Wairarapa Valley groundwater resource investigation

Proposed framework for conjunctive water management

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Executive summary

The groundwater resources of the Wairarapa Valley have a high environmental and cultural value in sustaining freshwater ecosystems and an important social and economic value in meeting water demands for domestic, municipal, agricultural and industrial purposes. Rapidly growing pressure on the water resources of the Wairarapa Valley over the past decade led Greater Wellington Regional Council to initiate a comprehensive investigation of groundwater in the Wairarapa Valley to re-assess the sustainable yields of aquifers in the valley. This report, which forms Phase 3 of the Wairarapa Valley groundwater resource investigation, focuses on the development of a water allocation methodology that will ensure both groundwater and surface water resources are sustainably managed. It follows a technical analysis of the groundwater environments of the Wairarapa Valley and the development of three sub-regional numerical groundwater flow models suitable for evaluating sustainable aquifer yields.

Development of a sustainable groundwater allocation methodology for the Wairarapa Valley has been approached from a conjunctive water management perspective. There are two fundamental components to the approach proposed:

1. Management of those groundwater abstractions that have a direct or immediate effect on the surface water environment through application of pumping controls based on minimum flows established for hydraulically connected surface waters; and
2. Establishment of fixed allocation volumes for individual groundwater management units that recognise that groundwater abstraction may cumulatively cause a reduction in river or stream baseflow. These allocation limits will apply where groundwater abstraction does not result in an immediate or direct streamflow depletion effect.

In order to implement these objectives, a three-tier management approach is proposed to establish a framework for managing groundwater abstraction according to the potential impact on surface water. The concept of '*hydraulic connectivity*' is utilised to differentiate those groundwater takes which have a direct and immediate effect on surface water from those where there is a considerable lag between pumping and resulting effects on surface water.

In areas of the hydrogeological system where there is a direct hydraulic connection with surface water (identified as *Category A*) it is proposed that groundwater abstraction will effectively be managed as equivalent surface water abstraction. In those areas where there is a moderate to low hydraulic connection (*Category C*), groundwater abstraction will be managed in terms of a groundwater allocation volume established to limit the maximum cumulative depletion of baseflow at a catchment (or sub-catchment) scale. In intervening areas (*Category B*), it is proposed to manage groundwater abstraction through a combination of temporal pumping restrictions (i.e. minimum flow cut-offs) and determine groundwater allocation on the basis of local hydrogeological conditions and abstraction rates.

Overall, the proposed framework effectively establishes a three-dimensional framework for the management of the cumulative effects of groundwater abstraction on surface water based on geographic location and depth criteria which vary according to the local hydrogeological environment and resulting connectivity between surface and groundwater resources.

Contents

1. Introduction

The groundwater resources of the Wairarapa Valley have a high environmental and cultural value in sustaining freshwater ecosystems and an important social and economic value in meeting water demands for domestic, municipal, agricultural and industrial purposes. Rapidly growing pressure on the water resources of the Wairarapa Valley over the past decade has required Greater Wellington Regional Council (Greater Wellington) to review its current water allocation methodology to ensure both groundwater and surface water resources continue to be sustainably managed into the future.

At the current time approximately half of the 29 groundwater zones in the Wairarapa Valley defined in Greater Wellington's Regional Freshwater Plan (RFP, WRC 1999) are allocated at levels in excess of 60% of their calculated '*safe yields*'. In general, the most highly allocated zones contain the most productive aquifers in the Wairarapa Valley which are typically located along the riparian margins of the major river systems.

Due to the nature of its geology and geomorphology, the Wairarapa Valley is essentially a closed hydrogeological system in which outflow occurs predominantly as discharge into the Ruamahanga River system or Lake Wairarapa at the downstream basin margin[1]. As a consequence, groundwater abstraction has the potential to contribute to a cumulative reduction in basin outflow, although the timing and magnitude of effects are highly dependent on the hydraulic connectivity between source aquifer(s) and the surface water environment.

The RFP has separate policies for allocation of surface and groundwater resources. This lack of integration between management of groundwater and surface water allocation results in the potential for groundwater abstraction to result in stream depletion in hydraulically connected rivers and streams (particularly during periods of low flow) which is not accounted for within existing surface water allocation.

One consequence of the failure to account for potential effects of groundwater abstraction on surface water is a situation referred to as "double accounting". This can occur where groundwater that may otherwise contribute to surface water baseflow discharge is allocated for abstraction from hydraulically connected aquifers. If the consequent reduction in baseflow is not recognised in the allocation of surface waters, then the potential exists to essentially allocate the same water twice: once from the hydraulically connected groundwater system and again from surface water receiving baseflow discharge from the aquifer.

1.1 Background

In 2005 Greater Wellington commenced a three stage investigation to improve definition of the hydrogeology of the Wairarapa Valley and develop a framework for future sustainable management of the groundwater resource.

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[1] Losses from the basin also occur via direct evaporation from rivers and lakes and evapotranspiration where vegetation directly accesses the underlying water table.

This report outlines the final management recommendations developed from the preceding technical investigations. The three phases of the investigation are briefly outlined below.

Phase 1 – Regional conceptual and numerical modelling of the Wairarapa Valley groundwater basin

This preliminary phase of the investigation, reported by Jones and Gyopari (2006), consolidated existing knowledge of the hydrogeology of the Wairarapa Valley to provide a regional-scale evaluation of the groundwater resource. The investigation was largely based on existing information and resulted in a revised geological model. This phase of the investigation culminated with the development of a regional conceptual hydrogeological model and a 'bulked' steady-state numerical model to test conceptualisation and identify additional information requirements. Phase 1 also identified three sub-catchments (Upper, Middle and Lower Valley) that essentially set the scene for the comprehensive Phase 2 investigations.

Phase 2 – Detailed sub-regional resource analysis and modelling

The Phase 2 investigation focussed on development of transient groundwater flow models to provide a management tool to assist sustainable management of the groundwater resource. Investigations undertaken for this phase of the project included field studies to address key information gaps identified by the Phase 1 investigation, as well as detailed analysis and quantification of aquifer recharge processes, groundwater abstraction and hydrochemistry. The primary output from this phase of the investigation was the development of three separate groundwater flow models for the Upper, Middle and Lower Valley sub-catchments (documented in Gyopari and McAlister 2010a, 2010b and 2010c respectively).

Phase 3 – Groundwater resource sustainability assessment

The third and final phase of the investigation (this report) was the application of the outputs from the first two phases of the project to the development of a management framework to enable sustainable management of the groundwater resources of the Wairarapa Valley. In particular, this work utilised both the conceptual and numerical models developed for the Phase 2 investigations to develop recommendations for sustainable groundwater allocation limits as well as the management of stream depletion effects resulting from groundwater abstraction.

1.2 Report objectives

The overall objective of the report is to recommend an approach for the sustainable management of the groundwater resources of the Wairarapa Valley that takes into account potential effects of groundwater abstraction on surface water bodies. As the main focus of the report is on management options that may be considered as part of future policy development, the report is primarily intended for a technical/policy audience.

To provide context for the management options outlined, more general readers are directed to Appendix A and Appendix B which provide an introduction to general concepts relating to management of groundwater/surface water interaction and provide an overview of the nature and extent of groundwater/surface water interaction in the Wairarapa Valley (respectively).

1.3 Report structure

This report provides recommendations for the establishment of a framework for managing groundwater allocation in the Wairarapa Valley that considers both the sustainability of groundwater abstraction and cumulative effects on hydraulically connected surface water bodies. The report comprises the following sections:

- Section 2 – *Management framework*: A conceptual outline of the proposed framework for the conjunctive management of groundwater and surface water in the Wairarapa Valley.

- Section 3 – *Management of direct stream depletion effects*: Recommendations for the classification and management of groundwater takes which have a direct effect on stream flow.

- Section 4 – *Management of the cumulative effects of groundwater abstraction on river baseflow*: Recommendations for the rationalisation of existing groundwater management zones in the Wairarapa Valley including options for volumetric groundwater allocation limits.

- Section 5 – *Implications for monitoring and management*: A review of potential implications for monitoring and management of groundwater and surface water resources in the Wairarapa Valley that may result from adopting the proposed conjunctive water management framework.

- Section 6 – *Summary and conclusions*

Appendices to the report:

- Appendix A – *Technical and policy background*: A description of some of the basic concepts relating to management of groundwater/surface water interaction.

- Appendix B – *Groundwater - surface water interaction in the Wairarapa Valley*: Description of the nature of groundwater and surface water interaction in the Wairarapa Valley.

- Appendix C – *Quantifying groundwater abstraction on stream flow*: Application of the Upper, Middle and Lower catchment groundwater models to determine the spatial (and depth) variations in potential stream depletion effects across the Wairarapa Valley.

- Appendix D – *Upper Valley groundwater allocation*: Details of numerical modelling undertaken to determine potential groundwater allocation limits in the Upper Valley catchment.

- Appendix E – *Middle Valley groundwater allocation*: Details of numerical modelling undertaken to determine potential groundwater allocation limits in the Middle Valley catchment.

- Appendix F – *Lower Valley groundwater allocation*: Details of numerical modelling undertaken to determine potential groundwater allocation limits in the Lower Valley catchment.

- Appendix G – A3 scale maps of the proposed hydraulic connection categories for the Upper, Middle and Lower valleys.

2. Management framework

The groundwater resources of the Wairarapa Valley form an integral component of the overall hydrological cycle and have a significant role in sustaining freshwater ecosystems in riverine and wetland habitats. Significant use is also made of the groundwater resource for domestic, municipal, industrial and irrigation water supplies. Managing potential conflicts between maintenance of environmental values associated with the groundwater resource (including hydraulically connected surface water) and the potential social and economic benefits arising from consumptive use of water presents a major resource management challenge.

As described in greater detail in Appendix B, groundwater and surface water resources throughout the Wairarapa Valley typically exhibit a high degree of connectivity, particularly within the recent gravel deposits along the riparian margins of the main river systems. Due to the nature and extent of interaction between groundwater and surface water, the groundwater resource comprises a major component of the overall hydrological system. Managing both localised and cumulative effects of groundwater abstraction on hydraulically connected surface waters is therefore a key component of a framework to enable integrated management of surface and groundwater allocation to ensure environmental values can be maintained at or above thresholds established by the community through the Regional Plan review process.

2.1 Conjunctive water management

Recognising that surface water and groundwater resources within a catchment are fundamentally linked means that management of these resources needs to be undertaken in a coordinated way. Such an integrated approach has been termed *conjunctive water management*.

In its simplest application, the term conjunctive water management describes '*the management of hydraulically connected surface water and groundwater resources in a coordinated way, such that the total benefits of integrated management exceed the sum of the benefits that would result from independent management of the surface and groundwater components*' (Sahuquillo and Lluria 2003).

In this report, the term conjunctive water management is used to describe a framework for the management of groundwater allocation in the Wairarapa Valley which recognises the hydraulic connection between groundwater and surface water and enables consumptive groundwater use in a manner that is consistent with environmental flow and water levels established for hydraulically connected surface water resources.

Brodie et al. (2007) outlined general principles for the application conjunctive water management in the Australian context which include:

1. Where physically connected, surface water and groundwater should be managed as one resource;

2. Water management regimes should assume connectivity between surface water and groundwater unless proven otherwise;
3. Water users (both surface and groundwater) should be treated equitably.

These principles have been utilised to guide development of the suggested framework for conjunctive management for the Wairarapa Valley outlined in this report.

Brodie et al. (2007) also proposed the framework for conjunctive water management shown in Figure 2.1. This framework incorporates the principle of adaptive management which enables the regulatory response to a particular natural resource management issue to incorporate improved understanding of the dynamic response of the physical environment to development pressures and adapt to changing management objectives over time.

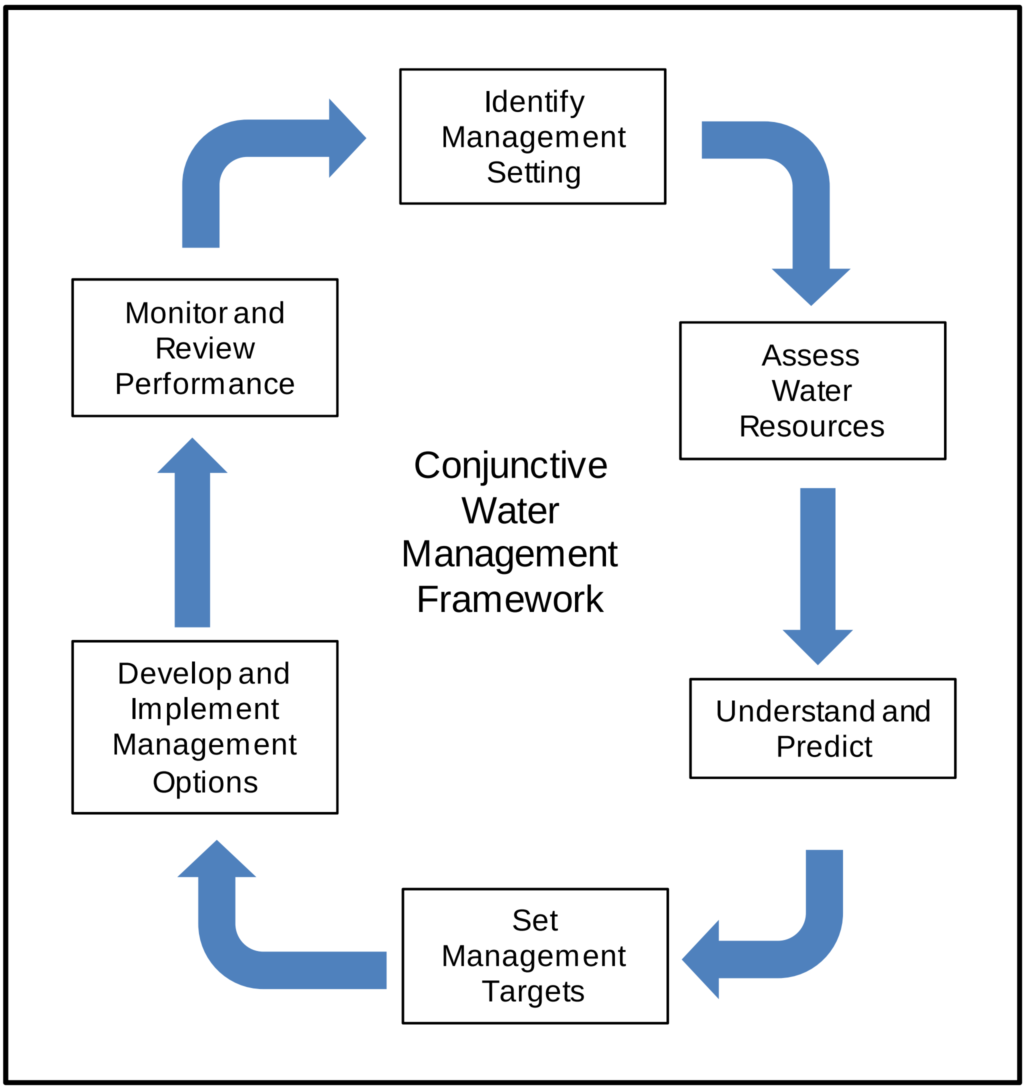

Figure 2.1: A framework for conjunctive water management (from Brodie et al. 2007)

Key elements of the process for successful development and implementation of a framework for conjunctive water management include:

- Development of a good conceptual understanding of the interaction between groundwater and surface water in a catchment;
- Development of a consistent, technically sound approach to the management of groundwater-surface water connectivity;
- Application of numerical models and other predictive tools to improve understanding of the dynamic behaviour of the resource, establish resource management targets and evaluate future management options;
- Co-ordinated monitoring of groundwater and surface water resources to characterise dynamic behaviour of the resource in response to development pressure and ensure management targets are being achieved.

2.2 Applying conjunctive water management to the Wairarapa Valley

Following the principles outlined in the previous section, Figure 2.2 provides a schematic illustration of the application of the conjunctive water management concept to the development of a framework for managing groundwater allocation in the Wairarapa Valley.

Development of the proposed management framework follows on from the extensive data collection and analysis undertaken for the Phase 1 and Phase 2 components of the Wairarapa Valley groundwater resource investigation. In particular, the conceptual hydrogeological model developed from these investigations was utilised to refine understanding of the potential nature of groundwater / surface water interaction across the range of hydrogeological environments present in the Wairarapa Valley and to develop a framework for management of ‘direct’ stream depletion effects.

Numerical groundwater flow models were then used to test a range of scenarios designed to characterise the hydraulic connectivity between groundwater and surface water over a range of spatial (and depth) scales and re-evaluate the spatial units (water management zones) utilised to manage groundwater allocation. Where hydraulic connectivity is not sufficient to enable active management (i.e. mitigation) of potential stream depletion effects during periods of low flow, scenario modelling was utilised to identify options for groundwater allocation limits intended to manage cumulative effects of groundwater abstraction on baseflow at a regional scale.

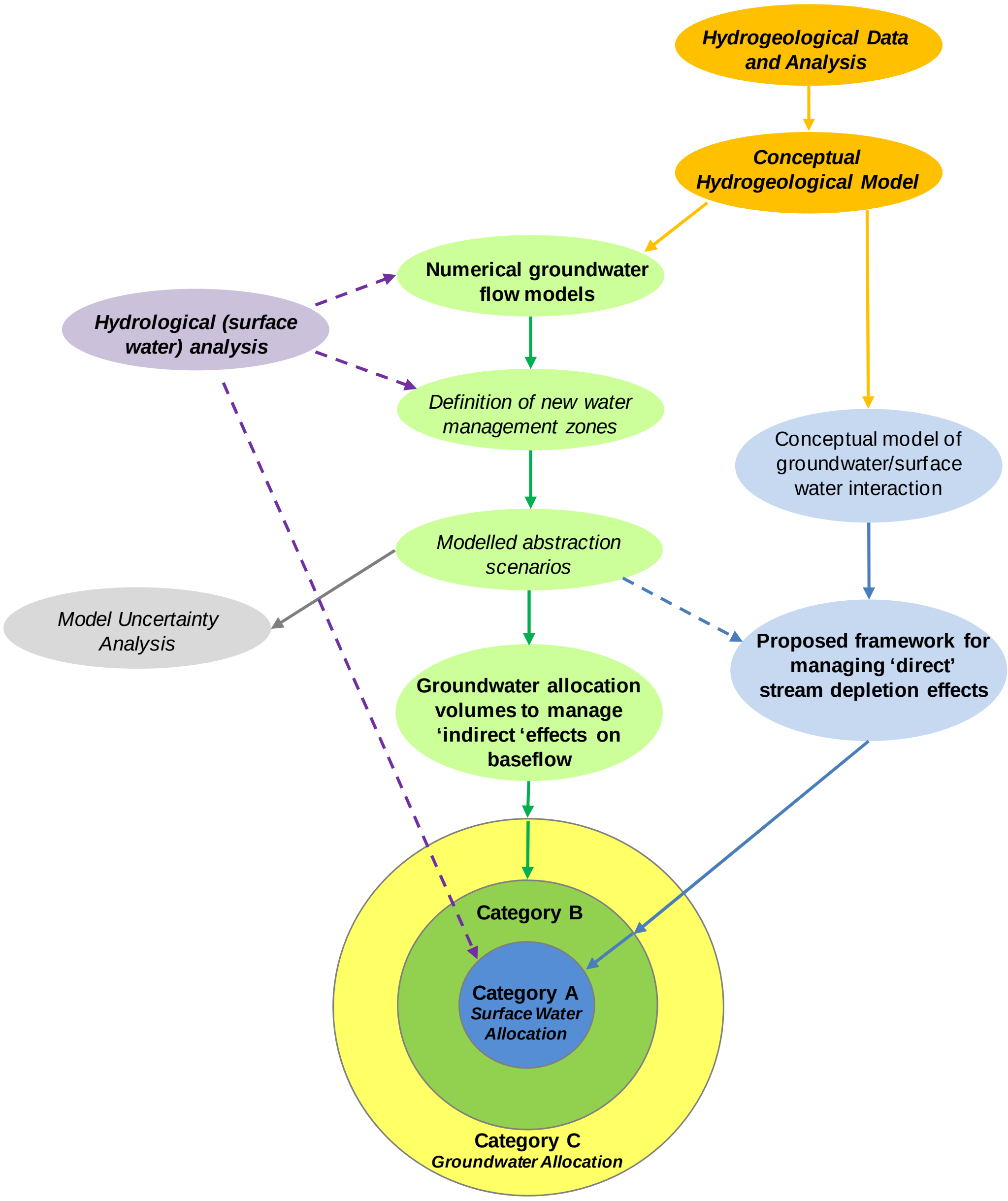

Figure 2.2: Conceptual outline of the development of a framework for conjunctive water management in the Wairarapa Valley

Given the significant reliance on groundwater modelling, analysis of model uncertainty is important to validate the proposed management approach. At the time of writing, this uncertainty analysis was still in progress for the three groundwater models (Upper, Middle and Lower Valley) developed for the Phase 2 investigations.

2.3 Proposed management approach

As described in Appendix B, virtually all groundwater in the Wairarapa Valley is hydraulically connected to surface water to some degree. As a consequence, groundwater abstraction has the potential to impact on surface water flows either as a result of localised (direct) stream depletion effects or through indirect effects on baseflow at a catchment scale. However, application of analytical and numerical modelling detailed in Appendix C shows that the exact magnitude and timing of effects on surface water resulting from groundwater abstraction varies considerably between individual hydrogeological environments. As a result, an effective management framework has to recognise and provide for the range of potential effects on hydraulically connected surface water resulting from groundwater abstraction across a range of hydrogeological settings.

This report proposes a conjunctive approach to management of the effects of groundwater abstraction on hydraulically connected surface water in the Wairarapa Valley that provides for:

1. Active management of those groundwater abstractions which have a direct or immediate effect on the surface water environment and can be effectively mitigated by the application of management controls (such as minimum flow cut-offs); and

2. Designation of spatially defined management units which are assigned volumetric allocation limits that take account of the potential cumulative effects of groundwater abstraction on river or stream baseflow at a catchment scale.

A three-tier management framework is proposed to manage groundwater abstraction according to the potential to impact on surface water. The framework allows differentiation between those groundwater takes which have a direct and immediate effect on surface water, from those where there may be considerable lag between pumping and resulting effects, based on three nominal categories of hydraulic connection. This effectively establishes a three-dimensional framework for the management of groundwater abstraction based on geographic location and depth criteria.

The hydraulic connection categories proposed are outlined below.

Category A: Direct hydraulic connectivity

Category A includes areas of the hydrogeological system which exhibit direct connectivity with surface water. Stream depletion effects occur shortly following the commencement of groundwater abstraction, rapidly increase to a level close to the overall pumping rate and dissipate quickly once pumping stops. As a consequence, a high proportion of the overall volume of groundwater pumped effectively represents induced flow loss from local surface waterways. Due to the immediacy of impact, groundwater abstraction from Category A aquifers can be considered analogous to direct surface water abstraction and managed in terms of the environmental flow and water level regimes established for hydraulically connected surface waterbodies.

Category B: High hydraulic connectivity

Category B includes those areas of the hydrogeological system where groundwater abstraction may potentially result in significant impacts on surface water but where pumping regulation does not always provide an effective option for mitigating direct stream depletion effects. Category B represents the transition between indirect and direct stream depletion effects where it may be appropriate to manage groundwater takes in terms of either surface water or groundwater allocation depending on localised factors (e.g. local aquifer hydraulic parameters, abstraction rate and location of pumping with respect to surface waterbodies).

Category C: Moderate to low hydraulic connectivity

Category C covers those areas of the hydrogeological system where groundwater abstraction may contribute to an overall reduction in baseflow discharge at a catchment scale but where active regulation of pumping does not provide effective mitigation of potential effects on surface water. Cumulatively, these takes are more appropriately managed at a catchment or sub-catchment scale through the establishment of volumetric abstraction limits.

The following sections of the report outline the development and application of a proposed conjunctive water management framework for the Wairarapa Valley.

Appendix C provides an overview of the numerical and analytical model analysis undertaken to characterise the nature and extent of groundwater/surface water interaction across a range of hydrogeological settings in the Wairarapa Valley. Based on this analysis, Section 3 outlines the proposed approach for managing direct stream depletion effects in Category A and B aquifers including the spatial (and depth) distribution of the proposed hydraulic connection categories. Section 4 then describes the spatial units (*water management zones*) proposed for the management of cumulative effects of groundwater abstraction on surface water from Category B and C areas which are not subject to pumping controls (minimum flow restrictions). Details of the numerical model analysis undertaken to define the groundwater individual water management zones and determine the spatial (and depth) extent of the Category A, B and C areas are provided in Appendices D, E and F.

3. Managing direct stream depletion effects

In the past, surface and groundwater resources in the Wellington region have been managed separately due to their different modes of occurrence, assessment and development. Although there has been increasing recognition of the interconnection between these resources in recent years, there has been limited formalisation of approaches to more closely integrate management of surface water and groundwater.

As described in the preceding section, the proposed framework for conjunctive water management in the Wairarapa Valley establishes three categories of hydraulic connection. This section of the report addresses the management of *direct stream depletion* effects (as defined in Appendix A) for groundwater takes located in areas classified Category A (direct hydraulic connection) and Category B (high hydraulic connection).

The initial concept for the management of direct stream depletion effects was to establish a generic framework which would apply uniformly to the entire Wairarapa Valley. However, based on a review of available hydrogeological information and outputs from model scenarios, it became apparent that it was impractical to develop a generic approach which would fit the wide range of hydrogeological environments identified. As a result, this section of the report outlines the criteria utilised to define the spatial and depth extent of the proposed Category A and B hydraulic connectivity areas based on outputs from the numerical modelling analysis outlined in (Appendices D to F) and outlines a recommended approach for classification and management of direct stream depletion effects.

As described in greater detail in Appendix A, the magnitude and timing of stream depletion effects resulting from groundwater abstraction depends on a wide range of factors which include the hydraulic properties of the aquifer system as well as the location and rate of pumping. Due to the buffer provided by aquifer storage, stream depletion effects tend to be diffuse, lag changes in abstraction rate and occur at a rate lower than the overall rate of groundwater abstraction. As a consequence, there are no clear thresholds between insignificant and significant effects and it is necessary to define arbitrary criteria to determine those groundwater takes that may have a significant effect on hydraulically connected surface water and may be amenable to mitigation by application of pumping controls. It is noted that although the criteria proposed for managing direct stream effects in the following section are largely arbitrary, they are consistent with existing management approaches adopted by other regional councils outlined in Appendix A.3.

3.1 Category A – Direct connectivity

3.1.1 Definition

The shallow, highly permeable gravel aquifers – often called Q1 aquifers[2] in this report – which occur along the riparian margins of the main river systems

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[2] Q1 is a geological unit name that describes the youngest aquifer material deposits in the Wairarapa Valley. See Table B.1 in Appendix B for a full list of geological units and descriptions.

in the Wairarapa Valley are classified as Category A aquifer systems. In these areas, both physical monitoring data and modelled pumping scenarios indicate a high degree of connectivity between the groundwater system and adjacent surface water resources. The proposed Category A classification is also extended to include the groundwater catchments of the major spring-fed streams (e.g. the Greytown Springs, Stonestead and Poterau streams) to reflect the sensitivity of these environments to changes in flow induced by relatively small reductions in groundwater levels resulting from groundwater abstraction. The extent of the proposed Category A classification is shown in Figure 3.6; a detailed description of the rationale applied to define the spatial extent of Category A in individual water management zones is outlined in Appendices D to F.

Figure 3.1 shows a representative stream depletion curve resulting from groundwater abstraction from a Category A aquifer over a nominal pumping period of 100 days[3] calculated using an analytical stream depletion model (Hunt 1999). The figure reflects the high degree of connectivity between groundwater and surface water and shows stream depletion effects develop rapidly once abstraction commences and dissipate quickly when abstraction ceases[4].

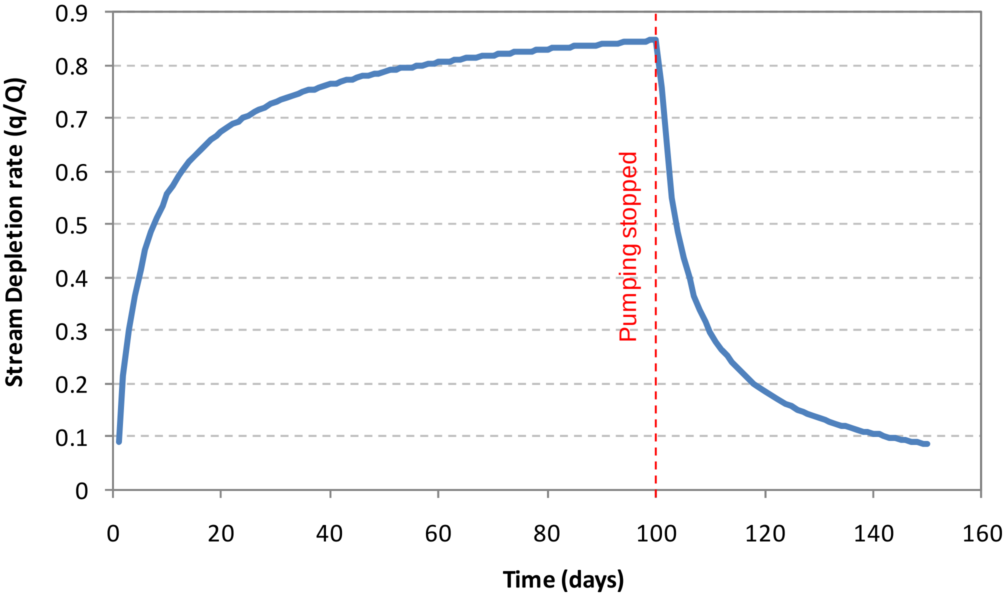

Figure 3.1: Representative modelled stream flow depletion curve resulting from groundwater abstraction in a Category A area

Figure 3.2 shows a corresponding plot of the relative contribution of groundwater storage and stream depletion to the overall volume of water abstracted[5]. In this case it is clearly evident that a bulk of groundwater pumped

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[3] The example shows illustrates a highly transmissive unconfined aquifer (T = 5,000 m^2/day, S = 0.1) where abstraction is located relatively close (500 metres) to a highly connected stream (streambed conductance = 100 m/day).

[4] The potential rate of stream depletion is commonly referred to in terms of q/Q which is the ratio of direct stream depletion (q) to the overall pumping rate (Q). In this report the q/Q term is also used to define the degree of hydraulic connection between an individual pumped bore and a hydraulically connected surface waterway and is used as part of the criteria to determine how potential stream depletion from an individual groundwater take will be managed.

[5] For the purposes of this illustration, assuming a nominal abstraction rate of 2,500 m^3/day for 100 days.

from the aquifer is derived from surface water with only a relatively minor contribution from groundwater storage.

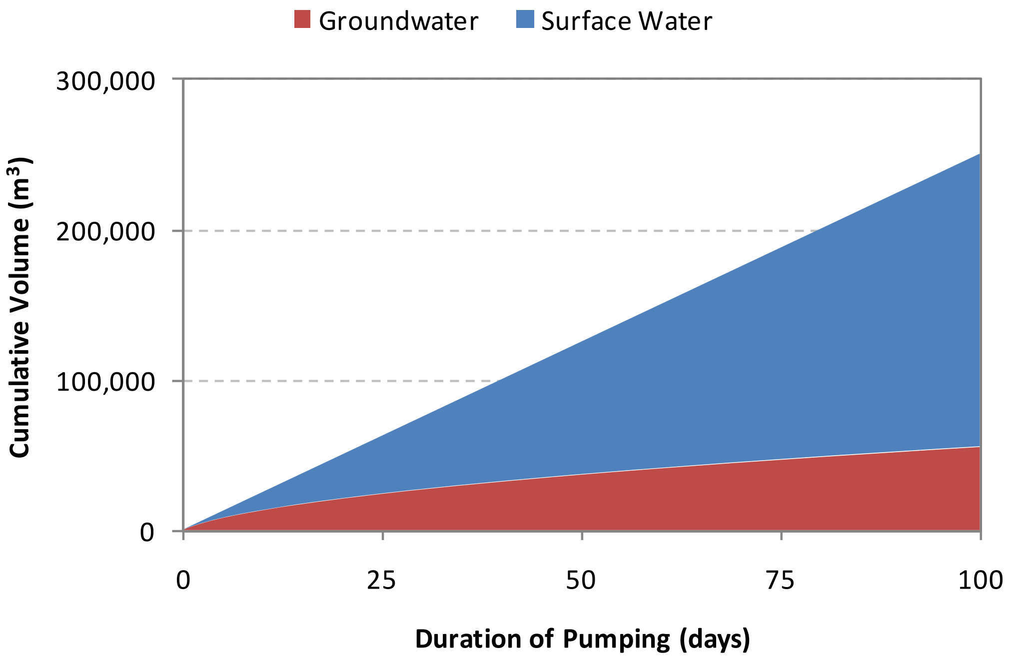

Figure 3.2: Relative contribution of groundwater storage and stream depletion for a representative groundwater take in a Category A area

Modelled pumping scenarios (summarised in Appendix C) demonstrate that, in proposed Category A hydrogeological settings in the Wairarapa Valley, stream depletion effects quickly develop to a level close to the maximum instantaneous pumping rate once abstraction commences and dissipate rapidly when abstraction is ceased. The overall proportion of the water abstracted derived from aquifer storage is low and groundwater abstraction can reasonably be managed as an equivalent surface water take.

3.1.2 Application of Category A classification

It is proposed that the relevant management controls apply to all groundwater takes which require resource consent within the nominated Category A areas. This would exclude permitted groundwater takes (e.g. stock and domestic uses under Section 14b of the Resource Management Act and takes below the permitted threshold, which is currently 20,000 L/day per property specified by Rule 7 of the Regional Freshwater Plan). However, Greater Wellington may also wish to consider exemptions or alternative pumping restrictions which may apply to nominated water uses such as public water supplies.

3.1.3 Pumping regulation

Given the immediacy of the stream depletion response to groundwater abstraction and the significant contribution of surface water to the overall volume of groundwater abstraction, it is considered that groundwater abstraction from Category A areas can be reasonably managed as equivalent takes from hydraulically connected surface waterbodies. The rapid decline in stream depletion effects following the cessation of pumping illustrates the effectiveness of pumping regulation based on surface water minimum flows as a means to mitigate effects on surface water during periods of low flow.

It is therefore proposed that environmental flows and water levels established for hydraulically connected surface water[6] be applied to groundwater takes from Category A aquifers.

3.1.4 Allocation

As illustrated in Figure 3.2, groundwater abstracted from Category A aquifers is predominantly derived from surface water, so it is reasonable to include this abstraction within the allocation calculated for relevant hydraulically connected surface water bodies.

However, as there is some lag between changes in pumping rate and corresponding changes in the rate of stream depletion, it is proposed that allocation from Category A aquifers is counted as primary allocation from the relevant hydraulically connected surface water bodies based on the average weekly consented abstraction rate. Using the short-term (weekly) average abstraction rate rather than the instantaneous rate of take is intended to avoid over-estimation of the likely effect on surface water where groundwater is abstracted at a high rate on an intermittent basis.

3.1.5 Resource consent assessment requirements for takes in Category A aquifers

Given the proposed inclusion of Category A groundwater takes within the primary allocation for hydraulically connected surface water, no specific assessment of potential stream depletion would be required to support resource consent applications for Category A groundwater takes. However, assessment to determine localised effects of groundwater abstraction (e.g. interference effects) or impacts on surface water environments (e.g. effects on aquatic ecosystems/ecology) could be required to support individual resource consent applications.

Any resource consent application for groundwater abstraction from Category A aquifers which seeks to avoid pumping restriction or inclusion within surface water allocation limits (e.g. small scale, short duration or intermittent takes) could be required to demonstrate through a combination of physical evidence and modelling of long term impacts, that the potential cumulative effect on surface water is *de minimus*.

3.2 Category B – High connectivity

3.2.1 Definition

The Category B classification includes those hydrogeological settings where groundwater abstraction may result in significant effects on surface water depending on factors such as local aquifer hydraulic properties, the location of abstraction relative to surface waterways (particularly spring-fed streams and

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[6] Including minimum flows and flow allocation in rivers and streams as well as minimum water levels in hydraulically connected wetlands or lakes.

wetlands) and the overall rate (instantaneous and/or seasonal) of groundwater abstraction. As a consequence, the extent of the proposed Category B classification varies both spatially and with depth reflecting the local hydrogeological characteristics of each water management zone.

In areas defined as Category B, the hydraulic connectivity with surface water is typically lower than that observed in Category A areas. Physical evidence to characterise the degree of interaction between groundwater and surface water in Category B areas may be limited, necessitating a greater reliance on modelling to determine the magnitude and nature of potential stream depletion effects. Modelled abstraction scenarios outlined in Appendices C to F show that the magnitude of direct stream depletion typically declines away from the outer margin of Category A aquifers (Q1 gravels) depending on the hydraulic characteristics of the surrounding alluvial fan materials. As a result, groundwater abstraction along the outer margin of Category A aquifers (i.e. recent Q1 floodplain gravels) may warrant pumping regulation if sufficient hydraulic connection exists with surface water.

Category B also includes those areas of the alluvial fan (Q2) systems where hydraulically connected surface water bodies (spring-fed streams, seeps and wetlands) are present. These features may be affected by groundwater abstraction depending on the relative proximity and rate of abstraction as well as local hydrogeological characteristics. Rather than defining an arbitrary buffer around individual surface water features, the Category B classification allows the potential for stream depletion effects to be assessed through the resource consent process according to localised factors particular to individual groundwater takes.

The extent of the proposed Category B classification is outlined in Section 3.3 with detailed description of the rationale applied to define the spatial extent of Category B in individual water management zones outlined in Appendices D to F.

Figure 3.3 shows a representative range of stream depletion curves expected in Category B aquifers over a nominal pumping period of 100 days calculated using the Hunt (1999) analytical method[7]. The curves demonstrate that as the degree of hydraulic connectivity (expressed in terms of q/Q, see footnote 3) decreases, the overall magnitude of stream depletion decreases and there is increased lag in response to variations in pumping rate (or cessation of pumping).

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[7] Calculated for a range of aquifer hydraulic properties to derive the nominated q/Q values of 0.7, 0.55 and 0.4.

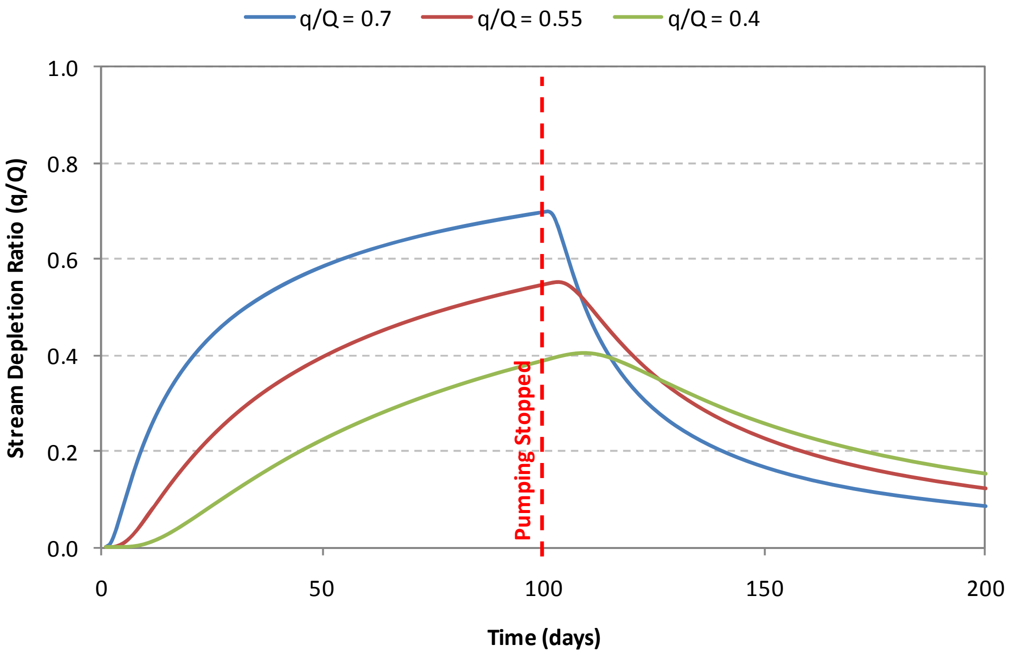

Figure 3.3: Stream depletion curves resulting from groundwater abstraction from a representative range of groundwater takes in a Category B area

Figure 3.4 shows a plot of the relative contribution of groundwater storage and stream depletion to the overall volume of groundwater pumped from a Category B aquifer (assuming q/Q=0.63 – see footnote 3 – and a nominal abstraction rate of 2,500 m^3/day). The graph illustrates that, while a majority of water pumped is derived from aquifer storage during the initial pumping period, stream depletion makes an increasing contribution to the total volume of abstraction over time, representing almost half of the total volume pumped after a period of 100 days in the example shown.

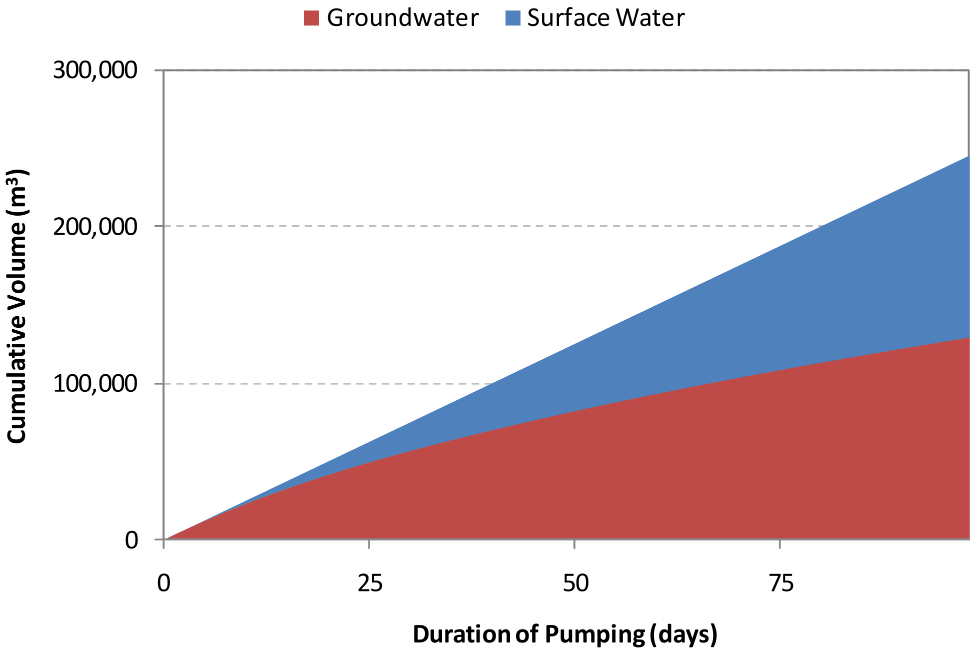

Figure 3.4: Relative contribution of groundwater storage and stream depletion for a representative groundwater take from a Category B groundwater area

3.2.2 Application of Category B classification

Due to the potential for takes from Category B aquifers to have a less direct effect on surface water than equivalent takes from Category A areas, it is proposed that groundwater takes with a weekly average abstraction rate less than an arbitrary minimum rate (proposed as 5 L/s) within areas designated as Category B be managed as solely as groundwater takes (i.e. included within the groundwater allocation limits outlined in Section 4). Takes above this threshold will be assessed in terms of the Category B hydraulic connection and volumetric assessment criteria.

The exemption for takes less than 5 L/s is proposed as a pragmatic means to ensure management of groundwater takes within Category B is focussed on those takes most likely to result in significant effects on surface water and avoid the requirement for stream depletion assessment to be undertaken where the rate of abstraction is relatively low. The potential cumulative effect of small takes will be managed in terms of the groundwater allocation for the relevant water management zone rather than in terms of local effects on surface water. It is also suggested that the arbitrary 5 L/s threshold should be determined as the total rate of groundwater abstraction per land parcel (consistent with existing Regional Freshwater Plan Rule 7) to avoid a situation where Category B controls could be circumvented by utilising multiple bores pumping at a low rate.

3.2.3 Pumping regulation

As illustrated in Figure 3.3 the rate at which stream depletion effects dissipate after pumping ceases declines for groundwater takes with lower hydraulic connectivity. As a consequence, while pumping regulation offers an effective means to mitigate potential effects on surface water where there is a high degree of hydraulic connection, stream depletion effects tend to persist for a longer time after pumping ceases where there is lower connectivity. This situation creates a trade-off between the overall magnitude of stream depletion (as a percentage of the pumping rate) and the ability to control resulting effects in a temporal sense.

Table 3.1 shows the effect of varying hydraulic connectivity on the calculated reduction in stream depletion effect following the cessation of pumping[8]. These data show that for aquifers with a relatively high degree of hydraulic connection to surface water (e.g. q/Q = 0.8) the calculated direct stream depletion effect from groundwater abstraction reduces by over 50% 10 days after pumping stops. However, where there is a lower degree of hydraulic connection (e.g. q/Q = 0.4), stream depletion effects may continue to increase for a period after pumping stops[9] then decline slowly over time.

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[8] Calculated for a range of aquifer hydraulic properties using the Hunt (1999) methodology.

[9] The continued increase in stream depletion once pumping stops illustrates the increasing lag which occurs where there is a low hydraulic connection between an individual bore and hydraulically connected surface water.

Table 3.1: Percentage reduction in stream depletion following cessation of pumping for a range of hydraulic connectivity (q/Q) values (assuming 100 days continuous abstraction prior)*

	Time since pumping stopped			
q/Q	10 Days	20 days	30 days	40 days
0.8	54%	71%	79%	83%
0.7	31%	53%	64%	71%
0.6	13%	34%	48%	57%
0.5	2%	18%	32%	43%
0.4	-4%	2%	13%	24%

* Calculated using the Hunt (1999) methodology.

From the range of values presented in Table 3.1 it is clear that there is no clearly identifiable point at which pumping regulation can be judged to be an effective option for mitigating stream depletion effects. However, when viewed in the context of typical low flow periods in the Wairarapa Valley (~4 to 6 weeks), it is clear that pumping regulation on groundwater takes where q/Q is less than 0.6 is likely to provide limited mitigation of the effects of groundwater abstraction on stream flow during critical periods. For example, the calculations shown indicate the stream depletion effect resulting from a groundwater take with a q/Q of 0.6 will reduce by approximately 50% within 30 days after pumping stops, while a take with a q/Q of 0.4 will show a reduction of only 13% over the same period. It is therefore proposed that a nominal q/Q of 0.6 be utilised as the threshold above which groundwater takes are subject to pumping regulation.

However, along with the degree of hydraulic connection, the overall rate of groundwater abstraction also influences the potential magnitude of streamflow depletion. For example, as shown in Figure 3.5, a groundwater take with a relatively high degree of hydraulic connection (e.g. q/Q of 0.7) may have a significantly lower overall effect on surface water than a take with a lower degree of hydraulic connectivity but a higher abstraction rate. Accordingly, it is proposed that groundwater takes from Category B are also subject to pumping regulation if they exceed a nominal rate of stream depletion of 10 L/s calculated on the basis of the average seasonal abstraction rate. Although pumping regulation may not necessarily provide a significant reduction in overall stream depletion effect from such takes in percentage terms, the actual volumetric reduction in effect for larger takes is likely to be sufficient to at least partially mitigate effects on surface water[10].

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[10] Overseas experience suggests that hydraulic connection (or distance) criteria on their own may not be entirely effective in all situations for managing the overall magnitude of stream depletion effects where large takes can be located to avoid requirements for minimum flow controls (e.g. in the case of the proposed management options, a large take could be located so as to justify a q/Q <0.6 but still result in a significant effect on surface water). A stream depletion rate threshold is proposed to ensure such takes can effectively be managed.

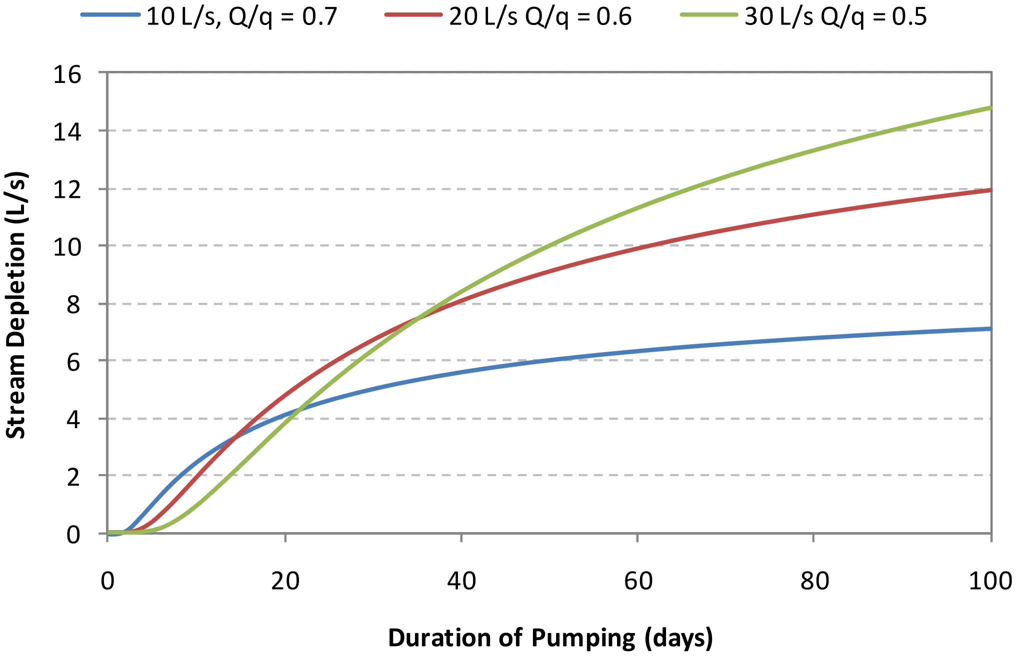

Figure 3.5: Calculated stream depletion resulting from groundwater takes with varying degrees of hydraulic connection (q/Q = 0.5–0.7) and pumping rates (Q = 10–30 L/s)

It is proposed that groundwater takes from Category B areas are subject to pumping regulation based on minimum flows and water levels in relevant hydraulically connected surface water bodies where either q/Q >0.6 <u>or</u> the calculated stream depletion effect exceeds 10 L/s.

3.2.4 Allocation

In order to account for the potential effects of groundwater abstraction from Category B takes the following is proposed:

- Where the potential effect of groundwater abstraction meets the criteria for application of pumping regulation (i.e. q/Q >0.6 or calculated stream depletion effect >10 L/s) the calculated stream depletion effect is included in the primary allocation for relevant hydraulically connected surface waterbodies with the balance of the seasonal allocation included in the groundwater allocation for the relevant water management zone;

- Where the potential stream depletion effect does not meet the criteria for application of pumping regulation (i.e. q/Q <0.6 and calculated stream depletion effect <10 L/s) the take is counted as part of the total groundwater allocation for the relevant water management zone.

3.2.5 Assessment requirements for takes in Category B areas

Assessment of the nature and magnitude of potential stream depletion effects resulting from groundwater abstraction in Category B areas requires a hydrogeological assessment utilising relevant analytical or numerical modelling techniques. Such assessment will require development of a conceptual model of the hydrogeological setting of the proposed take informed by results of aquifer testing at the proposed abstraction point, and supplemented by geological and hydrogeological data (including water quality) from the surrounding area.

Basic calculation of the potential magnitude of stream depletion effects can be undertaken utilising analytical modelling techniques such as Jenkins (1977), Hunt (1999) and Hunt (2003). It is anticipated such techniques will be the most commonly utilised methods for estimating direct stream depletion effects for individual resource consent applications[11]. However, in some situations, such as very large takes, or where abstraction is particularly contentious, it may also be appropriate to utilise a numerical groundwater model (either the Greater Wellington groundwater model or a suitable alternative).

One limitation of current analytical techniques is they are typically based on an assumption of aquifer heterogeneity (i.e. aquifer hydraulic properties do not vary spatially). In some areas of the Wairarapa Valley, there is a large contrast in aquifer permeability between the alluvial fan gravels and the reworked Q1 gravel aquifers (commonly up to one order of magnitude). While this non-uniform geological setting can be accounted for in numerical model simulations, it is more difficult to account for using analytical methods. In this situation one simple approach to address this issue (and provide a conservative estimate of potential stream depletion) may be to calculate the potential magnitude assuming the stream is located at the outer boundary of the adjacent Category A areas (since it is proposed to effectively manage these aquifers as part of the surface water system). Alternatively, it may be possible to develop a simple arithmetic relationship for applying analytical models in such situations using the results of numerical modelling (e.g. utilising a composite aquifer transmissivity or separation distance).

It is proposed that calculation of potential stream depletion effects be based on seasonal pumping at the maximum rate sought by a consent applicant (i.e. pumping at the maximum daily rate for the maximum continuous period provided for by the seasonal allocation). Alternatively, where intermittent abstraction is proposed, effects should be calculated based on pumping at the average weekly pumping rate over the seasonal duration of the proposed abstraction.

Where a proposed groundwater take may affect more than one surface water body, assessment of the potential relative effect on each should be calculated either by application of relevant guidance for the application of analytical assessment techniques (e.g. Environment Canterbury 2000) or by use of a numerical model.

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[11] Physical measurement (e.g. flow gauging) to determine the potential magnitude of stream depletion is typically problematic as a means to quantify potential stream depletion effects due to a combination of factors including errors inherent in streamflow measurements, natural variability in catchment discharge, the location of suitable measurement points and the time lag between pumping and effects and the overall duration of measurement. As a consequence, direct measurement of effects on surface water is typically only suitable for large-scale takes situated immediately adjacent to hydraulically connected surface water bodies.

3.3 Spatial and depth distribution of hydraulic connectivity categories

The proposed geographical distribution of Category A and Category B classifications is illustrated on Figure 3.6 (further versions of Figure 3.6 that focus on the Upper, Middle and Lower valleys are provided in Appendix G). This map is coloured to illustrate the spatial distribution of the hydraulic connectivity zones at the land surface with the depth distribution of the various hydraulic connection categories identified for each water management zone.

For example, the riparian margin of Mangatarere Stream is designated Category A to 20 metres (depth), Category B between 20 and 30 metres and Category C at depths greater than 30 metres. The width of each of the hydraulic conductivity categories in this area is determined on the basis of geology and results of numerical model simulations (further described in Appendix E). To illustrate the three-dimensional nature of the hydraulic connectivity zonation, Figure 3.7 and Figure 3.8 show the depth distribution of the various hydraulic connection categories along the two section lines marked on Figure 3.6.

Numerical model analysis undertaken to determine the spatial and depth distribution of the hydraulic connectivity zonation is described in detail in Appendices D to F for each individual water management zone.

Interpreting the map

Management zones

Upper Ruamahanga Zone name and boundary

Abstraction categories – spatial extent

🟦 Category A

🟩 Category B

🟨 Category C

Abstraction categories – depth extent

A
—20
B
—30
C

This example is for a bore located within a Category A spatial zone (e.g. like that in the Mangatarere management zone in the map).

Bores drawing water from a depth of less than 20 m remain Category A, but if they are between 20 and 30 m they become Category B and Category C if they are deeper than 30 m

See Figures 3.7 and 3.8 for further illustration of depth categories

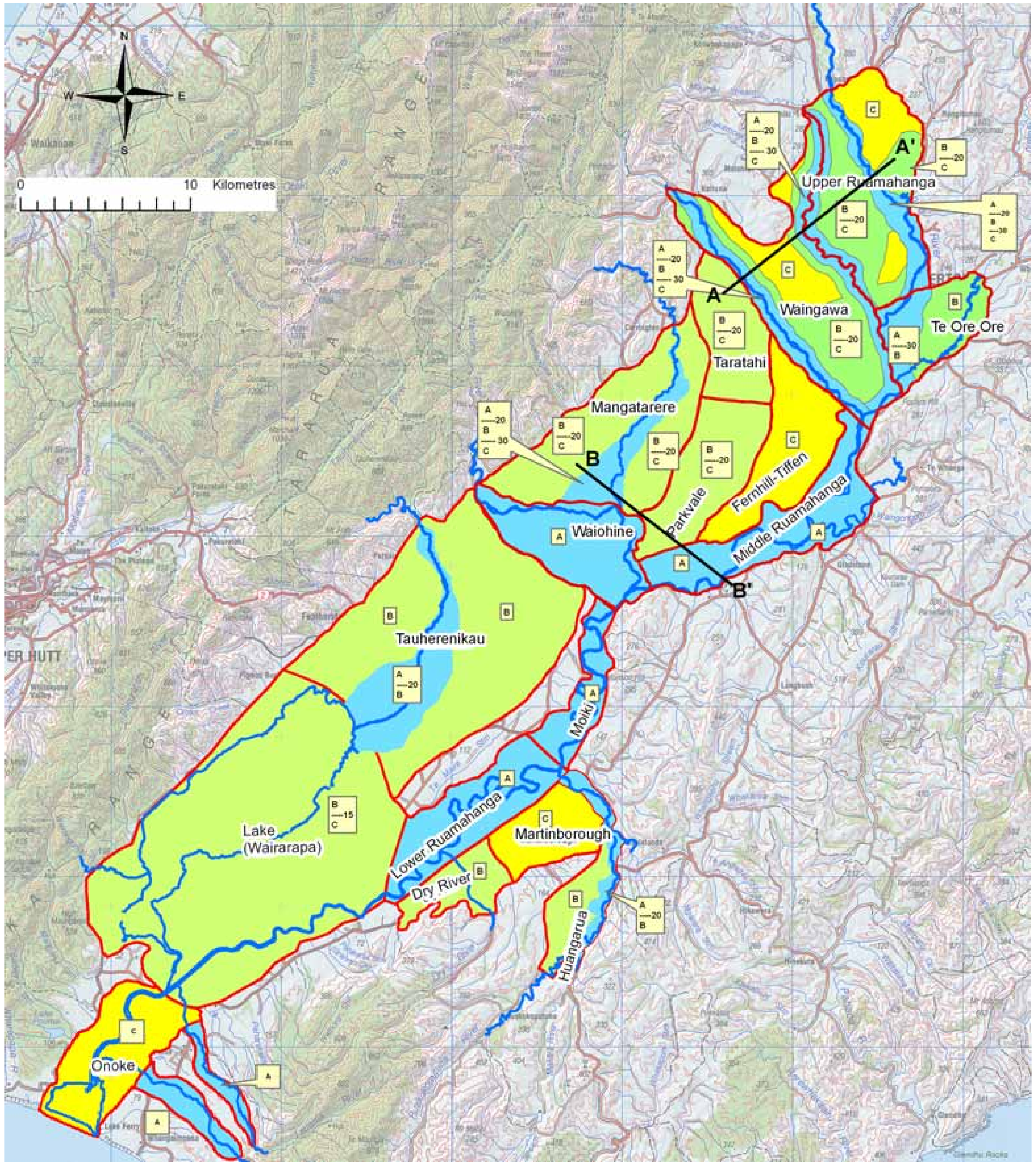

Figure 3.6: Geographical (spatial) and depth distribution of proposed hydraulic connectivity categories across the Wairarapa Valley. Cross sections A–A` and B–B` are illustrated in Figures 3.7 and 3.8.

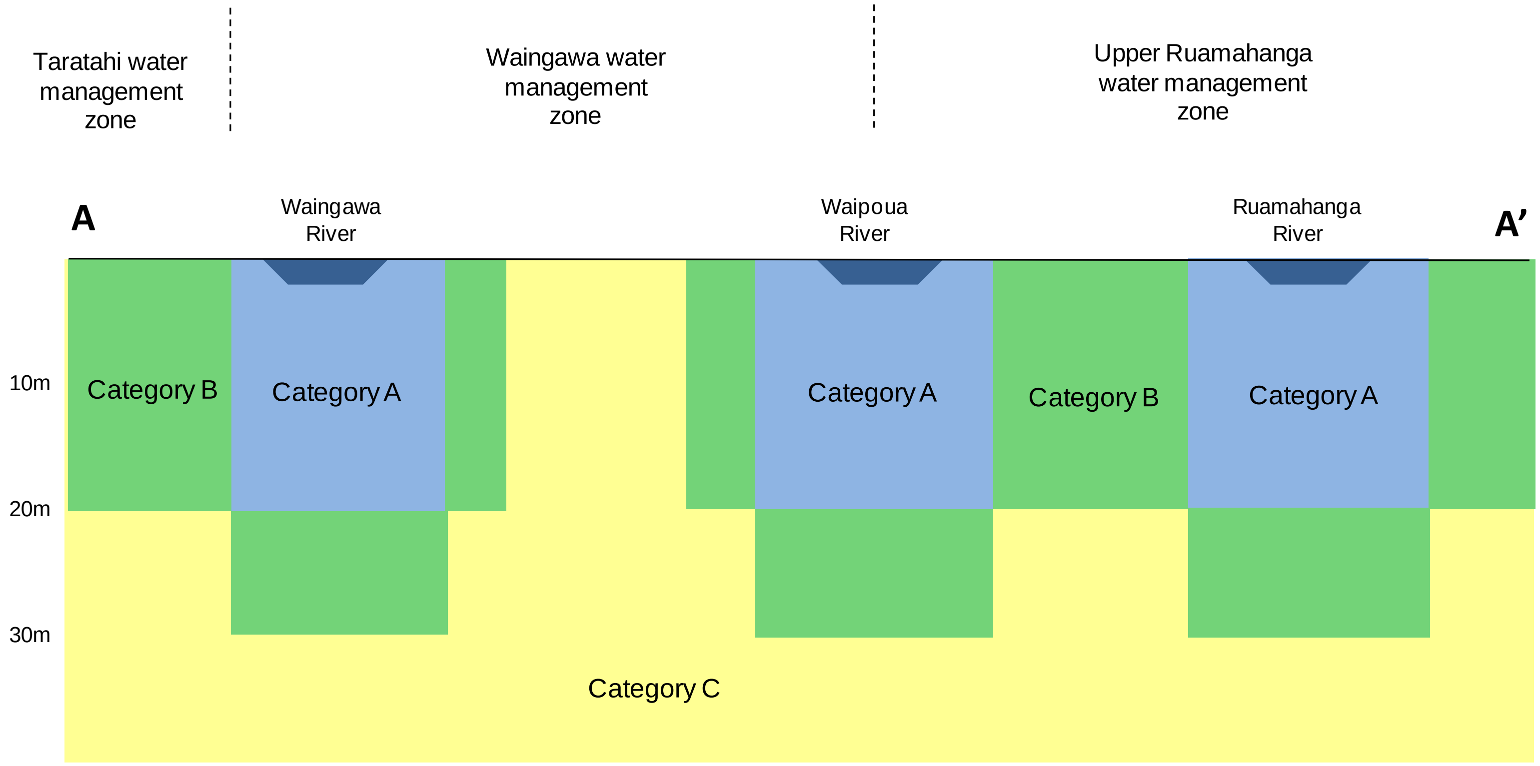

Figure 3.7: Schematic cross section illustrating depth distribution of hydraulic connectivity categories along section A-A' in Figure 3.6 (not to scale)

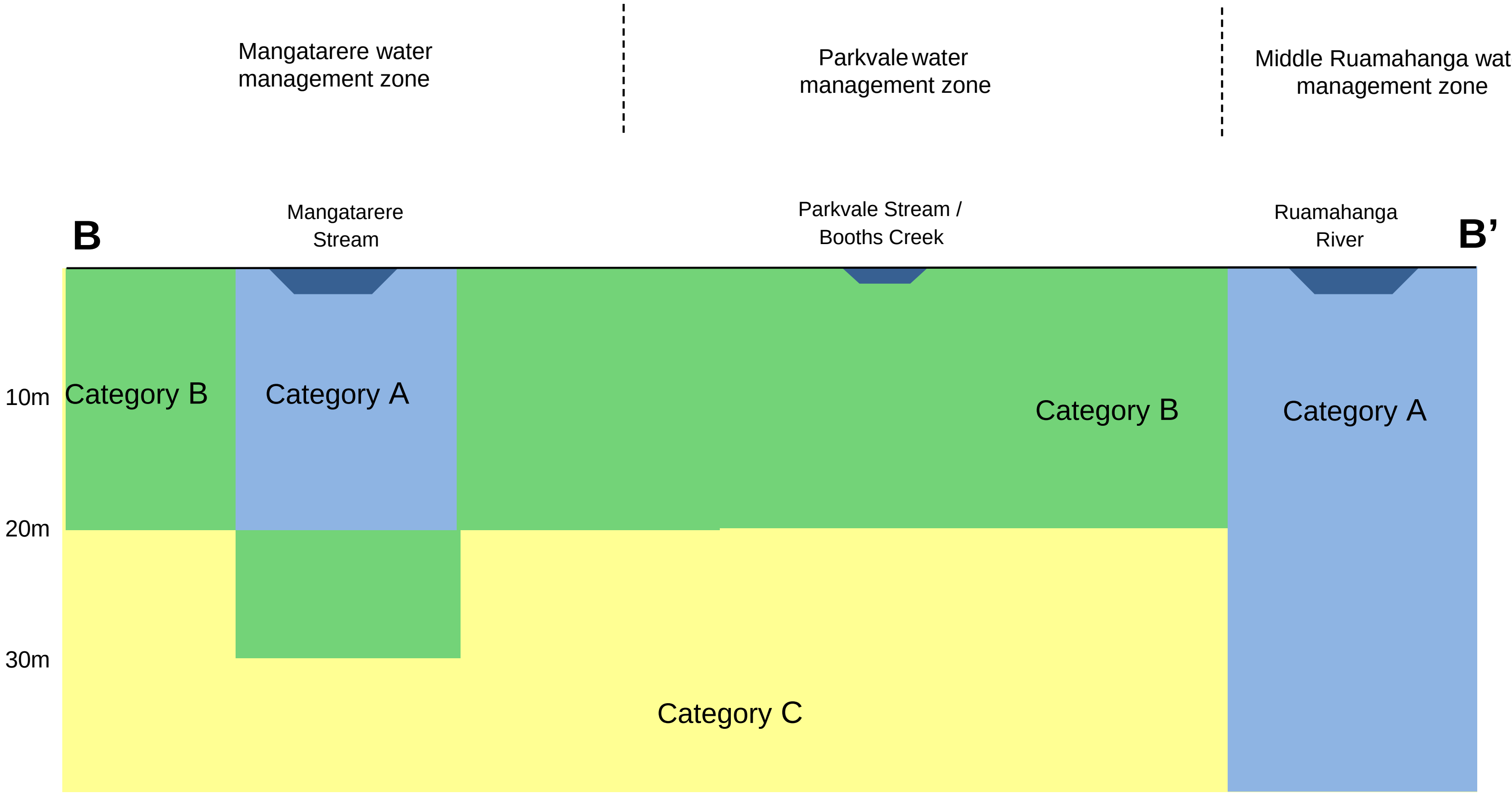

Figure 3.8: Schematic cross section illustrating depth distribution of hydraulic connectivity categories along section B-B' in Figure 3.6 (not to scale)

3.4 Summary of management recommendations

3.4.1 Category A

In order to manage direct stream depletion it is proposed to establish a hydraulic connectivity classification (Category A) within which groundwater abstraction is effectively managed as part of the environmental flow and water level regime established for relevant hydraulically connected surface water bodies. Category A effectively encompasses the portion of the hydrogeological system which exhibits a direct and immediate hydraulic connection with surface water.

Spatial Definition	Generally limited to the Q1 gravel aquifers along the riparian margins of the major rivers (the Ruamahanga, Waipoua, Waingawa, Waiohine, Tauherenikau and Huangarua rivers and Mangatarere Stream). The extent of proposed Category A is shown in Figure 3.6 and described in detail in Appendices C to F.
Application	All groundwater takes which require resource consent (i.e. excludes permitted uses under Section 14(b) of the Resource Management Act and takes permitted under the existing Regional Freshwater Plan (WRC 1999).
Pumping Regulation	Groundwater takes requiring resource consent will be subject to minimum flow or water level controls set for hydraulically connected surface water bodies.
Allocation	Groundwater abstraction from Category A aquifers will be included in the primary allocation for hydraulically connected surface water based on the average weekly rate of groundwater abstraction
Assessment Requirements	No specific assessment of stream depletion required. However, assessment to determine localised effects of groundwater abstraction (e.g. interference drawdown) or impacts on the surface water environment (e.g. effects on aquatic ecology) may still be required to support individual resource consent applications.

3.4.2 Category B

Category B includes those components of the hydrogeological system which exhibit a moderate to high degree of connectivity with surface water but where application of pumping regulation may or may not provide effective mitigation of stream depletion effects depending on local hydrogeological conditions and the rate of groundwater abstraction. The proposed management regime for Category B can be summarised as:

Spatial Definition	The spatial extent of Category B has been determined for each water management zone based on observed hydrogeological characteristics and modelling of potential stream depletion effects resulting from groundwater abstraction. Category B forms a buffer zone along the outer margin of the Q1 aquifers and also includes areas of the Q2 alluvial fans aquifers which exhibit potential hydraulic connection to local surface water (either Category A aquifers or local spring-fed streams and wetlands). The extent of the proposed Category B areas in each individual water management zone is shown in Figure 3.6 and described in Appendices D to F.
Application	All takes with a weekly average abstraction rate >5 L/s require assessment of potential stream depletion effects.
Pumping Regulation	Groundwater takes from Category B areas will be subject to minimum flow or water level controls (based on those established for hydraulically connected surface water bodies) when the calculated stream depletion effect exceeds 60% (i.e. q/Q>0.6) of the seasonal average pumping rate or is greater than 10 L/s calculated using the average seasonal abstraction rate.
Allocation	Calculated stream depletion effect from those takes subject to minimum flow control will be included in primary allocation for relevant hydraulically connected surface waterbodies with the balance of seasonal allocation counted as part of the total groundwater allocation for the relevant water management zone. Remaining takes (including those with a weekly average rate of take <5 L/s) will be counted as part of the total groundwater allocation for the relevant water management zone.
Assessment Requirements	Hydrogeological assessment of potential stream depletion utilising relevant numerical or analytical modelling techniques based on the cumulative (direct) stream depletion effect on hydraulically connected surface water. Assessment of stream depletion effects should be based on continuous abstraction at the long-term average abstraction rate being sought.

3.4.3 Category C

The final component of the proposed conjunctive water management framework for the Wairarapa Valley is designated as Category C. This classification includes those components of the hydrogeological system which exhibit a moderate to low degree of connectivity with surface water where application of pumping regulation is unlikely to provide mitigation of stream depletion effects during low flow periods. In these areas spatially defined management units (water management zones) are assigned volumetric allocation limits that take account of the potential effects of groundwater abstraction on river or stream baseflow at a catchment scale. The proposed water management framework, including options for volumetric allocation limits, are outlined in Section 4 and described in detail in Appendices D to F.

4. Management of the cumulative effects of groundwater abstraction on river baseflow

As outlined in Section 2, there are two main components of the proposed framework for conjunctive management of groundwater and surface water resources in the Wairarapa Valley:

1. Active management of direct stream depletion effects resulting from groundwater abstraction in aquifers (Category A and part Category B) that exhibit a direct or immediate hydraulic connection with surface water where such effects can be mitigated by application of temporal pumping restrictions. For such groundwater takes, temporal pumping restrictions will be established according to environmental flows and water level policies for hydraulically connected surface waterbodies to mitigate effects during low flow periods (refer to Section 3 for details).

2. Development of sustainable groundwater allocation limits at a catchment or sub-catchment scale to manage the cumulative effects of groundwater abstraction (Category C and part Category B), on river and stream baseflow[12].

This section provides an overview of the methodology developed to manage the cumulative effects of groundwater abstractions on sub-catchment baseflow through the definition of water management zones and associated allocation options. Details of the extensive analysis undertaken to delineate proposed groundwater allocation limits for individual water management zones are provided in Appendices D to F.

4.1 Water management zones

The management of the cumulative effects of groundwater abstractions with a moderate to low connection to surface water has been approached by delineating '*water management zones*' within each of the three Wairarapa Valley catchments (Upper, Middle and Lower). These zones are essentially discrete management units based on groundwater and surface water sub-catchment mapping. Zone delineation criteria include surface water catchment boundaries, hydraulic or physical groundwater flow system boundaries, the conceptual hydrogeological functioning of the zone and its context within the larger groundwater catchment.

The zones are designed so that the management of surface water resources can be easily integrated with groundwater allocation, thereby allowing the cumulative effects of groundwater abstraction on sub-catchment baseflow to be accounted for at a catchment or sub-catchment scale (i.e. enabling conjunctive management of groundwater and surface water resources).

It is important to recognise the water management zones are not, in most instances, isolated management units. Most zones have 'soft' boundaries based on hydraulic divides or represent transitional areas within a continuous groundwater flow system. Where significant interactions between zones are

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[12] In this context baseflow refers to groundwater discharge to surface water bodies including spring-fed streams.

recognised, the sensitivity of cross-zone groundwater fluxes to the cumulative effects of abstraction has been evaluated and provision is made in the proposed allocation options.

4.2 Groundwater allocation options

Sustainable groundwater allocation options are presented for each zone based on the outputs of abstraction scenarios run on the numerical groundwater flow models developed for each catchment (Gyopari and McAlister 2010a, b and c). These models simulate the cumulative effects of groundwater abstraction in terms of surface water depletion, aquifer drawdown, and changes in cross-zone throughflow dynamics. This information provides the basis for developing sustainable groundwater allocation options for each water management zone. Where appropriate, the proposed options for groundwater allocation limits (presented later in Section 4.6**)** are referenced to a potential cumulative effect on baseflow in relevant hydraulically connected surface water bodies**.**

For most water management zones it is proposed that the cumulative effect of groundwater abstractions is managed in relation to the long-term effect on river baseflow within the zone (or sub-catchment). In the context of this report, a manageable (or a perceived acceptable) effect on baseflow is considered in terms of a 'baseflow allocation' which represents the rate at which natural catchment discharge (occurring during stable, low flow conditions) is likely to be depleted by the effects of groundwater abstraction which cannot be mitigated by temporal controls on groundwater abstraction (i.e. pumping regulation). Cumulative depletion effects can be expressed as a proportion of baseflow in the principal surface water systems within a particular sub-catchment. In this report, the naturalised 7-day Mean Annual Low Flow (MALF) has been used as the river and stream baseflow index against which depletion effects are assessed.

Baseflow allocation may be taken into consideration in the formulation of future surface water allocation policy, or may simply be an acknowledged, but separately managed, quantity. Different approaches to establishing baseflow allocation may also be adopted in different water management zones reflecting the hydraulic characteristics and values associated with different surface water environments. As a result, the initial step in determining appropriate groundwater allocation thresholds for the various water management zones is determination of an acceptable level of effect at a sub-catchment scale. Once an acceptable level of effect has been determined, a corresponding groundwater allocation volume can be back-calculated using the relevant baseflow allocation for each individual water management zone (as determined by numerical modelling). In this regard, a range of potential groundwater allocation options have been presented for each water management zone to enable an acceptable level of effect to be selected. While the options presented are typically centred on current levels of allocation, data are also presented to allow for alternative allocation options to be easily calculated.

The proposed methodology is therefore 'effects-based' and produces an outcome focussed on environmental sustainability. This approach is very different from the traditional groundwater allocation methodology of assigning a proportion of the system input, typically specified in terms of land surface recharge (LSR).

It is noted that development of the conjunctive water management framework for the Wairarapa Valley described in this report relies heavily on the application of numerical groundwater modelling. As described in Gyopari and McAlister (2010a, b and c), the transient flow models utilised for the assessment were developed from the verified conceptual hydrogeological models and qualitatively and quantitatively calibrated to field measurements of groundwater level and fluxes to and from surface water environments following procedures that minimise non-uniqueness and predictive uncertainty. Therefore, while the current model set up and calibration represent the current 'state of knowledge', it is acknowledged there are inherent limitations in the accuracy and resolution of these tools for evaluation of abstraction scenarios, particularly at the localised scale.

Appendix D provides a detailed description of the water management zones defined for the Upper Valley catchment and outlines the analysis undertaken to develop the groundwater allocation options for each zone. Appendix E and Appendix F outline similar analyses for the Middle and Lower Valley catchments respectively.

4.3 Proposed water management zones in the Upper Valley catchment

Figure 4.1 shows the spatial extent of the three proposed water management zones in the Upper Valley catchment. The management objectives and allocation criteria for each zone are summarised in Table 4.1. The zones are based primarily on surface water and groundwater catchments, but are also locally constrained by geological boundaries. The delineation of water management zones is therefore based on the conceptual hydrogeological model and the recognition of distinct hydrogeological domains. The rationale behind each zone boundary and analysis undertaken to derive the proposed groundwater allocation options for each are provided in Appendix D.

Figure 3.6 shows the existing Regional Freshwater Plan (WRC 1999) groundwater management zones and outlines the proposed new water management zones to enable cross-referencing.

Table 4.1: Proposed water management zones, management objectives and allocation criteria for the Upper Valley catchment

Zone name	Area (km^2)	Management objectives	Allocation criteria
Te Ore Ore	27.1	• Managing baseflow depletion in the Ruamahanga River and Poterau Stream	• Ruamahanga River (MALF) • Poterau Stream (MALF) • Rainfall recharge
Waingawa	77.7	• Managing baseflow depletion in the Waingawa and Waipoua Rivers and Masterton Springs	• Combined discharge (MALF) for: – Waingawa River – Waipoua River – Masterton Springs • Recharge
Upper Ruamahanga	72.0	• Managing baseflow depletion in the Ruamahanga and Waipoua Rivers	• Recharge • Ruamahanga and Waipoua rivers (MALF)

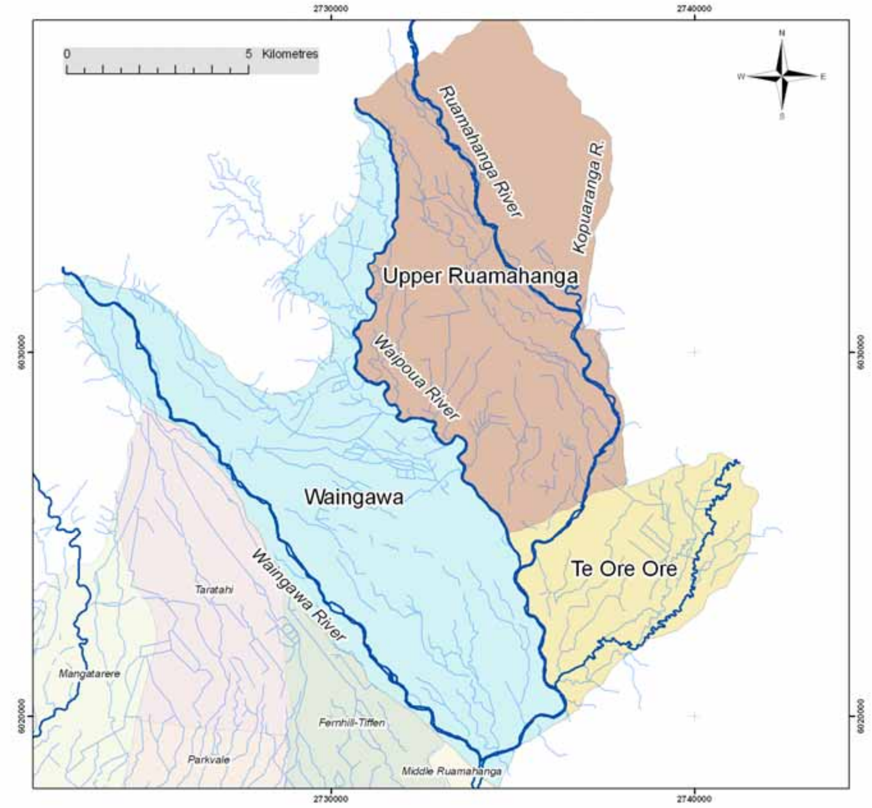

Figure 4.1: Proposed water management zones in the Upper Valley catchment

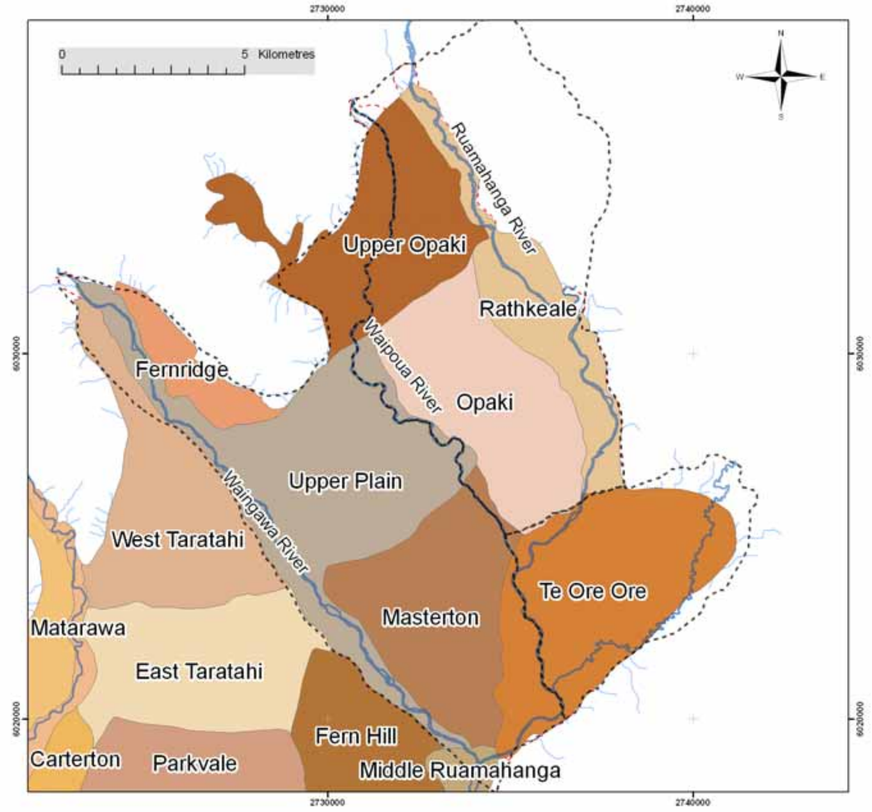

Figure 4.2: Map showing the extent of existing RFP (WRC 1999) groundwater zones in the Upper Valley catchment (spatial extent of proposed water management zones indicated by black dashed lines)

4.4 Proposed water management zones in the Middle Valley catchment

Figure 4.3 shows the spatial extent of the six water management zones proposed for the Middle Valley catchment. The management objectives and allocation criteria for each zone are summarised in 4.2. The zones are based primarily on surface water and groundwater catchments but are also locally constrained by geological boundaries. The delineation of water management zones is therefore based on the conceptual hydrogeological model and the recognition of distinct hydrogeological domains. The rationale behind each zone boundary as well as analysis undertaken to derive the proposed groundwater allocation options for each are provided in Appendix E.

Figure 4.4 shows the existing RFP (WRC 1999) groundwater management zones and outlines the proposed new water management zones to enable cross-referencing.

Table 4.2: Proposed water management zones, management objectives and allocation criteria for the Middle Valley catchment

Zone name	Area (km^2)	Management objectives	Allocation criteria
Waiohine	39.2	• Managing baseflow depletion in the Waiohine River, Papawai-Tilsons-Muhunoa springs	• Waiohine River (MALF) • Greytown springs (MALF)
Mangatarere	78.3	• Managing baseflow depletion in the Mangatarere Stream including spring-fed tributaries	• Mangatarere Stream MALF at Waiohine confluence
Parkvale	37.4	• Managing baseflow depletion in the Parkvale Stream, Booths Creek • Confined aquifer drawdown	• Parkvale springs mean flow • Drawdown threshold
Taratahi	29.3	• Managing baseflow depletion in the springs and wetlands associated with major faults	• Masterton and Carterton faultline springs (MALF)
Fernhill-Tiffen	38.1	• Drawdown	• Rainfall recharge
Middle Ruamahanga	43.8	• Managing baseflow depletion in the Ruamahanga River	• Ruamahanga River (MALF)

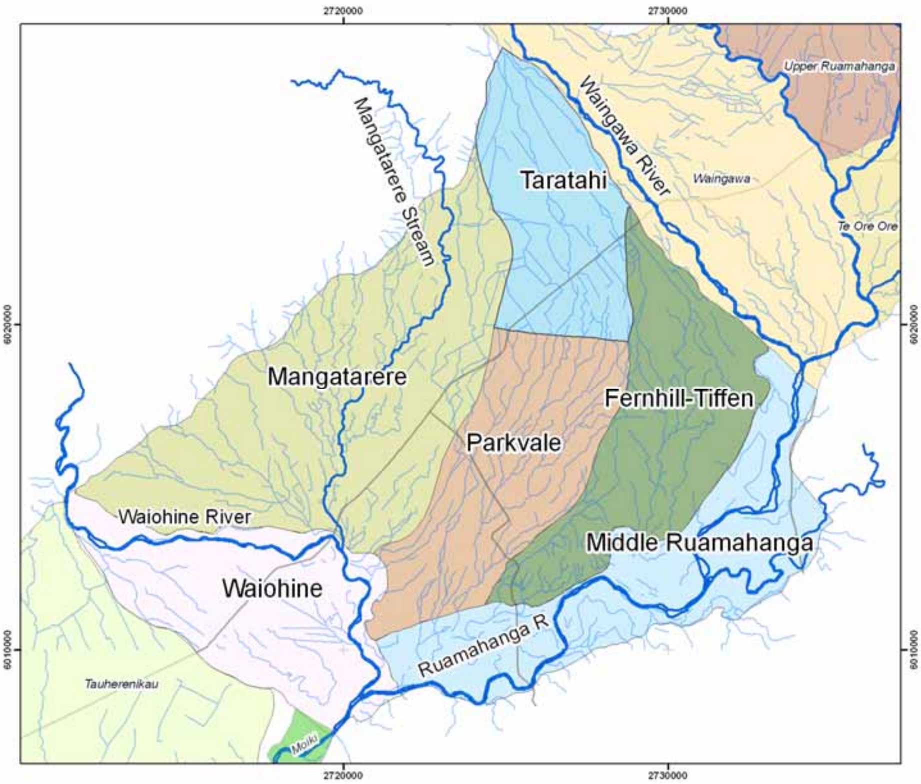

Figure 4.3: Proposed water management zones in the Middle Valley catchment

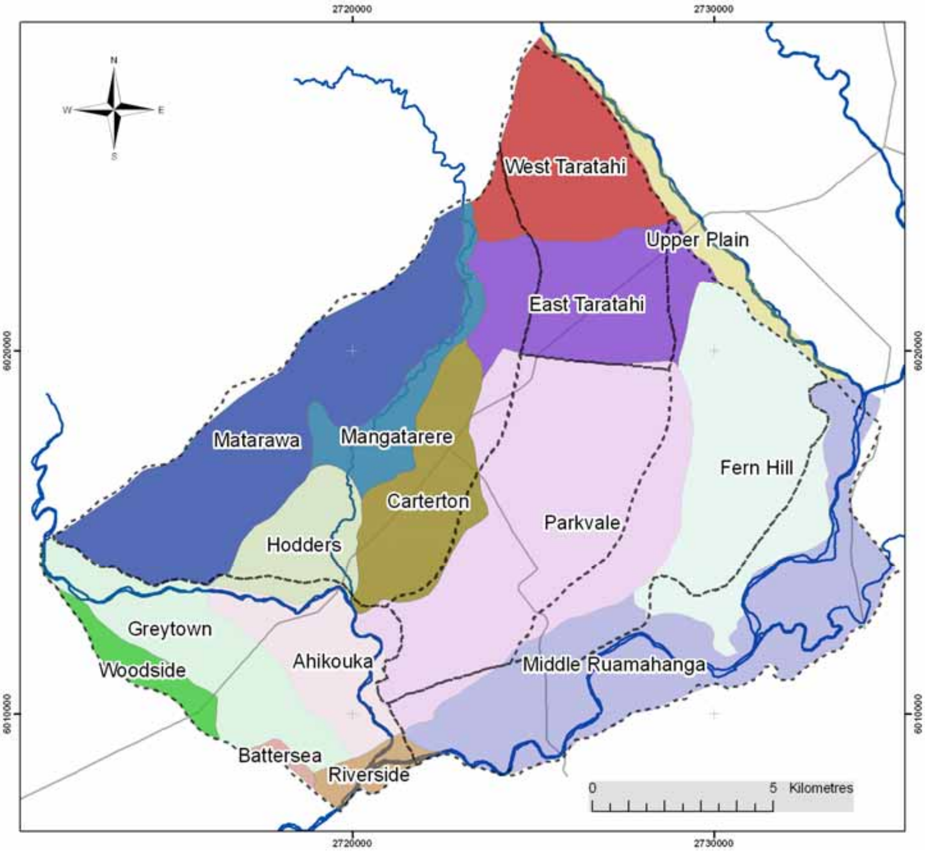

Figure 4.4: Map showing the spatial extent of existing RFP (WRC 1999) groundwater management zones in the Middle Valley (spatial extent of proposed water management zones indicated by black dashed lines)

4.5 Proposed water management zones in the Lower Valley catchment

Figure 4.5 shows the spatial extent of the eight proposed water management zones in the Lower Valley catchment. The management objectives and allocation criteria for each zone are summarised in Table 4.3. Unlike the Upper and Middle Valley catchments, the hydrogeological setting in the Lower Valley catchment is considerably more complex and ranges from shallow, unconfined areas in close contact with the surface water environment to deep confined aquifers (such as the Lake basin) which are remotely recharged from unconfined aquifers.

The delineation of water management zones in the Lower Valley catchment is therefore based on the conceptual hydrogeological model and the recognition of distinct hydrogeological environments. The zone design takes into consideration surface water catchments in combination with groundwater recharge and discharge areas. The rationale behind the identification of each zone is provided in the relevant report sections and further detailed information is provided by Gyopari and McAlister (2010c).

Many of the proposed Lower Valley water management zones are interconnected and represent parts of a continuous flow system from recharge areas on the Tauherenikau fan and Ruamahanga valley, to spring discharge areas on the lower fan areas and vertical leakage out of the Lake basin area. Water management zones which exhibit significant interdependence (or cross-zone interference effects), especially when they are pumped, are the Tauherenikau, Moiki, Lower Ruamahanga and Lake zones. The interactions between these zones and abstraction-induced interference effects between them have been taken into consideration when determining sustainable allocation options.

Figure 4.6 shows the current RFP (1999) groundwater management zones in the Lower Valley catchment. The outlines of the proposed new water management zones are superimposed on this map for cross-reference purposes.

Table 4.3: Proposed water management zones, management objectives and allocation criteria for the Lower Valley catchment

Zone name	Area (km^2)	Management objectives	Allocation criteria
Tauherenikau	152	• Managing baseflow depletion in the Tauherenikau River and associated spring-fed stream systems • Effects on throughflow into Lake Zone	• Tauherenikau River (MALF) • Stonestead Creek (MALF) • Featherston Springs (MALF) • Otukura Stream (MALF)
Moki	18	• Managing baseflow depletion in the Ruamahanga River	• Ruamahanga River (MALF)
Lower Ruamahanga	39	• Managing baseflow depletion in the Ruamahanga River • Throughflow into Lake Zone	• Ruamahanga River (MALF)
Martinborough	22.4	• Throughflow into Lower Ruamahanga zone • Drawdown	• Rainfall recharge
Dry River	16.7	• Throughflow into Lower Ruamahanga zone • Drawdown	• Rainfall recharge
Huangarua	22.5	• Managing baseflow depletion in the Huangarua River	• Rainfall recharge
Lake	219.3	• Throughflow effects on adjacent water management zones • Drawdown • Discharge to Lake Wairarapa	• Discharge to Lake Wairarapa
Onoke	40.4	• Discharge to coastal margin • Throughflow to Lake Zone • Managing baseflow depletion in the Turanganui and Tauanui Rivers	• Turanganui River • Tauanui River • Throughflow recharge from side valleys • Discharge to Ruamahanga River and Lake Onoke

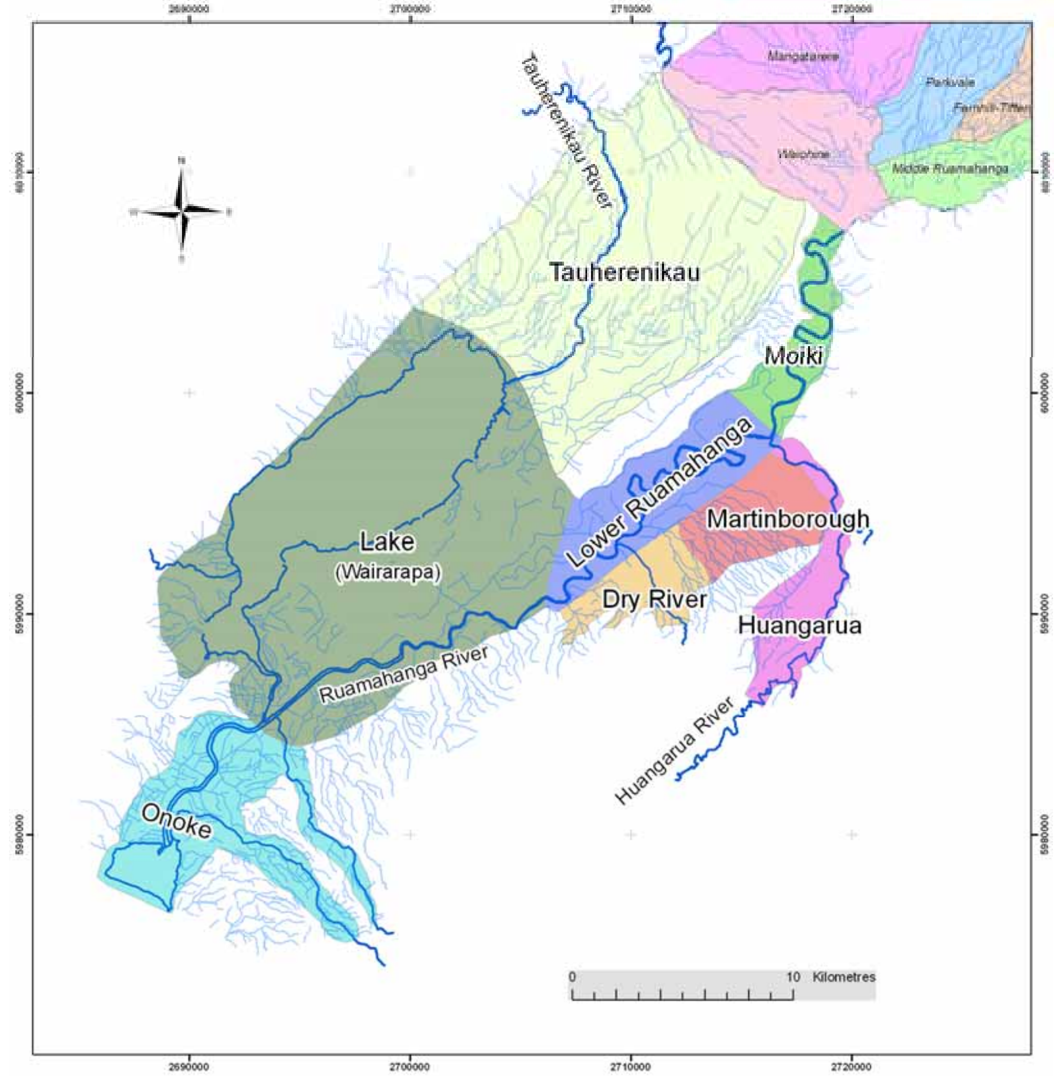

Figure 4.5: Spatial extent of proposed water management zones in the Lower Valley catchment

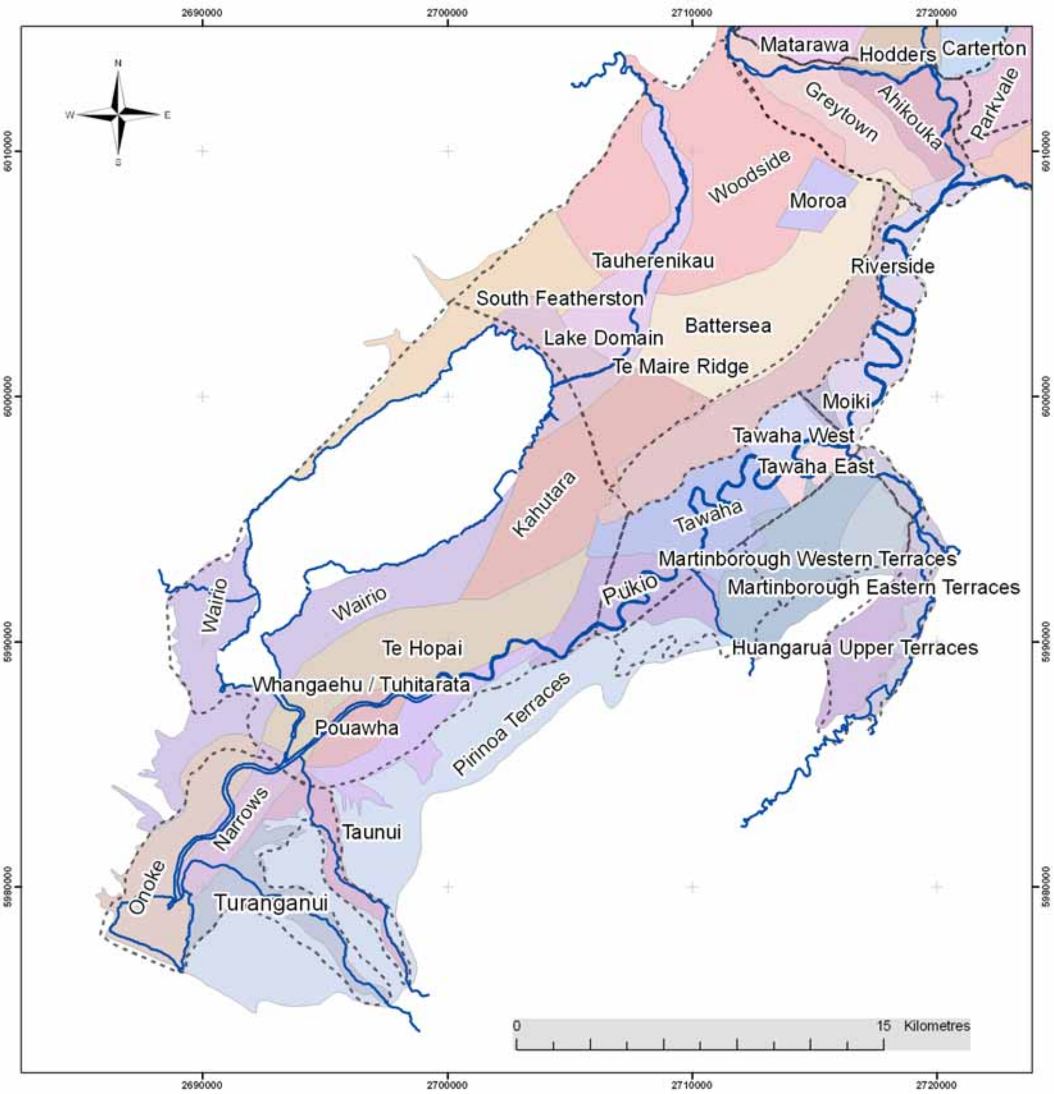

Figure 4.6: Map showing the spatial extent of existing RFP groundwater management zones in the Lower Valley, with the spatial extent of the proposed new water management zones indicated by black dashed lines

4.6 Summary of proposed groundwater allocation options

Tables 4.4 to 4.6 provide a summary of the proposed groundwater allocation framework and options for the proposed water management zones in each of the Upper, Middle and Lower Valley catchments respectively. Appendices D to F provide a detailed outline of the methodology used to calculate the allocation options for each zone. The tables provide the following information:

Aquifers:	Aquifer systems identified in the zone, either regarded to be a single groundwater resource, or separate resources.
Management objectives:	The principal objectives to be met by a sustainable groundwater allocation policy. Most commonly, these are managing cumulative baseflow depletion in principal surface water environments within the zones, or in adjacent hydraulically connected zones.

Allocation reference criteria:	Environmental flows usually relate to the mean annual low flow (MALF[13]) of critical surface water environments, and so simulated streamflow depletion effects have been referenced to this figure. Allocation options are therefore presented for a range of effects on MALF. A baseflow depletion factor, expressed as percentage of the seasonal average abstraction rate (i.e. q/Q)) is also recommended (based on modelling). Mean annual land surface recharge (LSR) is used to determine sustainable allocation limits in water management zones where there are no hydraulically connected surface waterbodies or where there is insufficient characterisation of river or stream flows. A 'primary' designation means that this criterion was used to derive the allocation options. Frequently, the options are also referenced to other criteria such as land surface recharge (LSR) or throughflow as a second-level check on the appropriateness of the allocation options.
Groundwater - surface water management zones:	These refer to the A, B and C hydraulic connection categories described in Section 2. Groundwater allocation applies to Category C and the portion of groundwater allocation from Category B not meeting criteria for application of temporal pumping restrictions. The location and depth of each zone is specified.
Groundwater allocation options:	Allocation is calculated on the basis of an effect on the reference criteria (i.e. a 1% depletion of MALF) using a baseflow depletion factor derived from numerical modelling (when allocation for the zone is based on surface water depletion). In this case, the reference flow is divided by the depletion factor to provide a groundwater abstraction rate which would cause the nominated rate of baseflow depletion. A range of allocation options are presented for each water management zone on the basis of a range of potential effects on the reference baseflow. This is discussed further on the next page. In some instances, allocation is based on a proportion of the mean annual land surface recharge, or the lower quartile annual recharge derived from the groundwater modelling described in Appendices D to F. In the Lower Valley catchment groundwater abstraction from some of the proposed water management zones may potentially impact on the surface water systems in adjacent zones. In such instances, the depletion effect from an adjacent zone is also taken into account when establishing groundwater allocation volumes.

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[13] All MALF figures presented in this report are naturalised 7-day MALFs and have been estimated for the most downstream points in the respective catchments. However, the robustness of the estimates varies between catchments depending on data availability and quality. More detail on the MALF estimates is provided in Keenan (2009).

Allocation volumes:	Expressed in m^3/day, m^3/week and m^3/year. The annual volume is based on a pumping duration of 180 days. It is probable that groundwater users would be restricted under weekly and annual pumping volumes to allow higher instantaneous abstractions.

Tables 4.4 to 4.6 provide two or more options for each water management zone. The range of options provided differs between management zones. For example, options for baseflow depletion of between 2% and 5% of MALF are given for the Waingawa Management Zone whereas the range is 10% to 25% of MALF for the Mangatarere Management Zone. This primarily reflects the difference between catchments in the current levels of allocation (and associated depletion effect) already occurring; that is, the current daily depletion effect in the Mangatarere is about 25% of MALF whereas it is less than 5% in the Waingawa. The options provided are therefore generally centred about the current situation as a starting point for looking at alternative scenarios of allocation and associated depletion effect.

Additional options can easily be developed using the information presented in the tables. Future application of the proposed conjunctive water management framework will require determination of an appropriate level of effect for each water management zone from which a corresponding groundwater allocation volume can be determined based on the relevant baseflow allocation derived from numerical modelling. This process may involve determining acceptable levels of environmental risk (associated with the anticipated magnitude of streamflow depletion) along with consideration of security of supply for water users in each water management zone and may result in different levels of baseflow depletion being adopted for different sub-catchments.

Table 4.4: Summary of proposed groundwater allocation framework and management options for Abstraction Categories B and C in water management zones in the Upper Valley catchment

Water management zone	Aquifers	Management objectives	Allocation reference criteria	Groundwater-surface water management zones	Groundwater allocation options	Daily allocation (m^3)	Weekly allocation (m^3)	Annual allocation (m^3 x 10^6)
Te Ore Ore	1: Unconfined+ semi-confined	Baseflow depletion: • Ruamahanga River • Poterau Stream	Primary: Ruamahanga River 7-day MALF Reference to: • LSR • Poterau Stream low flow	Western zone: Category A to 30 m; Category B >30 m Elsewhere all depths = Category B	MALF depletion			
					0.5%	2,660	18,600	0.48
					1.0%	5,200	31,200	0.94
					1.5%	8,000	56,000	1.44
Waingawa	1: Unconfined+ semi-confined	Baseflow depletion: • Waingawa River • Waipoua River • Ruamahanga River • Masterton springs	Primary: Combined MALF for Waingawa R, Waipoua R and Masterton springs. Reference to: • LSR	Q1 alluvium or 500 m river buffer: Category A to 20 m; Category B to 30 m; Category C >30 m Masterton springs area + 500 m Category A buffer: Category B to 20 m; Category C >20 m Elsewhere = Category C	MALF depletion			
					2%	7,000	49,000	1.3
					3%	10,400	72,800	1.9
					4%	14,000	98,000	2.5
					5%	17,300	121,100	3.12
Upper Ruamahanga	1: Unconfined+ semi-confined	Baseflow depletion: • Waipoua River • Ruamahanga River	Primary: LSR (annual lower quartile)	Q1 alluvium or 500 m river buffer: Category A to 20 m; Category B to 30 m depth Between Waipoua and Ruamahanga. Rivers + Lower Kopuaranga River: Category B to 20 m depth; Category C >20 m Lansdowne Hill and elsewhere, >20 m: Category C	LSR %			
					15%	14,800	103,600	2.66
					20%	19,700	137,900	3.55

Table 4.5: Summary of proposed groundwater allocation framework and management options for Abstraction Categories B and C in water management zones in the Middle Valley catchment

Water management zone	Aquifers	Management objectives	Allocation reference criteria	Groundwater-surface water management zones	Groundwater allocation options	Daily allocation (m^3)	Weekly allocation (m^3)	Annual allocation (m^3 x 10^6)
Waiohine	1: Unconfined (+semi-confined)	Baseflow depletion: • Waiohine River • Greytown springs	Waiohine River surface water allocation	All: Category A	Category A	n/a	n/a	n/a
Mangatarere	1: Unconfined + semi-confined	Baseflow depletion: • Mangatarere Stream • Springs	Mangatarere Stream 7-day MALF at Waiohine confluence Depletion factor = 0.5	Q1 alluvium + Beef Creek area: Category A to 20 m; Category B to 30m; Category C >30 m Elsewhere: Category B to 20 m; Category C >20 m	MALF depletion			
					10%	6,400	44,800	1.15
					15%	9,600	67,200	1.72
					20%	12,800	89,600	2.3
					25%	16,000	112,000	2.9
Parkvale	1: Confined 2: Unconfined	Baseflow depletion: • Parkvale Stream • Booths Creek Drawdown management: • Confined aquifers (<5 m drawdown)	Parkvale springs mean flow Depletion factors: Confined = 0.22 Unconfined = 0.3	All: Category B to 20 m; Category C >20 m	Spring low flow depletion			
					Confined aquifer:			
					15%	12,960	90,720	2.33
					20%	17,280	120,960	3.11
					25%	21,672	151,704	3.90
					Unconfined aquifer:			
					10%	6,336	44,352	1.14
					15%	9,504	66,528	1.71
					20%	12,672	88,704	2.28

Table 4.5 *cont*.: Summary of proposed groundwater allocation framework and management options for Abstraction Categories B and C in water management zones in the Middle Valley catchment

Water management zone	Aquifers	Management objectives	Allocation reference criteria	Groundwater-surface water management zones	Groundwater allocation options	Daily allocation (m^3)	Weekly allocation (m^3)	Annual allocation ($m^3 \times 10^6$)
Taratahi	1: Unconfined + semi-confined	Baseflow depletion: • Springs and wetlands along faultlines	Combined estimated MALF for Masterton and Carterton faultline springs Depletion factor = 0.22	All: Category B to 20 m; Category C >20 m	MALF depletion 30% 40% 50%	 11,800 15,700 19,600	 82,600 109,900 137,200	 2.12 2.82 3.53
Fernhill-Tiffen	1: Unconfined-confined	Drawdown management	Mean annual recharge	All: Category C	40% LSR 50% LSR	7,200 9,000	50,400 63,000	1.3 1.62
Middle Ruamahanga	1: Unconfined + semi-confined	Baseflow depletion: • Ruamahanga River	Ruamahanga River surface water allocation Throughflow reduction from Parkvale zone: Parkvale (confined) allocation * 0.12	All: Category A	Category A	n/a	n/a	n/a

Table 4.6: Summary of proposed groundwater allocation framework and management options for Abstraction Categories B and C in water management zones in the Lower Valley catchment

Water management zone	Aquifers	Management objectives	Allocation reference criteria	Groundwater-surface water management zones	Groundwater allocation options	Daily allocation (m^3)	Weekly allocation (m^3)	Annual allocation ($m^3 \times 10^6$)
Lake	1: Unconfined 2: Confined aquifers (Q2 + Q4)	1. Baseflow depletion: • Lake Wairarapa • Ruamahanga River • Stonestead Creek • Featherston springs • Tauherenikau River 2. Drawdown	Primary: Mean summer groundwater discharge into Lake Wairarapa. Additional: • Tauherenikau zone springs mean low flow • Throughflow enhancement from adjacent zones • Drawdown	Everywhere: Category B to 15 m >15 m: Category C	Lake Wairarapa GW inflow depletion 15% 20% 30% Add: Tauherenikau zone interference	10,300 20,600 41,000	72,100 144,200 287,000	1.85 3.7 7.4
Tauherenikau	1: Unconfined + semi-confined	Baseflow depletion: • Tauherenikau River • Stonestead Creek • Featherston springs • Otukura Stream • Lake Wairarapa	Primary: Total mean summer spring discharge Depletion factor: 0.5	Tauherenikau R. Q1 alluvium and Stonestead Creek capture zone: Category A to 20 m Elsewhere: Category B all depths	Depletion of mean summer spring flow 25% 35% 50% Add: Lake zone interference	35,400 52,200 77,400	247,800 365,400 541,800	6.37 9.4 13.93
Moiki	1: Unconfined	Baseflow depletion: • Ruamahanga River	Ruamahanga River surface water allocation	All: Category A	Category A	n/a (no Categories B or C in this zone so not necessary to calculate groundwater allocation options)		

Table 4.6 *cont.*: Summary of proposed groundwater allocation framework and management options for Abstraction Categories B and C in water management zones in the Lower Valley catchment

Water management zone	Aquifers	Management objectives	Allocation reference criteria	Groundwater-surface water management zones	Groundwater allocation options	Daily allocation (m^3)	Weekly allocation (m^3)	Annual allocation (m^3 x 10^6)
Martinborough	1: Semi-confined + confined	Drawdown management	Mean annual LSR	All: Category C	LSR			
					30%	3,600	25,200	0.65
					40%	4,800	33,600	0.86
					50%	6,000	42,000	1.075
Lower Ruamahanga	1: Unconfined+ semi-confined	Baseflow depletion: • Ruamahanga River	Ruamahanga River surface water allocation	All: Category A	Category A Add: Lake zone interference	n/a (no Categories B or C in this zone so not necessary to calculate groundwater allocation options)		
Dry River	1: Unconfined + semi-confined	Drawdown management	Mean annual LSR	All: Category B	LSR			
					50%	4,400	30,800	0.8
					60%	5,300	37,100	0.96
Huangarua	1: Unconfined 2: Semi-confined	Baseflow depletion: • Huangarua River	Mean annual LSR	Lower Q1 terrace: Category A to 20 m. Elsewhere: Category B	LSR			
					30%	5,400	37,800	0.97
					40%	7,200	50,400	1.29
Onoke	1: Unconfined 2: Confined	Baseflow depletion: • Tauanui River • Turanganui River Drawdown	Primary: Throughflow recharge Additional: Surface water discharge	Tauanui and Turanganui river valleys: Category A. Main valley: Category C	Throughflow depletion:			
					30%	8,700	60,900	1.44
					40%	11,600	81,200	1.73

5. Implications for monitoring and management

The proposed framework for conjunctive management of groundwater and surface water allocation in the Wairarapa Valley outlined in this report is a significant departure from current practice under the existing RFP (WRC 1999). As a consequence, implementation of the proposed framework is likely to present a range of challenges for Greater Wellington. This section discusses some of the factors which may be involved in adoption of the recommended conjunctive water management approach.

5.1 New and replacement resource consent applications

Adoption of the proposed conjunctive water management framework will have significant implications for the management of both new and existing resource consents. In particular, the proposed framework will result in the application of pumping controls (i.e. minimum flow cut-offs) on a significant number of consents which are currently unrestricted as and when they are reviewed or replaced.

In order to facilitate implementation of the proposed management framework it is recommended that Greater Wellington develop specific guidance to assist the resource consent process (including applications for new and replacement resource consents) until future amendments to current policies for groundwater allocation are adopted in the RFP (WRC 1999). This guidance may include:

- Procedures for the processing of new consent applications;
- Procedures for the processing of replacement consent applications;
- Minimum information requirements to support technical assessments;
- Application of step-down and minimum flow conditions on groundwater takes with a direct or high degree of hydraulic connection (i.e. Category A or Category B);
- Methods/procedures for calculating, recording and managing groundwater and surface water allocation; and
- Guidelines for the application of analytical stream depletion estimation techniques in ‘non-ideal’ hydrogeological settings.

As a starting point it is suggested that the groundwater management zones recommended in this report form the basis for assessment of current and future groundwater allocation.

It is also recommended that specific guidance be developed for aquifer testing (including analysis) to assist evaluation of new and replacement resource consent applications, particularly in Category B areas. Such guidance could include recommendations for pumping rates, test duration, location of observation bores, water level corrections and analysis methodologies similar to those in the recently published Environment Canterbury guidelines[14]. This process could also involve submission of an aquifer test plan to Greater Wellington prior to undertaking aquifer testing to ensure aquifer test specifications meet council requirements.

In order to enable reliable assessment of potential stream depletion effects (particularly in Category B areas) it is recommended that Greater Wellington develop guidance for the application of analytical stream depletion estimation methodologies. Such guidance could include recommendations for undertaking stream depletion assessment in non-uniform hydrogeological settings (e.g. in the case of multiple streams or where there is a significant contrast in hydraulic properties such as across the Q1/Q2 boundary) as well as recommendations for determining representative hydraulic parameters (e.g. streambed conductance or representative aquifer transmissivity where multiple aquifer test results are available). Such guidance could be developed on the basis of field studies and further application of existing numerical groundwater models to individual pumping scenarios.

5.2 Management of future surface and groundwater allocation

The proposed conjunctive water management framework will result in significant alteration to the management of groundwater and surface water allocation in the Wairarapa Valley. Changes resulting from the adoption of the proposed framework will be particularly significant for future surface water allocation policy which will need to address:

- Significantly increased levels of water allocation in many surface waterways due to the inclusion of hydraulically connected groundwater takes within the surface water allocation; and

- Management of baseflow allocation for unregulated groundwater abstraction particularly with regard to how this allocation relates to environmental flows and water levels.

Current levels of surface water allocation will significantly increase on many rivers and streams, if groundwater allocation from Category A (and part Category B) takes is incorporated in calculated surface water allocation as proposed. Development of future surface water allocation policy will therefore need to address situations where this will result in allocation significantly above core allocation specified in the existing RFP. As further discussed in Section 5.5 below, in some cases this over-allocation may occur ‘on paper’ rather than in terms of actual use.

In considering how to manage a transition from the existing RFP groundwater and surface water allocation provisions to the proposed conjunctive water management framework, it is also important to recognise that the cumulative effects of existing groundwater abstraction are likely to be incorporated (at least to some degree) within existing river flow records. Due to the significant increase in groundwater abstraction across the Wairarapa Valley in recent years

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[14] http://ecan.govt.nz/publications/Reports/AquiferTestGuidelines2008plusReportExample.pdf

these effects are likely to be most evident in data collected over the past five to ten years.

Overall, the effect of the proposed groundwater allocation volumes outlined in this report on existing levels of allocation is uncertain and will not be able to be accurately determined until Greater Wellington:

- adopts one of the recommended groundwater allocation volumes (or an alternative) for each water management zone. This process will involve determining acceptable levels of environmental risk (related to the anticipated magnitude of streamflow depletion) along with consideration of security of supply for water users; and
- assesses all existing resource consents in proposed Category B areas to determine the relative volume of allocation attributable to surface and groundwater allocation respectively.

5.3 Policies to support implementation of proposed management framework

Implementation of the proposed conjunctive water management framework is likely to require development of a range of supporting policies that may be included in the current review of the RFP. Such policies may include:

- Where not already established, application of common expiry dates on water permits (for both surface and groundwater takes) within individual water management zones to enable changes to the management of existing resource consents to be applied in a consistent and transparent manner;
- Possible exemptions from pumping regulation (i.e. minimum flow restrictions) for certain types of groundwater takes located in Category A or Category B areas. Such exemptions would enable provision to be made for essential water supplies such as municipal, water scheme and certain industrial uses which support public health and/or animal welfare considerations;
- Establishment of defined reliability of supply criteria for different categories of water use. These criteria could be utilised to assist setting allocation volumes for individual water users as well as to ensure that future allocation does not adversely affect the reliability of supply for existing water users; and
- Policies either reviewing existing consented allocation or facilitating the transfer of allocation between individual water users to improve allocative efficiency. The proposed conjunctive water management framework could be utilised to facilitate the transfer of existing water allocation within individual catchments to improve economic efficiency (e.g. higher value use). For example:

- Category A groundwater and surface water takes may be interchangeable (provided variations in instantaneous and short-term pumping rates are accounted for);
- Category C and unrestricted Category B groundwater takes could be transferrable between different aquifers within the same catchment provided baseflow allocation is equal or lower (and an assessment of local effects undertaken); and
- Category B groundwater subject to regulation could also be proportionally transferred to surface water or Category A or wholly transferred to Category C (subject to assessment of localised effects).

5.4 Environmental monitoring requirements

The proposed conjunctive water management framework focusses on management of the cumulative effects of groundwater and surface water allocation at a catchment scale. As a result, measurement of flow in the lower reaches of Wairarapa's rivers and streams is critical to establish catchment scale environmental flows and water levels and determine compliance with the proposed allocation regime. Flow monitoring is also critical for evaluating the effectiveness of the overall management approach and whether resource management objectives have been achieved.

At the current time, for a range of historical (e.g. flood warning) and practical (e.g. stable sections) reasons, flow monitoring in the Wairarapa Valley tends to be concentrated in upper catchment areas close to the points where the main rivers emerge from the Tararua Range or Eastern Hills onto the Wairarapa Valley. However, the main areas of groundwater/surface water interaction and critical ecological effects tend to occur as the rivers traverse the Wairarapa Valley. As a consequence, current monitoring is not particularly well-suited to the management of water allocation and associated environmental effects.

It is therefore recommended that Greater Wellington undertake a review of its existing hydrological monitoring network to support implementation of the proposed conjunctive water management framework. Such a review may focus on collection of additional flow information either by way of permanent or temporary flow monitoring sites in lower river reaches or through an increased frequency of gaugings in these areas to enable correlation with established flow monitoring sites.

Field investigations required to support implementation of the proposed conjunctive water management framework include the measurement of streambed conductance values in representative reaches of rivers and stream in the Wairarapa Valley. These investigations may be particularly important in smaller spring-fed tributaries (in Category B areas) to provide reliable estimates of streambed conductance values to inform analytical stream depletion assessments.

5.5 Aligning allocation with actual use

At the current time water permits issued by Greater Wellington authorising groundwater abstraction in the Wairarapa Valley specify maximum instantaneous and daily rates of take and set a maximum (volumetric) seasonal allocation. However, both metered water use data and irrigation abstraction modelling undertaken by Gyopari and McAlister (2010 a, b and c) suggest that actual groundwater abstraction (in terms of peak abstraction rates and seasonal usage) is significantly lower than consented volumes. Data collected through various metering studies typically show peak (weekly) water usage typically ranges between 60% and 75% of the maximum consented rate. However, on an annual basis seasonal water usage is generally much lower at around 30% of the total consented volume.

The mismatch between consented allocation and actual use significantly reduces allocative efficiency. This situation has potential implications for efficient and sustainable management of groundwater and surface water resource including:

- Where fixed volumes of water are available for allocation (either in terms of groundwater or surface water), allocation of water to individual users in excess of their 'reasonable' needs can prevent additional users accessing the available resource;

- The potential environmental effects of groundwater abstraction (such as potential stream depletion effects) may be significantly over-estimated when based on consented volumes;

- As water resources approach or reach full allocation incentives may increase for existing users to transfer the unused portion of their allocation in accordance with s136 of the RMA. This may result in unanticipated environmental effects as cumulative water use increases, particularly if existing allocation limits do not adequately incorporate uncertainty regarding resource availability and interconnection between surface and groundwater. Increased utilisation of consented allocation may also result in a reduction in supply reliability for existing resource users if this has not already been factored into existing allocated volumes.

It is therefore recommended that options be considered to improve alignment of actual water use and consented volumes. Calculations of potential water requirements should incorporate the concept of reliability of supply whereby sufficient water is allocated to meet potential demand under a given scenario. For example, in the case of pasture irrigation sufficient water may be allocated to satisfy crop demand 8 years out of 10 (i.e. providing 80% reliability of supply). It is noted that Greater Wellington has recently acquired a version of the SPASMO-IR[15] model which enables calculation of water requirements for a range of crop types under nominated climate conditions.

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[15] SPASMO-IR is short for Soil Plant Atmosphere System Mode for Irrigation, a computer-based tool developed for Greater Wellington by Plant and Food New Zealand. SPASMO-IR can be used to determine various crop water requirements to help enable efficient use.

5.6 Water metering

Actual water use data are critical for successful water resource management. Improved access to quality-assured water metering data in the Wairarapa Valley will be needed to both support and monitor the implementation of the proposed framework as well as better understand the disparity between consented and actual use (discussed in Section 5.5). National regulations will require more widespread installation of meters and Greater Wellington will need to concurrently invest in data management and systems to support the metering uptake.

6. Summary

The groundwater resources of the Wairarapa Valley sustain freshwater ecosystems and support important economic and social values and meet water demands for domestic, municipal, agricultural and industrial purposes. Rapidly increasing pressure on water resources over the past decade led to this review of existing water allocation methodology to ensure that both groundwater and surface water resources are sustainably managed.

The proposed framework for conjunctive management of groundwater and surface water allocation in the Wairarapa Valley outlined in this report provides for:

1. Designation of spatially defined management units which are assigned volumetric allocation limits that take account of the potential effects of groundwater abstraction on baseflow at a catchment scale; and

2. Active management of those groundwater abstractions which have a direct or immediate effect on the surface water environment which can be effectively mitigated by the application of management controls (such as minimum flow cut-offs).

In order to implement these objectives, a three-tier management approach has been proposed that establishes a framework for managing groundwater abstraction according to its potential impact on surface water. The proposed framework allows differentiation between those groundwater takes which have a direct and immediate effect on surface water from those where there may be a considerable lag between pumping and resulting effects on surface water, based on three nominal categories of hydraulic connection. The proposed framework effectively establishes a three-dimensional framework for the management of groundwater abstraction based on geographic location and depth criteria which vary according to the local hydrogeological environment and resulting connectivity between surface and groundwater. The hydraulic connectivity categories proposed are:

Category A: Direct hydraulic connectivity

Category A includes areas of the hydrogeological system that exhibit direct connectivity with surface water and typically encompasses the highly permeable Q1 gravel aquifers that occur along the riparian margins of the main river systems. In these areas both physical monitoring and modelled pumping scenarios indicate a high degree of connectivity with surface water. Due to the high degree of hydraulic connection, stream depletion effects occur shortly following the commencement of groundwater abstraction and rapidly increase to a level close to the overall pumping rate. As a consequence, a high proportion of the overall volume of groundwater pumped effectively represents induced flow loss from local surface waterways.

Due to the immediacy of impact, groundwater abstraction from Category A areas can be considered as being analogous to direct surface water abstraction in terms of the magnitude and temporal response of stream depletion effects. It is therefore proposed to manage groundwater abstraction from Category A areas in terms of the environmental flow and water level regimes (i.e. minimum flows and core allocations) established for relevant hydraulically connected surface waterbodies. At the time of writing, minimum flows and allocation levels for rivers and streams are being reviewed by Greater Wellington.

Category B: High hydraulic connectivity

Category B includes those areas of the hydrogeological system where groundwater abstraction may potentially result in significant impacts on surface water but where pumping regulation does not always provide an effective option for mitigating direct stream depletion effects. Category B effectively represents the transition between direct and indirect stream depletion effects where it may be appropriate to manage groundwater takes in terms of either surface water or groundwater allocation policies depending on localised factors (e.g. local aquifer hydraulic parameters, abstraction rate and location of pumping with respect to surface waterbodies).

The proposed Category B classification would apply to all groundwater takes with an average weekly abstraction rate of >5 L/s in nominated areas (takes <5 L/s would be included in the groundwater allocation for the relevant water management zone). Takes in Category B areas should be subject to minimum flow policies established for relevant hydraulically connected surface waterbodies where assessment indicates stream depletion effects are sufficiently high ($q/Q>0.6$ and/or >10 L/s). For those takes subject to minimum flow controls the calculated stream depletion effect should be counted as part of the total allocation for hydraulically connected surface waterbodies, with the balance counted as part of the groundwater allocation for the relevant water allocation zones.

Category C: Moderate to low hydraulic connectivity

Category C includes those areas of the hydrogeological system where groundwater abstraction may contribute to an overall reduction in baseflow discharge at a catchment scale but where active regulation of groundwater pumping does not mitigate effects on surface water.

For each water management zone options for groundwater allocation limits are presented based on the outputs of abstraction scenarios run on the numerical groundwater flow models developed for each catchment (Gyopari and McAlister 2010 a, b and c). These models simulate the cumulative effects of groundwater abstraction in terms of surface water depletion, aquifer drawdown, and changes in cross-zone throughflow dynamics. This information provides the basis for developing sustainable groundwater allocation options for each water management zone. Where appropriate the proposed groundwater allocation limits are referenced to the potential cumulative effect on baseflow at a sub-catchment scale in relevant hydraulically connected surface waterbodies.

The proposed framework for conjunctive management of groundwater and surface water allocation in the Wairarapa Valley outlined in this report is a significant departure from current practice under Greater Wellington's existing Regional Freshwater Plan. While there are a number of challenges to successful implementation of the proposed management framework, it offers a potential means to integrate the management of groundwater and surface water resources and provide an improved basis for sustainable allocation .

A number of recommendations have been made to assist with the adoption of the proposed conjunctive water management framework. In the short-term these recommendations include guidance to assist the resource consent process including:

- Procedures for processing new and replacement consent applications under the proposed management framework;
- Specification of minimum information requirements to support technical assessment of consent applications including guidelines for aquifer testing and application of analytical stream depletion methodologies;
- Guidance for the application of step-down and minimum flow conditions to groundwater takes with a high or moderate degree of hydraulic connection (Category A or Category B); and
- Methods and/or processes for calculating, recording and managing groundwater and surface water allocation.

Over the medium-term additional recommendations include:

- Development of policies covering common expiry dates for water permits, exemption from minimum flow/level controls for nominated water users (e.g. municipal supply), reliability of supply criteria for different water uses and the transfer of allocation between individual water users;
- Reviewing environmental monitoring programmes with a focus on data collection to support the proposed conjunctive management framework. This may involve a greater focus on flow monitoring in lower catchment areas and collection of field data (e.g. streambed conductance) to assist with assessments of environmental effects associated with groundwater abstraction; and
- Improving the alignment between rates and volumes of water allocation established through the resource consent process and actual water use by individual resource consent holders.

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