WAIMANU LAGOONS: AUTOMATED ECOLOGICAL AND FLOOD PROTECTION CONTROL GATE

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ABSTRACT (200 WORDS MAXIMUM)

The ecologically important Waimanu Lagoon system is situated in the tidal zone near to the Waikanae River mouth and is surrounded by residential development. Since around 1983 the pond level has been artificially maintained by a manually operated weir gate that has deteriorated in the coastal environment causing maintenance problems and potential upstream flood risk. The weir gate effectively prevents upstream migration of fish into an area that is ideal for spawning.

Kapiti Coast District Council has undertaken to replace the control gate so that the health of the ponds can be better managed, the upstream flood risk can be reduced and fish passage can be restored.

Our presentation will outline the key considerations in designing and implementing the control gate upgrade including:

- Manual, actuated and passive weir concepts
- The types of packaged weir available off the shelf and the features of these
- Risks involved with weirs including failure, malfunction, human interference
- Environmental benefits to lagoon management
- Aesthetics and safety considerations in a recreation environment
- Integration with fish passage
- Design, procurement and implementation

KEYWORDS

Obermeyer, adjustable weir, adjustable gate, ecological management, flood management.

PRESENTER PROFILE

Nick is a civil engineer with MWH Ltd where he has worked since 2005, and now recently based in Perth. Nicholas has been active in the surface water and rivers engineering industry, including modelling and engineering, since 1995 and has also worked in New Zealand, Australia, and Papua New Guinea on a variety of surface water related projects for local government and mining interests. He holds BE (Civil) from University of Canterbury, is a CPEng(civil), BREQ and MIPENZ.

1 INTRODUCTION

The Waimanu Lagoons are located adjacent to the mouth of the Waikanae River on the Kapiti Coast (KCDC). Historically they are a remnant of extensive wetlands that once spread throughout Kapiti and in the 1960's and 1970's parts of the lagoons were widened and deepened as a borrow site for residential fill development around the area. In the 1980's the excavations were made into recreational ponds by the installation of an earth causeway, 1800mm diameter culvert, and manual penstock with a weir overflow and backflow prevention flap. The lagoon system now consists of two man-made ponds in series adjacent to the penstock, separated by a lateral road, and a natural wetland pond further upstream.

The water quality in the lagoons is brackish – neither truly salty nor truly fresh water. In dry weather, the lagoons are fed by groundwater from the upper catchment. The ponds' water quality attracts particular birdlife and allows particular aquatic fauna to thrive. The ponds are now popular locally for recreational activities and bird watching.

The existing penstock is in a coastal and recreational environment. The penstock gear and frame have been exposed to prevailing westerly winds which are laden with sea salt spray. The mean tidal range at the penstock is between 0.9m below MSL and 1.1m above MSL so the frame and weir plate are exposed to the tidal cycle. KCDC maintain the lifting screw and slide rails by applying grease to ensure the gate can be wound open but the gate is not water tight.

Figure 1: The existing level control weir on the Waimanu Lagoon outfall is a manually operated penstock that can be wound upwards to increase discharge through the 1800mm diameter pipe.

The penstock maintains water levels in the ponds at about 1.0m above mean sea level (MSL) during dry weather. For heavy rainfall events the penstock is raised by KCDC to increase outflow capacity. The staff member must carry a winding wheel or lever that fits the winding mechanism.

Presumably the penstock was originally a galvanized steel installation, and it underwent a major refurbishment in 1994, but since then corrosion has taken effect and the seals are not watertight. At times the penstock has been interfered with by members of the public resulting in on-site repairs. Currently the penstock is difficult to operate and maintain, and is not an efficient salt water barrier.

The Waimanu Lagoons system has a significant flood storage volume between the controlled pond water level and the lowest floor level of the adjacent houses. The flood storage volume has given KCDC time to adjust the penstock manually in response to rainfall events or warnings.

With the penstock raised, the 1800mm diameter culvert in combination with the flood storage volume has been calculated to have the capacity to pass the 100 year average recurrence interval (ARI) rainfall event even with a mean high tide outlet condition. This meant that the focus of the upgrade could be on the level control mechanism alone.

When the Waikanae River is in flood for extended periods due to its much-larger catchment area, the penstock is maintained in its closed position to prevent the river back flowing into the Waimanu Lagoons. During these events, KCDC monitors the pond levels and opens the penstock to release the pond volume as the river levels subside. The earth causeway supporting the penstock has a crest level at 2.23m above MSL. KCDC accept that if river and tide levels combine to overtop that level then the lagoons will begin to fill. To date this event has not occurred.

In considering the requirements of the level control gate, KCDC determined that the new asset would perform a number of functions:

- Pass the 100 year ARI flood event.
- Prevent backflow from filling the lagoons with salt water, or Waikanae River flood water. The gate must seal from both flow directions.
- Automated level control, and off site monitoring of water levels and gate operation through SCADA (supervisory control and data acquisition) telemetry.
- Flexibility for KCDC to re-set the control levels of the lagoon water surface.
- Be tamper and vandal resistant, and durable in the coastal environment.
- Allow KCDC to remotely control a lagoon flushing regime where the tide is allowed to enter and exit through the control gate in the open position, and then to reinstate under remote control or on-site control over-ride.
- Allow for fish passage.
- Be aesthetically unobtrusive and inherently safe.
- Other requirements such as value of money.

These objectives come from KCDC's obligations to ratepayers, community, future generations and environment. For KCDC, the new asset must reduce flood risk, improve the environment in terms of fish passage and lagoon management, be safe and a low risk to members of the public, be visually unobtrusive, be monitored by council staff and under their control from off site to reduce maintenance effort, provide a reduced hazard to staff during storms or during physical maintenance, and to be an asset for future generations.

The position of the weir in the tidal zone and the specified functions combined to present a number of unusual factors for a level control weir. This included the need to prevent tidal backflow but allow flood flow; allow for fish passage while maintaining level control in the lagoons; be aesthetically unobtrusive to the public as well as vandal resistant, hazard free and interesting. Unlike a wastewater treatment plant or a hydro dam facility the level control gate is in a public space without a constant KCDC presence.

This paper describes the process that was used to select the preferred upgrade option. Firstly, the process required a methodical investigation of the types of level control needed and secondly, the types of product on the market that would best meet the design objectives.

The result of the selection process was that, in the case of the Waimanu Lagoons, an Obermeyer adjustable weir was specified for the level control gate replacement.

2 SELECTION PROCESS

A formal selection process was followed with KCDC because the design objectives presented a challenge in the location and environment. There did not appear to be an obvious solution or similar precedent.

The basic types of weir were considered against the critical design constraint - flood risk and the inherent risks of malfunction. The packaged "off-the-shelf" weir product preferred over the "construct-from-scratch" approach and then the products themselves were compared against the design objectives.

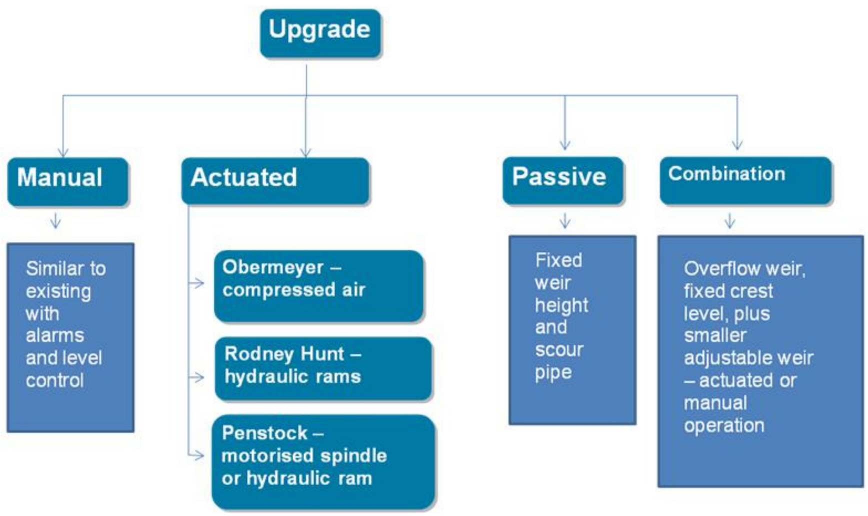


Figure 2: The weir selection process required a check of the weir type and then a further check of available products.

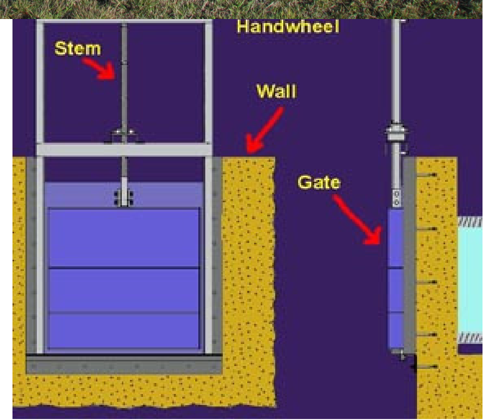
2.1 PASSIVE AND ACTIVE WEIR CONCEPTS

The main types of weir can be thought of as passive or active.

The passive type is considered to be a fixed structure where the weir level and shape do not change and the weir capacity is governed by the weir function which is a proportional to weir length and weir head to the power of 1.5. This is common in reservoir spillways. The passive weir has a low risk of failure due to human error and electro-mechanical faults, but is limited in its flexibility and secondary functions.

Figure 3: Example of a passive weir built to maintain fresh water levels for irrigation in the background while the tidal zone enters the foreground up to the rocks. A concrete overflow is to the right of the passive weir structure.

The active type involves input power to change the weir shape or level to make it function. This is seen in hydro dam sluice gates, pipe valves, open channel penstocks and level control weirs.



For small installations, the active weir type can be manually powered or motor actuated with on site or off-site controls. The manual active weir is moved by winding a hand wheel or lever to slide the weir plate across the water cross section. Another example is installing or removing a series of horizontal boards in a vertical frame to alter the control level. Manually controlled weirs and gates can have level control systems that inform a manual response.

Figure 4: Diagram of a hand operated active weir (penstock) that winds the sluice plate upwards to open the gate

An actuated weir replaces human effort with a motor attached to the windings. It can either be switched on/off manually on-site or controlled automatically from a response to level or flow measuring equipment on-site, or controlled from off-site via telemetry.

A combination of passive and active weir elements could be combined to maximize the benefits of a passive control system and the flexibility of function of an active system.

The passive weir cannot stop tidal back flow above the weir crest level unless a backflow valve or gate is installed in combination on a downstream culvert. The passive weir has advantages of simplicity and a fail-safe flood discharge. But it would require a length of weir crest that would pass the design flow without causing critical head build up that threatened the lowest floor levels in the area. This meant building a long perimeter semi-circular weir upstream in the lagoon. In the case of the Waimanu Lagoons, the passive weir concept was not continued.

An automatic controlled and actuated type weir was selected due to the design objectives of flexibility of operation and off-site control and adjustments. KCDC already manage an inventory of pump stations and the existing maintenance infrastructure and training within the council can be expected to manage an automated active weir.

2.2 RISKS INVOLVED WITH WEIRS

In hydro-power installations and large reservoirs, gate failure is due to a few general categories: failure of the drive mechanism or control system; human error; or structural inadequacy.

Failure of the drive mechanism can be due to power failure, inadequate testing or poor maintenance. Failure of control systems could be due to logic errors or external control inputs not working properly. Human error could be non-attendance or lack of response, poor training, willful damage, neglect of duty, mistakes and accidents. Structural inadequacy could be extreme loadings on a gate strut or abutment, buckling of compression members or plates, cavitation in the spillway, design failings. Blockage could be a factor in smaller scale situations.

Figure 5: An example of a motor mounted, actuated penstock in a wastewater treatment plant

In small installations like at Waimanu Lagoons, the risks include power failure to controls or actuation, vandalism and interference with the operation, blockage from upstream sticks and weed mats, fouling downstream due to tidal debris or flood debris, jamming of the weir due to corrosion, confusion in the level control inputs. Mechanical installations can be provided with back-up power, and some equipment return to a preferable status in the absence of power – such as fall to horizontal over time.

Designing a suitable weir from first principles was abandoned when the cost estimates involved in designing pieces of the weir became high. The design objectives and the parameters of the tides and public space made the weir complicated. The flood risks due to failure of the weir to function were too high.

The decision to use an off-the-shelf product was made to limit design costs and reduce the risk of failure by using an experienced and tested product.

2.3 TYPES OF PACKAGED WEIR AVAILABLE

In general, active weirs either lift upwards and a sluice flow outlets from the base of the weir plate or the weir crest lowers and water flows over the top of the weir plate. Lowering the weir crest means sliding the plate down into a floor recess or rotating the weir plate about a floor pivot. A search of packaged weirs came up with numerous slide or penstock gates that lift the plate up and two main rotating plate weirs.

The penstock or slide gate package requires a power supply, concrete support to the frame and seals to be effective. The frame supports the sliding plate and the motorized spindle that generally sits on top of the gantry. To allow full capacity through a pipeline the plate must be able to lift at least the pipe diameter above the pipe. To limit corrosion, prevent accidents and limit vandalism the motor and winding would be enclosed in steel housing. The penstock would have a visual impact in this particular location.

A rotating, hinged plate controlled by hydraulic rams embedded into the abutments was considered – the Rodney Hunt Bascule gate. The hinge is bolted to the floor slab and the hydraulic rams are connected between the torque end of the weir plate and concrete abutments underneath the weir plate. The rams can also be mounted above the weir plate on the surface. Hydraulic pump housing is needed nearby. The rotating weir plate with hydraulic rams would either have a visual impact above ground or be a major increase in concrete works below ground and tidal level.

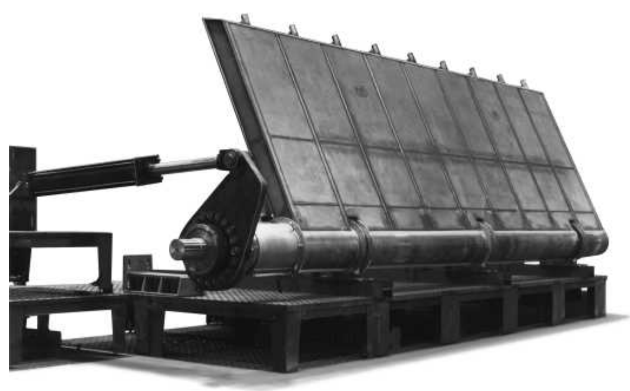


Figure 6: The Rodney Hunt Bascule gate with hydraulic ram and torque hinge.

The second rotating, hinged plate option considered was controlled by compressed air into heavy duty rubber bladders – the Obermeyer Adjustable weir. The hinge is bolted to the floor slab and the weir plate with the upstream water level is supported by compressed air bladders along the width of the weir. Upstream and downstream level control inputs increase or decrease the air pressure in the bladders causes the plate to rise and fall. The air compressor housing can be distant from the weir site and no above ground parts are required.

Figure 7: Obermeyer weir showing downstream components including rubber air bladders and restraining straps

2.4 ENVIRONMENTAL BENEFITS AND FISH PASSAGE

The Waimanu Lagoons weir provides a salt water barrier and a steady water level in the ponds throughout the tidal cycle. The new weir will need to provide a safe and controlled flushing function whereby the weir is removed and the lagoons are flushed by the action of the tide. KCDC decide to do this when weed mats build up in the ponds or midge fly populations increase too much or other ecological reasons, normally once a year for 1 or 2 weeks.

A weir cannot provide fish passage on its own. A supplementary water supply from the lagoon to the tidal area was provided through a 900mm diameter pipe and internal baffles offset from the weir structure. The controlled level of the weir provides a constant starting point at the top of the fish passage pipeline. The bottom end discharges to the tidal area and includes a tidal flap gate to prevent the highest parts of the tidal cycle back flowing into the lagoons. The continuous flow down the fish passage pipeline is expected to draw fish fry (inanga) upstream into the lagoon whilst blocking larger fish from migrating in.

The weir options all provide similar environmental benefits in this case.

2.5 AESTHETICS AND SAFETY

The three main weir options, penstock, Bascule gate and Obermeyer weir, would be constructed of stainless steel 316L materials to last in a coastal marine environment. Even this material will eventually corrode and look unsightly therefore the less exposed steel the better.

Aesthetically when viewed from above and from the surrounding vicinity, the less exposed steel and structure the better. For foot traffic and cyclists who use the path across the causeway the less structure above ground the better. All weir options have some minor machine operation noises and slow movements, and debris risks from upstream and downstream sources can be limited by the design of grills and outlet aprons.

The main safety hazards for the public are falling into the water when the water is high and falling from height when there is little water. For both hazards safety fencing would reduce this risk around the weir structure. For council maintenance, a hazards and operability study (HAZOPS) assessment would identify working hazards and focus attention on safe working procedures. The penstock option is likely to be better understood due to the familiarity of it in water and wastewater treatment plants.

All active weir options provide manual override controls and the upstream end of the 1800mm diameter culvert can be blocked off to allow weir maintenance.

The weir options all require some visible supporting construction in addition to safety fencing. The penstock would require the motor housing and frame above it, and the rotating plate weir options would require an extension of the outlet apron and wing walls.

Aesthetically, the Obermeyer weir and the Bascule gate with rams underneath are preferred but for maintenance safety the penstock is likely to be initially favoured due to its familiarity in water and wastewater treatment plants.

2.6 FINANCIAL COST

All of the weir options involved stainless steel 316L which is an expensive material and all off-the-shelf packages come from the USA or UK so transportation is a similar cost. The penstock option was the most cost effective but at the expense of aesthetics. The Obermeyer was the middle cost option as it has concrete wing walls and apron to incorporate into the weir. The Bascule was the most expensive due to extra concrete ram housing and motor housing at or below MSL adding to higher construction costs.

2.7 PREFERRED OPTION

The preferred option was determined after two main rounds of selection: a type selection and then a product selection. In summary the type selection for the Waimanu lagoons case is described in Table 1:

Objectives and Parameters	Passive weir type	Manual Weir type	Automatic weir type
Pass 100 year ARI flood	Yes	Maybe	Yes
Prevent tidal backflow	No	Yes	Yes
Automated level control	No	No	Yes
Flexibility to operate	No	Maybe	Yes
Vandal proof	Yes	Maybe	Maybe
Coastal corrosion resistance	Good	Maybe	Maybe
Fish Passage	No	No	No
Aesthetically unobtrusive	No	Maybe	Yes
Safe for public	Maybe	Yes	Yes
Safe for maintenance	Yes	Maybe	Yes
Drive mechanism robustness	Good (passive)	Poor (human)	Medium
Independent of Power supply	Yes (passive)	Yes (human)	No
Maintenance free	Yes	No	No
Low risk of Blockage from upstream	Yes	No	Maybe (alarms)
Low risk of Blockage from downstream	No	Yes	No

Table 1: Summary of Passive, Manual and Automatic Weir Types – Design Objectives and Parameters

Table 1 shows that the automatic weir type was strongest in the design objectives required by KCDC. These objectives out-weighed the advantages of the passive weir type in the case of power failure, blockage by debris, maintenance and technical failure. The advantages of the passive weir type were considered to be normal risks that KCDC could accept as it does with all of its pumping assets. The active weir type was selected.

The product selection for the Waimanu Lagoons case is described in Table 2:

Objectives and Parameters	Obermeyer weir	Bascule gate	Actuated penstock
Pass 100 year ARI flood	Yes	Yes	Yes
Prevent tidal backflow	Yes	Yes	Yes
Automated level control	Yes	Yes	Yes
Flexibility to operate	Yes	Yes	Yes
Vandal proof	Middle	Highest	Lowest
Coastal corrosion resistance (SS316L)	Highest	Middle	Lowest
Fish Passage	No	No	No
Aesthetically unobtrusive	Highest	Middle	Lowest
Safe for public	Yes	Yes	Yes
Safe for maintenance	Yes	Yes	Yes
Drive mechanism robustness	Highest (air)	Medium (hydraulic fluid)	Lowest (power)
Independent of Power supply	High (weir sinks if no power)	Low (weir locks in position)	Low (weir locks in position)
Maintenance free	Higher (less parts, robust parts)	Low (power and hydraulics)	Low (fine parts, exposed gear and seals)
Low risk of Blockage from upstream	Yes	Yes	Yes
Low risk of Blockage from downstream	Yes	Yes	Yes
Cost effectiveness	Medium	Lowest	Highest

Table 2: Summary of Obermeyer weir, Bascule gate and actuated penstock – Design Objectives and Parameters

The Obermeyer meets the design objectives and has the advantages of being best aesthetically, best failure mode and least maintenance. The disadvantages are it is more vandal prone than the Bascule and more expensive than the actuated penstock. For the

Waimanu Lagoons the advantages were considered to outweigh the disadvantages. The Obermeyer weir option was selected as the preferred option.

2.8 DESIGN, PROCUREMENT AND IMPLEMENTATION

At the time of writing this paper, the design and procurement stages were complete and construction tenders were being sought.

The design of the Obermeyer was carried by Obermeyer Hydro Ltd (Obermeyer) as part of the weir package purchase. Dimensions and engineering context were sent to Obermeyer and shop drawings were compared with civil and mechanical services design. The weir required a stainless steel pressurized air pipeline that was welded and wrapped to resist soil corrosion. The control housing was placed away from the weir on slightly raised ground and included the air compressor, telemetry, level sensor terminals, logic controller, and air control cabinet. The project required structural and civil additions to the existing outlet structure.

Procurement of the Obermeyer weir was without issue. Shop drawings were confirmed, the weir was built and transported to Los Angeles and shipped to Wellington. KCDC transported the shipping container to a warehouse on the Kapiti Coast in preparation for the implementation phase.

3 CONCLUSIONS

A weir selection process has been outlined to meet design objectives in a challenging environment that involved dry weather water level control, tidal variation, flood flows, adjacent river flows, flood risk and backwater risk.

The design objectives included reducing flood risk, improving fish passage, improving flexibility of weir operation to allow management of the lagoons, installing off-site control and monitoring, limiting visual aesthetics in a recreational beach setting, and maintaining a safe environment for the public and maintenance staff.

The procedure was firstly to look at the type of weir that is suitable: a passive weir, a manual weir or an automated actuated weir. Each has advantages and disadvantages, and the application depends upon the design objectives and situation. Secondly, look at the off-the-shelf products on the market.

If an automated weir type was selected then a marketed packaged weir would likely be preferable to a weir designed from first principles.

In situations where a weir is not a perfect fit, an assessment of the advantages versus the disadvantages must be made with the client to determine whether the disadvantages are able to be compensated by the client staff's experience, equipment and skills.

ACKNOWLEDGEMENTS

Kapiti Coast District Council, NZ

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