▪ report

Orakei Basin
Review of Flushing Regime Options

Prepared for

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By

Beca Infrastructure Ltd

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Table of Contents

Appendices

Executive Summary

The Orakei Basin, a recreation reserve for water sports, was created from a tidal inlet by the construction of the railway embankment in the late 1920s with sluice gates to flush water in and out of the Basin. These modifications resulted in separation of the Basin from Purewa Creek and Hobson Bay, and consequently reduced movement of water in and out of the Orakei Basin. The results of this reduced water movement were degradation in water quality, an increase in algal growth, and an increase in sedimentation of Orakei Creek and Basin.

Previous water quality modelling of the Basin and Creek (Orakei Creek Water Quality Modelling, Beca, November 2004) has shown small, but measurable, improvement in most water quality parameters when including the upstream catchment improvement works (wastewater catchment separation, network upgrades, and Waiatarua wetland enhancement etc). This modelling also concluded that the regular flushing of the Basin with seawater dominates the dynamics of water quality in the Basin.

Following on from the previous work this study extends the existing water quality and hydraulic modelling to assess the impact of potential Basin flushing regimes. These regimes have been assessed on the water quality and usability of the Basin based on the availability of suitable depths of water for recreational purposes.

Three gate flushing regimes were analysed in this study :

- Fortnightly flushing (existing situation);
- Maximised flushing (increased flushing frequency whilst maintaining usability of the Basin);
- and Fully tidal operation.

Additional options including having a reduced gate height with partial depth flushing as well as a weekly flushing regime were also considered and then discounted from further analysis. Subsequent to preliminary consideration these additional options were found to significantly decrease the usability of the basin while not providing a significant improvement in water quality or restoration of the natural environment.

Basin Usability

The assessment into the usability of the Basin identified that there is some scope to increase the amount of flushing from the current Fortnightly regime while maintaining usability levels. However, due to the nature of the peak tidal cycle the scope for this is limited and requires more frequent and onerous operation of the gates and less consistency of usable periods due to flushing. Refer to Table 4.1 for a summary of the comparison of flushing regimes and usability results.

The Fully tidal operation provides significantly increased flushing, but reduces the potential recreation value of the Basin for water based activities to prohibitive levels. Also, due to the significant number of increased flushes, it is expected that the potential for scouring of the Creek bed will increase. This loss of Creek bed may lead to a small reduction in the Creek bank slope stability. Although the decrease in slope stability is small, the risk that a potential failure being attributed to the change in flushing regime remains.

There may also be an opportunity to optimise the existing fortnightly flushing operating regime to improve the usability of the Basin as well as meet the levels desired by residents on the upper reaches of the Creek arms by improved management of the gate operation and top up events.

Water Quality

Recreational water quality guidelines for microbiology are likely to be exceeded in the Orakei Creek during storm flow events. None of the proposed flushing options will reduce the number of microbiological exceedence events.

The mean duration of action-level events with fortnightly or maximised flushing is about 24 hours and would result in public warning of unsafe recreational water contact.

For fully tidal flushing the mean duration of an action-level event is about 10 hours, which may not result in a public notification of water quality.

From a recreational view, point the water quality in the Creek is generally only considered suitable for secondary contact (i.e. boating, kayaking), and will fall outside the recreational water quality guidelines during large storm events. Permanent public warning signs may be required if the water is to be managed for recreation.

The Basin water is generally considered suitable for contact recreation under the fortnightly or maximised flushing regimes and no exceedences of the microbiological limit is predicted. The impact of stormwater, including any future remaining combined sewer overflows (CSO) from the Creek may give rise to local exceedences near the confluence of the Creek and Basin during storm events.

Overall there are relatively minor improvements in Basin water quality with the Maximised flushing routine compared with the Fortnightly flushing regime.

While there is some minor improvement in water quality in relation to recreational guideline values for the Maximised flushing regime, this option requires a more onerous operating regime which may not justify the benefits. The existing flushing regime demonstrates a practical frequency of flushing as it aligns well with the peak tidal cycles, and it provides a reasonable frequency of flushing to limit water quality issues in the Basin.

1 Introduction

In November 2004, Beca Carter Hollings & Ferner Ltd. was contracted by Auckland City to undertake a study to assess gate flushing regime options for Orakei Basin. This study looks into the impact on water quality in relation to contact recreation guideline values for Orakei Basin, and at the usability of the Basin based on the availability of suitable depths of water for recreational purposes.

The following principal objectives were identified for guiding the comparison of flushing options:

- improving the natural environment / marine habitat potential;
- maximising the recreation potential for Orakei Basin; and
- maintaining as far as possible, the perceived aesthetic quality.

2 Background

The Orakei Basin, a recreation reserve for water sports, was created from a tidal inlet by construction of the railway embankment in the late 1920s, with sluice gates to flush water in and out of the Basin. These modifications resulted in separation of the Basin from Purewa Creek and Hobson Bay and consequently reduced movement of water in and out of the Orakei Basin. The results of reduced water movement were a degradation in water quality, an increase in algal growth, and an increase in sedimentation of Orakei Creek and Basin.

The Orakei Creek and Basin also receive stormwater from Ellerslie-Waiatarua and Meadowbank catchments, and sewer overflows from the Meadowbank wastewater catchment. These inputs have added to the sedimentation and degradation of the water quality in the Creek and Basin.

As part of the larger goal of improving the natural environment in Orakei Creek and Basin and the suitability of water quality for contact recreation activities, a number of mitigation projects such as sewer separation, network upgrades, and the Waiatarua Reserve wetland enhancement have been or are currently being undertaken.

Previous water quality modelling of the Basin and Creek (Orakei Creek Water Quality Modelling, Beca, November 2004) has shown small but measurable improvement in most water quality parameters with the upstream catchment mitigation measures in place. This modelling also concluded that the regular flushing of the Basin with seawater dominates the dynamics of water quality in the Basin.

Following on from the previous work this study extends the existing water quality and hydraulic modelling to assess the impact of different flushing regimes on the water quality and usability of the Basin.

3 Options Considered

A number of potential options were considered for the Basin flushing regimes. Taking into consideration the potential benefits to water quality and the impact on water levels in the Basin the following list provides a summary of the main options :

1. Fortnightly flushing (existing situation)
2. Maximised flushing (increased flushing frequency whilst maintaining usability of the Basin)
3. Fully tidal
4. Reduced gate height / partial depth flushing
5. Weekly Flushing

Following an initial assessment options 1, 2, and 3 were selected for further analysis and modelling whilst options 4 and 5 have not been considered further.

Option 4 considered variations of having a gate which allowed regular tidal flushing down to a mid range level. This would allow flushing on each tide cycle but would always maintain some water in the Basin for recreational use and amenity value. When reviewing the bathymetry data for the Basin it became clear that with even very small reductions in gate levels the area of the Basin with a suitable depth of water decreases significantly. This option was therefore discounted as it provided significantly reduced usability for a limited increase in the relative amount of flushing.

Option 5 looked to increase the frequency of flushing to a period of one week or less, significantly increasing the frequency of flushing. This can be achieved, however only at the expense of approximately a 50% reduction in the duration of usable water levels. This is due to the frequency at which suitably high tides occur being approximately every two weeks. This option was therefore discounted based on the significant reduction in duration of usable water levels while not resulting in a benefit in terms of restoring the natural environment.

4 Assessment of Usability of the Basin based on Water Level

4.1 Methodology

Various groups and individuals use Orakei Basin for recreational purposes including: sailing, kayaking, rowing, water-skiing, wakeboarding and other water sports. In addition, the Basin provides a scenic location and environment for those living in the area and using the banks for walking or other recreational purposes.

To gain a better understanding of the water level required to provide sufficient depth for these activities, users of the Basin were consulted on their preferred conditions. Based on the consultation responses, a minimum preferred water level in the Basin of 1.26m above the mean sea level datum (MSL) and a maximum of 1.56 m MSL have been chosen for

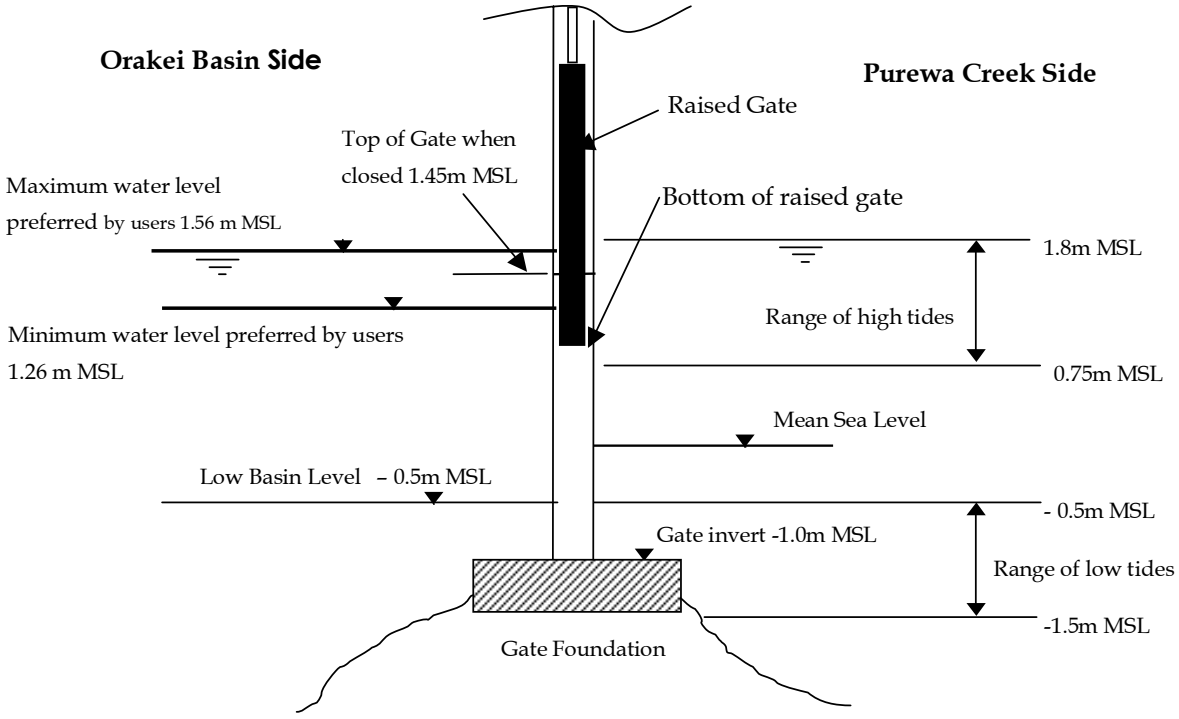
comparing flushing options. (These levels relate to 3.0m and 3.3m respectively, using Chart Datum).

Level monitoring was undertaken on either side of the gates over a period of 27 days to better understand the effects of the hydraulic restriction caused by the gates and to allow calibration of the hydraulic model. This monitoring and modelling shows that under normal tidal flushing the top water level in the Basin is typically about 200mm less than the external high tide and occurs approximately an hour after the time of high tide. Refer to Figure 1 in Appendix A for a plot of the water level monitoring data.

Using the hydraulic model and the water level monitoring data, recorded tide data for 2004 from the Port of Auckland was converted into an equivalent year of tide levels for the Orakei Basin. For the Fortnightly and Maximised options this data was then used to manually identify a series of flushing events throughout the year based on the guiding principals of each of the flushing options. For the Fully Tidal option the Basin tide data was analysed directly and the durations at which the water level met the preferred users levels calculated.

The following sections give a brief description of each of the flushing options and the resulting assessment of time that the Basin level meets the user requirements. Refer to Table 4.1 for a summary of the comparison of flushing and usability results. Figure 4.1 below is a section through the gates and sketches out the approximate range of water levels either side of the gates.

Figure 4.1 - Orakei Basin Gates - Approximate Water Level Ranges



4.2 Fortnightly flushing

This option is based on the current operating scenario of fortnightly flushes starting at the end of the day on Sunday and finishing on the first suitable high tide on the following Tuesday. From time to time it is necessary to reduce the impounded period to one week to align the flushing events with the peaks in the tide cycle. When the end of a flushing cycle falls in a period where the tide levels are too low to reach the preferred user levels, the next available tide has been identified and the Basin is 'topped up'.

Applying this logic to the tide data the following observations were made: 25 cycles of fortnightly flushes were identified and 2 cycles where the cycle is shortened to one week to shift to meet the higher tide. For each fortnightly cycle there is a period of inundation of typically just over 12 days followed by a typical period of 1.6 - 2 days of flushing. On average there are about 3 exchanges of water for each flush with a total of approximately 82 water changes for the year. Generally the gate operation times are kept within 6am to 8pm, however, to meet about five particular events where opportunities for filling the Basin were limited, the gate operation timing fell outside of these hours.

From a Basin users point of view, this results in the water in the Basin being above the minimum preferred levels of about 78% of daytime hours during the year (7am - 8pm).

4.3 Maximised flushing

The Maximised flushing option removes the restriction of starting a flushing cycle on a Sunday and aims to maximise the number of flushing events while still maintaining high levels of time during which the minimum preferred water levels are met.

Shorter but more frequent flushes were identified which results in a typical pattern of two short flushes in close proximity either side of a period of peak tides, followed by a period of longer inundation until the next suitable peak tide.

A significant number of variations of this regime can be developed depending on the start time and duration of flushing events. To give an indication of the resulting performance a couple of minor variations have been analysed giving a small range of results. With this regime it is possible to identify suitable locations for 34 short flushes (1.5 -2 exchanges of water), and 9 fortnightly flushes (3 exchanges), over a year. The duration of inundation between flushes is highly variable and ranges between 2 –13 days, with an average of 7 days duration. During periods with peak high tides there will be a short inundated period of about 3 days between flushes, there will then be followed by a longer inundated period which will generally be greater than one week but less than two weeks.

This regime results in between 92 – 94 changes of water in a year. As a consequence of the increased flushing time, the usable hours during which the water level meets the user requirements decreases slightly to between 75% - 76% of daytime hours.

The predictability of usable times is lower for this option as the day of the week in which a flushing event occurs varies from week to week. It is also more onerous in terms of gate operation and requires approximately 12 gate operations outside normal operational hours and 2 to 4 weekend days lost to flushing events during the year.

4.4 Fully tidal

The fully tidal option assumes no interference to the water level regime in the Basin other than the hydraulic restriction caused by the open gates. Analysing the water level data from the hydraulic model for the 2004 tide data shows that the preferred minimum user level of 1.26m is only exceeded about 2% of daylight hours during the year. Looking at the Basin water level data over the year clearly shows that there are only very infrequent periods and short durations when the Basin water levels meet the minimum criteria. As a result of allowing the Basin to act in a fully tidal manner the resulting number of changes of water however substantially increases and will occur approximately 710 times per year. Refer to Figure 3 in Appendix A for a plot of the water level exceedance results.

4.5 Inundation Summary

Due to the flat profile of the Basin bed and the high bed level relative to regular sea levels, the availability of Basin areas with a water depth suitable for recreational purposes is very sensitive to small fluctuations in water level.

The gates, therefore, play a significant role by retaining water at higher levels, providing a greater available area for recreational use, as well as increasing amenity value. Small changes to the operating regime of the gates has the potential to significantly effect the duration at which the water level in the Basin can be maintained at suitable depths for recreational use. There is some scope to increase the amount of flushing from the current fortnightly regime while maintaining similar usability levels; as can be seen from the maximised flushing regime. However, due to the nature of the tidal fluctuations, the scope for this is limited and requires more frequent and onerous operation of the gates and less consistency of usable periods due to flushing.

There may also be an opportunity to optimise the existing fortnightly flushing operating regime to improve the current durations at which the water levels are above the minimum preferred levels as well as above the levels desired by residents on the upper reaches of the Creek arms. This could be accomplished by taking advantage of more "top-up" events throughout the year. Currently many of these fall outside normal operational hours and therefore are not utilised due to the inconvenience. Through formalising the management and requirements for topping up based on level or through automated operation of the gates, the water level regime in the Basin could be managed more effectively for recreational use and amenity value.

Table 4.1 – Results for 2004 inundation analysis

	(1) Fortnightly Flush	(2) Maximised Flushing	(3) Fully Tidal
Number of flushes	25 fortnightly 2 weekly 27 total	34 short flushes 9 fortnightly 43 total	N/A
Number of water changes	82	92 - 94	Approx. 710
Impoundment durations	Avg. 11 days Range 5 - 16 days	Avg. 7 days Range 2 - 13 days	N/A
% of usable daylight hours (7am – 8pm)	78%	75% – 76%	2%
High user times lost to flushing (weekend days)	0	2 - 4	N/A
Out of hours gate operations to meet high tides (8pm – 6am)	8	12	N/A

As well as fortnightly flushing the current operating regime for the gates includes 'emergency flushing' following rainfall events that exceed predefined trigger levels, currently set at 5mm in one hour and 15mm in three hours. The emergency flushing events have not been taken into account when comparing the different flushing options, as the increase in flushing events would be consistent for both flushing options.

4.6 Leakage

The above calculations of usable time have not taken into consideration the reduction in water levels due to leakage of water through the gates. Therefore, the amount of actual useable time currently being observed will be less than the reported values. It has been assumed for the purposes of this study that if the Basin is to continue to be used for recreational purposes, the leakage from the gates will be fixed.

The primary source of this leakage from the Basin is thought to be through the gates, with the western most gate being responsible for the majority of the flows. Although there is the potential for leakage also to be occurring through the embankment, there has been no visual evidence of this. A previous report looking into options for remediation of the gates (Orakei Basin Sluice Gates Preliminary Report, TCB, August 2003) identified possible leakage rates from a desktop study of approximately 100mm per week (14.3mm/day).

Using the water level monitoring data collected in the Basin during December 2004 and January 2005, the drop in water level recorded following a period of dry weather was 93mm over 64 hours (2.7 days). This relates to a decrease of approximately 35mm/day. Using the bathymetry data to calculate the change in volume of water between these levels

gives an approximate flow rate of 200 L/s. Refer to Figure 2 in Appendix A for a plot of the Basin water level over the leakage period.

Over a dry 12 day inundation period there is the potential for a drop in water level of up to 420mm. During periods of rainfall some of the leakage will be mitigated by increased incoming flows. Following a relatively high tide with a top water level in the Basin of 1.4m MSL or above this lowering in the water level doesn't significantly effect the area of exposed mud in the Basin but has a reasonable impact in the upper arms of Orakei Creek. It does however have a significant impact on the available area with the minimum depth of water for recreational activities. Due to the flat profile of the Basin bed the depth of water in significant areas of high use quickly drops below preferred level with a relatively small drop in water level. Refer to Appendix B for maps of usable areas before and after leakage during a 12 day period of inundation.

Topping up of the Basin is currently sometimes carried out to mitigate the loss of water from leakage if there are suitable high tides during operational hours. Further benefit to usable water levels and amenity value, particularly in the upper reaches of the Creek, could also be achieved by topping up the Basin during all available suitable high tides. This would also require manual operation of the gates out of normal working hours or automation of the gates based on level sensors in the Basin and Purewa Creek.

If the gates are to continue being used to control the water level in the Basin and Creek and the recreation potential and amenity value are to be maximised, the leakage from the gates will need to be stopped or significantly minimised. The *Orakei Basin Sluice Gates Preliminary Report* by TCB in August 2003, investigated options for the remediation of the leakage from the gates. This report recommended reconstruction of the five gates but does not confirm whether these remedial works can be carried out through refurbishment of the existing gates or replacement with new gates and guides. Further inspection is recommended to identify the extent of the deteriation and scope of the necessary remedial works. The inclusion of an automated control system during any upgrade would allow improved management of the water level regime and maximise the usability of the basin and upstream amenity value.

5 Comparison of Water Quality

5.1 WASP Water Quality Model

The evaluation of water quality impacts from the different tidal flushing options has been carried out with the WASP (Water Quality Analysis Simulation Program) model that was previously used for the Orakei Creek water quality modelling report prepared by BCHF Ltd for Auckland City Utility Planning in November 2004. Details of the model setup are described in that report. Figure 5.1 shows the water segmentation of the WASP model.

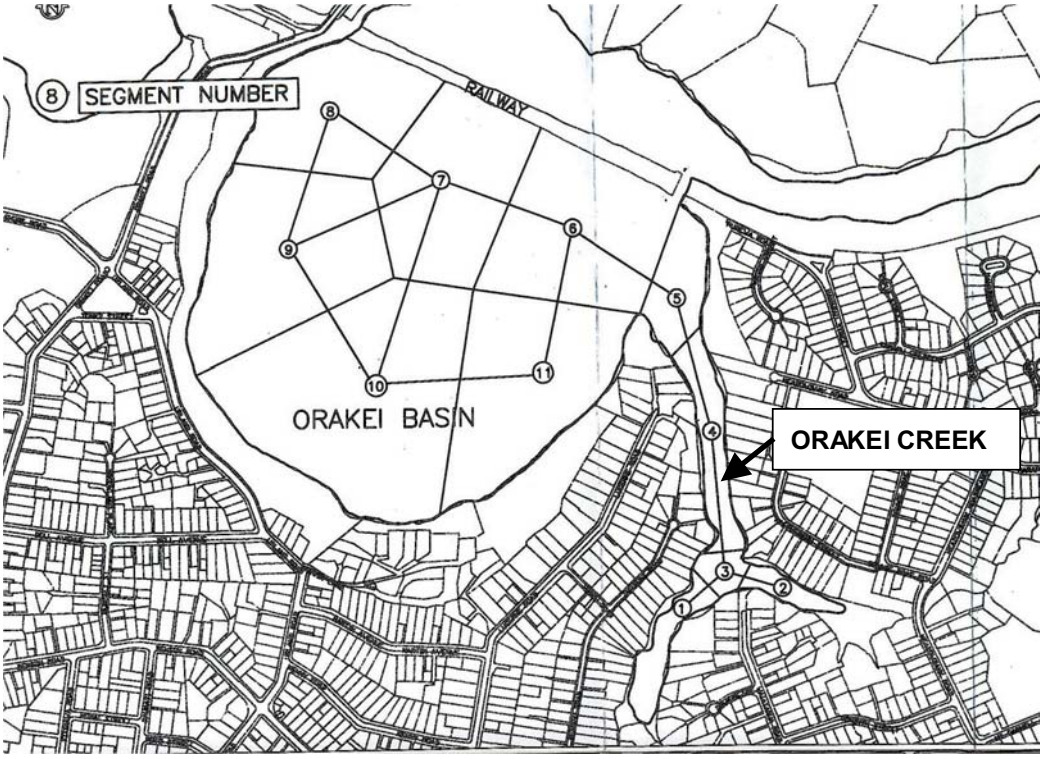


Figure 5.1 WASP model water segments

Three tidal forcing functions were used for the model;

- Regular fortnightly flushing consisting of 3 complete tide cycles every 14 days.
- Maximised flushing consisting of 2 complete tide cycles occurring at times when the tide level allowed maximum water level to be maintained in the Basin.
- Fully tidal flushing where the Basin water is exchanged every tide cycle.

For simulation of the tidal flushing options the following conditions were applied;

- The stormwater inputs and contaminant loads from the catchments draining to the Creek and Basin were derived from the MOUSE model outputs from the *Orakei Basin Integrated Study (OBIS)* carried out by City Design Limited in 2000. The MOUSE model simulated the 1996 year as the average rainfall year. The mitigated scenario results were used wherein the Waiatarua and Meadowbank catchment improvements are complete. These works are currently under construction, so the WASP water quality results relate to the near-future when the works are complete. Following these improvements the incoming water quality will be dominated by surface water flows, however, the remaining CSO's will still have an impact on the Creek and Basin water quality. As a simplification the movement of sediment derived nutrients from the bed has not been included.
- A hydraulic model of the Basin was prepared using EFDC (Environmental Fluid Dynamic Code) to provide the tidal exchange volume for the WASP simulations. Approximately 95% of the water impounded in the Basin can be exchanged during a

tide cycle. The hydraulic model was calibrated against Basin and Purewa Creek water levels measured over several tide cycles. Refer to Figures 5 and 6 in Appendix A for verification graphs comparing the actual measured levels and the predicted model output. The verification showed good correlation to the measured data. The monitoring period did not include a flushing event during a peak level tide and, therefore, it is not possible to verify the performance of the model during more extreme tides.

- The water quality of the tidal water exchanged from the Purewa Creek was based on a limited period of sampling in November and December 2004 during a flushing period. Additional data was collected in Purewa Creek for a non-flushing period however this was limited due to the scope of the study. As the sampled water quality is not representative of the dynamics of a full season or storm events the model results need to be interpreted with caution.

5.2 Water Quality Guidelines for Recreation

There are two guideline documents that provide a framework for management of recreational water quality that are applicable to the Orakei Basin.

- Australian and New Zealand Environment and Conservation Council (ANZECC), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000*
- Ministry for the Environment (MfE), *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas, June 2003* .

The ANZECC guidelines define two categories of recreational water contact:

- Primary contact – where the user comes into frequent direct contact with water, either as part of the activity or accidentally, for example swimming, or water skiing.
- Secondary contact – where the user generally has less frequent body contact with the water, for example boating or fishing.

A third recreational category concerns the passive use of water bodies, mainly as places to be near or view for aesthetic reasons with no body contact.

The water quality characteristics relevant to recreation use are summarised in Table 5.1, with values in Tables 5.2 and 5.3.

Table 5.1 Water Quality Characteristics

Characteristics	Primary Contact	Secondary Contact	Visual Use
Microbiological guidelines	✓	✓	
Nuisance organisms (algae)	✓	✓	✓
Physical and chemical			
Aesthetics (colour clarity)	✓	✓	✓
pH	✓		
Temperature	✓		
Toxic chemicals	✓	✓	
Oil, debris	✓	✓	✓

5.3 Water Quality Results

There are two broad zones of water quality with respect to the Orakei Creek and Basin, each with a different characteristic.

5.3.1 Orakei Creek Water Quality

The Orakei Creek water quality is dominated by the impact of upstream stormwater discharges, including combined sewer overflows, entering from the Waiatarua and Meadowbank catchments. The Creek is shallow and the tidal exchange volume is small in proportion to storm flows that enter from the catchments, leading to a greater variability of water quality. With the mixture of tidal and freshwater the general characteristic is considered brackish.

In the WASP model the Creek is defined as relating to water segments 1 – 5. For the purposes of this study the model results for segment 4 are considered most representative of the Creek water quality. A summary of the Creek results compared to the guideline values can be found in Table 5.2 below. Plots of the model output can be found in Appendix C. In the tables below, an 'event' is considered to be a storm event that causes the water quality in the Segment to exceed the guideline value. To put the number of occurrences into perspective Auckland receives approximately an average 170 rainfall occurrences (>1mm) a year, each of these having the potential to trigger a breach of guideline values.

Table 5.2 - Annual Water Quality Results- Orakei Creek (Segment 4)

Water Quality Guideline	Fortnightly Flushing	Maximised Flushing	Fully Tidal Flushing	Comment
Enterococci ■ Alert mode >140 cfu/100mL ■ Action >280 cfu/100mL	40 events Mean duration 40hr 25 events Mean duration 24hr	39 events Mean duration 41 hr 24 events Mean duration 28hr	42 events* Mean duration 21hr 26 events Mean duration 10hr	≠ Levels coincident with significant stormwater flows (inc wastewater overflows). ≠ Flushing does not significantly change frequency of events. ≠ Full flushing reduces duration of events
Ammonia ■ <0.01 mg-N/L	Mean 0.08 mg/L	Mean 0.09 mg/L	Mean 0.09 mg/L	■ Above Water Quality (WQ) guideline
Nitrate ■ 10 mg-N/L	Mean 0.52 mg/L	Mean 0.46 mg/L	Mean 0.16 mg/L	■ Compliant with the WQ guideline

Water Quality Guideline	Fortnightly Flushing	Maximised Flushing	Fully Tidal Flushing	Comment
Dissolved Inorganic nitrogen (DIN) ■ <0.2 mg-N/L	Mean 0.6 mg/L	Mean 0.55 mg/L	Mean 0.25 mg/L	■ Levels unlikely to promote algal blooms ■ Some potential for algal growth. ■ Full flushing further limits algal growth.
Total dissolved reactive phosphorus (DRP) ■ <0.008 mg-P/L	Mean 0.007 mg/L	Mean 0.01 mg/L	Mean 0.027 mg/l	■ Creek shows small potential for algal growth ■ Full tidal flushing enhances growth due to higher Purewa Creek DRP
Suspended Solids ≠ No guideline value given but high suspended solids is likely to result in high turbidity with poor colour and clarity.	Max 152 mg/L	Max 153 mg/L	Max 200 mg/L	≠ Maximum TSS function of stormwater inflow, not flushing frequency. ≠ TSS peaks shorter duration with full tidal flushing (see graph) ≠ Higher in Purewa Creek

*The Fully Tidal Flushing regime results for Enterococci indicate 42 events exceeding the Alert mode (140 cfu /100mL) as compared to 40 and 39 for the Fortnightly and Maximised regimes respectively. The reason for the Fully Tidal regime showing a higher number of events, relates to the relationship of the duration of the storm event (and therefore the duration of incoming high Enterococci levels) and the timing of a tidal water change. In some instances where a single long event was counted for the Fortnightly and Maximised options, multiple events were counted for the Fully tidal regime. This is due to a tide cycle occurring and bringing in clean water during the storm event which temporarily lowers the Enterococci levels, followed by a second peak due to the extended length of the storm event. This increased number of events does not indicate a reduced performance of this option.

Discussion

- The Creek water will regularly not meet recreational microbiological guidelines for Enterococci and there could be more than 40 events per year when the alert level of 140 enterococci/100mL could be exceeded. The mean event duration is around 40 hours for the fortnightly and maximised flushing options. For the full tidal flushing option the mean duration is reduced to around 21 hours.
- There are up to 25 events per year where the level would exceed the microbiological action level of 280 Enterococci /100mL. If these conditions persist for more than 24 hours public warning signs are required if the water is to be managed for contact recreation. The mean action event duration is about 24 - 28 hours for the fortnightly

and maximised flushing options, indicating that a repeat action transgression could occur within the 24 hour limit and that public warning would be required. This would not occur for the full tidal option.

- The Enterococci transgression events are coincident with stormwater (including wastewater overflows) discharges into the Creek.
- The level of nitrogen and phosphorus in the water is sufficient to produce mildly stimulating conditions for algal growth. However the relatively short hydraulic residence time in the Creek would preclude significant blooms of phytoplankton for all options. Under the full tidal flushing option the mean reactive phosphorus concentration is elevated due to the water quality of the Purewa Creek, but as the Creek is flushed twice daily the phytoplankton growth potential is low. The extent to which phosphorus concentrations from Purewa Creek elevate the Orakei Creek levels is uncertain as the data set for Purewa Creek water quality is limited.
- Generally for the Fortnightly and Maximised regimes the ratio of nitrogen to phosphorus indicates that phosphorus will be limiting. Under the Fully Tidal regime the ratios indicate that nitrogen will be limiting.
- There will be high concentrations suspended solids in the Creek during storm events with routine peaks in excess of 100mg/L TSS. This will create visually turbid conditions in the creek under these situations. Similar peaks occur under all the options.
- From a recreational view point the water quality is generally only considered suitable for secondary contact (boating, kayaking), and will fall outside the guidelines for large storm events. Permanent public warning signs may be required if the water is to be managed for recreation.
- The water quality in the creek will be primarily driven by the incoming water quality, however, the contaminated sediment in the bed of the creek will also have a detrimental effect. The dredging and removal of these sediments would provide a small increase in the water quality in the Creek and Basin.
- None of the flushing options significantly improves the Creek water quality.

5.3.2 Basin Water Quality

The Orakei Basin water quality is dominated by the tidal exchange from Purewa Creek and can be considered a marine body of water for application of recreational guidelines. The WASP model of the Basin relates to water segments 6 – 11. Water segment 10 has been used to represent the Basin water quality as it describes the water body closest to the shoreline likely to be used for swimming and contact recreation.

The water body closer to the tidal gate and confluence of the Orakei Creek (ie Segment 6 in Figure 5.1) will be more impacted by the stormwater (including wastewater overflows) discharges under the fortnightly or maximised flushing routines. A summary of the Basin results compared to the guideline values can be found in Table 4.3 below. Plots of the model output can be found in Appendix C.

Table 5.3 - Annual Water Quality Results – Orakei Basin (Segment 10)

Water Quality Guideline	Fortnightly Flushing	Maximised Flushing	Full Tidal Flushing	Comment
Enterococci ■ Alert mode >140 cfu/100mL ■ Action >280 cfu/100mL	0 events 0 events	0 events 0 events	0 events 0 events	■ Enterococci levels below alert levels for all flushing conditions. ■ Basin Enterococci level very dependent on Purewa Creek. ■ Maximum count typically about 60 cfu/100mL during storm event.
Ammonia ■ <0.01 mg-N/L	Mean 0.10 mg/L	Mean 0.12 mg/L	Mean 0.11 mg/L	■ Above theWQ guideline. ■ Organic nitrogen from Purewa Creek increases Basin ammonia level
Nitrate ■ 10 mg-N/L	Mean 0. 11 mg/L	Mean 0.07 mg/L	Mean 0.03 mg/L	■ Compliant with WQ guideline
Dissolved Inorganic Nitrogen (DIN) ■ <0.2 mg-N/L	Mean 0.21 mg/L	Mean 0.19 mg/L	Mean 0.14 mg/L	■ Basin unlikely to show excessive algal growth. ■ Full flushing produces lowest DIN.
Total dissolved reactive phosphorus (DRP) ■ <0.008 mg-P/L	Mean 0.032 mg/L	Mean 0.034 mg/L	Mean 0.035 mg/L	■ Basin shows potential for algal growth ■ DRP from Purewa Creek is major phosphorus source
Suspended Solids ≠ No guideline value given but high suspended solids is likely to result in high turbidity with poor colour and clarity.	Max 20 mg/L Mean 11 mg/L	Max 18 mg/L Mean 11mg/L	Max 33 mg/L Mean 10mg/L	≠ Maximum TSS function of Purewa Creek WQ. ≠ Lower mean TSS results in better water clarity. ≠ Max TSS for full tide flush relates to a single storm event

Discussion:

- With the upstream catchment improvement works in place (wastewater catchment separation, network upgrades, and Waiatarua wetland enhancement etc), the microbiological quality of the Basin (segment 10) is predicted to be significantly better than the Creek, with no transgressions of the alert or action water quality guideline for Enterococci predicted by the model. The input of Enterococci from the Purewa Creek strongly impacts on the Basin microbiological levels. The limited data set available

shows low Enterococci levels in the Purewa Creek, but the dynamics during storm events are unknown. This would need further monitoring during dry and wet conditions.

- The microbiological water quality nearer the discharge of the Creek into the Basin (segment 6) is more influenced by the Creek water quality and the microbiological alert level (>140 Enterococci/100mL) is predicted to be exceeded some 14 times in the 1996 year. The action level was not exceeded and therefore public notification would not be required.
- The Basin water is generally considered suitable for contact recreation under the Fortnightly or Maximised flushing regimes, although the impact of stormwater from the Creek may give rise to local exceedences near the confluence of the Creek and Basin during storm events. Under the Fully tidal flushing regime the Basin microbiological water quality is dominated by the Purewa Creek quality and the opportunity for contact recreation based on water depth is small.
- The predicted dissolved inorganic nitrogen (DIN) content of the Basin water is low and is close to the value where nitrogen starts becomes a limiting nutrient for algal growth. The dissolved reactive phosphorus (DRP) is however predicted to exceed the phosphorus limitation by a reasonable margin. Under these circumstances the limitation on algal growth is less pronounced and some phytoplankton growth could still occur under favourable light and temperature conditions. Under the Fully tidal flushing regime the water is replaced twice daily and there is no opportunity for algal growth.
- The regular and almost complete replacement of the Basin water (approximately 95%) volume twice per day with the Fully Tidal flushing regime means the Basin water quality is essentially equivalent to the Purewa Creek quality, except for short duration periods where a storm flow event coincides with the incoming tide and the Orakei Creek water is mixed with the incoming water. With the current limited data set for Purewa Creek it is not possible to confirm that additional flushing will always provide further improvement to Orakei Basin water quality.
- For the Fortnightly and Maximised flushing options there is minor advantage for the maximised option in terms of slightly lower nutrient concentrations in the Basin and the potential for algal is reduced due to the more frequent flushing.

5.3.3 Salinity

The salinity of the Orakei Creek is strongly influenced by the combined tidal flushing and freshwater inputs from the stormwater catchments. The percentile salinity distribution for the Creek has been determined from the model output for the different tidal flushing regimes. This is shown in Figure 5.2 below.

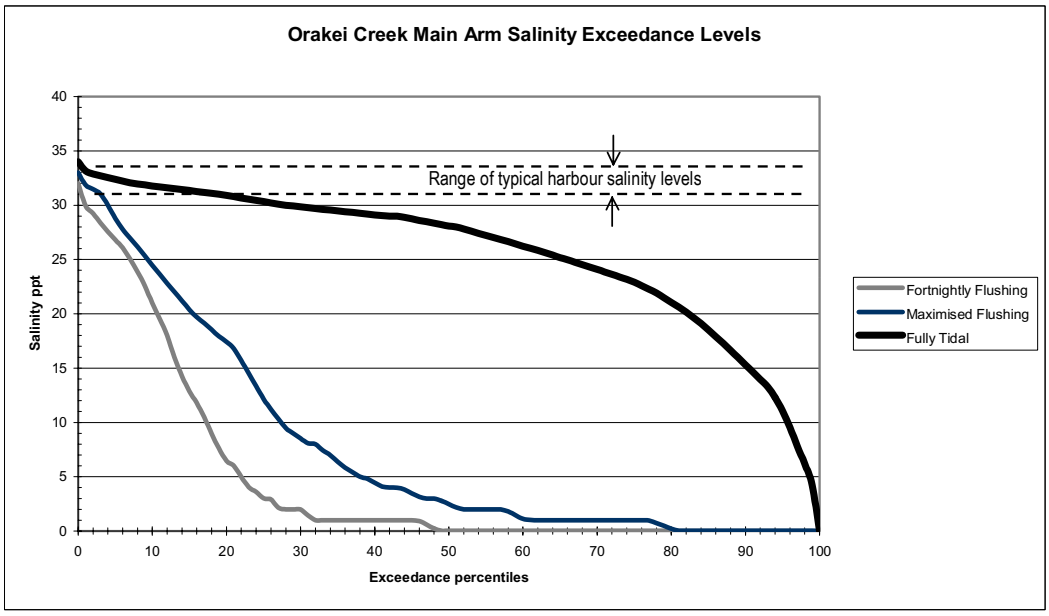


Figure 5.2. Salinity – percentage of time salinity levels are exceeded

The Fortnightly and Maximised flushing plotted lines show that both will maintain the Orakei Creek with an essentially freshwater character for about 50% of the time, with strongly saline conditions (>10 ppt) occurring between 20% - 25% of the time. In contrast the Fully tidal flushing option maintains a highly saline environment in the Creek in excess of 90% of the time. Thus it would be expected that the ecological character of the flora and fauna that will establish in the Creek may be significantly different for the Fully tidal flushing option.

5.3.4 Sedimentation

The variable frequency of flushing and therefore impoundment durations for the three options will govern the rate of sedimentation and re-suspension. The increased impoundment durations for the Fortnightly flushing option will tend to allow a greater amount of sediment to drop out when compared to the other options. The significantly greater frequency of flushing events for the Fully tidal regime, will minimise the time that any solids have to settle out within the Creek and Basin as well as increase the potential for re-suspension of sediment, particularly from the creek bed. This scouring effect may cause a lowering of the slope stability of the Creek banks. As a result of this reduced settlement and increased scouring, an increased sediment load will be discharged into the Purewa Creek and Hobson Bay receiving environment.

5.3.5 Water Quality Summary

The water quality of the Orakei Creek and Orakei Basin under the three proposed tidal flushing regimes has been investigated using hydraulic and water quality simulation models.

The impact of the flushing option on the water quality is summarised:

Asumptions

- The water quality predictions assume that the current upstream catchment improvements of wastewater catchment separation, network upgrades, and Waiatarua wetland enhancement have been completed. Following these improvements the incoming water quality will be dominated by surface water flows, however, the remaining CSO's will still have an impact on the Creek and Basin water quality.
- The measured quality data for the Purewa Creek only covers a limited time period. As the Basin water quality is dominated by the Purewa Creek quality, the model predictions for the Basin should be considered indicative only until a longer time series of data is obtained.

Orakei Creek

- The Orakei Creek water quality is strongly impacted by the quality of stormwater (including any remaining wastewater overflows) entering from the Waiatarua and Meadowbank catchments.
- Recreational water quality guidelines for microbiology are likely to be exceeded in the Orakei Creek during storm flow events. None of the proposed flushing options will reduce the number of microbiological exceedence events.
- The mean duration of action-level events with Fortnightly or Maximised flushing is about 24 hours and would result in public warning of unsafe recreational water contact.
- For fully tidal flushing the mean duration of an action-level event is about 10 hours, which may not result in a public notification of water quality.
- Nutrient levels are dominated by the nitrogen and phosphorus inputs from the storm water catchments. The nutrient levels are sufficient to be stimulating to phytoplankton growth, however, the regular tidal flushing reduces the residence time and potential for nuisance growth. The more frequent the flushing the greater the reduction for potential growth.
- Turbidity caused by suspended solids in water column is strongly correlated with the storm events. Suspended solids concentrations over 150mg/L are predicted, which would result in increased turbidity. None of the flushing options significantly reduces the peak TSS event.
- The salinity of the Orakei Creek will be determined by the flushing regime. For Fortnightly and Maximised flushing the water character will be predominantly fresh. For the Fully tidal flush the dominant character will be saline. This may have implications for the type of ecosystem that will establish.
- From a recreational viewpoint, the water quality in the Creek is generally only considered suitable for secondary contact (i.e. boating, kayaking etc), and will fall outside the recreational water quality guidelines during large storm events. Permanent public warning signs may be required if the water is to be managed for recreation.

Orakei Basin

- The Basin water quality is dominated by the water quality entering from the Purewa Creek during flushing.
- The Basin will have a typically saline water characteristic with the greatest salinity occurring under the Fully tidal flushing condition. The fresh water inputs from the Orakei Creek stormwater will minor effect on the Basin salinity. The ecology will be typically estuarine.
- The Basin water is generally considered suitable for contact recreation under the Fortnightly or Maximised flushing regimes and no exceedences of the microbiological limit is predicted. The impact of stormwater from the Creek may give rise to local exceedences near the confluence of the Creek and Basin during storm events.
- Under the Fully tidal flushing regime the opportunity for contact recreation is very small and the Basin microbiological water quality is dominated by the Purewa Creek quality. The microbiological quality of the Purewa Creek is currently not well defined and further testing is required to confirm data range.
- The nutrient status of the Basin is generally low, without major elevation of nitrogen and phosphorus concentrations. The potential for significant phytoplankton blooms is small with the regular flushing options. With Fully tidal flushing the potential for phytoplankton growth will be low and determined almost entirely by the Purewa Creek water quality.
- Overall there are relatively minor improvements in Basin water quality with the Maximised flushing routine compared with the Fortnightly flushing.

6 Geotechnical Stability

As a part of separate studies into improving the water quality of Orakei Creek and Basin by dredging contaminated sediments from the Creek bed, the risk that any slope failures or land instability could be attributed to the dredging works was identified. Due to the potential high financial consequences to Auckland City Council should this occur it is also important to consider any impact on geotechnical stability from the flushing options being considered.

6.1 Fortnightly Flushing

The existing Fortnightly flushing regime represents an artificial state of stability due in part to the long durations of impounded water. This stability results from the additional mass of water acting against slope failure, as well as increased buffering against high inflows and the potential for scour and erosion. Although this regime is not natural, it represents the current state of stability and, therefore, any changes to this regime could potentially cause a reduction in stability. This could be cited as the reason for a slope failure.

6.2 Maximised Flushing

The Maximised flushing regime is considered to create a similar state of geotechnical stability to the Fortnightly option. Although there is increased frequency of flushing events the total number of additional changes of water is small and not considered to be significant. The Basin still remains predominantly impounded.

6.3 Fully Tidal

The Fully tidal option represents a significant change to the management regime of the Basin through major modifications to the period during which the Basin remains full of water. Due to the significant number of increased flushes it is expected that potential for scouring of the Creek bed will increase. In addition, the potential for large rain events occurring during a low tide scouring out channels is higher. The actions of scouring will result in a removal of sediment material at the base of the Creek. This represents an alteration of the Creek bed and may lead to a small reduction in the Creek bank slope stability. Although the decrease in slope stability is small, the risk that a potential failure being attributed to the change in flushing remains high.

7 Summary and Conclusions

Three gate flushing regimes were analysed in this study - Fortnightly flushing (existing situation), Maximised flushing (increased flushing frequency whilst maintaining usability of the Basin) and a Fully tidal operation. Additional options such as having a reduced gate height with partial depth flushing as well as a weekly flushing regime were also considered and then discounted from further analysis.

The objective of this study was to investigate the different flushing options and assess the usability of the Basin based on the availability of suitable depths of water for recreational purposes and assess water quality for each option against contact recreation guideline values.

Usability

The assessment into the usability of the Basin identified that there is some scope to increase the amount of flushing from the current Fortnightly regime while maintaining usability levels. However, due to the nature of the peak tidal cycles the scope for this is limited and requires more frequent and onerous operation of the gates and less consistency of usable periods due to flushing.

The Fully tidal operation provides significantly increased flushing but reduces the potential recreation value of the Basin to prohibitive levels. In addition, due to the significant number of increased flushes, it is expected that potential for scouring of the Creek bed will increase. This reduction in the Creek bed level may lead to a small reduction in the Creek bank slope stability. Although the decrease in slope stability is small, the risk that a potential failure being attributed to the change in flushing remains high.

Significant levels of leakage were measured during the water level monitoring of the Basin. The resulting drop in water level of up to 35mm/ day can have a large impact on the

available areas with suitable water depths between flushing events, as well as reduce amenity values in the upper arms of the Creek. The reduction or elimination of this leakage will help improve the usability of the Basin as well as amenity values in the Creek.

There may also be an opportunity to optimise the existing fortnightly flushing operating regime to improve the usability of the Basin as well as meet the levels desired by residents on the upper reaches of the Creek arms by improved management of the gate operation and top up events.

Water Quality

Recreational water quality guidelines for microbiology are likely to be exceeded in the Orakei Creek during storm flow events. None of the proposed flushing options will reduce the number of microbiological exceedence events.

The mean duration of action-level events with fortnightly or maximised flushing is about 24 hours and would result in public warning of unsafe recreational water contact.

For fully tidal flushing the mean duration of an action-level event is about 10 hours, which may not result in a public notification of water quality.

From a recreational view point the water quality in the Creek is generally only considered suitable for secondary contact (boating, kayaking), and will fall outside the recreational water quality guidelines during large storm events. Permanent public warning signs may be required if the water is to be managed for recreation.

The Basin water is generally considered suitable for contact recreation under the fortnightly or maximised flushing regimes and no exceedences of the microbiological limit is predicted. The impact of water discharging from the Creek may give rise to local exceedences near the confluence of the Creek and Basin during storm events.

Overall there are relatively minor improvements in Basin water quality with the Maximised flushing routine compared with the fortnightly flushing.

While there is some minor improvement in water quality in relation to recreational guideline values for the Maximised flushing regime, this option requires a more onerous operating regime which may not justify the benefits. The existing flushing regime demonstrates a practical frequency of flushing as it aligns well with the peak tidal cycles, and provides a reasonable frequency of flushing to limit water quality issues in the Basin.