Department of Conservation

Fonterra

Living Water:

Collation of Baseline Environmental Data for the Lake Areare Catchment

KesselsEcology
SURVEY, ASSESSMENT AND RESTORATION

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EXECUTIVE SUMMARY

This report outlines and collates existing data about the Lake Areare catchment for the Living Water Partnership peat lakes project. The report's purpose is to inform future decisions on lake and catchment management by providing a collation of existing data and identifying gaps that may need to be remedied. Catchment data will then be used for hydrological modelling and to assist in determining the most effective restoration actions for the ecosystem. The report covers water quality, hydrology, biodiversity, climate and resource use.

The lake Areare catchment is on the margins of the historic Kainui peat bog in the Horsham Downs area of the Waikato. Like much of lowland Waikato the catchment has been heavily modified since human settlement. Virtually all of the indigenous vegetation cover has been cleared for pasture and the peat bog has been drained to allow conversion to pastoral farming. The water quality in Lake Areare is poor and can currently be classed as Supertrophic but plans are in place to install infiltration wetlands on all inflowing waterways and a considerable amount of restoration work has already been done to restore wetland habitat around the lake and the Living Water project will be part of an expansion of the project to take in catchment-wide management of nutrients and sediment in association with private landowners.

While a considerable amount of restoration work has been done in the catchment there are still gaps in the knowledge which will need to be rectified so that future management decisions can be based on sound data. Areas where additional information may be required include lake and catchment hydrology and aquatic biodiversity. Of particular importance will be establishing the status of the pest fish populations so that these can be effectively managed. Gaps in the data on water quality have already been identified by the Department of Conservation and Waikato Regional Council began a 2-monthly monitoring programme in 2014.

1 INTRODUCTION & SCOPE

1.1 The Living Water Partnership

The Living Water Partnership is a collaboration between the Department of Conservation and Fonterra to protect and enhance sensitive water catchments beyond normal on-farm commitments. It recognises the importance of healthy waterways for their intrinsic natural value, biodiversity value and for the ecosystem services they provide. The partnership coordinates a $20 million community investment fund and is initially focusing on five key catchments or project areas across New Zealand. One of these project areas comprises the three peat lake catchments of Areare, Rotomanuka, and Ruatuna in the Waikato.

1.2 Scope

This report deals solely with the Lake Areare catchment and provides a summary of environmental information available for the catchment. Its purpose is to inform future decisions on lake and catchment management by collating existing data and identifying gaps that may need to be remedied. Catchment data will then be used for modelling and to assist in determining the most effective restoration actions for the ecosystem. The report covers water quality, hydrology, biodiversity, climate and resource use.

1.3 Data Availability

Although the catchment has not been as intensively studied as other peat lake catchments in the region there is a reasonable quantity of good quality data to form the basis of of future data gathering and monitoring programmes. Waikato Regional Council holds water quality, lake level and temperature data for Lake Areare derived from historic reports and one-off projects but more recently from a dedicated monitoring programme. A regular water quality monitoring programme was begun by WRC in 2014. Rainfall data is available for the catchment from a site to the southeast at Horsham Downs but the nearest site from which to access other climate data (temperature, frost days, sunshine hours etc.) is Ruakura.

Very good information is available on the state of terrestrial habitats and biodiversity around Lake Areare and an Action Plan and a Habitat Enhancement Plan have been developed (Wildland Consultants 2012; Reeves 2013). Information on aquatic biodiversity is more scarce, with little information on pest fish, invertebrates or algal diversity which was last surveyed in 1980 (Town 1980). Areare has been included in the LakeSPI programme but has not been surveyed for a number of years (Burton *et. al.* 2014). A very useful summary of the values and characteristics of Lake Areare and all other shallow lakes in the region is provided by Dean-Spiers *et. al.* (2014).

2 CATCHMENT DESCRIPTION

The Lake Areare catchment is located approximately 3.5 km east of Ngaruawahia in the Waikato District and is within the Hamilton Ecological District (Figure 1). The catchment is approximately 263 ha in size and comprises flat peatlands in the centre and south of the catchment and low hills to the north and west. Lake Areare occupies an area of approximately 32 ha at the northern end of the catchment and was likely formed by a small valley being blocked by debris from a historic course of the Waikato River sometime after 19,000 years ago when the river abandoned its course through the Hinuera valley to enter the Hamilton Basin (McGraw 2002). The flat peatlands which make up the southern part of the catchment are part of the historic Kainui peat bog (Figure 2). The catchment covers a

small altitudinal range of just 44 m from 22.5 m above sea level (Moturiki datum) at the Lake Areare outlet to 66.5 m at the far western edge of the catchment adjacent to Driver Road.

The catchment has recently been bisected by the new Ngaruawahia section of the Waikato Expressway which opened in December 2013. This four lane road discharges stormwater into the drains entering Areare but an infiltration wetland was built to offset the effects of additional runoff.

Lake Areare is part of the Horsham Downs Wildlife Management Reserve and is also listed in Section 3.7.7 of the Regional Plan as a wetland to which certain restrictions relating to drainage apply.

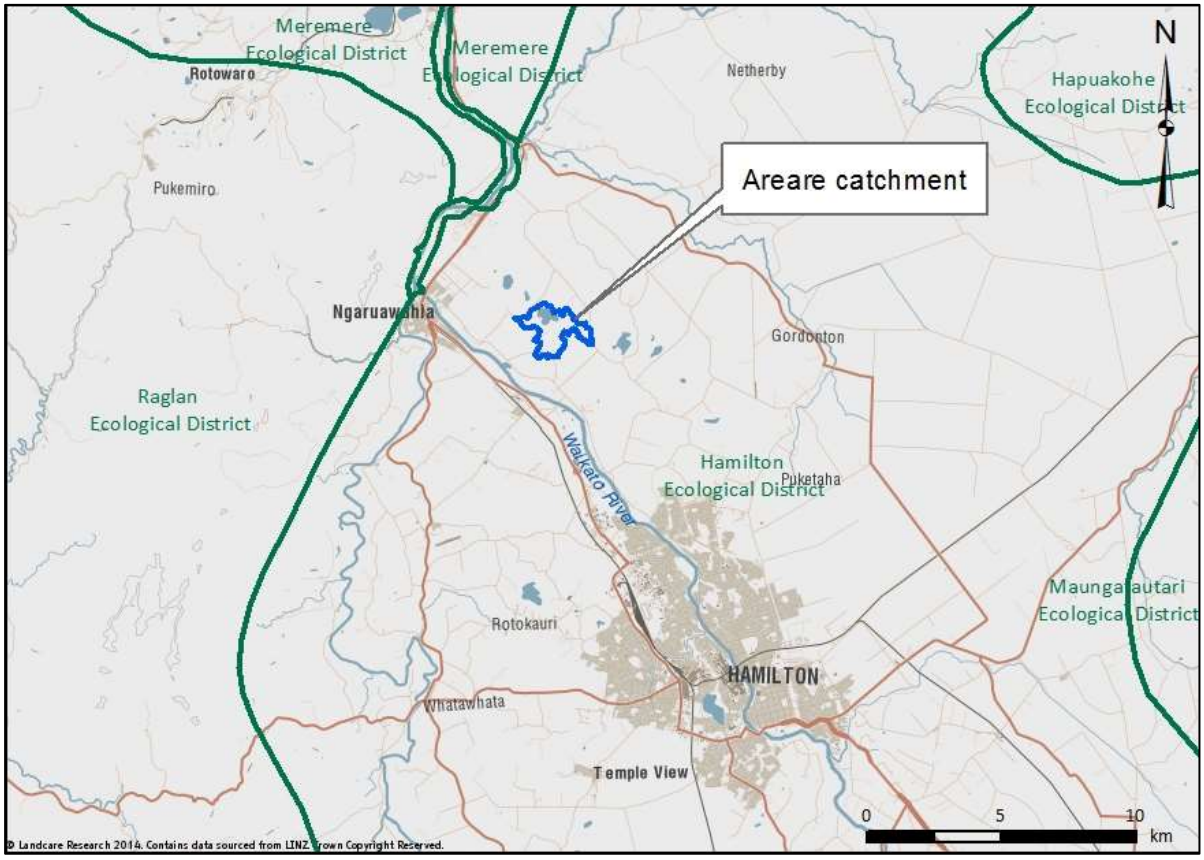

Figure 1: Location of the Areare catchment and surrounding Ecological Districts.

3 SOILS

Six different soil types have been mapped within the Areare catchment (Table 1). The soils of the flat lands around Lake Areare, and in the south and east of the catchment comprise predominantly Kaipaki loamy peat with smaller components of Te Rapa loamy peat and Ardmore peat. These soils are poorly drained and exhibit high structural vulnerability and moderate vulnerability to phosphorus leaching (S-Map 2015). Peat soil has very low bulk density (i.e. small amount of dry matter for the volume) and low mineral content (Environment Waikato 2006) and its structural vulnerability is manifested in the characteristic oxidisation and shrinkage when the water table is lowered or the soil is heavily pugged. If poorly managed peat tends to shrink until it catches up with the water table and again becomes waterlogged, after which drains need to be deepened. Peat soils are valuable to farming and if sensibly managed they can be sustained.

Kohuratahi loam covers the central ridge immediately south of the lake and occurs in small patches to the west of the lake. This soil is prone to erosion and water logging and has very

high vulnerability to nitrogen leaching. The upper slopes to the north and east of the lake are covered with Kainui silty loam over a clay base. This soil has moderate structural vulnerability and low nitrogen leaching vulnerability. Areas of Rotokauri loam occur adjacent to peat soils in several areas. Like the peat this soil is poorly drained and is moderately vulnerable to phosphorus leaching (S-Map 2015).

Table 1: Nutrient and water management characteristics of soils in the Areare catchment. Data from S-Map (Landcare Research and WRC).

	Ardmore Peat	**Kaipaki Loamy Peat**	**Te Rapa Loamy Peat over Clay**	**Kohuratahi Loam**	**Kainui Silty Loam over Clay**	**Rotokauri Loam over Clay**
Soil Sibling code (refer map)	Ardm_2.1	Kaip_2.1	Terap_1.1	Kohur_10.1	Kainu_2.1/Kainu_3.1	Rkaur_2.1
Soil classification (NZSC)	Acid Fibric Organic Soil	Mellow Mesic Organic Soil	Peaty Orthic Gley Soil	Pallic Orthic Brown Soil	Podzolic Yellow Ultic Soil	Typic Acid Gley Soil
Area in catchment (ha)	1.82	104.14	8.87	66.58	32.44	15.02
% of mapped catchment	0.8%	45.5%	3.9%	29.1%	13.7%	6.6%
Erodibility	Minimal	Minimal	Slight	Moderate	Slight	Slight
Structural vulnerability	Very High	Moderate	Very High	High	Moderate	Low
Water logging vulnerability	Medium	High	High	High	Low	High
Drought vulnerability	Low	Low	Low	Moderate	Low	Low
N leaching vulnerability	Very Low	Very low	Very Low	High	Low	Very Low
P leaching vulnerability	Medium	Medium	Medium	Low	--	Medium
Dairy effluent (FDE) risk category	C if >7°, otherwise B	C if >7°, otherwise B	C if >7°, otherwise B	C if >7°, otherwise B	C if >7°, otherwise D	C if >7°, otherwise B
Relative runoff Potential	Medium	Medium	Low	High	Low	Medium

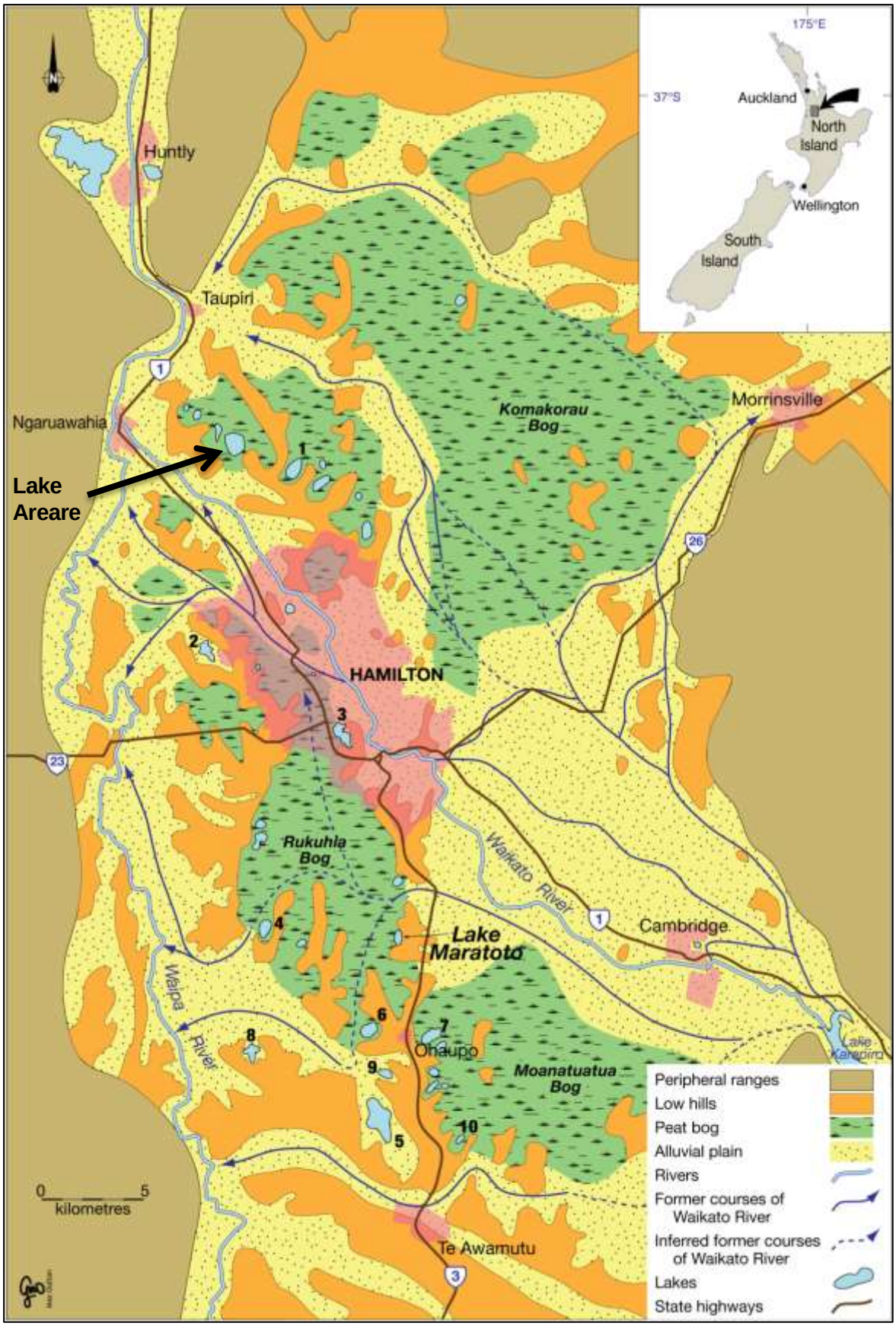

Figure 2: Landscape features of the Hamilton basin and the extent of peat bog soils. Areare is located within the Kainui peatlands to the east of Ngaruawahia. Figure by DJ Lowe (2010) after McGraw 2002.

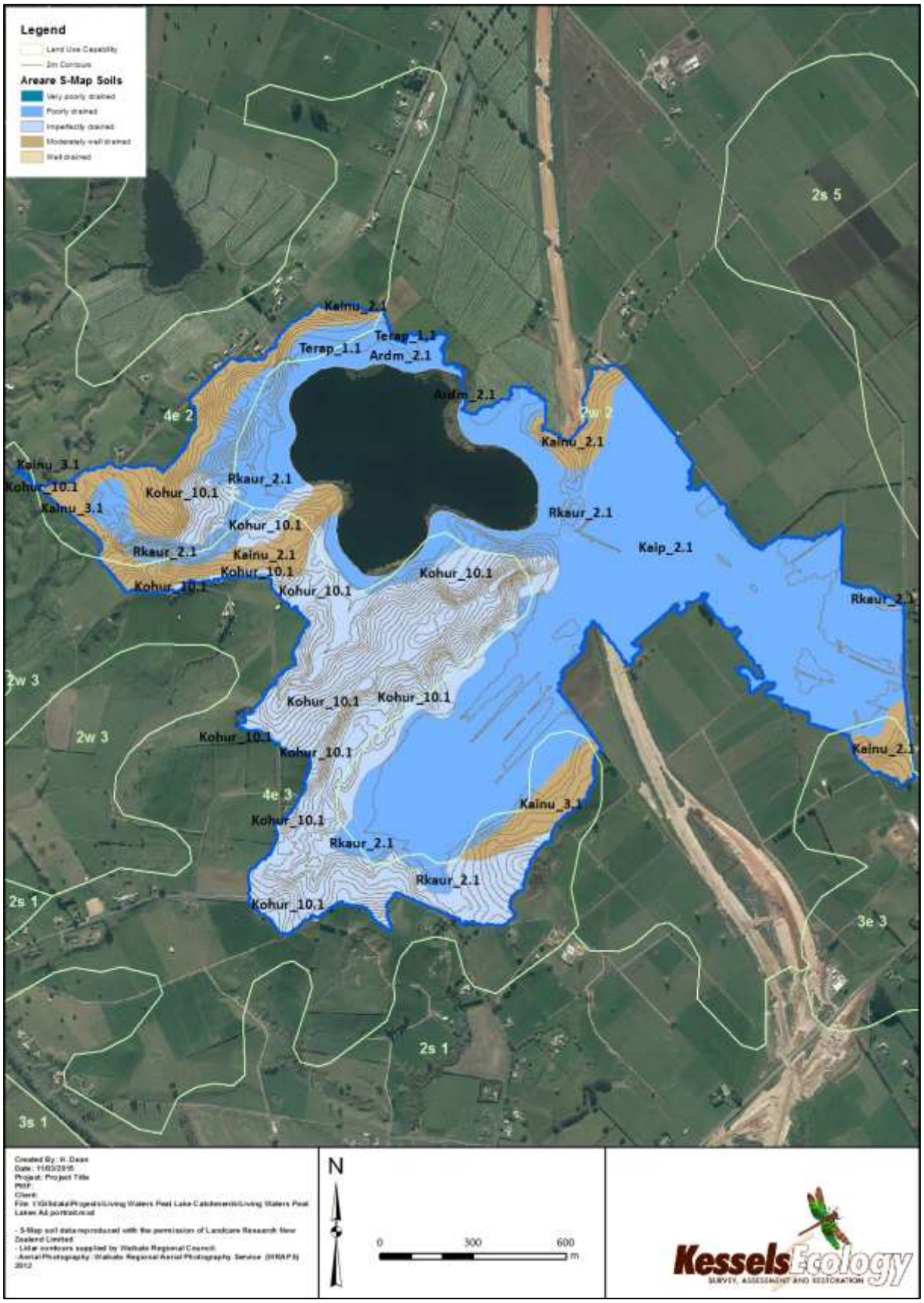

Figure 3: Soil types, drainage characteristics, Land Use Capability and contour of the Areare catchment. Refer to Table 1 for soil names and characteristics.

4 CATCHMENT LAND COVER AND USE

The Areare catchment land cover comprises more than 80% exotic pasture (Table 2, Figure 4) which is primarily dairy farms, especially on the flat peat land. At least one drystock farm operates at the northern end of the catchment and there are a number of lifestyle and rural-residential properties within the catchment. Herbaceous wetlands surrounding Lake Areare comprise approximately 9.85 ha and additional area has been planted in indigenous revegetation species (Broadleaved Indigenous Hardwoods - 2.82 ha). Lake Areare occupies approximately 11.5% of the catchment and the remaining 2.3% comprises roads.

Table 2: Landcover Classes in the Areare catchment. Based on LCDB4 but with alterations based on 2012 WRAPS aerial photography.

Landcover Class	Area (ha)	% of catchment
Broadleaved Indigenous Hardwoods	2.82	1.07%
Herbaceous Freshwater Vegetation	9.85	3.74%
High Producing Exotic Grassland	214.09	81.33%
Lake or Pond	30.39	11.54%
Transport Infrastructure	6.09	2.31%
Grand Total	263.24	100.00%

4.1 Land Use Capability

The Land Use Capability (LUC) classification is a long-established system for assessing the suitability of land for various uses. The system uses data from the Land Resources Inventory to classify land into eight major classes: Class 1 land is highly versatile, with no limitations and suitable for arable cropping or intensive grazing while Class 8 land is unsuitable for any farming or forestry and is highly limited (Lynn *et. al.* 2009). The system also incorporates a land use subclass which provides information about the limitations of the land.

All of the land on peat soils in the Areare Catchment is classed as 2w (Figure 3) indicating high suitability for arable cropping and pastoral grazing but limited by the water table (Lynn *et. al.* 2009). The hillslope areas in the northern and western part of the catchment are class 4e land which is moderately suitable for grazing with erosion being the limiting factor (Lynn *et. al.* 2009).

4.2 Land Ownership

The Areare catchment is predominantly privately owned (202 ha, 77%). The Department of Conservation administer the 38.5 ha which make up the Areare part of the Horsham Downs Wildlife Management Reserve; amounting to 14.7% of the catchment. The remaining 8.3% (21.9 ha) is Crown owned land which is all associated with roading. It is understood that a portion of this (approximately 10 ha) is in the process of being transferred to Department of Conservation control to augment the existing reserve land (Reeves 2013).

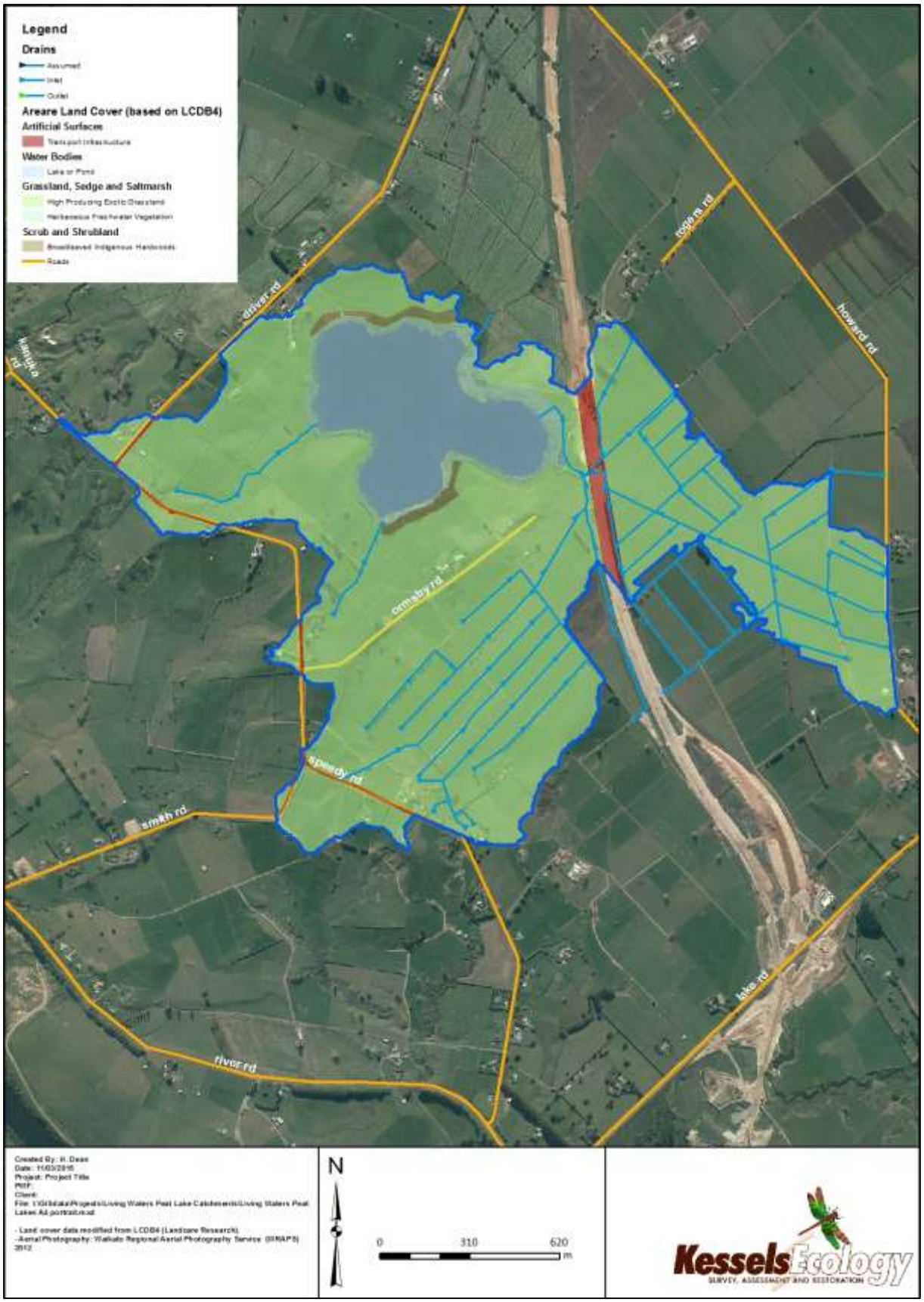

Figure 4: Landcover and drainage network of the Areare catchment. Data based on LCDB4 with alterations based on WRAPS 2012. Drains are indicative only.

5 CLIMATE

Climate data from within the catchment is not available but an automated rainfall guage is located approximately 4.8 km southeast of the catchment in the Horsham Downs area and the data from this station is available through NIWA's CliFlo database. No other climate and weather variables are measured at this station however and the next nearest station is at Ruakura around 14 km to the south. Data from both of these stations has been used to provide a summary of climate conditions in the area (Table 3).

Mean annual air temperature ranged between 12.1°C and 14.2°C during the six year period with maximum summer temperatures between 26.3°C and 30.5°C and minimum winter temperatures between -2.8°C and -4.6°C. The number of frost days per year has varied considerably over the six year, ranging between 12 in 2013 and 31 in 2009. Average annual rainfall for the six years from 2009 - 2014 was 1,226 mm. Summers can be very dry with water deficits in excess of 140 mm (CliFlo 2015).

Table 3: Climate data for Hamilton Airport between 2009 and 2014. Data from NIWA's CliFlo service.

Year	Mean Air Temp (°C)	Lowest Daily Mean Temp (°C)	Highest Daily Mean Temp (°C)	Extreme Maximum Air Temp (°C)	Extreme Minimum Air Temp (°C)	Total sunshine hours	Number of frost days	Mean Of 9am Relative Humidity (%)	Max water deficit (mm)	Total Rainfall (mm)
2009	12.8	1.6	23.7	29.8	-4.6	2119.9	31	85.1	131.3	1270.3
2010	14.0	3.2	24.4	29.8	-3.2	2009.5	16	84.3	138.4	1280.2
2011	13.2	1.0	24.4	29.3	-4.2	1940.7	22	85.8	129.6	1429.8
2012	12.1	1.8	22.1	26.3	-4.3	1974.4	30	85.1	105.1	1256.2
2013	14.2	4.3	21.6	30.5	-2.8	2113.9	12	75.9	146.7	1082.7
2014	14.1	4.0	22.1	28.5	-3.0	--	--	83.8	141.6	1038.9

6 HYDROLOGY

6.1 Drains and Streams

The peat soils in the catchment have been extensively drained and there are small drains running along at least one side of most paddocks in low-lying areas. The largest drain entering the lake brings water from the entire eastern portion of the catchment and the new highway and enters Lake Areare after being filtered through a treatment wetland. Drains were mapped using existing WRC data and WRAPS 2012 aerial photography and ground-truthed where possible (Figure 4). In total there are approximately 13.9 km of drains or modified streams in the catchment although some of these are very small and are likely to be dry for long periods. Visual assessments of drains indicated that the current catchment boundary may not be correct, especially in the southern part of the site and east of the highway. In these areas it appears that drainage water enters the system from outside the documented catchment boundary.

Four natural inflows enter the lake on the western side (Reeves 2013) although these are likely to have been altered and no data is available about the quantity of water these waterways carry.

6.2 Lake Areare

The lake was a closed system historically (Reeves 2013) but now is drained by an outlet at the eastern end of the lake. The lake would have received the majority of its water via the groundwater system with a minor component from the natural inflow streams draining the western hills. The lakes water level is set at a minimum 22.5 m above Moturiki datum by a weir which was constructed by Waikato Regional Council in 2008 (Reeves 2013). The level of the lake is set by a provision in the Waikato Regional plan (section 3.2.4.7) and cannot be changed without going through a plan change process.

Daily water levels were monitored by Waikato Regional Council between 2001 and 2013 in part to be able to accurately set the minimum level for the district plan but have now stopped as the conditions for the resource consent to construct the weir have now been met (Dean-Spiers *et. al.* 2014).

Seasonal fluctuations in water level have generally been around 0.5 m but in dry years water levels go below the weir level and the annual fluctuation is as much as 0.8m (Figure 5). The response time of lake water level to rainfall events appears to be relatively short but the residence time of water in the lake is prolonged after rainfall ceases (Figure 6). This suggests that the lake and the surrounding catchment are performing a valuable water storage and regulation function.

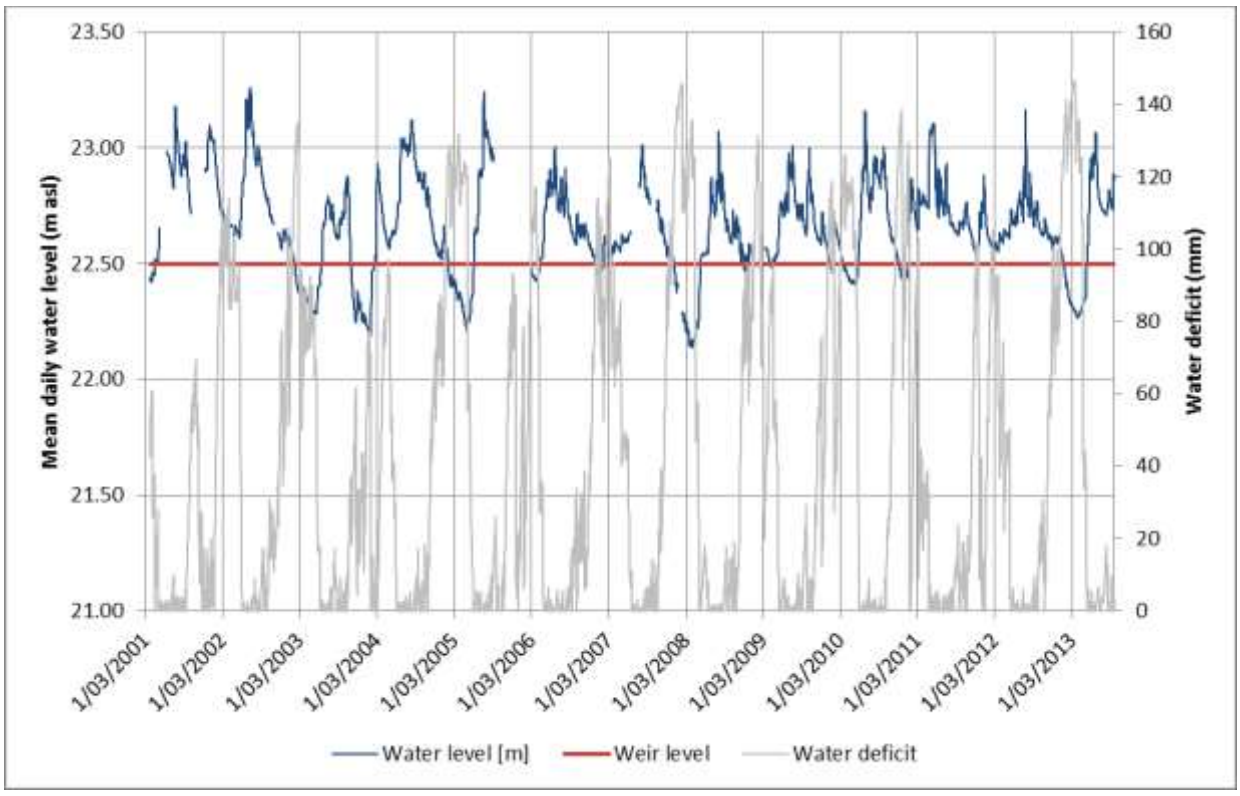

Figure 5: Daily water levels in Lake Areare and water deficit at Horsham Downs between 2001 and 2013. The red line is the current weir level (22.5m). Data from Waikato Regional Council.

6.3 Groundwater

No information about the groundwater in the Areare catchment appears to be available. However, the Areare catchment is part of the Hamilton Basin - North aquifer management area which has been assessed and water allocation limits have been set (Waikato Regional Plan Section 3.3, Table 3-6).

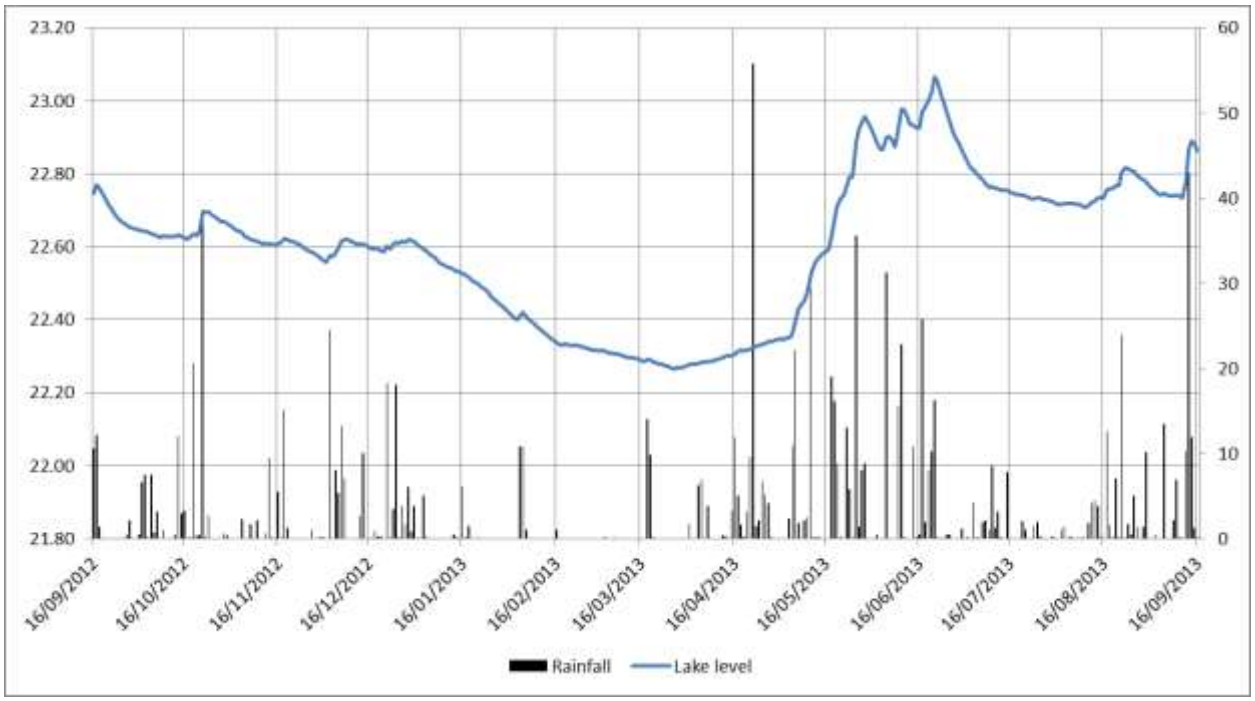

Figure 6: Lake water level and rainfall for one year between September 2012 and September 2013. Water level data from Waikato Regional Council and rainfall data from NIWA's CliFlo service.

7 BATHYMETRY

A recent survey of Lake Areare recorded a maximum depth of 4.56 m (de Winton *et. al.* 2014) while Fergie (2003) reported a maximum depth of 5.1 m. The differences in the two values can be accounted for by the seasonal variation in lake water level (Figure 5, Figure 6). The deepest part of the lake is close to the eastern shore where the bed drops away rapidly (Figure 8).

Figure 7: Lake Areare

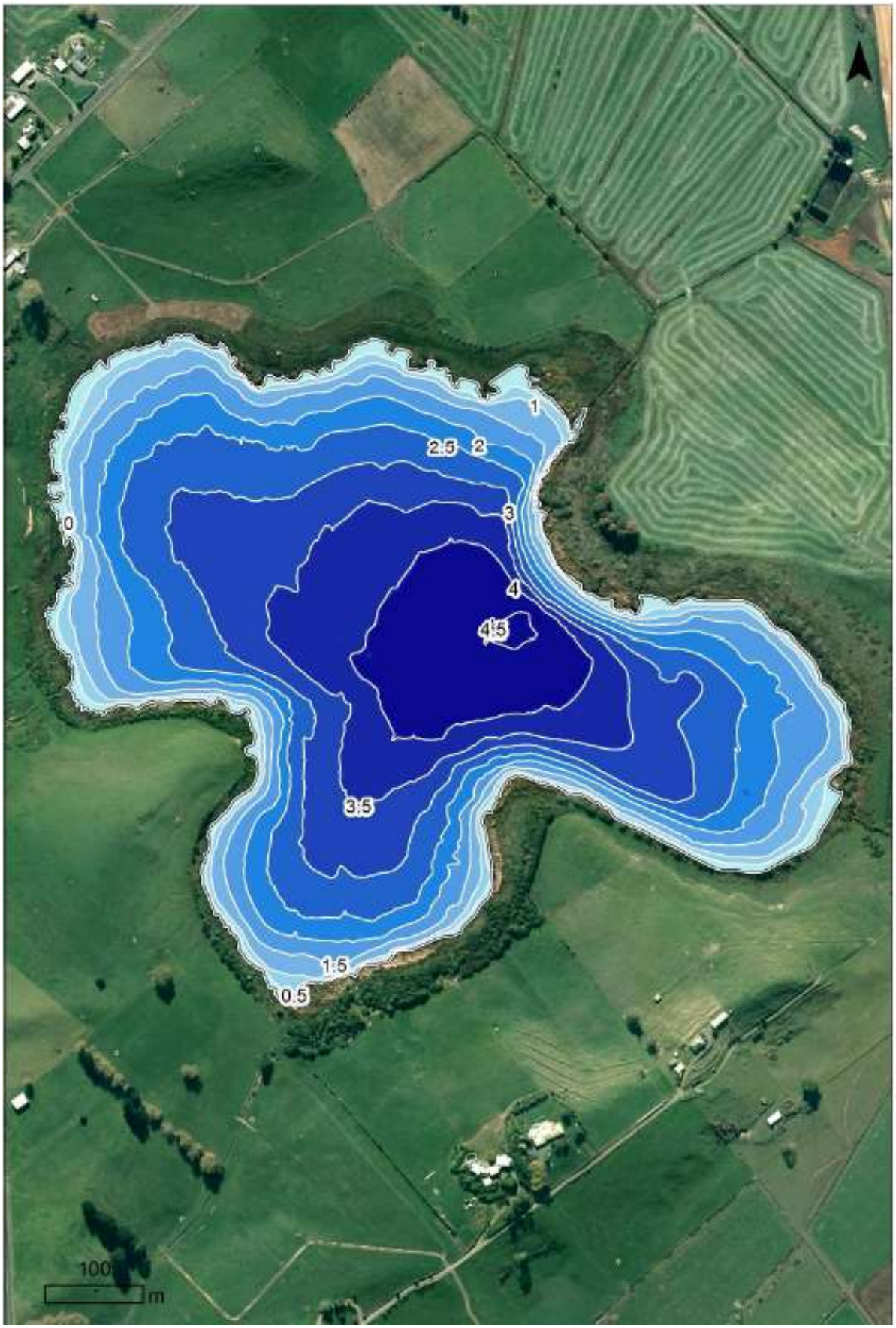

Figure 8: Bathymetry map of Lake Areare showing 0.5m contours. Map by de Winton *et. al.* (2014), supplied by DOC.

8 WATER QUALITY

Water quality monitoring in Lake Areare has been sporadic. A series of samples were taken in 1980 as part of a study into shallow lake trophic status by the Waikato Valley Authority (Town 1980) and discrete samples were taken in December 2010 and May 2011 by the University of Waikato (according to WRC data). More regular sampling has been undertaken since January 2014 at two-monthly intervals. This monitoring by Waikato Regional Council includes measurement of a full suite of water chemistry and physical properties of the water as well as depth profiles of dissolved oxygen and water temperature. If continued this data will yield very useful information about the success of restoration work in the catchment.

Trophic level Index or trends in water quality have not been formally assessed and scarcity of data will make this difficult until three or four years of regular monitoring has been conducted. However, available water quality information has been collated and an approximate trophic state has been assigned based on available parameters and the thresholds published by Burns *et. al.* (2000). A summary of water quality information is included in Table 4 and thresholds for each water quality parameter in relation to trophic state are included in Table 5. This information shows that Areare has been supertrophic or hypertrophic since at least 1980 with very high levels of Total Nitrogen (TN) recorded since 2010. Water clarity appears to have improved since 1980 although it is still very low and the data is likely to exhibit seasonal variation which would not be accounted for with such small sample sizes.

The most recent data from 2010, 2011, and 2014 have been collated and are displayed in Figure 9. Again this data does not cover a long enough time period to draw any meaningful conclusions from and much of the apparent variation is likely to be due to seasonal fluctuations.

Table 4: Summary of water quality information for Lake Areare. All available samples were averaged but results should be read with caution as seasonal affects have not been taken into account. Data from Waikato Regional Council.

	Chla (mg/m³)	Secchi disk (m)	DO (g/m3)	Conductivity (mS/m)	Conductivity @ 25°C (mS/m)	pH	Suspended solids (g/m³)	TP (mg/m³)	TP (discrete) (mg/m³)	TN (mg/m³)	Estimated trophic state
1980[1]		0.46	7.59	14.68		6.5	7.60				Supertrophic
2010/ 2011[2]	46				15.95	6.6	17.50	160		2934.50	Hypertrophic
2014[3]	26	0.78			20.45	6.9	7.50		80.67	1994.33	Supertrophic - Hypertrophic

Table 5: Thresholds of key water quality characteristics in relation to trophic state. From Burns *et. al.* 2000)

Trophic State	TLI	Chlorophyll α (mg/m³)	Secchi depth (m)	Total Phosphorus (mg/m³)	Total Nitrogen (mg/m³)
Ultra microtrophic	0 - 1	0.13 - 0.33	33 - 25	0.84 - 1.8	16 - 34
Microtrophic	1-2	0.33 - 0.82	25 - 15	1.8 - 4.1	34 - 73
Oligotrophic	2-3	0.82 - 2.0	15-Jul	4.1 - 9.0	73 - 157
Mesotrophic	3-4	2.0 - 5.0	7.0 - 2.8	9.0 - 20	157 - 337
Eutrophic	4-5	5.0 - 12	2.8 - 1.1	20 - 43	337 - 725
Supertrophic	5-6	Dec-31	1.1 - 0.4	43 - 96	725 - 1558
Hypertrophic	6-7	> 31	< 0.4	> 96	> 1558

[1] Town 1980
[2] University of Waikato - supplied by Waikato Regional Council
[3] Waikato Regional council monitoring data

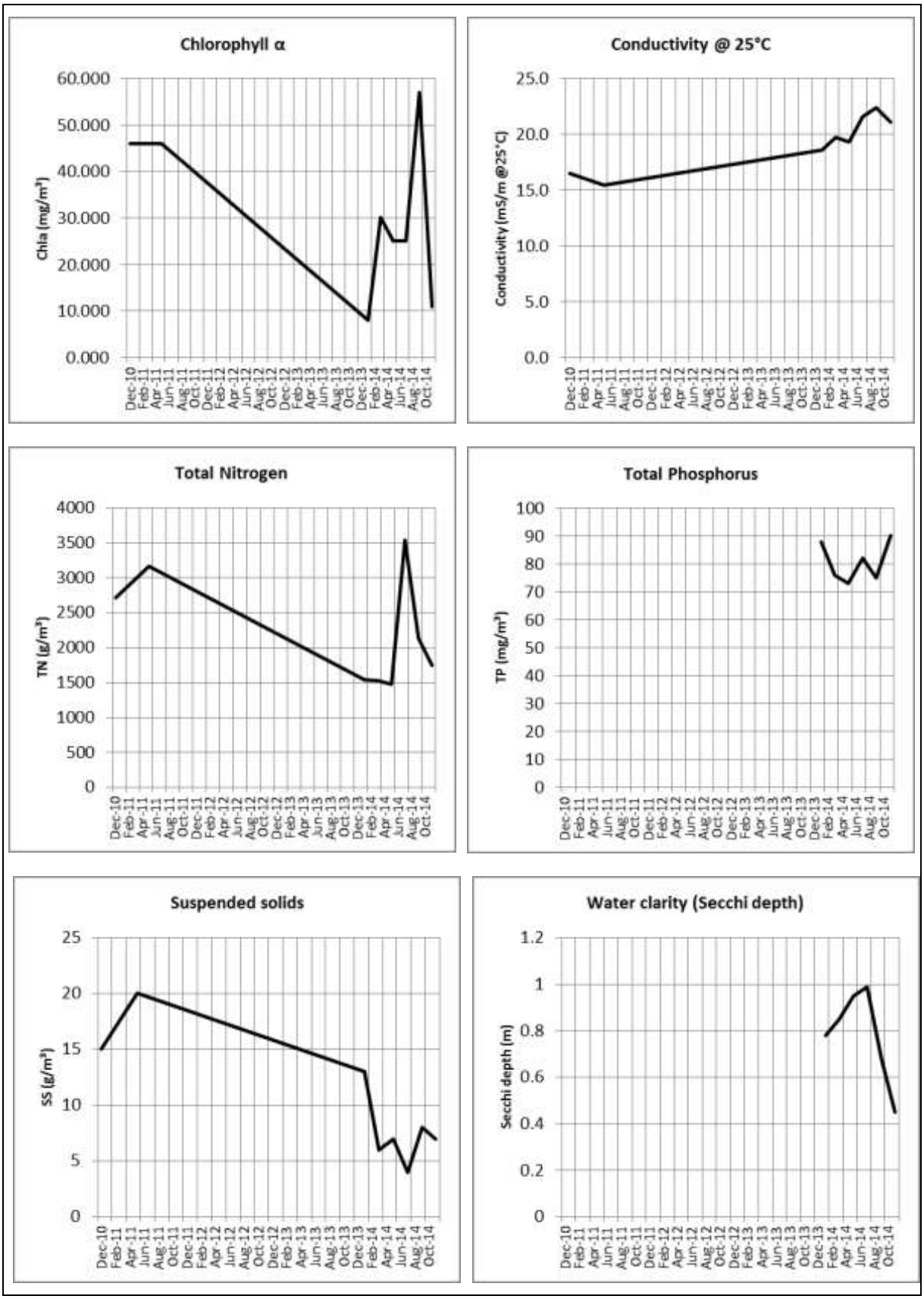

Figure 9: Lake Areare water quality parameters between 2010 and 2014.

8.1 Temperature and Dissolved Oxygen

Depth profile data from Waikato regional Council's monitoring in 2014 shows that the lake remained well mixed with dissolved oxygen (DO) and temperature relatively uniform throughout the water column. In contrast, lakes such as Rotomanuka regularly stratify and exhibit severely reduced dissolved oxygen levels towards the bottom of the lake.

Dissolved oxygen levels remained at a moderate level for most of 2014 with an increase in spring (Figure 10). These oxygen levels are likely to cause stress to only the more sensitive organisms for short periods (Davies-Colley *et. al.* 2013) and then only in the lower parts of the water column where oxygen levels are typically lower.

Daily water temperature in Lake Areare was monitored by Waikato Regional Council using and automated recorder between 2001 and 2013. Monthly averages from this data are plotted in Figure 12 and show a typical annual fluctuation in water temperature and no noticeable long-term trends. Water temperature generally reaches 22 - 25°C in the summer and drops to 10 - 12°C in the winter.

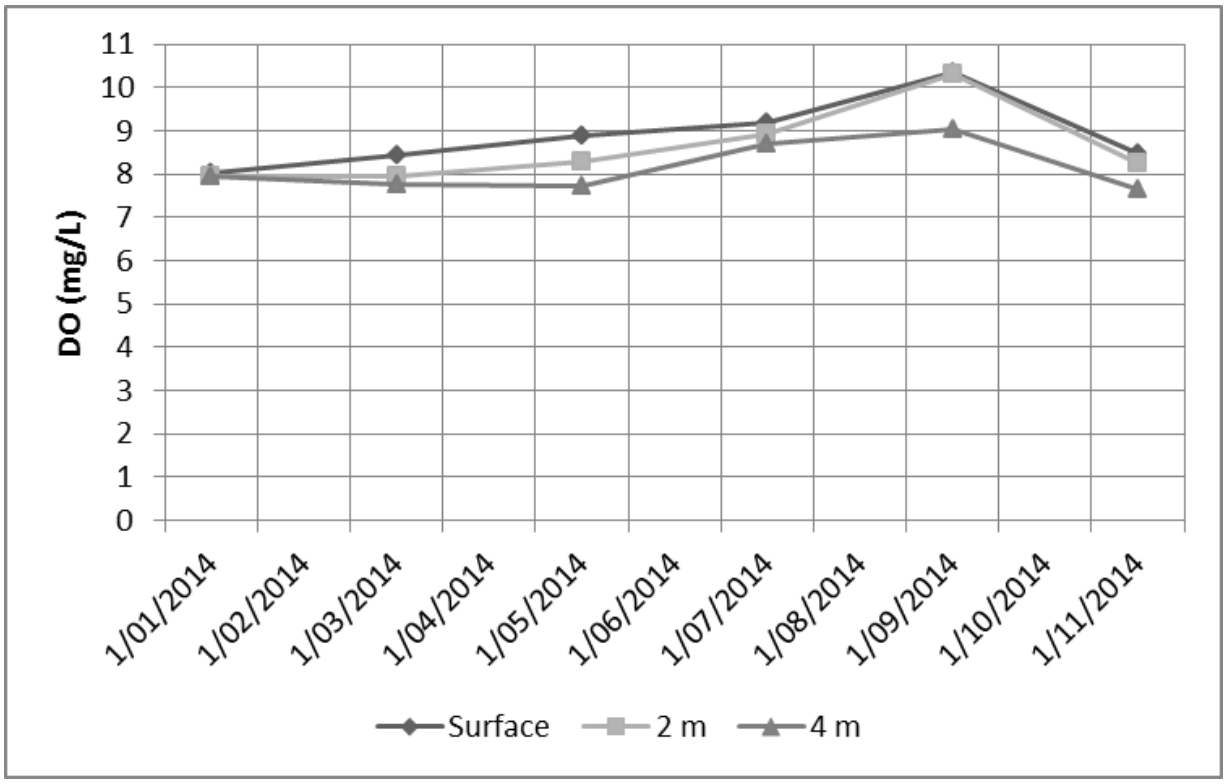

Figure 10: Lake Areare dissolved oxygen measurements at the surface, 2 m deep, and 4 m deep during 2014. Data from WRC.

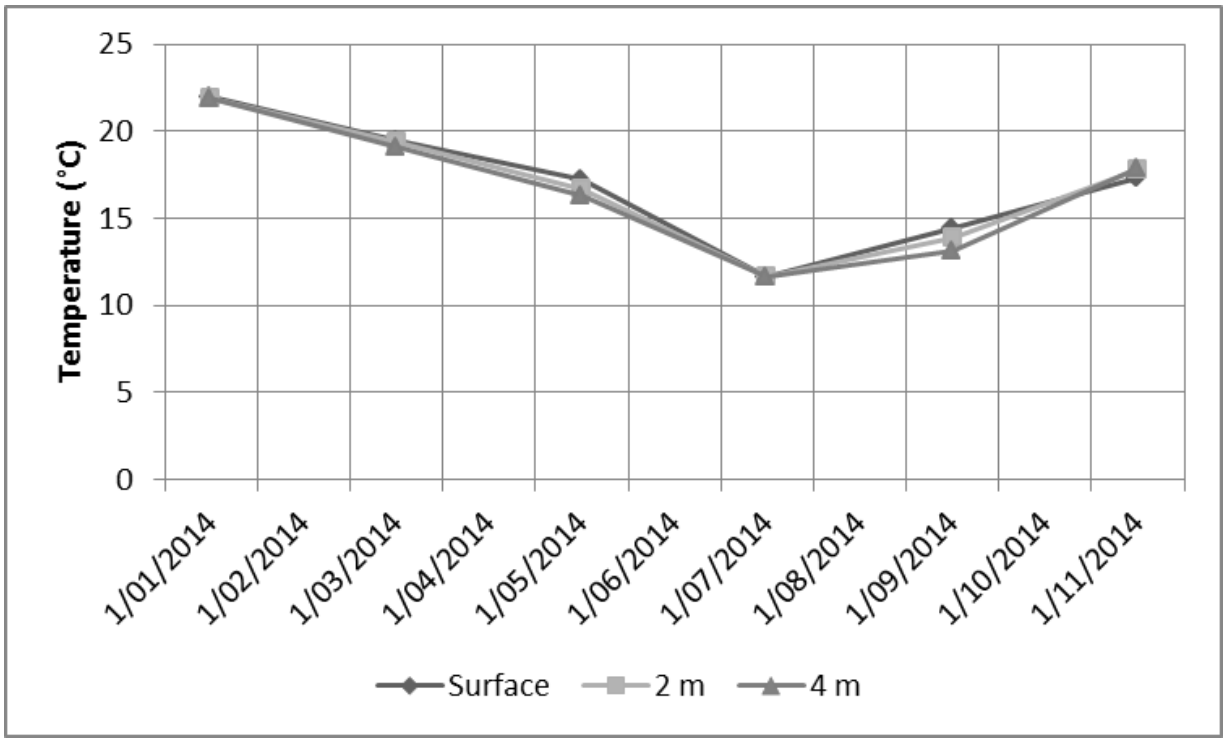

Figure 11: Lake Areare temperature measurements at the surface, 2 m deep, and 4 m deep during 2014. Data from WRC.

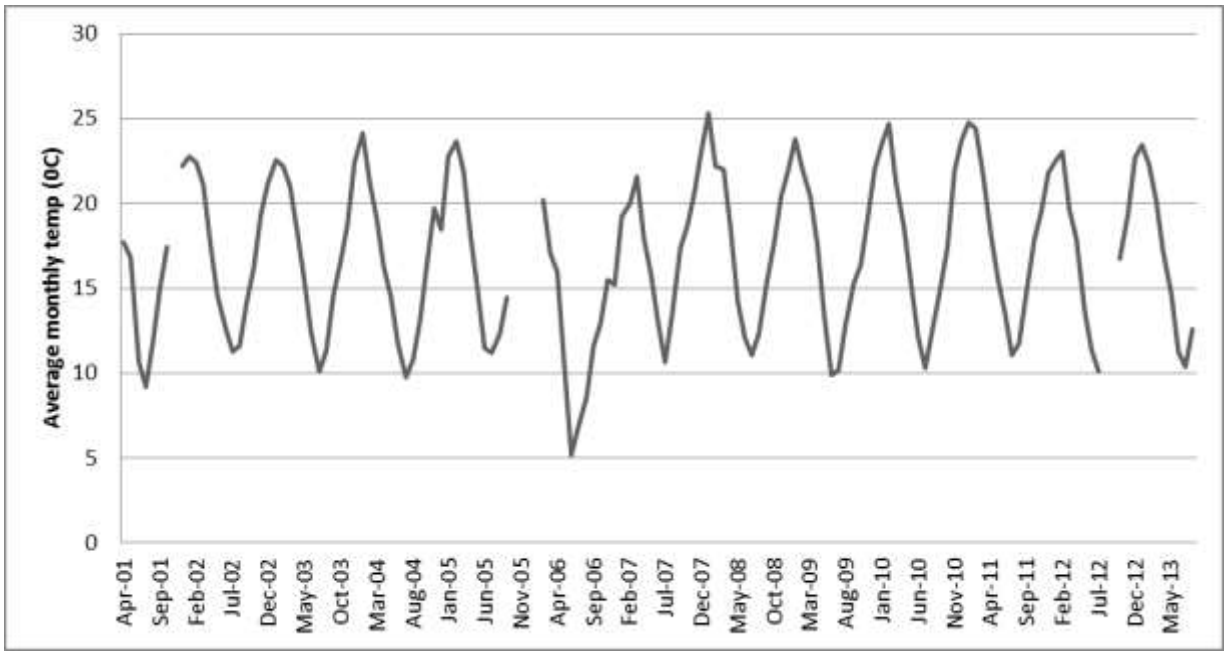

Figure 12: Monthly average water temperature in Lake Areare between 2001 and 2013. Data from WRC.

8.2 Lake SPI

Lake SPI uses the extent and diversity of submerged native and exotic plants to provide an indicator of lake health (Clayton & Edwards 2006). Historical data for the 1800s and data from more recent reports has been used to assess SPI and more recently dedicated surveys for submerged plants have been undertaken in a range of Waikato Lakes (Burton *et. al.* 2014).

Lake Areare has not recently been surveyed for submerged macrophytes but Burton *et. al.* (2014) concluded that it is likely to be effectively de-vegetated as it has been in this state since at least 1991 and the situation is unlikely to change without landuse change. Lake SPI scores are outlined in Table 6 below. Zero scores indicate submerged plant cover of <10%.

Table 6: LakeSPI scores for Lake Areare. Data from Burton *et. al.* 2014.

Year	LakeSPI Index (%)	Native Condition Index (%)	Invasive Impact Index (%)
1800s	95	90	0
1991	0	0	0
2003*	0	0	0

*Assumed score

9 RESOURCE USE

There are several active resource consents within the catchment or immediately adjacent to it. These include two consents to discharge farm effluent onto land, the consent for the Areare outlet weir, and bed-disturbance and stormwater discharge consents associated with the new highway (Figure 13). There were also several applications for groundwater takes immediately adjacent to the catchment at the time the data was obtained (October 2014) but these may now be active. These consents are likely to represent only minor effects on the natural values of the catchment.

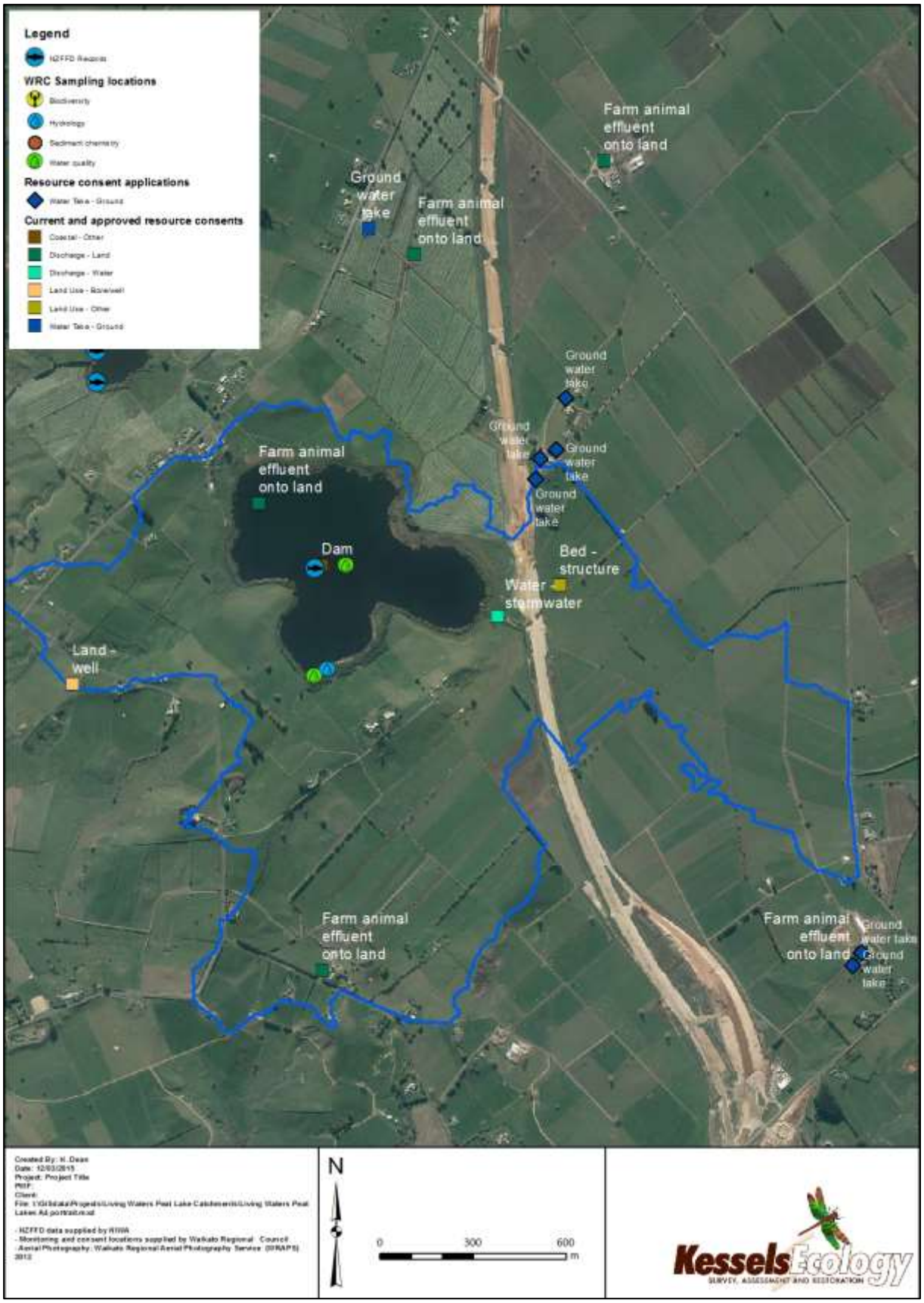

Figure 13: Biodiversity records, monitoring locations, and resource consents in and adjacent to the Areare catchment.

10 BIODIVERSITY

10.1.1 Aquatic Biodiversity

The New Zealand freshwater Fish Database (NZFFD) holds four records for Lake Areare from a single sampling event in 2003 carried out by Waikato regional Council (Fergie 2003). In addition rudd and longfin eel are noted as being present by Reeves (2013). Koi are not yet in Lake Areare although they are known to occur in the lower part of the outlet stream (Reeves 2013). Black mudfish have been recorded at the Kainui wetland relatively close to the Lake Areare catchment (Floyd 2010) and may well be present in drains or the lake. Mudfish are classed as At Risk - Declining (Goodman *et. al.* 2014). The Department of Conservation has recently (March 2015) completed a pest fish survey and results were being analysed at the time of writing.

Table 7: Fish species occurring in Lake Areare.

Common Name	Scientific name	Threat status[4]	Source
Shortfin eel	*Anguilla australis*	Native: Not threatened	NZFFD
Longfin eel	*Anguilla dieffenbachii*	At Risk - Declining	Reeves 2013
Mosquito fish	*Gambusia affinis*	Introduced and Naturalised	NZFFD
Goldfish	*Carrassius auratus*	Introduced and Naturalised	NZFFD
Catfish	*Ameiurus nebulosus*	Introduced and Naturalised	NZFFD
Rudd	*Scardinius erythrophthalmus*	Introduced and Naturalised	Reeves 2013

Champion *et. al.* (1993) surveyed submerged and marginal vegetation in Lake Areare in 1991. They recorded *Nitella hookeri* from two survey sites in the lake albeit with very low cover, and a single plant of *Myriophyllum propinquum* (Champion *et. al.* 1993). The lake is darkly peat stained which is likely to restrict submerged macrophyte growth (Burton *et. al.* 2014). Town (1980) listed at least 18 genera or species of phytoplankton from Lake Areare. Macroinvertebrates do not appear to have been surveyed in the catchment.

10.2 Terrestrial biodiversity

10.2.1 Flora

As discussed in Section 3 the catchment is dominated by exotic pasture grasses. However, the flora of the lake's marginal wetlands has undergone a significant change in recent years as a result of a considerable restoration effort by the Department of Conservation. In 1990 the vegetation was described as being dominated by *Salix cinerea - S. fragilis* carr which occupied 90% of the lake shore (Champion *et. al.* 1993). Manuka (*Leptospermum scoparium*) and gorse (*Ulex europaeus*) occupied smaller areas of the margins and areas of swamp meadow comprising *Isolepis distigmatosis, Eleocharis acuta, E. gracilis,* and *Schoenus maschalinus* occupied part of the eastern shore (Champion *et. al.* 1993). *Eleocharis sphacelata* beds occupied significant areas of the shallow lake margin.

A more recent account of the vegetation (Reeves 2013) documents a significant change from willow-dominated vegetation to vegetation dominated by indigenous plant species with virtually no willow remaining. This transformation is the result of a considerable amount of weed control work and planting of thousands of native seedlings by the Department of Conservation, Waikato District Council, Fish and Game, and the Living Legends project, a programme of restoration commenced by the Department of Conservation in 2000 (Dean-Spiers *et. al.* 2014). The vegetation map from the 2013 survey is included as Figure 14. Reeves (2013) also recorded 104 plant species at Lake Areare; 50 indigenous and 54 exotic species.

[4] Goodman *et. al.* 2014

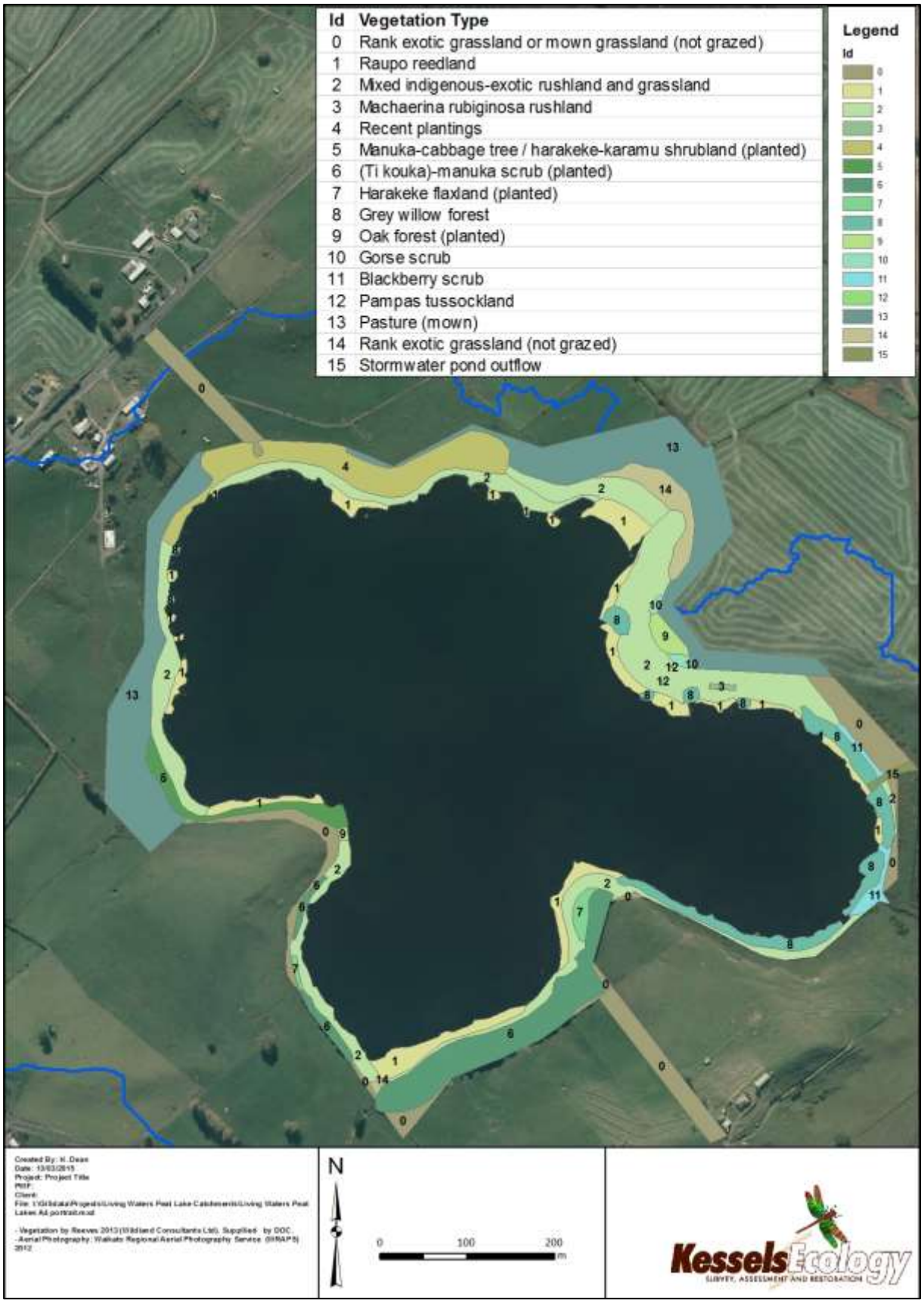

Figure 14: Vegetation types of the land surrounding Lake Areare. Data from Reeves 2013, supplied by DOC.

10.2.2 Fauna

Sixteen native and five introduced species of bird have been recorded at Lake Areare (Table 8). These include the Nationally Critical grey duck (*Anas superciliosa superciliosa*), Nationally Vulnerable New Zealand dabchick (*Poliocephalus rufopectus*) and At Risk - Naturally Uncommon black shag (*Phalacrocorax carbo novaehollandiae*) and little black shag (*Phalacrocorax sulcirostris*). Other species likely to utilise the site include Australasian bittern (*Botaurus poiciloptilus*) and spotless crake (*Porzana tabuensis tabuensis*).

A survey of long-tailed bats (*Chalinolobus tuberculatus*) was undertaken as part of the Ngaruawahia bypass consenting process and automated bat detectors were deployed at Lake Areare. No bats were recorded at the lake site but they were recorded at the Kainui wetland 3.5km to the north and at Simpson's Gully less than 2.5 km to the south (le Roux *et. al.* 2011). Simpson's Gully was found to be a roosting site for bats (le Roux *et. al.* 2011) and it is likely that they visit or roost in the Areare catchment from time to time.

A number of pest mammals are also likely to be present in the catchment including Norway rats (*Rattus norvegicus*) ship rats (*Rattus rattus*), mice (*Mus musculus*), stoats (*Mustela erminea*), ferrets (*M. furo*), weasels (*M. nivalis*), cats (*Felis domesticus*), possums (*Trichosurus vulpecula*), and hedgehogs (*Erinaceus europaeus*). Control of many of these species would benefit native fauna by reducing predation. The current status of pest control in the catchment is not known.

11 ECOLOGICAL SIGNIFICANCE

Lake Areare has been ranked as 33rd = in the list of significant lakes of the Waikato (Reeves et. al. 2011). The wetlands surrounding the lake have been initially ranked as Regionally Significant under the current Waikato District Significant Natural Area project (Kessels Ecology, *in prep.*) in accordance with Waikato Regional Policy Statement criteria for determining significance. The lake and its wetlands represent a small area of what was once a more extensive peat wetland. The Hamilton Ecological District has suffered significant loss of wetlands since European settlement. Once featuring extensive peat bogs including the large Komakorau, Moanatuatua, and Rukuhia bogs and the smaller Kainui bog of which Areare was a part (Figure 2), it is estimated that less than 2% of these now remain (Leathwick *et. al.* 1995). Furthermore, only around 10% of the Ecological District remains in any form of indigenous vegetation (Leathwick *et. al.* 1995).

The entire Areare catchment is classified as Acutely Threatened under the LENZ Threatened Environments Classification (Figure 15). The Threatened Environments Classification uses Land Environments data along with land cover and information about the protected area network to assess the severity of indigenous ecosystem loss (Walker *et. al.* 2007). Acutely Threatened environments are those that retain less than 10% of their land area in indigenous vegetation (Walker *et. al.* 2007) and comprise many of the lowland areas of New Zealand which have been most affected by clearance for agriculture, horticulture and other developments. These areas are the highest priority for protection and restoration.

Table 8: Records of birds from the Lake Areare catchment.

Common Name	Specific name	Threat status	Notes (see Source)	Source
Austalasian bittern	*Botaurus poiciloptilus*	Threatened - Nationally Endangered		Floyd 2010
Australian magpie	*Gymnorhina tibicen*	Introduced and naturalised	In neighbouring farmland	Reeves 2013
Black swan	*Cygnus atratus*	Not threatened	Several observed by Reeves (2013)	Reeves 2013
Blackbird	*Turdus merula merula*	Introduced and naturalised	Common	Reeves 2013
Canada goose	*Branta canadensis*	Introduced and naturalised	Common	Fergie 2003, Reeves 2013
Eurasian skylark	*Alauda arvensis*	Introduced and naturalised	Common	Reeves 2013
Fantail	*Rhipidura fuliginosa placabilis*	Not threatened	Common	Fergie 2003, Reeves 2013
Grey duck	*Anas superciliosa superciliosa*	Threatened - Nationally Critical		Fergie 2003
Grey teal	*Anas gracilis*	Not threatened		Fergie 2003
Grey warbler	*Gerygone igata*	Not threatened	Common on lake margins	Reeves 2013
Kahu, harrier hawk	*Circus approximans*	Not threatened	Occasional	Fergie 2003, Reeves 2013
Kawau, black shag	*Phalacrocorax carbo novaehollandiae*	At Risk - Naturally uncommon	Occasional	Fergie 2003, Reeves 2013
Kawau tūi, little black shag	*Phalacrocorax sulcirostris*	At Risk - Naturally uncommon	Occasional	Fergie 2003, Reeves 2013
Kotare, sacred kingsisher	*Todiramphus sanctus vagans*	Not threatened	Common	Reeves 2013
Kotuku, white heron	*Ardea modesta*	Threatened - Nationally Critical	Occasional visitor	Floyd 2010
Mallard	*Anas platyrhynchos*	Introduced and naturalised		Fergie 2003, Reeves 2013
Paradise shelduck	*Tadorna variegata*	Not threatened	Common	Fergie 2003, Reeves 2013
Pukeko	*Porphyrio melanotus melanotus*	Not threatened	Common	Fergie 2003, Reeves 2013
New Zealand shoveler	*Anas rhynchotis variegata*	Not threatened		Fergie 2003
Silvereye	*Zosterops lateralis lateralis*	Not threatened	Common	Reeves 2013
Spotless crake	*Porzana tabuensis tabuensis*	At Risk - Relict		Floyd 2010
Spur-winged plover	*Vanellus miles novaehollandiae*	Not threatened	Common	Reeves 2013
Taratimoho, New Zealand dabchick	*Poliocephalus rufopectus*	Threatened - Nationally Vulnerable		Fergie 2003
Welcome swallow	*Hirundo neoxena neoxena*	Not threatened	Common	Fergie 2003, Reeves 2013

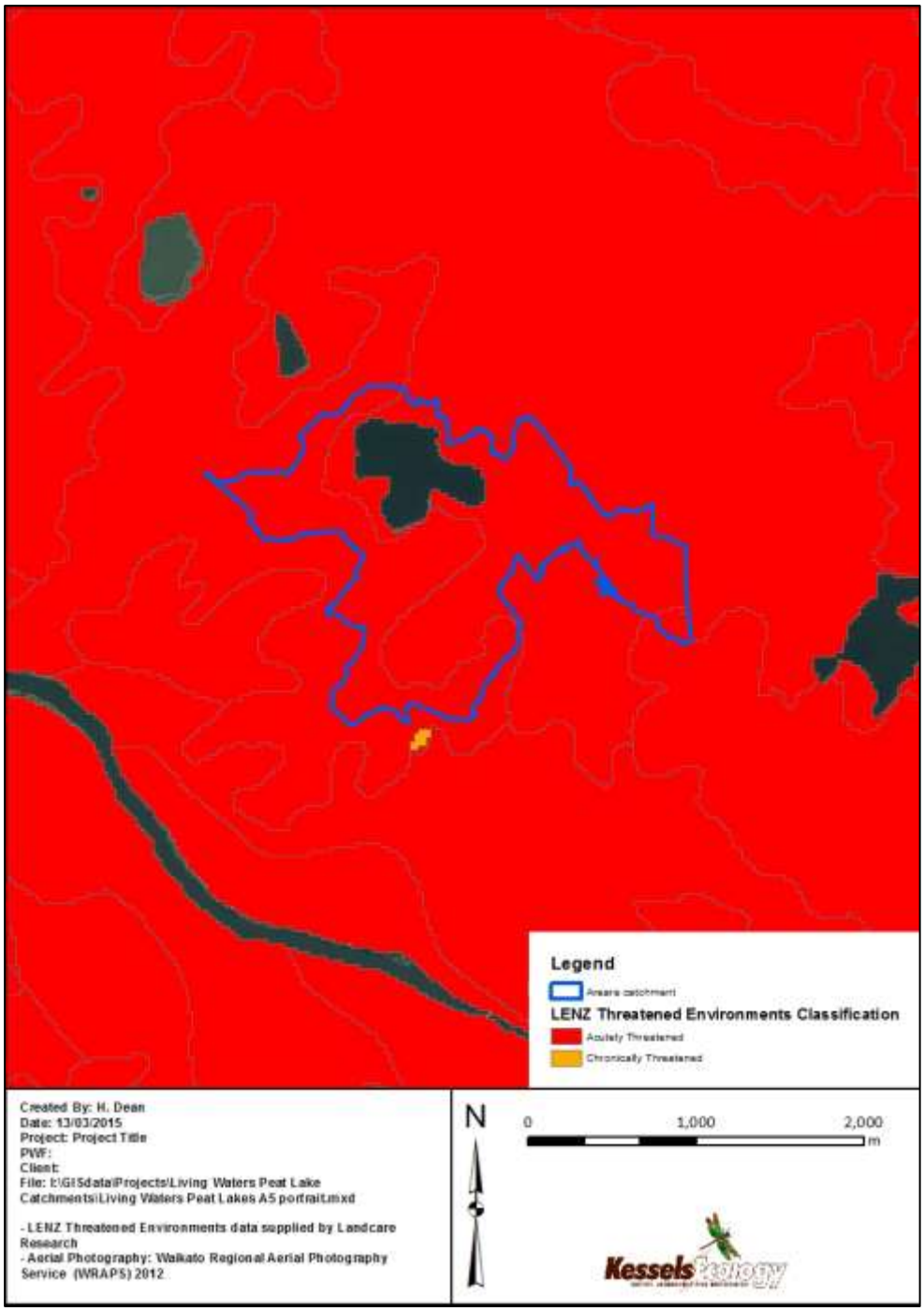

Figure 15: LENZ Threatened Environments Classification for the Areare catchment.

12 MANAGEMENT

Lake Areare is part of the Horsham Downs Wildlife Management Reserve which is administered by the Department of Conservation. However, a number of agencies are involved in the management of the lake. This section provides a brief outline of previous and current management of the lake and the catchment.

Lake Areare has been subject to a significant amount of management for biodiversity and environmental purposes over the last 10 - 15 years. The Department of Conservation has

taken the lead role in the restoration of the lake and its surrounding wetlands and have been assisted by the other members of the Waikato District Lakes and Wetlands Memorandum of Agreement Group; Waikato Regional Council, Waikato District Council, Auckland-Waikato Fish and Game Council and Waikato-Tainui. In Addition, the project has been supported by the Living Legends project, Waikato River Clean-up Trust, and NZTA (Reeves 2013, Dean-Spiers *et. al.* 2014). Restoration work to date has included the commissioning of an Inter-agency Action Plan (Wildland Consultants 2012) which identified a number of goals for restoration work, as well as fencing, weed control (aerial and ground spraying of willow, blackberry and gorse), planting of some 33,000 plants, and the construction of a parking area and dedicated access from Driver Road (Reeves 2013, Dean-Spiers *et. al.* 2014).

The lake is completely fenced although the area included in the buffer varies in width around the lake. The fenced area has recently been expanded considerably and large areas have been planted in indigenous revegetation species. A habitat enhancement plan was commissioned by DOC in 2012 to guide the restoration of marginal vegetation which identified existing habitats, proposed target vegetation communities, and provided management guidelines for restoration work (Reeves 2013).

A 7,500 m^2 treatment wetland and silt trap was built at the eastern end of Areare as part of the Waikato Expressway construction. This treats water coming from the entire eastern part of the catchment but is thought to be too small to treat flows greater than 5-year flood events (Dean-Spiers *et. al.* 2014). Infiltration wetlands are also planned for the four other inflows to the lake and will be constructed before 2016 (Dean-Spiers *et. al.* 2014).

Management of sediment and nutrients entering the lake and in the wider catchment is of prime importance to the overall health of the system. The current state of the drains in the catchment is not known and there does not appear to be any catchment-wide coordination of land management at this stage but this work will follow the current project.

13 KNOWLEDGE GAPS

This section provides an outline of gaps in the data which may need to be filled in order to efficiently manage the catchment and restoration work within it. Other data gaps may be revealed as restoration work progresses. Although a considerable amount of habitat restoration work has been done at Lake Areare there are information gaps in key areas such as aquatic biota, hydrology, and pest fish. These gaps are outlined below and should be addressed as part of the Living Water project.

13.1 Catchment Extent and Hydrology

The extent of the Areare catchment has been mapped by Waikato Regional Council using fine-scale Lidar data. However, it appears from brief visits to the site that the catchment boundary is inaccurate where it crosses the peat land to the east and south of the lake. In these areas there are drains originating outside the defined catchment boundary which flow into the main eastern drain and then the lake. This will need to be confirmed and rectified so that the entire catchment can be effectively managed. A simple survey of drains during rainfall complemented by the existing Lidar data would be the most efficient way to establish catchment boundaries.

The Department of Conservation are already aware that the information on lake and catchment hydrology is insufficient to enable effective catchment management and hydrological modelling has been identified as one of the short-term objectives of the Living Water project. As part of this it may be useful to establish a climate station within the catchment. This will allow better analysis of the correlations between climate conditions and catchment hydrology and may be useful for nutrient and sediment management.

13.2 Water Quality

Historic water quality data is very sparse but Waikato Regional Council has recently commenced more regular 2-monthly monitoring of the lake using protocols consistent with their regional monitoring network. This gives a good baseline but it is essential that monitoring is maintained so that changes in water quality can be detected as the project progresses.

13.3 Biodiversity

Information on terrestrial biodiversity in the catchment is good but aquatic biodiversity data is sparse. Of particular importance is establishing the status of the pest fish population in the lake and the drains and once this is done an assessment of the viability of controlling them should be done. A recent survey of pest fish will yield the appropriate data once it has been analysed. Re-establishing submerged macrophytes may be beneficial to lake water quality and ecosystem health but the suitability of the habitat and light environment would need to be assessed as it has for Rotomanuka (de Winton 2003; de Winton & Taumoepeau 2005). Monitoring of aquatic invertebrates would also be useful as a water quality monitoring tool. Regular monitoring of wader and wetland birds, and survey and monitoring of terrestrial invertebrates would also be beneficial and could aid management decisions.

14 SUMMARY

The Lake Areare catchment is highly modified but its relatively small size means that restoration of key catchment attributes is an achievable goal. The current state of key environmental attributes in the catchment, whether they are improving or deteriorating, and likely restoration actions needed to restore them are summarised in Table 9. In several cases insufficient data means that no meaningful trend can be detected.

Table 9: Current state, trend and potential restoration actions for the major catchment environmental attributes.

Attribute	Current State	Trend	Potential Restoration Actions
Soils	Peat soils make up approximately 50% of the Areare catchment area. Although there is no data available for this area peat soils generally degrade as a result of drainage.	Unknown. Likely to be deteriorating.	Maintenance of water level is important for maintaining peat and reducing shrinkage. If drains need to be cleaned they should be widened rather than deepened. Consideration should be given to fencing and retiring permanently wet areas which are prone to pugging.
Land use/cover	The catchment is currently more than 80% pasture, approximately 12% lake and the remaining areas are in wetland, roads and indigenous plantings.	N/A	Increasing the indigenous cover would benefit wildlife and may provide ecosystem services such as buffering and filtering. However, the economic viability of the land is of prime importance and vegetation restoration may be restricted to riparian planting and the wetlands around Lake Areare.
Climate	Average annual rainfall is approximately 1.2 m and average annual temperature is approximately 13 degrees C.	N/A	N/A
Hydrology	Historically a closed system (i.e. no outlet stream). Approximately 13.9km of drains now deliver water into Lake Areare and an outflow drain feeds into the Waikato River. The minimum lake level is set by a control structure at 22.5 m asl and the lake fluctuates by as much as 0.8 m seasonally. Recent addition of stormwater from the highway may have altered peak flows.	Lake level is now set by a Regional Plan rule. Further alterations to hydrology may occur as a result of further drainage or cleaning of existing drains but no definite trend is apparent.	Maintenance of both lake and ground water levels is important. Drainage works should be limited to maintenance of existing drains and this should be by herbicide application, rather than mechanical cleaning, where possible.

Attribute	Current State	Trend	Potential Restoration Actions
Water Quality	Water quality in Lake Areare is poor. Total Nitrogen and Total phosphorus are very high (1994.33 mg/m3 and 80.67 mg/m3 respectively in 2014). Water clarity is low (0.78m in 2014) and overall the lake is hypertrophic or supertrophic.	No clear trend from existing data. May be stable.	The key remedial action which has already been identified is to install sediment traps and treatment wetlands on all drains flowing into the lake. Additional actions include fencing all drains, riparian planting, retirement of permanently wet pasture or flood-prone areas, and smart management of effluent.
Lake SPI	Lake SPI uses the abundance and type of submerged water plants (macrophytes) as an indicator of the ecological health of the lake. Lake Areare has been devegetated (<10% submerged macrophyte cover, indicating very poor ecological health) since at least 1991.	Stable.	Water quality parameters (particularly water clarity) need to improve before water plants can establish. Pest fish will also be preventing macrophytes from establishing and a sustained control programme will need to be established.
Aquatic Biodiversity	Two native and four pest fish have been reported from Lake Areare. Relative abundance of each species is not known. *Nitella hookeri* and *Myriophyllum propinquum* are the only submerged plants to have been recorded.	Unknown. It is likely that pest fish numbers are increasing or are already at the maximum level the lake can sustain. Koi carp are not known to be present but have been recorded nearby.	Pest fish control is difficult but should be attempted as most of the pest fish species present have a significant impact on water quality and indigenous biota.
Terrestrial Biodiversity	While the catchment is predominantly pasture the lake and wetlands provide valuable habitat for native plants and animals. At least 50 native plant species are present around the lake and four threatened or at risk bird species have been recorded. Long-tailed bats may also use the area.	Habitat for indigenous plants has improved with the restoration work carried out by the Department of Conservation. Bird species recorded from the site are highly mobile and may not breed here.	A considerable amount has been done to restore indigenous vegetation communities in reserve land around the lake and this is continuing. Establishing wide riparian buffers of native plants on major drains would create more diverse habitat in the catchment and may help with local dispersal of native plants and animals. If not already established predator control around the lake would provide a significant benefit to waterfowl.

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