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An evaluation and prioritisation of ecosystem services models for inclusion into the Waikato Integrated Scenario Explorer (WISE)

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Te Kaunihera ā Rohe o Waikato

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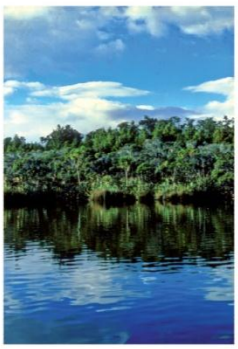

An Evaluation and Prioritisation of Ecosystem Services Models for Inclusion into the Waikato Integrated Scenario Explorer (WISE)

Landcare Research
Manaaki Whenua

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Summary

Project and Client

- Waikato Regional Council Ecosystem Services for the Waikato Integrated Scenario Explorer (Beat Huser, WRC/RIG Contract 308).

Objectives

- Initiate the development of an Ecosystem Services (ES) model to explore, assess, and quantify the effects of developments and policies on the wide range of ecosystem services including
  - Characterise, classify and map ecosystem types and their associated services throughout the Waikato region
  - Develop an ecosystem services model that explores the consequences and trade-offs of future development options and policies on ecosystem services and which is capable of being incorporated in the Waikato Integrated Scenario Explorer (WISE) integrated spatial decision support system.

Methods

- Search the Waikato Regional Council's (WRC) proposed Regional Policy Statement (RPS) and submissions for all references to ecosystem services
- Identify specific ecosystem services relevant to issues in the Proposed RPS in collaboration with WRC staff
- Undertake a pilot prioritisation of the identified specific ecosystem services
- Review the pilot prioritisation with WRC staff and revise it to produce a draft ecosystem services prioritisation
- Recommend options for characterising, measuring and mapping ecosystem services in WISE by comparing high-priority ecosystem services from the draft prioritisation with models of ecosystem services developed as part of Landcare Research's "Ecosystem Services for Multiple Outcomes" programme.

Results

- Results of the RPS review were synthesised in a separate report (Hart et al. 2012) but are briefly summarised here for completeness
  - RPS Objective 3.7 specifically identifies ecosystem services as an important and integrating objective that addresses 5 of the 6 key resource management issues
  - "Ecosystem services" appeared 49 times in the proposed RPS and was identified as being relevant to 27 of the 62 proposed policies
  - "Ecosystem services" appeared in 35 submission statements (17 supporting, 6 requested amendments, 3 opposed)
  - Implementation methods set out in the proposed RPS include recognising and identifying relevant ES and their value to the region, control activities to avoid

adverse effects on ES, develop a marine strategy that enables maximum utilisation of marine ES, provide information on freshwater ES and their values, and have regional and district plans recognise loss of ES as a result of adverse effects on indigenous biodiversity.

- Landcare Research and the Council undertook a collaborative process to identify ecosystem services and develop a draft ES prioritisation process. This involved Landcare Research preparing a pilot ES prioritisation, a workshop with WRC staff to discuss the pilot ES prioritisation, and an additional workshop with WRC staff and further WRC internal work and discussions to develop the draft ecosystem services prioritisation.
- The draft ES prioritisation identified 11 provisioning, 7 regulating, and 4 cultural ecosystem services and prioritised them using a scoring system based on Council Priorities (proposed RPS and Strategic Planning), Social-Cultural Wellbeing, and Risk Management.
- A total of 15 ecosystem services (7 provisioning, 4 regulating, 4 cultural) with total scores > 20 were considered high priority
- Five of the high priority ecosystem services corresponded with ecosystem services models developed under Landcare Research's "Ecosystem Services for Multiple Outcomes" programme. The remaining 10 high-priority ecosystem services had gaps where further research is necessary to identify existing ecosystem services models from other sources or develop new ecosystem services models.

Conclusions

- The draft ecosystem services prioritisation provides a sound basis for WRC to begin to make links between the high-level policy objectives and policies found in the proposed RPS, identification of specific ES for consideration in regional and district planning and resource management, and evaluation of trade-offs of different ecosystem services through models such as WISE.
- Five of the current Landcare Research ecosystem services models correspond with high priority ecosystem services and could be adapted for use in WISE, including
    1. Food provision – milk production
    2. Fibre provision – timber production
    3. Water supply – water yield
    4. Water regulation – nitrogen leaching
    5. Water regulation – sediment eroded

Recommendations

- Proceed with adapting the five Landcare Research ecosystem services models that correspond to the high priority ecosystem services for inclusion into WISE.
- Continue research to identify other existing models for high-priority ecosystem services (e.g., beyond the "Ecosystem Services for Multiple Outcomes programme such as a corresponding Marine ecosystem services programme underway currently at WRC).
- Initiate research collaborations to develop ecosystem services models for other high-priority ecosystem services where gaps exist, especially cultural services.
- Continue to develop and refine the draft ecosystem services prioritisation methodology.

1 Introduction

Landcare Research has been contracted to assist with new work around ecosystem services in the Waikato Region following the introduction of ecosystem services into the proposed Waikato Regional Policy Statement (proposed RPS). Waikato Regional Council (WRC) has reviewed its operative Regional Policy Statement and has proposed a revised RPS based on various changes to the region and environmental issues, as well as changes to the legislative context within which the RPS operates. The proposed RPS introduces 'ecosystem services' (see box for definition) as a new component and concept for environmental resource management in the Waikato region. Specifically, the proposed RPS introduces an 'Ecosystem Services' objective (Objective 3.7) that sets out an aspirational goal for the region to 'recognise and maintain or enhance ecosystem services' (Hart et al. 2012). Waikato Regional Council are now establishing ecosystem services focussed work to achieve the goal set in Objective 3, and to support related policies and methods.

Information about the state, trends and drivers of ecosystem services and how people rely on and affect ecosystem services in a region or locality can be incorporated into decision making processes so that decisions can acknowledge, consider and where possible protect and enhance ecosystem services provision to people. Inclusion of ecosystem services in a decision making approach (e.g., Ranganathan et al. 2008) can improve the environmental outcomes of decisions. Improved environmental outcomes can translate to improved (or protected) well-being for people.

Definition of Ecosystem Services

(Waikato Regional Council, proposed RPS 2012)

"The benefits people obtain from ecosystem services. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational and cultural benefits; and supporting services such as nutrient cycling that maintain conditions for life on earth".

2 Background

The Waikato Integrated Scenario Explorer (WISE) is a regional spatially-explicit policy support system designed to help WRC explore possible future development options, identify trade-offs of different combinations of policies and plans, and evaluate the potential consequences, both positive and negative, from those different combinations. WISE combines economic, population, climate, hydrology, water quality, biodiversity and land use models. WISE is a modular system that allows the incorporation of additional modules to the basic system (Rutledge et al. 2011a).

The proposed RPS includes an Ecosystem Services objective (Objective 3.7), with links to a number of policies. WRC's Regional Carbon Strategy[1] would also directly benefit from this work, both for planning and design (e.g. to identify most suitable areas and water quality and biodiversity co-benefits) and for implementation and on-going monitoring.

[1] www.waikatoregion.govt.nz/carbonstrategy

WRC, therefore, initiated the potential development of an Ecosystem Services model to include in WISE to explore, assess and quantify the effects of developments and policies on regional ecosystem services. This is particularly important for the resource-based regional economy (agriculture, forestry, tourism, aquaculture), which relies heavily on natural resources and associated ecosystem services. One step towards building an ecosystem services evidence base is to model and map ecosystem services using established models for the New Zealand context. These can be incorporated into the WISE model and used to look at future scenarios for the Waikato region and model how different policies could affect ecosystem services in the future.

3 Objectives

The aim of this project was to help the WRC initiate the development of an Ecosystem Services prioritisation framework to

- Identify and prioritise ecosystem services in the Waikato region
- Characterise, classify and map ecosystem types and their associated services throughout the Waikato region
- Initiate development of an ecosystem services modelling base for incorporation into WISE such that WRC can also consider the consequences and trade-offs of future development options and policies on ecosystem services in addition to the range of issues and resources already considered by WISE.

4 Methods

The project proceeded in a 5-staged approach described below:

4.1 Stage 1: Waikato Regional Policy Statement Review

The first stage of the project involved conducting an in-depth review of the proposed RPS (staff 'strike-through' version) and submission summary documents Volumes 1, 2, and 3 to identify and outline the uses of the "ecosystem services" concept and term and outline a pilot process and criteria for ecosystem services prioritisation.

4.2 Stage 2: Proposed RPS Review Workshop

Stage 2 involved a workshop with Landcare Research and WRC staff to discuss the results of the Proposed RPS review and undertake an exercise to develop an initial list of ecosystem services in the Waikato region to consider for the ecosystem services prioritisation exercise.

4.3 Stage 3: Pilot Ecosystem Services Prioritisation Exercise and Identification of Potential Ecosystem Services Models for Inclusion into WISE

Stage 3 involved the development of a pilot prioritisation of ecosystem services resulting from the Stage 2 workshop and identification of potential ecosystem services models for inclusion into WISE.

Development of the pilot ecosystem services prioritisation drew substantially on existing research conducted as part of Landcare Research's "Ecosystem Services for Multiple Outcomes" programme, especially from research to develop the ecosystem services approach for policy and planning. Development of the pilot prioritisation also included a series of meetings in person and by video conference between Landcare Research staff and key WRC staff. Identification of potential ecosystem services models focused primarily on those models under development as part of the "Ecosystem Services for Multiple Outcomes" programme. In addition to those models, we also canvassed other LCR staff to identify additional ecosystem services models that could be considered for incorporation into WISE.

4.4 Stage 4: Ecosystem Services Prioritisation Workshop

Stage 4 involved a second workshop with Landcare Research staff and WRC staff to discuss the pilot ecosystem services prioritisation and the relevance and utility of the prioritisation across all WRC functions (policy, planning, resource management consents, etc.) The workshop included a review of the pilot prioritisation methods and the current list of potential ecosystem services models available.

4.5 Stage 5: Draft WRC Ecosystem Services Prioritisation and Recommendation of Ecosystem Services Models for Inclusion in WISE

Stage 5 involved refinement of the pilot ecosystem services prioritisation to develop a draft ecosystem services prioritisation based on further consultations between Landcare Research staff and internal WRC discussions.

The draft ecosystem services prioritisation became the basis for determining which ecosystem services models to recommend for inclusion into WISE. The prioritisation also served to identify gaps in high-priority ecosystem services for which models are currently lacking, thus informing both future research on ecosystem services and further development of appropriate policy and planning methodologies.

5 Results

5.1 Review of Proposed Waikato Regional Policy Statement

5.1.1 Review

The full results of the Proposed RPS review can be found in Hart et al. (2012). For completeness, a brief summary is provided here.

The Proposed RPS staff report contained a total of 49 references to "ecosystem services." At the highest level, the Proposed RPS identified six regionally significant resource management issues and issues of significance to iwi authorities of the region as required by Resource Management Act. Issue 1 directly refers to ecosystem services: State of Resources identified the declining quality and quantity of natural resources, including ecosystem services, and the potential impacts to life-supporting capacity and wellbeing.

The Proposed RPS identified 25 objectives that addressed the six issues and will be achieved through the implementation of the proposed policies. Objective 3.7 specifically targeted ecosystem services:

> *"The range of ecosystem services associated with natural resources are recognised and maintained or enhanced to enable their on-going contribution to regional wellbeing."*

Objective 3.7 was identified as addressing five of the six regionally significant issues and would be achieved via implementing a combination of 27 of the 62 proposed policies.

'Ecosystem services' appeared three times in the main text of policies; five times in policy implementation methods; three times in policy explanations'; and once in the policy statement's design principles.

Implementation methods set out in the proposed RPS that directly referred to 'ecosystem services' were:

- Recognise and identify relevant ecosystem services and assess their role and value to the region
- Control activities to avoid adverse effects on ecosystem services
- Develop a marine strategy that enables maximisation of utilisation of marine ecosystem services
- Provide information on freshwater ecosystem services and the value of the region's rivers
- Regional and district plans to recognise ecosystem services lost as a result of adverse effects on indigenous biodiversity
- Control activities to avoid adverse effects on soil ecosystem services;
- A broad definition of ecosystem services is outlined in the glossary.

"Ecosystem services" appeared in the text of 35 submission statements as summarised in the Submission summary documents Volumes 1, 2, and 3. Of these, 17 directly supported ecosystem services being included and emphasised within the proposed RPS (6 of these requested amendments). Three directly criticised the inclusion of ecosystem services, requesting that it be removed from the document. Criticism of the term was focussed on the broadness of its definition and lack of clarity about what was to be achieved, where and by when, under Objective 3.7 and some related policies.

5.1.2 Initial Steps for Ecosystem Services Prioritisation

The review also outlined an initial set of steps for ecosystem services prioritisation as follows:

1) Select or develop a high-level ecosystem services framework.
2) Identify what Waikato Regional Council policies relating to ecosystem services will take precedence as requiring actions.
3) Identify additional organisational priorities that have been recently determined that may impact upon ecosystem service prioritisation (i.e. focus on water plan changes and the marine spatial plan).
4) Identify what understanding there is of the ecosystem service and what data are available.
5) Identify which ecosystem services will have the greatest effect on the six key issues identified in the proposed RPS.
6) Identify which ecosystem services are most relied on for, and most affected by, the region's highly productive activities and land uses (i.e. identify the activities that contribute most to Waikato's GDP and land use and identify what ecosystem services are most relied on and most affected by those activities).
7) Examine how substitutable the ecosystem service is.
8) Examine how reversible changes to the ecosystem service are.
9) Identify which sectors/stakeholder groups depend on the ecosystem service, and how much.

5.2 Workshop #1: Proposed RPS Review and Ecosystem Services Identification

On 12 March 2012 Landcare Research staff and WRC staff (Table 1) held a joint workshop at WRC offices at Marlborough House in Hamilton. The aim of the workshop was to update WRC staff on the findings of the review of the proposed RPS and to discuss and begin identifying ecosystem services for the Waikato region and a potential prioritisation process.

Table 1 Workshop #1 Attendees

Landcare Research	Waikato Regional Council
Georgina Hart, Policy Analyst Daniel Rutledge, Project Leader	Mark Brockelsby (Programme Manager Energy, Resource Use) Malene Felsing (Coastal Scientist, Resource Information) Blair Keenan (Environmental Economist, Resource Information) Tracey May (Programme Manager Regional Integration, Policy & Transport) Peter Singleton (Programme Manager Coasts, Land & Wetlands, Resource Information) Matthew Vare (Senior Policy Advisor, Policy & Transport)

The workshop commenced with a presentation from Landcare Research that included an introduction to the project for WRC staff and an update on the Proposed RPS review. Following the presentation attendees discussed ecosystem services and its inclusion in the RPS, potential issues of the ecosystem services approach, and finally undertook an exercise to identify specific ecosystem services relevant to each issue in the Proposed RPS.

5.2.1 Development of Ecosystem Services in the Proposed RPS

Development of the Ecosystem Services as a specific objective arose from WRC's recognition that many of the region's environmental issues stem from an inadequacy of ecosystem services, many of which are approaching or now below critical levels. Another issue identified was the perception that many people only equated ecosystem services with indigenous biodiversity and that a clear connection had not been made between human activities and wellbeing and ecosystem services or other factors relating to ecosystem services.

WRC staff noted that the draft RPS only referred to ecosystem services in the Indigenous Biodiversity section. Through the process of refining the RPS, WRC staff developed the ecosystem services concept into its own cross-cutting objective to address the increasing recognition of the importance of ecosystem services as noted above. The development of the ecosystem services objective also partly stemmed from the proposed RPS Section 32 analysis, for which ecosystem services were considered against every policy. At the time, the policies and implementation for the ecosystem services objective were still being formulated and the expectation was that once the RPS is operative, an implementation of an ecosystem services approach would be developed.

5.2.2 Potential Issues of an Ecosystem Services Approach

The incorporation of ecosystem services into the terminology and framework of the proposed RPS was considered a very difficult task and a major milestone. However, achieving that milestone raised a number of potential issues that workshop attendees discussed.

The first issue related to ecosystem services terminology. Given the wide range of understanding regarding what is an "ecosystem" and therefore what are "ecosystem services,

WRC staff noted that adopting the appropriate terminology and its meanings for ecosystems services will be critical for the success of adopting or introducing an ecosystem services component to resource management in the Waikato Region.

The second issue that was discussed was whether "ecosystems" include abiotic factors such as hydrological, nutrient, and sediment cycles. The term "ecosystem services" can become confusing because ecosystem services encompass much more than just animal and plant functions. It was suggested that terminology such as 'natural services' or 'environmental services' could be used instead, and that either of these terms could have clear meaning for a much broader audience than 'ecosystem services'. Landcare Research pointed out that the basic definition of an ecosystem (e.g., Tansley 1935, McApline & Wotton 2009) includes both abiotic and biotic components and their interactions. Hence a conflict does not exist in use of the term 'ecosystem' for the ecosystem services approach, which includes benefits people gain from abiotic processes such as the sediment and hydrological cycles. However, more effective communication to gain broad acknowledgement and understanding of these definitions may be required.

The third issue discussed focused on the need for monetary valuation of ecosystem services. It was argued that monetary valuation can provide a strong argument for prioritising funding for preserving and conserving ecosystem services. On the other hand, there is substantial criticism of monetary valuation of ecosystem services on a number of ethical and methodological grounds. Attendees noted, however, that many monetary valuation exercises that are methodologically fraught proceed nonetheless, and such drawbacks do not stop other sectors from using these monetary valuation methods to guide decision making. It was also pointed out that quantification is helpful in the regulatory environment because decision-making is about trade-offs and quantification helps guide the way through those decisions. Overall attendees agreed that monetary valuation of ecosystem services requires further exploration. Monetary valuation may yield benefits by offering a directly comparable metric that could be used weighed against other monetary values and therefore help conserve and restore ecosystem services. However, the use of such metrics may lead to unintended outcomes, as any valuation is only as good as the underpinning science and information.

5.2.3 Identification of Specific Ecosystem Services Relevant to the Proposed RPS

Following the overview of the project, RPS review and general discussion of ecosystem services, attendees undertook a broad discussion of ecosystem services prioritisation and an exercise to identify specific ecosystem services related to the issues identified in Part B of the Proposed RPS.

General Comments on Ecosystem Services Prioritisation

Attendees commented on the prioritisation criteria Landcare Research developed as a starting point (see Appendix 1) and suggested that the following additional criteria need to be considered:

- What ecosystem services are in critical decline?
- What ecosystem services are at risk? (of decline/degradation to a critical level) i.e. more vulnerable than others to a change in land use, or some other driver?
- What organisational priorities exist that may make some ecosystem services higher priority than others (e.g. focus on water plan changes)?

WRC staff also commented that the prioritisation should take account of recent WRC organisational priorities i.e. focus on water plan changes that will also link to land/soil and aquatic biodiversity and the marine and coastal strategy and spatial planning work.

Overall attendees agreed that a generic, robust process that can be followed to identify the ecosystem services that are important in a specific place or region needs to be developed.

Ecosystem Services Identification Exercise

The exercise considered and discussed specific ecosystem services in relation to each section of Part B of the proposed RPS (air quality, built environment, coastal marine area, fresh water, geothermal, heritage, indigenous biodiversity, landscape natural character and amenity, natural hazards, and soils) and conducted a rapid analysis of the key ecosystem services relevant under each section.

Identification of specific ecosystems services followed a high-level classification framework that Landcare Research has developed for the New Zealand context, which is based on the work of the of the Millennium Ecosystem Assessment (2005). This classification includes the same 17 ecosystem services outlined in the MEA classification framework (MEA 2005, p.7) and several additional ecosystem services considered important in the New Zealand context (Rutledge et al. 2011b). (Table 2).

Table 2: High-level ecosystem services framework for New Zealand

PROVISIONING *Products obtained from ecosystems*	**REGULATING** *Benefits from regulation of ecosystem processes*	**CULTURAL** *Non-material benefits obtained from ecosystems*
Biochemical, natural medicines & pharmaceuticals	Air Quality Maintenance	Aesthetic Values
Food & Fibre	Biological Control	Cultural Heritage Values
Freshwater	Climate Regulation	Cultural Diversity
Fuel	Erosion Control	Educational Values
Genetic Resources	Human Disease Regulation	Inspiration
Ornamental Resources	Pollination	Knowledge Systems
	Storm Protection	Recreation & Ecotourism
	Water Purification	Sense of Place
	Water Regulation	Spiritual & Religious Values
		Social Relations

SUPPORTING *Services necessary for the production of all other ecosystem services*	
Nutrient & water cycling	Provisioning of habitat
Primary production	Soil formation & retention
Production of atmospheric oxygen	

Workshop participants then identified specific ecosystem services for each combination of high-level ecosystem service and Proposed RPS policies. The result was a draft matrix with high-level ecosystem services as rows, proposed RPS policy section as columns, and sets of specific ecosystem services in each cell of the matrix (Table 3).

Table 3 Matrix of relevant ecosystems services versus Proposed RPS issues. The matrix shows the specific Waikato Region relevant ecosystem services (or indicators) identified by Waikato Regional Council for regionally significant issues and broad ecosystem service categories. A question mark (?) indicates cases where a specific ecosystem service exists but could not be articulated at the time.

Ecosystem Service	Regional policy statement section headings									
	Air Quality	Built Environment	Coastal Marine Area	Fresh water	Geothermal	Heritage	Indigenous biodiversity	Landscape, natural character & amenity	Natural hazards	Soils
Provisioning Services										
Food			• Traditional harvest (kai moana) • Recreational fisheries • Commercial capture fisheries • Aquaculture	• Traditional harvest (whitebait, eel) • Recreational (Trout) • Commercial			• Wildfoods from indigenous ecosystems • Aquaculture: Green lipped mussels			• High quality soils • Dairy products • Beef • Lamb • Wool Pork? Venison? Poultry? Other?
Fibre							• Timber • Harakeke			• Timber
Transport			• Shipping • Ferry • Waka • Recreational (boating and kayaking)							
Fresh water				• Town and rural supply • Hydro-power • Irrigation • Livestock						
Fuel							• Fire wood (Kanuka, Manuka)			• Fire wood (timber)

Genetic resources					• Thermal vent species		• Native and endemic species of NZ			
Ornamental resources										
Biochemical, natural medicines Etc.					• Cosmetics, natural products		• Medicinal resources			
Energy generation			• Potential energy generation source (West Coast)		• Thermal electricity generation					
Regulating Services										
Air Quality maintenance	• Sink for emissions to air - Odour control	• Green space					• Pollution filtration • Carbon sequestration			
Biological Control / Pest control Influence ecosystems have on the prevalence of crop and livestock pest and regulation										
Climate regulation	• Atmospheric part of hydrological cycle	• Trees/Green space			?		• Climate regulating services of forest are important for the Trout fishery			?
Erosion regulation Role vegetation plays in soil retention			• By coastal environment (wetlands and dunes) against coastal wave				• Soil retention by forests and vegetation			

			energy/storms causing erosion at the coast							
Human disease regulation										
Pollination							• Pollination • Avian seed dispersal			
Storm protection		• Flood protection – Hamilton's gully's act as storm water drainage	• Storm protection from erosion and inundation – wetlands and dunes etc.	• Flow paths for storm water to a given level				• Wetlands • Forest vegetation • Dunes		• Peat wetlands
Water purification			• Pollution dilution (sink for human wastes)	• Sink and dispersal of discharges / pollutants						• Water purification (filtration) • Root activity in the soil • Reservoir for nutrients
Water regulation				• Timing and magnitude of flood run off			• Timing and magnitude of flood run off		• Timing and magnitude of water runoff, flooding, and aquifer recharge (e.g. the water storage potential of the ecosystem or landscape)	• Water regulation (filtration, reservoir, and surface)

Cultural Services										
Aesthetic values		• Visual amenity • Psychological wellbeing – green space	• Huge importance of landscape, natural character, and amenity values	• Iconic rivers, streams and lakes • Also, just the freshwater bodies people grew up with (may not be iconic)		• Historic places, sites	• Important aesthetic values associated with indigenous flora and fauna • Tourism in indigenous remnant vegetation (tramping/visiting) • Fauna attract tourism and recreation also	?		
Cultural heritage values			• Tangata whenua cultural values incredibly important in relation to the CMA • Historic: shipping, whaling, migration		• Geothermal resources in the region an important part of cultural heritage of Tangata whenua	• Tangata whenua values associated with places of significance historically • Historic places, sites (events associated with sites)	• Tangata whenua are spiritually connected to all living species in the region, but especially Taonga (e.g. Harakeke) and Kai species			• Tangata whenua intimate connection to the land – Papatuanuku our Earth Mother • Generally strong cultural/social ties to the land
Cultural diversity										
Educational values										

Inspiration										
Knowledge systems										
Recreation & tourism			• Marine and coastal recreation: • Tourism • Holiday making • Bach culture (population) • Recreational sports and fishing • Safe swimming water • Ecotourism: • Diving, surfing, boating and fishing, walking/tramping, parks, camping, beaches, events	• Extensive recreation and tourism sectors • Taupo, Waikato, Rotorua Lakes: • Fishing • Swimming • Recreational boating, kayaking • Other water sports (water skiing, jet ski etc.) • Aesthetic appreciation of the environment (walks, look outs, iconic locations to visit)	• Significant recreation and tourism focussed on geothermal resources : • Cultural centres • Hot pools • Resorts • Sightseeing	• Historic places (in the natural environment) tourism		?		?
Sense of place		• Identity • Sense of place	• Sense of identity	• Strong connection between sense of place and your river/s • Tangata whenua and relationship with rivers -	?	?	?	?		• Strong associations with sense of place

				Te Awa.						
Spiritual & religious values Spiritual and religious values people attach to ecosystems, landscapes, or species			• Tangata whenua • Spiritual connections	• Tangata whenua and relationship with rivers - Te Awa.		?	?	?		?
Social relations										
Supporting Services										
Habitat Provision			• Habitat • Endangered species habitat	• For Native and endemic flora and fauna of streams, lakes etc. (??)	• For native and endemic species • Unique habitats for thermal vent species		Habitat provision			• Habitat provision
Biodiversity			• Biodiversity	• Habitat provision for native and endemic freshwater species of New Zealand (as well as exotics)	• Thermal vent species • Other species specific to geothermal environments		Biodiversity			
Primary production				?	?		?			• Growing medium for plants
Nutrient cycling			• Nutrient cycling	?	?		?			• Nutrient cycling

Water cycling			• Hydrological cycle	• Rivers • Lakes Wetlands	• Water cycling					• Water cycling
Soil formation					?			?		?
Soil retention								?		
Production of atmospheric oxygen	?							?		• Growing medium for plants
Sediment cycling (related to soil formation)			• Sediment erosion, transport and deposition	• Sediment erosion, transport and deposition by streams, rivers, lakes and wetlands.				?		• Sediment cycling

5.3 Pilot Ecosystem Services Prioritisation

Pilot ecosystem prioritisation included

- formulating a set of criteria against which the preliminary set of specific ecosystem services identified in Workshop #1 could be evaluated
- Landcare Research undertaking a preliminary scoring of the specific ecosystems services for discussion with WRC staff
- Preliminary identification of potential ecosystem services models for inclusion into WISE.

Following on from Workshop #1 and subsequent discussions with key WRC staff, the pilot prioritisation focused on consideration of seven key council priorities. Four priorities derived from the Proposed RPS and three derived from WRC's Strategic Planning Directions (Waikato Regional Council 2010) (Table 4). Pilot prioritisation involved a simple scoring (relevant/not relevant) of each specific ecosystem service against each criterion and summing the total relevant score (0 to 7). Although supporting services were discussed during Workshop #1 as part of the development of an understanding of the ecosystem services concept, supporting services are omitted from the prioritisation process because these services support the provision of all other ecosystem services to people and are part of the provision of food, regulating and cultural services. The Millennium Ecosystem Assessment (MEA 2005) ecosystem assessment methodology recommends the omission of supporting services to avoid double counting because of the relationship between supporting services and all other ecosystem services.

Table 4 Criteria used in the pilot ecosystem services prioritisation

Regional Policy Statement	Strategic Planning Directions (Flagship Goals)
Biodiversity	Economic Development
Soils	Co-Management with Iwi
Freshwater	Land & Water
Coastal/Marine	

Identification of potential ecosystems services models for possible inclusion in WISE focused mainly on those models already available via Landcare Research's "Ecosystem Services for Multiple Outcomes" programme. Where possible other possible ecosystems service models were also identified.

The pilot prioritisation underwent one round of review by key WRC staff prior to Workshop #2. The resulting prioritisation (Tables 5-8) reflects WRC feedback.

Table 5 Pilot prioritisation for provisioning ecosystem services in the Waikato Region. Score 1-2 = Low (green), Score 3-4 Medium (orange), Score 5-7 = High (red).

PROVISIONING SERVICES												
Ecosystem Services		COUNCIL PRIORITIES								AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions				Indicators	Data/models
MA (2005) Provisioning Ecosystem services	Waikato region relevant services, or land cover or land uses that provide an ecosystem service as defined by Waikato regional council staff	Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water	Prioritisation Score		
Food	Dairy	✓	✓	✓	✓	✓		✓	6	kilograms of milk soilds per hectare	LCR Ecosystem Services Programme Model
	Lamb	✓	✓			✓		✓	4		
	Beef	✓	✓			✓		✓	4	kilograms per hectare	LCR Ecosystem Services Programme Model
	Pork		✓			✓		✓	3		
	Venison		✓			✓		✓	3		
	Fruit and vegetables		✓	✓		✓		✓	4		
	Wild foods	✓	✓	✓				✓	4		
	Traditional harvest (e.g. kai moana)	✓	✓	✓	✓		✓	✓	6	To be developed (TBD)	Possible links to WRC Marine ES work with NIWA
	Recreational fisheries				✓	✓	✓		3		Possible links to WRC Marine ES work with NIWA
	Commercial capture fisheries	✓			✓	✓	✓	✓	5	TBD	Possible links to WRC Marine ES work with NIWA
	Aquaculture				✓	✓	✓	✓	4		Possible links to WRC Marine ES work with NIWA
Fibre	Timber (exotic)		✓	✓	✓	✓	✓	✓	6	metres^3 per year	LCR Ecosystem Services Programme Model
	Timber (indigenous)	✓	✓	✓	✓		✓	✓	6	TBD	
	Harakeke (flax)	✓					✓	✓	3	TBD	
	Wool		✓			✓		✓	3	kilograms per hectare	LCR Ecosystem Services Programme Model
Water supply	Water yield			✓	✓	✓	✓	✓	5	litres of runoff per year	LCR Ecosystem Services Programme Model
	Town and rural supply			✓				✓	2		
	Irrigation		✓	✓		✓		✓	4		
	Livestock			✓				✓	2	TBD	
	Hydro power supply		✓	✓		✓	✓	✓	5		

Fuel	Fire wood, indigenous and exotic	✓	✓		✓			✓	4		
Thermal energy	Energy derived from geothermal activity	✓	✓	✓		✓	✓	✓	6	TBD	
Genetic resources	Thermal vent species, hot springs bacteria, flora and fauna, thermal vegetation	✓	✓	✓		✓	✓	✓	6	TBD	
	Native and endemic species of NZ	✓				✓	✓		3		
Biochemical, natural medicines, pharmaceuticals	Cosmetics / natural products	✓			✓	✓	✓	✓	5	TBD	
	Medicinal resources	✓			✓	✓	✓	✓	5	TBD	

Table 6 Pilot prioritisation for regulating ecosystem services in the Waikato Region. Score 1-2 = Low (green), Score 3-4 Medium (orange), Score 5-7 = High (red).

REGULATING SERVICES												
Ecosystem Services		COUNCIL PRIORITIES								AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions				Indicators	Data/models
MA (2005) Regulating Ecosystem services	Waikato region relevant services, or land cover or land uses that provide an ecosystem service as defined by Waikato regional council staff	Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water	Prioritisation Score		
Air quality regulation	Pollution filtration	✓							1		
	Odour control (sink for emissions to air)					✓		✓	2		
	Urban green space (pollution filtration)							✓	1		
Pest control	Diversity of habitat for natural pest enemies/predators	✓	✓			✓		✓	4		
Climate regulation	Agricultural Greenhouse Gas Emisssions					✓		✓	2	Total greenhouse gas emissions per year Emissions (gigagrams per year)	LCR Ecosystem Services Programme Model
	Carbon sequestration	✓	✓	✓		✓			4	Carbon sequestration rate (tonnes / year)	LCR Ecosystem Services Programme Model
	Carbon flux		✓			✓	✓	✓	3		
	Aerosol emissions								0		
	Green space / trees	✓						✓	2		
	Local climate regulation by forests (indigenous and exotic)	✓		✓		✓		✓	4		
Erosion regulation	Wetlands and dunes	✓	✓	✓	✓	✓		✓	5	TBD	
	Soil retention by forests/vegetation	✓	✓	✓	✓	✓		✓	6	Sediment retention (tonnes/km^2/year)	LCR Ecosystem Services Programme Model
Pollination	Insect pollination and avian seed dispersal	✓	✓			✓	✓	✓	5	TBD	
Natural hazard protection	Vegetation cover	✓	✓	✓	✓			✓	5	TBD	
	Wetlands	✓		✓	✓			✓	4		
	Peat wetlands	✓		✓				✓	3		
	Coastal dunes	✓			✓	✓		✓	4		

	Marine plants (sea grass, salt marsh vegetation, mangroves)	✓			✓				2		
	Flow paths for storm water to a given level		✓	✓				✓	3		
Water purification	Pollution dilution (sink for human waste)		✓	✓		✓		✓	4		
	Sink and dispersal of discharges from activities		✓	✓		✓		✓	4		
	Soil filtration of water		✓					✓	2		
	Root activity in the soil		✓					✓	2		
	Soil acts as reservoir for nutrients (regulating water quality)		✓	✓		✓		✓	4		
	N Loading in Surface Waters	✓	✓	✓	✓	✓	✓	✓	7	Total Nitrate Leached (kilograms)	LCR Ecosystem Services Programme Model
	P Loading In Surface Waters	✓	✓	✓	✓	✓	✓	✓	7	Dissolved reactive phosphorus (milligrams per litre)	LCR Ecosystem Services Programme Model
	Sediment Loss	✓	✓	✓	✓	✓	✓	✓	7	TBD	
Water regulation	Timing and magnitude of flood runoff			✓				✓	2		

Table 7 Pilot prioritisation for cultural ecosystem services in the Waikato Region. Score 1-2 = Low (green), Score 3-4 Medium (orange), Score 5-7 = High (red).

CULTURAL SERVICES											
Ecosystem Services		COUNCIL PRIORITIES								AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions				Indicators	Data/models
MA (2005) Cultural Ecosystem services	Waikato region relevant services, or land cover or land uses that provide an ecosystem service as defined by Waikato regional council staff	Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water	Prioritisation Score		
Aesthetic values	Visual amenity, natural character, landscape (wellbeing / green space / natural environment)	✓		✓	✓	✓	✓	✓	6	TBD	
Cultural heritage values	Tangata whenua specific cultural heritage values associated in particular with: - Coasts - geothermal resources - Rivers - All places of significance throughout the region - all indigenous species in the region, but in particular taonga species (e.g. harakeke) and Kai species - sense of place in relation to cultural heritage and place.	✓	✓	✓	✓	✓	✓	✓	7	TBD	
	Non-tangata whenua cultural heritage values were associated in particular with: - Historic shipping, whaling, migration - Historic places - Rivers Sense of place, connection to the land			✓	✓	✓		✓	4		
Cultural diversity								✓	1		
Educational values						✓			1		

Inspiration									0		
Knowledge systems						✓			1		
Recreation and tourism	Bach owners / beach holiday culture Sports, fishing, boating, swimming, nature watching/bird watching, diving, surfing, beaches, Walking, tramping, parks visits, camping, events	✓		✓	✓	✓		✓	5	TBD	
	Fresh water lakes: Taupo, Waikato river, Rotorua lakes: fishing, swimming, boating, kayaking, other water sports, nature watching, walks, iconic places	✓		✓		✓	✓	✓	5	TBD	
	Geothermal areas: hotpools, cultural centres, resorts, sightseeing	✓				✓		✓	3		
	Sightseeing of historic places of nature					✓			1		
Sense of place	Cities, towns The coast Tangata whenua Rivers Geothermal resources/places The land / soils The bush and wildlife					✓			1		
Spiritual and religious values	Tangata whenua have deep and many spiritual connections to ecosystems and particular species and individual places plants, trees and animals					✓	✓		2		
Social relations		✓		✓	✓	✓	✓	✓	6	TBD	

5.4 Workshop #2: WRC Review of Pilot Ecosystem Services Prioritisation

On 12 February 2013 Landcare Research staff and WRC staff (Table 8) held a joint workshop at WRC offices at Marlborough House in Hamilton. The aim of the workshop was to:

- Provide an update on the project including work to date and introduce the national ecosystem services research
- Discuss the ecosystem services concept in the context of regional policy development, planning and resource management including how staff members view ecosystem services from the perspective of their operations (e.g., policy, planning, consents, catchment services, etc.).
- Review the pilot ecosystem services prioritisation and discuss its strengths and limitations as a basis for developing a more robust prioritisation process
- Identify next steps for this project.

Table 8 Workshop #2 Attendees

Landcare Research	Waikato Regional Council
Daniel Rutledge, Project Leader Georgina Hart, Policy Analyst	Amanda Banks (Policy Advisor, Policy & Transport) Catherine Beard (Wetland Ecologist, Resource Information) Mark Brockelsby (Programme Manager Energy, Resource Use) Kevin Collier (Freshwater Ecologist, Resource Information) Yanbin Deng (Terrestrial Ecologist, Resource Information) Malene Felsing (Coastal Scientist, Resource Information) Beat Huser (Programme Manager Sustainability) Blair Keenan (Environmental Economist, Resource Information) Tracey May (Programme Manager Regional Integration, Policy & Transport) Yvonne Phillips (Environmental Economist, Resource Information) Peter Singleton (Programme Manager Coasts, Land & Wetlands, Resource Information) Urlwyn Trebilco (Policy) Matthew Vare (Senior Policy Advisor, Policy & Transport)

The workshop commenced with a presentation from Landcare Research that included an overview of Landcare Research's Statement of Core Purpose and outcomes, followed by an overview of the project and progress to date including the review of the proposed RPS (Hart et al. 2012) and Workshop #1.

Following the presentation Landcare Research introduced the pilot ecosystem services prioritisation (Tables 5-7). Attendees then discussed the strengths and limitations of the pilot ecosystem services prioritisation. Key points raised in discussion around the example prioritisation exercise included:

- A question around leaving supporting services out of the analysis and whether or not this is problematic in that it could oversimplify the system/s we are considering. Daniel responded that this was not really a problem at this stage.
- Gaps in cultural services were discussed. Questions regarding what is being done in this area, and what can be done were raised.
- Several attendees found the table either not useful or hard to make sense of.
- Many comments were made regarding how prioritisation could be improved, including:
    - Prioritising based on the perceived relationship between each ecosystem service and each of the four well beings[2]
    - Aspects of ecosystem services associated with social wellbeing are largely missing. It was suggested to include a column 'social capital' to list any links between the ecosystem services (column 1 & 2) to social aspects.
    - Prioritising based on the level of decline of the ecosystem service / WRC should prioritise those ecosystem services that are *resources (or ecosystems and their services) under stress.* For example - what ecosystem services provide clean water? We need to know about them, and how to protect and improve them.
    - Prioritising based on the risk of decline or loss that each ecosystem service is at, was suggested and agreed to as an important prioritisation criterion by most attendees. One attendee suggested a table format of:

Ecosystem Service	Scale of Risk		
	Low	Medium	High
Food			
Fibre			
Clean water supply			
…			

[2] Note that identifying, characterising and mapping of cultural ecosystem services will require iwi/hapu involvement. Tai Ranga Whenua (Carol Henry) has been invited to the workshop but could not attend due to other commitments.

- Another suggestion was to prioritise based on the relationship between each of the RPS objectives relevant to resources/ecosystems and each ecosystem service[3]:

WRC resource goals	Enhanced water quality	Enhanced indigenous biodiversity		
Ecosystem Service				
Dairy production	Impacts on water quality and relies on water supply			
Wool production	Impacts on water quality and relies on water supply			
Clean air				
Clean water supply	When this ES is in high quality supply this RPS objective is met			

- Also the following four prioritisation criteria were identified as important:
    1. Resources/ecosystem services under pressure - what natural resources and associated ecosystem services are under threat?
    2. Substitutability – can the decline or loss of ecosystem services be replaced?
    3. Reversibility – can the decline or loss of ecosystem services be reversed? Are there any critical thresholds or tipping points?
    4. WRC relevance - can Council directly make a difference and influence the decline or loss of any ecosystem service(s)?
- A question was raised as to whether or not the time frame was considered in the prioritisation exercise. Timeframe was not considered in pilot prioritisation. The importance of both the short term and long term implications for relationships between ecosystem services and prioritisation criteria was emphasised.
- A question was raised about what the prioritisation is for; and comment was made to note that what we are prioritising for will determine and possibly alter the prioritisation criteria and how each ecosystem service is assessed against them. The overall purpose of prioritising ecosystem services is to identify priorities for action. This means to ensure that WRC efforts are most effective to achieve the best environmental outcomes for the limited resources (e.g., staff,

[3] The RPS specifically includes policies and methods for ecosystem services related to biodiversity, freshwater, soil and marine/coastal. These were included in the draft prioritisation table as one example of prioritising ecosystem services.

budgets) available. This implies that prioritisation is largely driven by the RPS (objectives, policies, methods), and reflected accordingly in gathering of policy-relevant information (e.g. GIS layers of ecosystem services for WISE). LCR explained that three key prioritisation questions were being posed to WRC staff:

1 What ecosystem services would WRC define as high priority for inclusion into the WISE model? This information is needed for the current project.

2 What ecosystem services would WRC define as high priority for the region?

3 A further question we are posing is what criteria are required to define high priority ecosystem services in these two contexts?

The current project addresses the first question. The second and third questions are broader questions that WRC staff will need to consider going forward when thinking about how to adapt an ES approach to their policy, planning and resource management processes.

5.5 Draft Ecosystem Services Priorities

5.5.1 Draft Prioritisation Process

Following Workshop #2, WRC staff undertook further work to revise the pilot ecosystem services prioritisation and produce a draft ecosystem services prioritisation (Tables 9, 10 and 11).[4] The purpose of the refinement was to improve the prioritisation process to better identify those ecosystem services that are of particular relevance to WRC's roles and functions and that are under pressure and vulnerable given that they are non-substitutable and possibly subject to irreversible changes, and to extend the scope to include social aspects (in recognition of the holistic nature of the ecosystem services concept).

The revised approach included a two-step process. The first step was based on the original pilot prioritisation and involved scoring each ecosystem service relative to the seven criteria (four RPS priorities, three Strategic Direction priorities). As in the pilot prioritisation process, this first step resulted in a score from 0 to 7 for each individual ecosystem service.

The second step involved evaluating the 22 top-scoring ES from the first step against an overall social and cultural well-being criterion (scored from 1-5) and four additional risk-based criteria (each also scored from 1-5). The four risk-based criteria were:

- Pressure/Threat – degree of pressure or threat for a particular ecosystem service (1 = low risk of pressure/treat; 5 = high risk of pressure/threat)
- Substitutability – how easy or difficult it would be to provide an ecosystem services by a man-made service (1 = low risk, substitutability feasible; 5 = high risk, substitutability difficult)

[4] Huser B. and Vare M. (2013). Draft ecosystem services prioritisation table and notes, Waikato Regional Council doc# 2376506 and doc # 2362619.

- Reversibility – how easy or difficult it would be to restore an ecosystem service if it was degraded or lost (1 = low risk, feasible to reverse degradation or loss; 5 = high risk, difficult to reverse degradation or loss)
- WRC Function – the ability of WRC to influence a particular ecosystem service via various legislative mandates, institutional capacity, expertise and resources (1 = low risk; high potential for WRC influence; 5 = high risk, low potential for WRC influence).

The social and cultural wellbeing score was based on recent definitions from Statistics NZ[5] and OECD[6]. The four risk-based criteria were derived from discussions at Workshop #2.

The scores from step 1 and step 2 were added to generate an overall prioritisation score ranging from a minimum of 10 (minimum of 5 from Step 1 + minimum of 5 from Step 2) to a maximum of 32 (maximum of 7 from Step 1 + maximum of 25 from Step 2).

The draft prioritisation produced scores ranging from 17 to 26 (Tables 9-11). Scores above 20 were considered as high-priority, which included a total of 15 ecosystem services (7 provisioning, 4 regulating, and 4 cultural). The three highest scores were for cultural services values (26, Table 11), traditional harvest of food resources such as kai moana (25, Table 9) and aesthetic values (23, Table 11).

Overall ecosystem services with high priority scores based on the initial 7 criteria also had corresponding high total risk scores. However, three high-priority ecosystem services (genetic resources/geothermal; N loading in surface waters; sediment loss) had a low risk score despite having the highest (6 or 7) priority score. This is mainly because WRC has a statutory role in reducing these ecosystem services risks.

Of the 15 high priority ecosystem services, 5 had corresponding ecosystem service models for possible inclusion into WISE:

1. Food Provision: Plant & Animal Growth – Milk Production (kg milk solids/ha/year)
2. Fibre Provision: Timber (exotic) – *Pinus radiata* (m^3/ha/year)
3. Water Supply: Water Yield (mm/year)
4. Water Regulation: N-loading in surface waters – Nitrate Leaching (kg/ha/year)
5. Water Regulation: Soil Erosion – Sediment Eroded (tonnes/km^2/year)

The model for water regulation provides similar analyses to the existing water quality model in WISE (Rutledge et al. 2011a). Incorporating the proposed ecosystem services water quality model into WISE would therefore generate two different estimates that could be useful for evaluating variation and uncertainty of nitrate loading into surface waters.

Those ecosystem services models are discussed in more detail below (section 5.5.2).

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[5] http://www.stats.govt.nz/browse_for_stats/environment/sustainable_development/sustainable-development/further-discussion-on-defining-sustainable-development.aspx

[6] http://www1.oecd.org/els/pdfs/EDSMINDOCA003.pdf

Table 9 Draft ecosystem prioritisation for high-ranking provisioning ecosystem services

PROVISIONING SERVICES																				
Ecosystem Services		COUNCIL PRIORITIES								Social and Cultural Wellbeing		Risk-based Prioritisation Criteria						AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions			Prioritisation Score	Score	Comment	Pressure / Threat	Substitutability	Reversibility	WRC Function	Risk-score	Total Score	Proposed Indicator(s)	Data/models
		Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water		Low Medium High									
Food	Dairy	✓	✓	✓	✓	✓		✓	6	2		2	4	2	5	15	**21**	kilograms/ha/year	LCR Ecosystem Services Programme Model
	Traditional harvest (e.g. kai moana)	✓	✓	✓	✓		✓	✓	6	5		4	4	4	2	19	**25**	To be developed (TBD)	Possible links to WRC Marine ES work with NIWA
	Commercial capture fisheries	✓			✓	✓	✓	√	5	3		2	3	4	4	16	**21**	TBD	Possible links to WRC Marine ES work with NIWA
Fibre	Timber (exotic)		✓	✓	✓	✓	✓	✓	6	3		2	2	3	5	15	**21**	meters^3/ha/year	LCR Ecosystem Services Programme Model
	Timber (indigenous)	✓	✓	✓	✓		✓	✓	6	1		4	4	2	4	15	**21**	TBD	
Water supply	Water yield			✓	✓	✓	✓	✓	5	5		2	3	3	3	16	**21**	litres of runoff per year	LCR Ecosystem Services Programme Model
	Hydro power supply		✓	✓		✓	✓	✓	5	2		2	2	2	5	13	18	TBD	
Thermal energy	Energy derived from geothermal activity	✓	✓	✓		✓	✓	✓	6	2		1	2	4	2	11	17	TBD	

PROVISIONING SERVICES																				
Ecosystem Services		COUNCIL PRIORITIES								Social and Cultural Wellbeing		Risk-based Prioritisation Criteria						AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions			Prioritisation Score	Score						Risk-score	Total Score	Proposed Indicator(s)	Data/models
		Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water		Low Medium High	Comment	Pressure / Threat	Substitutability	Reversibility	WRC Function				
Genetic resources	Thermal vent species, hot springs bacteria, flora and fauna, thermal vegetation	✓	✓	✓		✓	✓	✓	6	2		3	3	4	2	14	**20**	TBD	
Biochemical, natural medicines, pharmaceuticals	Cosmetics / natural products	✓			✓	✓	✓	✓	5	3		2	2	2	5	14	19	TBD	
	Medicinal resources	✓			✓	✓	✓	✓	5	3		2	2	2	5	14	19	TBD	

Table 10 Draft ecosystem prioritisation for high-ranking regulating ecosystem services

REGULATING SERVICES																			
Ecosystem Services		COUNCIL PRIORITIES								Social and Cultural Wellbeing		Risk-based Prioritisation Criteria						AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions			Prioritisation Score	Score								Proposed Indicator(s)	Data/models
		Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water		Low Medium High	Comment	Pressure / Threat	Substitutability	Reversibility	WRC function	Risk-score	Total Score		
Erosion regulation	Wetlands and dunes	✓	✓	✓	✓	✓		✓	5	1		4	4	4	2	15	**20**	TBD	
	Soil retention by forests/vegetation	✓	✓	✓	✓	✓		✓	6	1		3	3	2	2	11	17	Soil retention (tonnes / year)	LCR Ecosystem Services Programme Model
Pollination	Insect pollination and avian seed dispersal	✓	✓			✓	✓	✓	5	3		3	3	4	4	17	**22**	TBD	
Natural hazard protection	Vegetation cover	✓	✓	✓	✓			✓	5	3		2	3	2	2	12	17	TBD	
Water Purification	N Loading in Surface Waters	✓	✓	✓	✓	✓	✓	✓	7	1		4	4	3	1	13	**20**	Total Nitrate Leached (kg/ha/year)	LCR Ecosystem Services Programme Model
	P Loading In Surface Waters	✓	✓	✓	✓	✓	✓	✓	7	1		3	4	3	1	12	**19**	Dissolved reactive phosphorus (milligrams per litre)	LCR Ecosystem Services Programme Model
	Sediment Loss	✓	✓	✓	✓	✓	✓	✓	7	2		3	4	4	2	13	**20**	Tonnes sediment eroded/km2/year	LCR Ecosystem Services Programme Model

Table 11 Draft ecosystem prioritisation for high-ranking cultural ecosystem services

CULTURAL SERVICES																			
Ecosystem Services		COUNCIL PRIORITIES								Social and Cultural Wellbeing		Risk-based Prioritisation Criteria						AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions			Prioritisation Score	Score						Risk-score	Total Score	Proposed Indicator(s)	Data/models
		Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water		Low Medium High	Comment	Pressure / Threat	Substitutability	Reversibility	WRC function				
Aesthetic values	Visual amenity, natural character, landscape (wellbeing / green space / natural environment)	✓		✓	✓	✓	✓	✓	6	5		4	3	3	2	17	23	TBD	

CULTURAL SERVICES																			
Ecosystem Services		COUNCIL PRIORITIES								Social and Cultural Wellbeing		Risk-based Prioritisation Criteria						AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions			Prioritisation Score	Score						Risk-score	Total Score	Proposed Indicator(s)	Data/models
		Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water		Low Medium High	Comment	Pressure / Threat	Substitutability	Reversibility	WRC function				
Cultural heritage values	Tangata whenua specific cultural heritage values associated in particular with: - Coasts - geothermal resources - Rivers - All places of significance throughout the region	✓	✓	✓	✓	✓	✓	✓	7	5		4	4	3	3	19	**26**	TBD	
	- all indigenous species in the region, but in particular taonga species (e.g. harakeke) and Kai species - sense of place in relation to cultural heritage and place.																		

CULTURAL SERVICES																			
Ecosystem Services		COUNCIL PRIORITIES								Social and Cultural Wellbeing		Risk-based Prioritisation Criteria						AVAILABLE INFORMATION	
		Regional Policy Statement				Strategic Planning Directions			Prioritisation Score	Score						Risk-score	Total Score	Proposed Indicator(s)	Data/models
		Biodiversity	Soils	Freshwater	Coastal/Marine	Economic Development	Co-Management	Land & Water		Low Medium High	Comment	Pressure / Threat	Substitutability	Reversibility	WRC function				
Recreation and tourism	Bach owners / beach holiday culture Sports, fishing, boating, swimming, nature watching/bird watching, diving, surfing, beaches, Walking, tramping, parks visits, camping, events	✓		✓	✓	✓		✓	5	5		3	2	4	3 2	17	**22**	TBD	
	Fresh water lakes: Taupo, Waikato river, Rotorua lakes: fishing, swimming, boating, kayaking, other water sports, nature watching, walks, iconic places	✓		✓		✓	✓	✓	5	5		3	2	4	3	17	**22**	TBD	

5.5.2 Ecosystem Services Models to Address High Priority Ecosystem Services

Landcare Research (Ausseil et al. 2013) has modelled and mapped a set of ecosystem services under the "Ecosystem Services for Multiple Outcomes" programme. Indicators of ecosystem services were selected and methods for modelling and mapping each indicator have been developed based on existing data sets available in New Zealand, such as AgriBase, the Land Cover Data Base (LCDB), and Statistics New Zealand data. The ecosystem services that Landcare Research selected were chosen because they are considered important in terms of New Zealand society and because it is possible to develop quantitative indicators for the chosen services. Five of the indicators corresponding to high-priority ecosystem services identified in the draft prioritisation exercise (Table 12).

Table 12 Ecosystem services models corresponding to high-priority ecosystem services in the Waikato region.

Ecosystem Service	Process	Indicator	Units
Food Provision	Plant and animal growth	Milk Production	kg milk solids/ha/year
Fibre Provision	Timber (exotic) (*Pinus radiata)*	Timber Production	$meter^3$/ha/year
Water Regulation and Provision	Water yield	Water yield	mm/year
Water Purification	N-loading in surface waters	Nitrate leaching	kg/ha/year
Water Purification	Soil erosion	Sediment eroded	tonnes/km^2/year

More detailed information about each ecosystem service follows.

Food Provision – Milk Production

Food production is a key activity in New Zealand that makes a significant contribution to the New Zealand economy. The main food production activities are livestock production, including dairy products, sheep meat, beef, pork, and venison (Ausseil et al. 2013).

To derive the national maps of milk production an animal distribution map and Statistics New Zealand data on food supply at the district level were used to show where milk production occurs. To achieve the animal distribution map, animal numbers are scaled based on statistics of livestock numbers at the district level (Statistics New Zealand 2007). Animal numbers are spatially distributed using a metric of 'potential carrying capacity' derived from fundamental soil layers (Landcare Research 2011).

Required Data Inputs

- Land use from AgriBase™ (AssureQuality), the Land Cover Database (Landcare Research) and Fundamental Soils Layer Database (Landcare Research)
- District level food supply (Statistics New Zealand)

Fibre Production – Exotic Timber Production

The ecosystem services model of timber production uses the CenW model (Kirschbaum & Watt 2011). CenW (Carbon, Energy, Nutrient, Water model) is a process-based model that can estimate tree growth and has been calibrated across New Zealand for *Pinus radiata*, by far the dominant species for timber production. The model runs on a daily time step simulating forest stand characteristics including leaf area development, stand height, basal area development, litter fall, and exchange of both water and CO_2. CenW estimates the annual timber production (m^3/hectare/year), which can be multiplied by annual estimates of the area of plantation forestry to estimate total annual wood supply.

Required Data Inputs

- Air temperature (NIWA)
- Soil fertility (Landcare Research)
- Soil water holding capacity (Landcare Research)
- Soil texture (Landcare Research)

Water Provision – Water Yield

Water flow regulation is the effect ecosystems have on the amount of water in rivers and groundwater. Water in rivers and groundwater is provided by ecosystems that people then access for water supply to homes, for stock drinking water, farm irrigation, and hydropower generation. Ausseil et al. (2013) modelled water yield (mm/yr) as an indicator of water-flow regulation services provided by ecosystems in New Zealand. Water flow levels also indicate quantities of the water provisioning service supplied for use by people.

To model water yield, the WATYIELD model was run for New Zealand. WATYIELD estimates water yield based on daily water transfers of rainfall, interception, evapotranspiration and drainage associated with a soil profile. To run WATYIELD Ausseil et al. (2013):

- divided New Zealand into soil-climate units based on LENZ Level II (100 land environments)
- ran the model for each of the 100 soil-climate units using mean soil properties derived from the fundamental soil layers database
- ran WATYIELD for four different land covers (forest, scrub, tussock, pasture) for each of the 100 soil-climate units
- stored a look-up table of the proportion of rainfall that becomes water yield for each of the soil-climate units and land cover types.

Required Data Inputs

- Daily rainfall (NIWA)
- Daily potential evapotranspiration (NIWA)

- Fraction of intercepted rainfall (Landcare Research)
- Land cover factors for evapotranspiration (Landcare Research)
- Total soil water holding capacity (Landcare Research)
- Readily available soil water holding capacity (Landcare Research)
- Land Environments New Zealand classification (LENZ)
- Fundamental Soil Layers (Landcare Research)

Water Purification – Nitrate Leaching

Fresh water pollution in New Zealand is mostly attributable to agricultural activities that result in the run off and/or leaching of nitrogen and phosphorus to waterways. Because New Zealand is considered a low nitrogen environment with low levels of nutrient loss from soils where native vegetation exists, almost all nutrients measured in waterways can be attributed to human activities.

Ausseil et al. (2013) selected nitrogen leaching from the soil as an indicator of water quality provision. The map of nitrogen produced shows the spatial distribution of sources of nitrogen leaching, thus showing where in the landscape pollution sources are coming from, and also indicating the catchments where water quality can be expected to be lowest.

The indicator modelled for clean water provisioning services is nitrogen leaching (kg/ha/year). To model nitrogen leaching Ausseil et al. (2013) estimated nitrogen leaching using OVERSEER version 5.4 (Ministry of Agriculture and Forestry et al. 2011). They ran OVERSEER for the 100 combinations of soils and climate from level II of LENZ (Leathwick et al. 2003). Stocking rate was set based on the carrying capacity of the land according to the New Zealand Land Resource Inventory (Landcare Research 2011b), and calculated the annual leaching rate per stock unit. The national leaching rates per stock unit were then combined with the map of animal numbers to produce a map of nitrogen leaching for New Zealand.

Required Data Inputs

- Soil type (loam etc.) and climate (LCR, LENZ)
- Farm types (e.g. sheep and beef or dairy) (Derived from Agribase)
- Stocking rates (Landcare Research)
- Statistics New Zealand farm data (Statistics New Zealand)

Water Purification and Erosion Regulation – Sediment Eroded

Erosion regulation is the effect ecosystems have on soil retention. Trees and vegetative cover typically stabilise soil, preventing it from being eroded and lost. Soil retention is preferable to retain productive soils and prevents sedimentation in waterways (a water purification service). Sedimentation in waterways can adversely affect water quality and aquatic ecosystems. In New Zealand the main erosion process is ‘mass-movement’ erosion, which most often occurs in one-off precipitation events. Tree roots are the main way mass-

movement erosion can be prevented. The indicator selected to map erosion regulation was soil erosion rate (kg/km^2/year). This model is also considered as an indicator of water purification service as avoided sedimentation of waterways.

To determine erosion rates the NZeem model was run for the full extent of New Zealand using national rainfall and erosion terrain datasets, and a land-use dataset. The NZeem erosion model estimates long-term mean erosion rate from all sources of erosion – mass movement and surficial – and all sizes of rainfall events. NZeem has been calibrated with sediment discharges from New Zealand rivers (Dymond et al. 2010, cited in Ausseil et al. 2013).

Required Data Inputs

- Annual rainfall (NIWA)
- National erosion terrains dataset (Landcare Research)
- Land Cover Database (Landcare Research)

6 Conclusions

The project undertook a collaborative process between Landcare Research and Waikato Regional Council to identify models of high-priority ecosystem services that could be adapted to run in the WISE spatially-explicit decision support system.

The process began with a review of the Proposed RPS to identify how ecosystem services were considered. Following the review, Landcare Research and the Waikato Regional Council worked through a collaborative and iterative process to first identify specific ecosystem services of relevance to the Proposed RPS and second develop a draft prioritisation scheme for ranking identified ecosystem services based on a set of RPS and strategic direction priorities, relevance to social and cultural wellbeing and risk management.

The result of the prioritisation process was the identification of a suite of 15 high-priority ecosystem services for further investigation including characterisation, mapping, and modelling. Five of the high priority ecosystem services corresponded to existing ecosystem services models developed by Landcare Research and are therefore suitable candidates for adaptation into WISE.

The draft ecosystem services prioritisation still requires further discussion, development and refinement. While incomplete, it provides a foundation of specific ecosystem services for consideration and integrating across all of WRC's functions, including policy development, planning, resource management, economic development, consent processing, education and outreach, and co-management with iwi.

Also, despite being new, the draft prioritisation provides a sound basis for WRC to begin to link high-level ecosystem services policy objectives found in the Proposed RPS with specific ecosystem services for consideration in regional and district planning and resource management. Furthermore the potential implementation of existing models of ecosystem services into WISE would provide a nascent capability for WRC to evaluate explicitly the consequences of different policies and planning options on a core set of high-priority ecosystem services.

Finally, both the list of ecosystem services identified and the prototype prioritisation process will yield benefits for research as well. The list of specific services substantially expands on the initial set of ecosystem services considered in Landcare Research's "Ecosystem Services for Multiple Outcomes" programme. The expanded list and associated prioritisation provide guidance to future research by indicating where current gaps exist and how future effort should be prioritised. It also provides a common ground for discussion among researchers and stakeholders by making initial links between high-level ecosystem services concepts, specific ecosystem services, and every day experience. As highlighted by WRC staff, the future success of ecosystem services as an enabling and integrative concept will hinge on the ability to translate those high-level concepts into understandable terms and develop practical means to implement conservation of ecosystem services at all levels of resource management.

7 Recommendations

- Proceed with adapting the five Landcare Research ecosystem services models that correspond to the high priority ecosystem services for inclusion into WISE.
- Continue research to identify indicators and other existing models for high-priority ecosystem services (e.g., additional to those developed in the "Ecosystem Services for Multiple Outcomes" programme, such as those developed in a corresponding Marine ecosystem services programme underway currently at WRC).
- Initiate research collaborations to develop ecosystem services models for other high-priority ecosystem services where gaps exist, especially cultural services.
- Continue to develop and refine the draft ecosystem services prioritisation methodology.

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