

Resilient Waters

Tide Gates, Flood Gates, and Fish Passage on the Lower Fraser

A literature review and case studies from around the world



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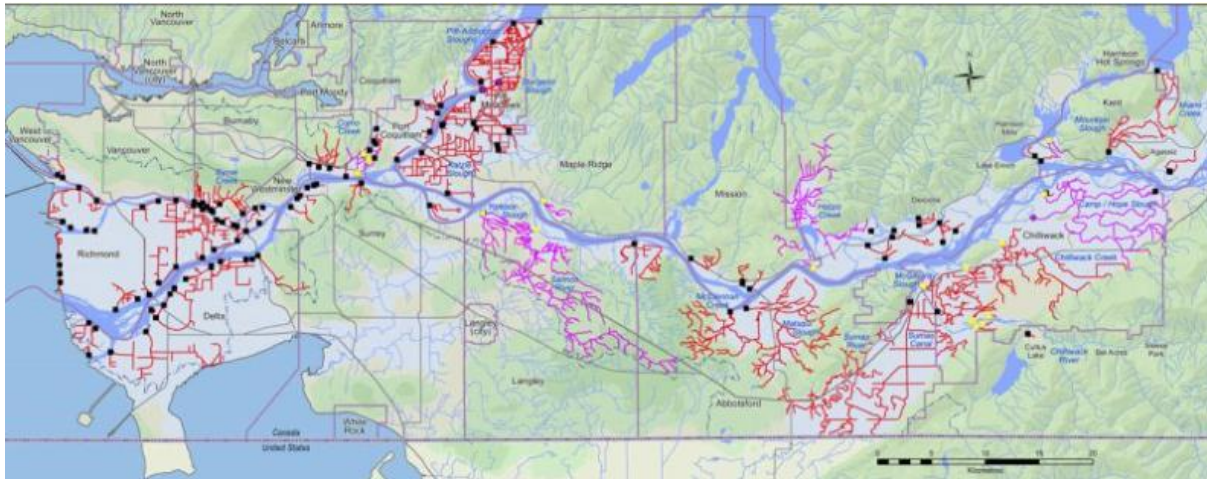
2021 by Resilient Waters

Tide Gates, Flood Gates and Fish Passage on the Lower Fraser

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Introduction



Map of the Lower Fraser River, depicting sites of flood control infrastructure and disconnected waterways¹

The Lower Mainland serves as the beginning of one of the most prolific salmon rivers in the world, supporting more than half of the Fraser River's Chinook (*oncorhynchus tshawytscha*) and Chum (*oncorhynchus keta*), 65% of its Coho (*oncorhynchus kisutch*), 80% of its Pink (*oncorhynchus gorbuscha*), and significant stocks of Sockeye salmon (*oncorhynchus nerka*). It is also more impacted by human land-use than any other watershed in BC. Recent research estimates that 85% of historic floodplain habitat has been alienated from the main stem Fraser². One significant cause is aging flood control infrastructure (FCI) which inhibits connection to vital habitats for spawning, rearing, and migrating salmonids, as well as other species at risk. In 2018 Watershed Watch Salmon Society identified over 1,500 km of potential habitat disconnected from the main stem of the Fraser by 150+ floodgates, tide gates, pump stations, and 250 km of dikes. These waterways are known rearing habitats for Chinook and Coho salmon and are integral to ensuring their ability to begin their transition to life in the ocean, which is the most vulnerable point in their lives. Restoring access to these important habitats in the lower Fraser will be an important part of any recovery strategy for these endangered salmon.

Much of the FCI blocking these waterways was constructed between 1950 - 1970 and requires replacement in the near future due to impending climate change impacts such as increased flooding and sea level rise and/or reaching the end of its service life. This represents a unique moment and urgent opportunity to ensure that FCI throughout the lower Fraser watershed is replaced with fish-friendly and climate resilient infrastructure to protect salmonids and the communities that rely on them.

The thirty-one First Nation communities of the lower Fraser River watershed are especially impacted by the overlapping crises of salmon loss, increasing flood risk, and climate change. As the majority of First Nations' reserve lands are located within floodplains, they are disproportionately impacted by increasing flood events and sea level rise caused by climate change. The current FCI is increasingly

¹ [Watershed Watch Salmon Society, 2018. Disconnected Waters Regional Map](#)

² [Quantifying lost and inaccessible habitat for Pacific salmon in Canada's Lower Fraser River, 2021](#)

ageing and is inadequate to protect their communities and sites of cultural significance. The Fraser River serves as a crucial source of economic and cultural subsistence for First Nations here, and throughout the Fraser Basin.

The Lower Mainland (made up of Metro Vancouver and Fraser Valley Regional Districts) is rapidly being developed for residential, agricultural, industrial and other land uses. Metro Vancouver is the 12th fastest growing region in North America projected to grow by 20% between 2020 and 2030. Meanwhile, despite making up just 2.4% of agricultural land in the province, the Fraser Valley Regional District (FVRD) produces 38% of provincial gross annual farm receipts and is the most intensively farmed land in Canada. Farmers rely on flood infrastructure for both water storage for irrigation and to keep flood waters at bay.

Concerns for Salmonids

There are five predominant species of salmon in the Lower Fraser; Chinook, Coho, Chum, Pink and Sockeye. All of which require cool, clean and unobstructed water to complete their life cycles and migrations back to their ancestral streams. The implementation of flood control infrastructure is just one of many impacts affecting salmon health including climate change, overfishing, development and pollution all stand in the way of the species' success.



Chum Salmon ³

Not only does FCI physically disconnect waterways it also impacts water quality and can change the salinity lens upstream. This affects juvenile salmon which may go into shock, delay or cut migration short due to the sharp change in salinity. For example, if a smolt migrating downstream passes through a gate that is more often closed, the pH will likely differ dramatically on the opposite side, which can cause the fish to go into osmotic shock (Guillermo Giannico and Jon A. Souder, 2005). Juvenile salmon require a slow, moderate change in salinity as they transition from their vulnerable juvenile stages to smolt, and then adult (Guillermo Giannico and Jon A. Souder, 2005). The absence of this intrusion of saltwater in upstream habitats also affects soil health and can lead to oxygen

³ Resilient Waters, 2021. Photograph of Chum Salmon

depletion (Guillermo Giannico and Jon A. Souder, 2005). Flood control infrastructure such as dams, tide gates, floodgates, dikes, locks, and other FCI all pose this problem.

Old, cast iron tide/floodgate system ⁴

Fish-friendly Tide gates and Floodgates

For decades FCI such as tide gates and floodgates (sometimes referred to as flap gates) prevent tidal waters and rivers from flooding adjacent farmland while floodgates similarly control seasonal flooding. Most of these structures are not properly maintained or replaced, and are now failing across North America. On top of which the old designs, though having served their purpose, were not designed with ecosystems and fish passage in mind.

Many of these structures usually feature a simple design that blocks flow from a river or ocean from moving up a stream or across a floodplain, while allowing flow from a stream into a river or ocean. Top hinge gates were prominently and historically used for managing floods, however the top hinge design prohibits flows most of the time decreasing connectivity. This is due to their design and operation, as they rely on head pressure to open, and their narrowness and infrequency of opening makes it almost impossible for fish to pass.

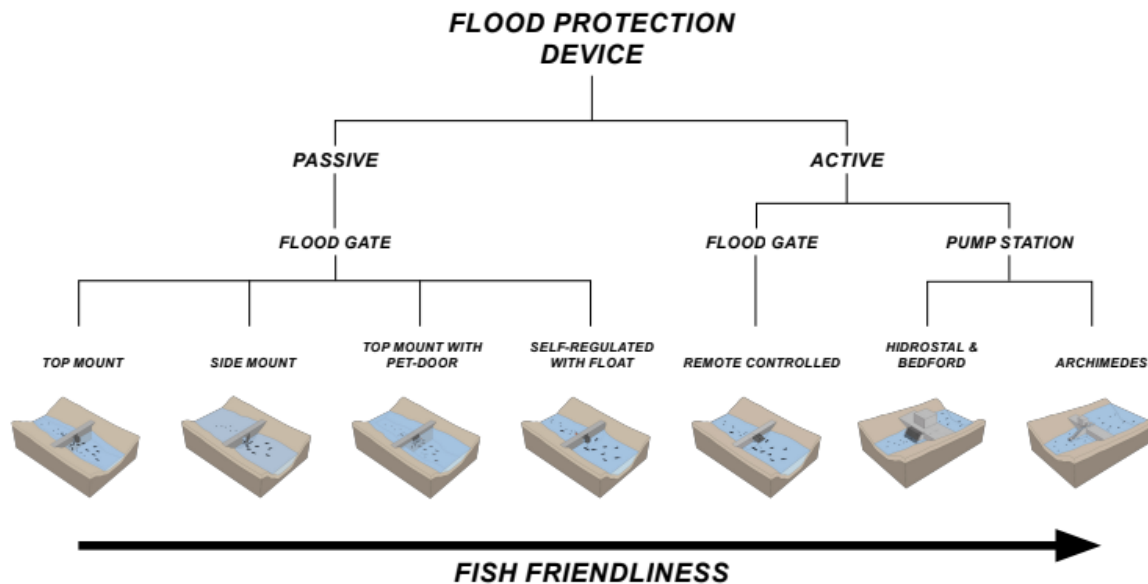


Interdisciplinary, and more fish-friendly gates feature at the very least; a side-hinge design (optimal for fish passage), a wide opening, and an extended opening time. Additionally, many gates are now able to self-regulate based on water levels behind the gate (optimal for connectivity) allowing for maximum connectivity before closing. Although self-regulating features allow the operator to pre-determine how high inundation levels may reach gates, they should also allow for simple manual operation.

⁴ Nehalem Marine Manufacturing, 2013. West Coast Salmon Summit PDF

Non-Fish-Friendly Vs Fish-Friendly Tide gates and Floodgates

Non-Fish Friendly	Fish-Friendly
• Tide gates and floodgates focused solely on preventing tidal or seasonal flood waters from inundating adjacent dry lands	• Modern day tide gates and or floodgates allow for increased connectivity for fish, while preventing flooding for many more years to come.
• Seldomly open and therefore block fish passage	• New technology can self-regulate based on predetermined water levels (of the estuary) set by the user. • Can also be manually operated (or closed) at any given time.
• Often made out of wood or a heavy metal in a square, box-like form with a top hinge design which often collects debris. • Manually operated.	• Preferably made out of aluminum, in a square or circular shape with a more efficient side-hinge design. • They can be remotely or manually operated.
• Most are well past their end-of-life and are failing across North America. • No maintenance/ post monitoring plan.	• Longer life-span. • Interdisciplinary. • Maintenance/ post monitoring plan.



Tide gate or Floodgate?

The naming convention for tide gates and floodgates varies depending on region and circumstance. Although the structural components and design of both tide gates and floodgates are mostly the same, they do differ in their use case and this in turn can affect some design aspects. Tide gates are implemented in tidal zones and function in response to daily tidal fluctuations. Floodgates on the other hand are usually implemented more inland, in areas that experience seasonal flooding such as freshets. Of course, there are areas that are influenced by both tide cycles and river freshet. As you move upstream (up in elevation) tidal influence is diminished. For the Fraser River system tidal influence stops having much of an effect around the City of Surrey. Gates in these cases must serve both use cases so terminology becomes more difficult.

Currently the terms are often used interchangeably, and gate manufacturers may only refer to them under one name, which can be unintentionally misleading. The Nature Conservancy has been found to make a point of using the correct terminology based on use-case, which suggests that making a distinction between the two is beneficial.

Designs and Manufacturers

Today there are a handful of solution companies that manufacture tide and flood gate technology. Many common manufacturers' products are part of a larger range of water infrastructure solutions, and are not usually developed with salmonids or other fish species in mind. These solutions often feature older, heavier designs and regulate based off of the incoming direction of flood waters which in many cases prematurely close the gate. There are many other old, and new tide and flood gate solutions all bearing different features attempting similar goals.

Top Hinge

Still a popular design today, and the most prevalent design used in the lower Fraser watershed, older models of top-hinge gates are most often made of cast iron (while some more modern designs may use a lighter aluminum. The oldest structures can also be made out of wood. Due to the location of the hinge / fulcrum being at the top, it requires a significant amount of hydraulic head difference to open the gate. Due to this feature this style of gate has been widely installed throughout tidal and flood zones successfully preventing agricultural lands from flooding (Guillermo Giannico and Jon A. Souder, 2005).



Top-hinge style tide/floodgate (Pre-install) ⁵

Top-hinge style tide/floodgate (Pre-install) ⁶

Pros	Cons
• Requires little maintenance • Heavy cast iron material keeps the device closed for long periods • Efficiently prevents flooding from rivers and streams backflowing	• Heavy cast iron material keeps the device closed most of the time, for longer than necessary • Older wooden designs become waterlogged • Collects debris • Discourages and or prevents fish passage • Default closed position

⁵ Nehalem Marine Manufacturing, 2021. Products, Product List

⁶ Nehalem Marine Manufacturing, 2021. Products, Product List

Bottom Hinge

An older design, the bottom-hinged gate features an arm and adjustable float. The hinging system was designed with a trip mechanism that closes the lid whenever the float rises. They are usually made out of wood and fiberglass for a buoyant design (Guillermo Giannico and Jon A. Souder, 2005).

Pros	Cons
• Adjustable float	• Closes with small tidal fluctuations • Easily clogged and or disabled by debris. • Prevents fish passage • Default closed position

Rubber Duckbill

The Rubber Duckbill design is unique in comparison to other technologies. It is made out of a flexible rubber with a vertical slot opening that is attached to the end of a culvert (Guillermo Giannico and Jon A. Souder, 2005). Their opening is pliable yet strong with a default closed position. Similar to the Radial gate this design requires just a small differential in the hydraulic head to open. This design is also known as (and is manufactured by) the company Tideflex.



⁷ Rubber Duckbill design by Tideflex

Pros	Cons
• Low maintenance (collects little debris) • May pass small juvenile fish	• Prevents fish passage (may pass small juveniles) • Prevents upstream water movement, causing water quality and environmental degradation • Default closed position

Vertical Sluice Gate

Vertical Sluice Gates are simple mechanisms, square or rectangular in shape that vertically slide to open and close. They are often used to manage reservoirs or canals but have also been implemented for flood control within floodlands. They can be manually or remotely controlled and are usually made of aluminum or stainless steel.

⁷ Measurit, 2020. Tideflex used on Forres Flood Alleviation Scheme



Vertical sluice gate by Watch Technologies ⁸



Vertical sluice gate installation by Watch Technologie ⁹

Pros	Cons
Can be remotely controlled	- Lacks a dynamic design - May collect debris - Default closed position

Side Hinge

There are many different versions of side-hinged gates, most of which today are manufactured out of aluminum or stainless steel in a square or circular design attached to a culvert (sometimes integrated into cement). The aluminum gates are lighter in design and require little upstream water pressure to open. To ensure this function, the top side hinge should be installed closer to the culvert's mouth which creates the restorative force (by creating a slight tilt) necessary for the gate to close (Guillermo Giannico and Jon A. Souder, 2005).



Side-hinged tide/floodgate array by Nehalem Marine Manufacturing ¹⁰

Pros	Cons
Collects less debris	Can be more costly

⁸ Watch Technologies, 2019. Sluice Gates/ Slide Gates Gallery

⁹ Watch Technologies, 2019. Sluice Gates/ Slide Gates Gallery

¹⁰ Nehalem Marine Manufacturing, 2013. West Coast Salmon Summit PDF

• Allows for a wider opening	• Requires precise angles and engineering • Default closed position
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Side-Hinged Radial Gate

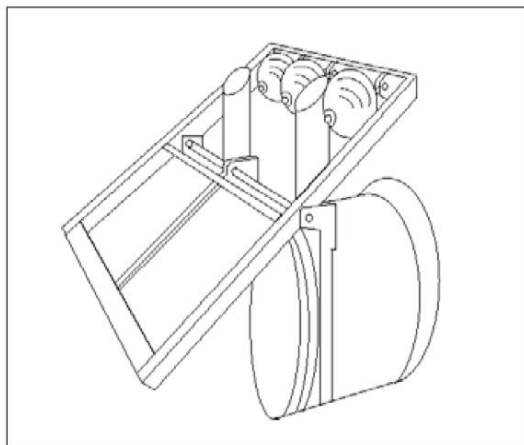
Another version of the side hinge gate is the radial gate. A radial tide/ flood gate is distinguished by its concave lid, with the crescent shape of the lid protruding outside the structure (Guillermo Giannico and Jon A. Souder, 2005). This design is also referred to as the Gator Gate.

Pros	Cons
• Inexpensive	• Vulnerable to damage • Crescent shaped lid may prevent fish passage • Default closed position

Manufacturer/ Function-Specific Designs

Self-regulating or Buoy

A variation of the top-hinged design, a self-regulating gate differentiates itself by its buoyant lid and counterbalancing arms coupled with floats that keep the gate in a default open position (Guillermo Giannico and Jon A. Souder, 2005). As most gates feature a default closed position this design allows



for a much greater exchange in flow and connectivity. The floats can also be adjusted to the demands of its distinctive environment allowing the gate to close during specific tidal or flood periods. [Golden Harvest](#) and [Waterman Industries Inc](#), both North American developers, have each manufactured their own unique, but similar goal-orientated designs that are commonly used today.

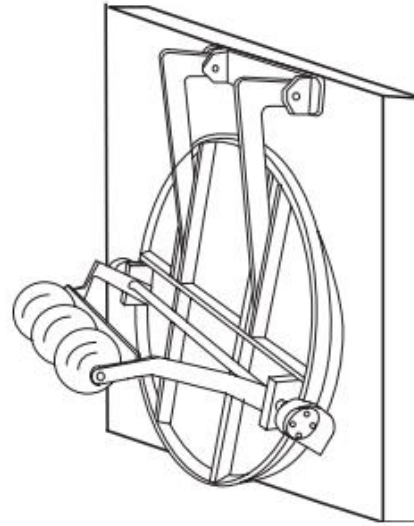
Self Regulating, top-hinged tide/flood gate, with buoy¹¹

Pros	Cons
• Default open position • Adjustable floats • Allows for a greater tidal exchange	• Floats collect debris • Can be more costly

¹¹ Guillermo Giannico and Jon A. Souder, 2005. Tide gates in the Pacific Northwest, Operation, Types, and Environmental Effects

Mitigator Fish-Passage Device

The Mitigator Fish Passage Device features a unique design that was invented by [Nehalem Marine Manufacturing](#) (Guillermo Giannico and Jon A. Souder, 2005). The device is usually attributed to a top-hinged, round style gate (less often a side-hinge) and features an aluminum double hinge design. Its default open position allows for increased connectivity and its float and cam-lock system keeps the gate partially open during flood tide (until a certain level is met) (Guillermo Giannico and Jon A. Souder, 2005). The design was intentionally developed to increase fish passage and connectivity and has been widely implemented throughout the pacific west coast of the United States.



Mitigator Fish-Passage Device on a top-hinged style gate ¹²

Pros	Cons
• Default open position • Adjustable floats • Allows for greater tidal exchange • Increases fish passage	• Proprietary design (not easily replicable at scale) • Can be more costly • Collects debris • Although to a lesser extent, most structures still discourage fish passage

Muted Tidal Regulator

A Muted Tidal Regulator (known as an MTR) is another device invented by [Nehalem Marine Manufacturing](#) and is often attributed to a side-hinged gate. This device features similar characteristics to the Mitigator Fish Passage Device but regulates based off of the flood elevations of the inlet pool. While most designs respond to tidal levels of the site-specific estuary, or area of incoming headwaters, an MTR responds to water levels behind the mouth of the gate (Guillermo Giannico and Jon A. Souder, 2005). This greatly increases connectivity and allows for greater control

¹² Guillermo Giannico and Jon A. Souder, 2005. Tide gates in the Pacific Northwest, Operation, Types, and Environmental Effects

and response to freshwater inflows. Again, similar to the Mitigator Fish Passage Device this design has been successfully adopted.

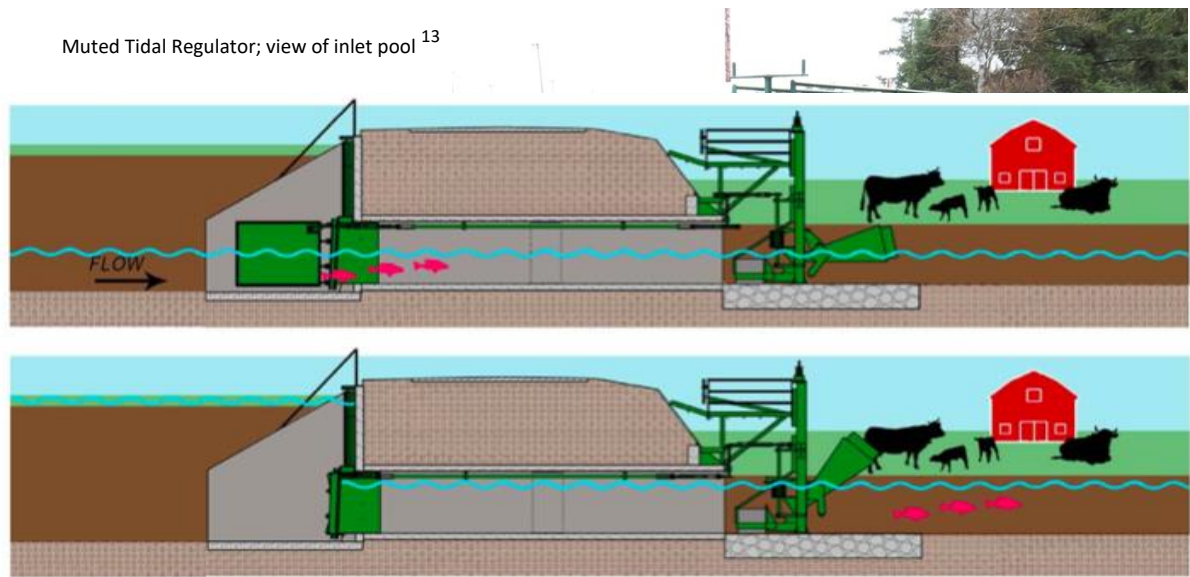
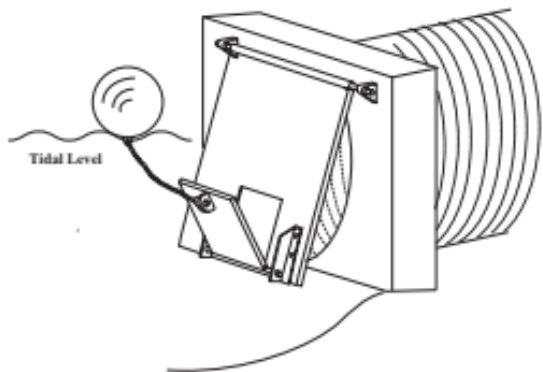


Diagram of Muted Tidal Regulator; depicting varying flows and function ¹⁴

Pros	Cons
• Default open position • Adjustable floats • Allows for greater tidal exchange • Increases fish passage • Allows for a greater response to freshwater flows • Low maintenance (collects less debris)	• Proprietary design (not easily replicable at scale) • Can be more costly • Can still discourage fish passage (to a much lesser extent)

Pet Door

A pet door is a feature that can be added to most tide or floodgates designed with an intent to increase connectivity. There are both bottom hinged and side hinged designs; bottom hinge designs operate through a float system while side-hinged designs through more precise engineering open with small hydraulic head (Guillermo Giannico and Jon A. Souder, 2005).



¹³ Nehalem Marine Manufacturing, 2021. Products, Muted Tidal Regulator

¹⁴ Nehalem Marine Manufacturing, 2013. West Coast Salmon Summit PDF

Bottom Hinged Pet Door

Pros	Cons
• May increase fish passage • Default open position	• Have been known to fail (finicky) • May collect debris

Side Hinged Pet Door

Pros	Cons
• May increase fish passage	• Often fails when the gate in which it is attached rotates slightly (finicky) • Default closed position

Operating Tide and Floodgates

Although not a design style the operations of our flood control infrastructure can also greatly impact our tidal and flood zones. Well regulated, manual operation of FCI can also increase connectivity and may be most suitable for areas in which flooding need only be managed seasonally. For example if a gate only needs to be opened or closed once or twice a year, a simple structure can be implemented and left open while the season permits. Although not a complete solution to increasing fish passage this does increase connectivity for part of the year. Manual operation is worth noting as many gates are left closed unnecessarily for the majority (or entirety) of the year, while many could be opened for months at a time without the risk of flooding.

Despite these innovative designs and practices it is clear that gate removal (where and when possible) is always best for increasing fish-passage. Though some designs have proven better than others most structures will likely always deter salmon to some degree.

Case Studies

Interdisciplinary flood infrastructure projects built with fish-passage in mind can be found throughout North America, but have been found to be concentrated along the Pacific West coast. The majority of projects included were accomplished in the United States, while some projects do exist in Canada, (mostly in British Columbia) however the detail in documentation is not as prevalent. The issue of the lack of post monitoring data is a common theme for most projects,

¹⁵ Guillermo Giannico and Jon A. Souder, 2005. Tide gates in the Pacific Northwest, Operation, Types, and Environmental Effects

including those found in the United States. Many claimed fish-friendly tide gates and floodgates once built seem to be left unmonitored soon afterward, leaving the project's success in doubt. Another issue within research is the fact that many FCI installations are part of larger restoration projects with various conservation, municipal, or academic entities involved who may refer to the project under a different name or category.

Fish-friendly gates can also be found abroad and a couple of which have been included here for comparison. The case studies range from least amount of data to those with some, or generous detail. Please note that many project costs are estimates, or may include the overall cost of restoration, not just gate production/ installation alone.

North American Case Studies

Nelson Creek, Columbia Estuary

Location: Wahkiakum County, Washington

Implementing Entity: Columbia Land Trust

Gate Manufacturer: [Waterman Industries Inc](#)

FCI Type: Tide Gate

Project Cost: \$285,840.74

Project Overview: Between 2006-2008 the Columbia Land Trust purchased 193 acres of land that was at risk of agricultural and recreational development. At first the main goal was to restore habitat for Columbia's endangered white tail deer population, but it was also recognized that the tidal and wetland habitat could be restored for multiple species of salmonids. Two top-hinged self-regulating tide gates provided by Waterman Industries Inc. were then installed to provide habitat for multiple salmonid species such as: Coho, Chinook, Chum, Steelhead and sea-run Cutthroat Trout.

Post Monitoring Results: No post monitoring data was found to be publically available for these particular gates. However the project is listed in Washington State's Salmon Recovery portal (linked below).

Conclusions: The lack of detail here demonstrates the common limited (publically) post-monitoring data available for most tide or floodgate projects. Many projects may also fall under overlapping or multiple restoration projects making it difficult to confirm detail on specific flood infrastructure installations.



References

[Land Trust starts restoration along Nelson Creek](#)

[Salmon Recovery Portal - Columbia Estuary - Elochoman River Hab Conservation](#)

Chinook River

Location: Lower Columbia Estuary, Washington

Implementing Entity: Washington Department of Fish and Wildlife

Gate Manufacturer: [Golden Harvest](#)

FCI Type: Tide gate

Project Cost: Unknown

Project Overview: In 2006 two large top-hinged gates provided by Golden Harvest were installed at the mouth of the Chinook River underneath Hwy 101. The gates were made of aluminum and were both installed and mounted on a frame featuring a mechanical lift. The lift allows the flap gate to be raised and lowered and opens with moderate flow. This specific model however (model number GH-52SC) is not displayed on Golden Harvest's website as the design did not function as needed at this location.

Post Monitoring Results: Post monitoring results revealed that the top-hinged gates did not increase fish passage. Additional restoration work was noted to have taken place from 2011-2014 which may have garnered more positive results.

Conclusions: It is likely that additional research and or considerations were needed prior to project start. It was noted that there was an initial dispute regarding upgrading the gates and due to the fact that the gate model is not marketed on the manufacturers website implies that it did not efficiently increase connectivity. It also demonstrates that fish require specific gate design or management that will likely differ based on location.

References

[Appendix C. Summaries of Primarily Non-OWEB funded tide gate projects in Oregon, and tide gate projects in Washington and California, 2006 – 2016.](#)

[Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis](#)

¹⁶ Fraser Basin Council, 2010. Environmental Protection in Flood Hazard Management

Wilson Farm North Tidal Flow Restoration and Habitat Enhancement Project

Location: Coquitlam, British Columbia

Implementing Entity: The Transportation Investment Corporation

Gate Manufacturer: Unknown

FCI Type: Floodgate

Project Cost: ---

Project Overview: In 2012 the Wilson Farm North Tidal Flow Restoration and Habitat Enhancement Project restored riparian, channel and over-stream habitat that had long been disconnected. A self-regulating floodgate was installed and since then Coho, Chum, Pink and Chinook salmon have since returned.



Top view of floodgate and riparian habitat after restoration ¹⁷

Post Monitoring Results: Post monitoring took place up until five years after the project was completed, within that time period fish presence data proved that fish populations had increased. Juvenile Coho were predicted to be overwintering at the site, Chum salmon were found both inside and outside the gate, and a small number of Chinook salmon were found within the floodplain each spring. In year three of monitoring water quality was still found to be poor in the summer months (this was expected however).

Conclusions: The project was largely a success as the fish-friendly gate did increase fish presence and passage. Opening the gate wider and for longer periods however could increase connectivity more so, which was noted to be possible. The project also shed light on connectivity issues due to beaver dams and the potential need for dam management.

References

[Wilson Farm Habitat Enhancement Project Effectiveness Monitoring Report - 2016](#)

[Wilson Farm Habitat Enhancement Project Effectiveness Monitoring Report Year 3](#)

McElroy Slough

Location: Puget Sound, Washington

Implementing Entity: Skagit County

Gate Manufacturer: [Golden Harvest](#)

FCI Type: Tide gate

¹⁷ Watershed Watch, 2014. Wilson Farm Habitat Enhancement Project Effectiveness Monitoring Report Year Three

Project Cost: \$841,461

Project Overview: In 2006 a total of four tidegates were installed within McElroy Slough, in Puget Sound. Three were traditional top hinged gates and one side-hinged self regulating gate manufactured by Golden Harvest that allows for greater saltwater intrusion. Additionally, two culverts beneath Flinn Road were replaced with a bridge.

Post Monitoring Results: Project findings report that the tidegate upgrades have increased fish-passage and improved tidal processes and estuary rearing areas. The project re-established; 4.75 acres of estuary, 1 mile of river and increased access to multiple surrounding creeks. Additionally, the new tide gates provided better flood and drainage easement to the local community.

Post monitoring for the project appears to have taken place until 2014 which included; documenting juvenile fish usage, channel cross sections, establishment of vegetation plots, and an aerial imagery to document baseline conditions.

Conclusions: Although the project did increase fish-passage to some capacity, political and engineering issues delayed the start of this project by four years as it was fully funded by 2001 (construction was completed in 2006).

References

[Appendix C. Summaries of Primarily Non-OWEB funded tide gate projects in Oregon, and tide gate projects in Washington and California, 2006 – 2016.](#)

[Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis](#)

The Coquille Working Landscapes Project, Winter Lake

Location: Winter Lake, Oregon

Implementing Entity: Oregon Watershed Enhancement Board

Gate Manufacturer: [Watch Technologies](#) and [Nehalem Marine Manufacturing](#)

FCI Type: Tide gate

Project Cost: Unknown

Project Overview: In 2018 new tidal channel networks were restored to mimic historic conditions while an array of seven different tide gates were built or retro-fitted with fish-friendly technology. Three of the gates are mounted on vertical slide gates (also known as sluice gates) developed by Watch Technologies which also included back up, side-hinged gates with Muted Tidal Regulator technology provided by Nehalem Marine. The gates were designed to operate individually allowing for more precise control. They operate and are programmed through a computer network located on site, and can be controlled remotely through a cellular modem connection. Additionally, three of

the gates are equipped with Sontek's SL3000 Side-Looking Doppler Current Meter to measure water velocity.

Post Monitoring Results: No velocity data was analyzed for 2018-2019 due to the complexity of the wiring, computer network, control, and multiple difficulties in data transfer and sorting. An additional issue was also endured with another water level logger (WL24) that could not be kept suspended during the winter months due to high water levels and accessibility concerns. Therefore the total day count was inaccurately low. However, more complex habitat for salmon has been restored and is predicted to mature over time. Salmon are now found to be twice the size as they were prior to the improvements as the new habitat provides better feeding and sanctuary for juvenile salmon.

Conclusions: The project was successful in its goal of restoring hydrological conditions for connectivity and coho salmon, however it's unclear if all flood control infrastructure and accompanying monitoring technology will work as intended long-term.

References

[Winter Lake Restoration Effectiveness Monitoring](#)
[Restoring Tidal Wetlands at Winter Lake](#)
[Coquille Working Landscapes Project Monitoring and Adaptive Management Plan](#)

Fisher Slough

Location: Conway, Washington

Implementing Entity: The Nature Conservancy

Gate Manufacturer: [Nehalem Marine Manufacturing](#)

FCI Type: Floodgate

Project Cost: \$8,000,000 (Including all additional restoration)

Project Overview: In 2011 an extensive restoration project was made to the Fisher Slough, including dike setback (to increase tidal habitat area), ditch realignment, excavation of new tidal channels, and three floodgate upgrades. Three, side-hinged aluminum tide gates with Muted Tidal Regulators were installed to increase fish passage and provide juvenile Chinook rearing habitat. Additionally, two

small pet doors were also installed along the headwall in an attempt to further increase connectivity (Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018).

Array of side-hinged tide/flood gates in open position¹⁸

Post Monitoring Results: After both dike setback and tidegate upgrade an increase in salmon and connectivity was demonstrated. The longer the gates remained open, the more juvenile salmon were noted upstream of the gate. Ecological conditions have improved, as well as saving an estimated \$9-\$21 million in reduced flooding (Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018).



Conclusions: It is important to note that floodgate upgrades alone did not increase fish passage, only after dike setback did a positive relationship occur. Top-hinge gates were reported to reduce connectivity by 75%, while the side-hinge gates that used a Muted Tidal Regulator (Manufactured by Nehalem Marine Manufacturing only reduced connectivity by 50% (Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018).

As additional restoration work was completed in cooperation with floodgate upgrades it was not possible to measure the success of the new floodgates alone.

References

[Appendix C. Summaries of Primarily Non-OWEB funded tide gate projects in Oregon, and tide gate projects in Washington and California, 2006 – 2016.](#)

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Willanch Creek

Location: The Coos Bay and Coquille Estuaries, California

Implementing Entity: Coos Watershed Association

Gate Manufacturer: [Nehalem Marine Manufacturing](#)

FCI Type: Tide Gate

Project Cost: \$161,956

¹⁸ Nehalem Marine Manufacturing, 2021. Projects, Fisher Slough

Project Overview: In 2010 one old top-hinged tidegate was replaced with a side-hinged aluminum gate with an MTR. In addition, large wooden debris was also added to the stream environment, and willows were planted alongside to improve fish habitat and increase stream complexity.

Post Monitoring Results: In 2016 inspection showed that the gate was working as intended and later monitoring demonstrated a gradual upward trend in coho smolt productivity. More complex pools, and a cover habitat were since documented and no site modifications or maintenance has been required (known and or prior to 2018) (Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018). The project also employed an innovative PIT tagging technology (Passive Integrated Transponder) that allowed researchers to tag and monitor smaller coho. However the first tag models did not work efficiently, it was only after a different type of tag (Half Duplex (HDX) transponders) was used that then increased monitoring accuracy.

Conclusions: Demonstrates that the right technology must be used to garner accurate data. Log placement within the stream environment also proved to be a success.

References

[Appendix B. Summaries of OWEB-funded Tide Gate Related Projects](#)

[Coho Life History in Tide Gated Lowland Coastal Streams 2016-2018 OWEB Grant 231-2031 Project Completion Report](#)

Whatcom County Farm

Location: Ferndale, Washington

Implementing Entity: Whatcom Conservation District

Gate Manufacturer: [Nehalem Marine Manufacturing](#)

FCI Type: Floodgate

Project Cost: \$60,000 (floodgates), \$288,367 (additional construction work)

Project Overview: In 2017 Appel Family Dairy in cooperation with Whatcom Conservation District installed two fish-friendly floodgates along the Nooksack river in Ferndale. Using gates provided by Nehalem Marine Manufacturing two side-hinged aluminum gates (double barrel configuration) featuring an MTR created essential side stream habitat for juvenile salmon. This new habitat prevents the smolts from being prematurely swept out to sea when the Nooksack River floods.



Post Monitoring Results: No hard post monitoring data could be found, but the project was deemed a success by local conservation authorities, farmers and flood districts.

Conclusions: The real success here is the cooperation between land owner (in this case the Appel's) and conservation district. Both goals of; strengthened flood protection and increased fish-passage were met through the work and chosen technology implemented.

References

[New floodgates installed on Whatcom County farms protect fish and farmland](#)
[Appel Farm Fish Barrier Removal and Floodgate Replacement Project](#)

Case Studies (International)

Awatapu Lagoon

Location: Whakatane District, New Zealand

Implementing Entity: Whakatane District Council

Gate Manufacturer: [ATS Environmental](#)

FCI Type: Tide Gate

Project Cost: Unknown

Project Overview: In 2012 two fish-friendly top-hinged gates were installed at the intersection of the Awatapu Lagoon with the intention of supporting Whitebait populations. The fish friendly gates delay closing through a cantilever weighted steel arm. The project was deemed a success, as increased passage did occur for whitebait and shrimp populations.

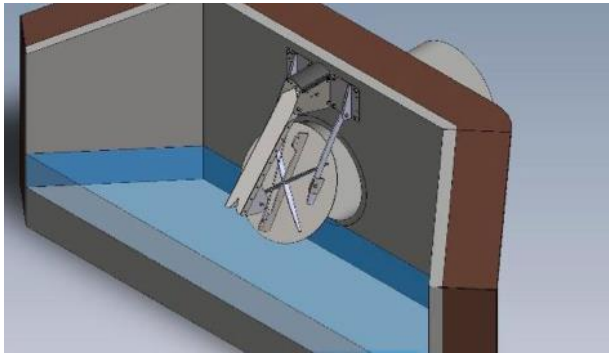
Post Monitoring Results: Although fish passage did increase, some pooling of whitebait could still be observed indicating that the gates can still deter fish to some degree. The new gates had minimal impact on flood risk, but rather produced only ecological benefits.



Top-Hinge gate with
cantilever weighted steel arm²⁰

¹⁹ Farmersforreal.org, 2019. New floodgates on Whatcom County farm protects fish and farmland

²⁰ New Zealand Fish Passage Advisory Group, 2020. Lessons Learnt 005, Fish Friendly Gate installation at Whakatane's Awatapu Lagoon facilitates upstream fish passage



Top-Hinge gate graphic depicting closing delay²¹

Conclusions: Although no salmonid species were studied, the top-hinge gate by ATS Environmental still seemed to improve connectivity.

References

[Lessons Learnt, Fish Friendly Gate installation at Whakatane's Awatapu Lagoon facilitates upstream fish passage](#)

Lower Clarence Floodplain Project

Location: Australia, Clarence Floodplain

Implementing Entity: Clarence Valley Council

Gate Manufacturer: Various/ Unidentified

FCI Type: Floodgates and Tide Gates

Project Cost: Unknown

Project Overview: The Clarence Flood Plain Project was an extensive restoration initiative that took place between 1997-2003 that incorporated over 80 individual restoration projects and involved over 250 land owners. The project successfully revived large expanses of the Clarence estuary and floodplain including the re-establishment of fish passage through hundreds of new and or retrofitted flood retention structures. The structures ranged from tidal gates, vertical lift gates, fish-flaps in weirs and both manual and automatic winched floodgates. Various water retention infrastructure was also used to raise water levels.



²¹ New Zealand Fish Passage Advisory Group, 2020. Lessons Learnt 005, Fish Friendly Gate installation at Whakatane's Awatapu Lagoon facilitates upstream fish passage

Post Monitoring Results: As a result of the project the Clarence Floodplain has become much healthier with habitat areas no longer disconnected from the estuary, increasing fish passage. Water quality improved, and the saltmarsh and mangrove habitat began to regenerate.

Conclusions: The major success of this project is likely the cooperation between the many stakeholders. Many landowners worked closely with council staff and became authorized flood or tide gate operators, managing the systems long-term. Another important aspect of the project is that the large majority of the detailed upgrades (such as flap gates and winches) were attributed to pre-existing structures.

References

[Case Study: 1. The Clarence River Catchment](#)

[Case Study: 2. Land and Water Management Issues in the Lower Clarence River Catchment](#)

Case Study Learnings, Common Themes and Conclusions

Although it has been demonstrated through case studies that multiple designs of FCI have shown to increase fish passage, it's clear that some features perform better than others. Additionally, the way in which organizations cooperate and implement the project have a huge impact on project success.

Standard Features of a Fish-Friendly Gate

Physical Features
Side-hinge Design: • Simple design/operation. • Collects less debris. • Wide opening radius.
Open default position: • Increases salinity lens. Salmon require a gradual increase/decrease in salinity as they migrate, otherwise this may cause smolts to go into shock, perish or delay migration. • Self regulating features allow gates to automatically close when floodwaters reach a predetermined level.

²² Ocean Watch Australia, 2016. Case Study: 2. Land and Water Management Issues in the Lower Clarence River Catchment.

Easy to use/manual operation:

- It has been found that if the structure is at all complicated in nature, operators will be discouraged to use the device.
- A manual function ensures that the land owner may adjust the device according to changing water levels.

Aluminum structure:

- Lightweight material.
- Durable.

Note: In addition to the physical structure in many cases additional restoration work may be needed if the current environment is severely degraded. Various restoration work, dike setback, and the excavation of new tidal channels is common practice.

Non-Physical Features**Implemented in Cooperation:**

- All stakeholders must work in collaboration to ensure that the gate is used efficiently long-term, and that projects do not create physical or economic problems for the landowner or local peoples.

Baseline and Post Monitoring Data

- Collect baseline data prior to any restoration work or new infrastructure.
- A monitoring plan ensures that the gate is; being used as intended, has chronically increased fish passage, and is free of debris/not leaking. This is important as many projects have not recorded detailed post monitoring data.

Note: If possible it is always beneficial to incorporate any traditional ecological knowledge or input from local First Nations, and or other long-standing neighbouring communities prior to project commencement.

Conclusions

Flood infrastructure today should be both interdisciplinary and resilient, anticipating the increasing pressures on our environment. As much of our water infrastructure is antiquated and in demand of replacement, it is only intuitive to attempt to solve more than one issue given opportunity. Although fish-friendly gates may not increase connectivity to the state prior to FCI installation it has proven to give salmon a chance to re-establish their historical routes. Working collaboratively will also be key to success. The



Lower Fraser Watershed²³

Lower Fraser is a vast and complex system that will require great cooperation and planning in order to withstand the impacts of climate change and protect our natural resources. As the health of the river affects First Nations, farmers, fisheries, and biodiversity as a whole, sustainable solutions like fish-friendly FCI should be an example of what our water infrastructure should look like today.

²³ Watershed Watch Salmon Society, 2020. Heart of the Fraser Campaign. About Heart of the Fraser.

Works Cited

Finn, R. J. R., Chalifour, L., Gergel, S. E., Hinch, S. G., Scott, D. C., and Martin, T. G.. 2021. Quantifying lost and inaccessible habitat for Pacific salmon in Canada's Lower Fraser River. *Ecosphere* 12(7):e03646. 10.1002/ecs2.3646
<https://doi.org/10.1002/ecs2.3646>

Guillermo Giannico and Jon A. Souder. 2005. Tide gates in the Pacific Northwest, Operation, Types, and Environmental Effects. Oregon State University, OR.
<https://seagrant.oregonstate.edu/sites/seagrant.oregonstate.edu/files/sgpubs/onlinepubs/t05001.pdf>

Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018. Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis. Report to Oregon Watershed Enhancement Board. Institute for Natural Resources, Oregon State University. Corvallis, OR. 136 pp. Submitted to Oregon Watershed Enhancement Board in fulfillment of grant #217-8500-14090.
https://inr.oregonstate.edu/sites/inr.oregonstate.edu/files/tide_gate_feb2018.pdf

Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018. Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis. Report to Oregon Watershed Enhancement Board. Institute for Natural Resources, Oregon State University. Corvallis, OR. 136 pp. Submitted to Oregon Watershed Enhancement Board in fulfillment of grant #217-8500-14090.
https://inr.oregonstate.edu/sites/inr.oregonstate.edu/files/tidegate_appendixc_feb2018.pdf

Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018. Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis. Report to Oregon Watershed Enhancement Board. Institute for Natural Resources, Oregon State University. Corvallis, OR. 136 pp. Submitted to Oregon Watershed Enhancement Board in fulfillment of grant #217-8500-14090.
https://inr.oregonstate.edu/sites/inr.oregonstate.edu/files/tidegate_appendixb_feb2018.pdf

Fraser Basin, 2010. Environmental Protection in Flood Hazard Management. The Fraser Basin Council, B.C
https://www.fraserbasin.bc.ca/_Library/Water/report_flood_and_environmental_protection_2010.pdf

Nehalem Marine Manufacturing, 2013. West Coast Salmon Summit, pdf
https://static1.squarespace.com/static/54ee04bce4b067ff94f0c5a8/t/54ee10d1e4b06d374ec01da5/1424888017949/narratedPrsnttn_05-20-13.pdf

Watershed Watch, 2014. Wilson Farm Habitat Enhancement Project Effectiveness Monitoring Report Year Three.
https://watershedwatch.ca/wp-content/uploads/2016/04/Wilson_Farm_Effectiveness-Year_3_Report_2014_FINAL.pdf

Watershed Watch Salmon Society, 2018. Disconnected Waters Map.
<https://watershedwatch.ca/disconnected-waters-map-web/>

Watershed Watch Salmon Society, 2020. Heart of the Fraser Campaign. About Heart of the Fraser.
<https://watershedwatch.ca/heart-of-the-fraser/>

Nehalem Marine Manufacturing, 2021. Products, Muted Tidal Regulator
<http://www.nehalemmarine.com/muted-tidal-regulator>

Watch Technologies, 2019. Sluice Gates/ Slide Gates Gallery
<https://watchtechnologies.com/gallery-of-gates/>

Measurit, 2020. Tideflex used on Forres Flood Alleviation Scheme
<https://www.measurit.com/tideflex-case-studies/tideflex-valves-forres-flood-scheme>

Waterman Valve USA, 2021. Radial Gates, Radial Gates Specification Brochure
https://watermanusa.com/wp-content/uploads/2020/12/Waterman_RadialGates_SpecSheet.pdf

New Zealand Fish Passage Advisory Group, 2020. Lessons Learnt 005, Fish Friendly Gate installation at Whakatane's Awatapu Lagoon facilitates upstream fish passage.
<https://www.doc.govt.nz/globalassets/documents/conservation/native-animals/fish/fish-passage/lessons-learnt-case-studies/lessons-learnt-005-fish-friendly-gate-installation.pdf>

Ocean Watch Australia, 2016. Case Study: 1. The Clarence River Catchmen
<https://www.oceanwatch.org.au/wp-content/uploads/2021/02/Clarence-River-CS.pdf>

Ocean Watch Australia, 2016. Case Study: 2. Land and Water Management Issues in the Lower Clarence River Catchment.

<https://www.oceanwatch.org.au/wp-content/uploads/2016/05/Case-Study-2-Land-and-Water-Management-Clarence-3.pdf>

Resilient Waters: <https://www.resilientwaters.ca>

Farmland Advantage: <http://farmlandadvantage.ca>

Farm Folk City Folk: <https://farmfolkcityfolk.ca>