Ecosystem Services Review of Water Projects

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Pressures

- Water becoming scarce and rivers stressed by abstraction for irrigation
- Water - multiple uses and society needs to consider all uses, not just consumptive uses
- Evaluations of water projects need to consider all values to be valid, accepted
- Economic evaluations struggle to include all values for water if they are not readily monetised
- Ecosystem Services approaches have arisen as a consequence.

Ecosystem Services

- Ecosystems have functions
- When ecosystems benefit humans they provide Ecosystem Services
- Debate over how to categorise ES, but Millennium Ecosystem Assessment approach seems most accepted.
- Four categories of ES:
  - Provisioning
  - Regulating
  - Cultural
  - Supporting

Classes of ecosystem services	Ecosystem services	Description of ecosystem service
Provisioning ecosystem services	**Food**	Ecosystem supplies food produce (*e.g*. fish, grains, wild game, fruits)
	Fibre	Ecosystem supplies extractable renewable raw materials for fuel & fibre (*e.g*. fuelwood, logs, fodder)
	Freshwater Supply	Ecosystem supplies freshwater for use & storage
	Biological Products	Ecosystem supplies biological resources that can be developed into biochemicals for medicinal or commercial use
	Abiotic Products	Ecosystem supplies extractable non-renewable raw materials such as metals and stones for commercial use
Regulating ecosystem Services	**Climate Regulation**	Ecosystem regulates air temperature and precipitation and acts as a source of and sink for greenhouse gases
	Disease Regulation	Ecosystem regulates the abundance of pathogens
	Water Regulation	Ecosystem regulates hydrological flows (*i.e*. surface water runoff, groundwater recharge/discharge)
	Water Purification	Ecosystem purifies & breaks down excess nutrients in water
	Pest Regulation	Ecosystem regulates the abundance of invasive or pest species
	Erosion Control	Ecosystem controls potential biological catastrophes & stabilizes against erosion, thus, retaining soils
	Natural Hazard Regulation	Ecosystem regulates and protects against extreme natural events (*i.e*. floods or droughts)
Cultural ecosystem services	**Educational Values**	Ecosystem provides opportunities for non-commercial uses (*e.g*. archaeological values, knowledge systems).
	Conservation Values	Ecosystem provides existence values for species including important values relating to biodiversity
	Aesthetic Values	Ecosystem provides aesthetic qualities
	Spiritual Values	Ecosystem provides spiritual and inspirational qualities
	Recreational Values	Ecosystem provides opportunities for recreational uses

Table 1: The various ecosystem services that an ecosystem may derive (adapted from Curtis, 2004; Capistrano *et al*., 2006).

ES in evaluations

- ES can be quantified to provide estimates of total ES values at a site
- Policy decisions typically require insight into how ES may change
- Few evaluations have used ES approaches
- Not surprising as ES are complex, disagreement on how to categorise ES, and data often lacking
- Environment Canterbury (the local regional council) sought our help to complete ES Review for a water project and its linked catchment

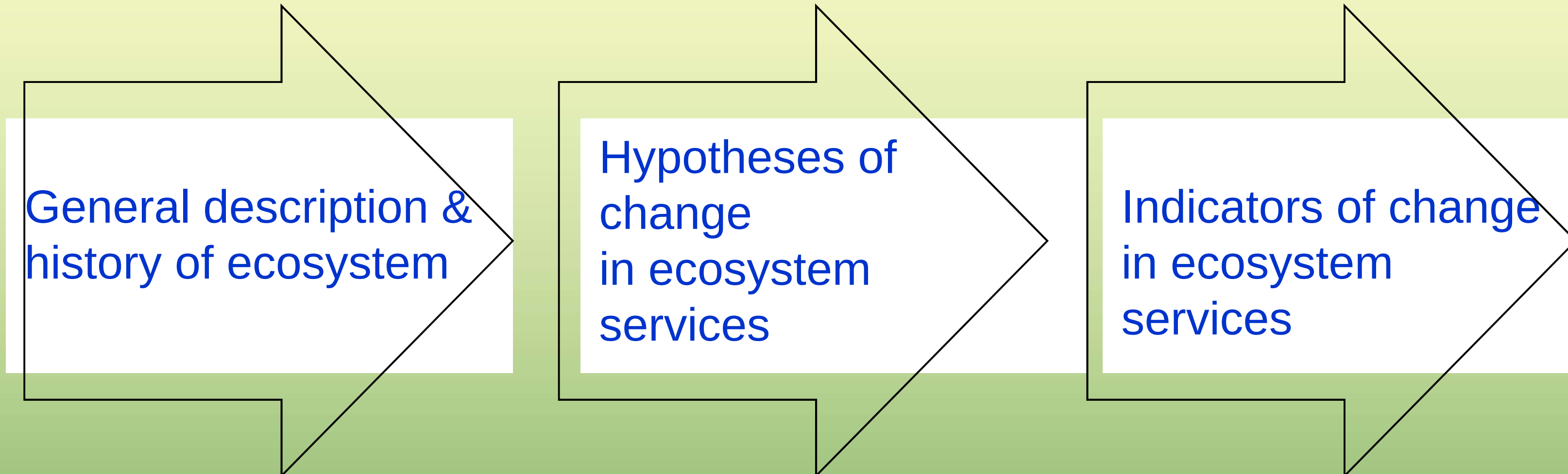
Approach used

General description & history of ecosystem

Hypotheses of change in ecosystem services

Indicators of change in ecosystem services

Approach used



- Literature review
- Secondary data sources
- Expert and stakeholder interviews
- Site visits

Opihi Catchment, South Canterbury

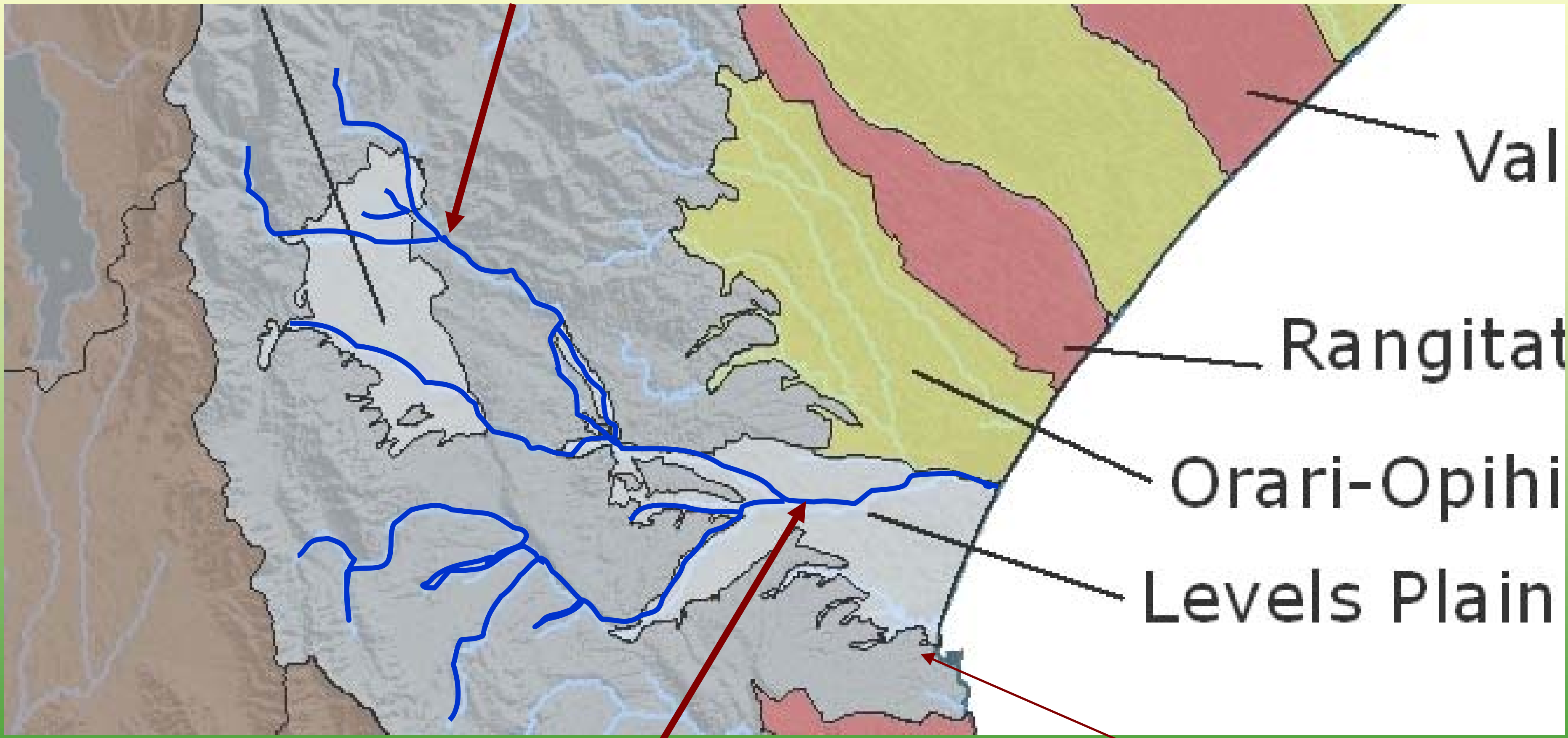
- Opihi river, 3 tributaries
- 245,000 ha in catchment
- Grazing, dairy farming, intensive cropping
- Small areas of wetlands, swampland, forest
- Rainfall 1400mm (west), 550mm (east)
- Summer droughts, soil moisture deficits
- Levels Plains irrigation began 1936, 3700ha

Opihi Catchment

- Irrigation abstraction, dry river in summers
- ES degradation
- Opuha Dam built 1997-98
- 710 ha lake, water storage for irrigation, electricity generation, boating, fishing, recreation, maintain summer flows in Opihi River
- Negative effects expected: increased algal growth, loss of natural character

Opihi River, Groundwater zones, South Canterbury

Fairlie Opuha Dam



Scale: |------|10km Opihi River Timaru

Ecosystem Service Hypotheses

- Ex ante evaluation of dam and literature on possible impacts of dams on ES
- Hypotheses for impacts on Opuha Dam on provisioning, regulating, and cultural Ecosystem Services

Hypothesised dam Impacts on *Provisioning* ES

Ecosystem service class	Ecosystem service	Notes and sub-class of ecosystem service		Hypothesized impact
Provisioning ecosystem services	**Food**	Fisheries	Salmon	+/-
			Trout	+/-
		Mahinga kai (*e.g*. eel, whitebait, flounder)		+/-
	Fibre	Flax, driftwood		+
	Freshwater supply	Irrigation		+
		Hydroelectric production		+
		Municipal water supply		+
		Industrial water supply		+
		Stock water supply		+
	Biological products	Not applicable		Na
	Abiotic products	Gravel extraction for road chip and concrete		0

The ecosystem services provided by the Opihi River and the hypothesized impacts (*i.e*. positive +; negative -; no change 0) of the Opuha Dam on provisioning ecosystem services.

Hypothesised dam Impacts on *Regulating* ES

Ecosystem service class	Ecosystem service	Notes and sub-class of ecosystem service	Hypothesized impact
Regulating ecosystem services	**Climate regulation**	Not applicable	Na
	Disease regulation	Parasite and toxic algae regulation	-
	Water regulation	Hydrological flow regulation (*e.g.* minimum river flows, flushing flows)	+/-
	Water purification		+/-
	Erosion control		+
	Pest regulation	Invasive non-native species (*e.g.* algae, willows, gorse, broom)	-
	Natural hazard regulation	Flood and drought protection	+

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Hypothesised dam Impacts on *Cultural* ES

Ecosystem service class	Ecosystem service	Notes and sub-class of ecosystem service		Hypothesized impact
Cultural ecosystem services	**Conservation values**	Native biodiversity and habitat		-
		Endangered native species		-
		Ecological landscapes of significance		+/-
	Educational values	Historical/archaeological values		0
		Knowledge systems		+/-
	Aesthetic values	Perceptive beauty		+/-
	Spiritual values	Māori values	Natural character	-
			Life supporting capacity or mauri	+
	Recreational values	Boating (*e.g*. sailing, rowing, kayaking)		+
		Fishing		+/-
		Hunting (*e.g*. duck hunting)		+
		Picnicking		+
		Swimming		+/-
		Walking		0

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Indicators for *provisioning* Ecosystem Services

- Seek biophysical, economic and social indicators for each Ecosystem Service

Socio-economic indicator	Indicator calculation	Unit	Revenue	Expenses	Surplus
Farm Level Impact of Irrigation	$/ha irrigated farms - $/ha non-irrigated farms	$/ha	$1211	$849	$362
Irrigation Impact per Hectare	Irrigation impact/ proportion of area irrigated (0.493)	$/ha	$2457	$1722	$735
Economic Impact over Irrigation Area	Irrigation impact per ha × irrigation area (16,000)	$/year	$39,740,000	$27,850,000	$11,890,000

Table 4: Economic benefits from reliable and increased freshwater supply for irrigation (adapted from Harris Consulting, 2006).

Indicators for *provisioning* Ecosystem Services

Socio-economic indicator	Unit	Irrigation	Hydroelectric production
Total Economic Benefits	($/catchment/year)	$123,200,000	$1,220,000
Full Time Employment	(FTEs/catchment)	480	4

Table 5: Impact of irrigation and hydroelectric generation in catchment area (adapted from Harris Consulting, 2006).

Indicators for *provisioning* Ecosystem Services

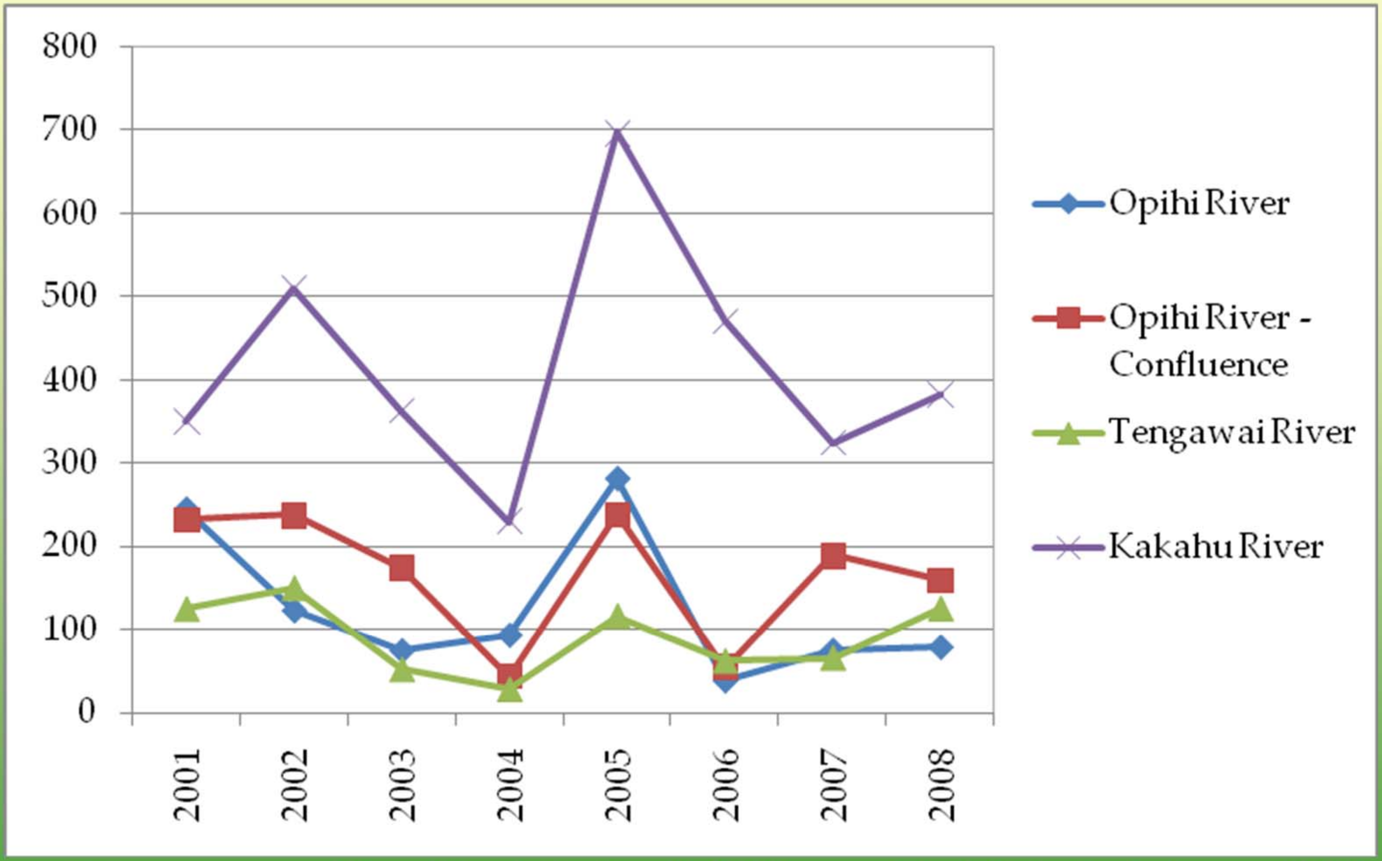

Figure 3: Average annual *E. coli* levels for the Opihi River and its tributaries between 2001 and 2008 (adapted from Environment Canterbury, 2009).

Indicators for *provisioning* Ecosystem Services

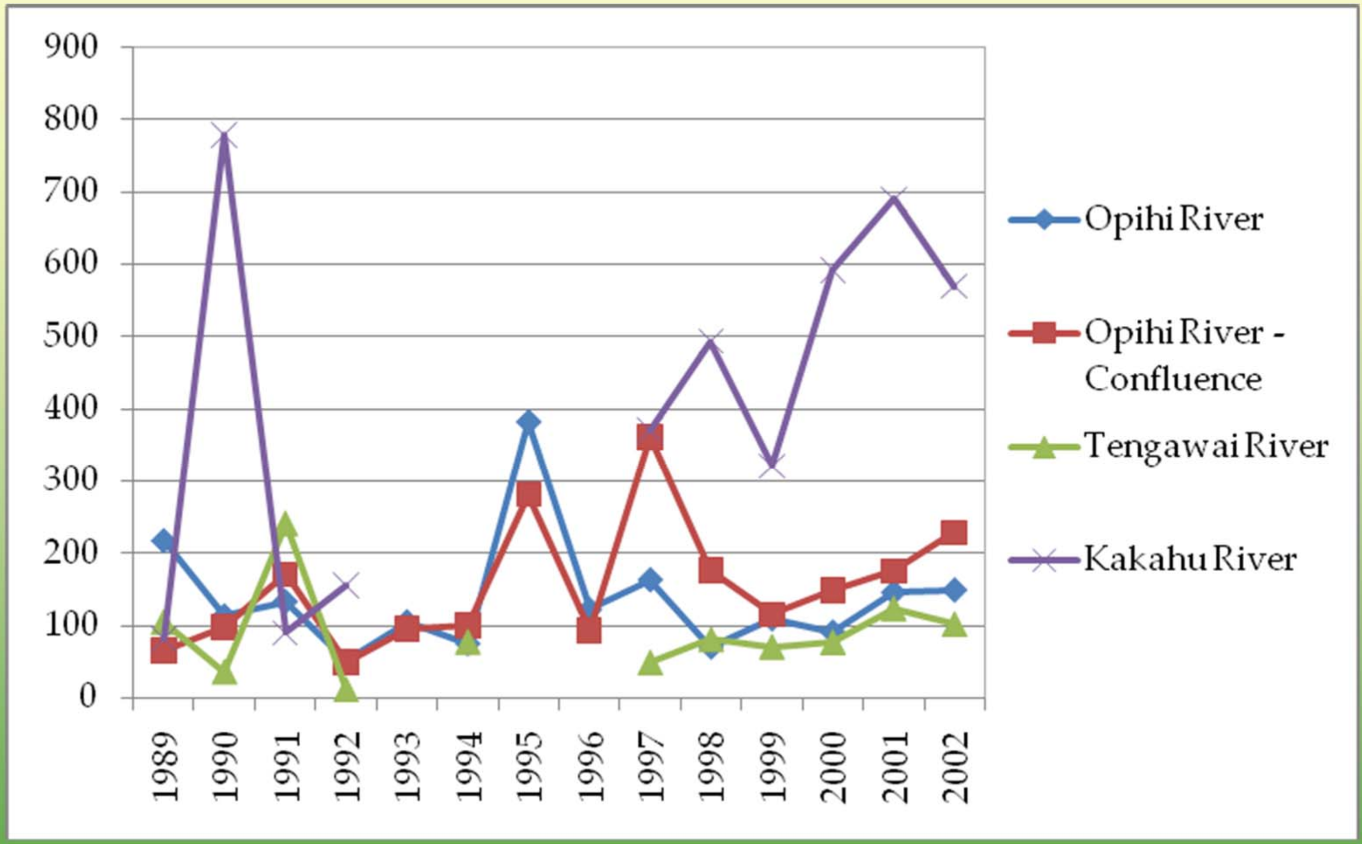

***Figure 4*: Average annual faecal coliform levels for the Opihi River and its tributaries between 1989 and 2002 (adapted from Environment Canterbury, 2009).**

Indicators for *provisioning* Ecosystem Services

Monitoring site / Biophysical indicator	Unit	Opihi River: Waipopo		Opihi River - Confluence: Rockwood		Opuha River: Skipton Bridge	
		2007	Trend	2007	Trend	2007	Trend
Minimum River Flows	m^3/s	7.67	+	2.95	0	4.45	+

Table 6: Trends in the average minimum river flows on the Opihi River and its tributaries 1989 - 2007 (Ministry for the Environment, 2009).

Period / Biophysical indicator	Pre-Opuha Dam	Post-Opuha Dam
Number of Days River Mouth Closed	100+	4-5

Table 7: The average annual number of days the mouth of the Opihi River is closed.

Indicators for *provisioning* Ecosystem Services

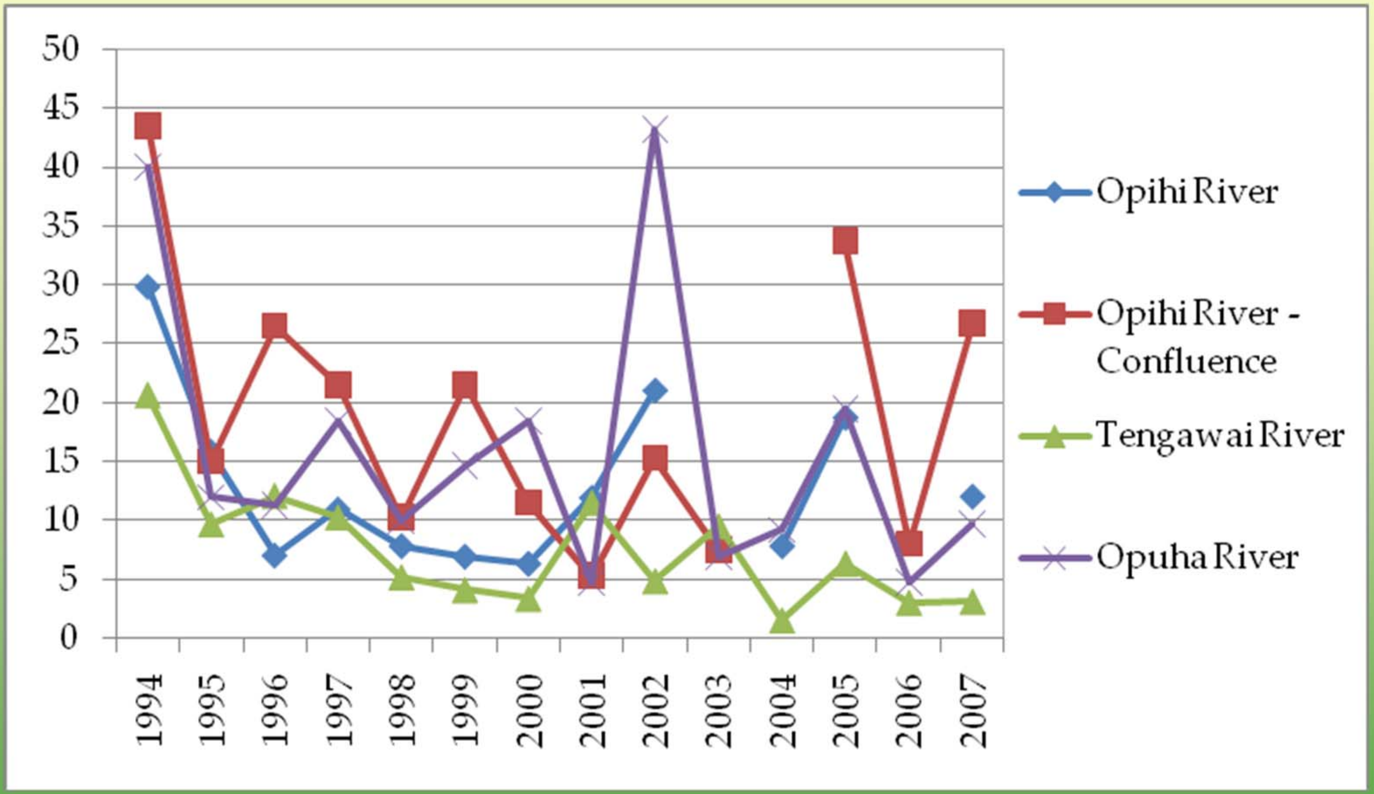

Figure 5: Average annual salmon spawning numbers between 1994 to 2007 for the Opihi River and its tributaries (adapted from Fish and Game, 2009).

Indicators for *provisioning* Ecosystem Services

Period River	Pre-Opuha Dam	Post-Opuha Dam
Opihi River	12.6	11.7
Opihi River – Confluence	9.9	10.2
Tengawai River	11.3	11.4
Kakahu River	10.7	11.3

Table 9: Average water temperature for the Opihi River and its tributaries before and after the Opuha Dam scheme (adapted from Environment Canterbury, 2009).

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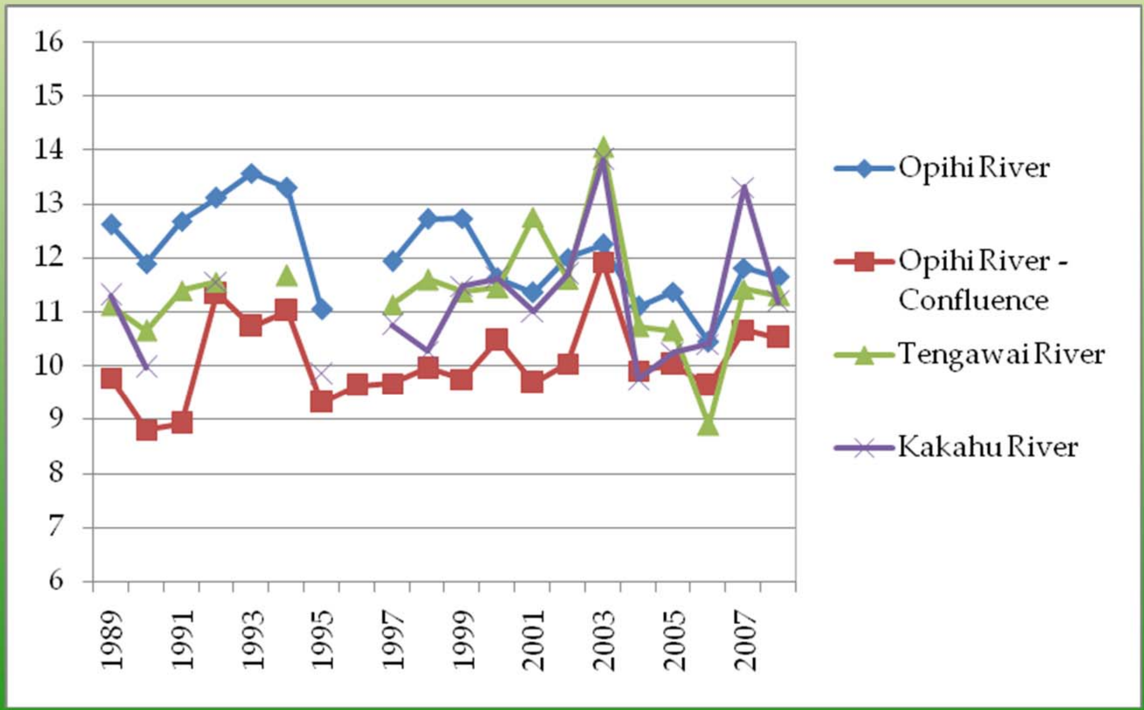

***Figure 6*: Average annual water temperature for the Opihi River and its tributaries between 1989 and 2008 (adapted from Environment Canterbury, 2009).**

Discussion

- Biophysical, economic and social data availability is patchy
- Indicators for Regulating and Cultural ES often rely upon biophysical data
- Difficult to quantify ES in any objective way (as well as in $ values)
- Can capture trends in ES if have time series data
- If have +ve and –ve impacts on ES of projects, an index of ES useful to gauge net effect
- Multiple uses of some indicators, danger of double counting
- Need criteria to score and potentially weight each indicator

Indicators with multiple uses

Indicator / Ecosystem service	*Annual Periphyton Cover*	*Clarity*	*Cultural Health Index*	*E. coli Levels*	*Irrigated Area*	*Macroinvertebrate Community Index*	*Native Biodiversity*	*Number of Days River Mouth Closed*	*Number of Flood Flows*	*Number of Salmon Caught*	*Total Suspended Sediment*	*Turbidity*
Freshwater Supply				×	×							
Food	×		×			×		×		×		
Fibre												
Abiotic Products												
Water Regulation						×			×			
Natural Hazard Regulation					×				×			
Water Purification	×				×							×
Disease Regulation	×											
Pest Regulation												
Erosion Control											×	×
Conservation Values					×		×					
Educational Values												
Aesthetic Values	×	×									×	
Spiritual Values		×	×		×		×					
Recreational Values	×	×		×				×		×		
Total	5	3	2	2	5	2	2	2	2	2	2	2

Table 12: Indicators that were used to indicate the state of multiple ecosystem services.

Expert scores for various evaluation criteria of several indicators representing the ecosystem service **Water Purification**

Ecosystem service	Criteria/sub-criteria Indicator	Data availability (0-3 scale)		Ability to communicate information (0-3 scale)		Cost (0-3 scale)	Indicator cost-effectiveness
		Scale monitoring	Processed	Intuitive	Accepted		
Water Purification	*Total Nitrogen Concentration*	3	3	2	3	2	5.5
	Total Phosphorus Concentration	3	3	2	3	2	5.5
	pH Levels	3	3	1	3	2	5
	Annual Periphyton Cover	3	2	2	2	1	9
	Average Percentage of EPT Taxa	3	2	2	2	2	4.5
	Macroinvertebrate Community Index	3	2	2	2	2	4.5

Sub-criteria for the criteria availability of data and ability to communicate information are:

1. Multiple scales: Data gathered at appropriate spatial and temporal scales;
2. Processed: Data processed into indicators that are widely used;
3. Intuitive: Indicator communicates information about ecosystem service in an obvious way that limits ambiguity, so that the mind can perceive a clear agreement between the indicator and the ecosystem service; and
4. Accepted: Indicator adheres to scientific principles and methods.

ES approaches to evaluation

- Plenty of issues to overcome to make ES approach readily usable and useful for policy makers
- Investment in appropriate time series data a key decision
- If can overcome the challenges, ES approaches could be used to evaluate future projects