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Economic valuation of the Waimea Plains groundwater system

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Abstract

The economic value of groundwater to abstractive users in the Waimea Plains, Nelson, is estimated to be approximately $250 million. The resource is worth an estimated $38 million to $42 million to the 260 irrigators on the Waimea Plains, $173 million to the fifteen commercial/industrial users, and an estimated $33 million to the bulk water supplier. The marginal value of water to irrigators is estimated in the range $240 to $300 per allocated cubic metre. The mean willingness to pay to maintain groundwater *in-situ* to keep springs and rivers flowing, and prevent salt water intrusion, could not be estimated from 180 responses to a questionnaire sent to Waimea Plains households. However an estimate on the lower bound of willingness to pay for a 20% reduction in extractive use is $183 per household. Aggregated over 6,300 households, the lower bound estimate provides an annual value of $1.2 million for the *in situ* groundwater. The net present benefits of reducing extraction by 20% range from $10.4 million to -$1.6 million, depending on the discount rate used.

New Zealand's total water resource is likely to be worth substantially more than the $2340 million calculated in a previous estimate because the economic value of groundwater abstraction estimated in this paper represents barely 1% of New Zealand's total consumptive water allocation and 3% of New Zealand's groundwater allocation.

Introduction

Groundwater has an economic value when abstracted for uses such as irrigation, commercial and industrial supply, and bulk water supply, because water is an input into the production of goods and services that are traded in markets. Groundwater that remains *in situ* also provides 'services', such as the maintenance of spring flows and the prevention of saltwater intrusion; it also has an economic value because individuals enjoy the environmental benefits. The total economic value of the groundwater resource is the sum of values that attach to both the extractive and *in-situ* services. Extractive services include direct water use by irrigators, industry and domestic users. *In-situ* services include protection against seawater intrusion, maintenance of spring flow and therefore recreation, a guarantee of water supply during periodic surface water shortages, and maintenance of wildlife habitat and ecological diversity.

Understanding of the total economic value of a groundwater resource provides water resource managers and the community with a framework for integrating the different values that attach to the resource. Furthermore, the total economic value model provides a basis for quantifying the trade-offs associated with changes to the management of groundwater quantity and quality. Even partial measurement of the total economic value can greatly aid decision-making by providing insight into how that value changes with management decisions, and measurement of only extractive services or only *in-situ* services can be of use in policy making (National Research Council, 1997). Furthermore, users of groundwater may care more about the resource, and understand the reasons for management decisions, when they know something of its values.

Undervaluation of groundwater in the United States has led to a misallocation of resources. The groundwater resource is not efficiently allocated relative to its alternative current and future uses and the authorities responsible for resource management and protection devote insufficient attention and funding to maintaining groundwater quality (National Research Council, 1997). The United States has spent billions of dollars cleaning up contaminated groundwater, with little comparison of costs or technological difficulty to future benefits (National Research Council, 1997).

This paper reviews the concept of total economic value and provides estimates of economic values of groundwater in Waimea Plains, Nelson. Waimea aquifers support agriculture (dairying, grapes, pasture irrigation, orchards, etc.), industrial activity (food processing, tree processing, animal products, etc.) and the domestic needs of approximately 6300 householders. Groundwater allocation in the Tasman District is 4.2 m^3/s (Robb, 2000), mostly from the Waimea Plains. This is approximately 1% of New Zealand's total consumptive water allocation of approximately 430 m^3/s and approximately 3% of New Zealand's total groundwater allocation of approximately 127 m^3/s.

Economic valuation of groundwater resources

The total economic value framework provides a basis for evaluating the economic impacts of a change in water resource management. To illustrate, consider a rural community that draws water for irrigation from a fully allocated aquifer. The aquifer is managed so as to maintain a given level of environmental 'services'. Let's also assume that the community has asked water managers to consider reducing total abstractions for irrigation to increase the amount of groundwater left *in situ* to maintain the environmental services. An economic analysis of the proposal would compare what people are willing to pay for the greater environmental benefits against the minimum amount required to compensate the irrigators who face a reduction in their water allocation (the cost). Quantifying benefits and costs is relatively straightforward when goods and services are traded in organised markets. However, in New Zealand, groundwater supplied to commercial enterprises is not explicitly priced. Even if water markets existed, as they do in the US, application of the total economic value framework would require an estimate of change in economic values attached to changes in the quantity and quality to maintain environmental 'services'. These benefits would have to be estimated using non-market valuation methods (Freeman, 1993).

Two broad categories of non-market valuation methods are available. Indirect methods use prices in related markets to infer value. In the land market, for example, properties may have different characteristics, such as soil type, aspect, buildings, and so on. A landowner can change some characteristics - for example invest in irrigation and increase profit per hectare. Other characteristics, such as rainfall and sunshine hours, cannot be altered. Now compare two farms - one with and the other without irrigation, but otherwise identical in all other characteristics. The land with irrigation will sell for a relatively higher price. The difference in price is the maximum a buyer would be willing to pay for the net benefits of water. This is the basic logic behind the hedonic valuation model, which uses prices generated in related markets (in this case the property market) to infer a value for the "unpriced" resource.

In contrast, direct valuation methods use surveys to ask individuals what they are willing to pay (or are willing to accept as compensation) for an increase (or decrease) in the available groundwater services. The contingent valuation method is used in this paper to estimate the community benefits associated with an increase in groundwater available to the environment. There are four key steps to producing estimates of willingness to pay (or willingness to accept compensation) using the contingent valuation method. First, the linkages between groundwater management and community values need to be clearly understood. Returning to the above example, water resource managers would need an estimate of the values of the abstracted groundwater and the value attached to the groundwater remaining *in situ*. Commercial use values would be based on what farmers are willing to accept as compensation for a decrease in their water allocation. *In situ* values would be based on what individuals within the community would be willing to pay for an increase in the quantity and quality of groundwater in the environment. Characteristics of the environmental "good" should be described in terms of quantity, quality, location and time. Added realism can be achieved using photographs and indices of environmental quality. For example indicator streams could be described, with and without the policy, in terms of their probable flows and quality during critical summer periods, for given policy options.

Second, because the aim is to estimate total economic value, care should be taken when identifying the relevant population of individuals to sample. It is relatively easy to identify user groups such as irrigators and other commercial water users - a sample can be drawn from the records of water permits. However, identifying the population of some user groups (for example, swimmers, trampers) and non-users (those attaching high values to the natural environment) may not be as straightforward. Community focus groups can assist in identifying these user groups.

Third, developing a questionnaire that provides an opportunity for respondants (as individuals or households) to accurately reveal the value attached to changes in the ambient environment is the greatest challenge facing the analyst. The basic idea is to present economic consequences for a given groundwater management scenario and then elicit the respondant's willingness to pay or willingness to accept compensation. Ideally the payment option should, as closely as possible, simulate the most likely means of payment. For example, a change in rates could be used as an option for paying for changes in water quality. It is usual for a questionnaire to go through numerous draughts before pre-testing and eventual use. Again, community focus groups can be of great assistance when developing the questionnaire.

Dichotomous choice is the most common valuation technique in use today. Individuals responding to the survey are presented with a contingent scenario, for example, if water abstraction is decreased by "x" then stream flows would increase by "y" and the risk of saltwater intrusion would decrease by "z". A randomly assigned dollar value (drawn from a distribution estimated during pretesting) is attached to the scenario and the individual's willingness to pay is recorded as a simple "yes" or "no". Socioeconomic questions, such as family size and household income, usually follow the valuation question.

The final step involves using the data to estimate a willingness-to-pay function (Mitchell and Carson, 1989). Once the parameters of the function have been estimated, the mean willingness to pay can be used to calculate total value. The contingent valuation method is flexible and can be applied to a broad set of environmental issues; currently it is the leading technique for quantifying important environmental values. The contingent valuation method has some advantages over other methods, for example it provides reliable estimates of value when the individual has a close connection to the resource being valued. The contingent valuation method, and other stated-preference approaches such as contingent ranking and paired comparison, are the only methods capable of measuring intangible environmental values; and the technique is not difficult to understand (National Research Council, 1997). The disadvantages of the method include the hypothetical economic values used, and the incentive to misrepresent values. The method is also relatively expensive.

New Zealand groundwater use and value

Toebes (1972) estimates that 80% of New Zealand's water resources are stored in its groundwater systems. These groundwater systems provide the drinking water needs of 37% of New Zealand's towns and cities (Thorpe, 1992). Consumptive water allocation in New Zealand is approximately 430 m^3/s of which approximately 127 m^3/s is from groundwater (Robb, 2000). Approximately 74% of the total national water allocation is for irrigation, and a large number of irrigators use groundwater, particularly in the east coast of the North and South Islands. The region with the largest percentage of water allocated from groundwater is Marlborough (74%) and the region with the least percentage is Northland (3%). Irrigation, industrial water use, and domestic water supply are all supported by groundwater resources in regions such as Gisborne, Hawke's Bay, Wellington, Nelson, Marlborough, and Canterbury. Thus in these areas, the groundwater resource is crucial to economic activity.

Waugh (1992) presents estimates of the value to New Zealand of the following water uses: water supply ($450 million), waste disposal ($450 million), freshwater fisheries ($100 million), recreation ($500 million), hydro-electric power generation ($800 million), and gravel resource replenishment ($40 million), giving an estimated total value of $2340 million. He states that it is difficult to place a monetary value on New Zealand's water resources. The intangible values of water resources are addressed, but not quantified.

The Waimea Plains groundwater system

The Waimea Plains (Fig. 1) is an area of about 7 500 ha, in the north of New Zealand's South Island. The plains are bounded by hills to the west, east and south, and to the north by an estuary and shallow bay. Two main rivers cross the Waimea Plains. The Wairoa River is the larger and rises in the eastern hills. It has a mean daily discharge of 16.2 m^3/s (1.4 x 10^6 m^3/day) for the period 1958-1984. The Wairoa River joins the Wai-iti River which has a mean daily discharge of 3.1 m^3/s (2.7 x 10^5 m^3/day) for the period 1980-1984, to form the Waimea River, which discharges to the Waimea Inlet and Tasman Bay. These rivers contribute to the recharge of an unconfined aquifer and two confined aquifers (Dicker, *et al.*, 1992).

Gravel units make up the unconfined aquifer (Fig. 2). The Appleby Gravel consists of reworked river gravels up to 15 m thick, which deepen towards the coast. Permeabilities are highest in the younger gravels adjacent to the Wairoa and Waimea Rivers and lowest in the Wai-iti River valley. Pumpage from the unconfined aquifer is used mainly for crop irrigation, but also for community supply, domestic, and industrial water.

The Upper Confined Aquifer consists of clean river gravel deposited by the old Waimea River. This aquifer extends from a recharge zone near the Wairoa Gorge to the coast at Rabbit Island and ranges in depth from 18 m to 32 m below ground. Pumpage from this aquifer is used for irrigation and household supply. Summer drawdowns average about 4 m in the centre of the aquifer.

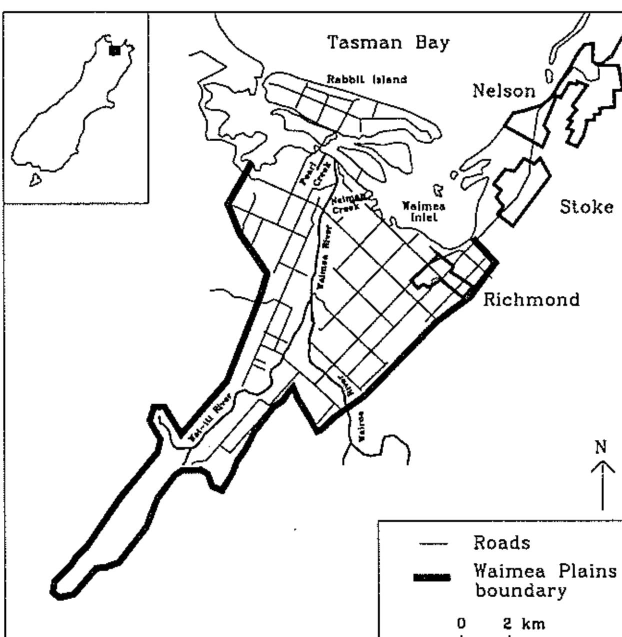

Figure 1 – The Waimea Plains, Nelson, showing the boundary of the groundwater system.

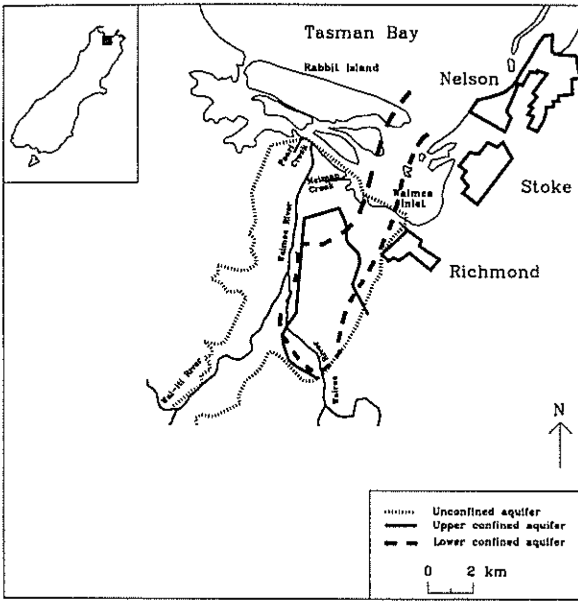

Figure 2 – Location of aquifers. Waimea Plains, Nelson.

The Lower Confined Aquifer, like the Upper Confined Aquifer, is made up of clean river gravel deposited within the clay-bound Hope Gravel, which lies on impermeable weathered clay-bound Moutere Gravel. The Lower Confined Aquifer extends from the Wairoa River and eastern hills in a northeasterly direction to Tasman Bay. It ranges from 30 m to 50 m deep, and is recharged from the Wairoa River and the eastern hills. Pumpage from this aquifer is used for irrigation, industry, and most of Richmond's municipal water supply.

Economic valuation of Waimea Plains groundwater

The total economic value of the groundwater resource in the Waimea Plains is estimated using the contingent valuation method. Three 'sectors' represent the majority of users of groundwater for productive uses: agricultural irrigation, and the commercial/industrial and bulk water supply.

A total of 260 agricultural irrigators using groundwater on the Waimea Plains are recorded on the Tasman District Council database, as of January 1999, in seven water use zones (Tasman District Council, 1991): Delta, Hope Aquifers, Lower Confined Aquifer, Upper Confined Aquifer, Reservoir, Waimea West and Wai-iti. The Tasman District Council records show 3226 Ha (Table 1) under irrigation. The total property area of properties with irrigation is estimated by summing the mean irrigated area of 12 Ha from Tasman District Council records and the estimated areas in dry-land pasture and unproductive land. The estimates of the mean dry-land pasture area (5 Ha) and unproductive land area (1 Ha) per property were the mean values of areas with these land uses determined from a survey of 48 irrigators described in the next section.

Table 1 – Irrigation from groundwater in seven water use zones on the Waimea Plains

Land Area (Ha)				
Area irrigated	Mean irrigated area per property	Mean estimated total property area	Total estimated property area	Standard deviation of property area
3226	12	19	4680	14

Water Allocation (m^3/day)		
Total water allocation	Mean water allocation per property	Standard deviation of water allocation per property
160,000	615	702

Number of properties with groundwater irrigation = 260

Economic valuation of groundwater for irrigation

Five local farmers tested the first draft of the questionnaire for irrigators. These farmers harvest a range of products and are considered representative of the Waimea Plains irrigators. Comments from this group resulted in improvements to the questionnaire. A random sample of 88 Waimea Plains irrigators (34% of the total) was made by assigning all users a number and drawing numbers from a hat.

These irrigators were contacted by telephone to discuss the project and obtain their consent to participate in it. A total of 49, or 16%, of the groundwater irrigators agreed to participate in the project. The number of participants was less than the random sample for a number of reasons: some irrigators could not be contacted in up to five phone calls over two months; some irrigators were 'too busy' or were not available during the period of the interview; and some irrigators had no phone. One irrigator expressed a lack of interest in participating in the survey. Participating irrigators were interviewed face-to-face. The irrigators provided information on their present operation, including land-use type, labour employed and the valuation of their property; how the farm would respond to changes in groundwater availability; household population; and household age range. Interviews occurred in February 1999, and 48 of the irrigators were able to provide government valuation information about their property (Table 2).

The mean government valuation of properties in the sample is $769,630 or $29,615/Ha of farm area. The predominant land uses in the sample are pasture and growing apples (Table 2). The predominant land use is the largest land use, on an area basis, in each property.

Properties in the sample range in size from 1 Ha to 143 Ha. The total land area in the sample is 24% of the estimated area of all properties with irrigation, and the average property area of the sample (26 Ha) is within a standard deviation of the estimated average property area of all irrigators (18 Ha). The mean water allocation of the sample is 603m^3/day and this is within a standard deviation of the mean water allocation to all groundwater users of 615m^3/day.

Irrigators described the impact that a reduction in groundwater availability would have on their present farming operation and on the government valuation of their properties. If less groundwater were available, production would decline, and property owners expect this to reduce property values. The questionnaire asked irrigators to consider the option of arranging

Table 2 – Summary of government valuation, land use, property size, and water allocation of the properties of 48 irrigators using groundwater

Government Valuation		**Predominant land use**	
Value ($)	**Number of properties**	**Crop**	**Number of properties**
0 – 400,000	18	Pasture	21
400,001 – 800,000	18	Apples	10
800,001 – 1,200,000	3	Horticulture	5
1,200,001 +	9	Dairy	4
		Market Gardens	4
Total government valuation	= $36.9 million	Grapes	2
Mean government valuation	= 769,630/property	Crops	2
Standard deviation	= 761,190/property		
Property Size		**Water Allocation**	
Area (Ha)	**Number of properties**	**Allocation (m^3/day)**	**Number of properties**
0 – 10	26	0 – 300	19
11 – 20	8	301 – 600	18
21 – 50	5	601 – 1000	5
51+	9	1001 +	7
Total land area	= 1,246 Ha	Total water allocation	= 28,963m^3/day
Mean property size	= 26.0 Ha	Mean allocation	= 603m^3/day
Standard deviation	= 35.0 Ha	Standard deviation	= 765m^3/day

a different water supply, but this is not practical for the majority of irrigators. The cost of an alternative supply, in most cases, would make the present farming operation uneconomic.

Two approaches to the valuation of the groundwater resource are provided. First, a 100% reduction in groundwater availability to irrigators is expected to reduce mean property value by $211,297 and mean land value by $8,127/Ha. Scaling up the difference in land value to the estimated land area of properties with irrigation in the Waimea Plains (4,680 Ha) produces a total estimate of value of the groundwater resource to irrigators of $38 million.

The second approach uses a model to unravel the factors – land, water, labour and capital – that contribute to the value of land. Government value per hectare (GV/HA) is considered a function of the water allocation per hectare (WATER/HA), the number of full-time labour equivalents per hectare (FTE/HA) and other explanatory variables such as the inverse of area (INVHA) and off-farm income per hectare (INCOME/HA). The inclusion of the variable INVHA is readily explainable. If property value is a linear function of capital improvements (k), the size of the property (HA) and the amount of water available (WATER), then:

$$GV = k + a*HA + b*WATER$$

GV per hectare is then:

$$GV/HA = k*1/HA + a + b*WATER/HA$$

Estimating the coefficients of the model using econometric methods provides an estimate of the contribution of water to land value (Table 3). Two types of model are employed. The revealed models attempt to explain the relationship between the dependent variable (GV/HA) and the set of independent variables shown in Table 3 using the existing cross-sectional data. In other words, the revealed models are based on observations of GV/HA and the independent variables. In contrast, the hypothetical models were run on both the existing observations and the reported responses to the hypothetical scenarios. Comparison of the two model types provides a convergent validity check on the hypothetical responses.

Models containing INVHA indicate that the marginal value of water is about $240-$300 per cubic metre per day. That is, holding other variables constant, the maximum willingness to pay for an additional cubic metre of water per day is $240-$300. Income per hectare earned off the property (INCOME/HA) appears to have a significant effect on property value that is not readily explainable by productivity-based arguments. It may simply reflect the influence of high incomes from other sources on capital investment in lifestyle properties, incorporating house quality and other developments such as swimming pools or tennis courts.

Scaling the estimated marginal value of water up to the total groundwater allocation in the seven water use zones on the Waimea Plains (160,000 m^3/day) gives an estimated value of the groundwater resource for irrigation as $38 million to $48 million.

Economic valuation of groundwater for commercial/industrial use

The questionnaire for commercial/industrial users was adapted from the irrigators' questionnaire. Users indicated their water source and water use; the present operation including the product type and unit production, labour employed, and market value of their business; the cost of water supply; how the business would respond to changes in groundwater availability; and alternatives for an alternate water supply should groundwater become unavailable. Interviews were carried out face-to-face.

Table 3 – Ordinary least sqares model estimates to calculate the marginal value of groundwater to irrigators

Dependent variable = V/HA	Parameter Estimates (*t*-values)					
Model	Revealed		Hypothetical			
	(1)	(2)	(3)	(4)	(5)	(6)
FTE/HA	78183 (11.90)	75396 (12.07)	74998 (12.27)	81573 (12.78)	77520 (12.49)	76652 (12.48)
WATER/HA	472 (3.55)	279 (2.22)	296 (2.17)	370 (3.38)	242 (2.34)	255 (2.39)
INCOME/HA	1916 (10.01)		516 (1.01)	2084 (14.90)		555 (1.56)
INVHA		179158 (10.92)	136799 (2.92)		190132 (16.00)	146127 (4.62)
Constant	10325 (2.11)	12795 (2.83)	12209 (2.70)	14511 (5.11)	13430 (4.91)	12880 (4.74)
R^2	0.94	0.94	0.95	0.85	0.85	0.87
Adjusted R^2	0.93	0.94	0.95	0.84	0.85	0.86

All fifteen commercial/industrial users of groundwater in the Waimea Plains on the Tasman District Council database were approached in June 1999 and twelve contributed to the survey. The combined total water use by the fifteen commercial/industrial users is estimated at 5848 m^3/day and the twelve users who contributed to the questionnaire use 95% of this amount.

The industrial users who contributed to the survey include those who process timber, animal products, fruit, and gravel. Businesses include those supplied with groundwater by the Tasman District Council. The total value of these businesses is $517.4 million.

Businesses were asked how their production, and therefore the value of their business would respond to a decline in groundwater availability. Other water supply options were presented in the questionnaire to commercial/industrial groundwater users. Alternative supplies were not a practical option for the majority of groundwater users, as the additional supply cost would make their businesses uneconomic. Eight of the businesses surveyed are relatively sensitive to groundwater availability, as a reduction would lead to a decline in product output or a closure of plant. A number of businesses would close down or relocate should groundwater be unavailable. Businesses that close in response to groundwater unavailability are valued at the estimated sale price of land, stock, and equipment.

The estimated total valuation of the twelve businesses in the survey, if there were no groundwater availability, is $378.8 million. The value of the groundwater resource to commercial/industrial users who contributed to the survey is therefore $138.6 million. The value of the groundwater resource to all commercial/industrial users is calculated as $173 million by scaling-up the results from the sample to all users.

Economic valuation of groundwater for bulk water supply

The questionnaire for the bulk water supplier was pre-tested with a bulk water supplier outside the Tasman region. The bulk water supplier was asked, in a face-to-face interview: the supply volume; the annual, and volumetric cost of the bulk water supply; the alternatives, and costs, of supply should groundwater become unavailable; and how the bulk water supplier would respond to changes in groundwater availability.

Tasman District Council is the bulk water supplier for householders in Richmond and Brightwater and for industry in Richmond and Stoke. Water is supplied to Richmond from wells drilled into the Lower Confined Aquifer near the coast. The council also supplies groundwater to industry in Stoke, and to coastal communities west of the Waimea Plains from wells near the Waimea River. The present scheme is estimated to have a capital value of $31 million, and annual running costs of approximately $1 million per year. Alternative schemes, should groundwater not be available, include water dams and piping water from the area near Nelson Lakes National Park. These two options are each estimated to cost an extra $20 million of capital expenditure. The annual cost of these schemes is estimated at $2.3 million, for supply dams, and $2.6 million for piping water from the area near Nelson

Lakes National Park. An estimate of the value of the groundwater resource to the bulk water supplier is $33 million, the sum of the capital expenditure required for a non-groundwater scheme ($20 million) plus the difference in annual running costs ($1.3 million) capitalised at 10%.

Valuation of *in-situ* groundwater resources

Two groups assisted with the development of a questionnaire to measure the value of groundwater resources left *in-situ*. The payment option to assess willingness to pay proved difficult to develop and several drafts of the method were required. A random sample of householders was chosen, using names and addresses in the telephone book with telephone number prefixes which identify Richmond and Waimea Plains residents. The questionnaire was sent to 398 of the approximately 6300 householders on the Waimea Plains. A total of 180 questionnaires were returned, which is a response rate of 45%.

Groundwater left *in-situ* would maintain spring flow, maintain groundwater quality and prevent saltwater intrusion. Householders were asked what they would be willing to pay to maintain these services associated with the groundwater system. The scenario proposed was that irrigators' allocation would be reduced by 20% to reduce the frequency of the Waimea River reaching low flow to maintain spring flow, and to reduce the risk of saltwater intrusion to the groundwater system. A reduction in irrigation would reduce rural property values, and therefore household rates would have to increase to maintain the services provided by the Tasman District Council. People were asked to respond 'yes' or 'no' (a 'dichotomous choice' model) to an increase in rates to maintain the environmental benefits of *in situ* groundwater. Each householder was given a rate increase figure that was a random number between $10/year and $250/year.

The contingent valuation is based on the value that individuals attach to changes in the *in-situ* groundwater resources and associated ecosystems. In this case we attempted to estimate what individual households were willing to pay for a 20% reduction in groundwater extraction. Other household data were collected, such as income, number of individuals in the household, household income, and so on. The relationship between willingness to pay and other socio-economic variables data was estimated using the logistic model. Estimates of coefficients from the dichotomous choice contingent valuation models applied to households to measure willingness to pay for a 20% reduction in groundwater extraction are reported in Table 4.

An increase in rates is not a significant variable in any of these models. The only significant independent variable is MORESALT, a dummy coded as 1 for respondants who thought that more groundwater extraction would increase the risk of sea water mixing with groundwater. The data were analysed further by drawing 600 bootstrap replications for each model. Positive slopes were estimated for 30% of the logistic replications and 18% of the log-logistic replications. All willingness-to-pay coefficient estimates derived using the log-logistic model were greater than –1, so no replication yielded a non-infinite estimate of mean willingness-to-pay (Hanemann, 1984). The logistic model yielded a lower bound 95% confidence interval on the mean of $183.

Table 4 – Dichotomous choice models (t-scores in parantheses)

		Logestic models		**Log-logistic model**
Constant	0.6111 (1.91)	-0.84 (-1.62)	-0.773 (-2.21)	1.413 (1.52)
Rate increase	-0.002 (-0.76)	0.0003 (0.09)		-0.238 (-1.11)
More salt		1.68 (4.03)	1.68 (4.03)	
N	145	142	142	145
Log-likelihood (constant only)	-97.59	-95.23	-95.23	-97.59
Log-likehood (unrestricted)	-97.29	-86.18	-86.18	-96.96
McFadden's R^2	0.003	0.10	0.10	0.006
$\chi 2$	0.585	18.12	18.11	1.251
$P(\chi 2)$	0.444	0.00012	0.00002	0.268

The survey was not successful in estimating a mean willingness-to-pay because a significant number of householders indicated they were willing to pay the highest values in the questionnaires, which means that that upper limit of willingness-to-pay could not be estimated. Scaling up the lower bound estimate of willingness-to-pay over 6300 households on the Waimea Plains, results in a value of approximately $1.2 million. This is an estimate of what the community would be willing to pay to reduce extraction of groundwater by 20%.

Trade-off evaluation

The total economic value model also provides a framework for evaluating trade-offs. For example, data were collected to estimate the benefits and costs of reducing water extraction by 20%. A lower bound estimate of what the community is willing to pay for a 20% reduction in pumping is $1.2 million per annum. Using discount rates of 5%, 8% and 10% the increase in annual benefits are $24 million, $15 million and $12 million respectively. The capitalised cost to irrigators of reducing extraction by 20% is $11.12 million. To this must be added the capitalised cost increase of $2.5 million incurred by commercial industry and the bulk water supplier. Clearly, the net benefits of a 20% reduction in groundwater extraction depend on the discount rate used. Table 5 provides a summary of net benefits.

Table 5 – Net benefits of 20% reduction in groundwater to agriculture and industry

Discount rate	Net present benefit
5%	$10.4 million
8%	$ 1.4 million
10%	–$ 1.6 million

The results do not support large-scale reductions in groundwater pumping. The results do suggest that managers should pay close attention to the relative value of water in commercial use and its *in situ* value to the community. .

Application of results to New Zealand water resources

It is the authors' opinion that New Zealand's water resources are of much greater economic value than the $2340 million estimated by Waugh (1992). The Waugh (1992) estimate includes the value of water supply, waste disposal, freshwater fisheries, recreation, hydro-electric power and gravel replenishment. Our estimate of an economic value of Waimea Plains groundwater for abstractive uses is $244 million to $248 million - made up of $38 million to $42 million for irrigators, $173 million for commercial users, and $33 million for bulk water supply. This economic value is associated with just a small proportion of New Zealand's total water allocation. Groundwater allocation on the Waimea Plains represents approximately 1% of New Zealand's total consumptive water allocation and approximately 3% of New Zealand's groundwater allocation.

The economic value of New Zealand's total consumptive water allocation would be estimated at $24 billion to $25 billion if the unit economic value of Waimea Plain's groundwater could be applied to all of New Zealand's water allocation. It is unknown if this extrapolation is reasonable because water uses in other regions of New Zealand may have different economic values, however the authors present this calculation solely to support our opinion that Waugh (1992) underestimates the value of water. The estimate of Waugh (1992) included water uses that are not considered in our Waimea Plains groundwater economic valuation. The inclusion of the economic values of waste disposal, freshwater fisheries, recreation, hydro-electric power, and gravel replenishment would probably increase the valuation of the New Zealand water allocation to a figure that is substantially greater than that estimated for New Zealand's total consumptive water allocation. Further, the values derived in the current study assume the existence of a substitute for groundwater from other water sources. Consequently, if the groundwater resource were to become unavailable on the Waimea Plains these other water sources could be utilised by some existing water users. If all New Zealand groundwater were unavailable, options for alternative sources would be diminished and consequently the impacts would be more serious than if the groundwater for only one region were unavailable.

Conclusion

Groundwater is a scarce resource in areas such as Gisborne, Hawke's Bay, Wellington, Nelson, Marlborough and Canterbury. Despite the economic significance of groundwater, little is known of its economic value. The total economic value model used in this study provides water resource managers with a coherent and comprehensive framework for incorporating a range of values that attach to water and a tool for evaluating alternative management strategies.

Waimea aquifers make a significant economic contribution to agricultural and other commercial users, and to households. In addition, the resource maintains important ecological services. If all extractive users had their allocations reduced by 100%, the total cost is estimated at $244 million to $248 million; comprising $38 million to $42 million (260 irrigators), $173 million (15 commercial users) and $33 million (the bulk water supplier). The marginal value of water to irrigators, as estimated by an econometric model, is between $240 and $300 per cubic metre. This provides an estimate of the value of an additional cubic metre of water.

The total economic value model also provides a framework for evaluating the economic impacts of reallocating groundwater. For example, the net benefits of reducing groundwater allocation to water extractive uses by 20%, thereby improving the level of groundwater within the natural environment, ranges from $10.4 million to -$1.6 million, depending on the discount rate used.

It is likely that the estimate of the economic value of New Zealand's total water resources is substantially greater than the $2340 million given by Waugh (1992). The economic value of groundwater for abstractive use on the Waimea Plains is estimated at approximately $250 million for an allocation that represents barely 1% of New Zealand's total consumptive water allocation and approximately 3% of New Zealand's groundwater allocation.

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