Osbornes Drain
Water Quality Improvements

Prepared for

Selwyn District Council

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DRAFT

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Please refer to Section 13.0 of this report for the report limitations

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Executive Summary

The Osborne drainage scheme is an extensive network of around 9km of drains operating over 1620 ha to facilitate farming activities. Water in the drain is primarily derived from overland flow and shallow groundwater derived from the local catchment. Water quality sampling indicates high nitrogen and phosphorus concentrations, low dissolved oxygen and occasional elevated turbidity. Elevated nutrients are also present in the sediments. The water quality environment is characterised as poor or very poor based on Environment Canterbury's Water Quality Index.

The poor water quality is expected to have adverse effects on the wetland at the drain mouth, although there is no specific monitoring to confirm this, and also contributes contaminants to Lake Ellesmere/Te Waihora. Due to the relatively low flow in Osbornes Drain it is a smaller contaminant source relative to other tributary streams. However in the interests of improving the water quality environment and giving effect to iwi and regional council planning documents, there is clearly a need to improve water and sediment quality in Osbornes Drain.

The contaminants are primarily derived from local land use activities. Historical activities have contributed to the build up of contaminants in sediments. Current land use is of a higher standard but further improvement are possible through the implementation of farm management plans and improved riparian management is required. This source control, followed by removal of contaminated sediments and implementation of a steady bore source of baseflow, are expected to be the most effective improvement measures. Consents will be required for their implementation. Further monitoring and assessment work within the catchment will be helpful to focus the remedial efforts and to measure the improvements that are created.

Finally, it is important to recognise that poor water quality issues, such as those that occur in Osbornes Drain, are best addressed on a catchment wide basis through a collectively agreed approval between land owners , Councils, iwi and interest groups. This report should be used as a basis for informing the development of the agreed collective approach to achieve effective improvements in the catchment.

1.0 Introduction

The Osbornes Drainage scheme was designed to drain an area of low lying flat land across a catchment area of approximately 1620 hectares and has a total of 9 km in length of drains. Osbornes Drain (and numerous side collector drains entering the main drain) is the collecting arm of this drainage scheme area, with a pumped discharge from the south eastern corner of the scheme area. Surrounding landuse in the catchment is currently used primarily for irrigated dairy farms, dry stock farms, and smaller lifestyle blocks. A large composting operation is also situated to the northwest of Osbornes Drain where materials are used for soil conditioning.

Selwyn District Council is in the process of redrafting a consent application for the discharge of land drainage water from Osbornes drainage scheme into Lake Ellesmere/Te Waihora. The draft application proposes a number of improvement / mitigation measures to improve the quality of the Osbornes Drain discharge along with a monitoring program to track actual water quality improvements. Key stakeholders have requested that the improvements to water quality which could be reasonably expected should be detailed in the consent application.

To assist with the implementation of this improvement process, Pattle Delamore Partners Ltd (PDP) have been engaged by Selwyn District Council (SDC) to provide information on the following five topics:

1. The current quality of Osbornes Drain, including in drain water quality, sediment quality, quality of discharges to the drain and the impact of these on the wetlands that the drain directly discharges too and Te Waihora/Lake Ellesmere;

2. The proposed improvement measures for Osbornes Drain including expected % reductions (or similar) of key water quality parameters and impact of these on the wetlands that the drain directly discharges to and Te Waihora/Lake Ellesmere;

3. Identification of any further work that needs to be undertaken to improve the quality in Osbornes Drain;

4. Recommendations relating to the potential design of Farm Plans, including, but not limited to, the inclusion of on farm or community wetlands (and recommended species etc) for treatment of the land drainage water before it enters the drain and the associated anticipated benefits (and likely timeframes) of implementing such a tool to achieve short and long term goals for the drain; and

5. A planning assessment of whether each proposed improvement measure is able to be undertaken under the current planning regime and identification of what (if any) resource consents may be required.

This report provides a summary of the available information on these topics, as requested in the work scope presented in Appendix B.

1.1 Environmental Setting

Appendix A, Figure A shows the catchment area and the surrounding geologic strata. The catchment occurs within low permeability sediments, primarily associated with a lake environment. These low permeability sediments form part of the coastal confining layer for deeper gravel aquifers. As such, the water in the drain is primarily fed from surface water and shallow groundwater derived from the local catchment area. The movement of any deeper groundwater from the underlying gravel aquifers into the drain will be impeded by the intervening low permeability sediments. This will lessen the contribution from inland groundwater and furthermore, any nutrients within that inland groundwater would be attenuated by the low permeability sediments. Therefore, the major source of water and associated contaminants within the drain is most likely derived from the local catchment area. The lake environment has also created highly saline soils which contribute to an elevated electrical conductivity in the drain water. This is part of the natural environment in this area.

The receiving environment of discharges associated with Osbornes Drain land drainage district is ultimately Lake Ellesmere/Te Waihora, although discharges firstly pass through an important wetland (Figure B, Appendix A).

Lake Ellesmere/Te Waihora, also known by the name Te Kete Ika a Rākaihautā, the fish basket of Rākaihauā, is a tribal taonga for Ngāi Tahu. It is one of New Zealand's largest coastal, shallow brackish water lakes, and has important fringing wetland systems (supporting significant bird populations). Furthermore, the lake represents a major mahinga kai and important source of mana to Ngāi Tahu. What was once an outstanding clean resource, the lake is now in a very degraded state. Degradation is primarily as a result of cumulative anthropogenic activities and land use change (Taylor 1996; Hughey and Taylor 2009).

In addition to nutrient enrichment the lake experiences several compounding management issues such as artificial lake level management, commercial fish harvesting, cumulative impacts from water abstraction from inflowing groundwater and streams, and the effects of invasive pests (Taylor 1996; Hughey and Taylor 2009; Taylor Hughey *et al*., 2013).

2.0 Current Quality of Osbornes Drain

2.1 Water Quality

2.1.1 Osbornes Drain Water Quality

Water quality data, obtained from Environment Canterbury (ECan) was analysed based on monthly results collected between May 2011 and May 2012 for the Osbornes Drain area (DO saturation (%) concentrations from loggers and discharge (L/s) events have also been investigated and is detailed in ECan (2013 DRAFT) and PDP (2013)). A location map and site list of water quality sampling locations around Osbornes Drain is presented in Appendix A, Figure B and Appendix C respectively. Key water quality parameters of interest include: Temperature, Dissolved Oxygen, Total Nitrogen, Dissolve Nitrogen, Total Phosphorus, Dissolved Phosphorus, Total Suspended Solids, visual appearance and odour (Appendix B).

The water quality of Osbornes drain has been analysed and reported in detail in ECan, 2013 DRAFT report. A summary table and box and whiskers plots of key water quality parameters along the drain are presented in Appendix D.

Water quality data from within the Osbornes Drain catchment were compared to relevant national and regional guidelines (Appendix A, Figures C – F; Appendix E). Table 1 below, provides an indication of the quality of water in Osbornes Drain and the percentage of time samples were in exceedance of guideline values.

Table 1: Water Quality Summary 2011 -2012

Osborne Drain	Temp	DO SAT	TSS	TURB	NH_4N	NNN	DIN	TN	DRP	TP	*E.coli*
Jarvis rd Site (SQ35762)	15	100	50	62	31	8	46	100	100	100	38
Garmick's rd (SQ35761)	15	73	38	23	23	0	31	100	100	100	8
US of main lateral site (SQ35759)	17	64	50	17	8	0	8	100	100	100	17
DS of main lateral Site (SQ35760)	0	70	55	36	9	0	9	100	100	100	9
US cattle crossing (SQ35758)	0	80	50	20	20	0	0	100	100	100	30
DS cattle crossing Site (SQ35757)	8	75	38	46	23	0	0	100	100	100	38
100 m US pump house (SQ35757)	8	67	62	31	0	0	0	100	92	100	8
Hudson's rd end (SQ34117)	0	83	54	38	0	0	0	100	100	100	8
Hudson's rd collecting drain (SQ35763)	0	83	54	38	0	8	8	100	100	100	23
20 m long bottom lateral drain (SQ35754)	0	67	62	31	0	0	0	100	100	100	8
Between pump house and mouth (SQ35754)	0	83	54	54	0	0	0	100	100	100	15
Mouth of Osborne Drain (SQ35752)	0	58	100	100	0	0	0	100	69	100	38
Halswell Canal (SQ34127)	0	9	25	17	0	100	100	100	100	100	8
Spring-fed guideline (NRRP) mg/L			≤10		≤0.9	≤1.7	≤1.5		≤0.016		≤550
ANZECC (2000) mg/L	≤20	≤80		≤5.6				≤0.614	≤0.033		

Key:

% Exceedance			
0-25	25-50	50-75	>75

These results show that the key water quality issues in the drain catchment are, in order of concern, high dissolved phosphorus concentrations (DRP; Appendix A, Figure F), total phosphorus (TP), total nitrogen (TN), reduced dissolved oxygen concentraiton (DOSAT), turbidity (TURB; Appendix A, Figure D) and suspended solids (TSS; Appendix A, Figure C) concentrations. Spikes in ammonia nitrogen (NH_4N) concentrations occurred at the two upper most sampling sites, Jarvis road and Gammicks road (Appendix D, Figure 3). Escherichia coli does not appear to be an issue for Osbornes Drain, although infrequent spikes >2400 MPN/100ml were observed (Appendix D, Figure 7).

Maps defining spatial distribution and classification of turbidity, suspended solids, dissolved inorganic nitrogen and dissolved reactive phosphorus are presented in Appendix A; Figures C - F. In general, water quality parameters improved the further towards the drain mouth, particularly DRP. The exception to this was TSS at the drain mouth, where highly turbid water from Lake Ellesmere/Te Waihora likely influenced results.

The measurement of TN takes into account all forms of nitrogenous matter in the water column both organic and inorganic. Given the elevation of TN compared to DIN (Appendix D), this indicates that a significant component of the nitrogen in the water is organic, i.e., locked up in biological tissue (Appendix D, Figure 4). Similarly, TP is a measurement of all forms of phosphorus, including DRP, organic P and particulate inorganic P. Concentrations of DRP and TP are similar indicating that DRP is a significant component to TP (Appendix D, Figure 4).

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With regards to visual appearance and odour, there have been reports from the community of a 'black water' discoloration and surface scums occurring immediately upstream of the pump house. There are several potential causes for the discoloration of the water, for example it may be due to algal blooms, very small particles of organic matter (reflection of suspended sediments) in the water column.

Likewise, odour issues may result from low flow situations where the pumps have not been operational for an extended period of time and sedimentation, anoxic conditions, algal and bacteria growth have developed. It is likely that once the pumps are initiated, the anoxic bottom layer sediments are disturbed and released into the water column and air, thus resulting in odour.

2.1.2 Water Quality Index for Canterbury

The application of a water quality index (*full methodology see* Appendix F*)* for Osbornes Drain and various lowland tributaries (primarily spring-fed basins) around Lake Ellesmere/Te Waihora have been calculated. This approach enabled water quality at each site to be classified into one of five categories determined by key water quality parameters (Appendix F) and helped identify areas of significance (focus of management efforts). The five classification categories include, Excellent (Very Good), Good, Fair, Marginal, Poor and Very Poor (*definition see* Appendix F).

Maps defining the water quality index (WQI) for the Osbornes catchment and tributaries are presented in Appendix A; Figures G. A prominent decline in health was observed in tributary streams from west to east around the lake (with the exception of Boggy Creek). Water quality in Osbornes / Halswell catchment was notably degraded, with water quality indexes scoring in the poor category (values ranging from 18 – 44) (Appendix A; Figures G, Appendix F). This indicates water quality in the Osbornes catchment is almost always threatened or impaired. The furthermost sampling location on the eastern side, Kaituna River (Banks Peninsula river type) water quality appeared to be good, scoring the highest WQI value of 72 for all sites measured (Appendix F, Table 2).

A very clear pattern emerged in the Osbornes catchment and indicates potential point sources of contamination (Figure 1), similar to that observed in phosphorus concentrations, water quality is degraded the most in the upper catchment, improving towards the drain mouth (Figure 1). Water quality of Osbornes Drain appears to be the most degraded from the top end of monitoring localities; Osbornes Drain at Jarvis Road bridge, scoring a very poor grade (WQI value = 16; Appendix A; Figure H). Although still water quality is still in a degraded state, WQI values improved the further down the drain, toward the mouth from 16 to 35 (Appendix A; Figure H).

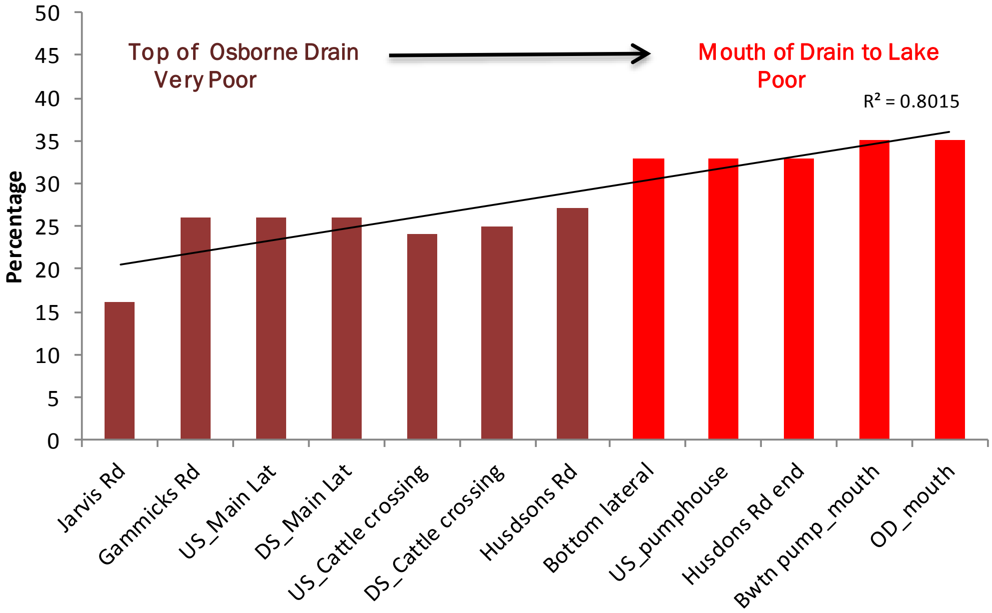

Figure 1: Water Quality Index results of sampling locations in the Osbornes Drain catchment.

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2.2 Sediment Quality

Two rounds of sediment samples have been undertaken. The first sediment grab sampling was conducted in April 2012 by Environment Canterbury at three sampling locations in Osbornes Drain; 1km upstream of the pumphouse, immediately upstream of the pumphouse, and downstream of the pumphouse (ECan 2013 DRAFT). The second sediment grab sampling was carried out by Selwyn District Council in September 2013 at two locations; immediately upstream of the pumphouse, and downstream of the pumphouse. Sediment samples were analysed by Hill Laboratories for a range of parameters described in Table 2. Sediment results were compared against ANZECC (2000) Sediment Quality Guidelines and for comparative purposed only, the typical background soils concentrations for the general area (ECan 2007; Appendix G).

Table 2: Sediment Quality Parameters

Environment Canterbury	Selwyn District Council	
Organic Matter	Arsenic	Mercury
Ash	Boron	Nickel
Total Carbon	Cadmium	Tin
Total Organic Carbon	Chromium	Zinc
Total Nitrogen	Cobalt	
Total Recoverable Phosphorus	Copper	
Carbon : Nitrogen Ratio	Lead	

Sediment Quality Data

Concentration of organic matter increases with distance downstream in Osbornes Drain, with higher concentrations downstream of the pumphouse in the floodplain area (Figure 2). A similar pattern was observed in Total Nitrogen (TN), Total Recoverable Phosphorus (TRP) and total organic carbon (TOC), concentrations which all increased downstream of the pumphouse.

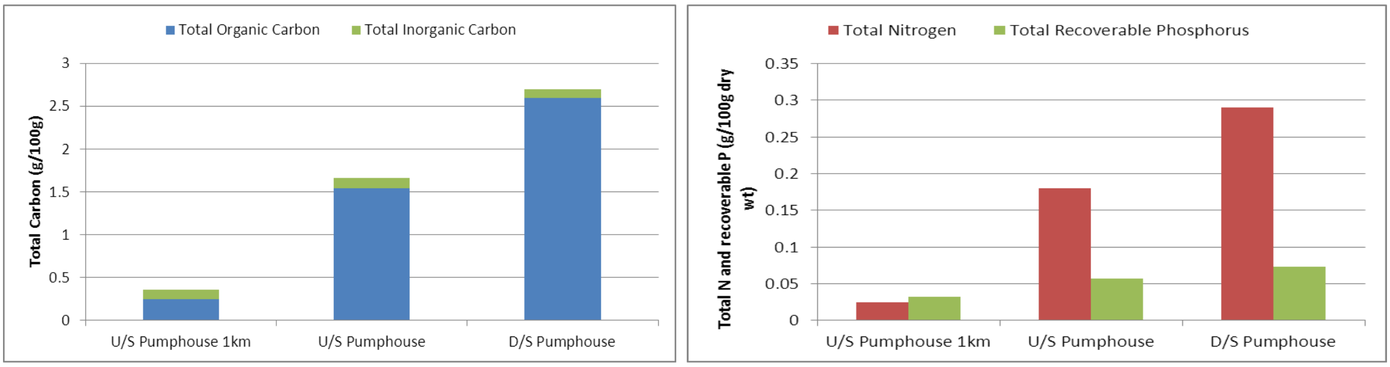

Figure 2 – (a) Total Carbon concentrations in sediment from Osbornes Drain, including organic and inorganic carbon concentrations. (b) Total Nitrogen and Total Recoverable Phosphorus concentrations in sediment from Osbornes Drain (sourced from Robinson and Meredith 2013 Draft).

ECan (2013 Draft) reported that while total nitrogen concentrations in the sediment increase downstream, there is less of an increase in total recoverable phosphorus. However, the opposite pattern was observed in water quality with phosphorus concentrations in the upstream water column. As a result of low dissolved oxygen (anoxic) conditions, phosphorus bound up in sediment may be being released and into the water column (Chaubey *et al*., 2007), therefore contributing to the high phosphorus loads from Osbornes Drain to Te Waihora/Lake Ellesmere.

2.2.1 Heavy Metal Sediment Quality Summary

Heavy metals in both samples, one immediately upstream of the pumphouse, and downstream of the pumphouse, contained acceptable concentrations of the test analytes with regard to the ANZECC 2000 Sediment Quality Guidelines (effects range-low) (Appendix G). Therefore, based on these results alone, the sediment appears acceptable to remain insitu from the perspective of protection of any ecological receptors that may be affected by metal concentrations. However, if the sediment is to be excavated for off-site disposal then further samples may be required to properly characterise the overall volume of sediment expected to be excavated and removed offsite.

2.2.2 Oestrogen and Endocrine Disrupting Chemical (EDCs)

No sampling information is available for oestrogen and EDCs for the Osbornes Drain catchment. These chemicals are of concern in the environment because of their ability to interfere with the natural functioning of the hormone systems in humans and wildlife. They are derived from a wide variety of sources, both natural and man-made including pharmaceuticals, personal care products, dioxin and dioxin like compounds, polychlorinated biphenyls, DDT and other pesticides and the components of plastics such as bisphenol A (BPA) and phthalates. EDC compounds also occur naturally in animal wastes. Dairy farm effluents in the Waikato have shown high levels of estradiol and its breakdown product (estrone; Sarmah *et al.,* 2006).It is difficult to judge the likely occurrence of these chemicals. If there is concern about ECDs then this would need to be assessed by a sampling survey.

2.2.3 Pesticides and Herbicides

No sampling information is available for pesticides and herbicides, however given the agriculture use of the catchment it is feasible that accumulations of these compounds could have occurred within the drain sediments. Therefore it is recommended that sampling be conducted to clarify and confirm.

3.0 Effects of the current water quality

3.1 Effects on the Wetlands into which Osbornes Drain discharges

The primary flow path of the Osbornes Drain is through a modified man-made channel which bypasses through a natural wetland. However, due to growth of aquatic plants such as raupo, the channel has become clogged and choked. Drain management activities, such as in-drain plant removal have been stopped, given concern over impacts to the wetland from DoC and Ngai Tahu. No drain maintenance has occurred below the pumphouse for approximately 10 years (*personal comments Simon Manson, local landowner*).

As a result of excessive plant growth in the channel, the volume of flow passing through the channel below the pumphouse has become reduced (this is indicative but unquantifiable) and during times of high flow, waters break out from the main channel and inundate surrounding land.

SDC has implemented some mitigation measures, such as construction of a floodwater protection bund on the upper most east side (below pumphouse), inhibiting floodwaters from overflowing and entering into the Halswell River and causing potential erosion to the boat ramp. It should be noted, that this area of land, (up to the pump station) also experiences periodic influxes of lake water during high lake water levels. This water can be present for long periods of time until lake levels recede. The potential adverse effects of this may include increased salinity and sediment load to soil, smothering of productive feed (grass), stagnation of waters which may cause vegetation die-off.

There is absence of monitoring data for the wetland, however, some of the water discharging from Osbornes Drain will be entering / passing through the receiving wetland to the west and east of the discharge channel. Given that suspended solids concentration downstream of the wetland is not overly excessive (Appendix D), the wetland would likely be helping to capture and retain sediment from the water column. Of concern, however, is that increased TSS loading entering the wetland could smother juvenile plants species and / or restrict further regrowth and establishment of plants and smother habitat and food resources for instream fauna. Nutrient enrichment, when combined with sediments and other physical stressors, can cause detrimental impacts on aquatic environments, particularly in downstream lakes and estuaries.

The initial flush of warm water and anoxic water (low dissolved oxygen) occurring immediately after the initial flush (once pumping has begun), although of short duration, may have negative influences on fauna. Given the sensitivity of some aquatic fauna, particularly fish and macroinvertebrate (important food resource for sustaining internationally important bird populations) further work to quantify the state of the wetland flora and fauna is recommended.

3.2 Effects on Te Waihora / Lake Ellesmere

As detailed in several reports (Larned and Schallenberg 2006; Hughey *et al.,* 2013) Lake Ellesmere/Te Waihora has poor water quality and experiences frequent algal blooms. The lake has particularly high concentrations of total nitrogen, total phosphorus, turbidity, suspended solids and Chlorophyll a (indicator of algal biomass).

Based on water quality results over 2011 – 2012 for Osbornes Drain and flow volume (PDP 2013), it is expected that the influence on water quality of Lake Ellesmere/Te Waihora is relatively small, although it is an ongoing source of nutrient load to the lake

Faecal contamination, as indicated by *Escherichia coli* (*E.coli*), doesn't appear to be an issue in Osbornes Drain. Although some spikes in *E.coli* were observed, median values were all well below alert values for contact recreation (260 MPN/100ml). Microbial contamination can have significant impacts on fauna and food resources in the lake, particularly with regards to Mahinga Kai and commercial fisheries (Dixon *et al.,* (2007).

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4.0 Causes of Poor Water Quality

4.1 Historical Land Use

Sediments in Osbornes drain most likely reflect the accumulation of effects from historical, unmanaged land uses such as direct discharge of dairy effluent into the drain and stock access into the drain. The build-up of contaminants from these historical land use effects remain in the drain and contribute to current poor water quality.

4.2 Current Land Use Effects

Current land use effects contribute to the current water quality and also provide an ongoing input to the sediment quality. Active consents and land use type within the Osbornes catchment to identify the relative significance of different catchment source.

4.2.1 Active Consents

A search of ECan's GIS database was conducted for active consents or permitted activity confirmations within the Osbornes catchment. Of particular significance are active discharge consents or permitted activity confirmations. This analysis identified 12 active records within the catchment associated with discharges (Appendix A, Figure E). Six of these records are associated with land application systems for on-site effluent disposal (following septic tank treatment), and of these six records, all bar one (CRC053182) specifies that secondary treatment is also installed. The common method of land application of secondary treated effluent is via pressure compensated drip irrigation Properly operated modern wastewater disposal systems should not adversely impact on Osbornes Drain.

Active resource consents associated with a composting facility within the catchment at Gammocks Road were also identified. The consent holder has a permit to discharge contaminants to air, and a land use consent to establish a green waste composting facility. The land use consent specifies that "The land use shall be only a green waste composting facility", and that "For the purposes of this consent, greenwaste means only unprocessed plant material and associated soil, and does not include general refuse, food material, or any animal matter". The consent search did not identify any resource consent associated with the discharge of leachate from the composting facility, however the land use consent does require the collection of groundwater samples in order to monitor any nitrogen leaching occurring from the composting operation. It would be prudent to check on the fate of stormwater and infiltrating water from the compost plant.

4.2.2 Land use

Land use within the Osbornes Drain Catchment consists of various agricultural land types as detailed in the table below (Table 3) and presented in Appendix A; Figures H and I. Each of these land uses create different levels and types of contamination, as well as different pathways in which these reach surface water. It is noted that all of the farming systems within this catchment are pastoral systems with no purely cropping or horticulture farms. Pastoral land use are typically associated with three principal pollutant types: nitrogen, phosphorus and sediment. Bioavailable nitrogen species concentrations are low and therefore, nitrogen is considered less of an issue in this catchment compared to phosphorus. As phosphorus is often bound to sediment, phosphorus and suspended sediment are closely related. Sediment also causes adverse effects due to siltation and smothering of aquatic habitat.

The contaminant load delivered from each farming type varies greatly depending on farm environmental practices and the general farm environment. The following sources provide a general indication of the likely potential sources of contaminant.

Table 3. Land use, Osbornes catchment

Property type description	Count	Area (ha)	% Land use	TSS	N	P
Sheep & Beef	3	611	44	High	Medium	Medium
Dairy	4	351	25	High	High	High
Deer	1	156	11	High	Low	Medium
Sheep	3	77	6	Medium	Low	Medium
Lifestyle block	12	76	5	Low	Low	Low
Contract grazing	1	42	3	High[1]	Medium[1]	Medium[1]
Beef	3	35	3	High[1]	Medium[1]	Medium[1]
Horse farming & breeding	3	33	2	Low[2]	Low[2]	Low[2]
Dairy dry stock	1	8	1	High[1]	Medium[1]	High[1]
Other livestock	1	6	0.4	Medium[3]	Low[3]	Medium[3]

1. As cattle grazing will be the main mechanism for contaminant runoff in Sheep & Beefs farms, it is assumed that Beef, contract grazing, dairy dry stock all have the same characteristics as Sheep & Beef. It is assumed that all of these properties do not spread effluent and irrigation application is minimal.
2. Horse farms are assumed to have a low stocking rate, so similar characteristics as Lifestyle Block
3. Other livestock is assumed to include goats, alpacas etc., and exclude piggeries. Therefore similar characteristics to Sheep.
Adopted for flat land, based on RW McDowell & RJ Wilcock (2008) Water quality and the effects of different pastoral animals, New Zealand Veterinary Journal, 56:6, 289-296, DOI: 10.1080/00480169.2008.36849
Land use information supplied by AgriBase® farm types within Osborne Drain catchment. AgriBase® (August 2013) is a product of AsureQuality.

The upper Osbornes drain catchment has a variety of farming land types, but is dominated by Deer and Dairy. As stated above, dairy has the potential to contribute large amount of nitrogen to shallow groundwater, which could migrate to Osbornes Drain. Dairy, if improperly managed, can often provide significant loss of phosphorus directly to waterways i.e. not bound to sediment, especially if waterways are not fenced and if effluent or fertiliser application is applied incorrectly. Pugging damage can also be a serious issue on dairy farms, depending on the wintering arrangement, and can often lead to serious losses of sediment. As stated above, it is noted that Deer farms can cause significant sediment and phosphorus losses to waterways. The lower Osbornes drain Catchment is dominated by Sheep & Beef operations, while this farming type has low nitrogen losses, the phosphorus and sediment losses can be quite high, especially if grazing cattle are not properly managed. In order to limit the phosphorus and sediment loss from these farms, it is important to ensure grazing cattle are kept out of waterways, and are wintered in areas that are not susceptible to pugging.

These general land use activities are all able to be minimised through good farm management practices.

5.0 Proposed Improvement Measures

Appendix H presents a range of mitigation measures that have been proposed and discussed by SDC, Ngai Tahu, ECan and DoC to improve water quality of the Osbornes Drain. Specific details relating to the definition of each of these mitigation measures were not provided in the scope of works. As such, attributes regarding each proposed mitigation measure were assumed in regards to general operation or function.

Where appropriate, the changes these improvements might make to water quality measures are presented as a percentage range. Percentage ranges are considered appropriate due to the considerable variability that may be experienced for each parameter and the limited environmental data available that can provide justification to the presented values. In some instances, it is considered inappropriate to provide values due to the degree of uncertainty. It also must be acknowledged that the results presented are dependent on the design of the proposed mitigation options. It is therefore considered that the presented values are to be used as an indicative guide only.

Based on the expected improvements that can be provided by the proposed mitigation options, it is considered that the implementation of farm management plans are the most favourable mitigation option. In comparison to other proposed mitigation options, farm mitigation management plans provide a holistic management approach to the identified contaminants of concern. They focus on the primary source of contaminantion. Sediment, dredging removes historical contaminant build up until the input sourced is minimised. Sediment removal may need to be repeated from time to time. It is also worth noting that some mitigation measures could make water quality worse downstream through mobilising sediment.

A suggested prioritisation of impro

vement measures is:

- Step1: Implement farmer education, implement individual farm management plans and riparian management strategies;
- Step 2: Remove contaminated sediment (as identified by a sampling survey) downstream of the pump station and for a short section upstream of the pump station. Install a weir to restrict the movement of upstream contaminated sediments into the excavated area. (Appropriate planning of this mitigation is required, with particular attention and detail to timing of year and consideration of potential impacts on the receiving environment if high flows were to occur immediately after earthworks);
- Step 3: Establish base flow augmentation using artesian bore water and instalment of a minimum flow meter;
- Step 4: Monitor water quality changes. Only consider recirculation or aerators if steps 1 – 3 do not show an improvement
- Step 5: Once implementation of farm management plans has reduced contaminant input to an acceptable level then complete excavation of other contaminated sediments.

6.0 Best Management Practice and Design of Farms Plans

A description of Best Management Practice (BMP) for land owners and the Farm Environment Management Plan (FEP) process is presented in Appendix I. Through the implementation of FEP and the specific BMP, win–win outcomes are often achieved whereby nutrient/contamination losses are reduced, whilst on farm spending and efficiency are also improved. Each individual farm could develop a comprehensive, individual FEP, suited to their farming operation and environment. These FEP's will allow goals to be set, and progress tracked. Each FEP will consist of various BMP's which will be developed, or their current use highlighted to ensure that each farm is being operated to a high environmental standard.

We are aware that specific FEP's are in the process of finalisation for three farm in the Osbornes catchment, including development of riparian planting plans. Some on farm improvement measures have already been conducted and more are currently being initiated. Such mitigation measures have and are include:

- Restricted stock access
- Relocation of certain fence lines to allow for riparian plantings
- Development plans for a herd home
- Development plans of a new dairy effluent system

A catchment-wide collaborative environmental approach, is also recommended as it will allow for knowledge, costs and methods to be shared, and the key contaminants of phosphorus and suspended solids to be focussed on in a catchment wide scale. It is advisable that the FEP are implemented prior, or soon after, the mitigation measures occur in order to minimise build of further contaminant.

7.0 Planning Assessment

7.1 Activity Status

An assessment has been undertaken to identify relevant regional planning rules with respect to the proposed improvement measures to identify potential consenting requirements for each of the proposed measures (Appendix A):

At the date of this report, there are two regional plans which must be considered, the Natural Resource Regional Plan (operative 11 June 2011) and the proposed Land and Water Regional Plan (notified 11 August 2012). On 18 January 2014, an amended version of the proposed Land and Water Plan (pLWRP) will be notified. This amended version reflects the recommendation made as a result of the hearing of submissions process. After 18 January 2014, this amended version of the plan must also be considered. Appendix J, Table A, provides a brief summary of the relevant activity classification for each of the three plans mentioned above.

In addition to the region-wide rules, the pLWRP will be amended to include sub-regional rules. At the date of this report, there are no relevant sub-regional rules contained in the Selwyn-Waihora sub-region. Proposed rules have been drafted, and are currently undergoing Schedule 1 consultation (Part of Variation 1 to the PLWRP – date 20 September 2013). An assessment has been made with respect to the draft document. , Appendix J, Table B identifies additional draft sub-regional rules as they relate to the proposed mitigation measures.

Where multiple plans classify an activity differently, the more restrictive activity status classification takes precedence. Table 4, shown below, provides a brief summary of the regional consenting requirements for each improvement measure based on its most restrictive classification.

To summarise, under the current and proposed plans, several of the mitigation measures may require resource consent, such as the removal of accumulated sediment and the use of a groundwater bore for base flow augmentation, from Environment Canterbury, while others, such as the use of an aerator and the construction of weir(s), do not require resource consent (Appendix J).

Table 4. Summary of Consenting Requirements

Improvement Measure	Activity	Prevailing Plan and Rule	Activity Status
Remove the accumulated sediment from the lagoon upstream of the pump station.	Excavation over the coastal confined aquifer	PLWRP (notified) – Rule 5.158	Discretionary
	Earthworks in erosion prone areas	PLWRP (notified) – Rule 5.150	Restricted discretionary
Remove all accumulated sediment for the entire length of Osborne Drain.	Excavation over the coastal confined aquifer	PLWRP (notified) – Rule 5.158	Discretionary
	Earthworks in erosion prone areas	PLWRP (notified) – Rule 5.150	Restricted discretionary
Base flow augmentation: use of local artesian bores to provide constant flow and installation of 'low flow' pump in the pump station.	Construction of groundwater bore (if not using an existing bore)	NRRP WQL31	Restricted discretionary
	Take and use of water from groundwater that exceeds 10 m^3/day but is less than 100 m^3/day	NRRP WQN11	Restricted discretionary
	Discharge of water into an artificial watercourse which may result in water entering a lake	NRRP WQL1	Permitted
Use of a recirculation pump where water is pumped from the pump house to a location upstream and continually recirculated.	Excavation over the coastal confined aquifer	PLWRP (notified) – Rule 5.158	Discretionary
	Take, use of water from an artificial watercourse, and discharge back into that same artificial watercourse	PLWRP (notified) Rule 5.99 and PLWRP (amended) Rule 5.126	Restricted discretionary
Use of an aerator to prevent anoxic/stagnant conditions in the drain.		No applicable regional rules.	No regional consent required
Construction of weir(s) directly upstream of the pump station.	Damming and/or diverting of water in an artificial watercourse	NRRP – Rule WQN23	Permitted No regional consent required
Implementation of farm management plans to achieve water quality standards in the drainage water.		No applicable regional rules.	No regional consent required

7.2 Iwi Management Plan

An assessment has also been undertaken to determine whether the improvement measures proposed are consistent with the policies contained in the relevant Iwi Management Plans. The review of the improvement measures was taken against the Te Taumutu Runanga Natural Resources Management Plan (2003), the Te Waihora Joint Management Plan Mahere Tukutahi O Waihora (2005) and Mahaanui Iwi Management Plan (2013).

Appendix J, Table C shows the relevant policies for each Iwi Management Plan with respect to the proposed improvement measures. The proposed improvement measures are consistent with, and not contrary to, the policies contained within these plans. When carried out, the proposed improvement measures assist in promoting the overall objectives and policies for managing the health of Lake Ellesmere/Te Waihora.

7.3 ZIP Addendum

The Selwyn-Waihora Zone Committee completed its Zone Implementation Plan (ZIP) in April 2012. An Addendum to the ZIP (August 2013) was released to reflect the community engagement and committee discussion necessary for developing the Selwyn-Waihora sub-regional section of the proposed Land and Water Plan.

An assessment of the proposed improvement measures has also been undertaken with respect to the recommendation contained within the ZIP addendum. Appendix J, Table D identifies the relevant recommendations with respect to the proposed mitigation measures. While it is noted that the promotion of catchment intervention, improved drain management and review of progress meeting water quality outcomes is key for all the proposed improvement measures, the ZIP addendum also places a heavy emphasis on farm management practices within the catchments.

8.0 Further Work

The following recommendations are made for further work:

- Detailed description of specific improvement measures;
- Remediation and Monitoring Management Plans for the improvement measures
- A centralized document outlining the framework for Osborne Drain improvement;
- Consideration of alternative channel maintenance options below pumphouse;
- Consideration of wetland enhancement (identify possible areas upstream of the drain);
- Further sampling to quantify sediment quality and quantity in Osborne Drain;
- Wetland baseline survey/investigation (including sediment);
- Sampling of EDCs and pesticides/herbicides at various point along Osbornes Drain
- Potential mitigation measure: floating treatment wetlands (*for detail refer* Appendix K)

Given the number of improvement measures, level of detail required, timing, cost and goals and objectives it is recommended that a Remediation Management Plan and Environmental Monitoring/Management Plan for the whol Osbornes Drain Catchment be established. This would provide the framework and direction for remediation and monitoring activities. A crucial component to determining the success of remediation progress is through appropriate data collection, 'Measure to Manage'. Without knowing 'baseline' environmental conditions prior to remediation work and without conducting post remediation monitoring, one cannot determine if they are conducting best practice or having an improvement on status quo.

9.0 Conclusion

The available data indicates that Osbornes Drain experiences poor water quality which, in turn, is discharged into Lake Ellesmere/Te Waihora. Due to its relatively low flow the contribution of content to the lake is of a small scale. The main source of contaminants is from land use activities of a small scale. The main source of contaminants is from within the drain sediments. Current land use activities are improving but the implementation of Farm Environment Plans and riparian management can further improve the condition of the Drain. Other improvement measures can also assist and are suggested.

Prioritisation of improvement measures is:

- Step1: Implement farmer education, implement individual farm management plans and riparian management strategies;
- Step 2: Remove contaminated sediment (as identified by a sampling survey) downstream of the pump station and for a short section upstream of the pump station. Install a weir to restrict the movement of upstream contaminated sediments into the excavated area. (Appropriate planning of this mitigation is

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required, with particular attention and detail to timing of year and consideration of potential impacts on the receiving environment if high flows were to occur immediately after earthworks);

- Step 3: Establish a base flow augmentation flow using artesian bore water and instalment of a minimum flow meter;
- Step 4: Monitor water quality changes. Only consider recirculation or aerators if steps 1 – 3 do not show an improvement
- Step 5: Once implementation of farm management plans has reduced contaminant input to an acceptable level then complete excavation of other contaminated sediment.

Various consents will be required to authorise these tables. It is recommended that the information in this report should be used as a basis for SDC, land owners, iwi, ECan, DoC, Fish and Game and other stakeholders to collectively develop an effective way to implement improvements to the Osborne Drain environment.

10.0 Report Limitations

1) The contents of this report are based on PDP's understanding and interpretation of current standards and guidelines and do not comprise legal advice. Selwyn District Council is responsible for taking its own legal advice on the legal effect and requirements of the standards and guidelines. Unless agreed in writing, the advice provided will not be updated by PDP to take account of subsequent changes to standards and guidelines.

2) The laboratory test results provide an approximation of the concentration of the tested parameters and are subject to the inherent limitations of the laboratory techniques used for the tests.

3) PDP has not sampled any environmental parameters that are described in this report.

4) The information contained within this report applies to water and sediment sampling undertaken on the dates stated in this report. With time, the site conditions and environmental standards could change so that the reported assessment and conclusions are no longer valid. Accordingly, the report should not be used to refer to site conditions and environmental standards applying at a later date without first confirming the validity of the report's information at that time.

5) This report has been prepared on the basis of information provided by Selwyn District Council and others not directly contracted by PDP for the work. PDP has not independently verified the provided information and has relied upon it being accurate and sufficient for use by PDP in preparing the report. PDP accepts no responsibility for errors or omissions in, or the currency or sufficiency of, the provided information.

6) This report has been prepared by PDP on the specific instructions Selwyn District Council for the limited purposes described in the report. PDP accepts no liability if the report is used for any other purpose. PDP also accepts no liability to any other person for their use of or reliance on this report, and any such use or reliance will be solely at their own risk.

11.0 References

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Chaubey, I. Sahoo, D. Haggard, B.E. Matlock, M.D. and Costello, T.A. (2007). Nutrient retention, nutrient limitation, and sediment-nutrient interactions in a pasture-dominated stream. American Society of Agriculture and Biological Engineers 50(1), 35-44

ECan, (2007). Background concentrations of selected trace elements in Canterbury soils. Appendum 1: Additional samples and Timaru Specific background levels. Report number R07/1/2. February 2007

ECan, (2013). Assessment of Water Quality Monitoring 2011 – 2012 (Draft). Prepared by Robertson, K. and Meredith, A. Environment Canterbury

Golders Associates, (2011). Te Waihora/Lake Ellesmere Catchment: Ecological Values and Flow Requirements

Hughey, K. F. D, Taylor, K. J. W. (2009). Te Waihora/Lake Ellesmere: State of the Lake and Future Management. Lincoln University. EOS Ecology

Hughey, K. F. D, Johnston, K. A. Lomax, A. J., Taylor, K. J. W, (2013). Te Waihora/Lake Ellesmere: State of the Lake

Larned, S., Schallenberg, M., (2006). Constraints on phytoplankton production in Lake Ellesmere/Te Waihora. Environment Canterbury Report No. U06/38. July 2006

McDowell, R. W, Wilcock, R. J, (2008). Water quality and the effects of different pastoral animals, New Zealand Veterinary Journal, 56:6, 289-296, DOI: 1080/00480169.2008.36849

Monaghan (2006). Prioritisation of farm scale remediation efforts for reducing losses of nutrients and faecal indicator organisms to waterways: A case study of New Zealand dairy farming, AgResearch, 25 July 2006. Invermay Agricultural Centre, Private Bag 50034, Mosgiel, New Zealand

PCE (2013). Water quality in New Zealand: Land use and nutrient pollution, Parliamentary Commissioner for the Environment, November 2013. www.pce.parliament.nz

PDP (2013). Osborne Drain Discharge Water Quality report. Prepared for Selwyn District Council.

Taylor, E. J. W, (Ed.) (1996). The natural resources of Lake Ellesmere (Te Waihora) and its catchment. Environment Canterbury Technical Report 96(7), 322 p, Christchurch

Sarmah, A.K., Northcott,G.L., Leusch, F.D.L., Tremblay, L.A., (2006) A survey of endocrine distruption chemicals (EDCs) in municipal sewage and animal waste in the Waikato region of New Zealand. *Science of the Total Environment* 355, pg 135-144.

1.0Appendix References

Ballantine D., Booker D., Unwin M. and Snelder T. (2010). Analysis of national river water quality data for the period 1998–2007. Report No. CHC2010-038 prepared for the Ministry for the Environment by NIWA, Christchurch.

Beech. M (2011), Unpublished - Osbornes Drain Water Quality Investigation: Update one. Environment Canterbury

Colorado Department of Public Health and Environment Water Quality Control Division, Colorado Mixing Zone Implementation Guidance, April 2002

EBoP (2004). 'Landuse Impacts on Nitrogen and Phosphorus Loss and Management Options for Intervention', Environment Bay of Plenty, June 2004.

FLRC (2012). Course notes for Sustainable Nutrient Management in New Zealand Agriculture course, Massey University, 2012. Fertilizer & Lime Research Centre & New Zealand Fertiliser Manufacturers', Research Association, Revised 2012.

Headley, T, Tanner, C. C, (2007). Floating Vegetated Islands for Stormwater Treatment: Removal of Copper, Zinc and Fine Particulate. Prepared for Auckland Regional Council. NIWA Client Report HAM2007-175, November 2007

Headley, T. R, Tanner, C. C, (2011). Innovations in constructed wetland treatment of stormwaters utilising floating emergent macrophytes. Critical Reviews in Environmental Science and Technology

Larned, S.T.; Scarsbrook, M.R.; Snelder, T.H., Norton N.J. (2005). Nationwide and regional state and trends in river water quality 1996-2002. National Institute of Water and Atmospheric Research, Christchurch.

McDowell et al (2013). Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters, Report prepared for Ministry for the Environment, June 2013.

MDA, (2012). The Agricultural BMP Handbook for Minnesota, Minnesota Department of Agriculture (MDA), September 2012. St. Paul, Minnesota.

MfE (2001). Managing Waterways on Farms – A guide to sustainable water and riparian management in rural New Zealand, Ministry for the Environment, May 2001. ISBN 0 478 24016-3, PO Box 10-362, Wellington, New Zealand

Osborne Drainage Scheme – Committee meeting (22 August 2013), Osborne Drain Consent Update.

Ozane, R. (2012). State of the Environment – surface water quality in Otago 2006-2011. Otago Regional Council.

Parfitt et al (2007). Best practice phosphorus losses from agricultural land, Landcare Research, September 2007. Prepared for Horizons Regional Council

Pierre, A.; Morar, S.; Milne, J.R., Greenfield, S. (2012). River and stream water quality and ecology in the Wellington Region – State and trends. Greater Wellington Regional Council.

Saffran, K., Cash, K., Hallard, K., (2001) Canadian Water Quality Guidelines for the Protection of Aquatic Life. *Prepared for:* Water Quality Technical subcommittee of the CCME Water Quality Guidelines Task Group.

Stevenson, M., Wilks, T., Hayward, S., (2012) An overview of the state and trends of water quality of Canterbury rivers and streams. Environment Canterbury. Report No. R10/117.

Appendix A

Figures

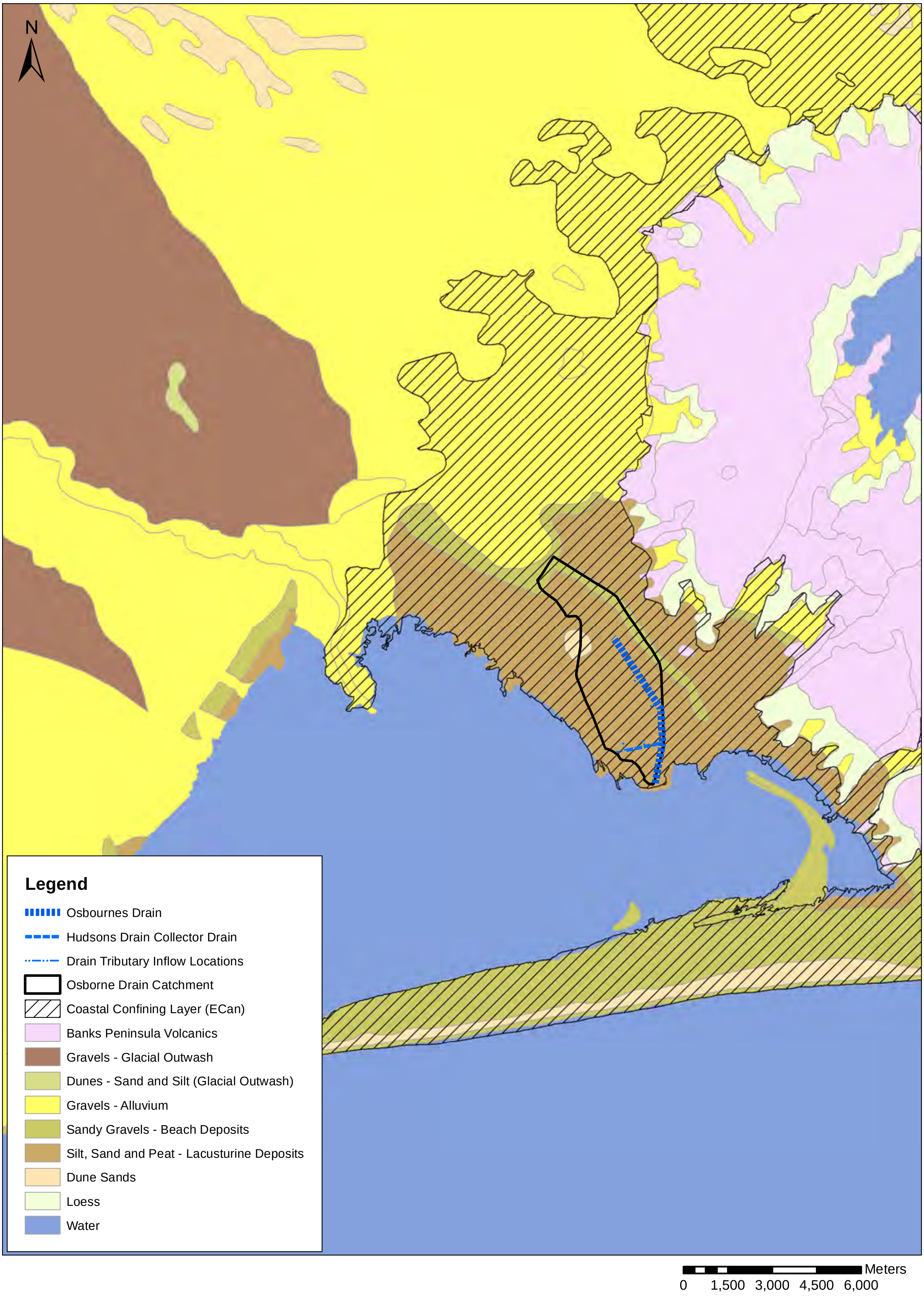

FIGURE A: GEOLOGICAL MAP OF OSBORNE DRAIN CATCHMENT AND COASTAL CONFINING LAYER

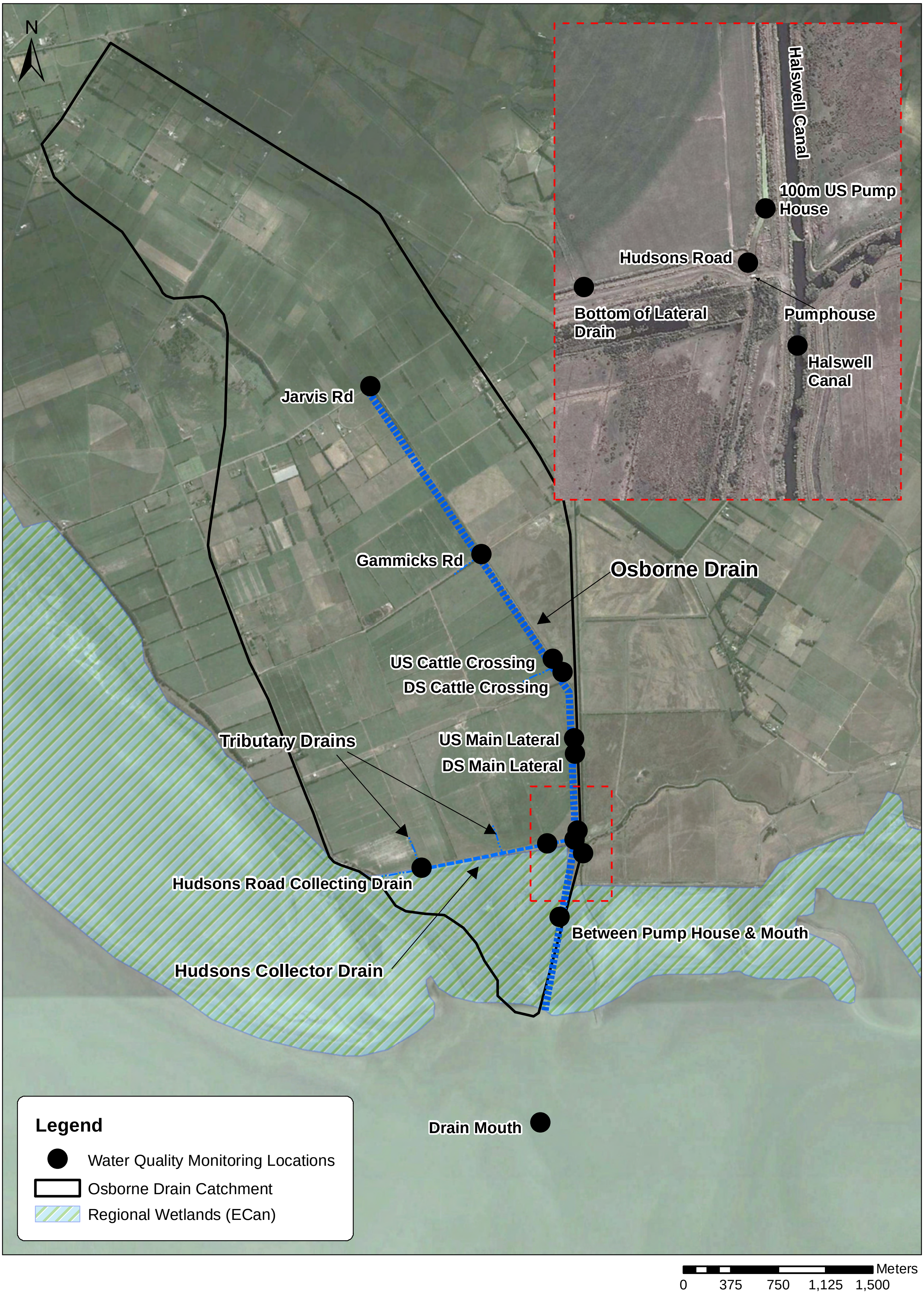

FIGURE B: WATER QUALITY MONITORING LOCATIONS, OSBORNE DRAIN

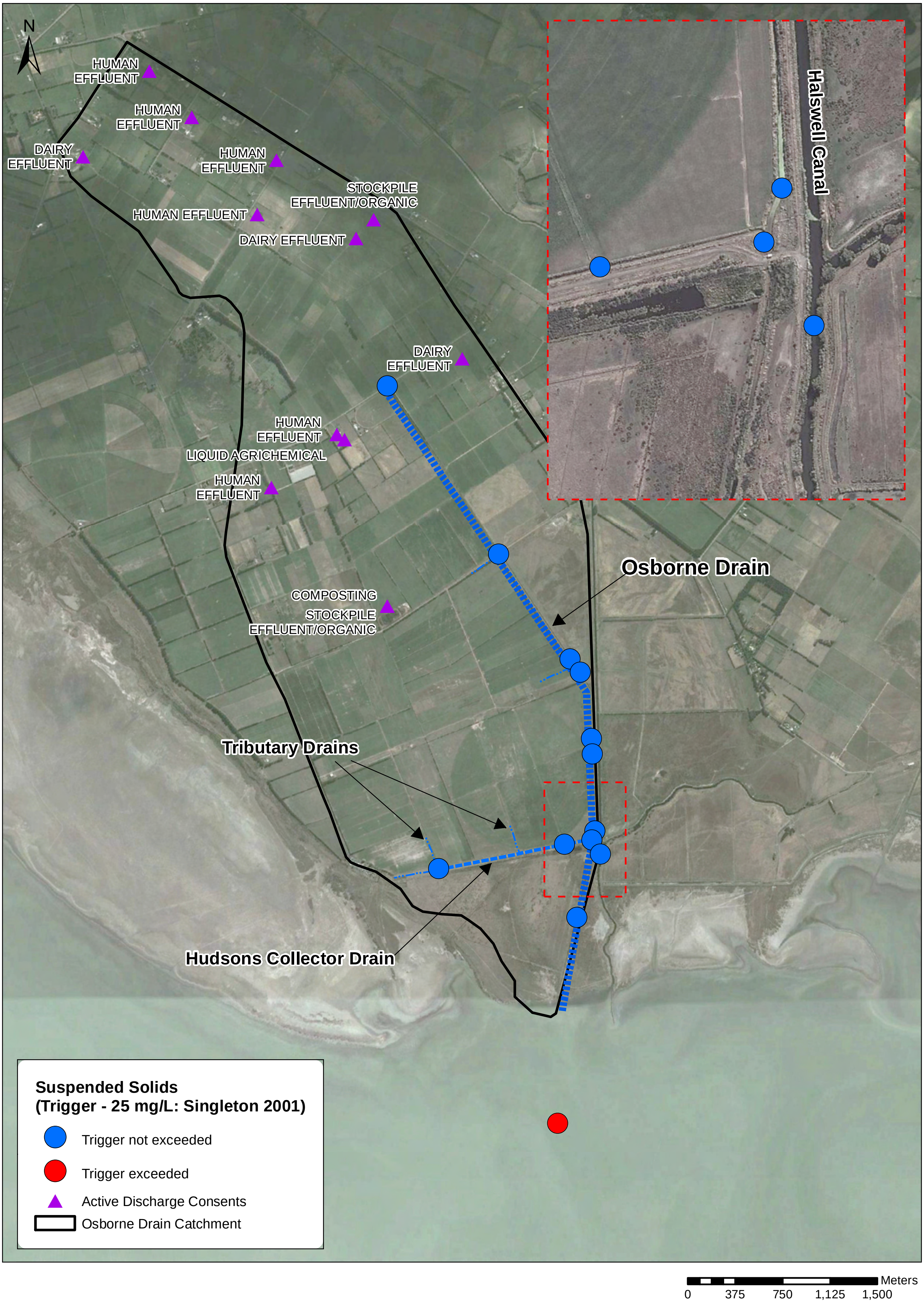

FIGURE C: WATER QUALITY MONITORING RESULTS (MEDIAN TOTAL SUSPENDED SOLIDS CONCENTRATION)

See Appendix D for Summary Table

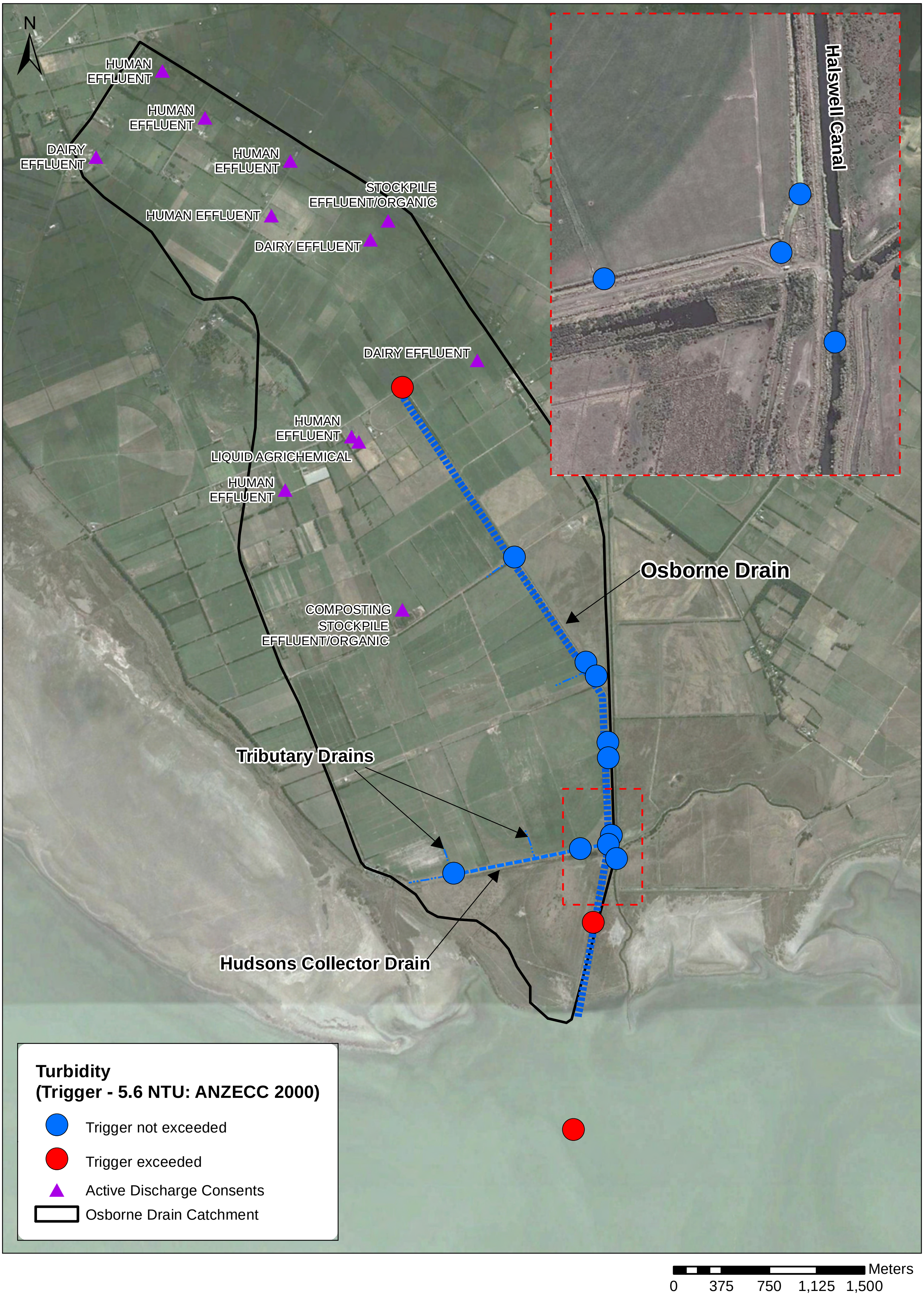

FIGURE D: WATER QUALITY MONITORING RESULTS (MEDIAN TURBIDITY)

See Appendix D for Summary Table

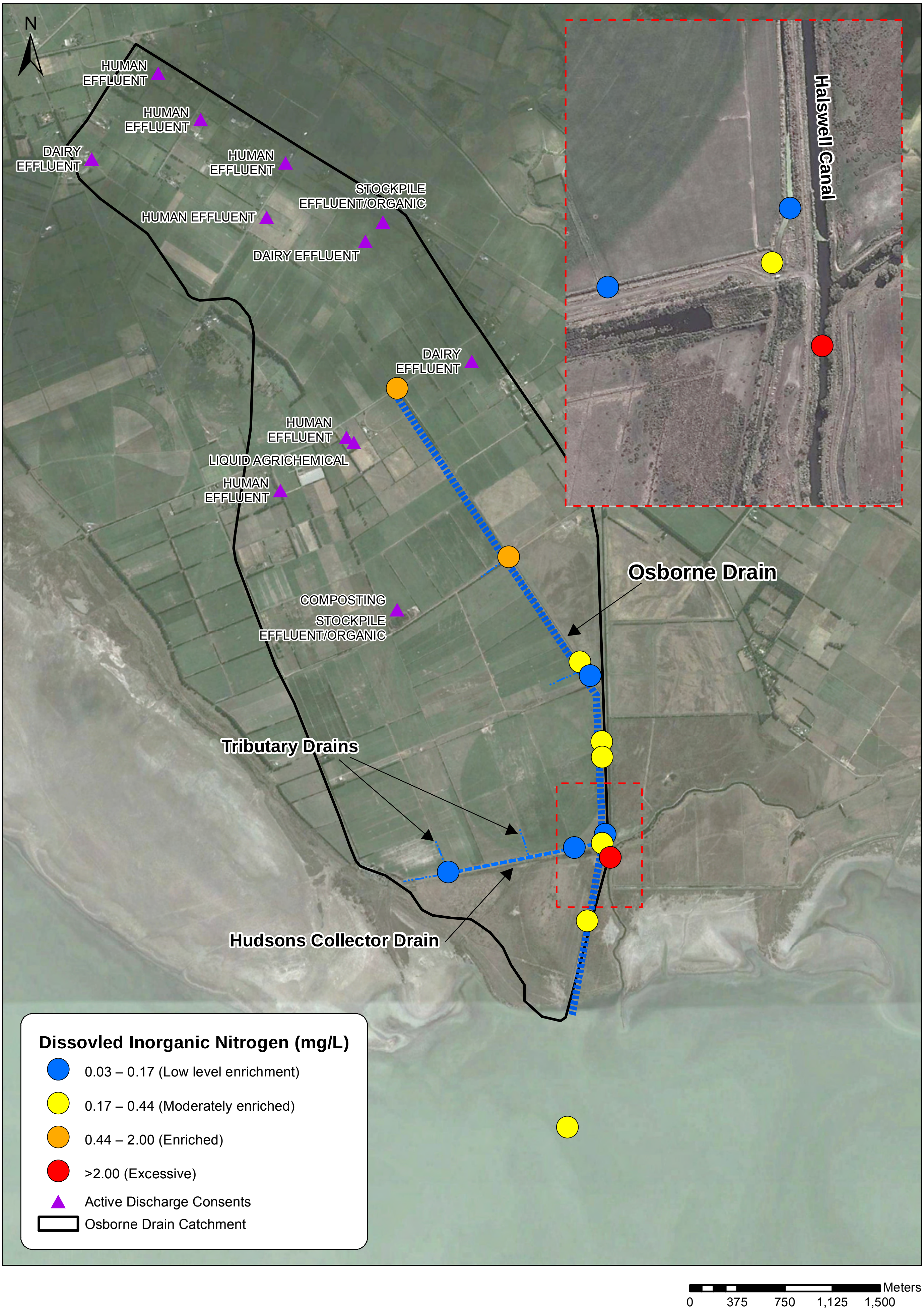

FIGURE E : WATER QUALITY MONITORING RESULTS
(MEDIAN DISSOLVED INORGANIC NITRGOEN CONCENTRATION)
See Appendix D for Summary Table

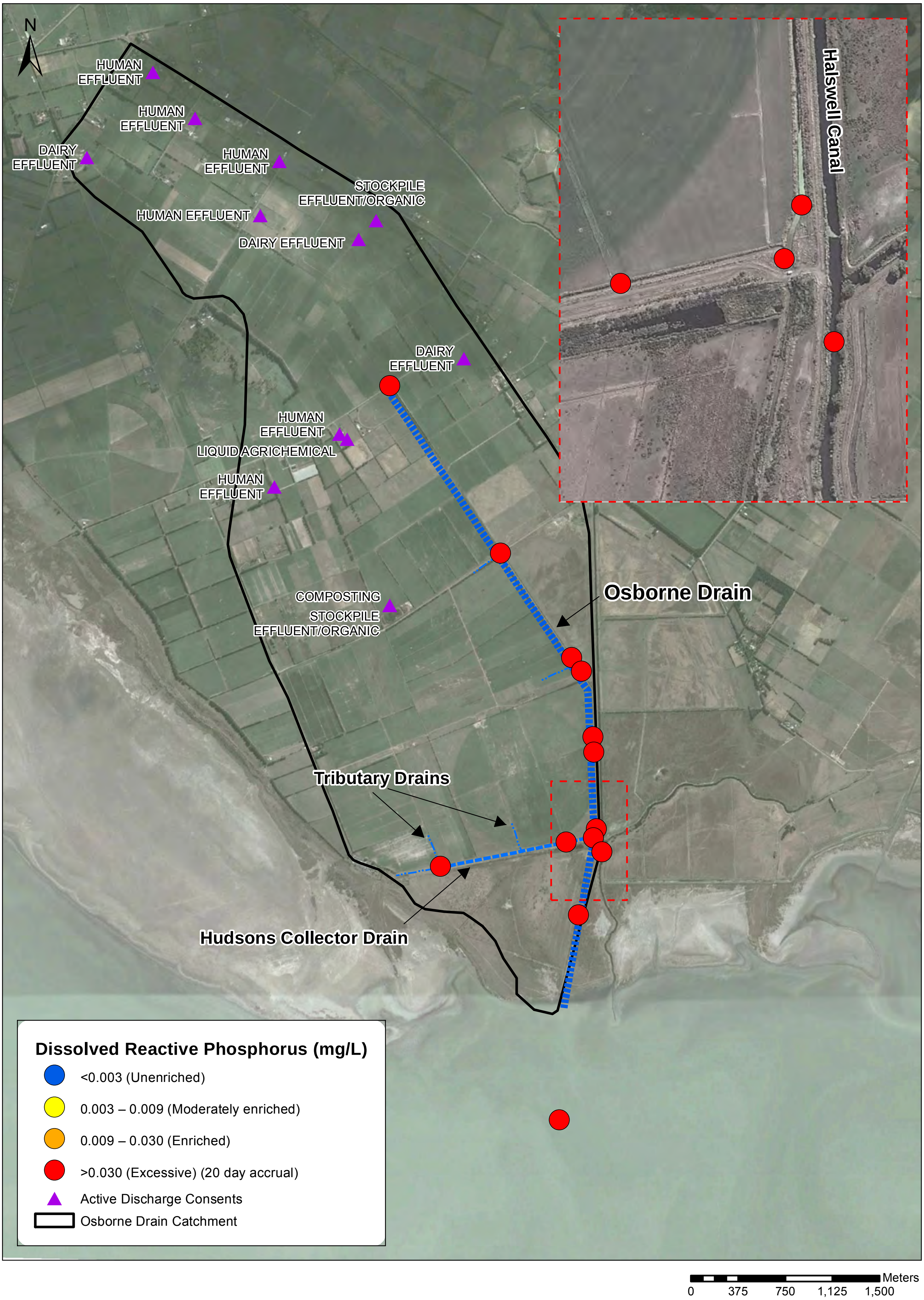

FIGURE F : WATER QUALITY MONITORING RESULTS
(MEDIAN DISSOLVED REACTIVE PHOSPHORUS CONCENTRATION)

See Appendix D for Summary Table

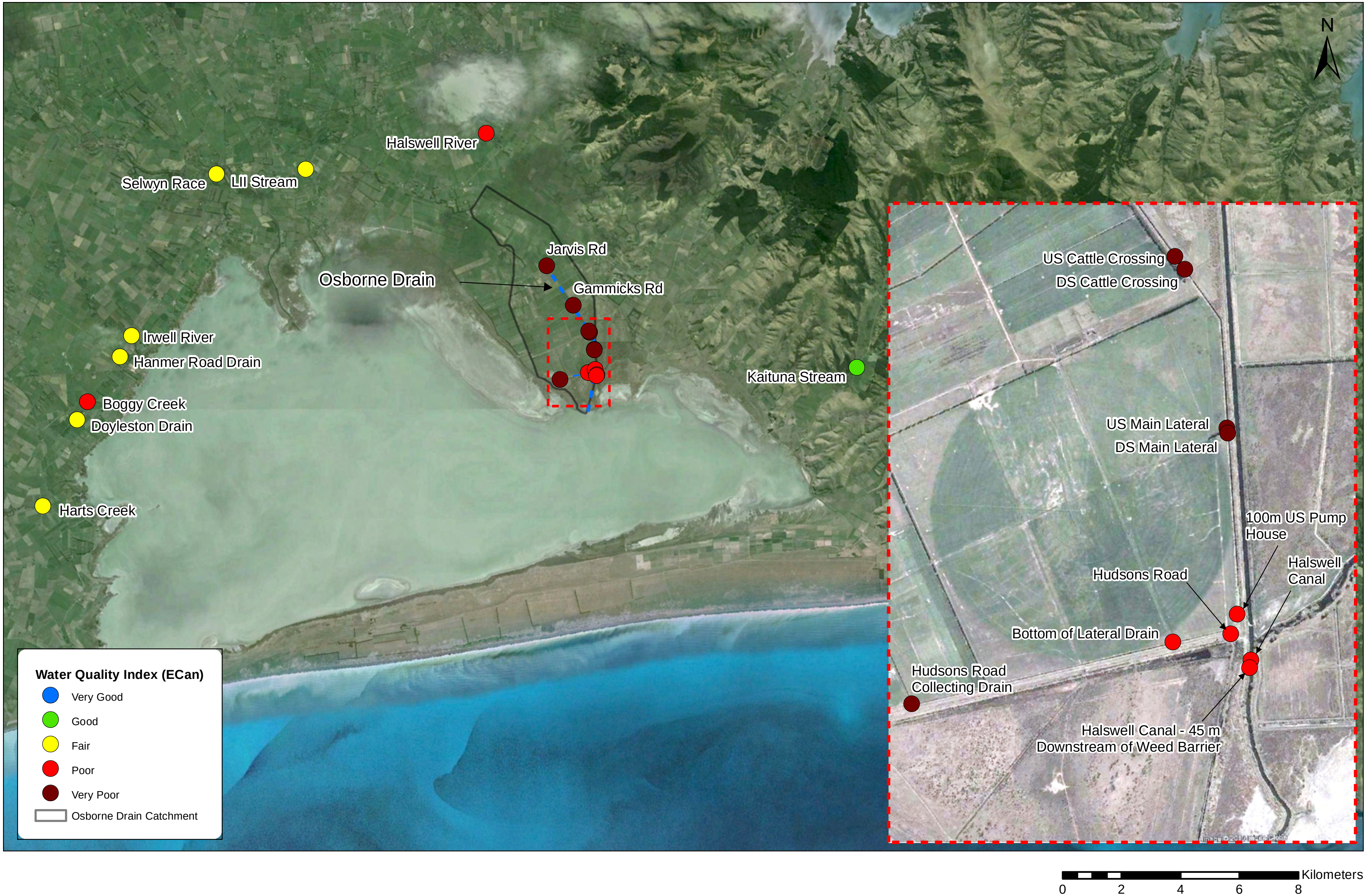

FIGURE G: WATER QUALITY INDEX (MAY 2011 - MAY 2012)

WQI values and grades for monitoring sites above the pumphouse on Osborne's Drain			
Stream Name	**WQI value**	**ECan Grade**	**Canadian Grade**
Bridge at Jarvis Rd (SQ35762)	16	Very Poor	Poor
Gammick's Rd DS culvert (SQ35761)	26	Very Poor	Poor
US of main lateral (SQ35759)	26	Very Poor	Poor
DS of main lateral (SQ35760)	26	Very Poor	Poor
DS cattle crossing (SQ35757)	24	Very Poor	Poor
US cattle crossing (SQ35758)	25	Very Poor	Poor
Hudson's Rd collecting drain (SQ35763)	27	Very Poor	Poor
Bottom of lateral drain (Hudson's Road SQ35754)	33	Poor	Poor
100m US pump house1 (SQ35756)	33	Poor	Poor
Hudsons Road end (SQ34117)	33	Poor	Poor
Between pump house & mouth (SQ35753)	35	Poor	Poor
Osborne Drain Mouth (SQ35752)	35	Poor	Poor

Water Quality Index categories			
Grade	Ecan	Grade	CCME
Very Good	85 - 100	Excellent	95 - 100
Good	70 - 84.9	Good	80 - 94
Fair	50 - 69.9	Fair	65 - 79
Poor	30 - 49.9	Marginal	45 - 64
Very Poor	0 - 29.9	Poor	0 - 44

Excellent or Very Good: water quality is protected with a virtual absence of threat or impairment; conditions are very close to natural or pristine levels

Good: water quality is protected with only a minor degree of threat or impairment: condition rarely depart from natural or desirable levels.

Fair: water quality is usually protected but occasionally threatened or impaired: conditions sometimes depart from natural or desirable levels.

Marginal: water quality is frequently threatened or impaired: conditions usually depart from natural or desirable levels.

Poor and Very Poor: water quality is almost always threatened or impaired: conditions usually depart from natural or desirable levels

FIGURE G Attachment

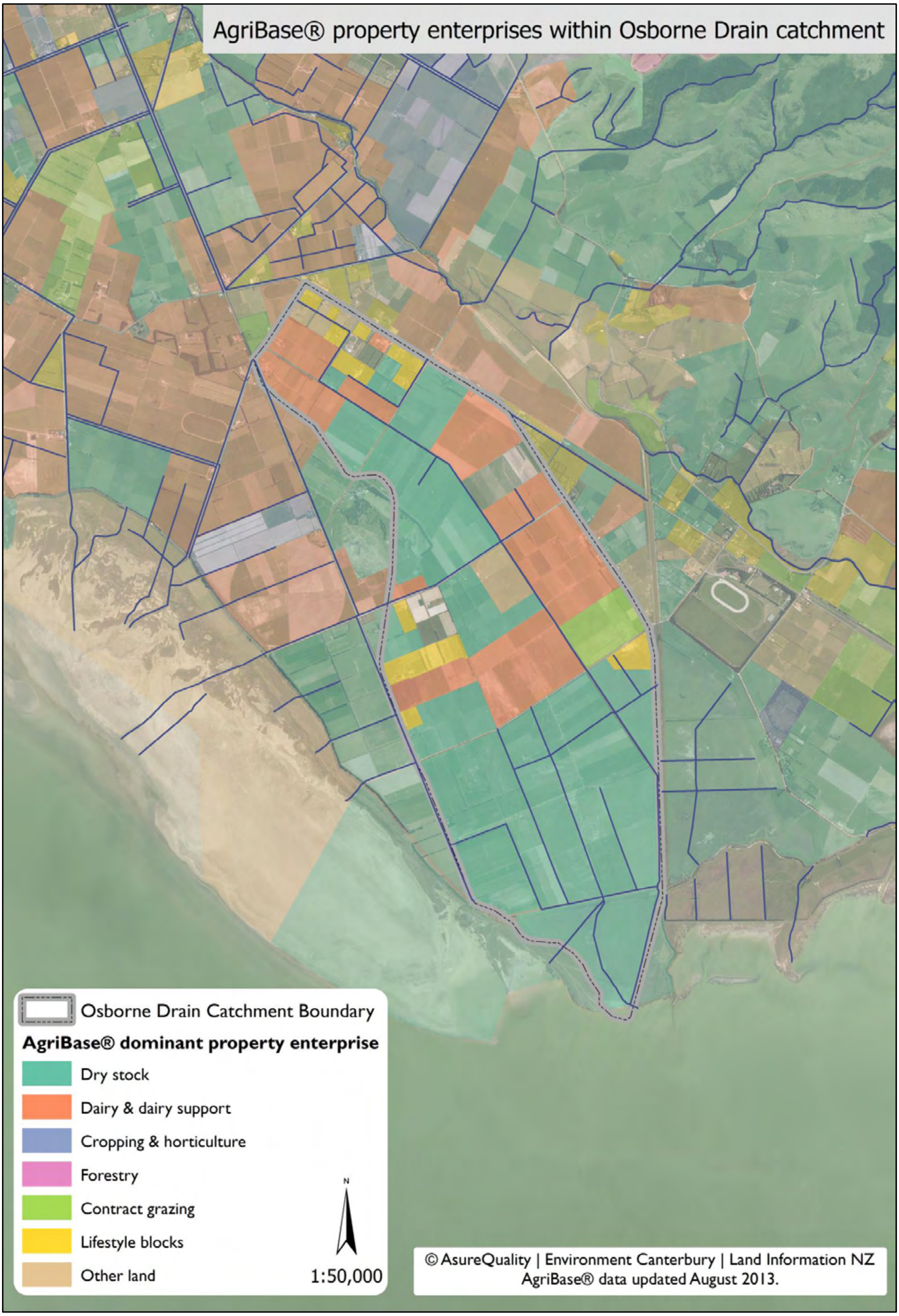

FIGURE H: Landuse Map for Osborne Drain and Wider Catchment

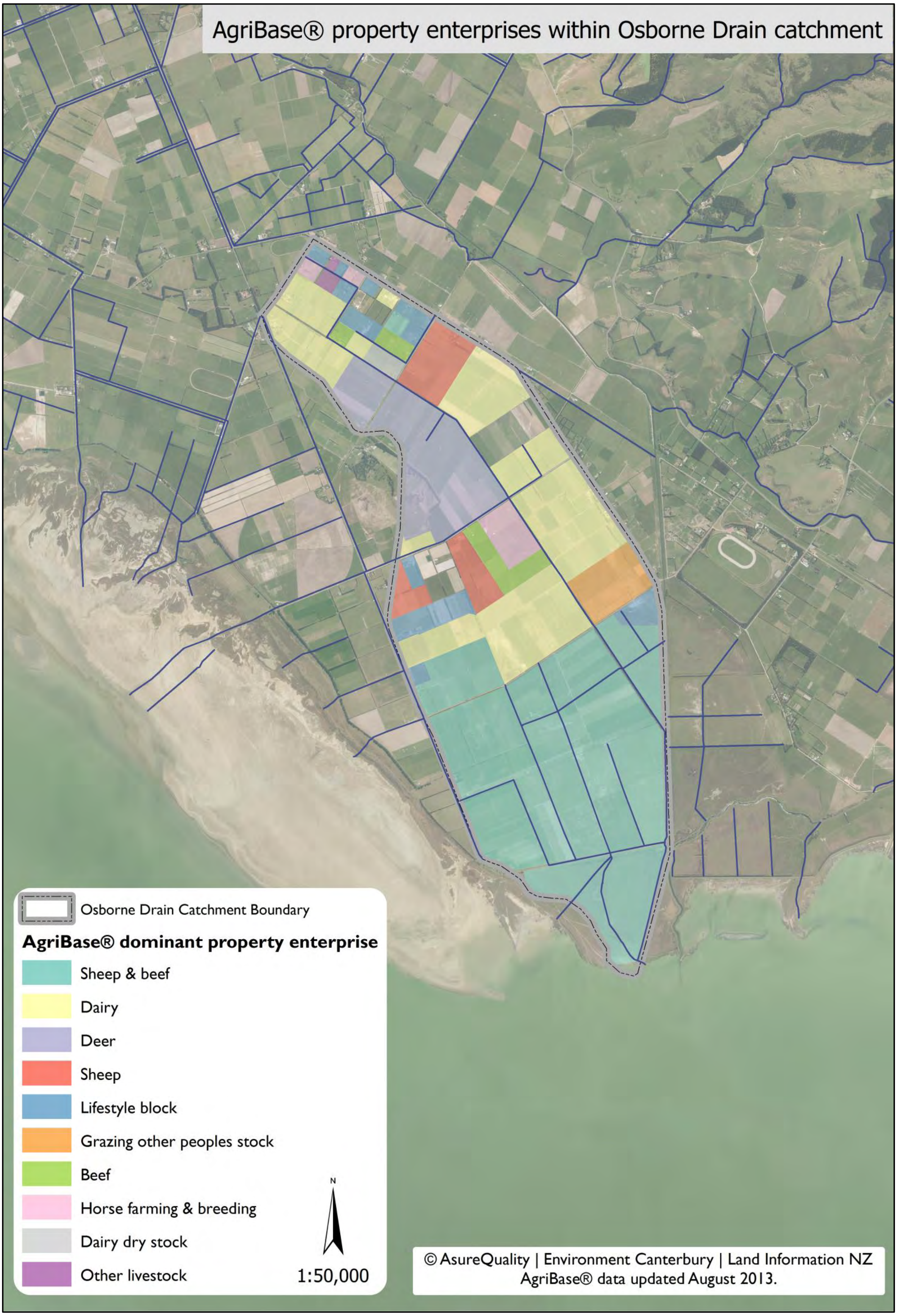

FIGURE I: Landuse Map for Osborne Drain Catchment

Appendix B

Scope of Works

OSBORNE DRAIN – WATER QUALITY (SELWYN DISTRICT COUNCIL)

SCOPE OF WORKS

1. Background

The Osborne Drainage scheme was designed to drain an area of low lying flat land. The land is currently used for irrigated dairy farms, dry stock farms, and smaller lifestyle blocks. The quality of the discharge, and its effects on private land and Te Waihora/Lake Ellesmere, is of significant concern to a number of stakeholders, including Te Runanga o Ngai Tahu, the Department of Conservation and Environment Canterbury. The Co-Governance Te Waihora Group has highlighted this issue as a matter of significant concern in the Te Waihora Catchment and is seeking immediate and long-term solutions to this discharge.

Council is in the process of redrafting a consent application for the discharge of land drainage water from this scheme into Te Waihora/Lake Ellesmere. The draft application proposes a number of mitigation measures to improve the quality of the discharged along with a monitoring program to track actual water quality improvements. Key stakeholders have requested that the actual improvements to water quality which could be reasonably expected should be detailed in this consent application.

2. Objective of Project

To calculate and report on the improvement to the water quality of Osborne drain, which could be expected from implementing the improvement measures proposed by Selwyn District Council.

3. Deliverables:

A report which evaluates:

a. The current quality of Osbornes Drain, including in drain water quality, sediment quality, quality of discharges to the drain and the impact of these on the wetlands that the drain directly discharges too and Te Waihora/Lake Ellesmere;
b. the proposed improvement measures for Osborne Drain including expected % reductions (or similar) of key water quality parameters and impact of these on the wetlands that the drain directly discharges too and Te Waihora/Lake Ellesmere;
c. Identification of any further work that needs to be undertaken to improve the quality in Osbornes Drain, including but not limited to, core sampling to identify the actual quality of sediment that may be removed and disposed of on land adjacent to or within the drainage catchment;
d. Recommendations relating to the potential design of Farm Plans, including, but not limited to, the inclusion of on farm or community wetlands (and recommended species etc) for treatment of the land drainage water before it enters the drain and the associated anticipated benefits (and likely timeframes) of implementing such a tool to achieve short and long term goals for the drain; and

e. A planning assessment of whether each proposed improvement measure is able to be undertaken under the current planning regime and identification of what (if any) resource consents may be required.

The proposed improvement measures and water quality parameters are outlined below.

Improvement measures:

- Remove accumulated sediment from the lagoon upstream of the pump station,
- Remove all accumulated sediment for the entire length of Osbornes drain
- Base flow augmentation
  - Local bores
- A recirculation pump
- Aerator e.g. typical waste water treatment plant kit
- Construction of weir(s) directly upstream of the pump station
- Farm plans designed to achieve water quality standards for drainage water in the current planning instruments in the short to medium term and contact recreation standard over the next 15-20 years

Key water quality parameters.

- Temperature
- DO
- Total Nitrogen and dissolved Nitrogen
- Total Phosphorus and dissolved Phosphorus
- Total Suspended Solids
- Visual appearance and odour
- Heavy metals
- Oestrogen & endocrine disrupting chemicals or EDCs
- Pesticides/herbicides (including but not limited to arsenic)

4. Timeframe

Offer of Service to be provided by 11 December 2013
Confirmation of acceptance by client 12 December 2013
Draft report provided to SDC, ECan and Te Runanga by 20 December 2013 - Please provide an alternative timeframe if this date is not achievable with an explanation.

5. Commercial Terms

IPENZ SHORT FORM AGREEMENT FOR CONSULTANT ENGAGEMENT (COMMERCIAL) applies to this project.

6. Information provided by client

- PDP report on Osbornes Drain,
- Water quality information held by ECan and SDC on Osbornes Drain
- Soil sampling results from sediment accumulated on the bed of the Drain

- Draft resource consent application for the discharge of land drainage water from Osbornes drain

7. Meetings / Communications

   These are to be sufficient to achieve the objectives of the project and shall include:

   - Initial meeting for project commencement and scope definition with representatives from SDC, ECan and Te Runanga
   - Weekly updates on progress (by phone & email to ECan and Te Runanga)
   - Liaison with the client or nominated contacts to obtain information
   - Formal meeting at milestones e.g. delivery of draft report
   - Meeting with client, ECan and Te Runanga to present draft report findings

Appendix C

Water Quality Monitoring Site List

Water quality sampling locations around Osborne Drain				
Site ID	**Waterway**	**Location**	**Easting**	**Northing**
SQ35762	Osborne Drain	Bridge at Jarvis Road	2473902	5720194
SQ35761	Osborne Drain	Gammick's Road DS culvert	2474803	5718856
SQ35759	Osborne Drain	US of main lateral	2475492	5717285
SQ35760	Osborne Drain	DS of main lateral	2475480	5717255
SQ35758	Osborne Drain	US cattle crossing	2475353	5718016
SQ35757	Osborne Drain	DS cattle crossing	2475336	5717973
SQ35756	Osborne Drain	100m US pump house	2475500	5716650
SQ34117	Osborne Drain	Hudsons Road end	2475530	5716550
SQ35753	Osborne Drain	Between pump house & mouth	2475410	5715976
SQ35763	Osborne Drain	Hudson's Rd collecting drain	2474313	5716345
SQ35754	Osborne Drain	Bottom of lateral drain	2475309	5716554
SQ35752	Osborne Drain	Osborne Drain Mouth at Lake Ellesmere	2475255	5714346
SQ34127	Halswell Canal	Halswell Canal	2475590	5716480

Appendix D

ECan Figures and water quality summary

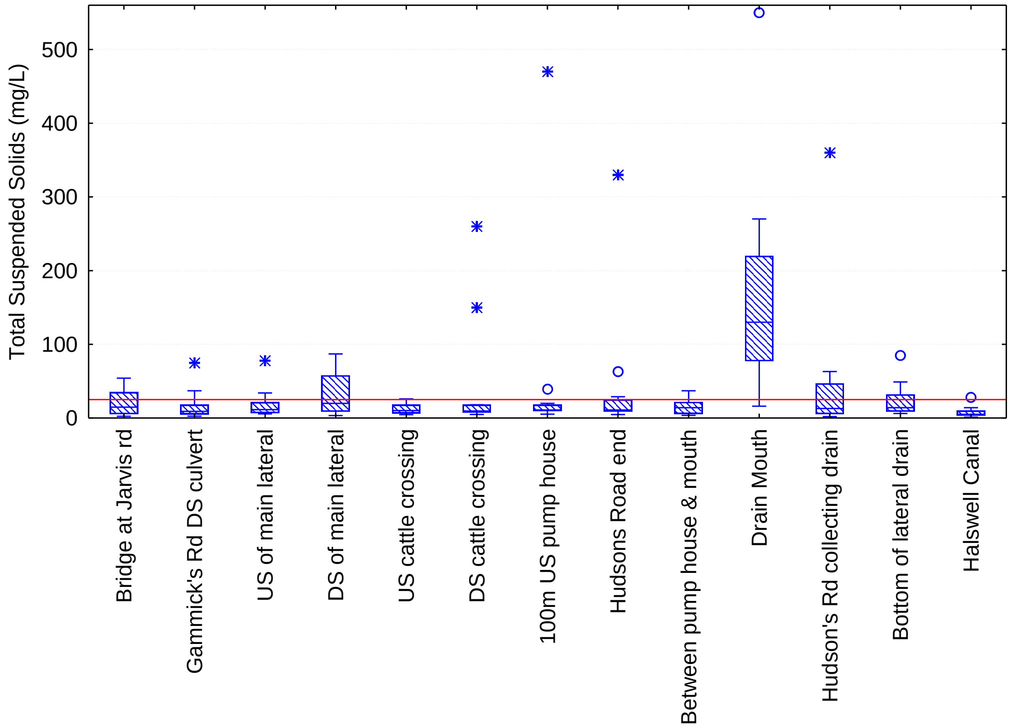

Figure 1: Total suspended solids (mg/L) concentrations in Osborne Drain (*sourced from* Robinson and Meredith 2013 DRAFT). Guideline value of 25 mg/L in red.

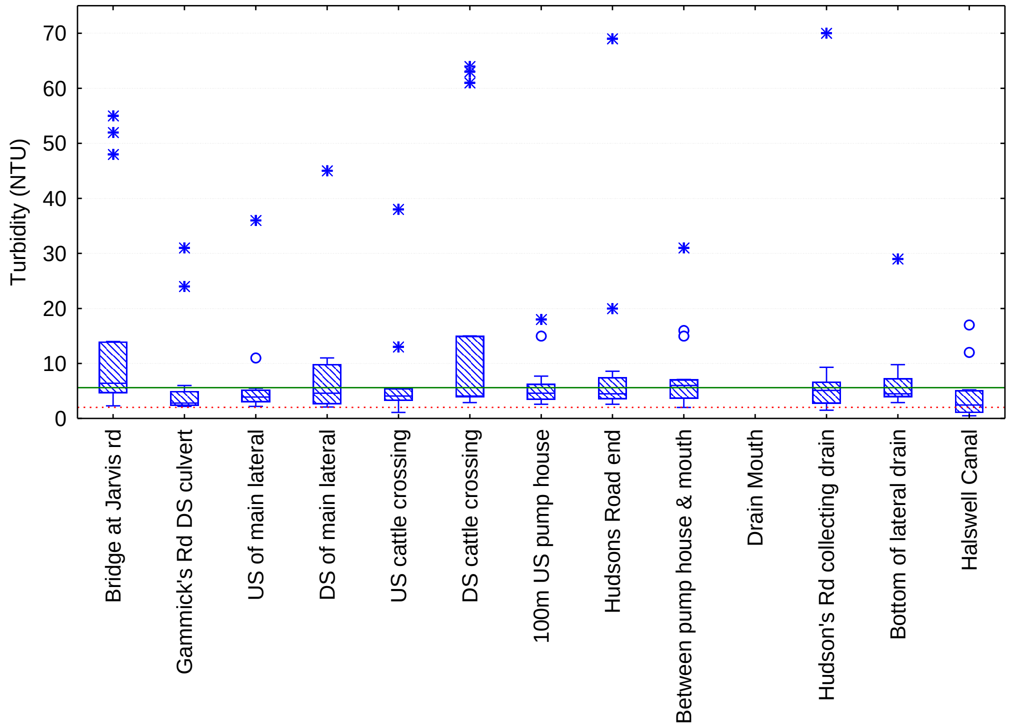

Figure 2: Turbidity (NTU) concentrations in Osborne Drain. Note: the Drain Mouth site is omitted for this graph due to elevated results (*sourced from* Robinson and Meredith 2013 DRAFT). The recreational/aesthetic guideline of 2.0 NTU is shown in red and the guideline for aquatic ecosystems of 5.6 NTU is shown in green.

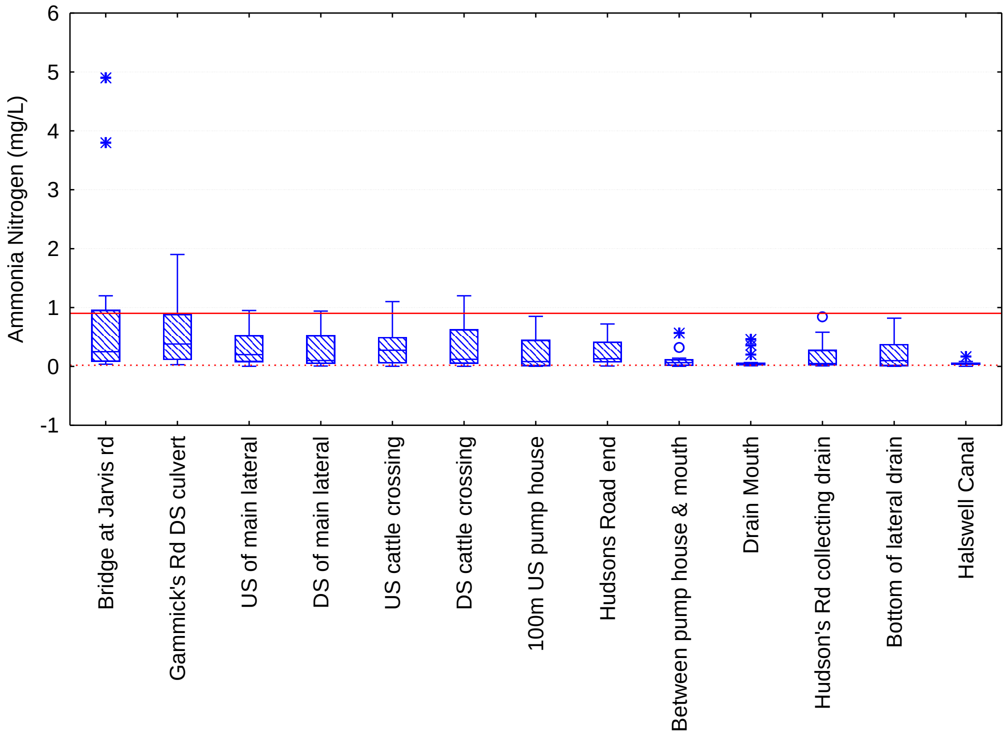

Figure 3: Ammonia Nitrogen (mg/L) concentrations in Osborne Drain (*sourced from* Robinson and Meredith 2013 DRAFT). The Guideline for aquatic ecosystems of 0.021 mg/L is shown as a dashed red line. The Standard for spring-fed surface water ways is 0.9 mg/L and is shown as a solid red line.

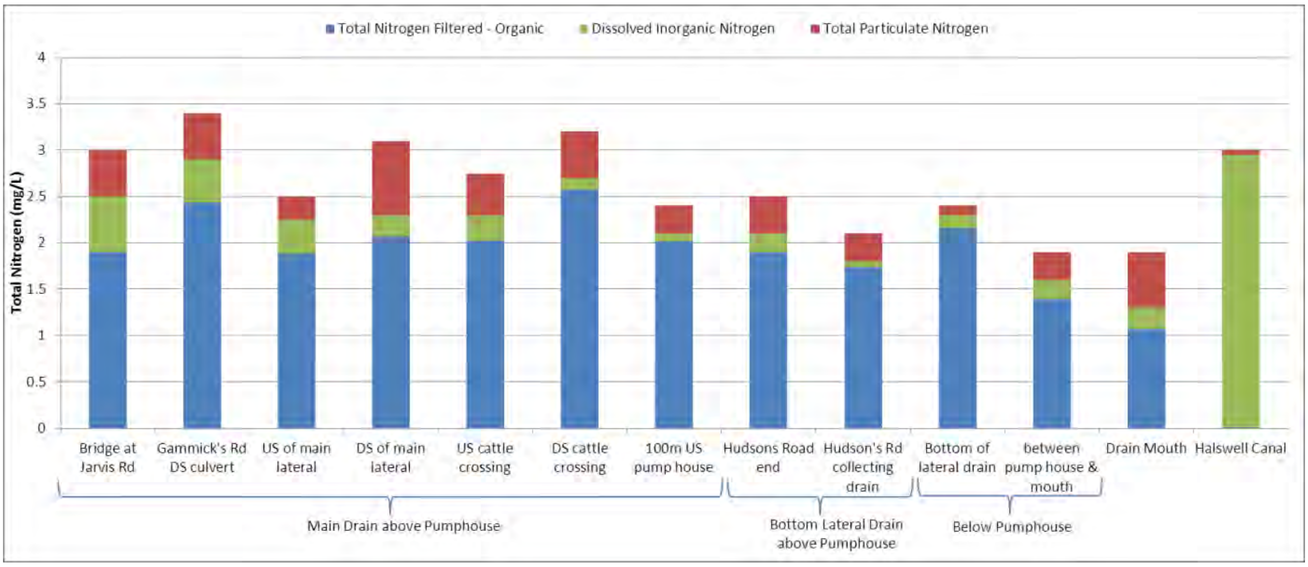

Figure 4 Total Nitrogen concentrations in Osborne Drain including organic and inorganic filtered nitrogen, and particulate nitrogen components (N.B. TN filtered = TN filtered – organic + Dissolved Inorganic Nitrogen; sourced from Robinson and Meredith 2012 DRAFT).

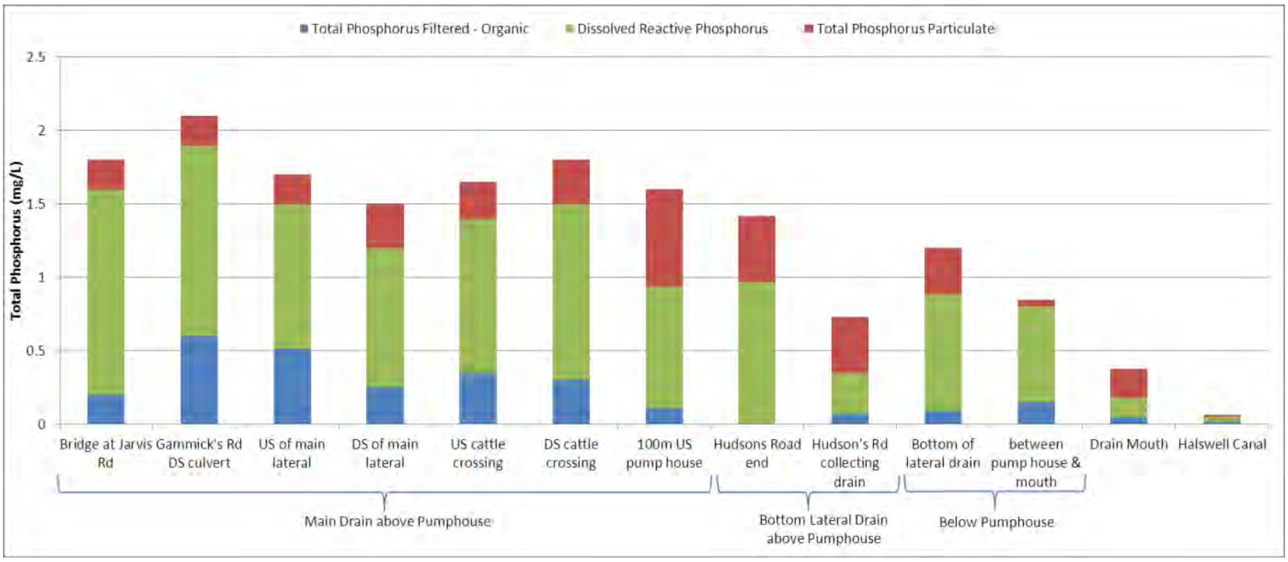

Figure 5 Total Phosphorus concentrations in Osborne Drain including organic and reactive filtered phosphorus, and particulate phosphorus components (N.B. TP filtered = TP filtered – organic + Dissolved Reactive Phosphorus; sourced from Robinson and Meredith 2012 DRAFT)

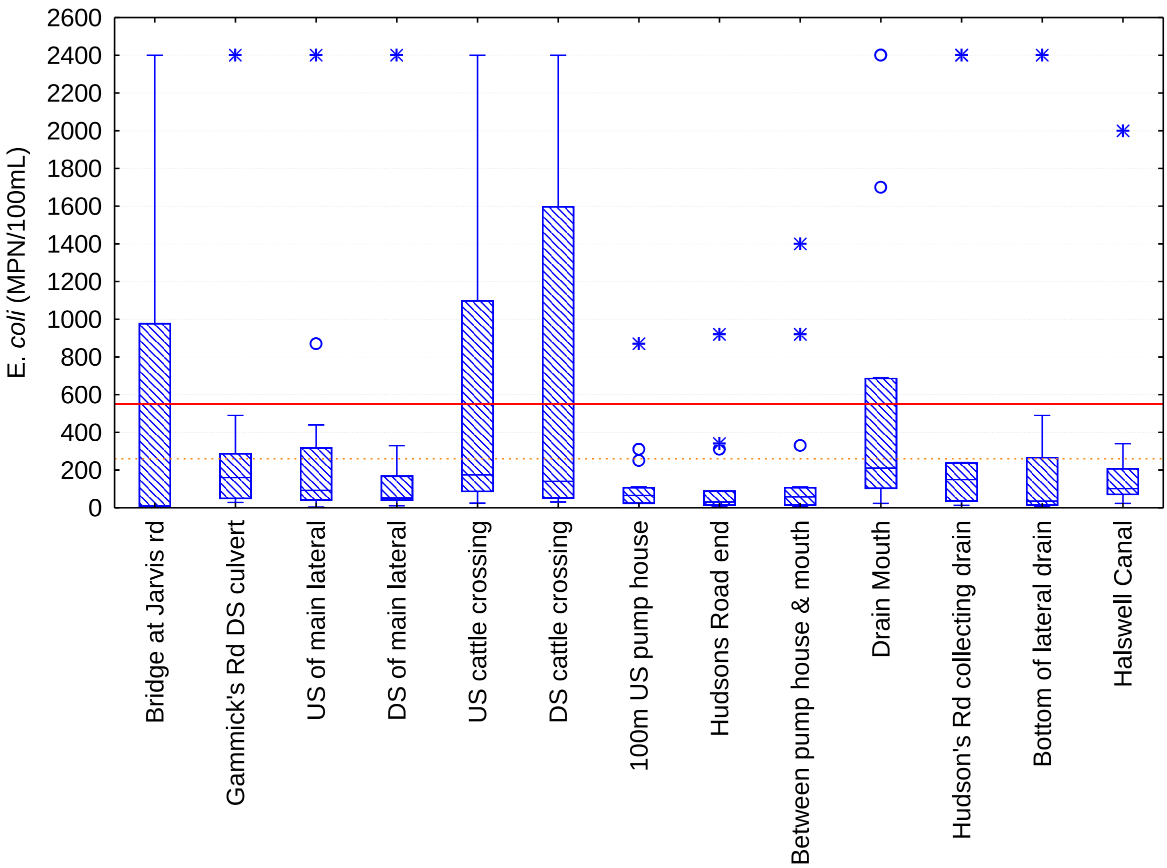

Figure 6: E. coli concentrations in Osborne Drain. (sourced from Robinson and Meredith 2012 DRAFT). The recreational alert trigger value of 260 MPN/100 ml is displayed as a dashed red line and the recreational action trigger value of 550 MPN/100 ml is shown as a solid red line.

Water Quality Summary

Site_ID		Water Temperature	Dissolved Oxygen	Dissolved Oxygen Saturation	Volatile Suspended Solids	Total Suspended Solids	Turbidity	Absorbance @ 270 nm	Absorbance @ 400 nm	Dissolved Organic Carbon	pH	Conductivity	Ammonia Nitrogen	Nitrate + Nitrite Nitrogen	Total Nitrogen	Total Nitrogen Filtered	Dissolved Reactive Phosphorus	Total Phosphorus	Total Phosphorus Filtered	E coli
Osborne's Drain Bridge at Jarvis rd Site No:SQ35762	Minimum	5.8	0.42	5.1	0.8	2.4	2.3	0.364	0.044	9.2	7.4	66	0.037	0.009	2	1.6	0.63	0.98	0.69	1
	Maximum	25.1	9.1	79	22	54	55	0.906	0.141	29	8	310	4.9	2	6.1	5.8	2.9	4.7	3.9	2400
	Mean	12.5	3.65	34.55	8.65	21.6	16.9	0.618	0.080	18.6	7.7	196.6	0.970	0.677	3.49	3.15	1.45	2.42	1.79	625
	Median	10.3	3.7	34	5.7	14.8	6.4	0.635	0.077	19	7.7	170	0.25	0.35	3	2.5	1.4	1.8	1.6	11
Osborne's Drain DS culvert at Gammick's rd Site No:SQ35761	Minimum	5.9	0.2	1.64	0.9	2.5	2.2	0.393	0.049	9.4	7.6	76	0.029	0.0025	1.9	1.7	0.53	0.68	0.57	28
	Maximum	26.6	9.2	87	28	75	31	1.142	0.182	31	8.2	310	1.9	1.6	4.2	4.1	2.8	4.3	3.9	2400
	Mean	13.2	4.53	43.59	7.3	16.8	7.1	0.674	0.091	20.6	7.8	177	0.578	0.419	3.1	2.83	1.51	2.11	1.96	340
	Median	10.9	4.8	41.2	4.4	9.1	2.8	0.675	0.083	21	7.8	180	0.38	0.08	3.4	2.9	1.3	2.1	1.9	160
Osborne's Drain US of main lateral Site No:SQ35759	Minimum	6.8	0.27	2.7	1.8	5.6	2.2	0.314	0.04	9.2	7.6	100	0.0025	0.0025	1.2	0.77	0.52	0.69	0.61	3
	Maximum	24.2	13.27	150.2	32	78	36	0.997	0.157	31	8.8	330	0.95	1.5	3.9	3.8	2.6	3.8	3.3	2400
	Mean	13.4	6.65	66.27	7.65	18.9	7.0	0.638	0.082	19.9	8	205.8	0.323	0.385	2.6	2.31	1.32	1.88	1.60	367
	Median	11.5	6.8	64.4	4.8	11.4	3.9	0.587	0.077	20.5	7.9	200	0.2	0.165	2.5	2.25	0.985	1.7	1.5	92
Osborne's Drain DS of main lateral Site No:SQ35760	Minimum	6.8	0.83	7.25	1.4	3.4	2.1	0.314	0.042	9.2	7.7	110	0.006	0.0025	1.9	1.6	0.52	0.69	0.61	11
	Maximum	18.9	13.9	135	42	87	45	1.021	0.15	31	8.8	330	0.94	1.5	3.9	3.9	3.5	5.9	5.4	2400
	Mean	12.4	6.66	63.72	12.6	28.6	9.0	0.636	0.082	20.0	8.0	201.8	0.300	0.405	2.89	2.49	1.25	1.96	1.64	309
	Median	11.4	5.77	58.2	5.6	20	4.6	0.584	0.074	20	7.9	180	0.099	0.13	3.1	2.3	0.95	1.5	1.2	52
Osborne's drain US lateral at 1st cattle crossing Site No:SQ35758	Minimum	7.8	0.6	5	1.9	4.6	1.1	0.328	0.042	9.2	7.6	150	0.0025	0.0025	1.5	1.5	0.43	0.98	0.42	25
	Maximum	18.6	12.32	115.9	1300	2000	38	0.887	0.118	30	8.5	280	1.1	1.4	6.9	6.9	3.2	5.4	5.3	2400
	Mean	13.04	5.56	54.85	134.7	210.1	8.0	0.642	0.079	20.3	8	216	0.379	0.224	3.1	2.76	1.23	2.09	1.64	636
	Median	12.5	5.055	48.65	3.9	10.2	4.1	0.6115	0.077	20.5	7.9	210	0.2735	0.00625	2.75	2.3	1.05	1.65	1.4	175
Osborne's Drain DS of lateral drain at 1st cattle crossing Site No:SQ35757	Minimum	5.8	0.21	2.1	2.4	4.9	2.9	0.329	0.046	9.1	7.6	130	0.0025	0.0025	1.5	1.4	0.46	0.66	0.54	31
	Maximum	21.9	12.3	115.7	1100	2700	64	1.037	0.164	30	8.6	350	1.2	1.4	6.7	6.7	4.8	5.5	5.2	2400
	Mean	13.3	5.15	50.53	107.6	246.6	18.9	0.688	0.089	21.2	8.0	225.4	0.375	0.255	3.45	3.05	1.57	2.27	1.93	726
	Median	13.2	5.34	56.1	5.7	9.5	4.1	0.75	0.086	22	8	210	0.12	0.007	3.2	2.7	1.2	1.8	1.5	140
Osborne's Drain 100m US pump house in main drain Site No:SQ35756	Minimum	4.8	0.8	7.3	0.25	5.2	2.6	0.329	0.041	8.8	7.7	150	0.0025	0.0025	1.4	1.2	0.0005	0.54	0.44	0.5
	Maximum	20.3	15.6	148.6	96	470	18	0.851	0.112	28	8.5	360	0.85	1.2	3.6	3.4	2.9	3.6	3.4	870
	Mean	12.8	6.04	59.48	12.7	48.5	6.3	0.598	0.072	19.1	8.1	237.7	0.240	0.215	2.48	2.2	1.13	1.64	1.35	145
	Median	12.3	5.8	59.6	3.1	11	4.6	0.57	0.066	19	8.1	230	0.081	0.0025	2.4	2.1	0.83	1.6	0.94	65
Osbornes Drain Hudsons Road end Site No:SQ34117	Minimum	4.1	0.5	4.4	1.5	4.8	2.6	0.137	0.026	3.5	7.5	120	0.006	0.0025	1.7	1.5	0.15	0.56	0.46	4
	Maximum	19.8	11.93	103.8	140	330	69	0.835	0.11	29	8.3	400	0.72	1.1	3.5	3.3	2.8	3.4	3.1	920
	Mean	11.81	6.04	56.9	17.98	40.92	10.78	0.58	0.071	19.1	7.97	251.54	0.25	0.21	2.5	2.17	1.18	1.60	1.32	147
	Median	12	5.795	54.55	5.3	11	4.5	0.548	0.064	21	8	230	0.13	0.072	2.5	2.1	0.97	1.4	0.95	31
Osborne's Drain Hudson's Rd collecting drain Site No:SQ35763	Minimum	4.4	1.35	13	0.8	1.9	1.5	0.238	0.036	6.9	7.5	110	0.009	0.0025	1.2	0.74	0.066	0.11	0.097	13
	Maximum	18	11	88.8	400	1800	240	0.636	0.126	26	8	700	0.84	2.7	7.1	5.7	1.8	2	1.8	2400
	Mean	11.2	5.60	51.22	41.3	181.3	27.6	0.467	0.060	15.1	7.8	430.8	0.192	0.275	2.25	1.92	0.481	0.711	0.557	633
	Median	11.6	4.595	47.55	6.6	13	5.1	0.462	0.051	15	7.9	390	0.049	0.012	2.1	1.8	0.28	0.73	0.35	150
Osborne's Drain 20m long bottom lateral drain (True R of main drain) Site No:SQ35754	Minimum	3.9	0.9	7.8	1.6	6.3	2.9	0.25	0.03	7.4	7.7	160	0.0025	0.0025	1.5	1.3	0.086	0.24	0.14	6
	Maximum	18	10.67	96	44	85	29	0.862	0.11	28	8.2	730	0.82	0.75	3.3	3	2.6	3.1	2.9	2400
	Mean	11.7	6.12	57.23	12.3	24.6	6.9	0.575	0.069	18.5	8.0	312.3	0.233	0.139	2.46	2.1	1.04	1.40	1.17	286
	Median	12.3	6.02	56.5	8.5	14	4.5	0.55	0.062	19	8	260	0.097	0.043	2.4	2.3	0.8	1.2	0.89	35
Osborne's Drain Osborne's drain between pump house & mouth Site No:SQ35753	Minimum	5.1	1.32	14.9	0.9	3.7	2	0.158	0.017	6.1	7.8	100	0.0025	0.005	0.87	0.75	0.18	0.42	0.34	6
	Maximum	18.7	8.9	91.4	14	37	31	0.854	0.113	28	8.1	930	0.57	0.96	3.3	3.2	1.4	1.7	1.7	1400
	Mean	12.4	6.71	63.62	6.2	15	8.3	0.443	0.053	14.4	7.9	420	0.117	0.287	1.97	1.72	0.713	0.937	0.885	236
	Median	12.9	7.425	65	6.7	14	6	0.426	0.05	13	7.9	350	0.064	0.14	1.9	1.6	0.65	0.85	0.8	58
Lake Ellesmere Mouth of Osborne's drain Site No:SQ35752	Minimum	4.5	5.81	57	4.1	16	6.4	0.018	0.014	2.7	7.8	150	0.01	0.006	0.04	0.04	0.001	0.092	0.004	23
	Maximum	18.4	10.4	90.1	99	550	270	0.774	0.095	27	8.2	1400	0.46	0.92	3.1	3	1	1.1	1.1	2400
	Mean	12.3	7.68	74.41	30.4	164	101.4	0.255	0.038	8.6	8.0	782.3	0.101	0.315	1.87	1.3	0.216	0.437	0.277	693
	Median	13.5	7.575	73.35	30	130	110	0.125	0.028	5.6	7.9	760	0.03	0.2	1.9	1.3	0.13	0.38	0.18	210
Halswell Canal 45m downstream of weed barrier Site No:SQ34127	Minimum	7.1	8.6	53.9	0.25	1.1	0.5	0.037	0.009	0.2	7.6	25	0.0025	2.1	2.3	2.3	0.023	0.037	0.034	23
	Maximum	18.8	11.12	117.4	7.5	28	17	0.324	0.052	9.3	8.5	37	0.17	3.5	4	3.8	0.06	0.15	0.094	2000
	Mean	13.19	9.79	91.17	2.4	7.6	4.3	0.094	0.019	2.35	8.0	28.4	0.049	2.8	3.14	3.04	0.034	0.071	0.050	282
	Median	13.75	9.7	88.7	1.4	5	2.45	0.0775	0.014	2.05	8	27.5	0.0385	2.9	3	2.95	0.031	0.0635	0.05	101.5

Table sourced from Robinson and Meredith 2013 DRAFT

Site ID		Water Temperature	Dissolved Oxygen	Dissolved Oxygen Saturation	Volatile Suspended Solids	Total Suspended Solids	Turbidity	Absorbance @ 270 nm	Absorbance @ 400 nm	Dissolved Organic Carbon	pH	Conductivity	Ammonia Nitrogen	Nitrate + Nitrite Nitrogen	DIN	Total Nitrogen	Total Nitrogen Filtered	Dissolved Reactive Phosphorus	Total Phosphorus	Total Phosphorus Filtered	E coli
[1]Osbornes Drain	**Minimum**	4.1	0.5	4.4	0.3	4.8	2.6	0.1	0.0	3.5	7.5	120	0.003	0.003	0.005	1.4	1.2	0.001	0.54	0.44	0.5
	Maximum	20.3	15.6	148.6	140.0	470.0	69.0	0.9	0.1	29.0	8.5	400	0.85	1.2	1.3	3.6	3.4	2.9	3.6	3.4	920
	Mean	12.3	6.0	58.2	15.3	44.7	8.5	0.6	0.1	19.1	8.0	245	0.24	0.21	0.46	2.5	2.2	1.2	1.6	1.3	145.6
	Median	12.1	5.8	56.8	4.5	11.0	4.6	0.6	0.1	20.0	8.0	230	0.12	0.044	0.43	2.5	2.1	0.84	1.5	0.95	58
[2]All sites in drain above pump house	**Minimum**	3.9	0.2	1.6	0.3	1.9	1.1	0.1	0.0	3.5	7.4	66	0.003	0.003	0.005	1.2	0.74	0.001	0.11	0.097	0.5
	Maximum	26.6	15.6	150.2	1300	2700	240	1.1	0.2	31.0	8.8	730	4.9	2.700	5.04	7.1	6.9	4.8	5.9	5.4	2400
	Mean	12.5	5.6	53.8	34.7	82.6	12.0	0.6	0.1	19.2	7.9	247	0.39	0.321	0.71	2.8	2.5	1.2	1.8	1.5	418
	Median	12.1	5.2	52.4	4.9	11.0	4.6	0.6	0.1	20.0	7.9	220	0.16	0.072	0.53	2.5	2.3	0.97	1.5	1.3	69

Data obtained from Environment Canterbury

[1]Osborne Drain = water quality data for 2 sites immediately above the pumphouse; 100m upstream of pumphouse and bottom of lateral drain (Hudsons Road)

[2]All sites above the pump house include median calculations of:

Osborne's Drain Bridge at Jarvis rd Site No:SQ35762

Osborne's Drain DS culvert at Gammick's rd Site No:SQ35761

Osborne's Drain Upstream of main lateral Site No:SQ35759

Osborne's Drain DS of main lateral Site No:SQ35760

Osborne's drain US lateral below 1st cattle crossing Site No:SQ35758

Osborne's Drain DS of lateral drain at 1st cattle crossing Site No:SQ35757

Osbornes Drain Hudsons Road end Site No:SQ34117

Osborne's Drain Huddson's rd collecting drain Site No:SQ35763

Osborne's Drain 20m long bottom lateral drain (true R of main drain) Site No:SQ35754

Osborne's Drain 100m US pump house in main drain

Appendix E

Surface Water Quality Guidelines

In most instances the Australian and New Zealand Environment and Conservation Council (ANZECC 2000) default guidelines values for lowland aquatic ecosystems were used. There were some exceptions, such as for different river types as outlined in Table below. For the purpose of this report, numerical guidelines of set categories were used to allow for easy comparison of water quality state within Osbornes Drain. These guideline values were developed by Stevenson *et al.*, 2012 and are considered appropriate for certain parameters and general values in Canterbury.

Parameter	Water Use/Value	Guideline value	Reference
Temperature (°C)	Aquatic ecosystems	20	Richardson *et al*. (1994); Alabaster and Lloyd (1980)
Turbidity (NTU)	Aquatic ecosystems	>5.6 (turbid)	ANZECC (2000)
Suspended Solids (mg/L)	Aquatic ecosystem	25	Singleton (2001); APEM (2007); Rowe *et al.* (2003)
	Standards for spring-fed surface waters – plains	<10	NRRP (2010)
Dissolved Inorganic Nitrogen, DIN (mg/L)	Recreational/aesthetic (40 day accrual periods)	<0.03 (Unenriched) 0.03 – 0.17 (Low level enrichment) 0.17 – 0.44 (Moderately enriched) 0.44 – 2.00 (Enriched) >2.00 (Excessive)	MfE (2000)
	Standards for spring-fed surface waters – plains	<1.50	NRRP (2010)
Total Nitrogen, TN (mg/L)	Aquatic ecosystems	<0.614	ANZECC (2000)
Dissolved Reactive Phosphorus, DRP (mg/L)	Recreational/Aesthetic (40 day accrual periods)	<0.003 (Unenriched) 0.003 – 0.009 (Moderately enriched) 0.009 – 0.030 (Enriched) >0.030 (Excessive) (20 day accrual)	MfE (2000)
	Standards for spring-fed surface waters – plains	0.016	NRRP (2010)
Total Phosphorus, TP (mg/L)	Aquatic ecosystems	<0.614	
Nitrate-nitrite nitrogen Toxicity (mg/L)	Aquatic ecosystems – nutrient for weed growth	<0.444	ANZECC (2000)
	% species protection level for chronic effects	3.6 (80%) 1.7 (95%) 1.0 (99%)	Hickey and Martin (2009)
	Standards for spring-fed surface waters – plains	1.7	Hickey and Martin (2009)
Ammonia-Nitrogen (mg/L)	Aquatic ecosystems – nutrient for weed growth	<0.021	ANZECC (2000)
	Standards for spring-fed surface waters – plains	0.9	ANZECC (2000)
E. coli	Recreational	260 MPN/100mL (alert mode) 550 MPN/100mL (action mode)	MoH (2003)
	Standards for spring-fed surface waters – plains	550 MPN/100mL	NRRP (2010)
Diurnally variable parameters			
Dissolved Oxygen	Aquatic ecosystems	6 mg/L 80 % saturation	ANZECC (2000)
Dissolved Oxygen Saturation	20% percentile	90 – 110% Excellent 80 – 90% Good 60 – 80% Fair <60% Poor	ANZECC (2000) RMA (1991) Stevenson *et al.* (2010) Stevenson *et al.* (2010)

Appendix F

Water Quality Index

Water Quality Index Methodology

An alternative approach to classifying the water quality is through the use of water quality indices which are commonly used to facilitate inter-site comparison of the state of water quality in an area. An index provides a mathematical framework for assessing ambient water quality conditions relative to the water quality objectives. The method of categorising streams based on a water quality index (WQI) has been used at both a regional (for example, Ozane 2012; Piere *et al.,* 2012) and national level (Larned *et al.,* 2005).

Furthermore, Ecan have developed a modified version of the standard Canadian Council of Ministers of the Environment (CCME) WQI (*for full methodology see:* Saffran *et al*., 2001) so that it is appropriate for streams within Canterbury. For the purpose of this report WQI calculations are based off ECan methodology.

The water quality index was calculated using raw data for the following six variables:

- Ammonia-nitrogen (NH_4-N) for toxicity
- Nitrate-nitrite nitrogen (NNN) for toxicity
- Dissolved reactive phosphorus (DRP) for effects on periphyton and macrophyte growth
- Total suspended solids (TSS) for effects on clarity and sedimentation
- *E. coli* for effects on suitability for recreation

Environment Canterbury have trialed a number of different scenarios/combinations of parameters. However, the above six parameters provide the most meaningful results for Canterbury waterways. Physical parameters such as dissolved oxygen, temperature and pH were excluded because these data are spot measurements and display considerable diurnal variability. Comparing spot data to guidelines values may therefore give a poor representation of whether criteria for these parameters, particularly DO and temperature, are being met.

The application of the water quality index enables water quality at each site to be classified into one of five categories (Table 1).

Table 1. Water Quality Index categories

Grade	Ecan	Grade	CCME
Very Good	85 - 100	Excellent	95 - 100
Good	70 - 84.9	Good	80 - 94
Fair	50 - 69.9	Fair	65 - 79
Poor	30 - 49.9	Marginal	45 - 64
Very Poor	0 - 29.9	Poor	0 - 44

Water Quality Index definitions

Excellent or Very Good: water quality is protected with a virtual absence of threat or impairment; conditions are very close to natural or pristine levels

Good: water quality is protected with only a minor degree of threat or impairment: condition rarely depart from natural or desirable levels.

Fair: water quality is usually protected but occasionally threatened or impaired: conditions sometimes depart from natural or desirable levels.

Marginal: water quality is frequently threatened or impaired: conditions usually depart from natural or desirable levels.

Poor and Very Poor: water quality is almost always threatened or impaired: conditions usually depart from natural or desirable levels.

For the purpose of calculating the water quality index grade and proving an overall picture of water quality in Osbornes Drain, two categories were created.

1. All ten monitoring sites above the discharge pump were grouped together to provide an overall picture of catchment water quality inputs to Osbornes Drain (Appendix D:Figure 2).
2. Two monitoring sites closest (upstream) to the pumphouse (100m upstream of the pumphouse and Osbornes Drain Husdons road end) were grouped to provide an indication of average contaminants within the water column immediately above the pumphouse (Appendix D: Figure 2).

Guideline values for index objectives

Parameter	Objective	Comments
NNN	Varies with river type	Use standards in Table WQL16 of NRRP
DRP	Varies with river type	Use standards in Table WQL16 of NRRP
NH_4-N	Varies with river type	Use standards in Table WQL16 of NRRP
TSS	< 10 mg/L	Spring-fed river types
	< 25 mg/L	All other river types excl. Alpine rivers
E. coli	Varies with river type	Use standards in Table WQL16 of NRRP

NRRP Table WQL16 standards[1]					
River type	**DRP**	***E. coli***	**Toxicants[2]**	**NNN[3]**	**NH_4-N[4]**
Alpine upland	0.005	260	99%	1.0	0.32
Alpine lower	0.007	550	95%	1.7	0.9
Hill-fed upland	0.006	260	99%	1.0	0.32
Hill-fed lower	0.006	550	95%	1.7	0.9
- urban	0.006	550	90%	2.4	1.43
Lake-fed	0.003	260	99%	1.0	0.32
Banks Peninsula	0.025	550	99%	1.0	0.32
Spring-fed upland	0.007	260	99%	1.0	0.32
Spring-fed lower basin	0.01	550	95%	1.7	0.9
Spring-fed plains	0.016	550	95%	1.7	0.9
- urban	0.016	550	90%	2.4	1.43

Notes: [1] Now Schedule 5 of pLWRP

[2] Ecosystem protection level (based on ANZECC 2000)

[3] From Hickey & Martin (2009)

[4] From ANZECC (2000)

Water quality index: Tributaries of Lake Ellesmere/Te Waihora

A water quality index was calculated for eleven tributaries of Te Waihora/Lake Ellesmere, including Osborne Drain (Table 2; Appendix A: Figure G). All water quality data were analysed over the same time period May 2011 – May 2013, in relation to available data for Osborne Drain. This allowed for a direct comparison of water quality condition between monitoring sites around the lake and to identify any spatial trends in water quality. It is recognised that the indices used are determined off a restricted list of parameters (as indicated above) and time frame. However for the purpose of geographic representation and providing an indication of water quality state over the 2011-12 periods, use of the water quality index provides useful information if there are key areas to which management efforts should be focused (prioritised). This may be particularly useful as a grading system for all water quality inputs to Lake Ellesmere/Te Waihora.

Spring-fed plains streams and drains around Lake Ellesmere/Te Waihora on the north, north-western side generally scored in the fair category, values ranging between 50 - 68 (according to Ecan scoring grades)(Table 1; Appendix A, Figure G). Boggy Creek was the exception, scoring a WQI value of 49.7 (border-line of poor and fair; Table 3; Appendix E). A grading of fair, generally indicates that water quality is usually protected, but is occasionally threatened or impaired.

Table 2. Water Quality Index values for water quality monitoring sites around Lake Ellesmere

Stream Name	WQI Value	Ecan Grade	CCME Grade
Harts Creek (SQ30992)	66	Fair	Fair
Doyleston Drain (SQ30977)	52	Fair	Marginal
Boggy Creek (SQ30976)	49.7	Poor	Marginal
Hanmer Drain (SQ30975)	57	Fair	Marginal
Irwell River (SQ30963)	51	Fair	Marginal
Selwyn River (SQ30916)	58	Fair	Marginal
LII Stream (SQ30878)	58	Fair	Marginal
[1]Osborne's Drain	33	Poor	Poor
Osborne's Drain - Catchment wide	18	Very Poor	Poor
Halswell River (SQ32872)	38	Poor	Poor
Halswell Canal (SQ34127)	44	Poor	Poor
[2]Kaituna Stream (SQ30782)	72	Good	Fair

[1]Osborne Drain = water quality data for two sites immediately above the pumphouse; 100m upstream of pumphouse and bottom of lateral drain (Hudson's Road)
[2]A Different set of guidelines values were used as Kaituna River is it classed as a Banks Peninsula river type (Appendix D).

A prominent decline in health was observed in tributary streams from west to east around the lake (with the exception of Boggy Creek). Water quality in Osborne / Halswell catchment was notably degraded, with water quality indexes scoring in the poor category (values ranging from 18 – 44) (Table 2; Appendix E). This indicates water quality in the Osborne catchment is almost always threatened or impaired. The furthermost sampling location on the eastern side, Kaituna River (Banks Peninsula river type) water quality appeared to be good, scoring the highest WQI value of 72 for all sites measured (Table 2).

Although outside the scope of this report, it is important to note that waterways in Table 3 are fed from different sources and thus background water quality concentrations can significantly vary. The majority of waterways in Table 2 are classified as spring-fed plains (fed by groundwater) with the exception of Osbornes Drain and Kaituna River, and generally have higher concentrations of nitrate reflecting background concentrations in their groundwater source (Stevenson *et al.*, 2012). The Kaituna River falls into the Banks Peninsula river type due to the geology, and thus generally has far lower nitrate concentrations. However, these river types generally have phosphors concentrations because of the volcanic soil properties.

Overall the WQI values for all the tributaries indicate that the quality of the water entering Lake Ellesmere/Te Waihora are of fair to poor quality. Osborne Drain and the Halswell River appear to be the most degraded. The water quality of these bodies is however significantly different to one another. High phosphorus concentrations are of most concern in Osbornes Drain, whereas in the Halswell Canal and River, high concentrations of nitrogen are of concern (Golder 2012).

Appendix G

Sediment Quality Results

Table 1: Osbourne's Drain Sediment Results - (Heavy Metals)

Sample Name	Osbournes Drain 1	Osbournes Drain 2	ANZECC Guidelines (2000)[2] - Recommended Sediment Quality Guidelines (effects range-low)	Environment Canterbury Background Soil Concentrations - 'SAGYRE' Soils[3]
Laboratory Reference	1179156.1	1179156.2		
Date	12/9/2013	12/9/2013		
Heavy Metals				
Arsenic	5	7	20	8.8
Boron	< 20	**42**	-	22.1
Cadmium	**0.21**	**0.26**	1.5	0.11
Chromium	**18**	**19**	80	14.6
Cobalt	10.1	12.4	-	-
Copper	**17**	**28**	65	14.7
Lead	18.3	21	50	53.1
Mercury	< 0.10	< 0.10	0.15	0.08
Nickel	**17**	**16**	21	10.6
Tin	1.1	1.1	-	-
Zinc	**83**	**97**	200	52.1

Note:
1. All results in mg/kg.
2. Criteria from Australian and New Zealand Environment and Conservation Council (ANZECC), Agriculture and Resource Management Council of Australia and New Zealand - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000).
3. Background concentrations of selected trace elements in Canterbury soils - Addendum 1. (ECan 2007, Report no. R07/1/2). Based on 'SAGYRE' soil type - background.

0.26 - Concentration above reported ECan Background soil concentration.

Appendix H

Proposed Improvement Options

Issues	Improvement Measure	Key WQ parameters that the measure effects	Indicative % change	Comments
The sediment sources will remain, therefore this management approach, on its own, will not provide a long term solution. Sediment from within the drain from the upper catchment will likely be transported to the dredged areas. The amount of sediment transported downstream will however, be dependent on multiple factors such as bed sediment size, cohesion of bed sediment, water velocities within the drain, drain depth etc. The amount of sediment that might be washed down cannot be quantified	Remove accumulated sediment from the lagoon upstream of the pump station,	Temperature	May cause negative effect (-20% to 0%)	Dependent on the volume of sediment that would be removed. If the sediment removal is of sufficient volume, water velocities would be expected to be reduced (due to an increased cross-sectional area of the drain), consequently turbulence and mixing will also be reduced. This would therefore cause the drain water to have an increased residence time within the drain, and consequently a greater opportunity for the water to be heated.
		DO	May cause negative short term effect (-20% to 0%)	If temperature were to become more elevated, due to reasons explained above, the ability for the water body to retain dissolved oxygen may become reduced. Minor improvement could be expected due to the removal of BOD contaminants from the drain. This would depend on the type of BOD (bacteria etc.) bound within in the sediment (this is not known) and a range of factors which cannot be quantified. The removal of particulate forms of nitrates and phosphates bound within the sediments would likely reduce BOD load and increase DO.
		Total Nitrogen and dissolved Nitrogen	Limited improvement (0% to 5%)	Increased removal of nitrogen would occur if increased sedimentation rates are provided. Based on ECAN sampling data (Figure 3.1.8) approx. 13% of Total nitrogen is in particulate form (from samples 100 m upstream of pump house), not all this particulate form will however adsorb with sediment and settle. It is therefore assumed that removal of nitrogen will be limited.
		Total Phosphorus and dissolved Phosphorus	Net improvement (30% to 50%)	Increased removal of phosphorus would occur if increased sedimentation rates are provided. Based on ECAN sampling data (Figure 3.1.9) approx. 47% of TP is in particulate form (from samples 100 m upstream of pump house), based removal on Total Suspended Sediment removal rate x 47%
		Total Suspended Solids	Good improvement (50% to 75%)	Removal of sediment will improve sedimentation processes due to reduced water velocities. The degree of improvement however, will depend whether the current sediment is being eroded and is a source of sediment.
		Visual appearance and odour	Water clarity could be improved. Odour issues may be present in the short term after dredging occurs if anoxic sediments are exposed, but would become more pleasant in the long-term.	If the removal of accumulated sediment improves sedimentation processes due to reduced water velocities within the drain, the visual clarity of the water would also improve. Odour issues may be experienced in the short term due to the mobilisation of anoxic sediments. Dredged sediments should be dewatered stabilised (or alternatively removed from the site) to eliminate the ability of the dredged sediment re-entering the drain during storm or inundation events.
		turbidity	potential improvement	Reduced water velocities would provide increased sedimentation rates and less opportunity for particulates to remain in suspension. This would therefore likely improve the clarity (turbidity) of the drain.
		Heavy metals	May cause negative effect (-20% to 0%)	If existing anoxic zones are removed, the treatment provided by the sulphide reducing bacteria within these anoxic zones will also be removed. As such, the heavy metal removal rates currently provided within the drain will be reduced in the short term, untill such time anoxic sediments are regenerated.
		Oestrogen & endocrine disrupting chemicals or EDCs	Minor improvement (10% to 30%)	SINGHAL, N.; SONG, Y.; JOHNSON, A.; SWIFT, S. (2009). Agricultural EDC's mainly in the form of nonylphenolethoxylates (NPEO) which are found in pesticides and fertiliser formations. NPEO can adsorb to sediment particulate. Therefore, if sedimentation processes are improved a slight reduction to EDC's can be achieved. Other EDC's are sourced from manure and urine from livestock feed stocks. Majority of degradation to these products are from anaerobic, aerobic degradation, biodegradation, sedimentation therefore this option would only provide a minor improvement to EDC discharges.
		Pesticides/herbicides (including but not limited to arsenic)	Good improvement (50% to 75%)	Depending on the volume of sediment that is removed, accumulated aquatic vegetation will also likely be removed. With increased water depths, habitat for future plant growth is expected to be reduced. This would therefore reduce the need to use herbicides in the drain for the short term, until channel depth returns back to such a depth where aquatic vegetation is supported. As such, it is expected that a good improvement could be achieved if drain sediment were to be removed.
The sediment sources will remain, therefore this management approach, on its own, will not provide a long term solution. Sediment from within the drain from the upper catchment will likely be transported to the dredged areas. The amount of sediment transported downstream will however, be dependent on multiple factors such as bed sediment size, cohesion of bed sediment, water velocities within the drain, drain depth etc. The amount of sediment that might be washed down cannot be quantified	Remove all accumulated sediment for the entire length of Osbornes drain	Temperature	May cause negative effect (-20% to 0%)	Dependent on the volume of sediment that would be removed. If the sediment removal is of sufficient volume, water velocities would be expected to be reduced (due to an increased cross-sectional area of the drain), consequently turbulence and mixing will also be reduced. This would therefore cause the drain water to have an increased residence time within the drain, and consequently a greater opportunity for the water to be heated.
		DO	May cause negative effect (-20% to 0%)	If temperature were to become more elevated, due to reasons explained above, the ability for the water body to retain dissolved oxygen may become reduced. Minor improvement could be expected due to the removal of BOD contaminants from the drain. This would depend on the type of BOD (bacteria etc.) bound within in the sediment (this is not known) and a range of factors which cannot be quantified. The removal of particulate forms of nitrates and phosphates bound within the sediments would likely reduce BOD load and increase DO.
		Total Nitrogen and dissolved Nitrogen	Limited improvement (0% to 5%)	Increased removal of nitrogen would occur if increased sedimentation rates are provided. Based on ECAN sampling data (Figure 3.1.8) approx. 13% of Total nitrogen is in particulate form (from samples 100 m upstream of pump house), not all this particulate form will however adsorb with sediment and settle. It is therefore assumed that removal of nitrogen will be limited.
		Total Phosphorus and dissolved Phosphorus	Net improvement (30% to 50%)	Increased removal of phosphorus would occur if increased sedimentation rates are provided. Based on ECAN sampling data (Figure 3.1.9) approx. 47% of TP is in particulate form (from samples 100 m upstream of pump house), based removal on Total Suspended Sediment removal rate x 47%
		Total Suspended Solids	Good improvement (50% to 75%)	Removal of sediment will improve sedimentation processes due to reduced water velocities.
		Visual appearance and odour	Water clarity would likely be improved. Odour issues will be present in the short term after dredging occurs due to the exposure of anoxic soils, but would become more pleasant in the long-term. net improvement (30% to 50%)	Removal of accumulated sediment will likely improve sedimentation processes due to reduced water velocities within the drain. Odour issues may be experienced in the short term due to the mobilisation of anoxic sediments. Dredged sediments should be dewatered stabilised (or alternatively removed from the site) to eliminate the ability of the dredged sediment re-entering the drain during storm or inundation events.
		turbidity	Net improvement (30% to 50%)	If reduced water velocities were to occur this would provide an increased sedimentation rate and less opportunity for particulates to remain in suspension. This would therefore likely improve the clarity (turbidity) of the water body.
		Heavy metals	May cause negative effect (-20% to 0%)	If the anoxic zones are removed, the treatment provided by the sulphide reducing bacteria within these anoxic zones will be removed. As such, the removal rates currently achieved within the drain will be reduced
		Oestrogen & endocrine disrupting chemicals or EDCs	Minor improvement (10% to 30%)	SINGHAL, N.; SONG, Y.; JOHNSON, A.; SWIFT, S. (2009). Agricultural EDC's mainly in the form of nonylphenolethoxylates (NPEO) which are found in pesticides and fertiliser formations. NPEO can adsorb to sediment particulate. Therefore if sedimentation processes are improved a slight reduction to EDC's can be achieved. Other EDC's are sourced from manure and urine from livestock feed stocks. Majority of degradation to these products are from anaerobic, aerobic degradation, biodegradation, sedimentation therefore this option would only provide a minor improvement to EDC discharges.
		Pesticides/herbicides (including but not limited to arsenic)	Good improvement (50% to 75%)	If sediments are dredged from the drain, accumulated aquatic vegetation will also likely be removed. With increased water depths, habitat for future plant growth is expected to be reduced. This would therefore reduce the need to use herbicides in the drain for the short term, until channel depth returns back to such a depth where aquatic vegetation is supported. As such, it is expected that a good improvement could be achieved if drain sediment were to be removed.
Principle mitigation is provided by dilution of contaminants only, say replace one full volume of the main ponding area per day 2500 m2 up to narrow part of drain at 1.2m deep = 3000 m3/day = 35 L/s, assume clean GW for dilution	Base flow augmentation from Local bores	Temperature	Limited improvement (0% to 5%)	Unlikely to provide much improvement given that the average bore temp is around 13 - 15 degrees and drain temp is slightly lower than this, may have minor improvement in periods of long hot days in summer at the lagoon
		DO	Minor improvement (10% to 30%)	If sufficient augmentation is provided, stagnant water can be eliminated. By doing so this provides some improvement to the dissolved oxygen concentrations within the drain.
		Total Nitrogen and dissolved Nitrogen	Minor improvement (10% to 30%)	Comparing groundwater quality data with water from Osbornes Drain (Kimberly and Meredith, *draft*) suggests that groundwater has lesser nitrogen concentrations than surface water concentrations. As such, augmentation would provide some dilution, thereby providing some minor improvement to nitrogen concentrations
		Total Phosphorus and dissolved Phosphorus	Minor improvement (10% to 30%)	Comparing groundwater quality data with water from Osbornes Drain (Kimberly and Meredith, *draft*) suggests that groundwater has lesser phosphorus concentrations than surface water concentrations. As such, augmentation would provide some dilution, thereby providing some minor improvement to phosphorus concentrations
		Total Suspended Solids	Minor improvement (10% to 30%)	It is assumed that TSS concentrations of groundwater are less than the drain (no information is provided). As such, it is expected that the TSS concentrations within the drain will become diluted. Improvement to TSS concentrations is however, considered to be only minor.
		Visual appearance and odour	Minor improvement to odour expected (10% to 30%), no improvement to water clarity	Odour would be expected to have minor improvement due to reduced stagnant areas that may cause potential anoxic zones. The clarity of the drain is not expected to improve.
		turbidity	May cause negative effect (-20% to 0%)	As the water flows are expected to be increased within the drain, thereby the residence time of the drain water being reduced, it is anticipated that particulates will have a greater opportunity to remain entrained. As such, turbidity may be slightly degraded.

		Heavy metals	Unknown due to lack of data, but potential improvement may occur (10% to 30%)	Heavy metals are likely to be also present in groundwater (but of a lower concentration). It is therefore possible that through augmentation, the concentrations of heavy metals may become diluted.
		Oestrogen & endocrine disrupting chemicals or EDCs	Minor improvement (10% to 30%)	EDC's may also be present in groundwater (but of a lower concentration). It is therefore possible that through augmentation, the concentrations of EDC's will become diluted.
		Pesticides/herbicides (including but not limited to arsenic)	Minor improvement (10% to 30%)	Assumes that augmentation would provide dilution of any pesticides or herbicides within the water column.
There is difficulty in estimating the potential improvement for this proposed mitigation option as it dependant on a range of variable present in the drain, and variables that could influence the function of the drain i.e. climatic imfluences.	A recirculation pump	Temperature	Minor improvement (10% to 30%)	A recirculation pump would increase the flows within the drain. As such the residence time of water within the drain will be reduced, thereby limiting the duration of solar radiation exposure. It is therefore expected that water temperatures within the drain would have minor improvement.
		DO	Minor improvement (10% to 30%)	The agitation to the water created by the pumping will cause a minor elevation to dissolved oxygen concentrations. In addition, if water temperatures are reduced, due to a reduced water residence time within the drain, it is expected that dissolved oxygen concentrations will have a minor improvement
		Total Nitrogen and dissolved Nitrogen	No change	Any aeration caused by the pumping of drain water may convert ammoniacal nitrogen concentrations to nitrates, however, no or limited nitrogen removal is expected. If denitrifying bacteria were to be present within the drain, it is assumed that there would be a limited carbon source for these bacteria to live. As such, it is not expected that any change to nitrogen concentrations would occur with this option.
		Total Phosphorus and dissolved Phosphorus	May cause negative effect (-20% to 0%)	Pumping of drain water will provide no removal of phosphates from the water column. Phosphorus however, that may be attached to previously deposited sediment particles, may however, become re-entrained because of the agitation process of the pumping. As such, the concentrations of phosphorus may be increased.
		Total Suspended Solids	May cause negative effect (-20% to 0%)	As the water flows are expected to be increased within the drain, thereby the residence time of the drain water being reduced, it is expected that total suspended sediment concentration may be slightly degraded. In addition TSS concentrations may become more concentrated due to the recycling of water.
		Visual appearance and odour	May cause negative effect to visual appearance of the water clarity (-20% to 0%), but minor improvement to odour(10% to 30%)	By providing an increased flow through the drain, stagnant water zones will be reduced. This therefore will reduce anoxic zones and consequently improve odour quality. Increased flows will however cause the water colour to look more turbid.
		turbidity	May cause negative effect (-20% to 0%)	As the water flows are expected to be increased within the drain, thereby the residence time of the drain water being reduced, it is expected that particulates will have greater opportunity to remain entrained. As such, turbidity may be slightly degraded.
		Heavy metals	May cause negative effect (-20% to 0%)	If sediments become re-entrained by the aeration process, it may increase the particulate concentration of heavy metals. As such, aeration may cause an increase to heavy metal concentration within the drain. In addition, If the anoxic zones are removed, the treatment provided by the sulphide reducing bacteria within these anoxic zones will be removed. As such, the removal rates currently achieved within the drain will be reduced
		Oestrogen & endocrine disrupting chemicals or EDCs	May cause negative effect (-20% to 0%)	Based on the present land use, EDC's are sourced from fertilisers, pesticides, and animal manure and urine. The EDC's derived from these sources can adsorb to sediment particles, therefore if sediment is retained within suspension because of the aeration process, it would be expected that the EDC concentrations will be more elevated than present. In addition EDC concentrations may become more concentrated due to the recycling of water.
		Pesticides/herbicides (including but not limited to arsenic)	No change	The use of a recirculation pump will not reduce the concentrations of any pesticides or herbicides within the drain
American Society of Civil Engineers (ASCE) "aeration efficiency of a particular aerator can only be obtained by running your own tests rather than relying on the data from past reports", furthermore aeration efficiency depends on temperature, water depth, type of aerator, rotor speed, power available to the aerator, length of operation, air pressure, maximum DO saturation at the time, inflow DO concentration, all of which are highly variable and cannot be estimated without the risk of serious error. According to Treatment Wetlands Second Edition (Robert H.Kaldec and Scott D.Wallace 2009), no conclusive data has been obtained for aeration performance of aeration in surface flow wetlands.	Aerator e.g. typical waste water treatment plant kit	Temperature	Excellent improvement in the vicinity of the aerator (50% to 75%), however a limited improvement will be experienced if stagnant water zones remain (<5%)	By agitating the water column, the water body will become aerated. This additional air within the water can provide a cooling mechanism. This benefit will however be experienced only in the immediate vicinity of the aerator . If however, stagnant water is present downstream of the aerator, water temperature will be expected to increase again.
		DO	Excellent improvement in the vicinity of the aerator (75% to 100%), however a limited improvement will be experienced if oxygen depleting substances remain (<5%)	By agitating the water column, dissolved oxygen concentrations within the immediate vicinity of the aerator will be improved. If however, BOD substances and aquatic plant life are still present, the discharge concentration will still remain poor.
		Total Nitrogen and dissolved Nitrogen	No change	Aeration of drain water may convert ammoniacal nitrogen concentrations to nitrates, however, no or limited nitrogen removal is expected. If denitrifying bacteria were to be present within the drain, it is assumed that there would be a limited carbon source for these bacteria to live. As such, it is not expected that any change to nitrogen concentrations would occur with this option.
		Total Phosphorus and dissolved Phosphorus	May cause negative effect (-20% to 0%)	Aeration of drain water will provide no removal of phosphates from the water column. Phosphorus however, that may be attached to previously deposited sediment particles, may however, become re-entrained because of the agitation process of the pumping. As such, the concentrations of phosphorus may be increased.
		Total Suspended Solids	May cause signficant negative effect (-100% to 0%)	The use of an aerator may mobilise previously deposited bed sediments within the drain. This would therefore cause an increase to the total suspended sediment load within the drain.
		Visual appearance and odour	May cause negative visual effect (-20% to 0%), will have a negative short term effect for odour (30% to 50%), but long term an odour benefit (30% to 50%)	In the short term, agitation of the drain water may cause a reduced odour quality. This is due to the potential remobilisation of anoxic sediments. However, long-term, in the vicinity of the aerator, dissolved oxygen concentrations would be increased therefore reducing the potential for anoxic sediment zones to exist. This therefore would cause an improvement to the odour quality. it is however noted, that once the agitation effects are not noticeable within the drain, no benefit to odour quality would be anticipated. Visually the clarity of the drain water will be reduced due the entrainment of sediment. As such, the visual quality of the water would be considered to have become worst.
		turbidity	May cause negative effect (-50% to 0%)	The use of an aerator may remobilise bed sediments and particulates within the drain. This would therefore reduce the water clarity within the drain.
		Heavy metals	May cause negative effect (-20% to 0%)	If sediments become re-entrained by the aeration process, it may increase the particulate concentration of heavy metals. As such, aeration may cause an increase to heavy metal concentration within the drain. In addition, If the anoxic zones are removed, the treatment provided by the sulphide reducing bacteria within these anoxic zones will be removed. As such, the removal rates currently achieved within the drain will be reduced
		Oestrogen & endocrine disrupting chemicals or EDCs	May cause negative effect (-20% to 0%)	Based on the present land use, EDC's are sourced from fertilisers, pesticides, and animal manure and urine. The EDC's derived from these sources can adsorb to sediment particles, therefore if sediment is retained within suspension because of the aeration process, it would be expected that the EDC concentrations will be more elevated than present.
		Pesticides/herbicides (including but not limited to arsenic)	No change	The use of a recirculation pump will not reduce the concentrations of any pesticides or herbicides within the drain
The increased performance of this option is achieved by increasing sedimentation rates within the drain. Improvement will be depend on time between pumping the high level overflow, sediment particle size (which is unknown), water depth, and water velocities which will be variable because of climatic influences.	Construction of weir(s) directly upstream of the pump station	Temperature	Potential negative effect if greater stagnation were to occur (-20% to 0%)	If weirs reduce the ability of flows to occur (due to the control structures reducing the extent in which pumping effects occur) then the water body upstream of the weir will become more stagnant. This would therefore increase the potential of water temperatures to be more elevated, due to a longer exposure of solar radiation.
		DO	Potential negative effect if greater stagnation were to occur (-20% to 0%)	Due to the potential increased water stagnation and increased water temperatures, it is anticipated that dissolved oxygen concentrations within the drain would become reduced.
		Total Nitrogen and dissolved Nitrogen	Limited improvement (<5%)	Based on ECAN sampling data (Figure 3.1.8) approx. 13% of Total nitrogen is in particulate form (from samples 100 m upstream of pump house), not all this particulate form will however adsorb with sediment and settle. It is therefore assumed that removal of nitrogen will be limited
		Total Phosphorus and dissolved Phosphorus	Net improvement (30% to 50%)	based on Evan sampling data (Figure 3.1.9) approx. 47% of TP is in particulate form (from samples 100m upstream of pump house), based removal on TSS removal rate x 47%
		Total Suspended Solids	Net improvement (30% to 50%)	upper limit found from mean value of field monitoring of 12 sediment basins and traps. Article 57, "The Limits of Settling", Technical Note #83 from Watershed Protection Techniques. 2(3): 429-433
		Visual appearance and odour	Improvement to water clarity is expected for the majority of the drain length. However odour issues may worsen	The weirs will assist with reducing suspended sediment concentrations for the majority of the drain length. This will therefore improve the clarity of the drain. No change or a degradation to the odour is expected to occur. This is due to the sources of the odour still being present and the potential for greater anoxic zones to become apparent.
		turbidity	Net improvement (30% to 50%)	The weirs are expected to cause an increased sedimentation performance within the drains upstream of the weirs. Velocities in the vicinity of weirs will however increase. The weirs should therefore provide an improvement to existing turbidity in the majority of the drain.
		Heavy metals	Net improvement (30% to 50%)	Providing weir are likely to increase anoxic zones. As such, heavy metal concentrations are expected to be reduced.
		Oestrogen & endocrine disrupting chemicals or EDCs	Minor improvement (10% to 30%)	SINGHAL, N.; SONG, Y.; JOHNSON, A.; SWIFT, S. (2009). Agricultural EDC's mainly in the form of nonylphenolethoxylates (NPEO) which are found in pesticides and fertiliser formations. NPEO can adsorb to sediment particulate. Therefore, if sedimentation processes are improved a slight reduction to EDC's can be achieved. Other EDC's are sourced from manure and urine from livestock feed stocks. Majority of degradation to these products are from anaerobic, aerobic degradation, biodegradation, sedimentation therefore this option would only provide a minor improvement to EDC discharges.
		Pesticides/herbicides (including but not limited to arsenic)	Potential negative effect if greater sedimentation were to occur (-20% to 0%)	If greater sedimentation were to occur, and increased stagnation, this may promote increased aquatic vegetation growth. This therefore may require greater herbicide control that what is presently used, thereby increasing potential herbicide concentrations within the drain.
		Temperature	Net improvement (30% to 50%)	If riparian planting is provided for, shading to the edges of the drain can be provided. This would provide some water temperature improvement to the drain, by limiting the solar radiation exposure. It is assumed that a variety of species would be allowed for, thus providing taller species to achieve greater shading

The effectiveness of farm plans will be dependent on; the objectives which are set, i.e. that they are specific, measureable, achievable, and have time bound milestones; that the monitoring of the plans is effectively carried out to ensure that the objectives are met; and that the prepared plans are endorsement by the owners that will implement them.	Farm plans designed to achieve water quality standards for drainage water in the current planning instruments in the short to medium term and contact recreation standard over the next 15-20 years	DO	Net improvement (30% to 50%)	DO is likely to increase due to the reduction in BOD loads entering the drain from dairy effluent activities. With improved temperature mitigation, it is also expected that the water bodies ability to retain oxygen will also be improved.
		Total Nitrogen and dissolved Nitrogen	Net improvement (30% to 50%)	Nutrient management plans and the establishment of nutrient budgets, would reduced the possibility of land being over fertilised allowing excess fertilisers to enter into the drain. It therefore can be assumed, that in general, there would be a reduction of nutrient load entering into the drain
		Total Phosphorus and dissolved Phosphorus	Net improvement (30% to 50%)	Nutrient management plans and the establishment of nutrient budgets, would reduced the possibility of land being over fertilised allowing excess fertilisers to enter into the drain. It therefore can be assumed, that in general, there would be a reduction of nutrient load entering into the drain
		Total Suspended Solids	Net improvement (30% to 50%)	If sediment management plans are implemented effectively, the sediment discharge concentrations entering into the drain from point sources would be expected to be reduced. Diffuse overland flow may also have reduced total suspended sediment concentrations if sufficient riparian margins (with appropriate species) are provided (width, and planting densities).
		Visual appearance and odour	Net improvement (30% to 50%)	By providing greater dissolved oxygen concentrations within the drain, and reducing BOD loading entering into the drain, the key sources that contribute to anoxic zones are reduced. It is therefore expected that there would be an improvement to odour. aesthetically the drain would be more pleasing due to vegetation hiding the current shape of the bank edges of the drain.
		turbidity	Net improvement (30% to 50%)	If sediment management plans are implemented effectively, the sediment discharge concentrations entering into the drain from point sources would be expected to be reduced. Diffuse overland flow may also have reduced particulate concentrations if sufficient riparian margins (with appropriate species) are provided (width, and planting densities).
		Heavy metals	Net improvement (30% to 50%)	Given that the majority of the heavy metals derived within the catchment are anthropogenic, it is assumed that through improved water treatment management practices the heavy metal discharge concentrations to the drain will be improved.
		Oestrogen & endocrine disrupting chemicals or EDCs	Net improvement (30% to 50%)	By limiting the discharge of dairy effluent entering the drain, a key source of EDC's is reduced. It is therefore expected that an overall reduction of EDC concentrations entering into the drain.
		Pesticides/herbicides (including but not limited to arsenic)	Unknown. Dependent on effectiveness of plans	If nutrient management plans are effectively implemented, the potential need to use herbicides within the drain may be reduced.

KEY

(shaded) Indicates that there is a particularly large degree of uncertainty regading this Indicative % change. This maybe due to a lack of data to provide interpretation for the result, or due to other processes that also may occur as a result of the proposed mitigation apporach which may also influence the result

References

SINGHAL, N.; SONG, Y.; JOHNSON, A.; SWIFT, S. (2009). Estrogenic Endocrine Disrupting Compounds. Prepared by UniServices for Auckland Regional Council. Auckland Regional Council Technical Report Number TR 2010/005

ECAN (2012). Proposed Canterbury Land and Water Regional Plan. Environment Canterbury.

Robinson K, and Meredith, A (draft). Osbornes Drain: Assessment of water quality monitoring, 2011 -2012. Draft report prepared for Environment Canterbury

Note: It is assumed that farm management plan would entail the management of contaminants via the following mechanisms: Nutrient management plans (nutrient budgets), riparian planting, sediment management, animal effluent management (ECAN, 2012)

Note: % improvement is defined the % change based from the existing state. % improvements are given based on the effective implementation of the chosen option only. It is to be recognised the assessment % improvement for combinations of options have not been undertaken.

Note: The only active consent for the use of herbicides within the drain is permitted by Regional Resource Consent CRC981580. This consent only permits the concentrations of herbicides in surface waters within 25 metres downstream of spray zones shall not exceed the following:(i) Glyphosate 0.1 grams per cubic metre(ii) Triclopyr 0.01 grams per cubic metre.

Note: No discussion has been provided on pesticides due to the lack of information present regarding there existence in this catchment and their concentration

Additional options that could be considered

OPTION	BENEFIT
floating vegetated wetlands	provides improved sedimentation process through filtration process of the root biomass provides biological uptake of contaminants such as heavy metals provides for improved chemical process mitigation, via anaerobic, aerobic degradation processes depending on size, can provide minor localised temperature and DO mitigation by shading of the drain

Appendix I

Farm Management Plans

1 Potential Design of Farms Plans

It has been recognized that agricultural activities and the moderate to high soil salinity in the Osbornes Drain scheme area are influencing the quality of shallow groundwater and surface runoff collecting in Osborne's Drain. Of particular concern are the quality of this discharge and potential impacts on the receiving environments; wetlands and Lake Ellesmere/Te Waihora.

Since the commissioning of this scheme in 1967-68, farming practices have developed to a point where productivity has improved greatly. This can be attributed to the increased machinery use and a more competitive market. Subsequently, the stocking rates and farm practises are much closer to the carrying capacity of the land. This can lead to excessive applications of nutrients to land through animal products, such as urine and faecal matter, fertiliser application or imported feed and also the increased application of water, which can increase drainage.

Nutrients, in particular phosphorous and nitrogen, are the main contaminants associated with agricultural activities. These contaminants are considered to be non-point source (NPS) pollutants. This means that the contaminants originate from diffuse sources that can cover broad areas, these sources can be either natural (for instance geological erosion, dissolution of nutrient-rich rocks and soils) or linked to human activities (eg. runoff and/or subsurface flow from agricultural, forestry and urban land). It is considered that the degraded water quality in Osbornes Drain is a result of the runoff and drainage associated with the agricultural activities taking place in the catchment, as well as the inherently saline soils.

This section outlines a range of farming 'best management practises' (BMP) that will serve to reduce contaminants entering Osborne Drain as runoff and drainage, and will also provide an outline for the farm environmental plan (FEP), which will be ultimately tailored for this catchment. It is recommended that collaboration takes place in the preparation of these FEP's, in order for a catchment wide collaborative approach to be adopted. Whilst the proposed mitigation methods are valuable in reducing or removing historical background contaminants from individual properties, improvements in aquatic health will only be minor, unless a catchment wide approach is undertaken.

1.1 Contaminants of concern

In order to identify the suitable farm BMP to mitigate the contaminants of concern, it is important to identify how, and in what form, these contaminants enter and exits the farm environment. Table 1 below, outlines each contaminant, how it enters the farm environment and how it exits to the environment. The particular contaminants of concern are phosphorous, conductivity, total suspended solids (TSS) and high organic matter.

Table 1: Contaminant Pathways		
Contaminant	**Entering the Farm**	**Exiting to the Environment**
Nitrogen (N)	Fertilizer, imported feed and OM, nitrogen-fixing of plants, in highly N concentrated 'urine patches'	As nitrogen is highly soluable, any excess N in the soil profile, exits the farm as drainage, typically in the form of nitrate
Phosphorous (P)	Fertilizer, Soil weathering, Soil organic matter, animal faecal matter	P is strongly adsorbed to soil particles. Therefore the majority of the P losses are in its particulate form, and associated primarily with surface runoff carrying soil particles (i.e. erosion).
Conductivity	Given the reclaimed land was historically submerged under water from Te Waihora/Lake Ellesmere, soils are of moderate to high salinity levels.	Drainage water would expect to be influenced by the salts and experience elevated conductivity/salinity concentrations.
High Organic Matter (OM)	Organic compost from a nearby green waste processor (CRC081117) is spread onto farmland as a method of soil conditioning to build up the topsoil overlying the saline soils.	As for P, OM is expected to be mostly transferred through surface runoff.
Bacterial	Faecal contamination from animal excreta, effluent application	Through surface runoff and shallow drainage
Total Suspended Solids (TSS)	Existing onsite soils	Erosion through farm practises, grazing, pugging etc.
Notes:		

1.2 Best Management Practises

Simplistically there are two ways to reduce the NPS pollutants exiting a farm system. The first option is to reduce the amount of contaminants entering the farm environment, i.e. the “Entering the Farm” column in Table 1. This could be achieved by reviewing current FEP and utilising existing software, such as OVERSEER™ to investigate the possible reduction in the amount of fertilizer applied, or to reduce stock numbers or imported feed. Increasing the efficiency of a farming operation in order to reduce contaminant losses, often has both an economic and environmental benefit. The second option is to mitigate the pathways in which contaminants exit the farm environment, i.e. the “Exiting the Farm” column in Table XX. There are many ways in which nutrient losses can be mitigated, and contaminant pathways reduced. The applicable BMP are listed below:

- Disposing of dairy shed effluent on to land, thus using it as a fertiliser in a manageable application rate which is within the range the land can handle.
- Reducing surface runoff from erosion-prone country.
- Fencing gullies and letting them revert to native bush.
- Nutrient budgeting to avoid using excess fertiliser application and runoff.
- Fencing streams and bridging crossings to exclude cattle, thus reducing both direct deposition of faecal matter and urine and erosion of banks.
- Planting riparian strips along stream banks so that nutrients will be absorbed by growing plants before they reach the water. Riparian plants also provide instream shading and a terrestrial food resource for aquatic fauna.
- Keeping cattle off pasture at critical times using concrete stand-off pads and wintering barns.
- Constructing wetlands in low-lying areas.

These BMP are explained in detail below, along with details regarding their likely contaminant reductions and timeframes, as well as the farming systems they are applicable to.

1.2.1 Disposing Effluent to Land

This BMP reduces N loss to shallow groundwater through drainage. For N leaching to occur, there needs to be an accumulation of nitrate in excess to plant requirements, and sufficient water to cause drainage. When conditions are suitable for plant growth, much of the available N is taken up and the risk of leaching is relatively low. N is lost to shallow groundwater when the applied N is greater than the plant demand and storage capacity of the soil. This can occur in a variety of situations, such as in intensive cropping where large quantities of N fertiliser are added, when the soil is bare or the crop is not yet fully established, or in late summer or autumn where winter rainfalls flushes any excess N in soil profile to shallow groundwater.

However the most important mechanism to Osborne Drain, is where N is lost to shallow groundwater in grazed pastoral systems. Due to the increased focus on farm productivity, pastoral farms have increased their N inputs through either nitrogenous fertilisers or imported animal feedstuffs, these high N inputs are often reflected in increased stocking rates. Grazing animals concentrate and return, in faecal matter and urine deposits, approximately 75 -90% of the herbage N that they ingest (FLRC, 2012). Much of this N, particularly that in urine, is quickly converted to nitrate and is vulnerable to leaching. There may be as much as 300 - 600 kg mineral N ha^{-1} under urine patches (FLRC, 2012). This difficulty is exacerbated by the preference of animals to camp and, therefore, deposit greater amounts of excreta in specific areas e.g. near watering troughs, flat ground and shelter. Ultimately this leads to a situation where there are many urine patches, with extremely high N concentrations, located around a paddock. It has been estimated that nutrients in a hectare of lush pasture are recycled as faecal matter and urine on less than 0.02ha (2% of the grazed area) (FLRC, 2012). When drainage is encountered (i.e. rainfall/irrigation is in excess of the water holding capacity of the soil), the excess N in these urine patches is often leached from the soil profile into shallow groundwater.

As a grazing animal digests any grazed pasture, and uses a portion of the herbage N in biological function, the total N found in effluent is less than what was previously stored in the pasture, therefore applying effluent to land provides a nutrient source less than typical plant requirements, therefore is unlikely to cause N leaching. This is dependent on selecting an appropriate application rate, and applying effluent to an appropriate sized area and in suitable conditions, such as avoiding times where drainage is occurring.

This BMP is limited due to the location and timing of where you can collect effluent from, i.e. in a dairy situation, effluent collected from a milking shed is limited to the time in which the cows spend in the milking shed, and the requirements of effluent storage. This BMP, if improperly executed can lead to increased loss of nutrients to the environment, particularly phosphorous, especially if excessive effluent is applied and surface ponding occurs.

1.2.2 Reducing Surface Runoff and Drainage

As stated in Table XX, P is strongly adsorbed to soil particles forming particulate P. Therefore only small amounts of P are leached from the soil profile, with most P losses being in particulate form and associated primarily with surface runoff carrying soil particles (i.e. erosion). As such, P losses to waterways mainly occur through surface runoff, as particulate P; with subsurface flow, transporting dissolved P, only contributing minimally to the overall P losses (EBoP, 2004).

Furthermore it has been reported that particulate P makes up to 75 – 90% of the P transported from cropping land, whereas P transport from forest or grassland is generally dominated, but at much lower quantities, by dissolved P. However it is estimated that 66 % of consumed P, is returned to the soil as faecal matter, therefore there is also a significant risk associated with surface runoff occurring where grazing animals congregate, such as near watering troughs, flat ground and shelter (FLRC, 2012). These areas also typically have reduced plant growth due to animal traffic.

Due to the flat topography of the Osbornes Drain scheme, sheet and rill erosion could possibly be generated. Sheet erosion occurs when rain falls on bare or sparsely covered soil, loosening fine surface particles, including faecal matter, that are carried downhill in surface run-off. Rill erosion occurs when surface runoff collects in many small V-shaped channels or rills, this also transports surface sediments. The areas where animals congregate, harvested areas on cropping farms, and areas where cattle are wintered on crops are all especially susceptible to these erosion mechanisms. If this runoff reaches a surface way un-impeded it can provide a significant pathway for particulate P and OM associated with the compost application to enter waterways.

Various BMP's can be utilised to reduce surface runoff, or to reduce the sediment contained within surface runoff through filtration. These practices include conservation tillage, contour strip-cropping, terraces, filter strips, sediment retention ponds, and sediment traps. These are outlined below:

- **Conservation tillage** includes any tillage or planting system that maintains at least 30 percent of the soil surface covered by residue after planting to reduce soil erosion by water or wind. Surface residues reduce soil compaction from raindrops and provide soil cover during critical times in the cropping cycle. This mainly applies to cropping operations, but a similar approach is recommended when grazing animals are strip grazed on forage crops.
- **Contour strip farming** is the process where strips of vegetation perpendicular to the natural slope, are left ungrazed and vegetated, this reduces erosion and sediment production, thus decreasing the transport of sediment and related pollutants to receiving waters. This BMP has been reported to reduction estimate for total sediment runoff of between 83% and 91% (MDA, 2012).
- **Filter strips** are an area of vegetation planted between fields and surface waters to reduce sediment, organics, nutrients, pesticides, and other contaminants in runoff. Field borders are strips or bands of permanent vegetation established at the edge of or around the perimeter of a crop or

grazing fields. Studies have shown that 90 percent of sediment can be withheld by an effectively constructed filter strip (MfE, 2001)

- **Sediment traps and sediment basins**, these BMP's function by either filtering out or detaining and settling sediment for erosion water. Sediment basins can remove between 60% and 90% of TSS and from 34% to 73% of total phosphorous (MDA, 2012).

1.2.3 Fencing and Riparian Planting

The banks of waterways (and gully heads) are areas of high erosion susceptibility. The grazing of these areas further increases the erosion susceptibility of these areas, due to the reduction of vegetation and tread damage. The exclusion of stock and the replanting of these areas are effective in reducing erosion. As P is tightly bound to soil and the plant roots stop the banks from eroding and carrying sediment into the water, as well as filtering any surface runoff, the overall particulate P loss is reduced. In contrast, much of the nitrogen is dissolved in ground water and travels through the soil without coming into contact with the plant roots.

Pollutant removal in these zones has been attributed to processes of infiltration, deposition, filtration, adsorption, and absorption. These processes can operate concurrently: for example, infiltration of overland flow reduces runoff velocities, thereby encouraging deposition, and also increases soil-water contact, thereby increasing the opportunity for adsorption.

Furthermore, creating shade, particularly at the point where the water meets the stream bank, can reduce germination of weeds and the amount of weed growth across the channel. (MfE, 2001)

ECan under their now discontinued project, Living Streams, produced a document titled *A Companion Guide To Managing Waterways On Canterbury Farms Lowland Plains Streams And Drains*. This recommends initial planting hardy species which will grow quickly on the open lowland plains and fulfil the important riparian functions of providing shade and protecting the instream habitat. Once these initial plantings have established, they will provide shelter to establish some of the less hardy, secondary species. The specific plants are listed in this document.

1.2.4 Targeted Fertilizer and Effluent Application

Precision agricultural technologies allow digital maps to be created to identify areas with separate nutrient demand, and machinery has been developed to allow for a variable application rate based on these maps. These methods can be used to manually avoid fertiliser application to sensitive or low productivity areas. This has the advantage of not only being able to better target nutrient applications but also it will provide detailed fertiliser application rate maps for record keeping.

The timing of fertilizer application is also a very important mechanism to reduce the nutrients lost to the environment. When P fertilizer is applied it is essential that there is sufficient time for the mineral P to breakdown and enter the soil profile, if heavy rain follows the addition of P fertiliser, then there is an increased opportunity for particulate P movement. When applying N fertiliser, consideration needs to be given to the likelihood of drainage and, the plant type and demand for N at the time (season) of application. Some farming practises, such as urea application in early spring, to increase the N reserves in the soil profile, often leads to excess N being leached into shallow groundwater when excess rainfall induces drainage.

The use of technology, such as soil moisture probes can allow for the more efficient use of resources, which ultimately reduces excess nutrients being supplied to the farm.

1.2.5 Nutrient Budgeting

A nutrient budget is a measure of the nutrient balance of a farming operation. It takes into account all nutrient inputs on a farm and all those removed from the land. An accurate nutrient budget is an important tool for avoiding unnecessary applications of plant nutrients. It also allows for better management of farm blocks, for example, it can identify areas that are receiving too much of a particular nutrient from effluent applications, so allowing action to be taken to remedy the situation. Overall, nutrient budgets help ensure that farming practices are conducted in an environmentally sustainable manner. It is expected that most large-scale farms will have OVERSEER^{tm} nutrient budgeting taking place on their property through there fertilizer supplier representative. This software identifies areas where nutrient is being lost and the generated values can be used as a measurable target to reduce nutrient loss.

The P loss from soil, via surface runoff or subsurface flow, is generally proportional to soil P reserves, which is dependent on the cation exchange capacity (CEC) of the soil. Therefore operating on a soil with a CEC outside the optimal range can lead to P loss. Monitoring of this can be done through achieving an optimal soil test P concentration (e.g. Olsen P) with the help of nutrient budgeting software such as OVERSEER^{tm}.

1.2.6 Stream Fencing

Stream fencing often takes place when riparian buffers are established and are very much interrelated. This section includes where bridges or culverts are constructed ove waterways. The main purpose of stream fencing is to exclude stock from waterways through fences and bridges. As animals grazing within a waterway can have many negative effects on a waterway, including bank erosion and providing a direct pathway of phosphorous, nitrogen and bacterial contaminates entering the water way through urine and faecal matter. The fencing of water ways reduces phosphorus loads significantly, but has virtually no impact on nitrogen loads. This is because only a small proportion of nitrogen gets into water through 'direct deposition' of urine. Whereas, direct deposition of faecal matter and the breaking down of banks by stock are important pathways for phosphorus (PCE, 2013).

The Dairy Clean Streams Accord provides a framework to promote sustainable dairy farming in New Zealand (PCE, 2013). It specifies the management requirements for waterways, effluent and wetlands on dairy farms. Compliance with the accord is reported each year. The fencing of waterways is estimated to reduce P loss by 0.5 kg per hectare, and the introduction of appropriate effluent management is estimated to reduce P loss by 1 kg per hectare. Furthermore replacing stock water crossings with bridges/culverts for dairy farms could reduce the P loss by 0.1 kg per hectare (Parfitt *et al*, 2007)

1.2.7 Infrastructure/Capital Investment

As the majority of N loss occurs through urine patches, investment in infrastructure which reduces the time grazing animals spend on land, when drainage is occurring can limit nutrient runoff, particularly nitrogen. As plant nutrient demand reduces in winter, combined with generally higher rainfall levels, winter presents a significant risk period for N loss to shallow groundwater. As any available N in the soil profile, or any N applied to the paddock (i.e. in urine) will not be taken up by pasture growth and will likely leach out in drainage water. Wintering pads are specifically built shelters to house cattle over winter. These cattle spend minimal time grazing on paddock during winter and receive some feed on the wintering pad. Effluent collected off the pad is stored and utilised when plant requirements increase. It is estimated that if farms located on sedimentary soil, installed and used wintering pads, a 15 – 30 percent reduction in P loss, would result (Motu, 2012).

1.2.8 Treatment Wetlands

The filtering functions of natural wetlands and their ability to remove sediments and pollutants from water passing through them are well known (NIWA, 1997). Constructed wetlands are designed to harness processes that occur in natural wetlands for the treatment of wastewaters. These wetlands work in several ways to reduce contaminants associated with agriculture.

- Settling and sedimentation of particulate material (suspended solids) occurs readily in the shallow, slow-flowing waters of wetlands.
- Microscopic organisms (bacteria, fungi, algae, and protozoa) break down organic matter, and mineralise and transform nutrients in the wastewater
- Plants both uptake nutrients for their grass growth as well as enhancing oxygen levels at their root zones, which increase microbial activity.

These wetlands are typically located in low-lying areas so receive both surface runoff and intercept shallow groundwater, therefore are effective in treating both phosphorous and nitrogen. Two types of wetlands can be formed as an approach to reduce agricultural contaminants; constructed wetlands, which require the modification of landscape features such as depressions and gullies to form wetlands; and natural seepage wetlands, which are formed when naturally wet areas are allowed to return to wetland.

Wetlands, depending on factors such as loading rates and layout, can be sinks or sources of P. Sukias (2011) found that P removal was generally poor in wetlands, with twice as much TP exported overall than received in some years, although modest removals of up to 32% occurred in other years. The retention of particulate bound P is usually large via sediment deposition and filtration. However, over time the ability of wetlands to retain particulate bound P decreases as the wetland becomes choked with sediment. Furthermore, as the wetland becomes reductive (anoxic) P in sediment becomes soluble, resulting in dissolved P release (McDowell *et al,* 2013). Therefore it is important that if individual or communal wetlands are installed, they are used in conjunction with other sediment control measures as outline in Section XXX, this will ensure that the wetland will not become inundated in sediment after a large erosion event. In order to ensure that a wetland will act as a sink of particulate P, as opposed to supplying the outflow with dissolved P several methods can be utilised. These include planting and harvesting of wetland plants, which will remove P from the waterways. An adaptation of this would be the inclusion of floating wetlands plants (emergent wetland plants grown hydroponically on floating mats) to remove significant quantities of dissolved P. However, it is also noted that while the regular harvesting and removal of plants growing on wetland sediments may increase P removal from the wetland, unless the biomass has an economic value, harvesting is not a cost-effective strategy (McDowell *et a*l, 2013). A range of P-sorbing materials are potentially suitable for improving P retention in constructed wetlands have been identified, these include: allophanic clays, lime, alum, smelter slag, and some volcanic tephras.

The rates of removal of settleable organics in well-designed wetlands are very high on account of deposition and filtration in subsurface-flow systems. BOD removal rates vary, but usually range from 50% to more than 90%. If both macrophytes and microphytes (such as algae) are harvested as suggested above, good nutrient removal rates can be achieved; if not, as previously stated, nutrients can accumulate and only N is exhausted. P and K concentrations in treated effluent are reduced, but wetlands act to trap any surplus nutrients, ultimately increasing their concentrations. (Dairy Australia, 2008)

Previously remediation works carried out around Lake Ellesmere/Te Waihoraby WET, have utilised Kahihikatea communities that can withstand the salinity of the lake water inundation on lower land. On the raised land on the outside of the wetland totara/matai forest plant community have been successfully planted. Furthermore ECan (2012) recommends certain species that are suitable wetland plants, these are outlined in Table 2, below.

Table 2: Wetland Suitable Plants				
Scientific Name	**Common Name**	**Plant Type**	**Growth Rate**	**Recommended Spacing (m)**
Carex secta	Tussock sedge	Grass	Medium	0.5 - 1
Phormium tenax	Flax; Harakeke	Flax	Medium	1.5 – 2.0
Coprosma propinqua	Mingimingi	Shrub	Medium	1.5 – 2.0
Leptospermum scoparium	Manuka	Small tree	Fast	1.5 – 2.0
Dacrycarpus dacrydioides	Kahikatea	Tall Tree	Slow	2.0
Elaeocarpus hookerianus	Pokaka	Tree	Slow	2.0
Notes:				

1.3 Farm Environmental Plans

A farm environmental plan (FEP) is a plan which ensures that a farming operation is operating with environmental responsibility and incorporating industry 'best management practises', as stated above. Therefore FEP's will vary between different farm types and different localities and operations. The minimum requirements of a FEP, prepared for consent compliance purposes, are outlined in Schedule 7 of Environment Canterbury's proposed Land and Water Regional Plan (pLWRP), attached in Appendix XX. In general, the plan will be required to identify and map key areas of the farm, outline the risks associated with major farming activities and describe how these risks will be/are managed. It may also require measurable targets for a variety of management objectives to be set. Overseer budgeting is also required to be a undertaken. The plan shall take into account all sources of nutrients used for the farming activity and identify all relevant nutrient management practices and mitigation measures.

Specifically these plans will outline how the below management objectives will be met. The plan shall include for each management objective a user defined measurable targets that clearly set a pathway and timeframe for achievement of the objective, a description of the BMP's required to achieve the objective and targets and allow for the records for measuring performance and achievement of the target to be kept.

- **Nutrient management**: To maximise nutrient use efficiency while minimising nutrient losses to water in order to meet specified nutrient allowances.
- **Irrigation management**: To operate irrigation systems that are capable of applying water efficiently and management that ensures actual use of water is monitored and is efficient.
- **Soils management**: To maintain or improve the physical and biological condition of soils in order to minimise the movement of sediment, phosphorus and other contaminants to waterways.
- **Wetlands and riparian management**: To manage wetland and waterway margins to avoid damage to the bed and margins of a water body, avoid direct input of nutrients, and to maximise riparian margin nutrient filtering.
- **Collected animal effluent management**: To manage the risks associated with the operation of effluent systems to ensure effluent systems are compliant 365 days of the year.
- **Livestock management**: To manage wetlands and water bodies so that stock are excluded as far as practicable from water, to avoid damage to the bed and margins of a water body, and to avoid the direct input of nutrients, sediment and microbial pathogens.

As these FEP will vary from property to property depending on the exact activities taking place, it is considered best practise to individually prepare a unique FEP for each property.

1.4 Conclusion

Through the implementation of FEP and the specific BMP, win–win outcomes are often achieved whereby nutrient/contamination losses are reduced, whilst on farm spending and efficiency are also improved. Each individual farm could develop a comprehensive, individual FEP, suited to their farming operation and environment. These FEP's will allow for goals to be set, and progress tracked. Each FEP will consist of various BMP's which will be developed, or their current use highlighted to ensure that each farm is being operated to a high environmental standard. A catchment-wide collaborative environmental approach, will allow for knowledge, costs and methods to be shared, and the key contaminants of phosphorous, conductivity, total suspended solids (TSS) and high organic matter to be focussed on in a catchment wide scale. It is advisable that the FEP are implemented prior, or soon after, the treated mitigation measures near the pumphouse are installed, to minimise the contaminant build up and enforce the catchment wide approach for improving the water quality exiting Osborne drain.

BMP such as targeted use of irrigation water and fertiliser, shed effluent management, and stock exclusion from waterways generally reduce losses of nitrogen by up to 20% (PCE, 2013) The addition of large capital-intensive mitigation methods, such as stand-off pads, wintering barns and artificial wetlands as well as good management practices can reduce losses of nitrogen by up to 50% (PCE, 2013).

Many of the mitigations methods that target reductions in total P are projected to deliver reductions in P loss from farms of between 28% and 52% (Monaghan, 2006). This is mainly due to the reduction in sediment transport and erosion, which is delivered to waterways as particulate P. Furthermore, sediment trapping and detention practises, such as buffer strips, sediment ponds and riparian plantings are capable of reducing TSS loads by up to 90%. The reduction in surface runoff and the exclusion of stock from waterways also reduces microbial contamination entering waterways

Many of these BMP's provide improved conditions for aquatic life, either through contamination reduction or habitat construction. Riparian zones provide shading and terrestrial food source for aquatic species as well as increasing DO and lowering water temperature.

Schedule 7 - Farm Environment Plan

A Farm Environment Plan shall be prepared by a person with the appropriate professional qualifications. The plan shall take into account all sources of nutrients used for the farming activity and identify all relevant nutrient management practices and mitigation measures.

The plan requirements will apply to:

1. a plan prepared for an individual property; or
2. a plan prepared for an individual property which is part of a collective of properties, including an irrigation scheme, an Industry Certification Scheme, or catchment club.

Plan requirements

The farm environment plan must clearly identify how when the assigned industry 'good practices' and/or property nutrient allowances will be achieved. The plan shall contain as a minimum:

1. Property details
   (a) Physical address
   (b) Description of the ownership and name of a contact person
   (c) Legal description of the land and farm identifier

2. A map(s) or aerial photograph at a scale that clearly shows:
   (a) The boundaries of the property
   (b) The boundaries of the main land management units on the property.
   (c) The location of permanent or intermittent rivers, streams, lakes, drains, ponds or wetlands.
   (d) The location of riparian vegetation and fences adjacent to water bodies.
   (e) The location of storage facilities, offal or refuse disposal pits, feeding or stock holding areas, effluent blocks, raceways, tracks and crossings.
   (f) The location of any areas within or adjoining the property that are identified in a District Plan as "significant indigenous biodiversity".

3. An assessment of the risks to water quality associated with the major farming activities on the property and how the identified risks will be managed.

4. A description of how each of the following management objectives will, where relevant, be met.
   (a) ***Nutrient management:*** To maximise nutrient use efficiency while minimising nutrient losses to water in order to meet specified nutrient allowances.
   (b) ***Irrigation management:*** To operate irrigation systems that are capable of applying water efficiently and management that ensures actual use of water is monitored and is efficient.
   (c) ***Soils management:*** To maintain or improve the physical and biological condition of soils in order to minimise the movement of sediment, phosphorus and other contaminants to waterways.
   (d) ***Wetlands and riparian management:*** To manage wetland and waterway margins to avoid damage to the bed and margins of a water body, avoid direct input of nutrients, and to maximise riparian margin nutrient filtering.
   (e) ***Collected animal effluent management:*** To manage the risks associated with the operation of effluent systems to ensure effluent systems are compliant 365 days of the year.
   (f) ***Livestock management:*** To manage wetlands and water bodies so that stock are excluded as far as practicable from water, to avoid damage to the bed and margins of a water body, and to avoid the direct input of nutrients, sediment, and microbial pathogens.

   The plan shall include for each management objective;
      (i) user defined measurable targets that clearly set a pathway and timeframe for achievement of the objective
      (ii) a description of the good management practices together with actions required to achieve the objective and targets.
      (iii) the records for measuring performance and achievement of the target.

5. Nutrient budgets are prepared using the OVERSEER™ nutrient budget model, for each of the identified land management units and the overall farm.

Appendix J

Planning

Table A. Summary of Possible Regional Rules and Planning Classifications for Proposed Mitigation Activities for Osborne's Drainage Scheme

For the purpose of this assessment, Osborne Drain is classified as an artificial watercourse as it has no stream history. It is located above the Coast Confined Gravel Aquifer System.

Relevant Plans – NRRP [operative as of June 2011] and pLWRP [notified as of 11 August 2012, and amended (to be notified on 18 January 2014)] rules. Activity status under both the NRRP and pLWRP need to be determined and where the NRRP and pLWRP classify the activities differently the more conservative classification should apply.

<table>
<tr><th rowspan="2">Improvement Measure</th><th rowspan="2">Activity</th><th colspan="2">NRRP [operative]</th><th colspan="2">pLWRP [notified]</th><th colspan="2">pLWRP [amended]</th></tr>
<tr><th>Rule</th><th>Tentative Classification and Rational</th><th>Rule</th><th>Tentative Classification and Rational</th><th>Rule</th><th>Tentative Classification and Rational</th></tr>
<tr><td rowspan="2">Remove the accumulated sediment from the lagoon upstream of the pump station.</td><td rowspan="2">Land Use</td><td>WQL36</td><td>This rule only applies to the excavation of >100 m^3 of material in any 12 month period. Given the small volume of sediment that needs to be removed from the lagoon (<<100 m^3), then this rule does not apply and the activity does not require resource consent.</td><td>5.157
5.158</td><td>The use of land to excavate material is a discretionary activity under Rule 5.158 as it does not comply with Condition 2 of Rule 5.157 (i.e. excavation is within 50 m of the bed of a permanently flowing river (the Halswell), lake, or wetland boundary).</td><td>5.175</td><td>The use of land to excavate material is a permitted activity as less than 100 m^3 of material is to be excavated within 50 m of a river, lake, or wetland boundary, and all other conditions are met.</td></tr>
<tr><td></td><td>Deposition of sediment over a confined aquifer does not trigger any regional rules.</td><td>5.150</td><td>Site is located within Area LH2 (high soil erosion risk) of Planning Maps. The use of land outside any riparian margin for earthworks where the volume is less than 10 m^3 per site or per hectare and the maximum depth of cut or fill is less than 0.5 m, is a permitted activity if conditions are met, or a restricted discretionary activity if not.

Note: the term 'earthworks' applies to both excavation and deposition of sediment.</td><td></td><td>This area is now classified as having a low to moderate soil erosion risk.</td></tr>
<tr><td>Remove all accumulated sediment for the entire length of Osborne Drain.</td><td>Land Use</td><td></td><td>Same rules and activity status apply as above.</td><td></td><td>Same rules and activity status apply as above.</td><td></td><td>Same rules and activity status apply as above.</td></tr>
</table>

Base flow augmentation: use of local artesian bores to provide constant flow and installation of 'low flow' pump in the pump station. Note: the installation of a 'low flow' pump in a pump station does not require resource consent.	Land Use	WQL31	Construction of a groundwater bore is a ***restricted discretionary*** activity. Rule WQL31 only applies if new bores are to be constructed for this mitigation purpose; if existing bores are to be utilized then this rule does not apply.	5.78	The use of land for the installation, maintenance and use of a bore is a ***permitted*** activity, provided all conditions are met.	5.103	The use of land for the installation, maintenance and use of a bore is a ***permitted*** activity, provided all conditions are met.
		WQL32	The use and maintenance of a groundwater bore is a ***permitted*** activity, provided all conditions are met.				
	Abstraction	WQN9	Taking and using of water from groundwater, in small quantities not exceeding 5 L/s and 10 m³/day, is ***permitted***, provided all conditions are met. OR, if exceeds this:	5.86	The taking and using of less than 5 L/s and 10 m³ per day of groundwater is ***permitted*** activity, provided all conditions are met. OR, if exceeds this:	5.113	The taking and using of less than 5 L/s and 10 m³ per day of groundwater is ***permitted*** activity, provided all conditions are met. OR, if exceeds this:
		WQN10	Taking and using of water from groundwater, in small quantities not exceeding 100 m³/day is a ***restricted discretionary*** activity.	5.87	The taking and using of less than 5 L/s and more than 10 m³ but less than 100 m³ per day of groundwater is a ***permitted*** activity, provided all conditions are met.	5.114	The taking and using of less than 5 L/s and more than 10 m³ but less than 100 m³ per day of groundwater is a ***permitted*** activity, provided all conditions are met.
		WQN11	Taking of water from groundwater for bore development and pumping tests is a ***permitted*** activity, provided all conditions are met. If required.	5.82	The taking of groundwater for the purpose of carrying out bore development or pumping tests, and the associated use and discharge of that water is a ***permitted*** activity, provided all conditions are met. If required.	5.109	The taking of groundwater for the purpose of carrying out bore development or pumping tests, and the associated use and discharge of that water is a ***permitted*** activity, provided all conditions are met. If required.
	Discharge	WQL1	The discharge of water into an artificial watercourse which may result in water entering a lake is a ***permitted*** activity, provided all conditions are met.		No applicable regional rules.		No applicable regional rules.
		WQL2	The discharge of bore development water into an artificial watercourse which may result in water entering a lake is a ***permitted*** activity, provided all conditions are met.				

Use of a recirculation pump where water is pumped from the pump house to a location upstream and continually recirculated.	Land Use	WQL36	This rule only applies to the excavation of >100 m^3 of material in any 12 month period. It is assumed that the volume of material needed to be excavated to allow the installation of the pipeline will be <100 m^3 and therefore Rule WQL36 will not apply and the activity ***does not require resource consent***. Should conditions change to require >100 m^3 of material to be excavated, the activity will be a ***non-complying*** activity (as the excavation will be within 50 m of the Halswell River, and the wetland boundary).	5.114 5.118	The drilling, tunneling, or disturbance in or under the bed or a river and the installation, and maintenance of pipes is a ***permitted*** activity, provided all conditions are met. Temporary structures and diversions associated with undertaking activities in Rule 5.114 are ***permitted*** activities	5.136 5.140	The drilling, tunneling, or disturbance in or under the bed or a river and the installation, and maintenance of pipes is a ***permitted*** activity, provided all conditions are met. Temporary structures and diversions associated with undertaking activities in Rule 5.136, and artificial watercourses, are ***permitted*** activities
				5.157 5.158	The use of land to excavate material is a ***discretionary*** activity under Rule 5.158 as it does not comply with Condition 2 of Rule 5.157 (i.e. excavation is within 50 m of the bed of a permanently flowing river (the Halswell), lake, or wetland boundary).	5.175 5.176	The use of land to excavate material is a ***permitted*** activity as less than 100 m^3 of material is to be excavated within 50 m of a river, lake, or wetland boundary, and all other conditions are met. Should conditions change to require >100 m^3 of material to be excavated, the activity will be a ***restricted discretionary*** activity under Rule 5.176.
	Abstraction and Discharge			5.99	The taking and use of water from an artificial watercourse and discharge of the same water to the same artificial watercourse is a ***restricted discretionary*** activity, provided all conditions are met.	5.126	The non-consumptive taking and use of water from an artificial watercourse and discharge of the same water to the same artificial watercourse is a ***restricted discretionary*** activity, provided all conditions are met.
Use of an aerator to prevent anoxic/stagnant conditions in the drain.			Note: the aerator will be located in the lagoon upstream of the pump house. No applicable regional rules.		No applicable regional rules.		No applicable regional rules.
Construction of weir(s) directly upstream of the pump station.		WQN23	Damming and/or diverting of water in an artificial watercourse is a ***permitted*** activity, provided all conditions are met.		No applicable regional rules.		No applicable regional rules.

Implementation of farm management plans to achieve water quality standards in the drainage water.			No applicable regional rules. However, rules may apply to activities set out in farm management plans.		No applicable regional rules. However, rules may apply to activities set out in farm management plans.		No applicable regional rules. However, rules may apply to activities set out in farm management plans.

Table B. Summary of Possible Sub-regional Regional Rules and Planning Classifications for Proposed Mitigation Activities for Osborne's Drainage Scheme			
Variation 1 to the Proposed Land and Water Regional Plan – Section 11 Selwyn Waihora First Schedule Consultation (20 September 2013). This variation contains sub-regional rules specific the Selwyn Waihora subregion. Please note that the document is under consultation has not yet been notified. Where there are no relevant sub-regional rules, the activity is assessed under the relevant regional rule. For the purpose of this assessment, Osborne Drain is classified as an artificial watercourse as it has no stream history. It is located above the Coast Confined Gravel Aquifer System.			
Mitigation Measure	**Activity**	**Variation 1 Section 11 Selwyn-Waihora**	
		Rule	**Tentative Classification and Rationale**
Remove the accumulated sediment from the lagoon upstream of the pump station.	Land Use/Discharge	11.6.36 to 11.6.37	These rules apply to fine sediment removal from rivers and streams only (not artificial watercourses), and therefore there are no additional proposed sub-regional rules relevant for this activity.
Remove all accumulated sediment for the entire length of Osborne Drain.	Land Use/Discharge	11.6.36 to 11.6.37	These rules apply to fine sediment removal from rivers and streams only (not artificial watercourses), and therefore there are no additional proposed sub-regional rules relevant for this activity.

Base flow augmentation: use of local artesian bores to provide constant flow and installation of 'low flow' pump in the pump station. Note: the installation of a 'low flow' pump in a pump station does not require resource consent.	Abstraction	11.6.18 to 11.6.20	Taking and using of water from groundwater, in small quantities not exceeding 5 L/s and 100 m³/day, is ***permitted***, provided all conditions are met. (11.6.18 and 11.6.19) OR, if exceeds this: Taking and using of water from groundwater, in small quantities not exceeding 100 m³/day is a ***restricted discretionary*** activity.(11.6.2)) These rules will prevail over the regional rules.
	Discharge	11.6.28	The discharge of water into water for the purpose of enhancement stream flows for environmental benefit within the Selwyn-Waihora catchment is a ***discretionary*** activity, as the discharge will greater than 5 years and is not from Rakaia or Waimakariri rivers.
Use of a recirculation pump where water is pumped from the pump house to a location upstream and continually recirculated.	Discharge	11.6.28	The discharge of water into water for the purpose of enhancement stream flows for environmental benefit within the Selwyn-Waihora catchment is a ***discretionary*** activity, as the discharge will greater than 5 years and is not from Rakaia or Waimakariri rivers.

Use of an aerator to prevent anoxic/stagnant conditions in the drain.			No applicable sub-regional rules.
Construction of weir(s) directly upstream of the pump station.			No applicable sub-regional rules.
Implementation of farm management plans to achieve water quality standards in the drainage water.			No applicable sub-regional rules which required consent to implement a farm management. However, there are land use rules contained in this section which reference farm management plans (Rules 11.6.1 to 11.6.8)

Table C. Summary of Relevant Policies for Proposed Mitigation Activities for Osborne's Drainage Scheme

Relevant Management Plans for consideration – Te Taumutu Runanga Natural Resource Management Plan (2003), Te Waihora Joint Management Plan (2005) and Mahaanui Iwi Management Plan (2103).

Osborne Drain is located within the JMP area.

Mitigation Measure	Te Taumutu Runanga Natural Resource Management Plan (2003)		Te Waihora Joint Management Plan (2005)		Mahaanui Iwi Management Plan (2103)	
	Section	Relevant Policies	Section	Relevant Policies	Section	Relevant Policies
Remove the accumulated sediment from the lagoon upstream of the pump station.	4.4.1 Water quality in Te Waihora	2, 4, 6	4.2 Water Nga wai	4.2.1, 4.2.3. 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
			7.1 Commercial activities Nga mahi arumoni	7.1.3		
	4.4.5 Te Waihora tributaries	1, 11	7.2 Other activities Nga mahi ke	7.2.1	6.11 Te Waihora Cultural Health of Te Waihora	TW4.3, TW4.8
			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2, TW7.5, TW7.7
Remove all accumulated sediment for the entire length of Osborne Drain.	4.4.1 Water quality in Te Waihora	2, 4, 6	4.2 Water Nga wai	4.2.1, 4.2.3. 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
			7.1 Commercial activities Nga mahi arumoni	7.1.3		
	4.4.5 Te Waihora tributaries	1, 11	7.2 Other activities	7.2.1	6.11 Te Waihora	TW4.3, TW4.8

			Nga mahi ke		Cultural Health of Te Waihora	
			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2, TW7.5, TW7.7
Base flow augmentation: use of local artesian bores to provide constant flow and installation of 'low flow' pump in the pump station.	4.4.1 Water quality in Te Waihora	1, 2, 4, 6	4.2 Water Nga wai	4.2.1, 4.2.3. 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
			7.1 Commercial activities Nga mahi arumoni	7.1.3	6.11 Te Waihora Cultural Health of Te Waihora	TW4.3, TW4.8
	4.4.5 Te Waihora tributaries	1, 9, 11	7.2 Other activities Nga mahi ke	7.2.1	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2, TW7.5, TW7.7
			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6		
Use of a recirculation pump where water is pumped from the pump house to a location upstream and continually recirculated.	4.4.1 Water quality in Te Waihora	2, 4, 6	4.2 Water Nga wai	4.2.1, 4.2.3. 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
			7.1 Commercial activities Nga mahi arumoni	7.1.3		
	4.4.5 Te Waihora tributaries	1, 9, 11	7.2 Other activities Nga mahi ke	7.2.1	6.11 Te Waihora Cultural Health of Te Waihora	TW4.3, TW4.8

			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2, TW7.5, TW7.7
Use of an aerator to prevent anoxic/stagnant conditions in the drain.	4.4.1 Water quality in Te Waihora	2, 4, 6	4.2 Water Nga wai	4.2.1, 4.2.3. 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
			7.1 Commercial activities Nga mahi arumoni	7.1.3		
	4.4.5 Te Waihora tributaries	1, 9, 11	7.2 Other activities Nga mahi ke	7.2.1	6.11 Te Waihora Cultural Health of Te Waihora	TW4.3, TW4.8
			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2, TW7.5, TW7.7
Construction of weir(s) directly upstream of the pump station.	4.4.1 Water quality in Te Waihora	2, 4, 6	4.2 Water Nga wai	4.2.1, 4.2.3. 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
			7.1 Commercial activities Nga mahi arumoni	7.1.3		
	4.4.5 Te Waihora tributaries	1, 9, 11	7.2 Other activities Nga mahi ke	7.2.1	6.11 Te Waihora Cultural Health of Te Waihora	TW4.3, TW4.8

			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2, TW7.5, TW7.7
Implementation of farm management plans to achieve water quality standards in the drainage water.	4.4.1 Water quality in Te Waihora	4, 6	4.2 Water Nga wai	4.2.1, 4.2.4	6.11 Te Waihora Te Waihora Joint Management Plan	TW3.1
	4.4.5 Te Waihora tributaries	11	7.1 Commercial activities Nga mahi arumoni	7.1.3, 7.1.4	6.11 Te Waihora Cultural Health of Te Waihora	TW4.3, TW4.8
			7.3 Research and monitoring Rangahau me te aroturuki	7.3.6	6.11 Te Waihora Cultural Health of Lowland waterways and groundwater	TW7.1, TW7.2

Table D. Summary of Relevant ZIP Addendum Recommendations for Proposed Mitigation Activities for Osborne's Drainage Scheme		
Selwyn- Waihora Zone Implement Programme (ZIP) Addendum (August 2013)		
Mitigation Measure	Selwyn- Waihora Zone Implement Programme (ZIP) Addendum	
	Section	**Recommendation**
Remove the accumulated sediment from the lagoon upstream of the pump station.	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1
	4.4 Improved drain management	Recommendation 4.4
	4.6 Sediment management	Recommendation 4.6
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
Remove all accumulated sediment for the entire length of Osborne Drain.	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1
	4.4 Improved drain management	Recommendation 4.4
	4.6 Sediment management	Recommendation 4.6
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
Base flow augmentation: use of local artesian bores to provide constant flow and installation of	2.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 2.1
	2.12 Managed recharge of water to groundwater and targeted stream augmentation for environmental benefit	Recommendation 2.12
	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1

'low flow' pump in the pump station.	4.4 Improved drain management	Recommendation 4.4
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
Use of a recirculation pump where water is pumped from the pump house to a location upstream and continually recirculated.	2.12 Managed recharge of water to groundwater and targeted stream augmentation for environmental benefit	Recommendation 2.12
	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1
	4.4 Improved drain management	Recommendation 4.4
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
Use of an aerator to prevent anoxic/stagnant conditions in the drain.	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1
	4.4 Improved drain management	Recommendation 4.4
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
Construction of weir(s) directly upstream of the pump station.	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1
	4.4 Improved drain management	Recommendation 4.4
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
Implementation	4.1 Catchment interventions are essential to meet ZIP outcomes	Recommendation 4.1

of farm management plans to achieve water quality standards in the drainage water.	4.4 Improved drain management	Recommendation 4.4
	5.1 Regular review of progress in relation to water quantity outcomes, and revision, if required, of sub-regional section and work programmes	Recommendation 5.1
	5.3 Nitrogen loads from agriculture	Recommendation 5.3
	5.4 Managing nitrogen load – expectation of existing users	Recommendation 5.4
	5.5 Managing to nitrogen lad target at the property level	Recommendation 5.5
	5.8 Audited Farm Environment Plans	Recommendation 5.8

Appendix K

Floating Treatment Wetlands

Floating Treatment Wetlands

Although Osborne Drain water quality is degraded, there is a lot of potential for improvement, particularly with regards to catchment management, reducing contaminants entering waterways and removing historic contamination. Utilising the already degraded area above the pumphouse for treatment of contaminants would be recommended as opposed to using the receiving wetland (which currently appears to be unintentionally occurring). Utilising natural systems such as the efficiently of plants to bind and process nutrients, sedimentation, aid cooler water temperatures and provide instream habitat and food resource for fauna is advisable were practicable.

Construction of specific treatment wetlands is discussed in Appendix I. An alternative to these are Floating Treatment Wetlands (FTW). These are an innovative tool for nutrient management in lentic systems which integrate the nutrient attenuation capabilities of wetlands with the flexibility of deeper pond systems. They comprise of emergent aquatic plants growing on tethered buoyant mats or rafts on the water surface (Figure 1). The suspended media provide a large surface area of active substrate for pollutant-digesting microbes and bacteria to bio-remediate (use of micro-organisms to remove pollutants) eutrophic waters, heavy metals or suspended solids. The floating media can be used in a variety of water environments requiring treatment (Headley and Tanner 2007).

There are several case studies on the use of FTW for municipal wastewater, industrial wastewater, stormwater treatments and results are self-explanatory (Headley and Tanner 2007).

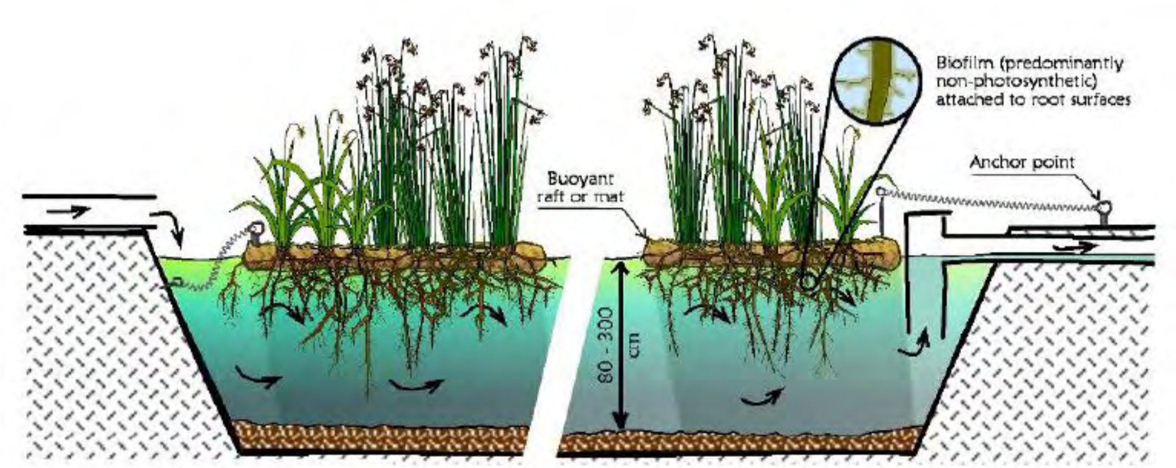

Figure 1. Cross section of FTW in a treatment pond (from Headley and Tanner 2011).

In a case study presented by Waterclean Technologies (www.waterclean.co.nz), utilisation of FTW enabled significant removal of key water quality parameters of concern from wastewater. For example 57% of total nitrogen and 70% of total phosphorus concentrations were removed after wastewater was passed through FTW. Although this example is not directly related to the proposed scenario, given the more varied flow rates expected (from stagnant to flood flow), the results do however show that significant reduction of nitrogen and phosphorus species is possible using the FTW systems. As a result of the varied flow through the Osborne Drain, the level of treatment that can be expected will also vary depending on the retention time. During low flow conditions (i.e. stagnant), aeration and recirculation would be required to ensure the water passes through the media. As such, the design of the aeration / recirculation system in the proposed improvement measures should consider the possibility of FTW being installed.

It is envisaged that the mats /rafts would be secured to the banks of the Osborne Drain and as they float they rise to allow flood water to pass beneath and then lower again into the normal operating position.