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Waihou River ecosystem services assessment

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Prepared by:
Brenda R Baillie & Richard T Yao
(Scion)

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Peer reviewed by:
Mark Hamer and Femi Olubode-Awosola Date May 2018

Approved for release by:
Ruth Buckingham Date July 2018

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Waihou River Ecosystem Services assessment

Brenda R. Baillie & Richard T. Yao

Report information sheet

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Authors	Brenda R. Baillie & Richard T. Yao, Scion (New Zealand Forest Research Institute Ltd.), Rotorua, New Zealand
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Executive summary

Introduction

The Waikato Regional Council (WRC) is undertaking an ecosystem services (ES) approach to identify, value, quantify and describe the freshwater ES in the Waikato Region. This project is contributing to Objective 3.8 of the Waikato Regional Policy Statement (RPS) which relates to ES, defined as “the range of services associated with natural resources and are recognised and maintained or enhanced to enable their ongoing contribution to regional wellbeing” (Waikato Regional Council, 2016).

In Phase 1 of this project, a pilot study was undertaken in the Waikato River catchment to assess the freshwater ES provided by a sample of river, stream, lake and wetland sites within the catchment. Scion completed the assessment of the freshwater ES for the river and stream component of the project. In Phase 2, the project has been extended into the Waihou River catchment and Scion has been contracted by WRC to complete a similar ES evaluation.

The Waihou River has a catchment area of 198,769 ha. The spring-fed headwaters originate in the Mamaku Plateau and the river flows in a northerly direction through the townships of Te Aroha and Paeroa and across the Hauraki Plains before emptying into the Firth of Thames. High producing exotic grassland is the dominant land-use in the catchment (57%). Indigenous vegetation (28%) is confined mainly to Kaimai-Mamaku Ranges along the eastern edge of the catchment, with most of the exotic forest located in the catchment headwaters (10%).

This project

The freshwater ES evaluation was undertaken at 10 river and stream sites across the Waihou catchment to cover a range of catchment sizes, geology, hydrology, topography, land-uses and ES. A desktop evaluation was undertaken for each site on key provisioning, regulating and cultural ES and indicators, based on those that were relevant and applicable for New Zealand freshwater ecosystems. The desktop data were collated into a spreadsheet developed during Phase 1. Field visits were made to five of the 10 sites. Data from the field visits were also incorporated into the spreadsheet and in this report. To maintain the project within scope, the ES assessment of smaller catchments included the entire catchment. For large catchments, the evaluation was confined to the immediate vicinity of the site. Cultural ES such as recreational fishing, walking and boating, were assessed. However, spiritual ES were outside the scope of this project and are being considered as a separate exercise by the WRC.

Key results

The ES that we were able to quantify in monetary terms during this desktop assessment mainly applied to provisioning services. We found some relevant data for bottled water and commercial eel fisheries. Values of some ES were available in ecological and flow quantities, for example hydrological regulation values expressed in cubic metres per second. Others have been qualitatively described (e.g. historical values) based on relevant publications. However, a large majority of the ES that we evaluated remain to be valued, quantified and studied in future freshwater ES assessments.

Water supply was the key provisioning ES identified in the Waihou River catchment. In particular the Blue Springs (Site 1), near Putaruru Township, provides a major source of bottling water. Most of the other sites provided water supply to local townships. Commercial eel fisheries were limited to the main stem of the Waihou River and Ohinemuri River (a major tributary of the Waihou River). Recreational fishing, particularly trout fishing, which extends throughout the catchment, will most likely be providing a provisioning food supply, but we were unable to quantify this in the desktop evaluation. Water allocation pressures are present in the Waihou catchment and for the Ohinemuri and Matatoki sub-catchments, municipal use is the main pressure on water allocation.

The natural high water quality ES provided by the forested headwaters in the Coromandel, Kaimai and Mamaku Ranges declined downstream, particularly for sediment, microbial contamination and key nutrients such as nitrogen and phosphorus, most likely in response to the increasing proportion

of more intensive agricultural activities in the lower parts of the catchment. The combined microbial contamination and high sediment levels have had adverse impact on the human health ES and the 'swimmability' in these sections of the Waihou River system. Wastewater regulation was mainly confined to sites with nearby townships, where the Waihou River received discharges, primarily from urban stormwater.

The spring-fed headwaters and the smaller forested headwater catchments in the Waihou catchment will provide a moderating influence on the hydrological flow, sediment and nutrient regulation ES along with water yield in smaller catchments where forests are the dominant land cover. However, the steep topography in these catchments together with intense rainfall events that are frequent in these areas, means that these catchments are prone to flooding. The lower reaches of the Waihou River system, along with the Ohinemuri River have been identified as flood-prone areas. The natural flood regulation provided by the historically forested floodplain and wetland areas in the Hauraki Plains has been largely lost through conversion to farmland and the disconnection of the Waihou River from its floodplains. The establishment of stopbanks to manage the flood risk along this section of the river system have contributed to this disconnection. However, Munro (2007) stated that the 'river flooding hazards pose the greatest risk in terms of potential loss of human life, social disruption, economic cost and infrastructure damage in the Hauraki District. Munro (2007) estimated that 35% of the total capital value of the Hauraki district falls within the flood hazard zone currently identified in the district.

The cultural ES we found data on, included recreation (e.g. fishing, walking, boating) and history/heritage values for the iconic sections of the Waihou River (e.g. Karangahake, Waihou at Whites Road, Te Aroha and Paeroa). Very limited data were found on smaller streams, as expected. We found significant recreation values i.e. greater than $1 million per year in walking visits in the Blue Spring and Karangahake Gorge sites due to the presence of walkways (which also serve as mountain biking trails).[1] Historically, the section of the Waihou River from the mouth of the river upstream to Te Aroha provided a major water transport avenue, particularly in the 1800s.[2] The river also provides important cultural and natural heritage values.

In this assessment project, we have recognised that the provision of some ecosystem services (e.g. flood mitigation) can also be limited due to factors such as topography and intense and frequent rainfall. We provided examples which show that while forests and other vegetation in the upper section of the catchments provide some flood regulation services, they cannot totally stop floods from occurring. We have also shown examples of reduction in flood regulation services (or disservices) as a consequence of conversion of natural landscapes into productive land use. Including ecosystem limitations and disservices in ecosystem assessment provides a more holistic view of the value and limits of ecosystems.

Conclusions

The research identified and, where possible, valued the ES provided by a sample of stream and river sites in the Waihou catchment. It will contribute to the larger body of work being undertaken to value the ES provided by a range of freshwater bodies (i.e. rivers, streams, lakes, wetlands) in the Waikato region. This information will contribute to the on-going development of the methodology and tools (i.e. freshwater ES databases & interactive maps) needed for assessing and valuing the freshwater ES in the region. The inclusion of the initial set of values identified from this project into a publicly accessible database could be a good start to communicate and socialise these values and to make the public more aware of the key services and disservices that rivers and streams provide. The public can also provide the council and the project team feedback on their interpretation of the values and may suggest what other ecosystem values or indicators should be included on the list in the future.

Further work

Phases 1 and 2 of this project have provided a valuable basis for assessing freshwater ES in two large catchments in the Waikato region (Waikato and Waihou). There is the opportunity to build

[1] The 173-kilometre Hauraki Rail Trail walkway which passes through our two catchment sites provides a good avenue to enjoy the aesthetic views of Karangahake and Paeroa river sites.
[2] http://ohinemuri.org.nz/journals/14-journal-3-april-1965/375-water-transport-in-the-thames-valley

and expand on this desktop assessment process by undertaking a more comprehensive economic, environmental, cultural and social assessment of the freshwater ES at the sub-catchment level. Methodologies developed during this process could then be adapted and applied to other catchments in the region (refer to Recommendations for further details).

It is recommended that the ES values from Phase 1 (Waikato River catchment) and Phase 2 (Waihou River catchment) should be further refined and integrated into a cohesive environmental accounting system. This integration will allow a more robust comparison of the market and non-market ES values as well as ES physical quantities. Adopting a water accounting framework in combination with market and non-market valuation methods and other ES quantification methods could be piloted in a small catchment in the region by a multidisciplinary team.

Waihou River Ecosystem Services assessment

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Introduction

Ecosystem services (ES) are referred to as the benefits that people derive from ecosystems, and the direct and indirect contributions of ecosystems to human well-being (MEA, 2005; TEEB, 2010; UKNEA, 2011). The ES concept helps to demonstrate the key role of ecosystem functions that support the delivery of multiple benefits to humans. Understanding the linkages between the natural capital, socio-economic systems and the flow of ES can lead to improved and more sustainable management of natural and productive ecosystems (Maes et al., 2012; Yao et al., 2013; Yao and Velarde, 2014; Guerry et al., 2015; Jackson et al. 2016).

A large variety of ES have been addressed by assessments such as Millennium Ecosystem Assessment (MEA, 2005), The Economics of Ecosystems and Biodiversity (TEEB, 2010), Mapping and Assessment of Ecosystems and their Services (MAES) (Maes et al., 2016), and national assessments (e.g. UKNEA, 2011). MAES analysed the ES per typology of ecosystem, considering the services delivered by rivers, lakes, groundwater and wetlands in the freshwater pilot study, and those provided by transitional waters, coastal waters, shelf waters and open oceanic water in the marine pilot study. With a slightly different approach, Brauman et al. (2007) discussed the 'hydrologic ecosystem services', defined as the ES that "encompass the benefits to people produced by terrestrial ecosystem effects on freshwater", each hydrological service being characterised by the hydrological attributes of quantity, quality, location and timing. Freshwater ecosystems have also been assessed to provide significant recreation and scenic values as well as maintenance of fisheries and sustaining freshwater-dependent ecosystems such as mangroves, inter-tidal zones, and estuaries, which provide important services to local communities and tourists (Aylward et al., 2005).

Objective 3.8 of the Waikato Regional Policy Statement (RPS) relates to ES, which are referred to as "the range of services associated with natural resources and are recognised and maintained or enhanced to enable their ongoing contribution to regional wellbeing" (Waikato Regional Council, 2016). This ES objective of the council applies to key aspects or key activities in the region such as primary production, air quality, built environment, coastal marine areas and freshwater bodies.

As part of this objective, the council is undertaking an ES approach to identify, value, quantify and describe the freshwater ES in the Waikato Region. The aim of this project is to develop a methodology and tools (i.e. freshwater ES databases and interactive maps) for assessing and valuing the freshwater ES in the region. This will enable a better representation of the broader values of freshwater ecosystems in policy discussions and planning for on-going improvements in the management of freshwater resources. This will benefit the well-being of the communities and peoples within the region.

Phase 1 of this project was a scoping study undertaken in the Waikato River catchment that included a desktop review to identify and value (where possible) the freshwater ecosystems services for a selection of lake, wetland, stream and river sites in the Waikato River catchment. The Millennium Ecosystem Assessment (MEA) framework was used as the basis for this assessment (Olubode-Awosola, 2016).

In Phase 2, the desktop evaluation of freshwater ES has been extended into the Waihou River catchment in the Waikato region of New Zealand. The evaluation covers river, stream, lake and wetland freshwater environments. Waikato Regional Council has commissioned Scion to undertake the freshwater ES evaluation of the river and stream components of this project.

Site selection

The headwaters of the Waihou River originate in the Mamaku Plateau, draining the western slopes of the Kaimai-Mamaku Ranges. The river flows in a northerly direction, travelling through the Hauraki Plains in the lower reaches before emptying into the Firth of Thames. The tidal influence extends up-river to the township of Paeroa (Munro, 2007; Figure 1). The Waihou River has a long narrow drainage basin (Figure 1) encompassing a total catchment area of 198,769 ha. High

producing exotic grassland is the dominant land-use throughout the catchment (57%), indigenous vegetation (28%) is confined mainly to the eastern side of the catchment extending along the Kaimai-Mamaku Ranges, with most of the exotic forest located in the catchment headwaters (10%) (Figure 1).

Ten river and stream sites were selected within the Waihou catchment by the WRC in consultation with Scion. They covered both the main stem of the Waihou River and its tributaries and included a range of catchment sizes, geology, hydrology, topography, land-uses and associated ES (Figure 1, Table 1).

Table 1: Details and location of the 10 sites in the Waihou catchment.

Site No.	Site Code.	Site Name	Easting	Northing
1	1122_41	Waihou River @ Whites Rd	1847029	5788310
2	781_2	Pohomihi Stream @ Above Water Intake Consented Site MPD	1845033	5839251
3	619_20	Ohinemuri River @ SH25 Br	1853801	5859777
4	619_16	Ohinemuri River @ Karangahake	1840302	5855651
5	23_2	Apakura Stream @ Puriri Valley Rd	1836860	5877653
6	1122_22	Waihou River @ Puke Br Paeroa	1834488	5862243
7	1122_34	Waihou River @ Te Aroha	1839179	5841242
8	234_11	Kauaeranga River @ Smiths Cableway/Recorder	1830040	5884528
9	531_4	Matatoki Stream @ Matatoki Rd	1830950	5878339
10	669_6	Oraka Stream @ Lake Rd	1843532	5799203

Source: Waikato Regional Council

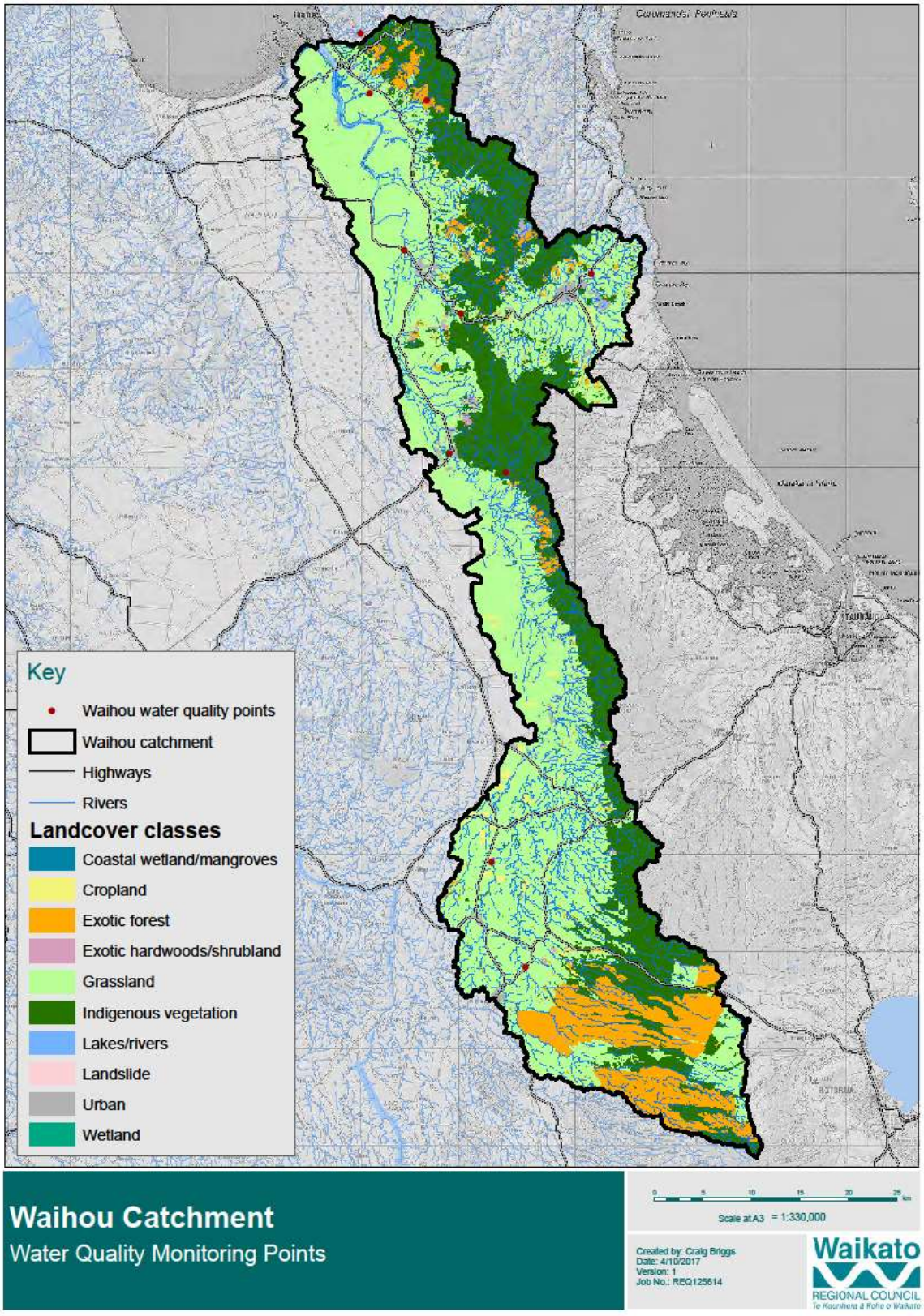

Figure 1: The Waihou catchment and river system showing the location of the 10 river and stream sampling points and the key land-uses in the catchment. Source: Waikato Regional Council.

Methods

Project Implementation

Phase 2 of the Freshwater Ecosystem Services Project was implemented in four stages (Figure 2), similar to the process used in Phase 1 (Baillie & Yao, 2016). The first stage of Phase 2 involved a one-day WRC-led scoping meeting to discuss the outcomes of Phase 1, to outline the scope of Phase 2 with all parties involved, and to determine the number and location of the sites to be included in the freshwater ES assessment (see Table 1 for the river and stream sites).

The second stage involved the development of a freshwater ES assessment template spreadsheet. During Phase 1, a blueprint spreadsheet was provided by the WRC which contained a comprehensive list of potential freshwater ES and indicators. This spreadsheet, along with other key references (i.e., MEA, 2005, TEEB, 2010, UKNEA, 2011, Grizzetti et al., 2015), was used to develop a set of ES considered most relevant to the assessment of the selected river and stream sites in the Waikato River catchment. Key economic, environmental and social indicators were identified and developed for each of these ES, based on those that were relevant and applicable to New Zealand. The resulting evaluation template that was used in Phase 1 has provided the template spreadsheet for Phase 2's freshwater ES evaluation of the Waihou River catchment.

The evaluation focused on three groups of ES: provisioning, regulating and cultural. These groups of services directly and indirectly contribute to key components of human well-being that include security, basic materials for good life, health and social relations (Figure 3). Provisioning services refer to the tangible goods provided by the freshwater ecosystem. These include consumptive use of water for drinking, domestic use and for irrigation as well as non-consumptive use for power generation and transport. Regulating services are the benefits obtained from regulation of the freshwater ecosystem processes. They include maintenance of water quality (e.g. natural filtration), flood flow regulation and erosion control through water/land interactions. Cultural services are the non-material benefits from the freshwater ecosystem, such as recreation, aesthetic experience, historical and heritage values. We focused on these three groups of ES (provisioning, regulating and cultural), and did not include any items under the group of supporting services, to avoid double counting. This is because supporting services are the ecosystem processes (e.g., nutrient cycling, primary production) that underpin the provision of the above three groups of ES. Double counting can be avoided by employing measures such as accounting only for the value of the final ecosystem service benefits (Fisher and Turner, 2008).

We used the finalised template spreadsheet where the evaluation focused on 12 provisioning services, 15 regulating services and 13 cultural services (Microsoft Excel files: Freshwater ES study Phase 2 Waihou River & Streams).

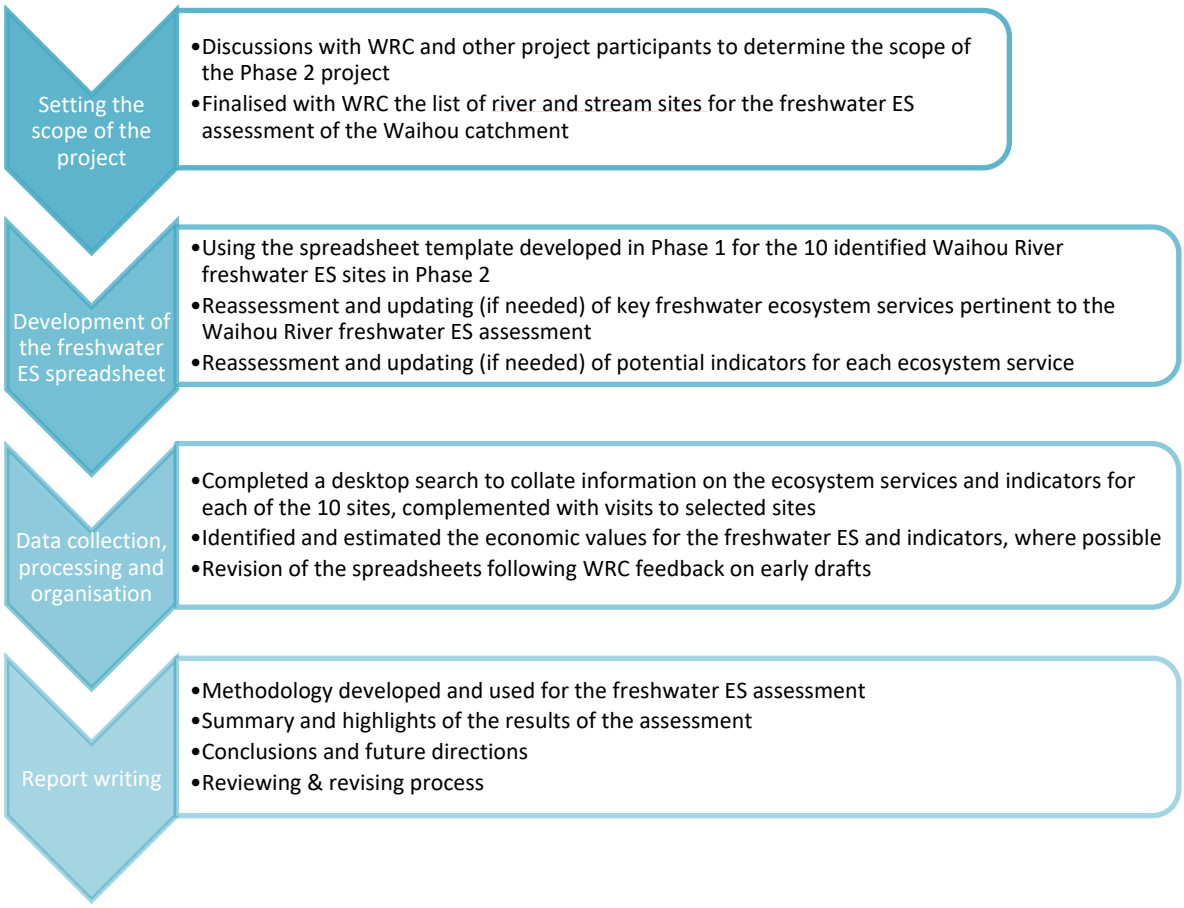

Figure 2: Flow diagram showing the four stages of the project.

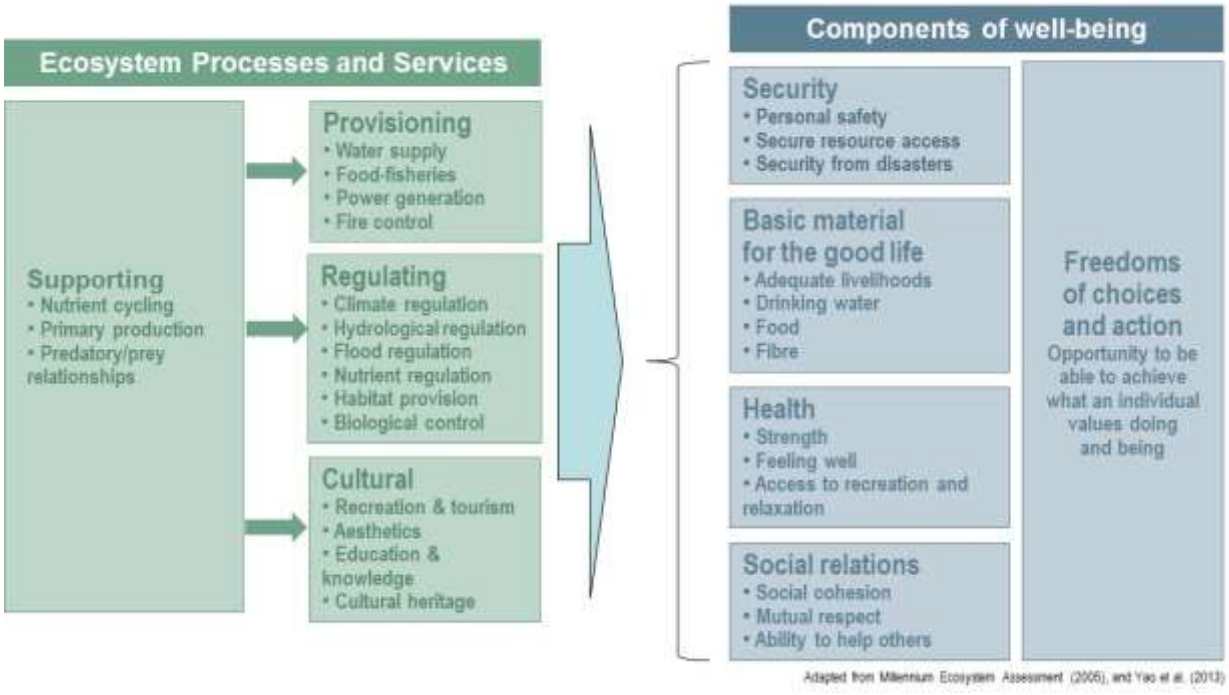

Figure 3: Freshwater ecosystem services and their contributions to human well-being.

In the third stage of the project, the assessment of the freshwater ES in the Waihou catchment involved a desktop evaluation in which readily available data sources were used to populate the spreadsheets with economic, quantitative and qualitative/descriptive information on each of the provisioning, regulating and cultural ES indicators for each of the 10 sites. Key search engines and data sources included Google, Google scholar, Scion's National Forestry Library, Worldcat, the WRC website databases, specific data provided by the WRC, the Land Air Water Aotearoa (LAWA) website and NIWA (National Institute of Water and Atmospheric Research) databases. A water engineer of the South Waikato District Council was consulted to provide clarity on the information about the abstraction (extraction) of freshwater at the first of the 10 river monitoring sites in the Waihou catchment.

The economic values used in the economic assessment component of Phase 1 of this project were revised and updated for Phase 2 and were compiled in the spreadsheet "Summary of ES econ values" in the Microsoft Excel file. More than half of the economic values were identified in Phase 1 while the rest were identified in Phase 2. For Phase 2, all economic values have been converted to the 2017 (second quarter) NZ dollar values (using the Reserve Bank of New Zealand inflation calculator)[3] before using the numbers to calculate the aggregate ecosystem service values. Quantitative and economic data were collated for each ecosystem service where available, along with any qualitative information, which was summarised in the 'Comments' column of the spreadsheet. Where no information was found in the desktop evaluation, this was also noted in the 'Comments' column. If an ES was not relevant to a particular site, this was recorded as N/A (not applicable) in the 'Quantitative' section of the spreadsheet along with a comment to that effect; e.g. the provisioning ecosystem service of power generation was N/A for all the sites that we assessed in the Waihou catchment.

Field visits to five of the sites (Sites 5, 6, 8, 9 and 10) complemented the desktop assessment. We chose sites that weren't already familiar to the authors and which covered the extent of the Waihou catchment from the upper reaches to the Firth of Thames and included a range of catchment sizes and land uses. Site visits included field assessments of observable ES, land-use effects and any other information relevant to the freshwater ES assessment. Both man-made and ecological infrastructure features of each site were noted. Data from the field visits were incorporated into the spreadsheets and into the results section of this report.

The fourth stage involved preparing this report.

Scope and limitations

- The assessment of freshwater ES for sites with large catchment areas upstream was confined to the immediate vicinity of the site to keep within the scope of this study, although the wider catchment was included for some ES. This localised assessment included sites 4, 6, 7, 8 and 10. For Sites 1, 2, 3, 5 and 9, the entire upstream catchment was considered in the freshwater ES assessment.
- For the Cultural ES - scientific studies, we used the Google Scholar search engine to identify any scientific publications relevant to the site, published from 1965 onward. Note that this search engine did not identify Waikato Regional Council reports.
- We recognise the strong spiritual (including Māori cultural) links with the Waihou River (i.e. Phillips 2000). However, this component was outside the scope of this study and will be assessed separately by the WRC.
- In Phase 1 we estimated the water supply value (under provisioning services) based on the consented volume of extraction. However, in Phase 2 we found that the actual volume of water extracted can be significantly less than the consented volume. Water loss can also occur due to evaporation. Therefore, in Phase 2 we only valued the approximated volume of water distributed to end users.
- Some freshwater ES have values that are observed in market transactions (e.g. $1 per cubic metre of metred drinking water) while the value of some ecosystem services are not observed in the market (e.g. $6 per person for a picnic visit at a public park by the river). In calculating an approximate aggregate value per year of a particular ES, we would need the total volume of drinking water consumed, or the total number of visits. Usually, the volume

[3] https://rbnz.govt.nz/monetary-policy/inflation-calculator

of water received by households, as well as the total number of visits are not available hindering the calculation of approximate annual values of those services.
- Both the desktop assessment and field trip provided a ‘snapshot’ assessment of ES in the Waihou catchment and had limited scope to incorporate a temporal component in the assessment methodology.

The inherent limitation of a desktop evaluation is that it can only provide an initial indication of the freshwater ES at each of these sites. The extent of the desktop evaluation was governed by the time availability in the project and is a pre-cursor to potentially more comprehensive freshwater ecosystem service assessments (see Recommendations). We acknowledge that the indicators identified in this desktop evaluation are not a comprehensive list and there may be additional indicators that would be appropriate to include e.g. sequestration services for sediment and nutrients.

Results

Each of the 10 sites is described below, along with a summary of the key ES relevant to each site. We recommend that this section be read in conjunction with the accompanying spreadsheet which contains the detailed information and references (Microsoft Excel files: Freshwater ES study Phase 2 Waihou River & Streams).

Site 1 - Waihou River @ Whites Rd

This site has an upstream catchment area of 4,204 ha. Exotic forest is the predominant land-use (60%), located in the upper reaches of the catchment, primarily in the Mamaku Plateau along with smaller areas of indigenous forest (11% of land cover). High producing exotic grassland (22%) is located in the lower section of the catchment (Figure 4). The hydrology is predominantly spring-fed in this headwater site.

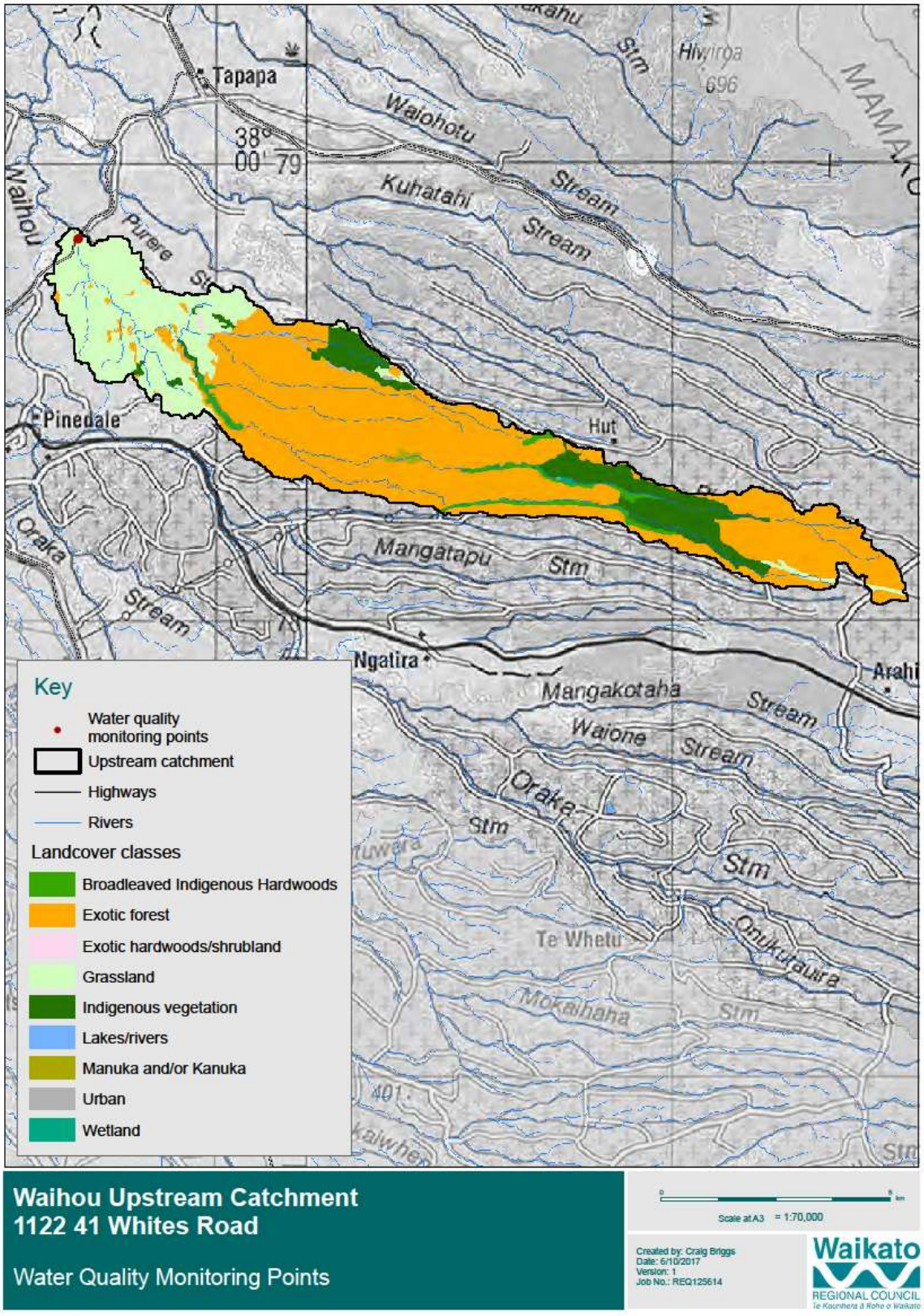

Figure 4: Site 1 upstream catchment area and land cover.

Summary of ecosystem services

The catchment site is located in the South Waikato District near Putaruru. The catchment contains the internationally acclaimed Blue Spring and the 4.7 km Te Waihou Walkway built beside the river site.[4] The clean, blue-coloured water is a popular attraction as almost everything under water is visible from above (Figure 5). The walkway is open to the general public all year round.

The main provisioning ES for this site was water supply. The Blue Spring has been found to produce approximately 22 million m^3 of clear water.[5] This water is an excellent drinking water source for the community and those who consume the bottled water "Kiwi Blue".[6] A consent for water abstraction exists about 1.8 km upstream from the water monitoring site. The consented water abstraction rate is about 4,000 m^3 per day (1.46 million m^3 per year). The South Waikato District Council extracts about 1,000 m^3 of water per day (Pascoe, 2017). Estimating the value of the volume of water distributed to households would require data on the actual volume of water received by households and water users. The council charged about \$1.05/m^3 for the water distributed to households with water metres. Multinational bottling company, Coca Cola (makers of the Kiwi Blue bottled drinking water), paid \$40,000 in 2016 to the South Waikato District Council for the right to bottle up to 200 m^3 of water a day for a year (The Guardian, 2017). While this site may be providing other provisioning ES, no qualitative or quantitative information was found in the desktop assessment.

The spring-fed source in the upper headwaters of the Waihou River, along with the predominantly exotic forest land cover, provides hydrological flow and flood regulating ES at this point in the Waihou River catchment and will assist in moderating high flows and flood events (depending on size and duration). The predominantly forested catchment will also influence water yield. While the water quality is rated high for water bottling purposes it is noted that the LAWA website shows degrading water quality for total nitrogen. The WRC habitat score indicated that in-stream habitat was good and the WRC human health ES ranking for this site was excellent.

The site provides valuable recreation services. Visitors can engage in recreational walking, mountain biking, fly fishing, duck hunting (recreational anglers and hunters need to obtain a license) and scenic viewing.[7] The site is open to the general public and received between 30,000 and 50,000 visitors per year from 2015 to 2017 (Kirkeby, 2017). Based on our calculations, the aggregated recreational value per year can range between \$823,000 and \$1,371,000 (in 2017 NZ\$). The site is also suitable for picnicking (LAWA 2017; SWDC 2017)[8]. A website of the South Waikato District Council discourages swimming in the river due to the damages that this activity can cause[9], although the authors have observed people swimming in the river.

The Blue Spring is not in the Waikato Region's list of outstanding natural features and landscapes or outstanding freshwater bodies, but is described as ' internationally acclaimed' and of historical and cultural significance on the South Waikato District Council website (WRC, 2016). The Te Waihou/Blue Spring website indicates that while kayaking is not prohibited, access is difficult along this section of the Waihou River.

[4] http://www.southwaikato.govt.nz/our-district/sport-and-recreation/parks-and-reserves/Pages/Te-Waihou-Walkway.aspx
[5] http://www.hamiltonwaikato.com/experiences/walking-hiking-trails/blue-spring-te-waihou-walkway/
[6] https://ccamatil.co.nz/brands/kiwi-blue-still/
[7] http://www.hamiltonwaikato.com/experiences/walking-hiking-trails/blue-spring-te-waihou-walkway/
[8] A value of a picnic visit per person per day was approximately \$8.45 as reported by Kaval and Yao (2010).
[9] http://www.southwaikato.govt.nz/our-district/sport-and-recreation/parks-and-reserves/Pages/Te-Waihou-Walkway.aspx

[10]**Figure 5:** Site 1 – Google map photo of the Blue Spring and the Te Waihou Walkway.

Site 2 - Pohomihi Stream @ Above Water Intake

This small headwater stream has an upstream catchment area of 487 ha. The catchment is in indigenous forest (Figure 6), providing high quality water to downstream users.

[10] https://www.google.co.nz/maps/place/Blue+Spring/@-38.0356502,175.8382942,799m/data=!3m1!1e3!4m12!1m6!3m5!1s0x6d6c4f2941648d99:0x35070aee0b1e61aa!2sBlue+Spring!8m2!3d-38.0362089!4d175.8352064!3m4!1s0x6d6c4f2941648d99:0x35070aee0b1e61aa!8m2!3d-38.0362089!4d175.8352064

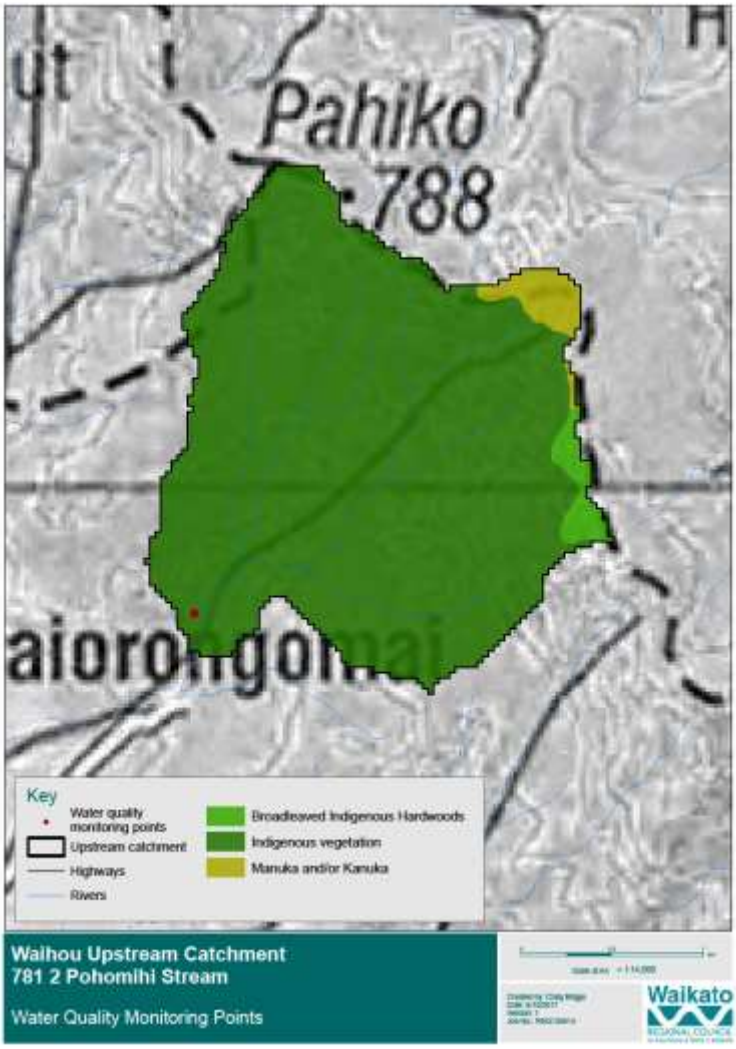

Figure 6: Site 2 upstream catchment area and land cover.

Summary of ecosystem services

Qualitative and quantitative information found on the ES at this site during the desktop evaluation was limited. The main provisioning ES identified was the provision of water supply to the township of Te Aroha. Although specific data was lacking on most of the regulating services at this site, the indigenous forested headwaters may be providing hydrological ES to downstream land owners and communities, such as reducing water yield, moderating flow regimes and reducing peak flood flows for smaller flood events (i.e. Davie & Fahey, 2005; Duncan & Woods, 2004). Similarly, small forested catchments such as this will be moderating sediment and nutrient export from the catchment. Although data was lacking on the physical and chemical components of water quality, the aquatic invertebrate data indicated excellent water quality at this site. The WRC habitat score and site conditions described on the LAWA website indicated that this site is providing a high habitat provisioning service. Given the small size and location of this catchment, cultural ES were limited, particularly for tourism and recreational activities. However, the intrinsic ES values (e.g. existence value) provided by the indigenous fish communities present in this stream are recognised.

Site 3 - Ohinemuri River @ SH25 Br

This site has an upstream catchment area of 2,621 ha. The headwaters are in indigenous vegetation (29% of land cover) with most of the remaining catchment area in high producing exotic grassland (58%) (Figure 7). While the water quality is generally good at this site some aspects of water quality (i.e. nitrogen) are most likely compromised by land-use activities in the catchment.

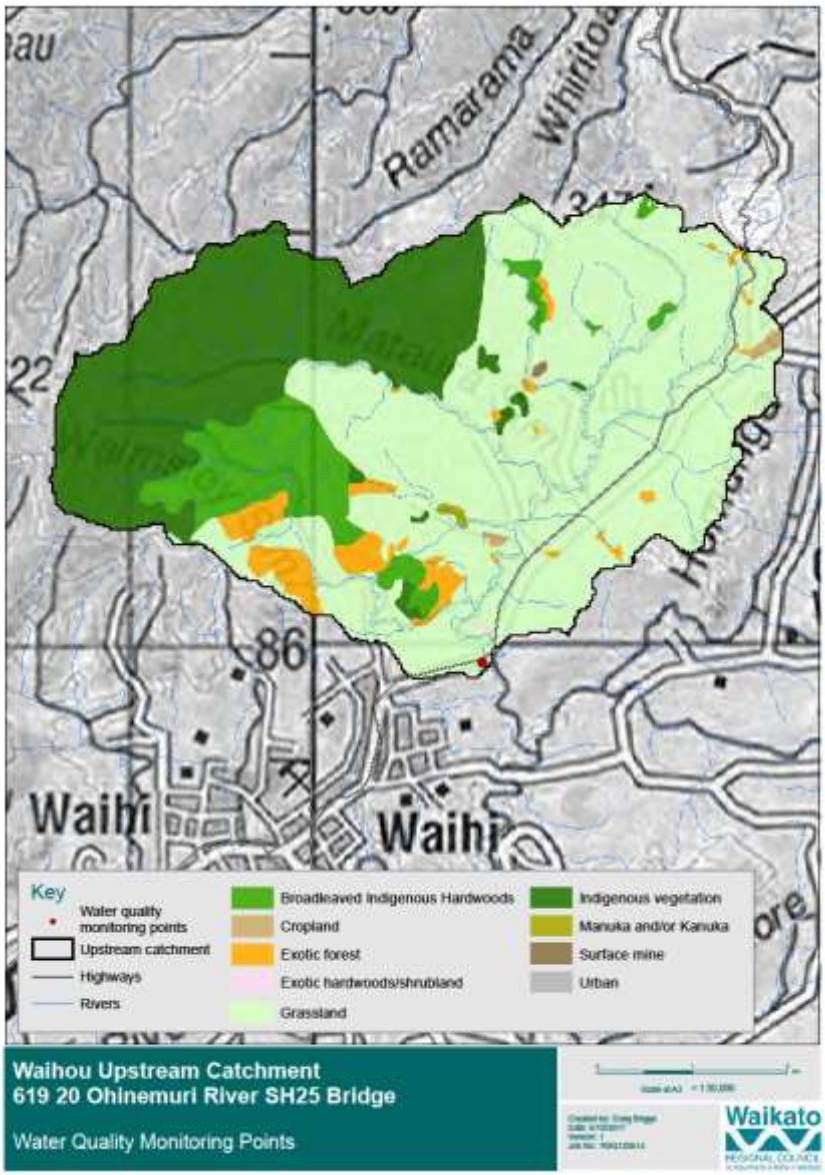

Figure 7: Site 3 upstream catchment area and land cover.

Summary of ecosystem services

The forested headwaters of this catchment are providing a provisioning water supply ES to the nearby township of Waihi. No quantitative or qualitative information was found for the remaining provisioning ES in this catchment although the water supply to Waihi also provides a source of water for firefighting purposes. Municipal supply is putting pressure on water resources at this site.

The Ohinemuri River is prone to flooding (Munroe, 2007) indicating that the headwaters where this site is located are providing limited hydrological regulation. Although the forested headwaters at this site will have a moderating influence on the hydrological regime, the combination of predominantly pasture land cover in the catchment, steep catchment drainage and the regular high intensity rainfall events that occur in the Coromandel Ranges (Munroe, 2007), all contribute to the flood risk at this site. No sediment and nutrient regulation information was located for this site but the water quality data, along with the presence of trout at this site, indicates that water quality is good, with the exception of nitrogen, most likely a result of the intensive agriculture in the catchment. This site also provides waste treatment ES for the discharge up to 8 cubic metres per day of treated dairy effluent into a tributary of the Ohinemuri River. *E.coli*. counts indicate that the human health ES at this site is ‘Satisfactory’.

This section of the Ohinemuri Stream is good for trout fishing. While other cultural ES such as other recreational activities, may be occurring at this site, no information was found during the desktop evaluation.

Site 4 - Ohinemuri River @ Karangahake

This site has an upstream catchment area of 28,617 ha. The predominant land cover is high producing exotic grassland (46%), along with indigenous forest (41%) located primarily in the steeper catchment headwaters of the Coromandel and Kaimai Ranges (Figure 8). The combination of steep topography, susceptibility to high rainfall events and limited hydrological flow regulation provided by the existing forest cover and other vegetation in the catchment, make this site prone to flooding.

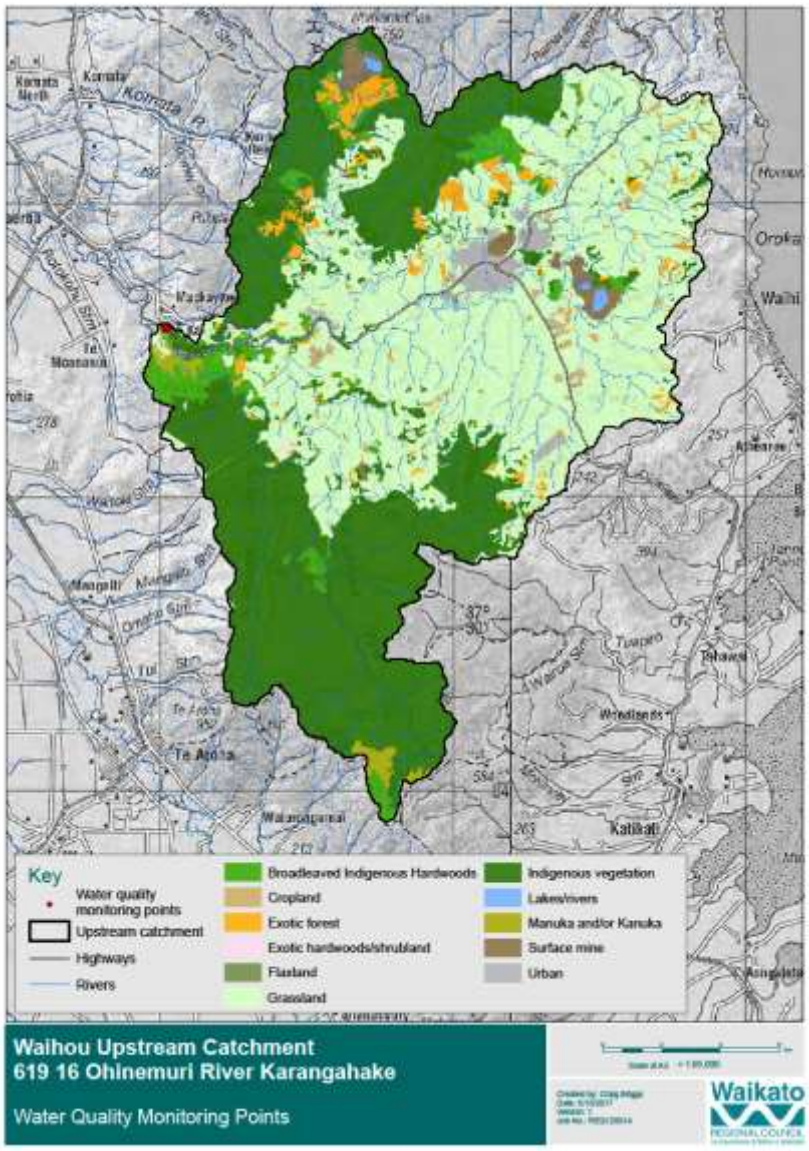

Figure 8: Site 4 upstream catchment area and land cover.

Summary of ecosystem services

This part of the Waihou River provides a number of benefits to society such as water supply, commercial eel fishing, and recreation. About 1.3 km upstream from the water monitoring station, there is a resource consent for water extraction of up to 2.5 million m^3 that is distributed to Paeroa residents (Resource consent AUTH101995.01.02). Water allocation is under pressure in this catchment, particularly for municipal use. Beentjies (2016) indicates that commercial fishing of longfin eel occurs at the site about two to three times a year. A rough figure from Beentjies (2016) suggests that the volume of fish caught from this section can be approximately 3.6 tonnes per year. Multiplying this volume by the average price of $21.56/kg, the approximate market value of fish caught is about $78,000 per year. Commercial eel fishing exists in the Paeroa and Te Aroha sites, but we assume that the value of the eels caught in those sites also contributes to this aggregate value. This is to prevent double counting. Furthermore, the indicative market value of eels reported here should be verified and supported by additional data before using for decision making.

The headwaters of this catchment are indigenous forest and provide some regulating services for erosion and hydrology. However, the combined steep topography and propensity for intense rainfall events provide a low natural flood regulation ES. As a result, this section of the Ohinemuri River is prone to flooding and a flood alarm has been installed in Karangahake. There is a generic resource consent held to divert and discharge urban stormwater runoff and associated contaminants at multiple locations including the Ohinemuri River and encompassing Karangahake and Mackaytown urban areas.

The water monitoring site in Karangahake is situated near the Hauraki Rail Trail walkway. Part of the walkway is located 600 m southeast of the site (Figure 9). The walkway received close to 103,000 visitors per year between 2005 and 2006, including both domestic and international tourists (Kaval, 2006). The walkway from Paeroa to Waihi passes through the Karangahake Gorge which provides a view of the Ohinemuri River (DOC, 2013; Hauraki Rail Trail website, 2017). According to Kaval (2006) approximately 62,781 New Zealanders walked on the Karangahake walkway. Matthews (2009) estimated that an indicative value per year of walking along a scenic river in the Waikato region (includes use, option use and non-use values) was about NZ$27.42. Multiplying this value by the number of New Zealand visitors results to a conservative public walkway value of approximately NZ$1.7 million per year. The value for international visitors would likely be higher. As we did not have the walking value of overseas visitors, we did not include this in the calculation.

The trails situated close to the monitoring site also provide mountain biking and dog walking amenities.[11] There is contradictory information on the ‘swimmability’ at this site. The LAWA website indicates that the site was suitable for swimming and boating.[12] However, the WRC website says that swimming is "not OK" while MfE says "it's OK, every now and then”.[13]

The section through the Karangahake Gorge is the most popular and productive section of the river for trout fishing.[14] Access to much of the Ohinemuri is relatively easy as SH 2 follows the river for much of its length. Within the Karangahake Gorge, there are a number of good access points and parking spaces.[15] A couple of recreational fishing videos on Ohinemuri were found on YouTube on 20 Nov 2017.[16,17]

[11] http://www.doc.govt.nz/parks-and-recreation/places-to-go/bay-of-plenty/places/kaimai-mamaku-forest-park/things-to-do/tracks/karangahake-gorge-historic-walkway/ and http://www.doc.govt.nz/Documents/parks-and-recreation/tracks-and-walks/waikato/karangahake-gorge-brochure.pdf
[12] https://www.lawa.org.nz/explore-data/waikato-region/river-quality/waihou-river/ohinemuri-at-karangahake/
[13] https://www.waikatoregion.govt.nz/environment/natural-resources/water/rivers/our-other-rivers/water-quality-monitoring-map/ohinemuri-river-at-karangahake-niwa-site/
[14] https://fishandgame.org.nz/dmsdocument/9
[15] http://www.nzfishing.com/FishingWaters/AucklandWaikato/AWFishingWaters/AWOhinemuri.htm
[16] https://www.youtube.com/watch?v=zNXS17K1mkg
[17] https://www.youtube.com/watch?v=0JFaksKrSN4

Figure 9: Site 4 – A Google map photo showing the section of the Ohinemuri River next to the Hauraki Rail Trail walkway which is located approximately 600 m southeast of the water monitoring station.

Site 5 - Apakura Stream @ Puriri Valley Rd

This small headwater catchment on the western side of the Coromandel Range, has an upstream catchment area of 301 ha. The predominant land-use is indigenous forest (62%) followed by exotic forest (34%) (Figures 10 and 11). While this catchment is prone to flooding downstream, the predominantly forested cover in this headwater catchment is likely to have some moderating influence (depending on the flood size and duration).

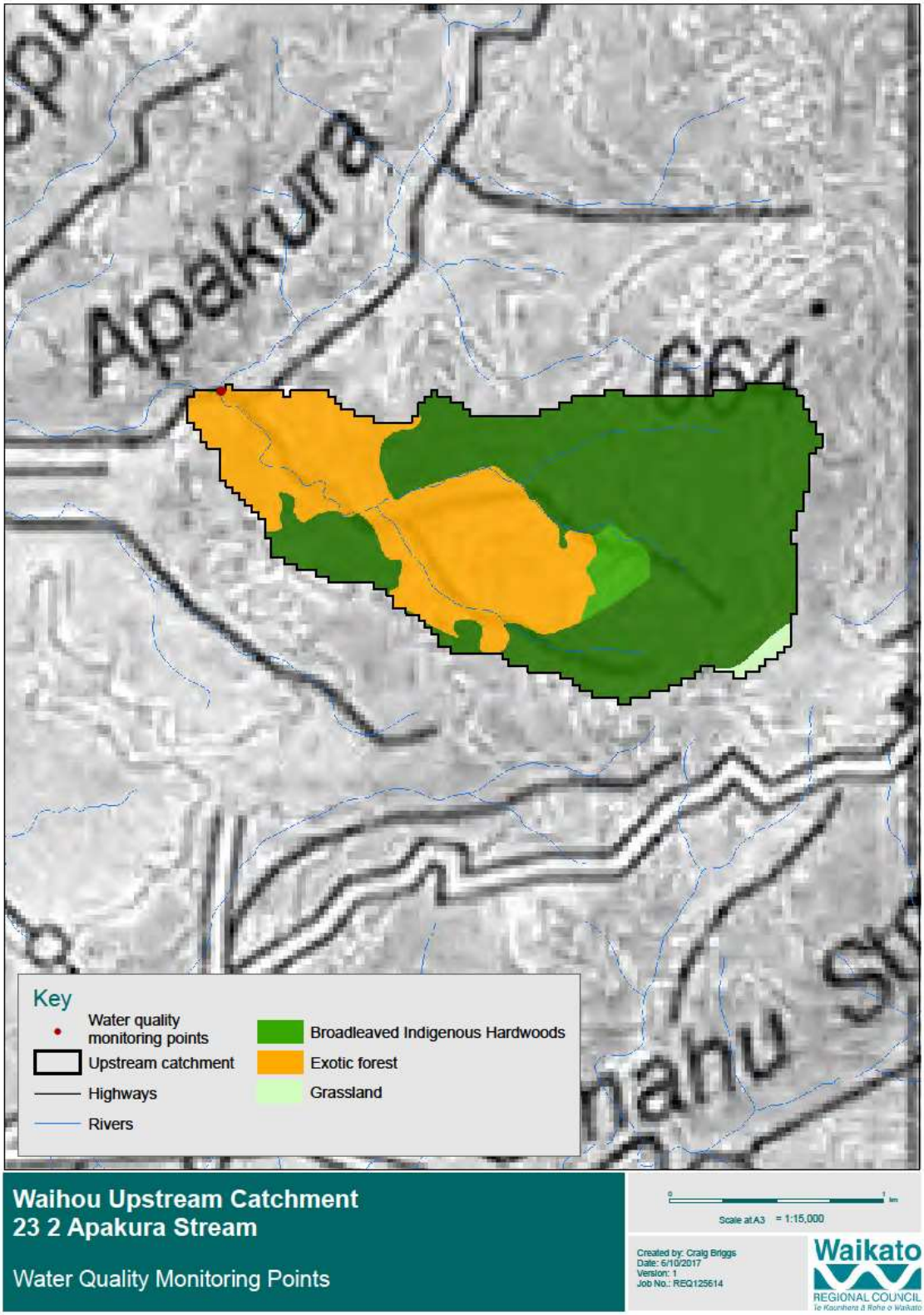

Figure 10: Site 5 upstream catchment area and land cover.

Figure 11: Water supply system in the Apakura catchment.

Summary of ecosystem services

This site provides a water supply to settlements in the Thames Valley (Figure 10) and was the only quantitative provisioning service identified at this site. While other provisioning services may be occurring here, they were not identified in the desktop evaluation.

The forest cover in this upper catchment would likely influence hydrological regulation such as reducing water yield. The forest cover can also have a moderating influence on flood regulation particularly for smaller flood events. However, because of the steep topography and susceptibility to intense rainfall events, this site is still susceptible to flooding (there were indications of this at the site visit). Apakura Stream is a tributary of the Puriri River and the flood stopbanks downstream on this river are further indications that the influence of the forested headwaters on flood regulation ES is having a limited influence at the larger catchment scale. While no information was found on the sediment and nutrient regulation ES, the forested cover is likely supporting these ES. Both the WRC habitat score and the visual inspection of the in-stream substrate and riparian cover during the field visit (Figure 11), along with the aquatic invertebrate data, indicate that this site provides a high habitat provisioning ES.

No cultural ES such as recreational and tourism activities and heritage and aesthetic values were identified at this site from both the desktop evaluation and the field visit, perhaps due to a reflection of the small catchment size and associated limited access into the site.

Site 6 - Waihou River @ Puke Bridge, Paeroa

This site is on the main stem of the Waihou River downstream of the township of Paeroa. It has an upstream catchment area of 155,487 ha, predominantly in high producing exotic grassland (57% of land cover). The indigenous forest (25% of land cover) is located in the along the western margins of the Coromandel and Kaimai Ranges, with exotic forests (12%) located in the headwaters of the Mamaku Plateau (Figure 12). There is a tidal influence at this site.

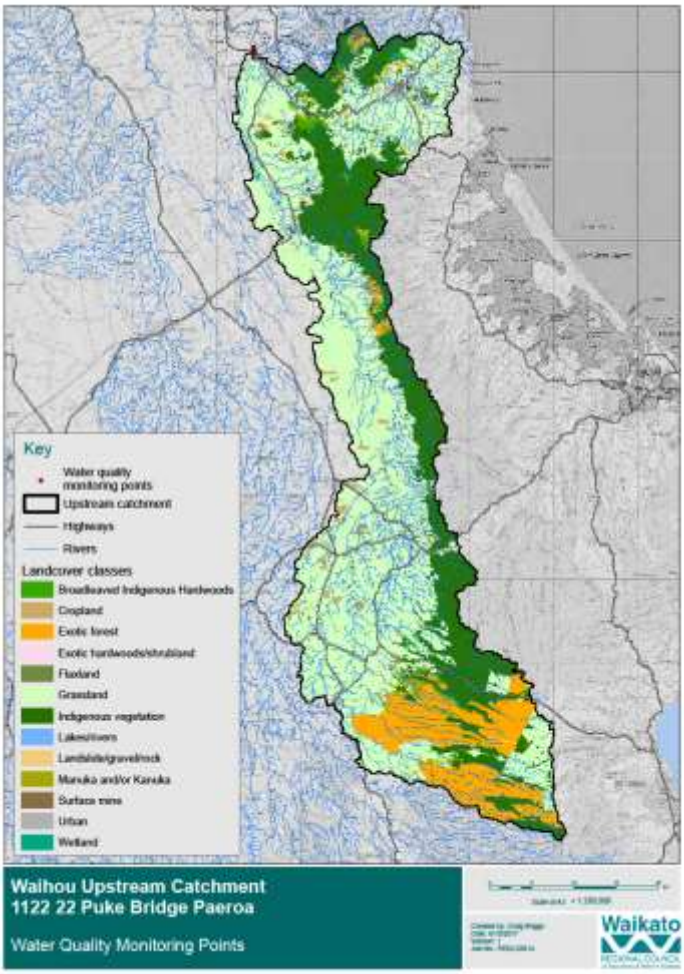

Figure 12: Site 6 upstream catchment area and land cover.

Summary of ecosystem services

The main provisioning ES at this site include commercial eel fishing. The river provides a navigation pathway for boating traffic from the Firth of Thames up to this point in the river system. Beentjies (2016) indicates that commercial fishing of longfin eel occurs along this section of the Waihou River at greater than three times a year with an estimated value that is part of the $78,000 per year reported in the Karangahake Gorge site (Site 4).

While other provisioning ES may be present at this site, no quantitative or qualitative information was found during the desktop assessment or field trip.

The regulation freshwater ES provided by the Waihou River at this point in the system are likely to be limited. This site is located downstream from the confluence of the flood-prone Ohinemuri River with the Waihou River and has been identified as a high flood risk area by the WRC. Any natural flooding and sediment regulation ES provided by the historic forested floodplains and wetlands in this area would have been lost with the conversion to agricultural land. Stop banks along the river (Figure 13) and pumping stations at Paeroa, have been established as part of the Waihou Valley Scheme to control flooding. The muddy waters observed during the field visit indicated limited

sediment ES at this site and the stopbanks will be inhibiting the natural hydrological and sediment regulation ES along this section of the Waihou River, increasing the amount of sediment exported to the Firth of Thames. We were unable to quantify other regulation ES at this site either because of a lack of data located in the desktop assessment or the tidal influence making it difficult to fully assess the freshwater ES, i.e. maintaining aquatic populations and water quality.

This site on the Waihou River supports a number of cultural ES. This is a well-researched site as indicated by the number of scientific publications. There is a boat ramp and jetty (loading platform) (Figure 13) at this site, supporting motorised (observed during the field visit) and non-motorised boating and fishing activities and there are also consented whitebait stands in the vicinity of this site. Landscape plantings along the stopbanks (Figure 13) provide some aesthetic ES at this site. The tidal influence limited the ability to fully evaluate the intrinsic value of indigenous freshwater fish but the presence of exotic pest fish species (e.g. goldfish) may be compromising this ES value at this point in the Waihou River system.

Figure 13: Waihou River at Site 6, looking downstream.

The Hauraki Rail Trail walkway that passes through the Karangahake site (Site 4), also passes through this site. This site therefore gets a large number of walking and mountain biking visits from the 103,000 domestic and international visitors (Kaval, 2006). This section of the Ohinemuri River is known for trout fishing.[18,19] This part of the river is also rich in history as it used to have eels and whitebait, and water was fit for drinking.[20] This section of the river also provides recreational boating opportunities (e.g. kayaking).[21]

[18] http://www.nzfishing.com/FishingWaters/AucklandWaikato/AWFishingWaters/AWOhinemuri.htm
[19] http://www.pedlarsmotel.nz/trout-fishing
[20] https://forms.justice.govt.nz/search/Documents/WT/wt_DOC_68331905/Hauraki%20Vol%203.pdf
[21] http://www.womentravelnz.com/kayak-waihou-river/

Site 7 - Waihou River @ Te Aroha

This site has an upstream catchment area of 110,689 ha. High producing exotic grassland is the main land cover throughout the catchment (57%) with indigenous forest (22% of land cover) confined mainly to the steeper western margins of the Coromandel and Kaimai Ranges. Exotic forests (16%) were located in the headwaters of the Mamaku Plateau (Figure 14). Water quality is poor at this site, most likely a result of the intensive agriculture in the catchment, and the area is prone to flooding.

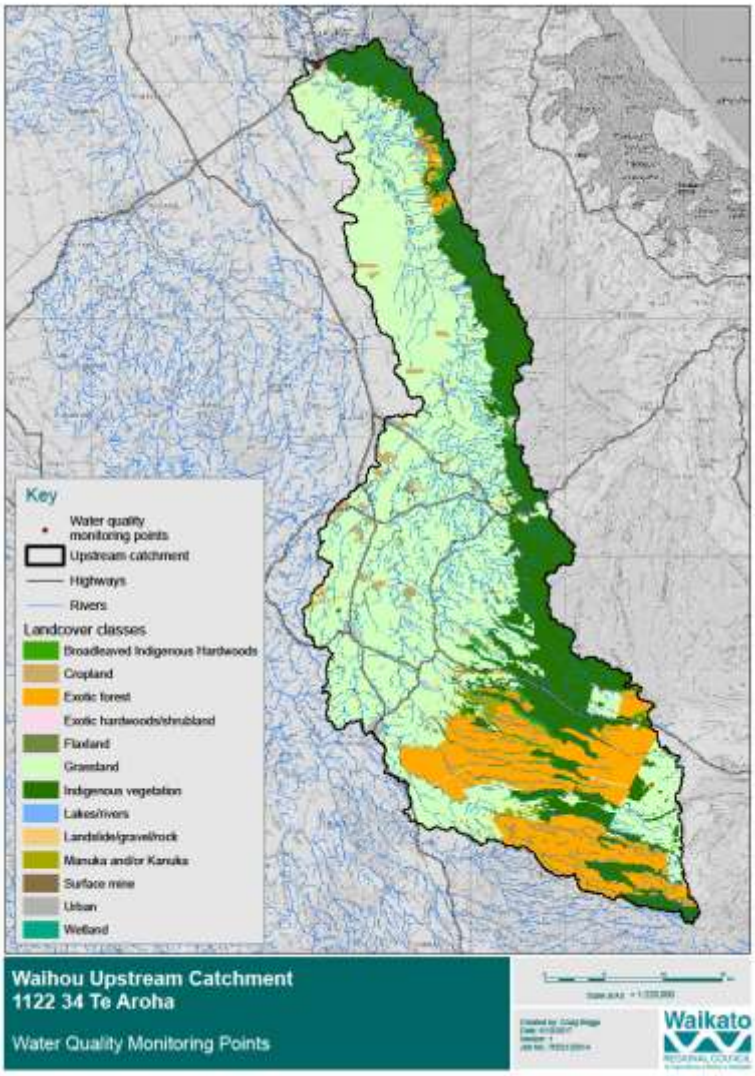

Figure 14: Site 7 upstream catchment area and land cover.

Summary of ecosystem services

This part of the Waihou River provides important benefits such as water supply, commercial eel fisheries, recreation and historical/heritage values. Water supply is a key provisioning ES at this site and at about 0.75 km upstream from the monitoring station, a resource consent allows an annual water extraction of up to 3.6 million m^3 and this is distributed to Te Aroha residents (Resource consent AUTH109740.01.01). Water sourced from a tributary of the Waihou originating from under Te Aroha Mountain supplies the Te Aroha Health Spa thereby contributing an input to the tourism industry. Beentjies (2016) indicates that commercial fishing of longfin eel occurs at the site greater than three times a year with eels caught to have an approximate value of about $78,000 a year and this value is part of the aggregated commercial eel value in the Karangahake Gorge site (Site 4). Similar to the Karangahake Gorge and Paeroa sites, this value is only indicative and should be recalculated using more comprehensive and updated data before using for decision making.

The natural hydrological, flooding and sediment regulating ES are limited at this site. This site is prone to flooding and the flood risks associated with steep topography and high rainfall events will have been exacerbated by the historic loss of the forested floodplains and wetlands in the catchment, and by conversion into agricultural land. There is a flood warning system at Te Aroha and stop banks have been established in the vicinity of this site as part of the Waihou Valley Scheme to control flooding. The stop banks will increase the disconnection between the river and its floodplain and may increase the amount of sediment exported to the Firth of Thames. The Waihou River at Te Aroha provides a waste water treatment ES for storm water and for treated meat processing effluent from the Te Aroha Township.

The river site is in the middle of the town and has important landscape and aesthetic values.[22] It is located at the centre line where the Waihou River divides the Te Aroha Township into two built up areas. The water monitoring site has a bridge on top painted in heritage colour (Figure 15). Based on Google Maps, the site is close to at least four recreational parks (e.g. Herries Park, Kenrick Street Reserve, Te Aroha Skate Park) (Figure 16).[23] This section of the river also provides recreational boating opportunities (e.g. kayaking).[24]

This section of the Waihou River is a designated duck shooting area by Fish and Game, although this activity is unlikely to occur specifically at this site due to its proximity to the township of Te Aroha.[25] No data on the number of hunting visits have been found in the desktop evaluation.

This section of the river in Te Aroha has rich Māori cultural heritage values. The river has been photographed from the mountain and referred to as “Down by the Willowed Banks of the Waihou River” (Figure 17). Historically, the river was also famous for duck hunting.[26] The section of the Ohinemuri River in Te Aroha had been a major water transport avenue in the 1800s. It also provides other values such as cultural heritage.[27]

Figure 15: A Google map captured photo (taken in February 2013) showing the bridge above the Waihou river site in the township of Te Aroha which has been painted with a “heritage colour”.

[22] http://nzetc.victoria.ac.nz/tm/scholarly/tei-Gov05_07Rail-t1-body-d8.html
[23] https://www.google.co.nz/maps/place/Waihou+River/@-37.546115,175.7088898,437m/data=!3m1!1e3!4m5!3m4!1s0x6d6d9b874c1d3f33:0x2a00ef61665968b0!8m2!3d-37.4209188!4d175.6843238 -
[24] http://www.womentravelnz.com/kayak-waihou-river/
[25] https://fishandgame.org.nz/auckland/game-bird-hunting-in-new-zealand/hunting-locations-and-access/
[26] http://www.mpdc.govt.nz/our-community/498.html?start=1
[27] http://ohinemuri.org.nz/journals/14-journal-3-april-1965/375-water-transport-in-the-thames-valley

Figure 16: A Google map captured satellite photo showing the river site being adjacent to recreational parks in Te Aroha.

DOWN BY THE WILLOWED BANKS OF THE WAIHOU RIVER.

(Rly. Publicity photo.)

Te Aroha as seen from the historic mountain.

Down by the Willowed Banks of the Waihou River.
(Rly. Publicity photo.)
Te Aroha as seen from the historic mountain.

Figure 17: A photograph of the Waihou River in the Te Aroha (Mountain of love) in the early 1900s (Accessed at http://nzetc.victoria.ac.nz/tm/scholarly/tei-Gov05_07Rail-t1-body-d8.html).

Site 8 - Kauaeranga River @ Smiths Cableway

This steep land catchment is upstream of the township of Thames and drains the western side of the Coromandel Ranges. This site has an upstream catchment area of 11,993 ha which is almost entirely in indigenous forest (79%) with 6% of land cover in low producing grassland in the lower part of the catchment (6%) and 4% exotic forest cover (Figure 18). Although the extensive forest cover will provide some moderating influence on flows, the steep topography combined with high rainfall results in frequent flooding in this catchment.

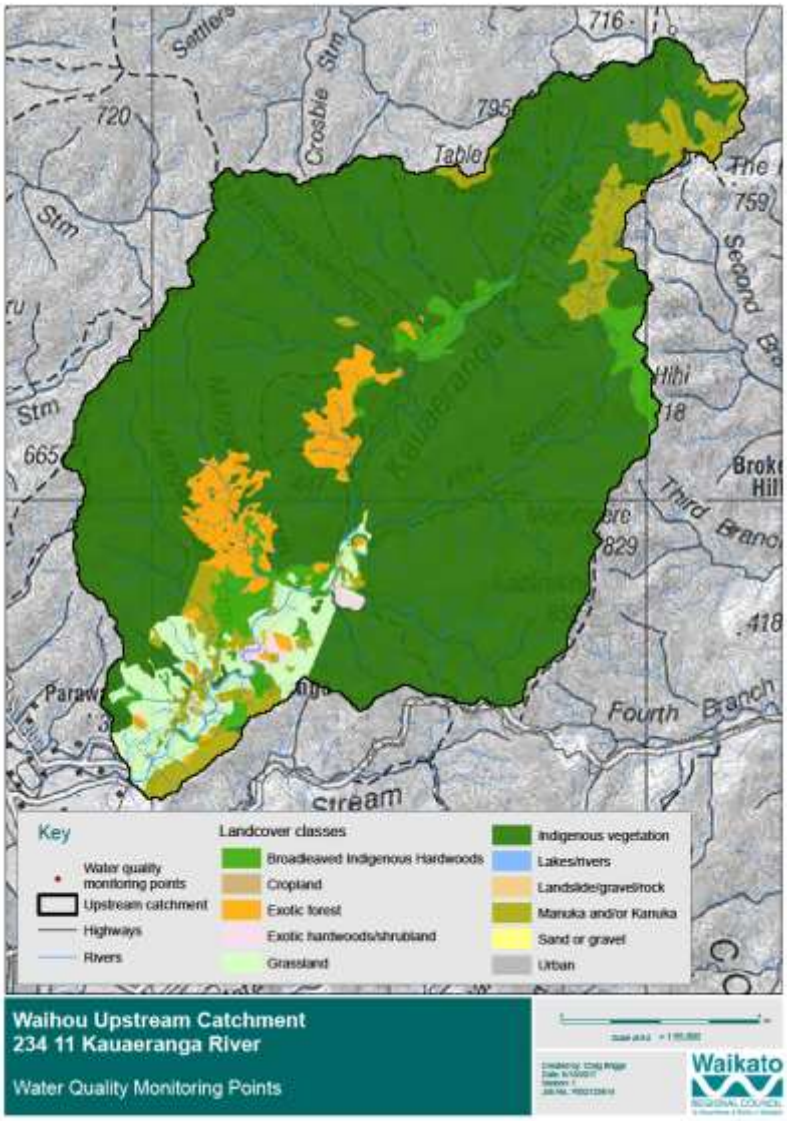

Figure 18: Site 8 upstream catchment area and land cover.

Summary of ecosystem services

This predominantly indigenous forested catchment is a source of domestic and municipal water supply to the downstream Thames area. This water supply also provides water for firefighting purposes. While the trout fishery in the Kauaeranga River will provide a food supply to those fisherman that keep their catch, no quantitative information was found for this, and the remaining, provisioning ES in the desktop evaluation and field visit.

While the forested land cover has an influence on the hydrological and flooding regulation ES, and reducing water yield, the steep topography at this site combined with intense rainfall events means that flooding is a regular occurrence and risk to the downstream township of Thames. A flood

protection scheme is in place including stopbanks and spillway downstream of this site and WRC provides a flood warning system. This site exports an estimated average annual sediment yield of 30,000 tonnes per year. The downstream stopbanks will limit natural deposition into floodplains in the area, most likely increasing sediment export into the Firth of Thames. The forested catchment cover will be contributing to the high water quality (as indicated by the water quality and aquatic invertebrate data), and satisfactory human health regulating ES and low nutrient exports from this catchment. The field visit observed very good habitat provisioning services at this site as indicated by the composition of the in-stream substrate and the riparian vegetation (Figure 19) and the aquatic invertebrate community composition.

The number of publications found on this site during the desktop evaluation, indicate that the Kauaeranga River provides a valuable site for freshwater research. The river supports recreational trout fishery, and a relatively diverse indigenous fish population. The authors of this document noted the presence of tourist, recreational, tramping and camping ES further up the catchment .[28,29] No evidence was found for these cultural ES in the vicinity of this site during the field visit on 17 November 2017, most likely because private land bordering the river along this section restricts public access. However, during the field visit we were able to access a section of the river where we observed good water clarity. Patches of exotic and regenerating native vegetation in the vicinity of the site (Figure 19) and upstream may provide some landscape or aesthetic values. This river system has been historically linked with kauri timber industry and some limited gold mining activities.[30,31]

Figure 19: Site 8 – Section of the Kauaeranga River visited by the team on 17 November 2017.

[28] https://www.tripadvisor.co.nz/Attraction_Review-g255369-d4687999-Reviews-Kauaeranga_Visitor_Centre-Thames_Coromandel_Peninsula_Waikato_Region_North_Island.html
[29] https://www.rankers.co.nz/experiences/4219-Whangaiterenga_Camping_Ground_Kauaeranga_Valley
[30] http://www.ohinemuri.org.nz/journals/40-journal-14-october-1970/707-kauri-timber-industry-kauaeranga-valley
[31] https://teara.govt.nz/en/photograph/30432/logging-kauri-driving-dams

Site 9 - Matatoki Stream @ Matatoki Rd

This site has an upstream catchment area of 902 ha. The headwaters are located on the western side of the Coromandel Ranges and are predominantly in forested land cover (indigenous forest - 30%; exotic forest - 18%) (Figure 20). The lower, flatter part of the catchment is high producing exotic grassland (33%) (Figure 21). High quantities of snails observed in the stream during the field visit (Figures 22a and 22b) indicate that water quality may be compromised at this site, whereas in the forested headwater water quality is of a sufficient standard to provide a water supply. This site is prone to flooding.

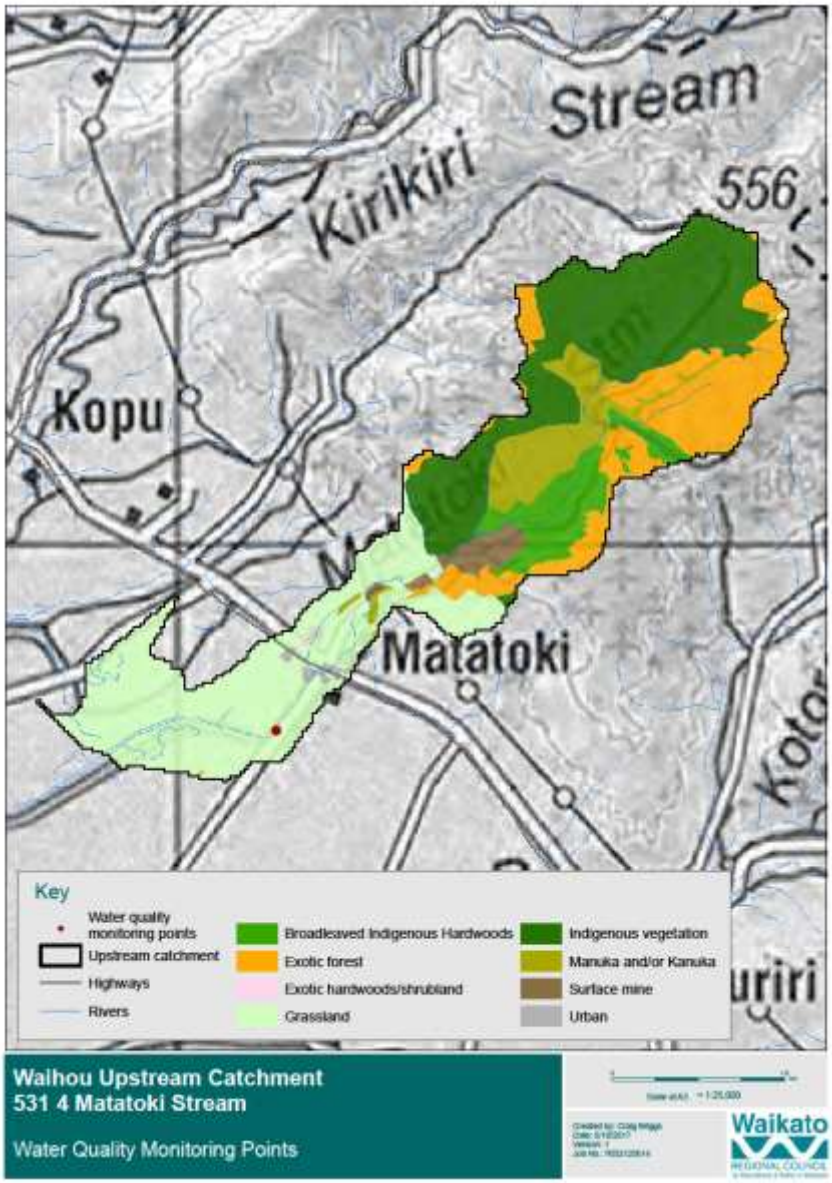

Figure 20: Site 9 upstream catchment area and land cover.

Summary of ecosystem services

The Matotoki Stream provides water to the Matatoki Township. About 3.6 km upstream from the monitoring station (where the quality of water next to forests is up to the standard), up to 94,688 m^3 of water can be extracted to supply water to the residents of the township of Matatoki. This is putting pressure on water resources in this catchment. While other provisioning ES may exist, they were not identified in the desktop evaluation and site field visit.

While the forested cover (indigenous & exotic) in the headwaters of this catchment will have some moderating influence on the hydrological, sediment and nutrient regime, and water yield, the Matatoki Stream is prone to flooding and the site lies within the river flood hazard zone. A proposal to use excess material accumulating in the Matatoki canal downstream of this site as stop bank material indicates that there is some sediment accumulation occurring in this stream system. The channel has been straightened both upstream and downstream of this site (observed in the field visit), which will also adversely affect natural hydrological, flooding, geomorphic and ecological characteristics of this stream and is likely to be compromising the natural habitat provisioning/maintenance ES in this section of the Matatoki Stream. The aquatic invertebrate community indicators (i.e. Macroinvertebrate Community Index), indicate poor to good ecological health, and this assessment was supported by the prolific cover of snails present in the stream at the time of the field visit.

We found only one publication for this site from a search in Google Scholar.[32] No additional recreational, aesthetic and tourism values were found for this site from the desktop evaluation and field visit.

Figure 21: Site 9 – Dairy pasture areas surrounding the section of the river next to the monitoring site.

[32] Tremblay, L. A., Gadd, J. B., & Northcott, G. L. (2018). Steroid estrogens and estrogenic activity are ubiquitous in dairy farm watersheds regardless of effluent management practices. Agriculture, Ecosystems & Environment, 253, 48-54.

Figures 22a and 22b: Snail populations at the Matatoki Stream site.

Site 10 - Oraka Stream @ Lake Rd

This site has an upstream catchment area of 25,590 ha. The spring-fed headwaters of the Oraka Stream are located in the Kaimai-Mamaku ranges, predominantly in exotic (38%) and indigenous forest (13%) land cover. The lower parts of the catchment are mainly in high producing exotic grassland (45%) (Figure 23). Downstream of this site is the confluence of the Oraka Stream with the Waihou River. Water quality is poor at this site, most likely affected by agricultural practices in the catchment.

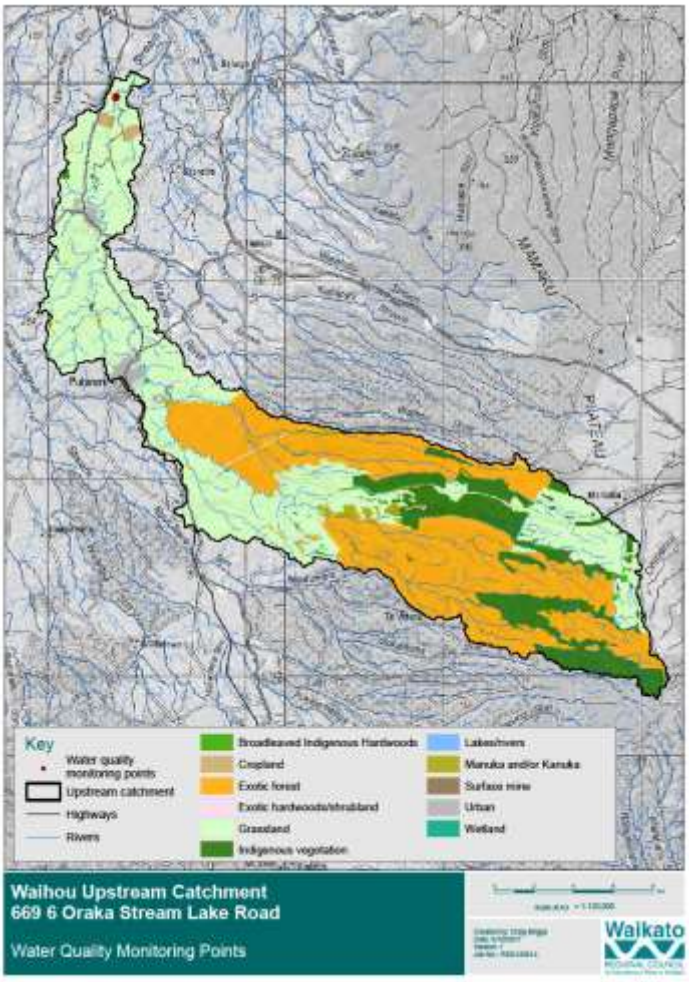

Figure 23: Site 10 upstream catchment area and land cover.

Summary of ecosystem services

The Oraka Stream provides some important benefits to society, including water supply and recreation. About 1.5 km downstream from the monitoring station, there is a consent allowing extraction of up to 612,000 m^3 of water per year to supply irrigation water to farms, horticulture and gardens. Another consent 1.3 km downstream from the station allows extraction of up to 6,388 m^3 to supply an unknown type of water to the end users (refer to the Excel spreadsheet for details).

About half (51%) of the upper part of the catchment consists of forested headwaters that can be expected, along with the spring-fed headwater sources, to provide some hydrological flow regulation services (Duncan & Woods, 2004, Davie & Fahey, 2005). In terms of cultural services, two related scientific studies on freshwater were found. The field visit shows that the site was surrounded by dairy farms with the riparian vegetation comprising a combination of both exotic and indigenous trees and shrubs (Figure 24) and sections of grass cover (Figure 25). No recreational and tourism values were found at the site.

Figure 24: Site 10 – Field trip photo taken on 17 November 2017 showing riparian vegetation along the Oraka Stream banks.

Figure 25: Site 10 – Field trip photo taken on 17 November 2017 showing a section of grassland along the banks of the Oraka Stream.

Summary and recommendations

We have identified and summarised some indicative values, and quantities and qualitative descriptions of freshwater ES provided by the Waihou River catchment. These values represent some preliminary indicators of the freshwater values that can potentially be represented and discussed in policy and investment decisions.

We aimed to quantify the ES values in dollar terms where possible, especially for the provisioning services identified in this desktop evaluation. We found some relevant data available for bottled water and commercial eel fisheries. Values of some ES are available in ecological and flow quantities. Others have been qualitatively described. However, a large majority of the ES have yet to be valued, and quantified. As already noted, Māori cultural ecosystem services, were out of the scope of this study.

Water supply was the key provisioning ES identified in the Waihou River catchment. In particular the Blue Springs currently provide a major source of bottling water, and a number of sites were providing water supply to local townships. Commercial eel fisheries were limited to the main stem of the Waihou River and Ohinemuri River. Recreational fishing, particularly trout fishing, which extends throughout the catchment, will most likely be providing a domestic trout consumption provisioning food supply as well, but we were unable to quantify this in the desktop evaluation.

Hydrological and flood regulation were the key regulating services for every site that we studied in the Waihou catchment. For most sites the natural flooding ES was limited and in the lower catchment stop banks have been established to assist in flood mitigation and management. The sediment, nutrient and microbial contamination ES tended to decline down the river system and were associated with a similar decline in the human health regulation ES and ‘swimmability’ at these sites. The wastewater regulation services provided by the Waihou River were mainly located at sites close by to townships.

For the cultural group of ES, we found data on recreation (e.g. fishing, walking, boating) and history/heritage values for the iconic sections of the Waihou River (e.g. Karangahake, Waihou at Whites Road, Te Aroha and Paeroa). Very limited data were found on smaller streams, as

expected. The field trip allowed the project team to physically inspect five of the sites and include those field data (e.g., presence of snails, mayflies, jetty, boat ramp) in the database.

In the assessment of ecosystem services for each site, we recognised that although all ecosystem services are providing positive benefits to the economy, environment and society, some of these services are limited. We provided an example that, while forests and other vegetation in the upper section of the Apakura, Ohinemuri and Paeroa sites provide some flood regulation services, they still cannot totally stop floods from occurring due to other factors such as topography and intense and frequent rainfall. We have also shown examples of a reduction in flood regulation services (or disservices) as a consequence of conversion of natural landscapes into productive land uses. Recognising the limitations of the ecosystem services provided by the natural capital as well as the existence of ecosystem disservices are important in considering the multiple values of an ecosystem in policy and investment (United Nations, 2014a, United Nations, 2014b, Guery et al., 2015, World Business Council for Sustainable Development, 2010).

Our key recommendations are:

- Putting the initial set of values from this desktop evaluation into a database that is publicly accessible would be a good start to communicate and socialise these values and to make the public more aware of the key services and disservices that rivers and streams provide. The public can also provide the council and the project team feedback on their interpretation of the values and perhaps suggest what other ecosystem values or indicators that should be included on the list in the future. A potential mechanism to capture this, and other information from the public, could be a web based service where people could record their use of the environment, perhaps something similar to Naturewatch (http://naturewatch.org.nz).

- The values from work in both Phase 1 (Waikato River catchment) and Phase 2 (Waihou River catchment) of this project should be further refined and integrated into a cohesive environmental accounting system to allow a more robust representation of the market and non-market ES values as well as ES physical quantities in policy.[33] [34]

- The ability to fully assess the freshwater ES via a desktop evaluation is inherently limited although it was a good starting point for highlighting and collating readily available information on the freshwater ES in the Waihou catchment. Therefore, we recommend undertaking a comprehensive economic, environmental, cultural and social assessment of

[33] An example of this accounting system is the System of Environmental Economic Accounting (SEEA) which has been continuously developing in both developed and developing countries (United Nations 2014a, 2014b). The SEEA Central Framework and the SEEA Experimental Ecosystem Framework have been initiated by the United Nations, the Organisation for Economic Cooperation and Development and the World Bank and are now being applied in Australia, USA, UK, New Zealand, The Netherlands, The Philippines, Costa Rica, Indonesia and many other countries (WAVES Programme). The UN Statistical Commission recognises SEEA as an important internationally-agreed set of statistical frameworks for broader measures of progress. SEEA "provides a single coherent measurement framework across the various policy frameworks and targets" (Alfieri 2013).

[34] Statistics New Zealand (SNZ) has developed and continuously updates environmental accounting systems for freshwater to explore how the economy and the environment interact. This freshwater accounting system can also provide some indicators on how our natural resources contribute to our national (as well as regional) wealth. SNZ's water environmental accounts include: (1) water asset physical stock (complete); (2) water asset monetary account (partially estimated) and (3) asset value of water and other renewables for electricity generation (Harkness and Tipper 2016). The water physical accounts include a national aggregate volume of water used for hydroelectricity generation. Although it may require a significant amount of resources, there are a number of lessons learned from other countries (e.g. Australia, UK, The Netherlands) that can be applied in New Zealand to help further develop water accounts in a cost effective manner. For example, Australia has recently developed a water account that presents the flows of water within the national economy, and between the economy and the environment (Figure 26). In addition, existing water accounts have the potential to be expanded to include other freshwater ES values such as volume of abstracted and distributed water for irrigation, private domestic use, industrial use, geothermal generation, fire prevention, as well as aggregated monetary values of commercial eel extraction, recreational fishing, swimming and walking, and also water flow regulation. Having an environmental accounting system enables better representation of the economic, environmental and social values of freshwater at the local, regional and national levels which can be useful for addressing water issues in policy and investment discussions (United Nations 2012; United Nations 2014a).

the freshwater ecosystem services at the sub-catchment level to gain more detailed qualitative and quantitative information on the freshwater ES for a given catchment as the next step in assessing and valuing the ecosystem services in the Waikato region. There is a need to determine the scale of the ES assessment as well as the most appropriate assessment approaches that can be used. There are several ways of undertaking such an assessment, ranging from a rapid scoping assessment project and all the way to comprehensive, multi-year assessment programme (Peh et al., 2013, Yao and Velarde, 2014, Sharp et al., 2015). The methodologies could then be further developed, tested, up-scaled and applied elsewhere in the region. Key considerations are:

  - Selection of a small catchment that is data-rich and captures a full range of freshwater ecosystem services. A possible approach would be to investigate the suitability of using one of the freshwater management units (FMUs) that Regional Councils are establishing under the National Policy Statement for Freshwater as a trial site. These FMUs, along with their collaborative stakeholder groups, could provide a suitable framework to advance the assessment of freshwater ecosystem services in the Waikato region.
  - A team approach should be used by incorporating multi-disciplinary skills such as an assessment of ecosystem services by combining freshwater modelling (i.e. biophysical, hydrological), environmental economic models, geographic information services (GIS), social and political expertise.
  - If suitable data sets were available, some services, particularly regulating services (i.e. flow, sediment and nutrient regulation) could potentially be quantified and valued by undertaking further modelling work (i.e. Guo et al., 2000, Vigerstol and Aukema, 2011). This would provide an opportunity to capture these ecosystem services more comprehensively than was possible in the desktop assessment.
  - Many of the provisioning and cultural ecosystem services that could not be readily identified through a desktop exercise (i.e. local food sources, recreational activities, and cultural values) could be assessed and valued by other means such as interviews and surveys of key stakeholder groups and communities residing within or regularly visiting the catchment (Aylward et al., 2010; Phillips, 2014; Matthews, 2009; Yao and Kaval, 2010; Yao & Velarde, 2014).This approach would allow an objective estimation and representation of key ecosystem services values in policy decision making as well us future policy modelling work (MEA, 2005; TEEB, 2010; UKNEA, 2011).
  - There are several tools that have been developed in New Zealand and overseas to assess ecosystem services. These tools include: Forest Investment Framework – FIF (Yao et al. 2016); Land Utilisation and Capability Indicator – LUCI (Jackson et al., 2013); Integrated Valuation of Ecosystem Services and Tradeoffs - InVEST (Kareiva et al., 2011; Tallis et al., 2013), and Artificial Intelligence for Ecosystem Services - ARIES (Bagstad et al., 2011; Villa et al., 2011). Each tool or a combination of these tools can potentially be applied to the catchment in question. Model selection would depend on what ecosystem services (e.g. flow regulation, recreation) will be assessed and what assessment approach is needed (e.g. economic valuation, biophysical assessment or both) (Grizzetti et al., 2016).

- Emerging markets for ecosystem services (e.g. nutrient trading) and potential markets should be identified as part of the study. Candidate mechanisms to achieve this include tax credits, bonds and payments from downstream or neighbouring beneficiaries (to compensate for the cost incurred by suppliers who can efficiently and effectively sustain ecosystem services provision) (Hall et al., 2017; Valatin et al., 2017; Wűnscher et al., 2008). The development of such mechanisms can be complemented by using “behavioural nudges” which is a behavioural approach to help people to make better choices based on their situation (Matthies et al., 2016). Studies on assessing ecosystem services values and the identification of the most appropriate policy and behavioural instruments are essential components in the development of new markets for ecosystem services (Gómez-Baggethun et al., 2010; Barry et al., 2014; Valatin et al., 2017).

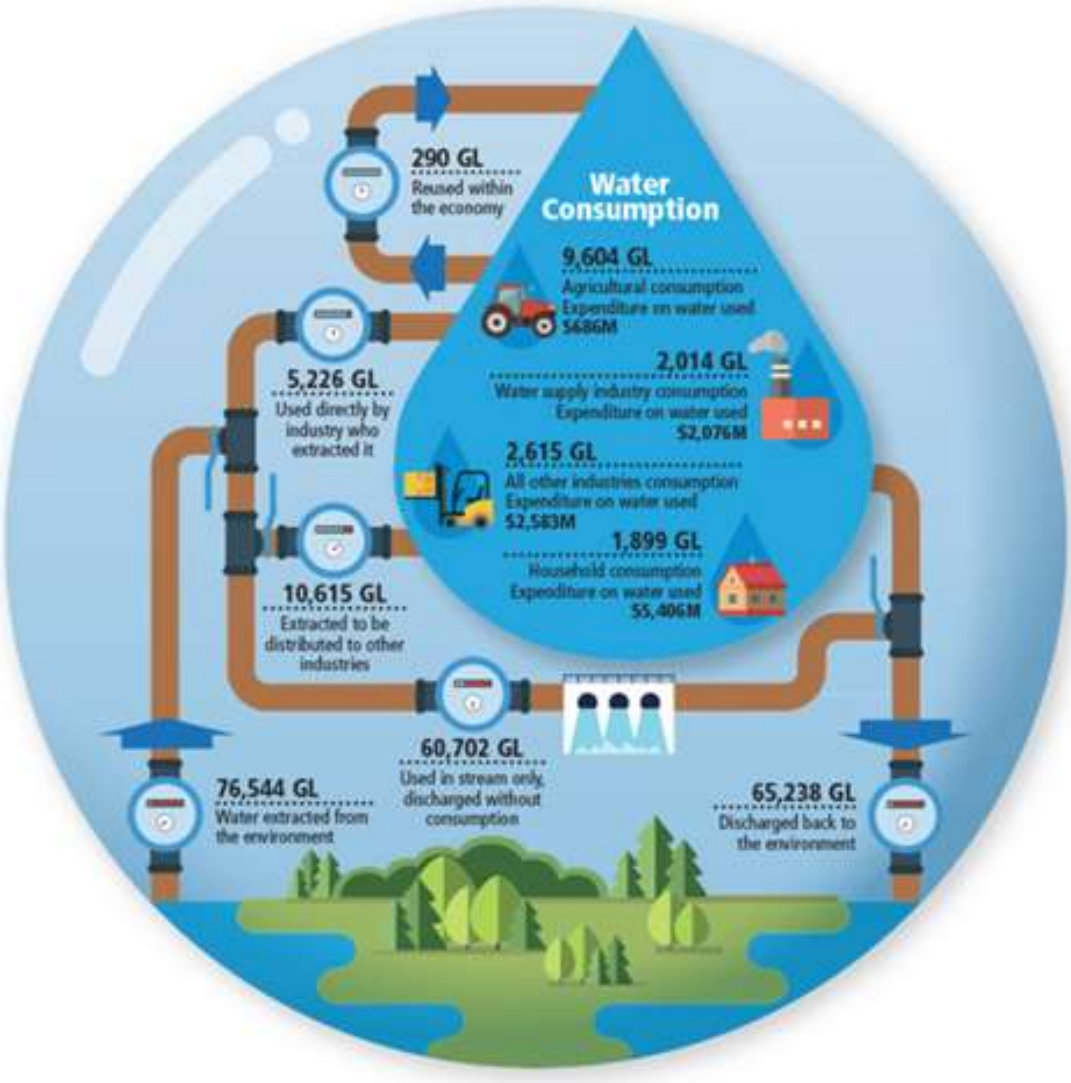

Figure 26: Diagram of Australia's water account showing the flows of water from the source, to consumers and back to the environment (Available online at http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0).

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