REPORT NO. 2440

FOXTON WASTEWATER — ESTUARY ASSIMILATIVE CAPACITY ASSESSMENT
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CRAIG ALLEN, ROGER YOUNG, PAUL GILLESPIE

Prepared for Lowe Environmental Impact
EXECUTIVE SUMMARY

Horowhenua District Council (HDC) operates the Foxton Wastewater Treatment Plant (WWTP), which currently discharges treated effluent to the Foxton Loop, which flows into the lower Manawatu River.

HDC are currently developing a long-term management strategy for the discharge of effluent from their WWTPs. The assessment presented in this report forms part of a wider series of technical investigations that aim to inform the development of this strategy.

A number of options involving the discharge of some or all of the treated effluent from the Foxton WWTP to the Manawatu River are being considered. The aim of this report is to provide a technical assessment of the potential assimilative capacity of the Manawatu River in the vicinity of the Foxton WWTP. This report does not make recommendations as to what discharge regime should be preferred or adopted — it merely assesses the assimilative capacity of the aquatic environment at the point of discharge to inform the development of a wider, long-term discharge management strategy.

The assimilative capacity can be defined as the amount of a given contaminant that can be received by a river at a given point in space and time without compromising the full range of values supported at that point or further downstream. Since water quality is highly correlated with flow, the assimilative capacity of a given water body will vary over time depending on the flow and the tidal phase. The assimilative capacity of a river should not be seen as a constant quantum, but should, on the contrary, be seen as constantly varying (Ausseil & Death 2013).

For the purpose of this report, the following principles were used:

- When / where the background water quality is better than the water quality targets, (i.e. when ‘positive’ assimilative capacity is available) for a given discharge constituent, the available assimilative capacity is calculated as the difference between the background water quality and the water quality target.
- When the background water quality is worse than the targets, the One Plan policies essentially require that the water quality be maintained or improved.
- In these situations, the assimilative capacity is calculated in this report as being the amount of treated wastewater that can be discharged so the discharge does not cause any measurable increase in concentration in the receiving environment.

An increase in concentration that is equivalent to the analytical detection limit is considered unlikely to be detectable in the receiving environment, particularly given the high background concentrations, and is also considered, for the purposes of this report, consistent with the proposed One Plan policy requirement of “maintaining water quality” (Ausseil & Death 2013).
The degree of influence of the tide on flows and mixing in the Manawatu River in the vicinity of the Foxton Loop is likely to be substantial and it is unlikely that waters within the Loop mix adequately to afford sufficient assimilative capacity to receive effluent from the WWTP. Discharging effluent into the Foxton Loop is therefore not recommended, particularly in light of contact recreation and mauri values noted by Ausseil and Clark (2007).

Calculations of assimilative capacity in this report are specific to the Manawatu River at Whirokino, which is approximately 3 km upstream from Foxton Loop WWTP discharge. Whilst little is known about the duration and timing of slack water caused by the tide in the lower Manawatu River, there is evidence of tidal influence at least 30 km upstream from the WWTP at all of the flow bands assessed in this report. A conservative approach has therefore been adopted, which assumes that assimilative capacity is reduced to zero for 12 hours per day during incoming tides, regardless of the flow. Thus, the maximum daily mass values set out below should be discharged only during an outgoing tide.

Calculations of assimilative capacity in the Manawatu River at Whirokino indicate that the ‘determining constituent’ (i.e. that used to determine the maximum allowable discharge so that the concentration of all other constituents stay within One Plan targets) during high flows is ammoniacal nitrogen. The maximum daily mass of ammoniacal nitrogen that can be assimilated by the river at:

- High flow (at the 20th flow exceedance percentile) is 1,997 kg/day.
- Very high flows (greater than the 20th flow exceedance percentile) are capable of assimilating more than that at ‘high flow’.

When flows are lower than the 20th flow exceedance percentile, background concentrations of dissolved reactive phosphorus and, in particular, soluble inorganic nitrogen, are greater than the water quality targets set in the One Plan. Hence soluble inorganic nitrogen is the ‘determining constituent’ for all flow bands below the 20th flow exceedance percentile. The maximum daily mass of soluble inorganic nitrogen that can be assimilated by the river at:

- Mid to high flows (median to 20th exceedance percentile) is 7.18 to 15.85 kg/day
- Mid to low flows (between half median and median) is 3.59 to 7.18 kg/day
- Low flows (between mean annual low flow and half median) is 1.66 to 3.59 kg/day
- Very low flows (below the mean annual low flow) are capable of assimilating less than that at the mean annual low flow (i.e. less than 1.6 kg/day)

For comparison, the current mean daily mass of soluble inorganic nitrogen in effluent discharged from the Foxton WWTP is 14.9 kg/day. Therefore, it appears unlikely that the entire annual discharge volume from the WWTP could be assimilated in the Manawatu River at Whirokino.
To put this scheme into perspective, the average discharge from the WWTP (1,028 m$^3$/day) is 0.01% of the average discharge of the Manawatu River (108 m$^3$/s; Henderson & Diettrich 2007). Dissolved nutrient loading from the Foxton WWTP discharge is similarly diminutive compared to that from sources upstream. Ideally, a more integrated catchment approach should be applied to discharges throughout the catchment and providing some assimilative capacity in the lower reaches.

It is important to point out that assimilative values estimated in this report use One Plan water quality targets that may need to be reviewed following further investigation into the fate of nutrients and baseline ecology of the Manawatu Estuary. Estuary monitoring is also necessary to “Protect and enhance the ecological values of the estuary”, as set out in the Manawatu Estuary Management Plan (2007) as part of the requirements of the Ramsar Convention (The Convention on Wetlands of International Importance).
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GLOSSARY

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDC</td>
<td>Horowhenua District Council</td>
</tr>
<tr>
<td>HRC</td>
<td>Horizons Regional Council</td>
</tr>
<tr>
<td>WWTP</td>
<td>Waste-water treatment plant</td>
</tr>
<tr>
<td>MALF</td>
<td>Mean annual low flow</td>
</tr>
<tr>
<td>DRP</td>
<td>Dissolved reactive phosphorus</td>
</tr>
<tr>
<td>SIN</td>
<td>Soluble inorganic nitrogen</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td><em>Escherichia coli</em></td>
</tr>
<tr>
<td>AK</td>
<td>Assimilative capacity</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

1.1. Background

Horowhenua District Council (HDC) operates the Foxton Wastewater Treatment Plant (WWTP) that currently discharges treated effluent to the Foxton Loop, which flows into the tidal zone of the lower Manawatu River.

HDC are currently developing a long-term management strategy for the discharge of effluent from their WWTPs. The assessment presented in this report forms part of a wider series of technical investigations that aim to inform the development of this strategy.

1.2. Aim and scope

A number of options regarding the discharge of some or all of the treated effluent from the Foxton WWTP to the lower Manawatu River are being considered. The aim of this report is to provide a technical assessment of the assimilative capacity of the tidal zone of the lower Manawatu River under varying river flows and tidal conditions.

This assessment considers water quality parameters only: non-technical issues such as community aspirations or cost are not taken into account. Similarly, this report does not make recommendations as to what discharge regime should be preferred or adopted — it merely assesses the assimilative capacity of the aquatic environment of the lower Manawatu River and estuary.

The assessment presented in this report is based on information (values) and data (river flow and water quality) available at the time of writing. Contaminant thresholds are largely based on the water quality targets proposed for the Coastal Manawatu water management zone in the Horizons Regional Council One Plan, but consideration was given to the appropriateness of these targets for protecting each of the values identified, given the specific characteristics of the Manawatu Estuary.

Using the assimilative capacity calculations we determine the allowable mass of critical pollutants that could be discharged under different flow and tidal conditions. This mass is then compared with the current annual average discharge from the wastewater treatment plant.

A number of assumptions have been made as part of the assessment and may need to be tested or refined at some future time, depending on the discharge regime that is adopted. These assumptions are identified within the report.
2. THE MANAWATU ESTUARY AND FOXTON LOOP

2.1. Physical description

Located approximately 100 km north of Wellington, the estuary of the Manawatu River is the largest in the lower North Island, covering more than 250 ha. Surrounding the estuary is a mixture of plantation forestry (south), grazed farmland (east), and urban settlement (north) (Figure 1). Foxton Loop, a remnant river channel (or ‘oxbow’), borders the estuary to the east and feeds back into the true right bank of the Manawatu River.

Bordering the north-eastern side of Foxton Loop is Foxton township, with a population of 2,715 (Statistics New Zealand 2006). Treated wastewater from the Foxton WWTP is currently discharged into the Foxton Loop from oxidation ponds on Matakarapa Island at an average rate of 1,028 m$^3$/day (Figure 1) (pers. comm. Katie Beecroft, Lowe Environmental Impact, 6 November 2013).

With a mean annual flow of 108 m$^3$/s (Henderson & Diettrich 2007), the Manawatu River is one of New Zealand’s largest rivers by volume. Only a small percentage of this discharge will flow into Foxton Loop, where water level is largely controlled by tidal fluctuation. The lower Manawatu River maintains a shallow gradient as it meanders across the Manawatu Plains from Palmerston North to the coast, so the 2.3 m spring tidal range is thought to influence river levels as far upstream as the Horizons Regional Council (HRC) flow site ‘Manawatu at Opiki Bridge’ (Figure 1) (Henderson & Diettrich 2007).
Figure 1. The lower Manawatu River with the Manawatu Estuary (as defined by RAMSAR), Foxton Loop and Horizons Regional Council (HRC) monitoring sites mentioned in this report.
2.2. Values

As the Manawatu River flows into the estuary, large areas of mudflat, saltmarsh and sand-spit provide habitat for a wide range of fauna, particularly birds. Described by the Ornithological Society as ‘the most important estuary in the lower North Island’, the area provides refuge for thousands of migratory wading birds, from both the northern hemisphere (during the southern summer), and the South Island (during the southern winter). Some of the 93 species of bird recorded are regarded as threatened species or critically endangered.

The estuary has been recognised internationally for its importance as a feeding ground for migratory bird species through inclusion in the Ramsar Convention. The Ramsar Convention is an intergovernmental treaty that provides a framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. While there are over 2000 Ramsar sites world-wide, the Manawatu estuary is the smallest of six wetlands currently listed in New Zealand.

The estuary is also highly regarded by the community for its natural, historical and recreational values (Boffa Miskell 2011). Contributing significantly to the identity of the local and regional communities, the area is popular for boating, fishing, walking and, of course, bird watching. To Māori, the estuary is highly significant as a mahinga kai (traditional food) gathering site, as well as the location of historic battles, waahi tapu (sacred place) and urupā (burial site).

These values have been recognised by both the regional (HRC) and district (HDC) councils, which designate the estuary as an ‘Outstanding Natural Landscape’ in recent policy (HRC’s One Plan and HDC’s District Plan). This designation affords the estuary protection against inappropriate subdivision and development under the Resource Management Act (1991), noting that it is:

- Nationally important as a nursery for freshwater and estuarine species
- An internationally important strategic site for migratory bird species
- Providing habitat for rare and threatened bird species
- Important as a roosting and feeding area for wading birds
- Providing habitat for regionally important plant species
- Internationally recognised as a wetland of international importance under the RAMSAR convention
- Regionally important for its high degree of naturalness and diversity

(Treadwell & Associates 2009)

In partial fulfilment of the requirements under the Ramsar Convention, a management plan (Ravine 2007) was prepared by the Manawatu Estuary Trust, Horowhenua.
District Council, Horizons Regional Council and the Department of Conservation in consultation with local iwi, community groups and landowners. According to the plan, management of the Manawatu Estuary will be guided by five main objectives:

- Establish current values of the estuary; these include ecological, cultural and social values and will be done by surveys and research of current knowledge
- Protect and enhance the ecological values of the estuary
- Promote wise use of the estuary
- Encourage learning; the estuary will be a place for learning about the natural environment and estuarine processes
- Respect for cultural heritage values.

Finally, HRC assessed freshwater values of communities in the Manawatu region in 2007 as part of the One Plan. Table 2 summarises the values ascertained for the Foxton Loop (subzone ‘Mana 13f’) alongside those of the lower Manawatu River (subzone ‘Mana 13a’), which encompasses the Manawatu Estuary and a substantial length of river upstream (in the order of 30 km).

Table 1. Values of the Foxton Loop (‘Mana 13f’) and lower Manawatu River (‘Mana 13a’) (Ausseil & Clark 2007).

<table>
<thead>
<tr>
<th></th>
<th>Contact recreation</th>
<th>Amenity</th>
<th>Mauri</th>
<th>Stock water</th>
<th>Capacity to assimilate pollution</th>
<th>Site of significance for aquatic biodiversity</th>
<th>Site of significance for riparian biodiversity</th>
<th>Native fish spawning</th>
<th>Native fishery</th>
<th>Water supply</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foxton Loop</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coastal Manawatu</strong></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
3. METHODOLOGY

3.1. Definition of assimilative capacity

The assimilative capacity (AK) relates to the amount of a given contaminant that can be received by a river at a given point in space and time without compromising the full range of values supported at that point or further downstream. Since water quality is highly correlated with flow, the assimilative capacity of a given water body will vary over time depending on the flow and the tidal phase. The assimilative capacity of a river should not be seen as a constant quantum, but should, on the contrary, be seen as constantly varying (Ausseil & Death 2013).

The assessment provided in this report therefore considers assimilative capacity as a function of daily river flow within five flow bands:

- High flows (greater than the 20th flow exceedance percentile)
- Mid to high flows (between the median flow and the 20th flow exceedance percentile)
- Low to mid flows (between the half median and median flow)
- Low flows (between the mean annual low flow (MALF) to half median flow)
- Very low flows (below the MALF).

Using threshold contaminant targets / trigger values detailed in HRC’s One Plan, assimilative capacity was calculated for each flow band for soluble inorganic nitrogen (SIN), dissolved reactive phosphorus (DRP), ammoniacal nitrogen, and *Escherichia coli* (*E. coli*). Total phosphorus and total nitrogen were also considered but the assimilative capacity could not be calculated because there are no targets / trigger values for these parameters in the One Plan.

To calculate assimilative capacity, the background (upstream) concentrations of contaminants were first accounted for in relation to the receiving water targets set out in the One Plan. Water quality data from the ‘Manawatu River at Whirokino’ monitoring site (approximately 3 km upstream from Foxton Loop WWTP discharge, Figure 1) was used to determine background concentrations for each of the aforementioned water quality parameters. Assimilative capacity is therefore a function of the difference between the target and background concentrations for each contaminant:

\[
AK = \text{Target concentration} - \text{Background concentration}
\]

In theory, if the concentration of a given contaminant upstream is less than the specified target, then there is ‘positive’ assimilative capacity available at the point of discharge (i.e. there is ‘space’ within the receiving environment for the addition of...
more of that contaminant without compromising downstream values). When the assimilative capacity at a given flow band is positive, then assimilative capacity for specific flows within the flow band can be calculated more precisely using a function derived from the minimum and maximum AK for that flow band:

For a given contaminant, the assimilative capacity will be expressed as:

$$ AK_q = X \times Q_r $$

Where:

AKq is the assimilative capacity for a given contaminant at flow Qr
X is a numerical function of the maximum and minimum AK

If the concentration of a given contaminant upstream is greater than the specified target (i.e. AK is negative), then in theory the addition of more contaminants should not be permitted because it would be detrimental to the values downstream. However, this is not particularly helpful, and essentially gives a priority of assimilative capacity usage to activities located upstream in the catchment. Obviously the discharge cannot be responsible for the background degraded water quality, but equally it cannot ignore it. In this case, assimilative capacity was calculated using a similar approach adopted by Ausseil and Death (2013), where some discharge is permitted but only if there is no resulting measureable increase in concentration of contaminants, as defined by the analytical detection limit for the given constituent. Values of one times the detection limit have been used in this report. It is considered unlikely that this level of increase will be detectable in the receiving environment, particularly given the high background concentrations; hence for the purposes of this report this approach is consistent with HRC policy requirements of “maintaining water quality”. Further work could be undertaken to refine this approach.

Once the assimilative capacity has been determined for each flow band, the amount of a given contaminant that can be discharged will essentially depend on the concentration of the contaminant in the wastewater. If the contaminant concentration in the effluent is known, then it is easy to determine the effluent volume that can be discharged. Using mean (for ammoniacal nitrogen, DRP, SIN and daily discharge volume) and median (E. coli) water quality values taken from Foxton WWTP discharge, the approximate daily allowable WWTP discharge was calculated using the assimilative capacity within each flow band.

In the context of managing the existing point-source discharge into the Foxton Loop, “water quality improvements” could be interpreted as a reduction of the effects of a given discharge compared with the current situation, and could result from a number of possible actions, including:

- Improved treatment of the wastewater
Changes in the timing of the discharge, for example by storing the discharge during times of low river flow and discharging at times of high river flows when the assimilative capacity is greater.

- Total or partial removal of the discharge from the aquatic environment, by diverting all or part of the discharge to a land treatment system.
- A combination of the above.

These options are the subject of the next phase of the project where discharge scenarios will be developed.

### 3.2. Water quality targets and discharge constituents

Horizons Regional Council’s (HRC) One Plan describes water quality targets for Water Management Zones and Sub-zones. The most relevant targets for the Foxton WWTP’s receiving water-body are those stipulated in the Foxton Loop Sub-zone and Lower Manawatu, as set out in Table 2.

<table>
<thead>
<tr>
<th>Targets</th>
<th>Full wording of the target</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>pH of the water must be within the range of 7 to 8.5</td>
</tr>
<tr>
<td></td>
<td>pH must not be changed by more than 0.5</td>
</tr>
<tr>
<td>Temp (°C)</td>
<td>Temperature of the water must not exceed 24°C</td>
</tr>
<tr>
<td></td>
<td>Temperature of the water must not be changed by more than 3°C</td>
</tr>
<tr>
<td>DO (%SAT)</td>
<td>Concentration of dissolved oxygen (DO) must exceed 60% saturation</td>
</tr>
<tr>
<td>sCBOD₅ (g/m³)</td>
<td>Monthly average five-days filtered/soluble carbonaceous biological oxygen demand (sCBOD₅) when the river is at or below the 20th flow exceedance percentile must not exceed 2 grams per cubic metre</td>
</tr>
<tr>
<td>POM (g/m³)</td>
<td>Average concentration of particulate organic matter when the river is at or below the 50th flow exceedance percentile must not exceed 5 grams per cubic metre</td>
</tr>
<tr>
<td>Periphyton: Chl-a (mg/m²)</td>
<td>Algal biomass on the river bed must not exceed 200 milligrams of chlorophyll-a per square meter</td>
</tr>
<tr>
<td>DRP (g/m³)</td>
<td>Annual average concentration of dissolved reactive phosphorus (DRP) when the river flow is at or below the 20th flow exceedance percentile must not exceed 0.015 grams per cubic meter, unless natural levels already exceed this target</td>
</tr>
<tr>
<td>Targets</td>
<td>Full wording of the target</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SIN (g/m³)</td>
<td>The annual average concentration of soluble inorganic nitrogen (SIN) when a river is at or below the 20th flow exceedance percentile must not exceed 0.444 grams per cubic meter, unless natural levels already exceed this target.</td>
</tr>
<tr>
<td>MCI</td>
<td>The Macroinvertebrate Community Index (MCI) score must be equal to or greater than 100.</td>
</tr>
<tr>
<td>Total ammoniacal nitrogen (g/m³)</td>
<td>The average concentration of ammoniacal nitrogen must not exceed 0.4 grams per cubic meter at all flows.</td>
</tr>
<tr>
<td></td>
<td>The maximum concentration of ammoniacal nitrogen must not exceed 2.1 grams per cubic meter at all flows.</td>
</tr>
<tr>
<td>Toxicants</td>
<td>For toxicants not otherwise defined in these targets, the concentration of toxicants in the water must not exceed the trigger values for freshwater defined in the 2000 ANZECC guidelines (Table 3.4.1) for the level of protection of 95% of species. For metals the trigger value must be adjusted for hardness and apply to the dissolved fraction as directed in the table.</td>
</tr>
<tr>
<td>Visual clarity (m)</td>
<td>The visual clarity of the water measured as the horizontal sighting range of a black disc must not be reduced by more than 30%.</td>
</tr>
<tr>
<td></td>
<td>The visual clarity of the water measured as the horizontal sighting range of a black disc must equal or exceed 2.5 meters when the river is at or below the 50th flow exceedance percentile.</td>
</tr>
<tr>
<td>E. coli (per 100ml of water)</td>
<td>The concentration of Escherichia coli (E. coli) must not exceed 260 per 100 milliliters 1 November–30 April (inclusive) when the river flow is at or below the 50th flow exceedance percentile.</td>
</tr>
<tr>
<td></td>
<td>The concentration of Escherichia coli (E. coli) must not exceed 550 per 100 milliliters year round when the river flow is at or below the 20th flow exceedance percentile.</td>
</tr>
</tbody>
</table>

For this assessment we have followed the exact wording for each of the relevant water quality targets, as set out in Table 2. For example, the DRP and SIN water quality targets in the One Plan are expressed as an annual average concentration based on samples collected at flows below the 20th flow exceedance percentile. The E. coli targets vary with river flow and season, and the ammonia targets include both an average and a maximum concentration.

A discharge of treated wastewater is composed of water and a number of constituents. An assimilative capacity could be determined in relation to each constituent present in the discharge. In line with Ausseil and Death (2013), however, for simplicity, only key constituents that have been used in this assessment are considered likely to be the ‘determining’ factor for a given discharge.
Other discharge constituents subject to specific water quality targets in the One Plan include particulate organic matter (POM) and ScBOD$_5$, but these are unlikely to become the determining factors in the case of the Foxton WWTP. Specific contaminants / toxicants, such as metals or organic micro-contaminants, are also unlikely to become the determining factor due to their generally very low concentrations in liquid treated domestic wastewater, and / or are likely to be an unknown quantity in the discharges being considered, and are not considered further in this report. Specific assessments should be conducted if / where warranted by discharge-specific characteristics.

3.3. Data

The following tables provide a summary of the data used in this assessment.

Table 3. Summary of water quality and quantity data used for this assessment: ‘Manawatu at Whirokino’ and ‘Manawatu at Teachers College’.

<table>
<thead>
<tr>
<th>Data</th>
<th>Data type</th>
<th>Period</th>
<th>N. samples</th>
<th>Notes</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>River water quality data: Manawatu at Whirokino (upstream from Foxton Loop)</td>
<td>Monthly</td>
<td>July 1991 to June 2013</td>
<td>108 to 282 (depending on the constituent)</td>
<td>Constituents include TN, TP, Nitrate, DRP, Ammoniacal nitrogen and E. coli</td>
<td>HRC</td>
</tr>
<tr>
<td>River flow data: Manawatu at Teachers’ College (closest flow measurement site)</td>
<td>Mean daily</td>
<td>Jan 1990 to June 2013</td>
<td>8,582</td>
<td>Flow for ‘Manawatu at Whirokino’ is assumed to be flow for Manawatu at Teachers College’ +20%</td>
<td>HRC</td>
</tr>
</tbody>
</table>

Table 4. Summary of river flow statistics used for this assessment.

<table>
<thead>
<tr>
<th></th>
<th>Manawatu at Teachers’ College</th>
<th>Manawatu at Whirokino (Q$_r$) (Teachers’ College statistics plus 20%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20$^{th}$ exceedance percentile$^1$ (m$^3$/s)</td>
<td>152.84</td>
<td>183.41</td>
</tr>
<tr>
<td>Median$^1$ (m$^3$/s)</td>
<td>69.24</td>
<td>83.09</td>
</tr>
<tr>
<td>Half median$^1$ (m$^3$/s)</td>
<td>34.62</td>
<td>41.55</td>
</tr>
<tr>
<td>MALF$^2$</td>
<td>16.0</td>
<td>19.2</td>
</tr>
</tbody>
</table>

$^1$ Source: HRC data Jan 1990- Jun 2013
$^2$ Source: HRC Environmental monitoring website ‘long term summary statistics’

<table>
<thead>
<tr>
<th></th>
<th>Ammonia nitrogen (g/m³)</th>
<th>DRP (g/m³)</th>
<th>SIN (g/m³)</th>
<th>E. coli (cfu/100mL)</th>
<th>Total nitrogen (g/m³)</th>
<th>Total phosphorus (g/m³)</th>
<th>Nitrate-nitrogen (g/m³)</th>
<th>Discharge volume (m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>144</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>14.7</td>
<td>2.94</td>
<td>14.75</td>
<td>370</td>
<td>23.8</td>
<td>4.48</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>14.1</td>
<td>3.07</td>
<td>14.48</td>
<td>-</td>
<td>25.6</td>
<td>4.78</td>
<td>0.38</td>
<td>1,028</td>
</tr>
<tr>
<td>95th%ile</td>
<td>25.9</td>
<td>4.77</td>
<td>28.14</td>
<td>6685</td>
<td>39.9</td>
<td>6.95</td>
<td>2.24</td>
<td></td>
</tr>
</tbody>
</table>

3.4. Adjustment for tidal flow

There is no detailed information on the effects of tidal fluctuations and river flows on flushing within Foxton Loop, so assimilative capacity cannot be reliably calculated at this point. Therefore this assessment principally addresses the capacity for WWTP discharge as it relates to the mainstem Manawatu River, not Foxton Loop. Comments on the assimilative capacity under varying tidal sequences are at a fairly high level and relevant to the tidal zone of the Manawatu River as a whole.

Water level data from Manawatu at Foxton (approximately 4 km downstream from Foxton WWTP discharge) and Manawatu at Moutoa (approximately 30 km upstream from Foxton WWTP discharge) were compared to flow data from Manawatu at Teachers’ College to estimate the influence of the tide on water levels at the different flow bands. In the example shown in Figure 2, water level at Moutoa is affected by the tide throughout the monitored flow range, which includes the upper flow band considered in this report (i.e. greater than 153 m³/s at Teachers’ College). An incoming tide will therefore potentially reduce the assimilative capacity of the Manawatu River substantially in the vicinity of Foxton Loop. To accommodate this, calculations of assimilative capacity have been made using a 12-hour day, assuming that effluent is only able to be discharged on an outgoing tide. That is:

\[ AK_{\text{final}} = (0.5 \times \text{Daily target mass}) - \text{daily background mass} \]
Figure 2. Water level data for Manawatu at Foxton (green) and Manawatu at Moutoa (red) compared to flow for Manawatu at Teachers’ College (black). Data within the circle highlights the fact that the Moutoa site, 30 km upstream from the Foxton WWTP, is affected by the tide, even at higher flows.

3.5. Summary of assumptions

For the purpose of this report, the following assumptions have been used:

- The river flow at the Manawatu at Whirokino site (approximately 3 km upstream from the point of discharge) is assumed to be equivalent to that of Manawatu at Teachers’ College, plus an additional 20%. This approach was recommended by Horizons Regional Council hydrologist, Brent Watson (pers. comm. 31 October 2013), and is in-line with a 2008 Council Hearing for a similar discharge from the Shannon WWTP. It is considered the most robust and practicable at this time, since the reach in question is subject to tidal influence and therefore very difficult to gauge.

- Full mixing of the discharge with receiving water is assumed in the calculations of the assimilative capacity. Actual mixing and mixing requirements (i.e. the degree of mixing that the discharge must achieve at the end of the zone of reasonable mixing) will be considered in the next stage of the project.

- Within a given river flow range, the background water quality is taken as the average (DRP, total ammoniacal-N, nitrate, total N, total P) or median (E. coli) concentration from river samples taken in the flow range being considered, based on the river water quality dataset described in Table 3.

- When the background water quality is better than the water quality targets, (for a given discharge constituent), the available assimilative capacity is calculated as the difference between the background concentration and the One Plan water quality target.
When the background water quality is worse than the targets, the assimilative capacity is calculated as the amount of treated wastewater that can be discharged so the discharge does not cause any measurable increase in concentration in the receiving environment of more than the detection limit for the given constituent. The detection limits for SIN, DRP, ammoniacal nitrogen and \textit{E. coli} were taken as 0.002 g/m$^3$, 0.005 g/m$^3$, 0.01 g/m$^3$ and 1 MPN/100ml, respectively.

The assimilative capacity is zero on an incoming tide at all flows. Little is known about the duration and timing of slack water caused by the tide in the vicinity of Foxton Loop when the river is at high flows. A conservative approach has therefore been adopted which assumes assimilative capacity is reduced to zero 12 hours per day regardless of the flow. When calculated with no allowance for tidal influence (\textit{i.e.} over 24 hours) the assimilative capacity is doubled, but this makes little difference to the conclusions and recommendations set out in this report.

### 3.6. Applicability of One Plan water quality targets

The One Plan defines water quality targets relative to dissolved nutrient concentrations (DRP and SIN) in all water management zones and sub-zones of the Manawatu catchment. In most of the Manawatu catchment, these targets were set to control periphyton growth. Dissolved nutrient targets in the lower Manawatu River were primarily set to be consistent with targets upstream as well as a precautionary measure to protect the Manawatu Estuary and the coastal environment from risks of eutrophication, acknowledging that little was known of the Manawatu Estuary’s sensitivity to nutrients at the time.

The complex hydrodynamics of the Manawatu / Foxton Loop Estuary have not been described in detail to date and consequently little is known about flushing rate/retention time. However it is reasonable to assume that these characteristics will vary considerably temporally depending on river flow and tidal state. There also appears to be a lack of data describing the physical, chemical and biological properties of estuarine waters and benthic habitats that can be used to assess ‘water quality’ and related implications for estuary health.

In a Proposed One Plan-Section 42A report (Zeldis 2009), it was recommended that the soluble inorganic nitrogen (SIN) standard should be 0.167 g/m$^3$ as opposed to 0.444 g/m$^3$, which was the target eventually agreed on by the commissioners. The rationale for this lower standard was based on modelled predictions of SIN concentrations and the potential for expression of environmental symptoms of over-enrichment (\textit{e.g.} micro- and macro-algal blooms, reduced dissolved oxygen concentrations). Because of the lack of critical data, these predictions were made according to simplified hydrodynamics (mixing properties) for the Manawatu Estuary and enrichment responses typical of a variety of other estuaries. Unfortunately the
lack of data describing (1) the range of SIN concentrations and (2) related biological responses presently occurring in the estuary, make it difficult to assess the effects of different nitrogen loading scenarios. Thus it is risky to identify appropriate thresholds, and the One Plan SIN target (0.444 g/m³) should be considered as ‘preliminary’ for the estuary until critical information gaps are filled.

Consideration must be given to setting a target in terms of its effectiveness in managing the enrichment status of the estuarine environment. This can only be achieved through baseline assessment and monitoring. The first step towards development of an effective monitoring programme would require collection of estuary water quality data and characterisation of the existing condition / enrichment status of estuary intertidal habitats. As a minimum, confirmation/revision of the target would require determination of the annual range of SIN concentrations that presently exists in the estuary in conjunction with in-situ depth profiling and related water quality parameters (e.g. conductivity / salinity, temperature, chlorophyll-a and dissolved oxygen.

In the interim, assimilative capacity has been calculated in this report using the One Plan SIN target (0.444 g/m³) as a ‘precautionary target’. Since SIN was found to be one of the two main ‘determining constituents’ in this report that contribute to the assimilative capacity, we recommend that baseline assessment and monitoring is carried out in the future. The Cawthron Institute Estuary Monitoring Protocol (EMP) could be used for broad-scale habitat mapping and fine-scale assessment of representative sites to provide a point-in-time baseline for ongoing monitoring. A water quality and benthic monitoring plan could be developed based on the EMP as soon as 2014. Recent examples of this approach are Gillespie et al. (2012, 2011 and 2009).
4. RESULTS

4.1. Background water quality

Water quality data from Manawatu at Whirokino (Figure 1) is summarised in Table 6. It is possible that water quality data collected at Manawatu at Whirokino is influenced by the upstream migration of effluent from the current WWTP discharge (3km downstream), via a combination of low river flow, tidal ‘shunt’ and unfortunate timing of monitoring work. However, Whirokino water quality data \( (n=385) \) is in line with that from Manawatu at Opiki Bridge \( (n=298) \), approximately 48km further upstream (Figure 1), so this seems unlikely to be an issue but further studies may be warranted. There is a decline in some water quality parameters something one might expect with distance downstream in a lowland river. For example, median \( E. coli \) counts from Whirokino at low flows were 109% higher; 88% higher at mid-high flows; and 52% higher at high flows than equivalent measurements at Opiki. Also, the average concentration of total phosphorus from Whirokino was 41% and 53% higher at low and mid to low flows, respectively, than at Opiki.

Table 6. Background water quality values for Manawatu at Whirokino that were used to assess the assimilative capacity (AK).

<table>
<thead>
<tr>
<th>Background WQ</th>
<th>n¹</th>
<th>DRP (mean) (g/m³)</th>
<th>SIN (mean) (g/m³)</th>
<th>Ammoniacal nitrogen (mean) (g/m³)</th>
<th>E. coli (Annual median) (MPN/100 ml)</th>
<th>E. coli (Summer median) (MPN/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High flows (&lt;20th Percentile)</td>
<td>58</td>
<td>0.028 ( (n=49) )</td>
<td>0.894 ( (n=44) )</td>
<td>0.074 ( (n=49) )</td>
<td>2030 ( (n=32) )</td>
<td>2050 ( (n=11) )</td>
</tr>
<tr>
<td>Mid to high flows (Median to 20th)</td>
<td>102</td>
<td>0.033 ( (n=83) )</td>
<td>0.763 ( (n=78) )</td>
<td>0.074 ( (n=82) )</td>
<td>473 ( (n=50) )</td>
<td>1225 ( (n=24) )</td>
</tr>
<tr>
<td>Mid to low flows (Half Median to Median)</td>
<td>99</td>
<td>0.038 ( (n=65) )</td>
<td>0.630 ( (n=64) )</td>
<td>0.097 ( (n=64) )</td>
<td>130 ( (n=49) )</td>
<td>185 ( (n=31) )</td>
</tr>
<tr>
<td>Low flows (Below Half Median)</td>
<td>126</td>
<td>0.034 ( (n=85) )</td>
<td>0.406 ( (n=59) )</td>
<td>0.069 ( (n=76) )</td>
<td>75 ( (n=76) )</td>
<td>75 ( (n=69) )</td>
</tr>
<tr>
<td>One Plan target</td>
<td></td>
<td>&lt;0.015</td>
<td>&lt;0.444</td>
<td>&lt;0.4</td>
<td>&lt;550</td>
<td>&lt;260</td>
</tr>
</tbody>
</table>

¹ Column ‘n’ gives the total number of samples at the given flow range. The value for ‘n=’ shown in brackets gives the number of samples for each parameter at the given flow range.

4.2. Assimilative capacity

4.2.1. High flows: Exceeding the 20th exceedance percentile

When the river is high \( i.e. \) at flows greater than the 20th flow exceedance percentile: 183.4 m³/s), the following One Plan water quality target is applicable:

- Ammoniacal nitrogen \(<0.4 \text{ g/m}^³\)
Under the One Plan, elevated concentrations of nutrient (i.e. DRP, SIN) during flood events are unlikely to cause significant effects in the river and estuary. Similarly, since conditions will be unsuitable for contact recreation during floods, microbiological targets (i.e. E. coli) do not apply. Therefore, as the sole water quality target applicable at high flows, ammoniacal nitrogen becomes the determining factor when considering the assimilative capacity at flows greater than the 20th exceedance percentile.

The average background concentration of ammoniacal nitrogen at the Manawatu at Whirokino water quality site when the river is at high flow is low relative to the target set in the One Plan (Table 7). This provides an available assimilative capacity (AK) that is ‘positive’ (i.e. there is ‘space’ within the system to add more — see Section 3).

Table 7. Assimilative capacity (AK) of the Manawatu River at Whirokino with flows greater than the 20th exceedance percentile (183.4 m³/s). Values for minimum and maximum AK allow for the influence of the tide. Values for ‘Maximum daily discharge from WWTP’ assume that concentrations are as measured in current effluent discharge regime (Table 5).

<table>
<thead>
<tr>
<th>Constituent</th>
<th>One Plan target (g/m³)</th>
<th>Background concentration (at high flows) (g/m³)</th>
<th>Available assimilative capacity (AKq) (kg/day)</th>
<th>Minimum AK (at 20th percentile flow: 183.4 m³/s) (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammoniacal nitrogen</td>
<td>&lt;0.4 and max 2.1</td>
<td>0.074</td>
<td>10.9 x Qr</td>
<td>1,997</td>
</tr>
</tbody>
</table>

The available assimilative capacity (AKq) for ammoniacal nitrogen at flows above the 20th exceedance percentile is calculated as 10.9 x Qr (where Qr is the flow of the river in m³/s). At the 20th percentile flow this equates to 1,997 kg of ammoniacal nitrogen /day that could be discharged below Whirokino without breaching the One Plan target (Table 7). Flows higher than the 20th percentile flow can accommodate greater volumes of ammoniacal nitrogen.

Based on the average daily discharge of treated effluent (1,028 m³/day) and the associated concentration of ammoniacal nitrogen (14.1 g/m³) from the Foxton WWTP (Table 5), the current average daily discharge of ammoniacal nitrogen is 14.5 kg/day: well within the maximum allowable discharge of 1,997 kg/day calculated above. Assuming the effluent concentration was the same as currently, the maximum volume of effluent that could be discharged from the WWTP without breaching the One Plan target for ammoniacal nitrogen is 141,608 m³/day. Thus, when the river is at high flow
(at or above the 20th exceedance percentile), the assimilative capacity is substantial when compared to the current average discharge from the Foxton WWTP.

It is important to point out that these calculations assess assimilative capacity in the Manawatu River, not Foxton Loop. The WWTP discharge is currently located within Foxton Loop, approximately 1 km upstream from the confluence with the Manawatu River. Hydrology within the loop is vastly different from that of the Manawatu River; hence the associated assimilative capacity within the Loop also differs. This is considered further in Section 4.3.

### 4.2.2. Mid to high flows: Between median and 20th exceedance percentile

When the river is above the median flow (83.1 m³/s), but below the 20th exceedance percentile flow (183.4 m³/s), the following One Plan water quality targets are applicable:

- Ammoniacal nitrogen: average <0.4 g/m³ and maximum of 2.1 g/m³
- DRP: average <0.015 g/m³
- SIN: average <0.444 g/m³
- *E. coli* (year-round): <550/100 ml

Table 8 summarises the assimilative capacity for these contaminants in the Manawatu River at Whirokino during these flows. At median flow, the average background concentration of ammoniacal nitrogen is low relative to the target set in the One Plan, thus providing a positive available assimilative capacity (AK). Conversely, background DRP, SIN and *E. coli* concentrations are greater than the One Plan target, hence assimilative capacity has been calculated using the detection limit for each.

For flows between the median and 20th exceedance percentile, the assimilative capacity is estimated to range between:

- Ammoniacal nitrogen: 905 kg/day to 1,997 kg/day
- DRP: 1 x DL: 17.95 to 39.62 kg/day
- SIN: 1 x DL: 7.18 to 15.85 kg/day
- *E. coli* (year-round): 1 x DL: 3,589 x10⁹ to 7,923 x10⁹ MPN/day
Based on this, the ‘determining’ constituent at this flow range is SIN. When the average concentration of SIN measured from wastewater discharged at the Foxton WWTP is taken into account, the daily volume of wastewater that can be discharged into the Manawatu River ranges from 496 m$^3$/day (at the median flow) to 1,094 m$^3$/day (at the 20$^{th}$ percentile flow).
Table 8. Assimilative capacity (AK) for Manawatu at Whirokino with mid to high flows: between the median (83.1 m$^3$/s) and the 20th exceedance percentile (183.4 m$^3$/s). Values for minimum and maximum AK allow for the influence of the tide. Values for ‘Maximum daily discharge from WWTP’ relate to concentrations as measured in current effluent discharge regime (Table 5). Values that are less than the average WWTP flow (i.e. 1,028 m$^3$/day) are shown in bold text.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>One Plan target</th>
<th>Background concentration (at mid to high flows)</th>
<th>Available assimilative capacity (AKq)</th>
<th>Minimum AK (at median flow: 83.1 m$^3$/s)</th>
<th>Maximum AK (at 20th percentile flow: 183.4 m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Amount per day</td>
<td>Maximum daily discharge from WWTP (m$^3$/day)</td>
</tr>
<tr>
<td>Ammoniacal nitrogen</td>
<td>&lt;0.4 and max 2.1 g/m$^3$</td>
<td>0.074 (g/m$^3$)</td>
<td>10.9 x Qr (kg/day)</td>
<td>905 (kg/day)</td>
<td>64,153</td>
</tr>
<tr>
<td>DRP</td>
<td>&lt;0.015 (g/m$^3$)</td>
<td>0.033 (g/m$^3$)</td>
<td>1 x DL: 0.216 x Qr</td>
<td>17.95 (kg/day)</td>
<td>5,846</td>
</tr>
<tr>
<td>SIN</td>
<td>&lt;0.444 (g/m$^3$)</td>
<td>0.763 (g/m$^3$)</td>
<td>1 x DL: 0.0864 x Qr</td>
<td>7.18 (kg/day)</td>
<td>496</td>
</tr>
<tr>
<td><em>E. coli (all year)</em></td>
<td>&lt;550/100 ml</td>
<td>473 /100 ml</td>
<td>1 x DL: 4320x10$^7$ x Qr</td>
<td>3,589 x10$^9$ (MPN/day)</td>
<td>9,701</td>
</tr>
</tbody>
</table>
4.2.3. **Mid to low flows: Between half median and median**

When river flow is higher than the half median (41.5 m$^3$/s) and lower than the median (83.1 m$^3$/s), the following One Plan water quality targets are applicable:

- **Ammoniacal nitrogen**: average <0.4 g/m³ and maximum of 2.1 g/m³
- **DRP**: average <0.015 g/m³
- **SIN**: average <0.444 g/m³
- **E. coli** (bathing season): <260/100 ml
- **E. coli** (year-round): <550/100 ml

Table 9 summarises the assimilative capacity for these contaminants in the Manawatu River at Whirokino during these flows. At half median and median flows, the average background concentration of ammoniacal nitrogen is low relative to the target set in the One Plan, thus providing a positive available assimilative capacity (AK). Conversely, background DRP, SIN and E. coli$^1$ concentrations are greater than the One Plan target, hence assimilative capacity has been calculated accordingly.

For flows between the half median and median, the assimilative capacity is estimated to range between:

- **Ammoniacal nitrogen**: 369 to 905 kg/day
- **DRP**: 1 x DL: 8.96 to 17.95 kg/day
- **SIN**: 1 x DL: 3.59 to 7.18 kg/day
- **E. coli** (bathing season): 1 x DL: 1,793 x10$^9$ to 3,589 x10$^9$ MPN/day
- **E. coli** (year-round): Between 1,253 x 10$^{10}$ (at half median flow) and 3,589 x 10$^9$ MPN/day (at median flow)

Based on this, the ‘determining’ constituent at this flow range is SIN. When the average concentration of SIN measured from wastewater discharged at the Foxton WWTP is taken into account, the daily volume of wastewater that can be discharged into the Manawatu River ranges from 248 m$^3$/day (at the median flow) to 496 m$^3$/day (at the 20$^{th}$ percentile flow).

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$^1$ With the exception of E.coli (year-round target) at the half median flow
Table 9. Assimilative capacity (AK) of the Manawatu River at Whirokino with mid to low flows: between the half median (41.5 m$^3$/s) and the median (83.1 m$^3$/s). Values for minimum and maximum AK allow for the influence of the tide. Values for ‘Maximum daily discharge from WWTP’ relate to concentrations as measured in current effluent discharge regime (Table 5). Values that are less than the average WWTP flow (i.e. 1,028 m$^3$/day) are shown in bold text.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>One Plan target</th>
<th>Background concentration (at mid to low flows)</th>
<th>Available assimilative capacity (AKq)</th>
<th>Minimum AK (at half median flow: 41.5 m$^3$/s)</th>
<th>Maximum AK (at median flow: 83.1 m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Amount per day</td>
<td>Maximum daily discharge from WWTP (m$^3$/day)</td>
</tr>
<tr>
<td>Ammoniacal nitrogen</td>
<td>&lt;0.4 and max 2.1 g/m$^3$</td>
<td>0.097 (g/m$^3$)</td>
<td>8.9 x Qr (kg/day)</td>
<td>369 (kg/day)</td>
<td>26,193</td>
</tr>
<tr>
<td>DRP</td>
<td>&lt;0.015 (g/m$^3$)</td>
<td>0.038 (g/m$^3$)</td>
<td>1 x DL: 0.216 x Qr</td>
<td>8.96 (kg/day)</td>
<td>2,920</td>
</tr>
<tr>
<td>SIN</td>
<td>&lt;0.444 (g/m$^3$)</td>
<td>0.63 (g/m$^3$)</td>
<td>1 x DL: 0.0864xQr</td>
<td>3.59 (kg/day)</td>
<td>248</td>
</tr>
<tr>
<td>E. coli (bathing season)</td>
<td>&lt;260/100ml</td>
<td>185 /100ml</td>
<td>1 x DL: 4320x10$^7$ xQr</td>
<td>1,793 x10$^9$ (MPN/day)</td>
<td>4,845</td>
</tr>
<tr>
<td>E. coli (all year)</td>
<td>&lt;550/100ml</td>
<td>130 /100ml</td>
<td>1,253x10$^{10}$ x Qr</td>
<td>5,199x10$^{11}$ (MPN/day)</td>
<td>1,405,000</td>
</tr>
</tbody>
</table>
4.2.4. Low flows: Between MALF and half median flow

When river flow is above the MALF (19.2 m³/s) and below the half median (41.5 m³/s), the following One Plan water quality targets are applicable:

- Ammoniacal nitrogen: average <0.4 g/m³ and maximum of 2.1 g/m³
- DRP: average <0.015 g/m³
- SIN: average <0.444 g/m³
- *E. coli* (bathing season): <260/100 ml
- *E. coli* (year-round): <550/100 ml

Table 10 summarises the assimilative capacity for these contaminants in the Manawatu River at Whirokino during these flows. At this flow range the average background concentration of ammoniacal nitrogen and *E. coli* ² are low relative to the target set in the One Plan, thus providing a positive available assimilative capacity (AK). Conversely, the background concentration of DRP and SIN is greater than the One Plan target, hence assimilative capacity has been calculated accordingly.

For flows above the MALF and below the half median, assimilative capacities under the current One Plan targets are estimated to range between:

- Ammoniacal nitrogen: 217 to 369 kg/day
- DRP: 1 x DL: 4.15 to 8.96 kg/day
- SIN: 1 x DL: 1.66 to 3.59 kg/day
- *E. coli* (bathing season): 9,124 x10¹⁰ (at MALF) and 1,793 x10⁹ MPN/day (at half median flow with 1 x DL).
- *E. coli* (year-round): Between 3,318 x 10¹¹ (at MALF) and 5,199 x 10¹¹ MPN/day (at half median flow).

The ‘determining’ constituent at this flow range is SIN. When the average concentration of SIN measured from wastewater discharged at the Foxton WWTP is taken into account, the daily volume of wastewater that can be discharged into the Manawatu River ranges from 115 m³/day (at the MALF) to 248 m³/day (at half median flow).

² With the exception of *E. coli* (bathing season) at the half median flow.
Table 10. Assimilative capacity (AK) of the Manawatu River at Whirokino with low flows: between the MALF (19.2 m$^3$/s) and the half median (41.5 m$^3$/s). Values for minimum and maximum AK allow for the influence of the tide. Values for ‘Maximum daily discharge from WWTP’ relate to concentrations as measured in current effluent discharge regime (Table 5). Values that are less than the average WWTP flow (i.e. 1,028 m$^3$/day) are shown in bold text.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>One Plan target</th>
<th>Background concentration (at below half median flows)</th>
<th>Available assimilative capacity (AK$q$)</th>
<th>Minimum AK (at MALF: 19.2 m$^3$/s)</th>
<th>Maximum AK (at half median flow: 41.5 m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Amount per day</td>
<td>Maximum daily discharge from WWTP (m$^3$/day)</td>
</tr>
<tr>
<td>Ammoniacal nitrogen</td>
<td>&lt;0.4 and max 2.1 (g/m$^3$)</td>
<td>0.069 (g/m$^3$)</td>
<td>11.3 x $Q_r$ (kg/day)</td>
<td>217 (kg/day)</td>
<td>15,412</td>
</tr>
<tr>
<td>DRP</td>
<td>&lt;0.015(g/m$^3$)</td>
<td>0.034 (g/m$^3$)</td>
<td>1 x DL: 0.216x$Q_r$</td>
<td>4.15 (kg/day)</td>
<td>1,351</td>
</tr>
<tr>
<td>SIN</td>
<td>&lt;0.444 (g/m$^3$)</td>
<td>0.406 (g/m$^3$)</td>
<td>1 x DL: 0.0864x$Q_r$</td>
<td>1.66 (kg/day)</td>
<td>115</td>
</tr>
<tr>
<td>E. coli (bathing season)</td>
<td>&lt;260/100ml</td>
<td>75 /100ml</td>
<td>4.752x10$^9$ x $Q_r$ (MPN/day)</td>
<td>9,124x10$^9$ (MPN/day)</td>
<td>247,000</td>
</tr>
<tr>
<td>E. coli (all year)</td>
<td>&lt;550/100ml</td>
<td>75 /100ml</td>
<td>1.726x10$^{10}$ x $Q_r$ (MPN/day)</td>
<td>3318 x10$^{11}$ (MPN/day)</td>
<td>896,692</td>
</tr>
</tbody>
</table>
4.2.5. Very low flows: Below the MALF

When river flow is below the MALF (19.2 m³/s) the following One Plan water quality targets are applicable:

- Ammoniacal nitrogen: average <0.4 g/m³ and maximum of 2.1 g/m³
- DRP: average <0.015 g/m³
- SIN: average <0.444 g/m³
- *E. coli* (bathing season): <260/100 ml
- *E. coli* (year-round): <550/100 ml

Water quality data for very low flows was sparse (six measurements of SIN, 19 measurements of *E. coli* and 17 measurements of ammoniacal nitrogen and DRP). Therefore, since SIN measurements were so few, and because this is likely to be the determining constituent, available assimilative capacities (AKq) for very low flows (Table 11) were calculated using the same background concentrations as ‘Low Flows’ (Table 10).

<table>
<thead>
<tr>
<th>Constituent</th>
<th>One Plan target</th>
<th>Background concentration (at below half median flows)</th>
<th>Available assimilative capacity (AKq)</th>
<th>Maximum AK (at MALF: 19.2 m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammoniacal nitrogen</td>
<td>&lt;0.4 and max 2.1 (g/m³)</td>
<td>0.069 (g/m³)</td>
<td>11.3 x Qr (kg/day)</td>
<td>217 (kg/day)</td>
</tr>
<tr>
<td>DRP</td>
<td>&lt;0.015(g/m³)</td>
<td>0.034 (g/m³)</td>
<td>1 x DL: 0.216xQr</td>
<td>4.15 (kg/day)</td>
</tr>
<tr>
<td>SIN</td>
<td>&lt;0.444 (g/m³)</td>
<td>0.406 (g/m³)</td>
<td>1 x DL: 0.0864xQr</td>
<td>1.66 (kg/day)</td>
</tr>
<tr>
<td><em>E. coli</em> (bathing season)</td>
<td>&lt;260/100ml</td>
<td>75 /100ml</td>
<td>4,752x10⁻⁷ x Qr (MPN/day)</td>
<td>9,124x10⁻¹ (MPN/day)</td>
</tr>
<tr>
<td><em>E. coli</em> (all year)</td>
<td>&lt;550/100ml</td>
<td>75 /100ml</td>
<td>1,728x10⁻¹ x Qr (MPN/day)</td>
<td>3318 x10¹ (MPN/day)</td>
</tr>
</tbody>
</table>
For flows below the MALF assimilative capacities under the current One Plan targets are estimated to range up to:

- Ammoniacal nitrogen: 217 kg/day
- DRP: 1 x DL: 4.15 kg/day
- SIN: 1 x DL: 1.66 kg/day
- *E. coli* (bathing season): $9,124 \times 10^{10}$
- *E. coli* (year-round): Between $3,318 \times 10^{11}$

When the average concentration of SIN measured from wastewater discharged at the Foxton WWTP is taken into account, the daily volume of wastewater that can be discharged into the Manawatu River when flows are below the MALF ranges up to 115 m$^3$/day (at the MALF).

### 4.3. Tidal influence and Foxton Loop hydrology

As discussed in Section 3.4, regardless of flow the lower Manawatu River is tidal, so effluent discharge is only possible on an outgoing tide. Calculations of assimilative capacity in this assessment accommodate this and assume that assimilation can only occur for 12 hours of the day and that river flows define the volume for dilution.

Due to the lack of detailed information on background water quality and the effects of tidal fluctuations and river flows on flushing within Foxton Loop, this assessment principally assesses the capacity for WWTP discharge into the mainstem Manawatu River below Whirokino (3.5 km upstream from the Foxton Loop). This section, however, provides some narrative on the likely hydrology within Foxton Loop.

Hydrology within the Loop is assumed to be largely controlled by two factors: the tide and the flow of the Manawatu River. On a rising tide, water from the Manawatu River flows into the downstream end of the Foxton Loop. The ability of the Foxton Loop to discharge this water is determined by both the tide and the flow of the Manawatu River (*i.e.* if the river remains high during low tide, water will not drain from the Loop). Work carried out by Horizons Regional Council (2012) determined that reduced water velocities within the Loop causes siltation of the channel bed and margins, particularly at the upstream end, where fine sediments are known to be accumulating.

The tidal range, as measured from water level monitoring at Manawatu at Foxton hydrometric monitoring site (September–October 2013), was compared to HRC measurements of minimum bed elevation within Foxton Loop, approximately 4 km upstream (Figure 3). This relationship is speculative, since the Loop is upstream from
the hydrometric monitoring site and water level in the Loop is known to be influenced by flow in the Manawatu River. However, Figure 3 shows that:

- The loop will never be completely emptied of water at low tide (thus some portion of effluent discharge at this site will not be flushed into the Manawatu River)
- There is likely to be at least 2 m of water in the Loop at all times (at the time that HRC’s survey was undertaken).

Therefore the assimilative capacity within Foxton Loop will be substantially reduced, as an unknown quantity of pollutants is likely to accumulate within the Loop.

![Figure 3](image)

Figure 3. Minimum bed elevation at points within Foxton Loop compared to the tidal range at the Manawatu at Foxton hydrometric monitoring site downstream.
5. CONCLUSIONS

Flow and mixing within Foxton Loop is limited by tide and flow in the Manawatu River, and it is unlikely that these waters mix adequately to afford sufficient assimilative capacity to receive effluent from the WWTP. Discharging effluent into the Foxton Loop is therefore not recommended, particularly in light of contact recreation and mauri values noted by Ausseil and Clark (2007).

The degree of influence of the tide on flows and mixing in the Manawatu River in the vicinity of Foxton Loop is likely to be substantial. All calculations of assimilative capacity have been made to account for this, whereby effluent discharge is restricted to the 12 hours per day when flows are assured to provide sufficient dilution and mixing.

Figure 4 summarises the results of this assessment, where the determining constituent (i.e. that used to determine the maximum allowable discharge so that all other constituents stay within One Plan targets) is represented by ammoniacal nitrogen (at high flows) and SIN (for all other flows).

Regarding the discharge of treated effluent from the Foxton WWTP into the Manawatu River (mainstem):

- High flows (at the 20th flow exceedance percentile (183.4 m³/s)) can assimilate approximately 1,997 kg of ammoniacal nitrogen per day whilst protecting downstream values. This is equivalent to an effluent volume of approximately 141,608 m³/day, assuming current effluent concentrations. Discharge should only be allowed during an outgoing tide. Flows greater than the 20th flow exceedance percentile are capable of accommodating increased quantities of ammoniacal nitrogen.

- Mid to high flows (between the median (83.1 m³/s) and 20th flow exceedance percentile (183.4 m³/s)), can assimilate 7.18 to 15.85 kg of SIN per day whilst protecting downstream values. This is equivalent to an effluent volume of between 496 and 1094 m³/day from the WWTP assuming current concentrations. Effluent should only be discharged on an outgoing tide.

- Low to mid flows (between the half median (41.5 m³/s) and median flow (83.1 m³/s), can assimilate 3.59 to 7.18 kg of SIN per day whilst protecting downstream values. This is equivalent to an effluent volume of between 248 and 496 m³/day from the WWTP, assuming current concentrations. Effluent should only be discharged on an outgoing tide.

- Low flows (between the MALF (19.2 m³/s) and the half median flow (41.5 m³/s)) can assimilate 1.66 to 3.59 kg of SIN per day whilst protecting downstream values. This is equivalent to an effluent volume of between 115 and 248 m³/day.
from the WWTP, assuming current concentrations. Effluent should only be discharged on an outgoing tide.

- Very low flows (at the MALF (19.2 m³/s)) can assimilate approximately 1.66 kg of SIN per day whilst protecting downstream values. This is equivalent to an effluent volume of 115 m³ / day from the WWTP, assuming current concentrations. Flows less than the MALF are capable of accommodating reduced quantities of SIN. Effluent should only be discharged on an outgoing tide.

Dissolved reactive phosphorus, like SIN, had a negative AK for flows below the 20th exceedance percentile (i.e. the background concentration was higher than the One Plan target). The assimilative capacity for *E. coli* was somewhat greater than SIN and DRP, since background concentrations were below targets in most flow bands. The current average daily discharge from the WWTP would introduce acceptable quantities of *E. coli* to the Manawatu River at Whirokino in most flow conditions.

Generally, when river flow is below the 20th flow exceedance percentile, the maximum allowable discharge of SIN is less than that currently being discharged from the WWTP (on average, based on the current mean daily mass of SIN contained in effluent discharged from the Foxton WWTP (14.9 kg/day) (Figure 4).

To put this scheme into perspective, the average discharge from the WWTP (1,028 m³/day) is 0.01% of the average discharge of the Manawatu River (108 m³/s (Henderson & Diettrich 2007)). Dissolved nutrient loading from the Foxton WWTP discharge is similarly diminutive compared to that from sources upstream. Ideally, a more integrated catchment approach should be applied to discharges throughout the catchment and providing some assimilative capacity in the lower reaches.

It is important to point out that assimilative values estimated in this report use One Plan water quality targets that may need to be reviewed following further investigation into the fate of nutrients and baseline ecology of the Manawatu Estuary. Estuary monitoring is also necessary to ‘Protect and enhance the ecological values of the estuary’, as set out in the Manawatu Estuary Management Plan as part of the requirements of the Ramsar Convention.
Figure 4. Approximate maximum allowable discharge of relevant ‘determining constituents’ (ammoniacal nitrogen and SIN in kg / day) from the Foxton Wastewater Treatment Plant (WWTP) into the Manawatu River (mainstem) with increasing flow. The determining constituent for flows below the 20th percentile flow is SIN. The mass of ammoniacal nitrogen (greater than 1,997 kg/d) and SIN (below the MALF) have been forecasted to show the approximate direction of increase / decrease.

6. ACKNOWLEDGEMENTS

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7. REFERENCES


