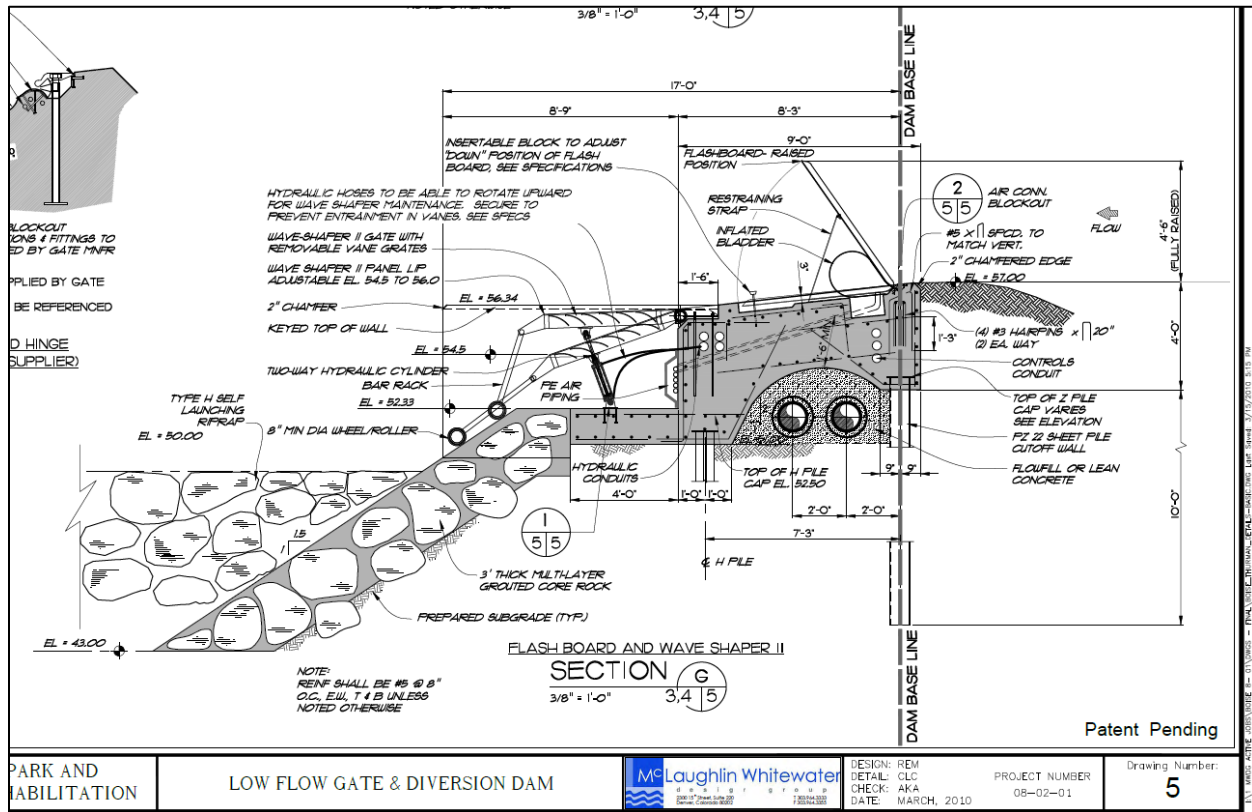


Figure 60: Profile drawings of Boise wave from public documents.²⁵



²⁵ (Bend Parks & Recreation District, 2016)



17.5.1.1.3 Adjustable wave 3 engineering drawing and photos from construction

Photos below are from the [Boise Whitewater Park Construction.MP4](#) by Kayak Idaho.

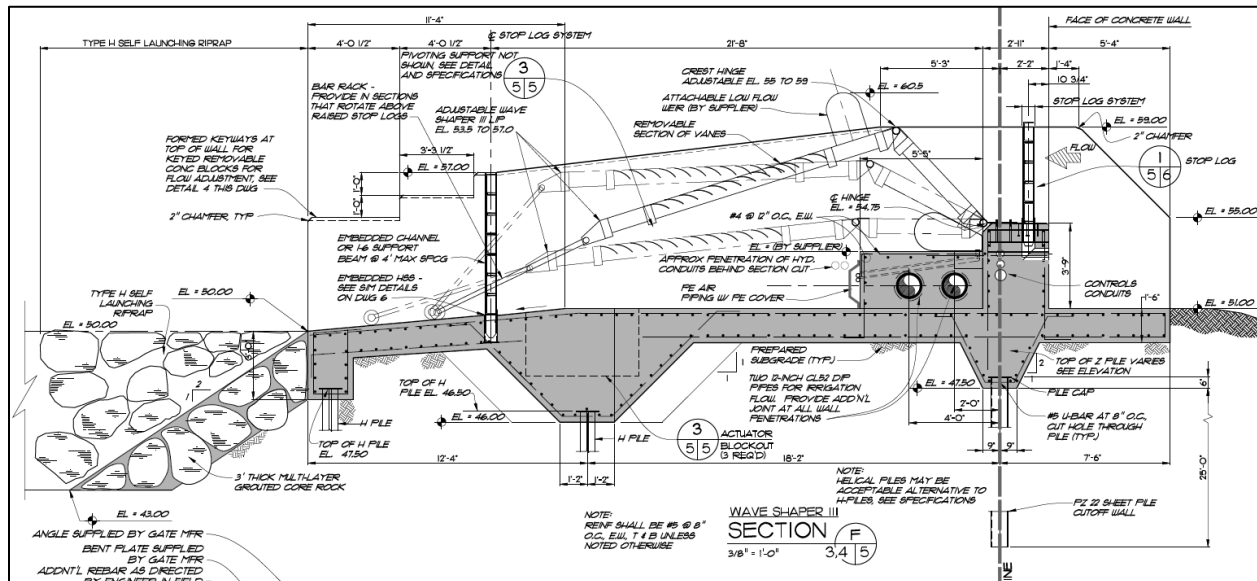


Figure 61: Profile drawings of Boise wave from public documents.²⁶



²⁶ (Bend Parks & Recreation District, 2016)

17.5.1.1.4 Diversion dam – Obermeyer flap gates

Images below are from the [Boise Whitewater Park Construction.MP4](#) by Kayak Idaho.



17.5.1.2 Bend Whitewater Park cost - 2016

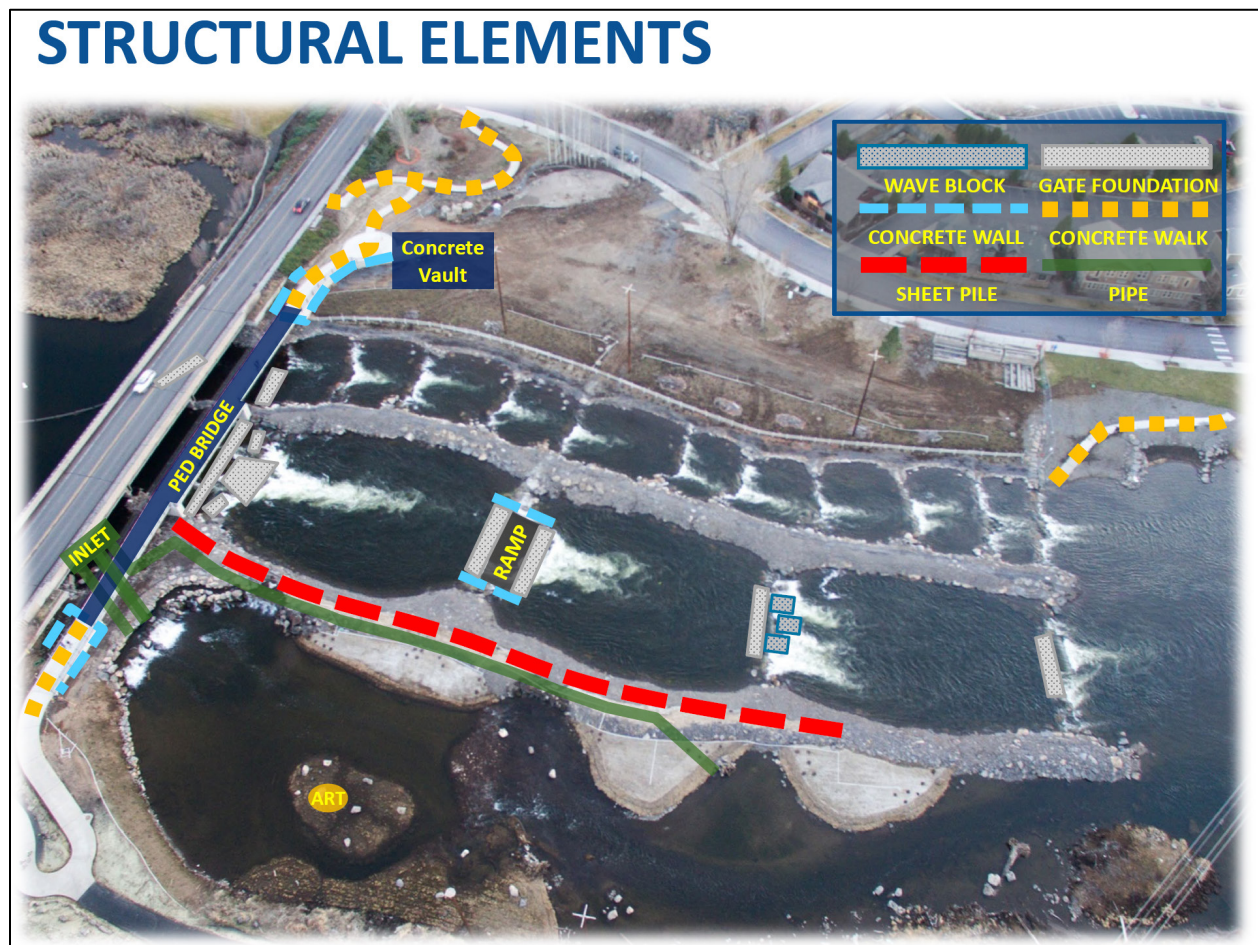


Figure 62: Bend – Habitat on left, Waves in middle, Tuber Passage on right. Replaced hazardous dam.

- Built in 2016
- Total cost of the project: \$11M USD
- Cost for centre channel: \$1.5M USD for parts and install of gates
- Four drops in centre channel with total width: 320ft or 96m
 - Each drop is about 80ft or 24m meters wide
- Cost per width: \$4,690 / ft or \$15,379 / m
- Cost for Calgary River Wave Park drop at 100' or 30m = \$469,000
- Centre channel has 23 of the 26 Obermeyer Hydro Inc. gates.
 - Six 12' x 4' gates at top of channel under bridge
 - Two angled rubber rocks secondary flow control 8' x 2'
 - Two steel 10' x 1' kickers
 - Three rubber rock tailwater control
 - Two 8' x 2'
 - One 10' x 2'
 - Two centre surf wave steel kickers 10' x 2'
 - Three rubber rocks surf wave tailwater control
 - Two 8' x 2'
 - One 10' x 2'
 - Three rubber rocks bottom wave control and second wave tailwater control
 - Two 8' x 2'
 - One 10' x 2'surf wave tailwater control

17.5.1.2.1 Adjustable gate layout and pneumatic system layout

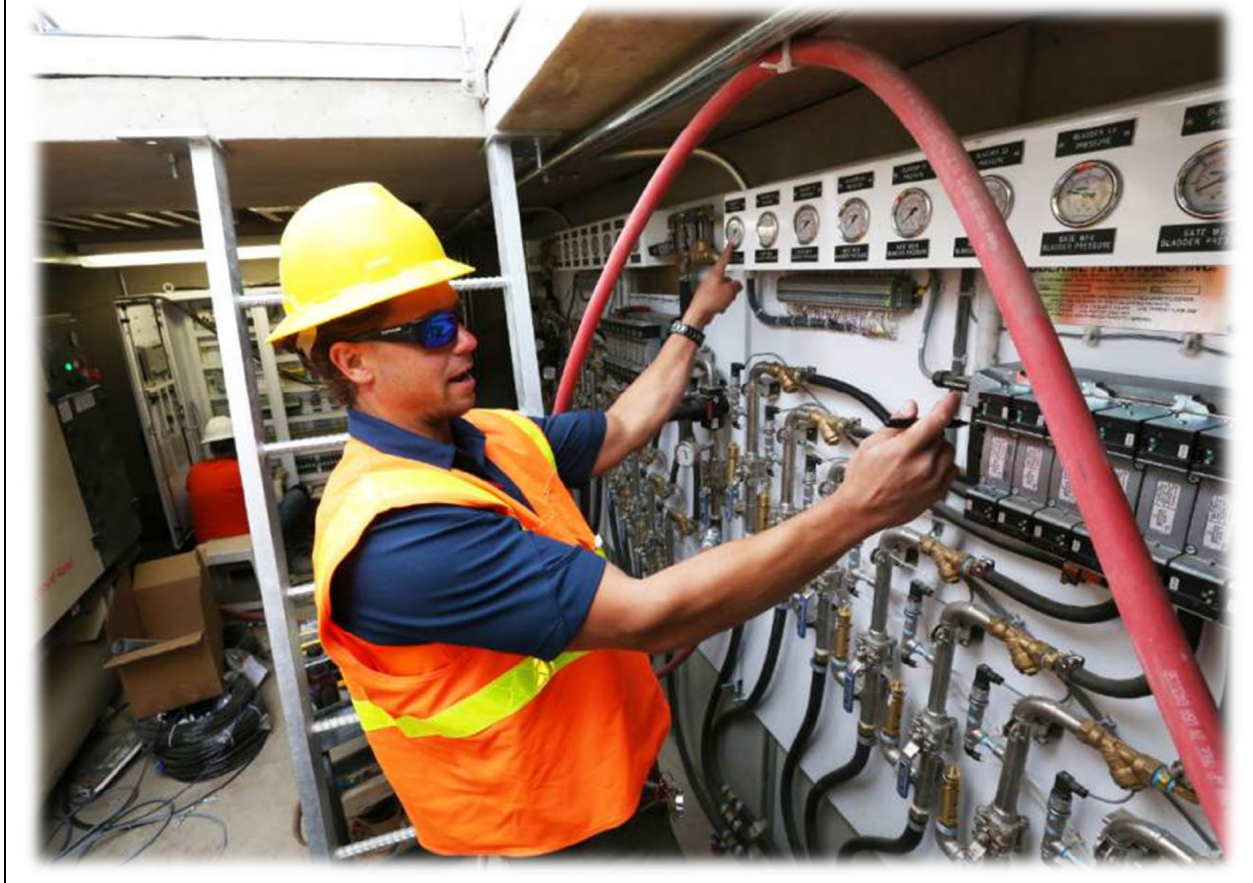
Drawings are from [OTAK overview of Bend Whitewater Park project](#).



PNEUMATIC SYSTEM DIAGRAM



THE CONTROL VAULT



17.5.1.3 Boise Phase 2 cost - 2020



Figure 63: Boise Phase 2

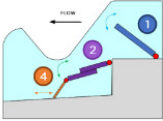
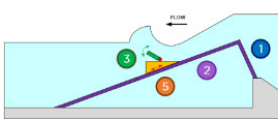
- Built in 2020
- Total cost of the project: \$10M USD
- Three drops with combined width of 480ft or 150m
 - Each drop is about 160ft or 50m wide
- Cost per width: \$20,850 / ft or \$68,351 / m
- Cost for Calgary River Wave Park drop at 100' or 30m = \$2,085,000
- Adjustable gates
 - Four 20' x 10' gates
 - Two 10' bypass channels
 - One 30' S2O designs apron style pneumatic crest gate with rapid bloc
 - Two downstream static kayak waves

17.5.1.4 Construction costs of additional waves

Surf Anywhere provides details of cost and wave styles from around the world at <https://www.surfanywhere.ca/articles/types-of-adjustable-river-waves/>



TYPES AND COSTS OF ADJUSTABLE RIVER WAVES

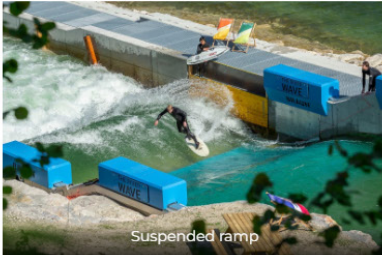

19 JUL 2022 | By Neil Egsgard | In Technology

A variety of adjustable river waves designs make good and consistent waves. Projects costs range from \$100,000 creative commons designs to \$3,500,000 patented wave systems. Low-cost wave designs can make excellent waves. This article provides simple diagrams and costs for wave types. All diagrams are based on published information in news articles, project pictures, or site visits.

Summary of wave costs

All of these wave designs make good waves. All costs are for completed projects except the multi adjustable kicker system which is in engineering.

Wave type	# of waves reviewed	Costs
Kicker at end of ramp	5	80,000 € to 100,000 €
Suspended ramps	3	1,400,000 € to 2,400,000 €
Adjustable ramps without kickers	2	\$1,000,000+ Hard to tell because part of larger projects.
Multi adjustable kicker system	1	\$300,000 Costs TBD still in engineering.

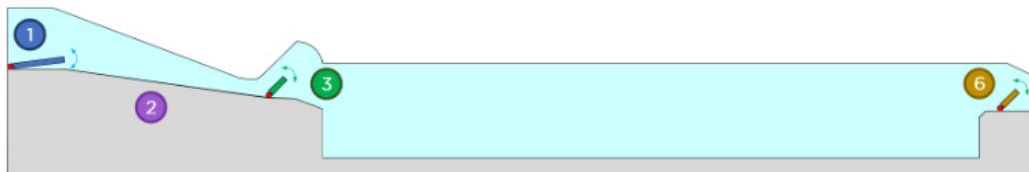





Kicker at the end of a ramp

The kicker at the end of a ramp wave type is a public domain design that consistently makes good perpendicular waves for low cost. More complex versions that adjust ramp angles as well as kicker angle may have patents.

Wave	Width	Cost of completed projects	Year built	Wave design
Almwelle, Austria	5m	Low. 90,000 EUR	2010	Craz Building Waves
Bend, USA	11m	Medium. Small part of a large \$9.7M whitewater and natural park.	2016	Surf Anywhere and River Restoration
Don-Surf, Russia	7m	Low.	2020	Don-Surf
AnnecyWave, France	8m	Low. 90,000 EUR.	2021	Surfeurs d'eau Douce and Hydrostadium
Blackforest Wave, Germany	4.5m	Low. 80,000 EUR.	2021	Blackforest Wave e.V.

Example waves that use variations of a kicker at the end of a rampSimple diagram of kicker at end of a ramp

1. Headwater gate controls the drop size.
2. Fixed ramp accelerates the water for the wave.
3. Kicker shapes the wave angle.
4. Not needed.
5. Not needed.
6. Tailwater gate controls tailwater elevation.

Suspended ramps

These wave systems produce excellent waves, are patented, and they are very expensive. The suspended ramp systems involved precisely lifting and controlling large steel structures weighing over 10 tonnes.

Wave	Width	Cost of completed projects	Year built	Licensor
The RiverWave, Austria	10m	High. Around 2,000,000 EUR.	2019	Patented by The RiverWave
Nuernberg Dauernwelle, Germany	8m	High. 2,400,000 EUR.	2022	Patented by DreamWave
Wolfschhausen wave, Germany	8m	High. 1,400,000 EUR.	On hold	Patented by DreamWave

The RiverWave

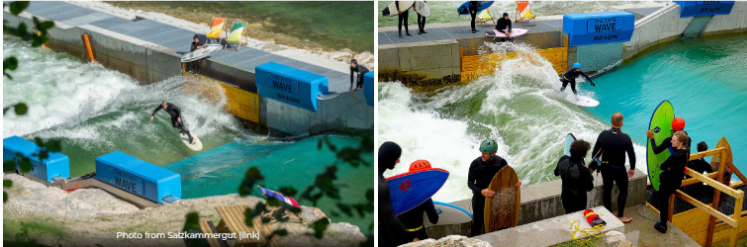
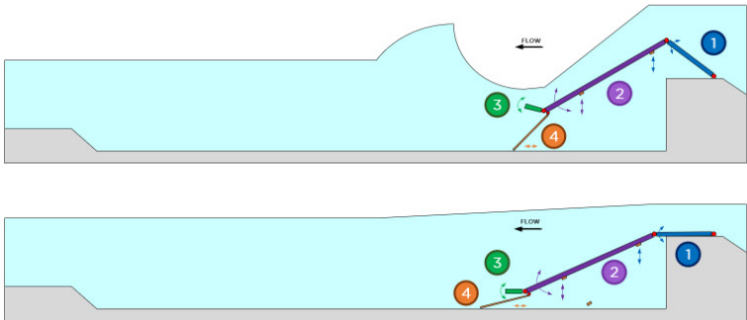


Photo from Salzkannergut (link)

Simple diagram of The RiverWave



Diagrams are not to scale. The ramp is lifted at both the upstream and downstream ends. Tailwater is managed by raising and the lowering the ramp. Wave can be made to disappear as needed.

1. Upstream part of ramp sets the height of the drop.
2. Ramp accelerates the water and helps set wave steepness. Ramp can be fully lowered.
3. Kicker angle shapes the wave steepness
4. Trash gate prevents large material and people from going under the ramp.

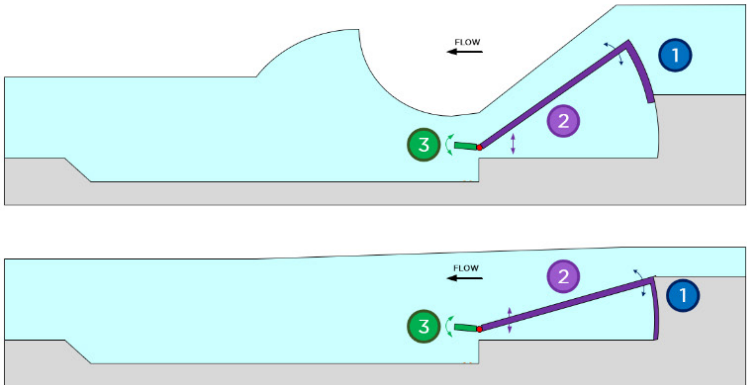
Nuernberg Dauernwelle



Photo from @TotallyRadTV (link)

Photo from Nuernberg-dauernwelle (link)

Simple diagram of Nuernberg Dauernwelle



Diagrams are not to scale. The ramp is rotated to lift upstream end. Downstream end may be liftable. Tailwater is managed by raising and the lowering the ramp. Wave can be made to disappear as needed.

1. Upstream part of ramp sets the height of the drop.
2. Ramp accelerates the water and helps set wave steepness. Ramp can be fully lowered.
3. Kicker angle shapes the wave steepness

Adjustable ramps without kickers

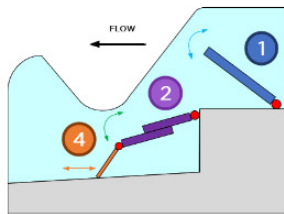
These wave systems produce good waves, are patented, and have a medium to high cost.

Wave	Width	Cost of completed projects	Year built	License
Boise Phase 1 – Waveshaper 2, USA	6.5m or 10m	Medium to high. Part of a \$3M+ whitewater park.	2012	Patented by McLaughlin Whitewater Design Group.
Boise Phase 1 – Waveshaper 3, USA	8m	Medium to high. Part of a \$3M+ whitewater park.	2012	Patented by McLaughlin Whitewater Design Group.

Boise Phase 1 – Waveshaper 2



Simple diagram of Waveshaper 2



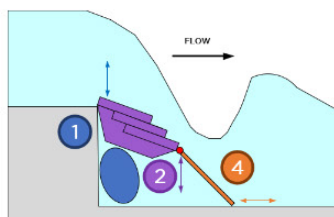
Diagrams are not to scale.

1. Headwater gate sets the drop height.
2. Ramp accelerates the water and sets wave shape.
3. No kicker.
4. Trash gate prevents objects and people from going under the ramp.

Boise Waveshaper 3



Simple diagram of Waveshaper 3



Diagrams are not to scale.

1. Pneumatic bladder inflates or deflates to raise or lower the ramp. The upstream end of the ramp sets the drop height.
2. The ramp angle sets the wave shape. The downstream end of the ramp is raised or lowered using hydraulics.
3. No kicker.
4. Trash gate prevents objects and people from going under the ramp.

17.6 Maintenance costs of Bend and Boise Phase 1

The maintenance costs of well designed river wave parks is low. These parks have an annual maintenance cost of under \$10,000 USD to \$20,000 USD.

17.6.1 Gate life span

Obermeyer Hydro Inc gates, bladders, and air lines in water are rated for 25 years without needing maintenance.

17.6.2 Compressor hour rating

Obermeyer gates require a compressor. Ingersoll Rand rotary compressors are rated for 100,000+ hrs of use.

17.6.3 Actual compressor hours

- Bend compressor was at 38,000 hours after 8 years of use.
- Boise phase 1 compressor was at 3,000 hours after 10 years of use.
- The difference is due to:
 - Number of gates
 - Bend has more gates
 - Length of air lines
 - Bend has much longer air lines
 - Frequency of manipulation
 - Bend gates are more often manipulated
 - Potential leaks in the system
 - Bend has more leaks due to the above factors and, potentially, lower quality fitting install on air lines

17.6.4 Compressor maintenance

The rotary compressors require oil and fluid changes every 2000 hours.

17.6.5 Operators

Both Bend and Boise have:

- 2 full time year-round operators
- Additional 2 full time seasonal operators in summer

17.6.6 Special maintenance

Boise Phase 1 requires season clearing of debris from under the wave. This is due is a design issue cause by the openings in the trash gate under the wave being to large and allowing debris under the wave structure.

18 Key considerations

These considerations inform the design recommendations.

1. Stylish appearance
 - a. Calgary public infrastructure projects are stylish. The appearance of the adjustable river wave needs to align with that image.
2. Existing and proven technology
 - a. The appetite for risk is low at the City of Calgary and technology used should have a long history of consistently making high quality river waves.
3. No negative impact on flooding.
4. Low safety risk.
5. Reasonable and understood maintenance requirements.
6. Relatively simple water diversion or dewatering for maintenance.

19 Key design criteria

These design criteria are critical for a high-quality wave that will provide substantial economic, cultural, and environmental returns. Fundamentals of river wave formation are detailed in the Surf Anywhere article [River Wave Formation at an Abrupt Drop](#). Additional wave design details are in other articles on the Surf Anywhere site.

19.1 Key design criteria for wave function

These criteria are general across most adjustable river waves where a single wave will be used by multiple user groups and with a wide range of flows.

19.1.1 Wave structure flattens to bottom

Minimizes flood impacts and allows wave to disappear when usage is not desired. Structure does not need to be flat but needs a very low elevation when lowered.

19.1.2 Horizontal water velocity

4 m/s horizontal water velocity in the wave trough is needed for good waves.

19.1.3 Flow intensity

1.7 m³/m to 6.5 m³/m. The flow per width that creates good to excellent waves.

19.1.4 Adjustable side walls

Allows higher quality waves for different user groups.

19.1.5 Adjustable width

Allows high quality waves for a wide range of flows by varying flow intensity.

19.1.6 Horizontal transition at different depths

Allows high quality wave for a range of tailwater elevations and ensures low risk wave at all tailwater elevations.

19.1.7 Single connected slope structure across wave channel

Simplifies movements of structure and makes it easier to raise and lower structure for maintenance.

19.1.8 Separately moving kickers across wave structure

Allows formation of a variety of different wave types.

19.2 Key design criteria for location

These criteria are based on location specific risks. Solutions for these issues exist in other wave and whitewater park locations and were considered.

19.2.1 Stylish appearance

Calgary public infrastructure projects are stylish. The appearance of the adjustable river wave needs to align with that image.

19.2.2 Existing and proven technology

The appetite for risk is low at the City of Calgary and technology used should have a long history of consistently making high quality river waves. Proven technology can be used in novel ways.

19.2.3 Flood risk

The Project Area regular gets high flow events that flood the surrounding banks and communities. The structure needs to have no negative impact on flood risk.

19.2.4 Ice jams

The Project area has a history of ice jams. The Project design must minimize the formation of ice jams and avoid flooding cause by ice jams. The collapsible wave structures will assist in the reduction of ice jam formation. There has been extensive study of ice jam formation on the Bow River through Calgary.

19.2.5 High water events

The project area is subjected to regular high water events. The structure needs to survive high water events. The structure needs to be able to generate waves up to 280 m³/s and be lower to near flat at higher flows.

19.2.6 Sediment deposition on the structure

There is substantial sediment deposition in the project area during high flow events. The structure needs to:

1. Minimize deposition of sediment on top of the structure.
2. Easily allow removal sediment if sediment is deposited on the structure.
Removal will be though self cleaning and removal by operations staff.

19.2.7 Sediment deposition under the structure

Sediment will collect under the structure. The structure needs to:

1. Minimize deposition of sediment under the structure.
2. Easily allow annual removal sediment when sediment is deposited on the structure. Removal will be through self cleaning and removal by operations staff.

19.2.8 Floating trees

Trees fall into the Bow and float downstream through the project area. The structure needs to avoid or withstand impacts from trees and other large material floating downstream.

19.2.9 Upstream users

River users will be passing through the wave structure from upstream. The structure needs to allow low risk passage.

19.2.10 Partial dewatering and flow reduction for maintenance

The structure needs to allow for partial dewatering and flow reduction at the structure.

19.2.11 Raising structure in case of lifting mechanism failure

In case the lifting mechanism on the structure fails, there needs to be a secondary method to raise the structure for maintenance.

19.2.12 Operations

Structure operation needs to be possible remotely and onsite

20 Four types of adjustable waves

Four types of existing adjustable waves met the requirements for the Calgary River Wave Park project and were identified from the 30+ adjustable waves reviewed. The recommended solution is a modified version of the flap gate with downstream slope. This section provides details on each of adjustable wave types including:

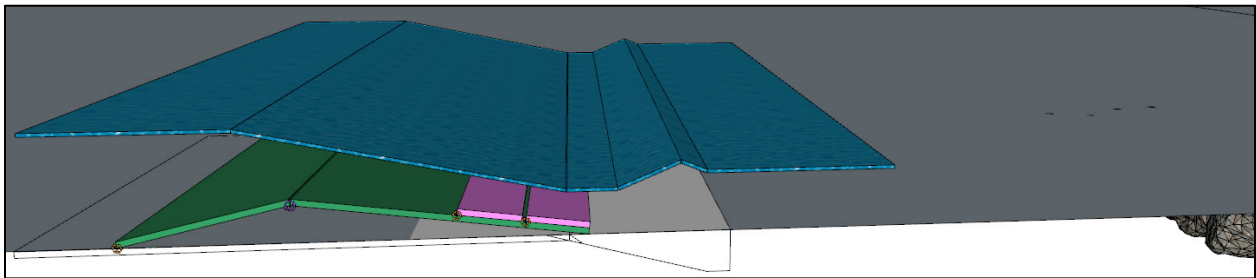
- Flap gate with downstream slope
- Rotating Ramp
- Lifting ramp
- Flap gate with no slope

20.1 Flap gate with downstream slope

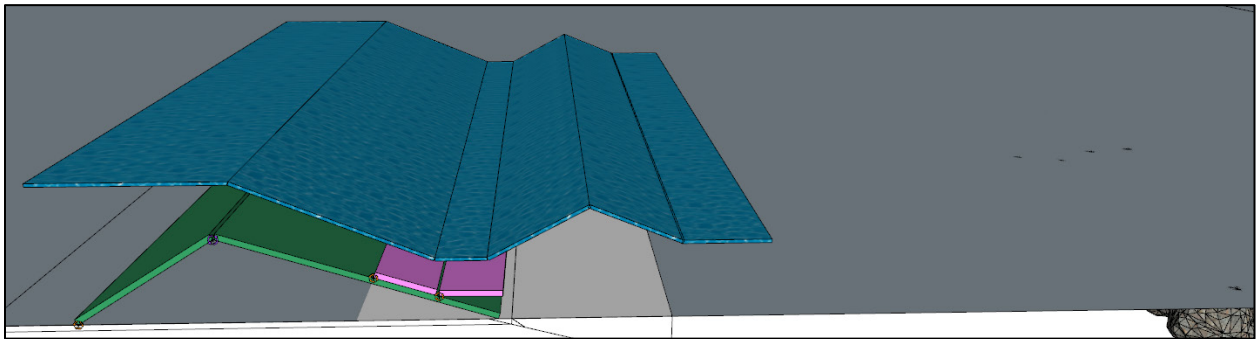
The design is a combination of existing waves technologies. The key design components are:

- Adjustable headwater gate and slope in green.
 - Controls headwater elevation, creates drop, and sets slope angle.
 - Prevents flow over part of channel to keep wave quality in low flow conditions and to make maintenance easier.
 - Continuous across channel.
- Adjustable kickers in purple.
 - Redirects the flow to form a wave. Allows for waves to form at widely different tailwater elevations. Prevents retentive hydraulic formation.
 - Multiple sections across slope. Allows different wave types.

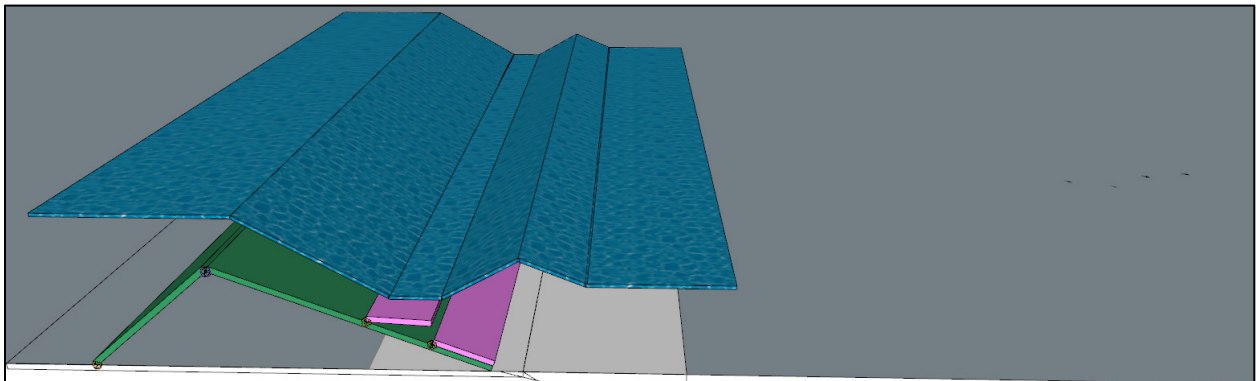
Low tailwater and fixed horizontal transition forms wave



Medium tailwater and first adjustable kicker forms wave



High tailwater and second adjustable kicker forms wave



20.1.1 Examples of existing wave technologies for flap gate slope

These examples explain components of the flap gate with downstream slope. These different components are combined to make the recommended solution,

Boise, Idaho, USA. Phase 2 surf wave.

Consists of:

- Concrete channel walls and floor.
- Continuous 10m flap gate with downstream slope that is raised by one Obermeyer bladder.
- Bolt on side walls to extend the channel walls.
- Bolt on kickers to shape the wave.

Key points:

- Continuous flap gate with down slope generates water velocity and conditions needed for surf wave.



Epinal, France

Consists of:

- Adjustable flap gate with downslope
- Concave concrete transition to sharp drop
- Concrete side walls
- Tailwater elevation control via manually adjustable constriction downstream

Key points:

- Flap gate upstream end slides forwards and backwards, downstream end it fixed.
- Concave transition to sharp drop forms a good wave but very sensitive to any changes in the slope angle or tailwater elevation.



Figure 64: Flap gate with downslope wave in Epinal, France.

Bend, Oregon, surf wave

Consists of:

- Concrete slope and walls.
- Adjustable header water gates at top of slope controlled by obermyer bladders.
- Separate kickers to shape wave.
 - Two kickers are adjustable with one obermeyer bladder under each kicker.
 - Two kickers are fixed.

Key points:

- Adjustable kickers shape high quality waves.





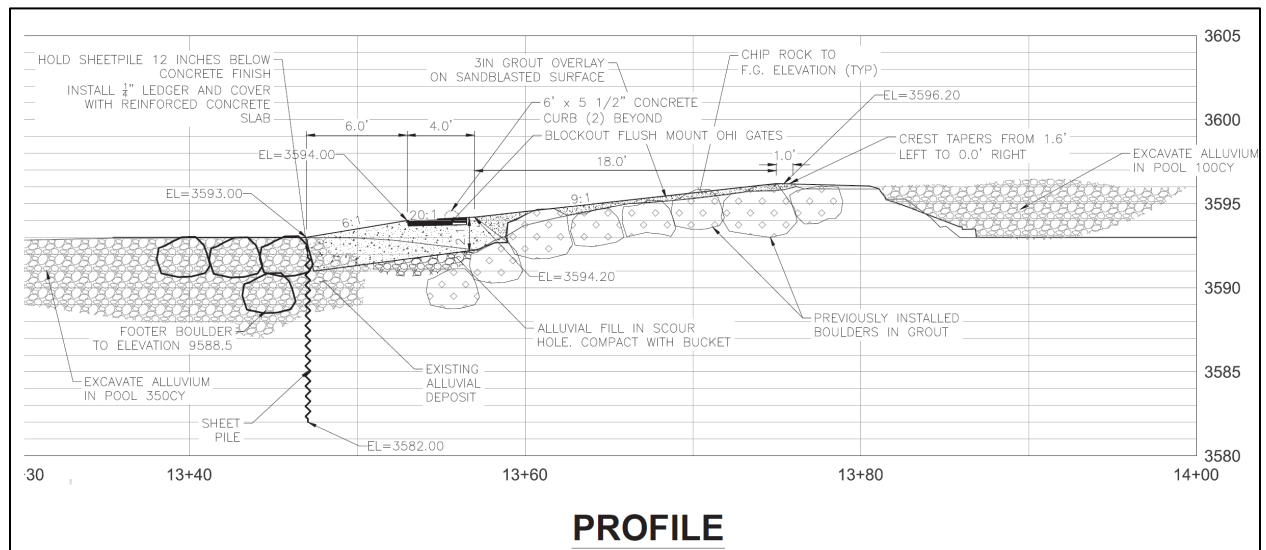
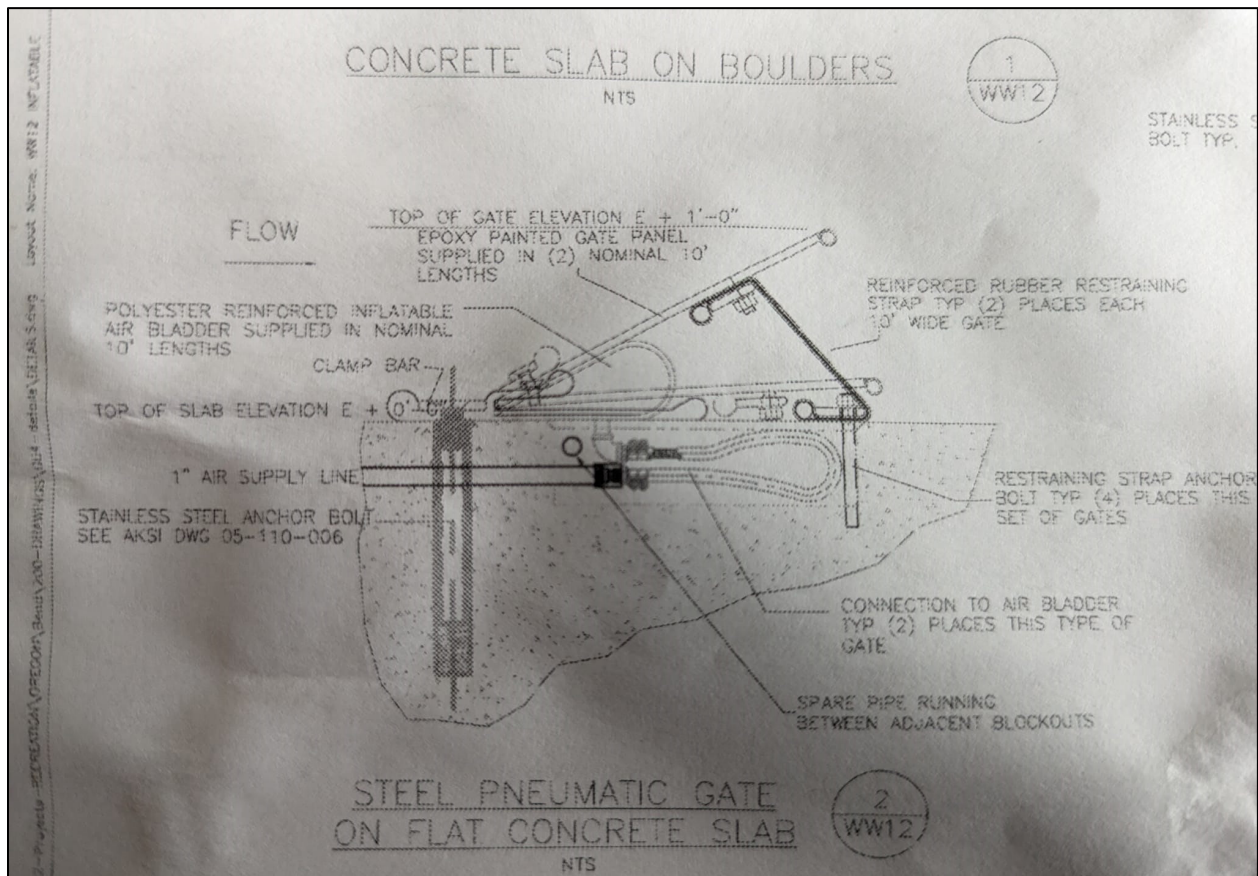
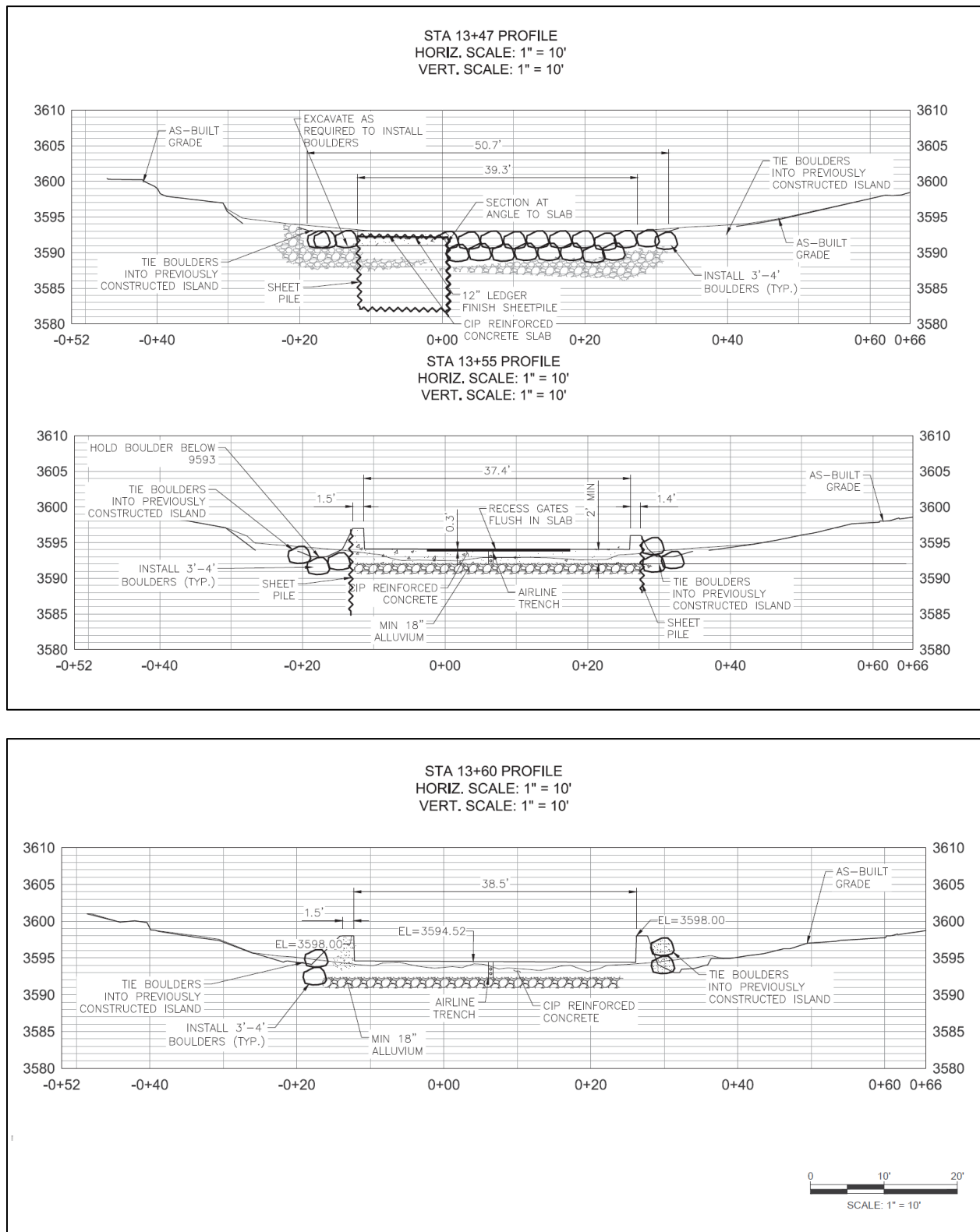


Figure 65: Profiles of Bend adjustable wave drawings from public documents.²⁷

²⁷ (Bend Parks & Recreation District, 2016)

Figure 66: Cross sections of Bend adjustable wave drawings from public documents.²⁸²⁸ (Bend Parks & Recreation District, 2016)

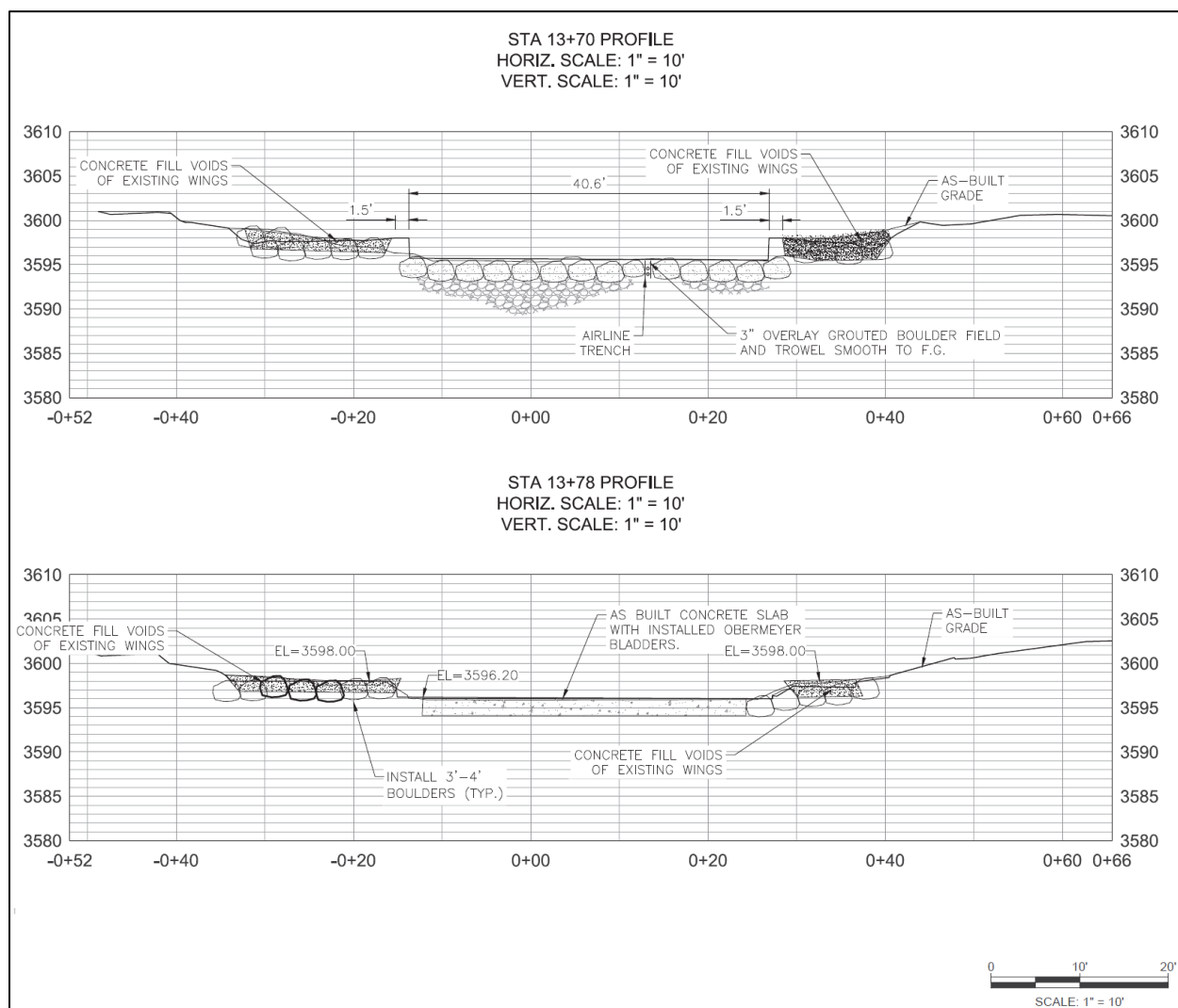


Figure 67: Cross sections of Bend adjustable wave drawings from public documents.²⁹

²⁹ (Bend Parks & Recreation District, 2016)

Scout Wave, Salida, Colorado

Consists of:

- Static wave structure
- Concrete slope
- Concrete transition to sharp drop
- Concrete side walls

Key points:

- Horizontal transition with sharp drop deeper water at end of transition creates good waves without kickers.



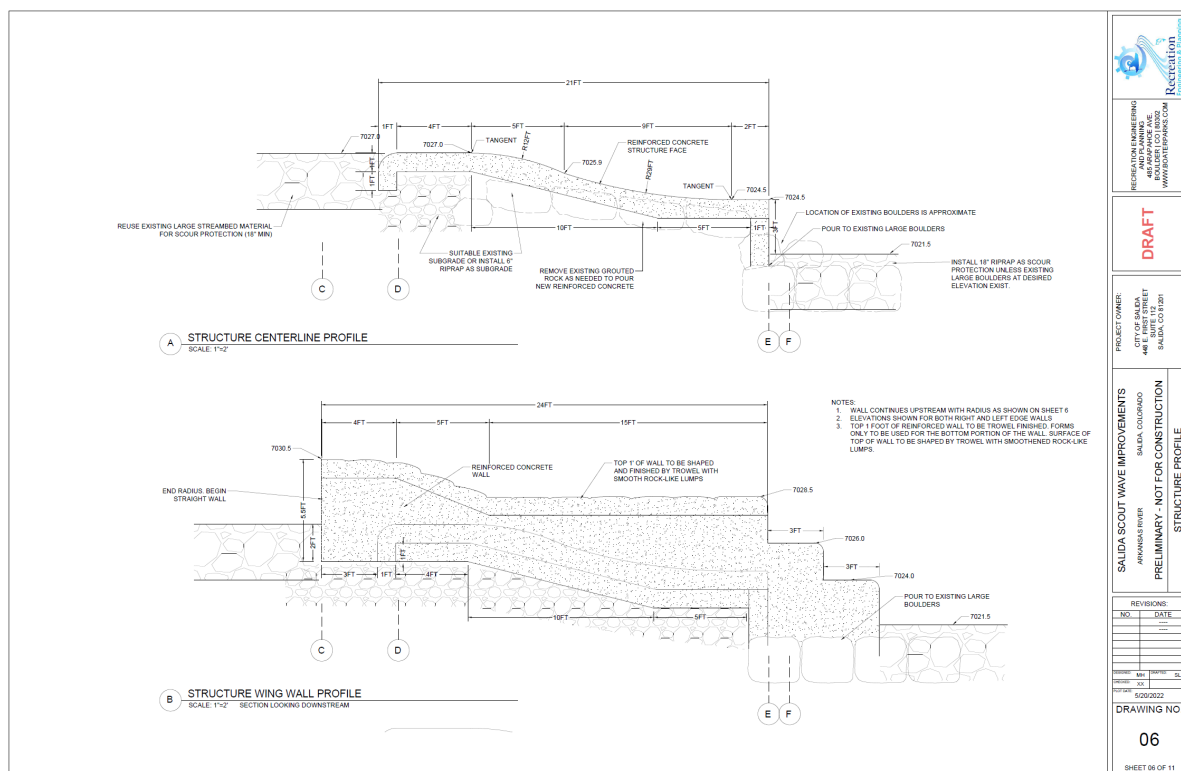
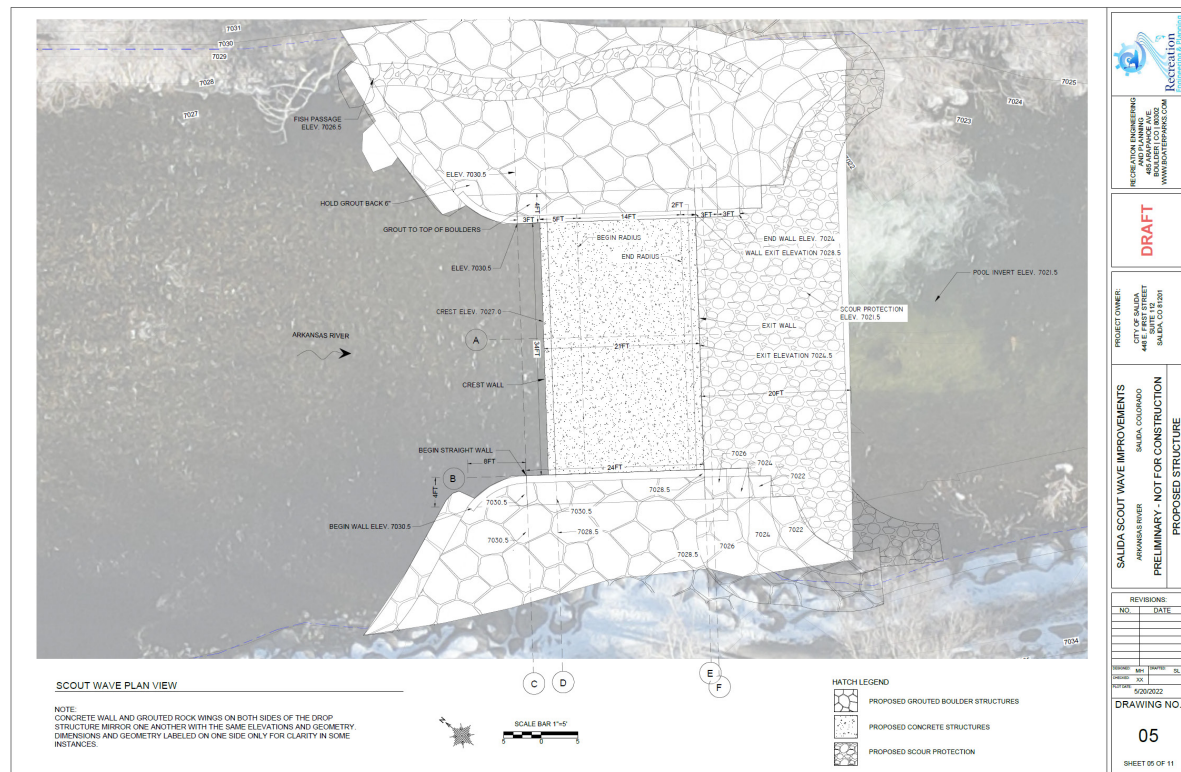


Figure 68: Profiles of Salida wave from public documents.³⁰

³⁰ (City of Salida, 2022)

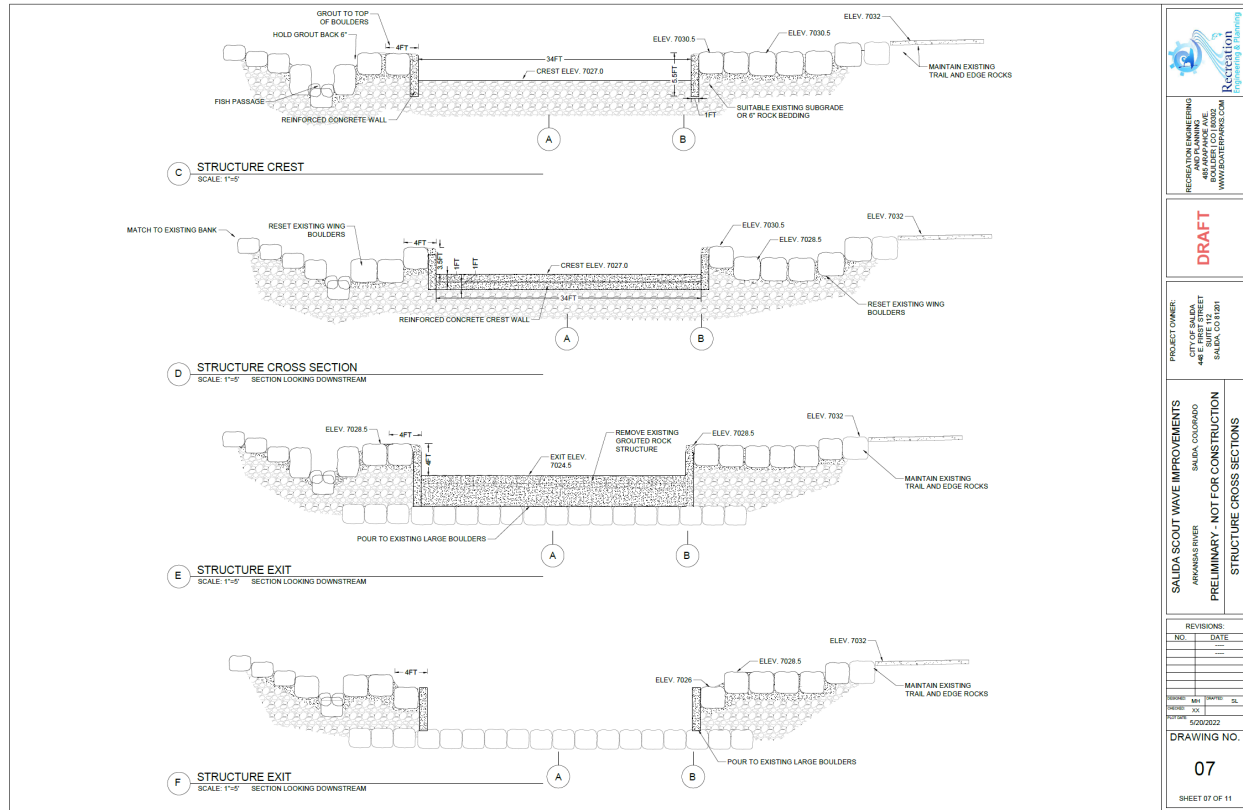


Figure 69: Cross sections of Salida wave from public documents.³¹

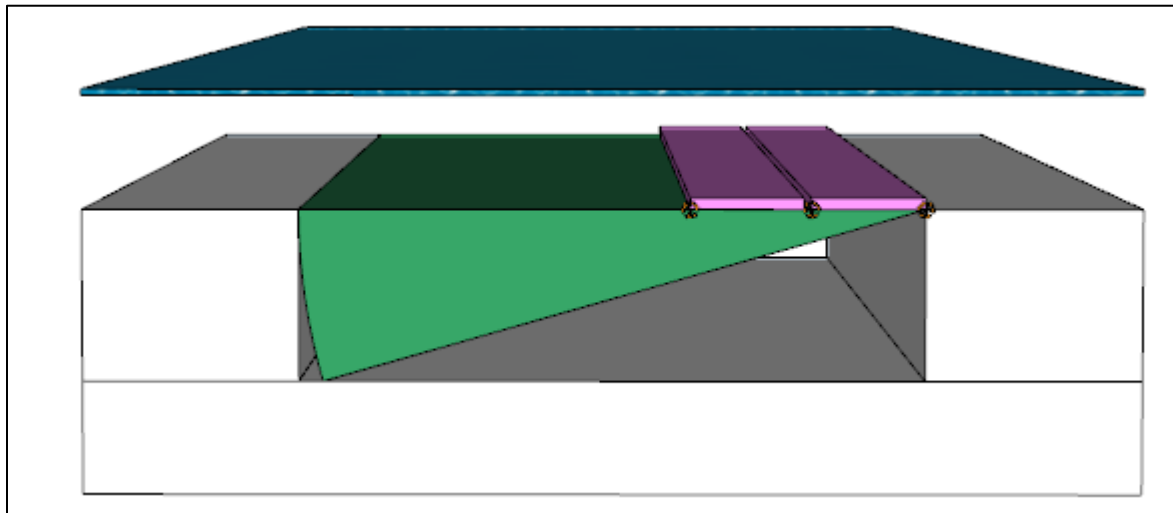
³¹ (City of Salida, 2022)

20.2 Rotating ramp

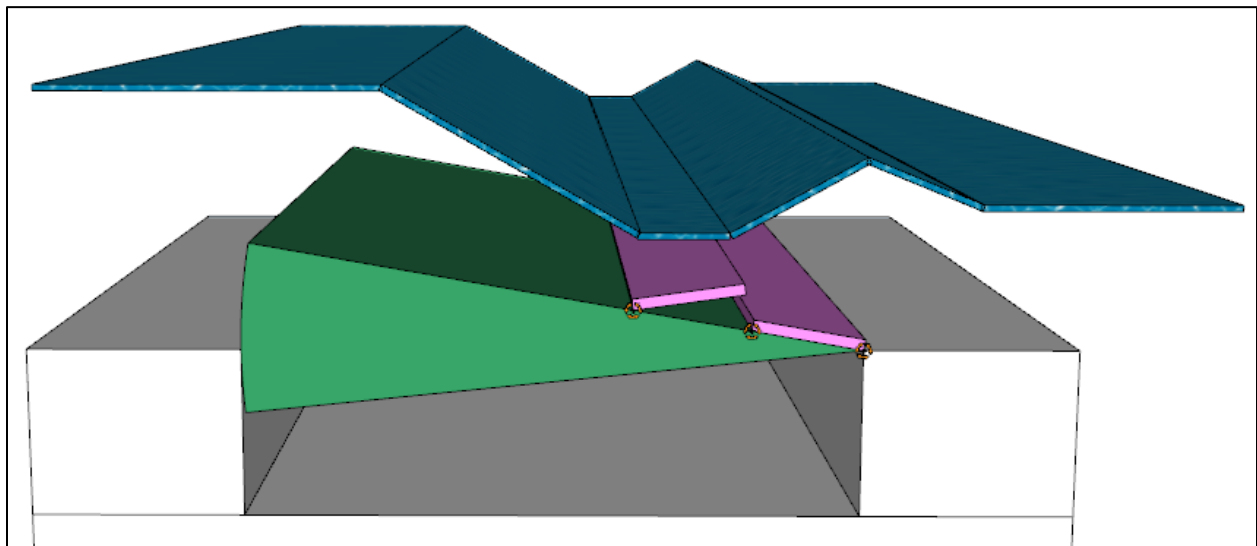
This design is a combination of existing waves technologies. The key design components are:

- Rotating slope in green.
 - Controls headwater elevation, creates drop, and sets slope angle.
 - Prevents flow over part of channel to keep wave quality in low flow conditions and to make maintenance easier.
- Adjustable kickers in purple.
 - Redirects the flow to form a wave.
 - Multiple parallel kickers allows for waves to form at widely different tailwater elevations.
 - Prevents retentive hydraulic formation.

Lowered to flat



Slope rotated up and kicker rotated to form wave



20.2.1 Example of existing wave technologies for rotating ramp

Installation of a DreamWave that rotates upwards



Three section DreamWave at LeineWelle, Hanover, Deutschland.



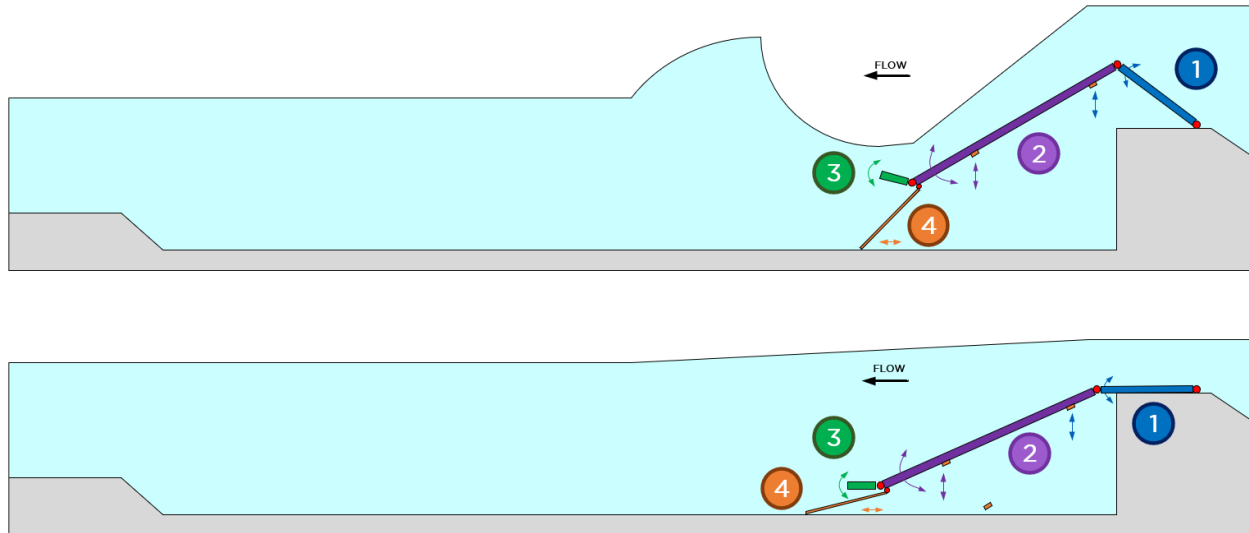
One section active and two sections blocking water.



20.3 Lifting ramp

This style of system produces waves using a fully suspended slope that lifts at both the upstream and downstream ends. The key design components are:

1. Upstream part of ramp sets the height of the drop.
2. Ramp accelerates the water and helps set wave steepness. Ramp can be fully lowered.
3. Kicker angle shapes the wave steepness.
4. Trash gate prevents large material and people from going under the ramp.



20.3.1 Example of existing wave technologies for lifting ramp

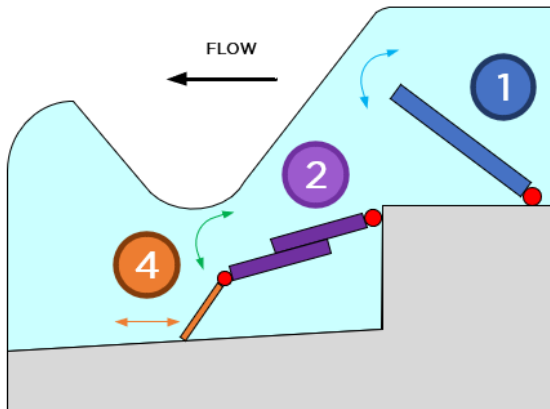
The.RiverWave in Ebensee, Austria.



20.4 Flap gate with no slope

This style of system produces waves using a flap gate and a separate adjustable river bottom. The key design components are:

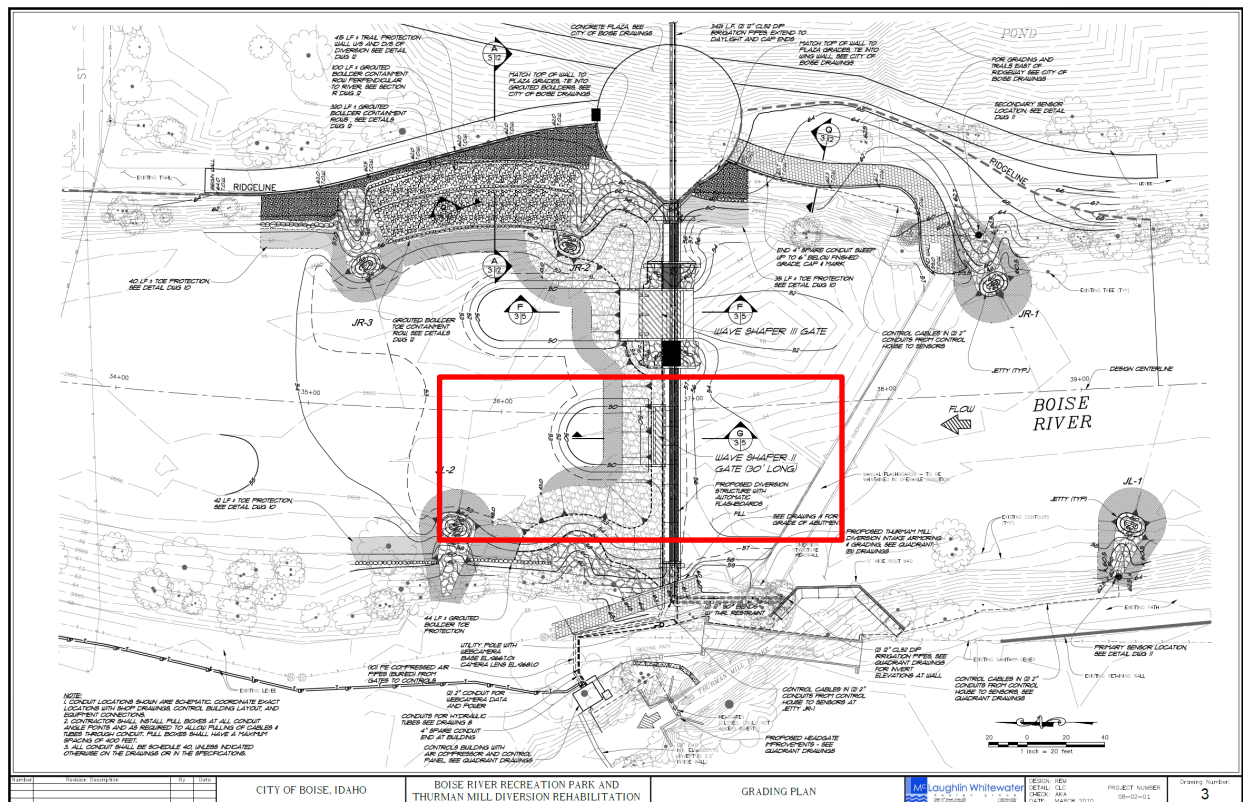
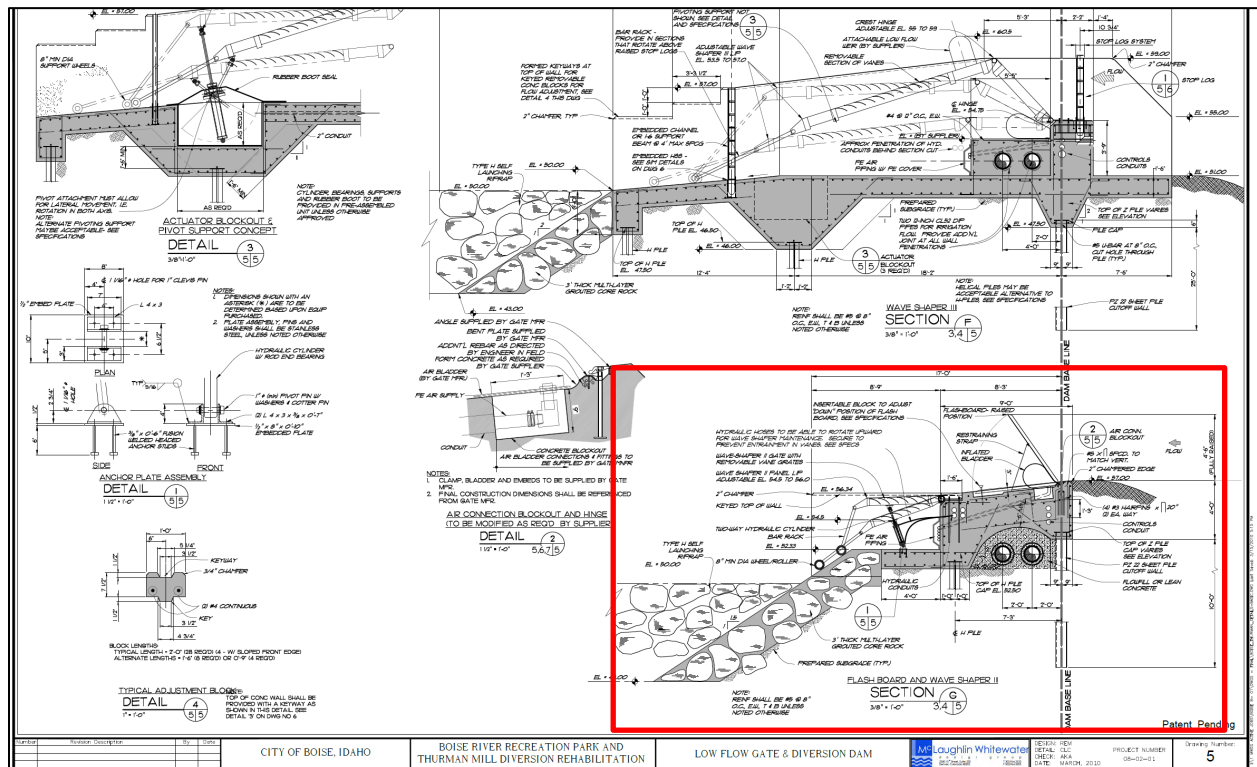
1. Headwater gate sets the drop height.
2. Ramp accelerates the water and sets wave shape.
3. No kicker.
4. Trash gate prevents objects and people from going under the ramp.

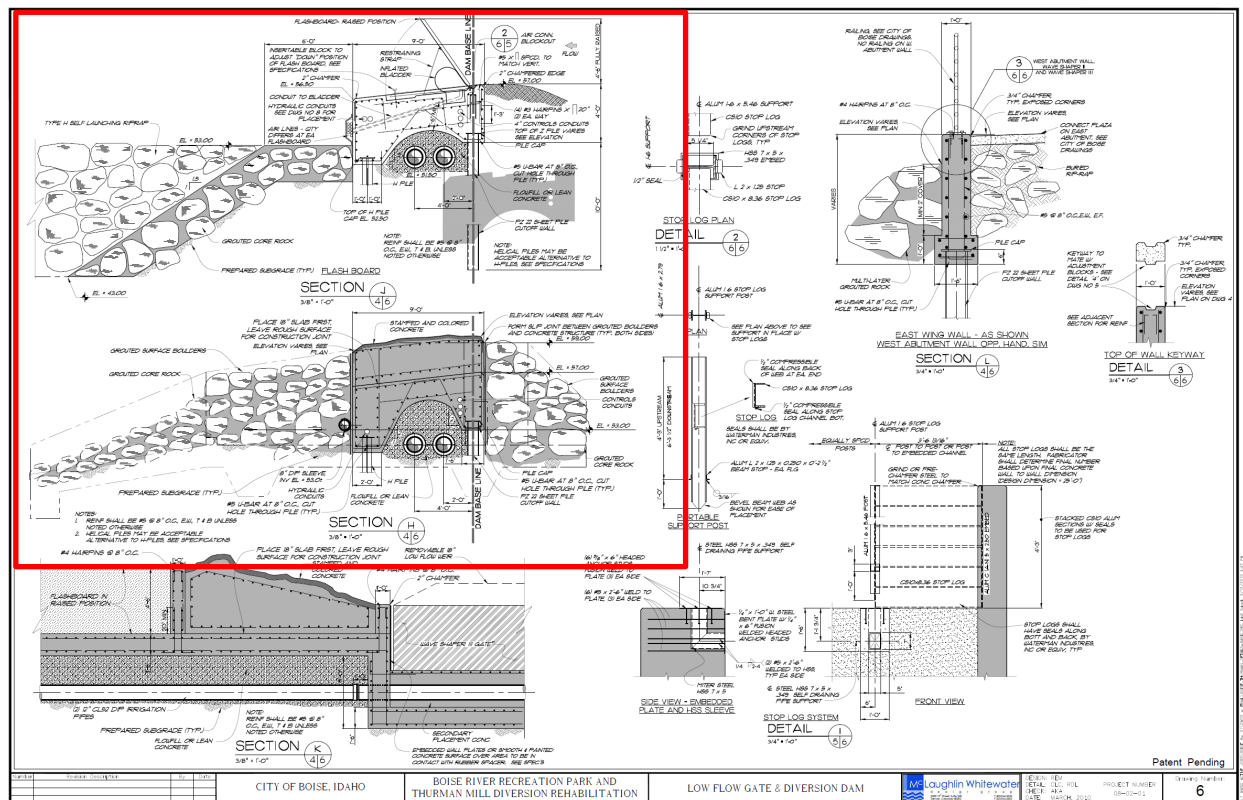
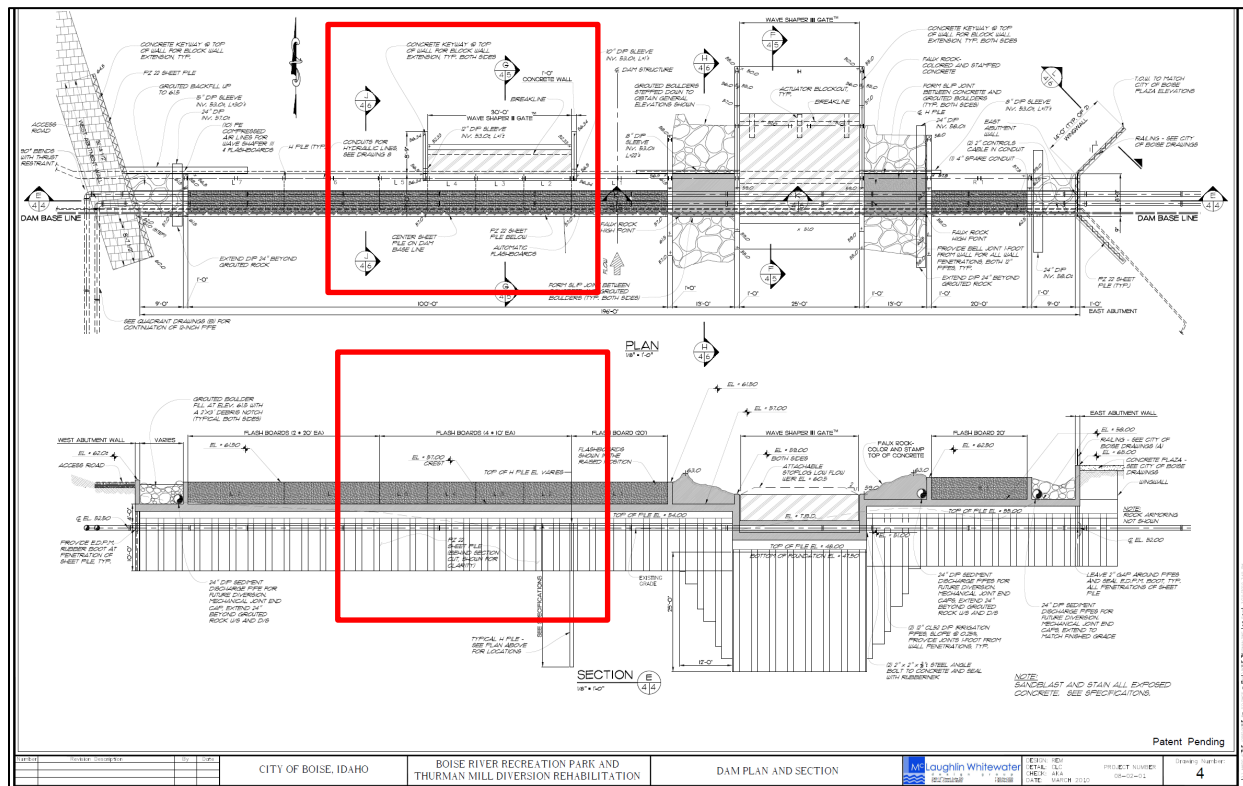


20.4.1 Example of existing wave technologies for flap gate with no slope

Boise Phase 1, Idaho, USA



Figure 70: Plan and profile drawings of Boise wave from public documents.³²³² (City of Boise Planning & Zoning Commission, 2011)

Figure 71: Cross section and profile drawings of Boise wave from public documents.³³³³ (City of Boise Planning & Zoning Commission, 2011)

21 Drawings from other projects

This documents contains excerpts from engineering drawings from other successful adjustable river wave projects. All drawings are from publicly posted reports on municipal council and administration and other government websites.

- Boise Phase 1, USA
 - [Boise Phase 1 engineering drawings](#) (2010)³⁴
- Bend, USA
 - [Bend surf wave engineering drawings](#) (2016)³⁵
- Boise Phase 2, USA
 - [Boise Phase 2 modification hydraulic analysis](#) (2023)³⁶
 - [Boise Phase 2 modification engineering drawings](#) (2023)³⁴
- Scout Wave, Salida, USA
 - [Scout Wave, Salida, engineering drawings](#) (2024)³⁷
- Springbank Off-Stream Reservoir, Alberta
 - [Springbank Off-Stream Reservoir tender drawings](#) (2021)³⁸

Boise Phase 1 (2010)



Boise Phase 2 (2020)



Bend (2016)



Salida (2024)



³⁴ (Public Hearing CFH11-00022, 2011)

³⁵ (Bend Whitewater Park Winter 2017 Modifications, 2016)

³⁶ (2023 Winter Spillway Modifications, 2023)

³⁷ (Council Action - Approve entering into a contract with Lowry Contracting Inc. upon legal team review., 2022)

³⁸ (Springbank Dam Project Tender, 2021)

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