PERFORMANCE OF NEW STORMWATER SYSTEM AT FONTERRA TIRAU

M. Peacey, J. Barlow (Fonterra)
C. Moore (Beca)

ABSTRACT

Fonterra has undertaken a program to significantly improve storm water management on a number of manufacturing sites in response to aging infrastructure, poor environmental performance, and rising expectations from stakeholders. A nationwide risk-based management approach has been recently developed to align stormwater projects, whereas in the past the approach varied between sites.

Tirau is one of the first large scale capital upgrades to be implemented, with construction and commissioning taking place in early and mid-2017. This provides an opportunity to review performance and adjust design criteria for current and future projects. The new system is separated from clean cooling water and comprises a 350 m^3 first flush and spill containment tank with online monitoring and divert. Contaminated water is sent to wastewater treatment with the remainder discharged to a swale which discharges to the Oraka stream after further monitoring. No non-compliant discharges have been reported since commissioning, despite high rainfall and influent flows from some drainage areas with contamination. This compares with five stormwater non-compliances reported in the previous season.

This paper analyses monitoring data including suspended solids, total nitrogen, phosphorus, COD, conductivity, pH, and turbidity of the new system. The volume and composition of diverted stormwater streams is also considered. Options for optimising the current system are given, as well as improvements to the approach to future projects on other sites.

KEYWORDS

Industrial Stormwater, Cooling water, Monitoring, Performance

1 INTRODUCTION

1.1 FONTERRA'S APPROACH

Stormwater discharges from dairy factories are complex and require good management to prevent pollution of receiving environments. Urban contaminants including suspended solids, heavy metals, hydrocarbons, and bacteria are normally present, as well as production related contaminants such as deposited powder and cleaning chemicals. Additionally, the risks of product or chemical spills and high loadings from process connections to storm water are often high and must be mitigated.

In the past Fonterra has implemented an incremental site-based approach to stormwater management with most drains discharging directly to surface water and connections from process water or cooling water common. This often included downstream manual isolation valves to prevent spills reaching waterways and allow truck transfer of contaminated water to wastewater treatment systems. In some cases downstream automated divert valves and pumps were used for transfer to wastewater.

This resulted in poor control and a reliance on manual intervention to manage spills, significant base contaminant loads in stormwater systems from process connections and poorly maintained drainage networks, and large volumes of both contaminated and clean stormwater diverted to wastewater treatment plants (WWTP) and irrigation platforms already at maximum capacity.

The new approach is based on managing risk according to the following hierarchy:

1. Divert upstream catchments.
2. Isolate high risk areas and connect to wastewater treatment.
3. Remove cross connections where possible.
4. Implement source controls such as bunds, interceptors, and filters.
5. Combine outlets to allow centralized monitoring.
6. Provide detection and storage/divert for managing spills.
7. Treatment of first flush volumes.
8. Quantitative (volume) controls.

This allows for low baseline contaminant levels, good control of any spills, and smaller volumes diverted to wastewater treatment.

A number of Fonterra sites have begun or recently completed stormwater system upgrades with this design approach. Examples include Stirling, where an upgraded drainage system, spill containment, wastewater divert, and new wetlands has been built; Edendale, where an extensive stormwater drainage upgrade and divert of process water sources is being implemented; and Kapuni, where diversion of high risk areas and a new 1000 m^3 retention pond with isolation valves has been installed.

1.2 TIRAU SITE

Fonterra Tirau is located adjacent to Tirau Township and the Oraka stream. It produces casein, lactalbumin, and ethanol. Wastewater and byproducts received from both the Tirau site and other sites in the region are treated in an anaerobic and aerobic treatment system with discharge to the Oraka stream. Bio-gas from the anaerobic process is used to fuel the boilers on site.

A new consent was granted in 2015 for the discharge of stormwater and cooling water which specified that a new storm water system was to be operational by 1 August 2017. The relevant discharge limits under the new consent are given in table 1.

Table 1: Discharge limits for Tirau stormwater and cooling water discharge

Parameter	**Limit**
$cBOD_5$	10 gm^{-3}
Suspended solids	80 gm^{-3}
pH	6 - 9
Oraka stream turbidity	Raised by no more than 10 NTU
Oraka stream temperature	Raised by no more than 3°C or to a maximum of 25°C

The existing storm water system was built in the 1970's and was designed to simply drain to the Oraka stream with no removal of contaminants. Town stormwater and site cooling water is also discharged through the same outlet. No valves or instruments were in place to control the discharge. Prior to the project the drainage network was also in poor condition and wastewater and process leaks caused a number of resource consent breaches due to elevated suspended solids and deviations in pH.

2 SYSTEM DESIGN

2.1 OVERVIEW

As shown in figure 1, the new system collects stormwater from the eastern and western catchments with a combined area of 4.3 ha. Manholes at the collection point for each catchment are fitted with weirs, isolation valves, and quality monitoring, and have overflow paths directly to the stream discharge for high intensity rainfall

From the manholes both catchments flow to a diversion chamber. The first-flush volume (first 10mm of rainfall) is automatically drained to a 350 m^3 first-flush tank, as well as any non-compliant flows including contaminated cooling water detected at other times.

Water from the diversion chamber below the divert limits is directed to two 65m long swales planted with *Apodasmia similis* (oioi), with the treated water at the end of the swale discharging to the Oraka stream. A monitoring station with an isolation valve at the swale outlet can be used to prevent any contaminated water exiting the swale or for containment of large spills.

The water in the first-flush tank is normally pumped to the WWTP, but can be pumped to the swales manually during dry periods if the quality is high enough.

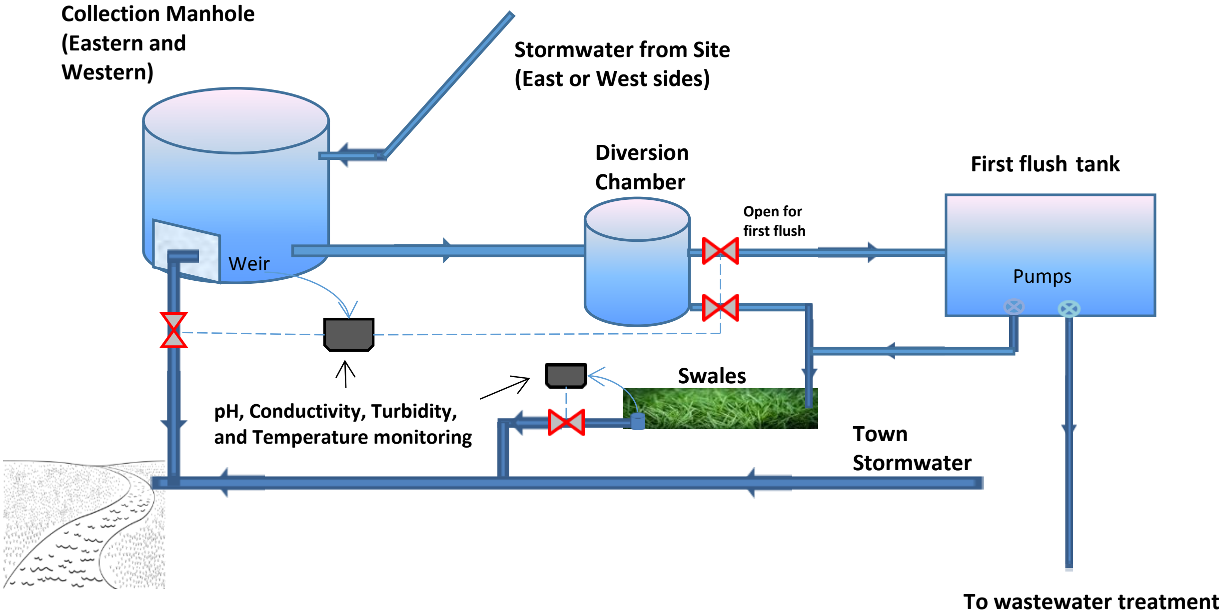

Figure 1: Overview of stormwater treatment system at Fonterra Tirau

2.2 DESIGN BASIS

The primary causes of non-compliances prior to the installation of the system were:

- First-flush rainfall events.
- Cross-contamination from drainage networks in poor condition.
- Construction or earthworks with no ability to contain spills or erosion.

This allowed the design to focus on detection and containment of first flushes and spills, with minimal treatment required for normal stormwater.

The first flush volume was based on 10mm of rainfall over the full 4.3 ha catchment, which allows for 0.65 ha currently discharging to the WWTP to be connected to the system in the future. This equates to 266 m^3. The first flush volume is designed to capture predominantly soluble pollutants which would not be removed in the swales and send these to wastewater treatment. Volumes beyond the 10 mm first flush are typically lower in soluble contaminants with higher concentrations of suspended solids which are effectively removed in the swale. The effectiveness of a 10 mm first flush has been validated by Beca using data collected at Edgecumbe.

All known cooling water connections were to be removed and rejoined downstream of the stormwater treatment system, however since commissioning some remaining connections have been found.

The WWTP was considered to be at capacity and unable to take the full hydraulic loading of stormwater, however spills or small first flush volumes could be accommodated there. To mitigate the risk of larger spills, isolation valves were to be included at strategic points throughout the system.

2.3 FIRST FLUSH TANK

The first flush tank is of concrete construction set below the ground surface as shown in figure 2. The overall capacity is 350 m^3 with 45 m^3 of dead storage to avoid resuspension of sediments. The 10 mm first flush volume of 266 m^3 (corresponding to 80% level in the tank, with 300 mm freeboard) is automatically sent to the first flush tank from the diversion chamber, and further water bypasses the first flush tank directly to the swale.

Figure 2: Overall view of first flush tank (centre) with swales (top) and monitoring sheds (bottom right, and top).

A pump station at the northern end of the tank (figure 3) automatically transfers water via two pumps at 2 - 4 ls^{-1} to the WWTP, which if the first flush tank is full, takes 21 - 42 hours to empty. The low flow rate is designed to minimise hydraulic loading to the WWTP during wet weather, especially during production when volumes are high.

Figure 3: Pump station from first flush tank for transfer to wastewater or swales.

There is also a pump to transfer water from the first flush tank to the swales at 5 ls^{-1}, which is activated manually if sampling of the water shows low COD (initially set at < 100 gm^{-3}) and the swales are dry.

2.4 SWALES

The wetland swales are twin 65 m long, 7 m wide channels separated by a 100 mm high concrete nib wall running down the centre (figure 4a). Influent enters via the concrete culvert and header box shown in figure 4a, is spread across the full width using a perpendicular concrete bar, and exits via a scruffy dome with sample pump and monitoring as shown in figure 4b.

(a)

(b) *(c)*

Figure 4: Photos of the stormwater treatment swales showing (a) inlet structure with riprap and centre wall, (b) outlet structure with sampling line, (c) detail of riprap and textile cloth with oioi planting near the outlet structure.

The bed of the swales comprises sand and topsoil covered with textile cloth (figure 4c). Below the sand and soil is a drainage network with HPDE liner underneath. The entry and exit to the swale are filled with riprap as shown in figure 4.

The swales are planted with *Apodasmia similis* (jointed wire rush, or oioi). These are tolerant of a range of wet and dry conditions and thus well suited for a wetland swale.

The sides have a bund of up to 1.3 m high to provide approximately 600 m^3 capacity for spill containment if required. The discharge point has an isolation valve which is closed automatically if the quality criteria are exceeded. In the event of a large spill, the quality will be tested and water discharged to the stream if quality allows, or removed by truck to the WWTP.

3 PREVIOUS PERFORMANCE

Prior to the installation of the new system, monitoring included online measurement of pH, temperature, flow, and conductivity, with weekly grab samples analysed for BOD and suspended solids. The stormwater at the discharge location and monitoring point included cooling water and town stormwater, thus making it difficult to isolate any sources of contamination. The monitoring was in real time, but without any means of ceasing the discharge when trigger values were exceeded (valve or divert), there was no means of preventing a discharge of contaminated stormwater to the stream once a spill had reached the underground infrastructure.

There were five external environmental non-compliances reported for stormwater in the year prior to the new system being installed. These included:

- Minor BOD contamination from a first flush rain event.
- High suspended solids due to erosion of soil surrounding a failed water pipeline.
- High pH and suspended solids due to construction and drilling works (two occurrences).
- High pH and suspended solids due to poorly controlled cementing work during the construction of the new stormwater system.

There were also a number of internal non-compliances recorded for deviations in discharge pH during the 2017 season because compliance was determined using the in-stream pH (instead of discharge pH) while the new system was being built. In each of the two previous seasons (2015 and 2016) there were six non-compliances reported for stormwater.

Averages for suspended solids and BOD_5 based on weekly grab samples over previous seasons are given in table 2.

Table 2: Average suspended solids and BOD_5 for Tirau stormwater and cooling water discharge over previous seasons.

Season	Average Suspended Solids (gm^{-3})	Average BOD_5 (gm^{-3})
2015	4	5
2016	6	3
2017	11	3
Consent limit	< 80	< 10

The low contaminant levels in table 1 show that under normal operation the stormwater was not significantly contaminated. As demonstrated by the non-compliance reports, almost all breaches were short-duration events with high contaminant load due to construction work, earthworks, failures in pipework, or in some cases first-flush rain events.

4 CURRENT PERFORMANCE

The new system has online monitoring of pH, conductivity, temperature, and turbidity at the diversion chamber, the exit of the swale, at compliance monitoring at the final combined discharge point. All online monitoring was downloaded from Fonterra's internal Data Extract tool with 30 s measurement intervals.

4.1 pH MONITORING

Given that pH has been the main trigger for non-compliances in the previous system, the continuous pH monitoring of the final discharge point over 2017, including periods both before and after the new system installation, was investigated.

Figure 5 shows that between January and June, pH commonly varied by around 0.5 units above and below neutral with few excursions beyond the 6 – 8 range (very low readings are due to loss of instrumentation signal). July and August saw a number of high pH events due to containment failures during construction events, soil erosion, and contamination from cross connections, as described in the non-compliance reports in section 3.

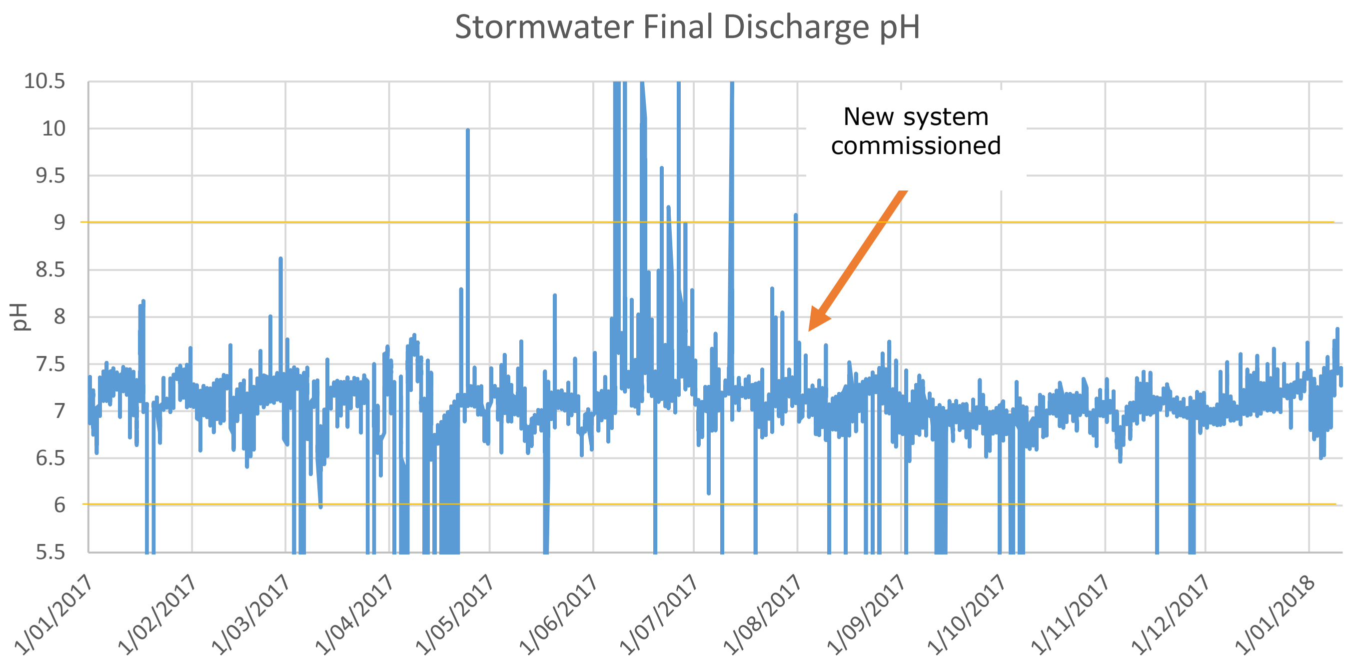

Figure 5: Online pH monitoring of final stormwater discharge to the Oraka stream for full 2017 year. Readings of zero are due to loss of instrument signal. Consented pH range is shown by the yellow lines.

After the new system was commissioned in August, the pH trend shows smaller variations than the first part of the year, of around 0.25 units either side of neutral, except for the period at the end of the year. There are also no discharges of stormwater outside of the 6 – 8 range. This demonstrates that the first flush tank and swale provide improved buffering and attenuation of high and low pH events.

4.2 ANALYSIS OF RAIN EVENT

To demonstrate the performance of the system during a rain event, the period from 10 – 14 February 2018 is studied. There is no NIWA rainfall monitoring in Tirau, so rainfall data for the nearest two stations at Karapiro and Matamata for the period were retrieved from NIWA's CliFlo database and are given in figure 6. Total accumulations for the period were 122.6 mm at Karapiro and 94.0 mm at Matamata.

The level in the first flush tank and the stormwater flow rate is shown in figure 7. In the 5 days preceding the event the rainfall totaled less than 10 mm and the first flush volume was not reached. It can be seen that the rainfall on the 10th and 11th begin to fill the first flush tank, but the 10 mm flush volume is not reached (80% level). In each case the tank is pumped out to the WWTP and the first flush volume is reset.

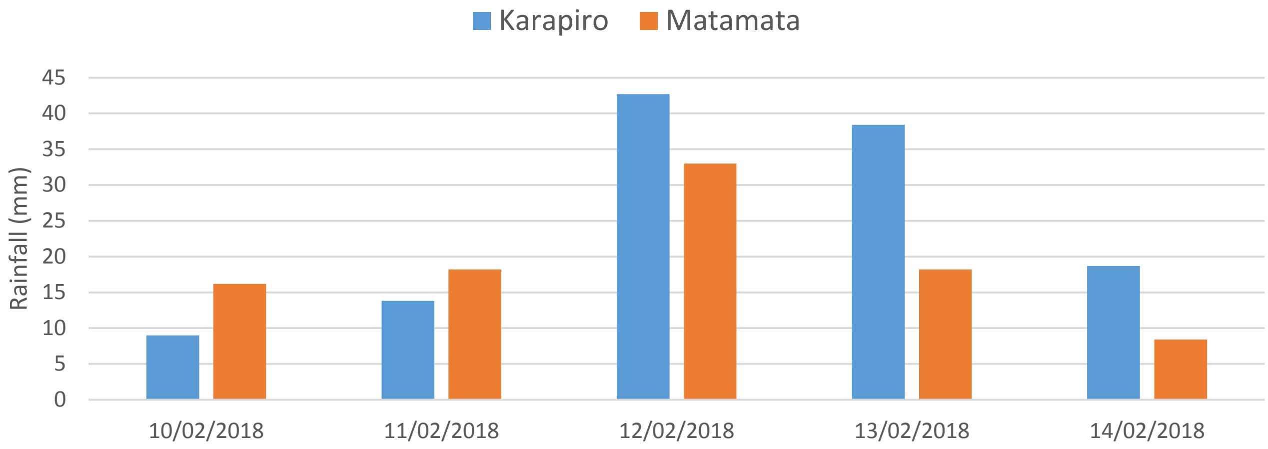

Figure 6: Rainfall totals at two sites near Tirau during 10 – 12 February rain event.

The higher rainfall on the 12th filled the first flush level requirement, and the diversion chamber began sending water to the swale directly while the first flush tank was pumped out again. The level in the first flush tank reduced to the dead volume and saw a small increase due to direct rainfall into the tank on the 13th.

The rainfall late on the 14th began diverting to the first flush tank again, because there was a pH probe fault which gave a reading outside of the discharge criteria. The three day first flush wait period (period in between first flush events where contaminant levels from runoff are expected to be low) had not passed yet so the flow would have discharged to the swale if the pH was within the limits.

Figure 8 shows the conductivity and turbidity of the stormwater influent during the event from the two eastern and western monitoring stations.

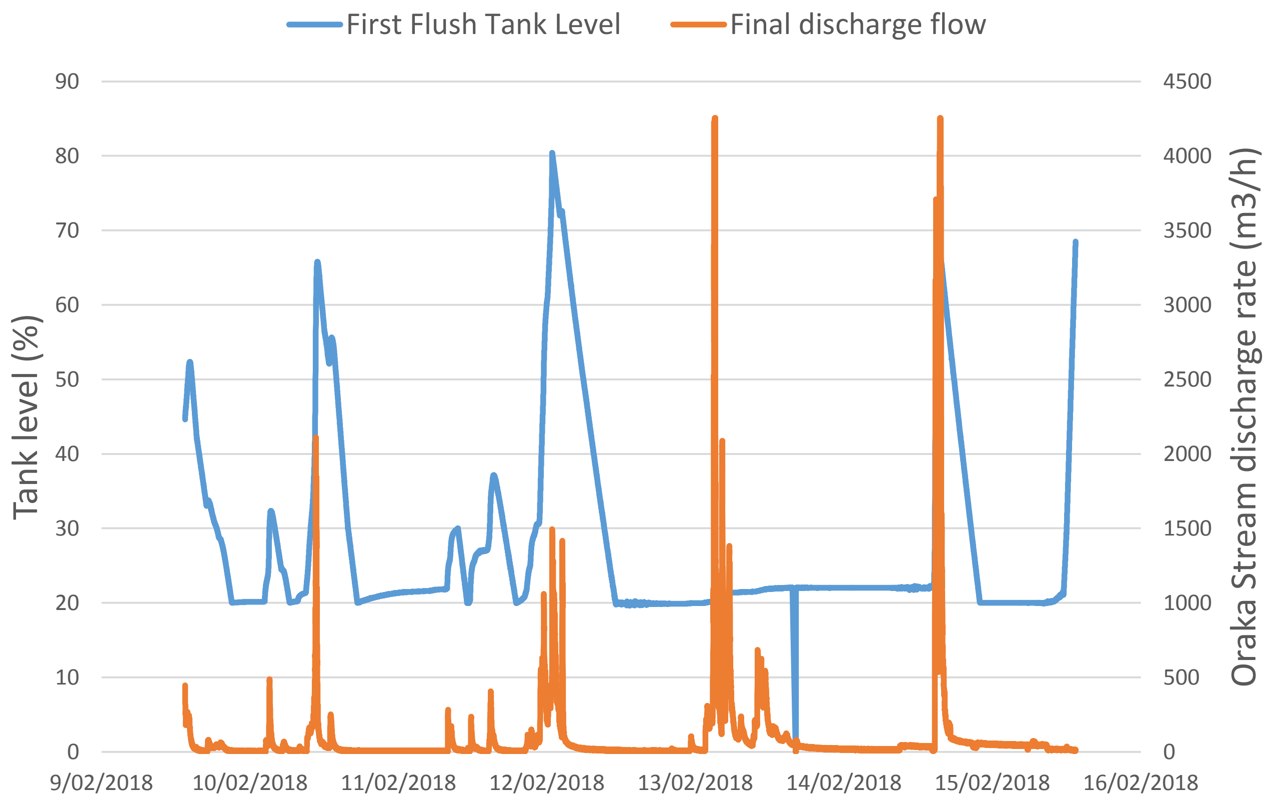

Figure 7: First flush tank level and stormwater final discharge flow rate (including town stormwater) over the rainfall event. See text for explanation.

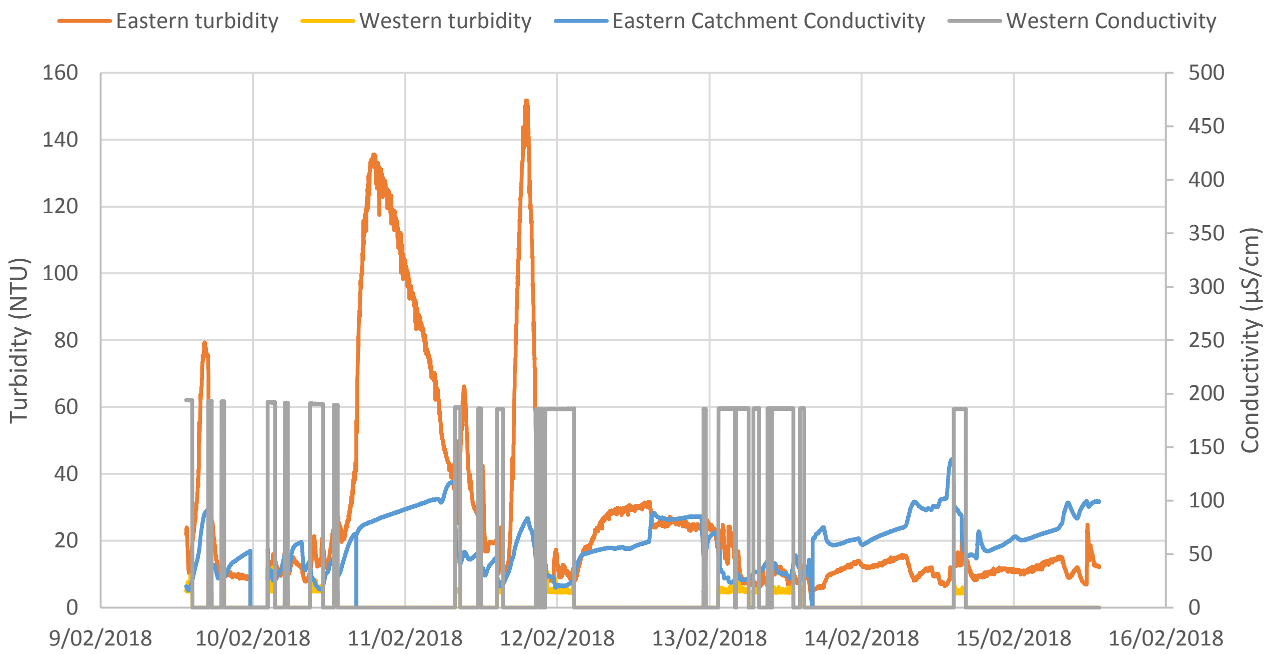

Figure 8: Conductivity and turbidity monitoring at the eastern and western catchment monitoring stations.

A number of observations can be made from this data:

1. The western catchment does not have any flow when it is not raining. This suggests there are no sources of water into the system apart from stormwater.

2. The western catchment has lower turbidity than the eastern catchment, although during rainfall they are similar. The conductivity probe for the western catchment appears to have faulted, with the same reading whenever flow is present.

3. The eastern system appears to have a base level flow with turbidity up to 150 NTU, as seen by the spikes during the dry periods on the 10th and 11th. These are diluted during rainfall events to give much lower measurements and do not reappear on or after the 12th, suggesting that the source of the flow had stopped at this point.

   Any sources of process water, especially with significant turbidity, need to be isolated and discharged to wastewater instead.

4. The base turbidity and conductivity are low and do not change significantly over the course of the event. This may be due to the smaller rainfalls on the preceding days washing away any first flush contaminants. As a result, all of the stormwater accumulations that occurred during rainfall in this period would likely be high enough quality for discharge directly to the swale and on to the stream.

5. There would be no need for filling the first flush tank during the rainfall on the 14th due to the low turbidity and conductivity. The pH probe was confirmed to have faulted during this period, leading to the diversion. In any case, the length of time between rainfalls that is used to trigger first flush collection should be reviewed regularly, and in cases like this the contents of the first flush tank should be discharged to the swale rather than the WWTP.

4.3 EFFECT OF SWALE TREATMENT

Figure 9 shows the change in turbidity between the two catchment monitoring stations, the end of the swale, and the final discharge point. The high turbidity in the eastern catchment is captured effectively by the swale, with a maximum of 6 NTU at the swale end across the period.

The final discharge point is much higher in turbidity than any of the catchments or the swale, suggesting there is a large sediment load coming from the township which is measured along with the site stormwater.

These results show the effectiveness of the swale in reducing turbidity, but raise concerns that Fonterra does not have control over the contaminant load in the final discharge though it holds the consent for this activity. Any exceedance of consent conditions in the future should be analysed thoroughly to determine whether the contamination came from the site or from the town connection.

Samples were also collected at 11am on 13/02/18, during heavy rain, from the inlet and outlet of the swales. One sample of each was submitted to Hill Laboratories for analysis, the results of which are shown in table 3. It should be noted that the flow through the swales was high, and overland flow was occurring as well as infiltration through the bedding and subsurface drainage (see figure 10).

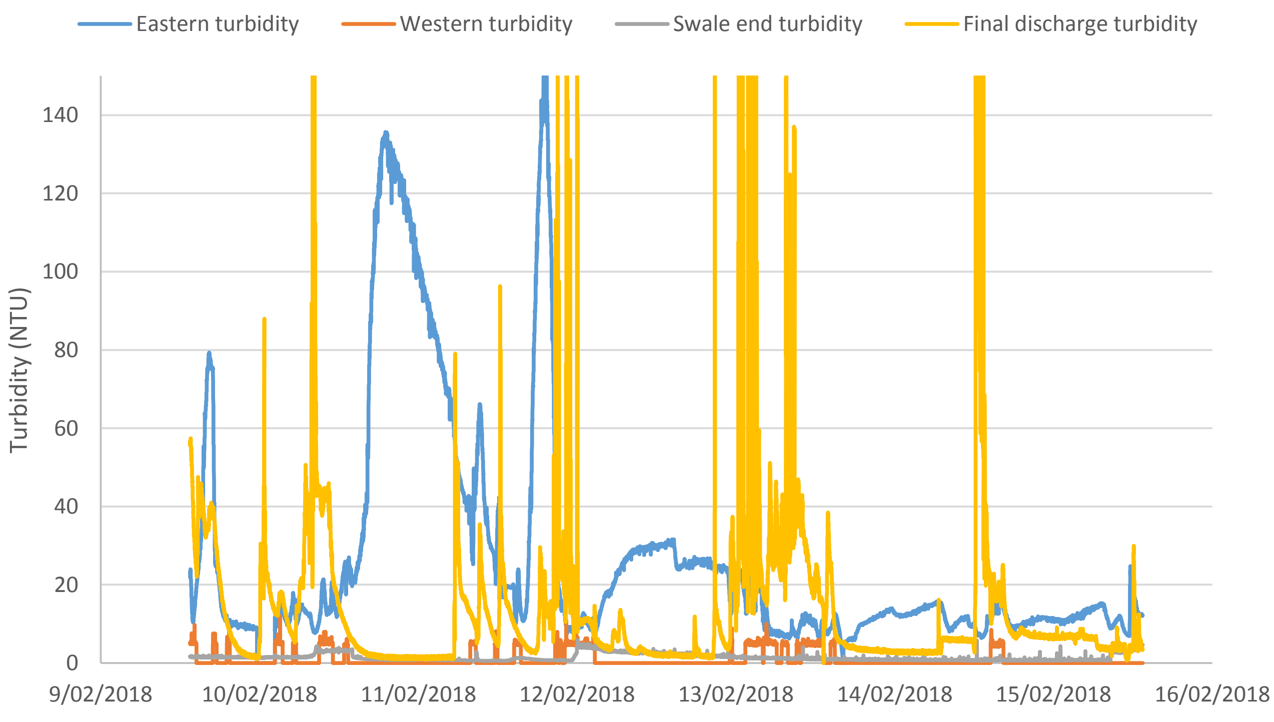

Figure 9: Turbidity over the rainfall event measured at the two upstream catchments, at the swale end, and at the final discharge after combining with town stormwater.

The suspended solids concentration reduced at least fourfold, which is consistent with the turbidity results in figure 9. The swale system is designed primarily to reduce suspended solids, which is demonstrated here. It is encouraging that even during heavy rain the reduction is significant, since during lower flows one would expect slower infiltration and less turbulent flow leading to greater reduction.

Table 3: Water analysis from the swale inlet and outlet during heavy rain event.

Contaminant	Swale inlet	Swale outlet
Total suspended solids (gm^{-3})	12	< 3
Total nitrogen (gm^{-3})	0.42	1.12
Total phosphorus (gm^{-3})	0.08	0.086
COD ($g\ O_2\ m^{-3}$)	12	12

Other contaminants were low in the inlet and did not reduce over the course of the swales, which is expected. In the case of total nitrogen the level increased, which is presumably due to organic matter or fertiliser from the soil and plants being picked up during infiltration.

This confirms that high nutrient and COD loads will not be effectively treated in a swale and first flush tank and spill containment should be employed as with this design.

Figure 10: Swale discharge during heavy rain event.

5 DISCUSSION

The new system has been successful in reducing contaminants discharging to the Oraka stream and there have been no non-compliant discharges since commissioning, thus the key objective of the project has been met. There are, however, a few issues that have arisen which affect its performance.

5.1 COOLING WATER

Despite cooling water discharges being removed from the stormwater system, there remains a small flow through the swale when the factory is running, and as demonstrated in section 4, this can contain significant turbidity. The source of this is currently unknown but needs to be identified and diverted as per the design hierarchy shown in section 1.

The flow results in the swales remaining wet throughout the manufacturing season, even when weather is dry. The oioi planting is tolerant of wet conditions, but still requires periods without water to remain in good health.

5.2 WEEDS

During December 2017 and January 2018 the swales grew weeds which were taller than the oioi planting. As well as reducing the visual quality of the facility, there is a risk that the weeds could reduce the effectiveness of the treatment or crowd out the oioi.

Advice was sought from Waikato Regional Council, who suggested trampling the weeds down to allow the oioi to grow higher and slow down weed growth. So far this has proved effective as can be seen in figure 11.

Figure 11: Oioi planting in the swales after weeds had been trampled (photo date 8/2/18).

5.3 VOLUMES TO WASTEWATER

Although not measured directly, the volume of first flush tank transfers to wastewater in the six day period studied in section 4 was in the range of 700 – 1000 m^3. Although at this time of year this volume is not problematic for the WWTP, this would be a significant volume over the season peak and may place pressure on capacity during significant rain events. This also increases the size and cost of any new WWTP upgrades required.

The first flush criteria should be reviewed regularly to ensure that the nutrient load going to the swale is low, and clean water is not being sent to the WWTP. Options for this include:

- Lengthening the time between first flush capture.
- Increasing the turbidity limit for divert to first flush tank.
- Testing the first flush tank contents more regularly and pumping to the swale if quality allows.

5.4 TOWN STORMWATER

The combined final discharge includes stormwater from the township and site cooling water which was not separated as part of this project. As demonstrated in figure 9, the town storm water can contribute very high suspended solids during rainfall.

Although upstream monitoring can be used as evidence that the Fonterra discharge does not contribute to any non-compliances generated from town stormwater, the consent is owned by Fonterra and this represents a substantial risk.

6 CONCLUSIONS

Fonterra Tirau had an ageing stormwater system with little ability to prevent contamination from leaks, spills, and first flush rainfall. This resulted in a number of non-compliant discharges over the past three years.

The new system is based on a 10 mm first flush capture with divert to wastewater, and two swales designed to capture suspended solids and provide emergency storage in the case of a large spill.

Monitoring carried out during a week of significant rain in February 2018 showed low conductivity and turbidity in the upstream catchments during rainfall, with a reduction in suspended solids and turbidity after treatment in the swale. First flush capture and transfer to wastewater also functioned as per design, with low levels of TP, TN, and COD detected in the water at the end of the swale. No non-compliant discharges have been recorded since the system was commissioned.

Further investigation needs to be undertaken to remove process water flows from the stormwater system as these can have significant contaminant loading and not allow the swale to dry out properly. First flush criteria should also be reviewed regularly to minimise the volumes transferred to the WWTP.

This system meets Fonterra's approach in reducing environmental risk and improving water discharge quality, while maintaining consent compliance.

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