Flap Gate / Tide Gate Alternatives

This document lists many of the available alternatives for flap gates and tide gates. It also includes my opinions and observations regarding the pros and cons of each design. If you are aware of some other flap gate / tide gate alternatives, or if you have comments regarding anything in this document, please e-mail me at Jeff.Juel@Jueltide.com. I will modify and expand this document periodically.

Top Hinged Flap Gates

Photo 1- Cast iron or ductile iron flap gate by Hydro Gate

Top hinged flap gates have been in use at tide gates for centuries. Top hinged flap gates are typically made from wood, cast iron, steel, aluminum, FRP (fiber reinforced polymer), or fiberglass. Designs are produced by a number of manufacturers. I have seen or worked on numerous top-hinged flap gates including some made of treated timbers with weights attached that simply hang on heavy chains (see photo below).

Light weight varieties of top hinged flap gates have less head loss and allow upstream fish passage under some flow conditions. None of the top hinged flap gate designs allow backflow unless they leak or are tied or propped open.

The photo to the right shows one of three very large timber flap gates as it is being removed from the Highway 101 bridge where it crosses the Chinook River near Ilwaco Washington.

Photo 2 - Large timber flap gate

Pros:

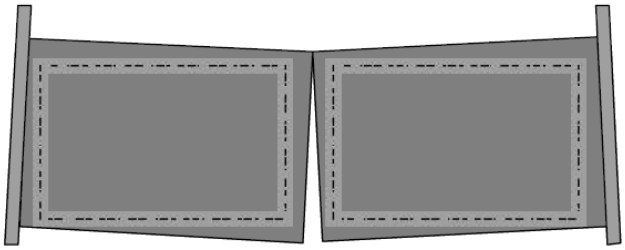
- Very simple operation.
- Reasonably durable and reliable.
- Prevents salt water intrusion.

Cons:

- Does not allow tidal flushing. This dramatically degrades the water quality of upstream watercourse and also causes sedimentation in the flow channel.
- If water-tight or nearly water-tight, a flap gate dramatically lowers the surface water and ground water levels upstream[1]. During dry periods, if there is any surface water upstream from a flap gate, it will typically be stagnant with low dissolved oxygen and poor water quality. Dry & hot weather will result in significantly elevated water temperatures.
- Top hinged flap gates don't pass floating debris easily. Debris may have to be manually removed periodically.
- Heavier gates don't open very wide. This results in significant head loss at the flap gate which reduces the conveyance capacity of the outlet.
- Fish have difficulty passing heavy flap gates since they are normally either closed or only barely cracked open with high velocity flow passing through a small opening.
- Aluminum flap gates have been reported stolen and presumably sold for scrap.
- If mixed metals are used, sacrificial anodes are required. Sacrificial anodes have to be inspected and replaced periodically.
- The hinge mechanism will eventually wear out with time.
- If the flap gate closes on debris and then experiences a large seating head, the wracking forces can damage the flap gate and/or hinges.

[1] Wetlands located upstream from flap gates are effectively dewatered during dry periods.

Side Hinged Tide Gates



Large, side hinged tide gates are angled inward, providing a small closing force, and are typically mounted over large, rectangular culverts.[2]

Sketch 1 – Side Hinged Tide Gates

Pros:

- Very simple operation.
- Reasonably durable and reliable.
- Opens wide with little flow - allowing fish passage during outflow.
- Does not collect floating debris.

Cons:

- Does not allow tidal flushing (unless lashed or propped open).[3]
- Fairly large forces are imposed on the hinge mechanism due to the cantilevered gate leaves.

Tide Flex Valve by RedValve

Photo 1 - Tide Flex Series TF-2 Check Valve

Tide Flex valves are also known as a "duckbill style check valve". The valve is attached to the downstream (tidal) end of a culvert. The check valve is made of a flexible synthetic material that deforms to provide an opening in the duckbill when there is a higher water level on the upstream end of the culvert.

Pros:

- Extremely simple operation
- Very durable and reliable

Cons:

- The device is virtually water-tight and does not allow any backflow for tidal flushing.
- The tide flex valve does not open very wide under low flow and only passes very small floating debris. Accumulated debris may have to be removed periodically. Manual removal of debris is very difficult.
- Rodents (muskrats) have been reported to chew on the tide gate.[4]
- Head loss at this type of valve may be unacceptable.[5]

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[2] From Tide Gate Modifications for Fish Passage and Water Quality Enhancement – Tillamook Bay National Estuary Project by Jay Charland, August 27, 1998.

[3] Someone must release the gates prior to floods or high water. If the tide gates remain lashed open during a flood, there will be liability issues.

[4] Personal communication with Shawn Shotzberger, AKRF Senior Environmental Scientist, November 2009.

[5] If you would like a Tide Flex valve, I have a contact with the City of Aberdeen who would love to sell a couple of Tide Flex valves that are like new and have been in storage for years. They were installed and then removed because they had excessive head loss and were nearly impossible to keep free of debris.

Sluice Gate with Electric Operator

<no photo available at this time[6]>

A motorized vertical lift slide gate or sluice gate is probably the most obvious alternative for a water control device that can be used to allow tidal flushing while preventing flooding during extreme tides. A number of suppliers are capable of providing a motorized sluice gate. A Program Logic Controller (PLC) can be programmed to operate the electric motor which raises and lowers the sluice gate. Limit switches detect when the gate is in the fully open or fully closed position. Intermediate gate positions are detected via a rheostat or some other device. Sensors monitor the water levels upstream and downstream from the sluice gate and provide input to the PCL. The PLC directs the electric motor to raise or lower the sluice gate according to the logic programmed in the PCL. The sluice gate can be fully open, fully closed, or partially open at any time depending on the water levels upstream and downstream of the sluice gate and the programming of the PCL.

There will be two operating modes with separate control schedules to address normal conditions and storm conditions. During normal operations, the gate will programmed to remain open until water levels reach a set elevation for a defined length of time, at which point it will close. In effect, natural tidal fluctuations will occur unless action is needed to prevent flooding of upstream properties.[7]

This alternative requires electric service at the tide gate.

Pros:

- The operation of the sluice gate (via the programming of the PCL) can be very sophisticated and can be modified over time if needed.
- The sluice gate can be used to impound water upstream[8].

Cons:

- Relatively complicated. [9]
- Relatively expensive.
- Requires reliable electrical service at the tide gate site and/or a power monitoring system with alarms and/or a backup power system.
- Requires a maintenance person capable of operating and programming the PCL.
- This device is not particularly fail-safe. Power outages, motor breakdowns, PCL programming errors, etc can result in the sluice gate being open when it should be closed and vice versa.
- Someone will be responsible to pay a monthly electric bill.

[6] This alternative is currently being considered for a project that is under design by Vine Associates. I am not aware of any existing tide gates that utilize this design. Similar systems are used in sewage treatment plants.
[7] E-mail correspondence from Gregory Robbins, Vine Associates, December 2009.
[8] This will reduce tidal flushing and negatively affect water quality. It will also preclude fish passage during part of the tide cycle.
[9] The PLC and motor control device is normally provided by a different supplier than the motorized sluice gate.

Waterman / Nekton Self-Regulating Tide Gate

Photo 2- Self Regulating Tide Gate by Waterman Industries

This is the original "Self Regulating Tide Gate" (or "SRT") produced by Waterman Industries. The flap gate is top-hinged and uses a buoyant plate (the "lid") along with floats which are secured to the frame above the culvert. The position of the floats controls when the tide gate closes on a rising tide. The buoyant tide gate lid floats opens with the rising tide. As the water level continues to rise, at some point the floats above the culverts become submerged and their buoyancy forces the lid to close, stopping the backflow through the culvert. For the configuration shown in the photo above, the "trip elevation" (the water level at which the gates close) must be higher than the top of the culverts. The culverts are vented to prevent water hammer when the lid slams shut during pipe-full flow.

Pros:

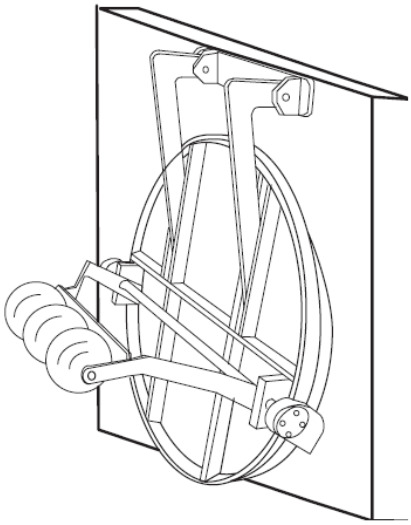
- Relatively simple operation.
- Floating debris is usually swept from the gate by high flows.
- Allows substantial volumes of tidal flushing.

Cons:

- Floating debris can get tangled in the frame above the culvert and interfere with the operation of the flap gate.
- Adjusting the floats to change the elevation at which the gate closes is difficult and limited to a small range.
- This type of flap gate can slam shut[10]. If the pipe can be flowing full when the gate closes, a vertical vent should be installed in the culvert behind the SRT to prevent a high pressure shock wave caused by water hammer. After the gate slams shut, surges can cause the gate to open and close several times.
- During very high water levels, the submerged vent tubes will pass flood water upstream.
- A Waterman SRT was installed at Edison Slough in Skagit County WA around 2003. It could not be made to operate properly and was removed in 2006.

[10] I have never watched this type of tide gate in operation. I suspect that it always slams shut. The associated noise may be unacceptable if the tide gate is located in a populated area and closes with regularity.

Mitigator Fish Passage Device, by Nehalem Marine / Leo Kuntz



What makes this tide gate different from other traditional top-hinged tide gates is the Mitigator Fish-Passage Device that is attached to the tide gate. The Mitigator Fish-Passage Device is a float-operated, cam-lock system that prevents a portion of the tide gate from closing during the lower part of the flood tide. [11]

Pros:

- Allows some tidal flushing.

Cons:

- Only opens to 20 degrees when the gate first opens.
- Moderately complicated.
- Floating debris can damage or interfere with the operation of the floats.
- Adjusting the floats to change the elevation at which the gate closes is difficult.
- Only a fraction of the culvert diameter is open on the rising tide.

Muted Tide Regulator, by Nehalem Marine / Leo Kuntz

<no photo available at this time>

This is a side-hinged flap gate with a mechanism that prevents the gate from closing until a float is raised by the rising tide. The float is located on the protected side of the tide gate and the device can be designed to accommodate adjustments in the float setting.

Pros:

- Allows tidal flushing.
- Very heavy-duty high quality fabrication.

Cons:

- This type of tide gate is relatively expensive.
- The control mechanism is fairly complicated.
- The float can be very large. At Fisher Slough in Skagit County, it's the size of a small economy car.
- The design is not inherently fail-safe. If the float fails to rise for some reason, the gates will be held open and flooding will occur.

[11] From Tide Gates in the Pacific Northwest - Operation, Types, and Environmental Effects by Guillermo Giannico and Jon A. Souder.

Armtec Side Opening Flap Gate

Photo 3 - Side Opening Flap Gate at Nanaimo BC

The photo to the left is a side hinged flap gate installed at Namaimo BC. The tide gate was installed with a torsion spring on the hinge. The spring was initially installed and tensioned "for closure assistance". As an afterthought, the spring was tensioned to hold the tide gate open - thereby allowing some backflow. The spring began corroding badly and in 2009 the spring was replaced with a very expensive stainless steel spring.

Pros:

- Allows some tidal flushing
- Minimal head loss during outflow

Cons:

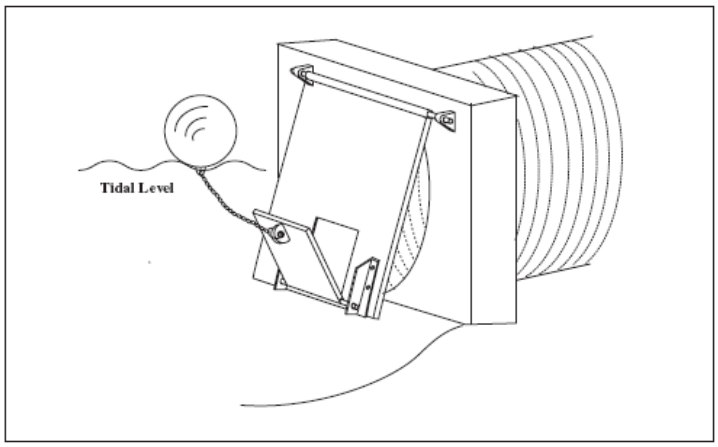
- Mixed metals in salt water - the gate was fabricated using 304 stainless steel and aluminum. If the insulated connectors fail, severe corrosion will occur.
- 304 stainless steel is not the best grade of stainless steel for salt water exposure. 316 stainless steel is a superior choice.
- The gate doesn't open very wide.
- The stiffness of the spring is not adjustable.

Tide Gates Produced By Golden Harvest

Kevin Buchanan, the owner of Golden Harvest, boasts that with his collection of tide gate designs, he is "like a paint store selling several colors of paint".[12] In my opinion, the various designs are simply a parade of Golden Harvest's multiple attempts to produce, copy, or steal a viable self regulating tide gate design. But you can be the judge.

The following tide gates are or have been produced by Golden Harvest:

Bottom-Hinged Pet Door



On a rising tide, the large flap gate is closed and the smaller gate – the "pet door" – closes when the water level is high enough to float the ball on the chain. [13] This design is the brain-child of OSU graduate student Jay Charland[14]

Pros:

- Probably would be relatively inexpensive.
- Very simple operation.
- Fish can pass through the "pet door" - until it gets plugged with debris.
- Allows some tidal flushing - until the "pet door" gets plugged with debris.

Cons:

- The "pet door" tends to get plugged with debris.
- The "pet door" is too small to allow much tidal flushing and flow velocities through the pet door are very high most of the time.
- It will not work in many locations.[15]
- Golden Harvest produced this device for the Tillamook Bay area, but it appears that they no longer actively sell this device since it is not mentioned in their on-line tide gate catalog.

[12] Personal Conversation, June 2008.
[13] The Effects of Tide Gates on Estuarine Habitats and Migratory Fish by Guillermo R. Giannico and Jon A. Souder
[14] OSU Develops Fish Friendly Tide Gate (2/18/98) http://oregonstate.edu/dept/ncs/newsarch/1998/Feb98/tidegate.htm
[15] Top-hinged tide gates with bottom-hinged pet doors have been installed in Tillamook Bay, Oregon (Charland 1997). However, as in the case of the tide gates with top hinged pet doors in Tillamook Bay, the gates with bottom hinged pet doors failed and were replaced with traditional top-hinged tide gates.

Golden Harvest GH-52SC Combination Gate

Photo 4 - Combination Gates were installed to replace existing timber flap gates on Highway 101 Bridge crossing Chinook River.

This tide gate is essentially a top-hinged flap gate mounted on a frame with a mechanical lift that allows the flap gate to be raised or lowered. When completely lowered, this is simply a top hinged flap gate that allows no backflow.

When partially raised, the flap gate allows some backflow during rising tides. The backflow passes beneath the bottom edge of the partially raised flap gate.

When fully raised, the flap gate is completely above the opening and full tidal exchange is allowed.

Pros:

- The aluminum flap gate is very light weight and opens wide under moderate flow.
- Simple operation.

Cons:

- At present, backflow is only allowed during summer months.[16]
- The flap gate does not automatically close during high water levels with high backflow.
- When partially (or fully) raised, the amount of backflow and the upstream water level will vary dramatically with variations in the tide levels downstream. Extreme high tides will result in very high backflow rates and higher water levels upstream.
- Floating and water-logged debris could hang up on the partially raised flap gate during a rising tide.
- The flap gate must be manually raised and lowered.
- Raising and lowering the gate is labor-intensive and requires a large hydraulic power operator on a trailer.
- Sacrificial anodes must be checked and replaced periodically.

[16] Personal communication with Kyle Guzlas, Washington Dept. of Fish & Wildlife, December 2009.

Golden Harvest Model GH-35

Photos 5 & 6- Golden Harvest Model GH-35

This tide gate is identical to the Waterman SRT[17]. Golden Harvest has been telling people that they purchased the rights to this design from Waterman Industries around 2004[18]. The photo above on the left was copied from Golden Harvest's on-line tide gate catalog. This particular tide gate is actually an SRT fabricated by Waterman Industries and delivered to Skagit County in 1998.[19]

In the photos above, the floats have been removed from the attachment points on the frame above the culvert and instead are attached to arms extending behind/down and alongside the end of the culvert. The reason for revising the location of the floats was to cause the tide gate to close earlier during a rising tide. The tide gate did not function properly and repeatedly flooded the upstream property owner. In 2006 (after this photo was taken), Skagit County let a contract to remove the GH-35 and replace it with a regular top-hinged flap gate. A Golden Harvest model GH-850 (see the photo on page 11) was installed on the culvert to the right of this culvert. It also failed to operate properly.

Pros:

- Same as for the Waterman SRT.
- Should be competitively priced. If you are interested in this tide gate alternative, be sure to also get a price from Waterman Industries at (800) 331-0808.

Cons:

- Same as for the Waterman SRT
- Golden Harvest was not able to get this design to work properly at Edison Slough.[20] At this site (located in the town of Edison in Skagit County Washington), the upstream property owner reports that he observed the tide gate slam shut and then pop open 21 times on a single tide. This particular flap gate flooded the upstream property several times.[21] The tide gate was eventually removed and a Golden Harvest Model GH-850 was installed. (See page 11.)

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[17] If you compare Golden Harvest's on-line tide gate catalog http://www.goldenharvestinc.com/pdfs/catalogs/tide_gate_cat.pdf to Waterman Industries' documentation on their Self Regulating Tide Gate http://watermanusa.com/PDF/SRT.pdf it is obvious that Golden Harvest not only copied Waterman Industries' tide gate design, they also plagiarized much of the documentation.

[18] *"…it is my understanding that the Golden Harvest Company bought out Waterman Industries about 6 to 8 years ago, including Waterman's patents and marketing material."* - E-mail from Tom Slocum (Washington Conservation Districts Northwest Region Engineer) to Jeff Juel dated December 8, 2009. In an e-mail dated December 8, 2009, the CEO of Waterman Industries informed me (Jeff Juel) that this is patently false.

[19] E-mail from Waterman Industries CEO dated 22 December 2009.

[20] In spite of this particular tide gate not being theirs, not working properly, and ultimately being removed, Golden Harvest uses a photo of this tide gate in their on-line Tide Gate Catalog.

[21] Personal communication with Mr. Duane Eitriem, January 2009.

Golden Harvest Model GH-37

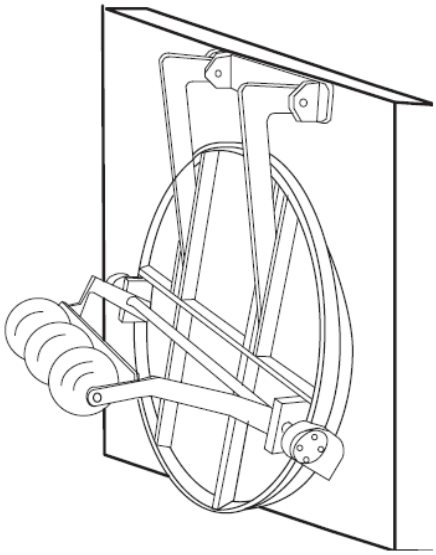

Photo 6 – Golden Harvest Model GH-37 at Beaufort SC

The photo above is from Golden Harvest's on-line tide gate catalog. This tide gate is not identical, but is operationally similar to the Mitigator Fish Passage device produced by Leo Kuntz - which is shown to the right of the photo[22]. In both designs, the floats activate a cam that allows the lower half of the tide gate to close when the floats are lifted by the rising tide

I do not have first-hand knowledge regarding the operation of this type of tide gate. In the photo above, the gate appears to be closed– or just barely cracked open. It could not possibly allow very much backflow in this configuration.

I presume that the pros and cons that apply to the Mitigator Fish Passage Device (produced by Leo Kuntz) also apply to the Golden Harvest Model GH-37.

[22] In November 2009, I met Leo Kuntz and I asked him about the similarities between his tide gate design and the Golden Harvest GH-37. He replied that he was aware of Golden Harvest and "their" tide gates, but he didn't pay too much attention to them. He felt that Golden Harvest has difficulties producing working self regulating tide gates - so they are actually not much of a threat. He told me that he just ignores them.

Golden Harvest Model GH-850-R

Photo 7 - Golden Harvest Model GH-850 at Edison Slough

The photo to the left is at Edison Slough, Skagit County WA. The photo is also from Golden Harvest's on-line tide gate catalog. The culvert in the bottom left corner of this photo (only the tops of the hinges are showing) is the culvert that used to have the Golden Harvest model GH-35 flap gate. (See page 9.) It was removed[23] and replaced with a normal top-hinged flap gate when the model GH-850-R was installed[24].

At this particular site, the tide gate was nearly always closed.[25] In fact it is closed in this photo. The photo was taken when the tide was falling and the water level is well below the high tide level - so it should be open. Golden Harvest has a working copy of their GH-850 at McElroy Slough, so their model GH-850 (my Aberdeen design) can be made to work – at least at some locations.

Pros:

- Works reliably in some locations and allows tidal flushing.
- Montesnano Office Fish and Wildlife Manager Bob Burkle (back in 1996) said: "I've never seen a tide gate as good."[26]

Cons:

- Very complicated[27] and not completely fail-safe. In 1995 when I explained how my proposed tide gate design would work to Aberdeen's City Engineer Ron Merilla, he quipped: "It's kind of Rube Goldberg, but I can't see why it wouldn't work." It does work, but it is overly complicated compared to the VBFG™ system.
- This is an overly expensive knock-off.28 If you are interested in this tide gate alternative, be sure to get a price from Juel Tide Gates at (206) 300-4204.
- Requires sufficient outflow for the gate to open fully – otherwise "Tide Gate Entropy Death" may occur.
- Golden Harvest did not succeed in getting this design to work – at least at Edison Slough. In January 2009, this tide gate was retrofitted with a VBFGTM control mechanism by Juel Tide Gates. It's been working flawlessly since then[29.]

For comparison, to the left is a photo of the Aberdeen Tide Gate designed by Jeff Juel in 1995. Juel Tide Gates can provide this design with the hydraulic control mechanism - however it costs more and has no advantages over an identical side-hinged flap gate using the new VBFG™ control mechanism.

[23] The winning bidder's cost for removal and disposal of the malfunctioning model GH-35 was $10,000.
[24] The winning bidder's cost for the new (and dysfunctional) model GH-850 was $62,000.
[25] Personal Communication with Duane Eitriem, the property owner located just upstream at Edison Slough.
[26] Quote from article about South Aberdeen and Cosmopolis Flood Control Project in 1996.
[27] The hydraulic control mechanism includes a large number of components: hydraulic cylinder, hoses, directional control valve, pressure-compensating flow control valve, check valves, and a hand pump.
[28] On a large tide gate project bid in June 2009, the fabricator of the Aberdeen design submitted a bid to supply the original tide gates as an equal. Their bid was 33% less than the bid submitted by Golden Harvest.
[29] Personal Communication with Duane Eitriem, November 2009.

Variable Backflow Flap Gate (VBFG™) by Juel Tide Gates

The patent pending VBFG™ tide gate is a side-hinged flap gate[30] that is controlled by tension in rigging that is continually pulling the tide gate open. During a rising tide, the backflow through the culvert generates a "draft force" drawing the gate closed. This draft force is resisted by the tension in the rigging. The draft force grows at an increasing rate with the rising tide due to: 1) the growing area of the submerged portion of the gate leaf – "the sail"; 2) the increasing flow velocity due to the growing differential volume of the tidal prism that is being filled by the rising tide & 3) the growing differential head. When the magnitude of the draft force is large enough to overpower the tension in the rigging, the gate closes. When tuned properly, the tension regulator in the control mechanism increases the tension as the gate closes, thereby preventing the gate from slamming shut.

It's a bit counter-intuitive, but the tide gate closes very consistently with little variability regardless of the variations in the tides. If there is a large difference between the low tide and high tide, a slightly greater differential head (for a given water level) may develop during the rising tide and the tide gate will close when the upstream water level is an inch or two lower than normal. If the difference between the low tide and the high tide is minimal and/or the high tide is only slightly higher than the normal closing elevation, the flow (for a given water level) is reduced and the gate will stay open and allow water levels that are a few inches higher than normal. This only happens sporadically – a few times a year. When this does happen, the flood tide is on the verge of cresting when the gate closes, so the water level will fall very soon after the tide gate closes.

At the four locations where tide gates have been retrofitted and are operating with the VBFG™ mechanism, the amount of variability in the water level when the gate closes is reasonably small (much less than one foot) and inconsequential.

Pros:

- Extremely durable heavy duty 316 stainless steel[31] and copolymer gate leaf.
- Remarkably simple control mechanism with very reliable operation.[32]
- It will work at any site.[33]
- The tide gate is either wide open (80-90 degrees from the headwall) or fully closed.
- Does not require any outflow to open. The rigging pulls the gate open when there is no seating head.
- Debris rarely (never?) hangs up on the open tide gate.
- Very minimal head loss.
- Fail-safe unattended operation. If any part of the control mechanism breaks, the flap gate simply opens and closes and does not allow backflow.
- Much less expensive than other more complicated tide gates.

Cons:

- Very minor variations in the upstream water surface elevation at which the tide gate closes.[34]

[30] The mechanism can be used for light-weight top-hinged flap gates as well. A top-hinged fiberglass flap gate at Fornsby Creek was retrofitted with the VBFG™ control mechanism in November 2009. However side hinged flap gates are preferred.
[31] 304 Stainless Steel may be used in fresh water locations to reduce fabrication costs.
[32] The four operating side-hinged tide gates retrofitted with this control mechanism have been operating unattended with minimal intervention for nearly one year as of December 2009.
[33] No outflow is required for the tide gate to open on a falling tide. It is therefore immune to Tide Gate Entropy Death. (See www.jueltide.com for information on Tide Gate Entropy Death.)
[34] The amount of variation depends on the tidal prism of the site. To date, the variation is minimal and inconsequential at all of the tide gates using this control mechanism.