



# Fractured Rock and Confined Aquifers

Recommendations for Sustainable  
Management

Liquid Earth  
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# 1. Introduction

## 1.1 Background

Extensive deposits of Quaternary and Tertiary sediments<sup>1</sup> in the Southland Region host a number of confined aquifer systems. These aquifer systems present a challenge for water resource management due to the limited information typically available to characterise:

- The physical extent of individual aquifer systems;
- The magnitude and nature of aquifer recharge and discharge;
- The hydraulic properties of the aquifer system including storage characteristics; and
- The dynamic response of the confined aquifers to groundwater abstraction including potential effects on hydraulically connected surface and groundwater resources.

Due to their unique hydrogeological characteristics, the requirement to manage confined aquifers in a different manner to unconfined groundwater resources was recognised in Variation 2 to the Regional Water Plan (RWP) developed in 2003 which adopted a staged management framework for confined aquifers based on groundwater level response to abstraction. However, subsequent experience with large-scale development of confined aquifers in the Northern Southland area suggests that the effects-based approach adopted in the RWP is not particularly effective in terms of addressing key resource management issues for confined aquifers, particularly in terms of aquifer sustainability.

A subsequent review of the management of confined aquifers (SKM, 2008) highlighted many of the shortcomings associated with the existing management framework for confined aquifers and suggested an alternative approach for determining aquifer sustainability. This report builds on the SKM (2008) report to provide a series of recommendations to assist development of more effective policy for the management of confined aquifers.

This report also provides recommendations for the management of groundwater allocation in fractured rock aquifers. Fractured rock aquifers were recognised as a distinct aquifer type in the RWP but due to their unique hydrogeological characteristics this aquifer type was not included within the allocation framework developed. This report addresses this anomaly by recommending a methodology which may be applied to manage localised allocation from fractured rock aquifers.

The report also canvasses various groundwater resource management issues that apply to all aquifer types (including confined and fractured rock aquifers) that may be addressed by relatively simple amendments to the current regulatory framework.

## 1.2 Key Concepts

The following section provides an introduction to some of the key concepts related to resource management in confined and fractured rock aquifers.

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<sup>1</sup> Quaternary sediments refer to those deposited over the last 2 million years and typically include the extensive alluvial gravel deposits found across the Southland Plains and inland basins. Tertiary sediments refer to those deposited over the period between 2 and 65 million years before present and include the extensive deposits of lignite, mudstone and limestone that underlie the Quaternary gravels across much of the Southland Region.

## Aquifers

The RWP defines an aquifer as a “*saturated rock or soil material capable of transmitting and yielding water in sufficient quantities for abstraction*”.

Following this definition there are two key aspects that determine the occurrence of aquifers. The first is that the geological material has to be fully saturated (as opposed to the unsaturated zone where the pore spaces in the geological materials are only partially filled with water). The point at which the material becomes fully saturated defines the *water table*.

The second key point is that the material must be capable of transmitting sufficient quantities of water to provide sufficient yield to enable economic quantities of water to be accessed by bores and wells. As a result, although virtually all geological materials (below the water table) are fully saturated, only those which have sufficient *permeability* (i.e. a measure of the ability of the material to transmit water) are classified as aquifers. Geological materials which are fully saturated but which have low permeability (i.e. do not readily transport sufficient quantities of water to enable viable groundwater abstraction) are typically referred to as *aquitards*. It is noted that while these materials are not classified as aquifers they may still have the capability to store and transmit appreciable quantities of water.

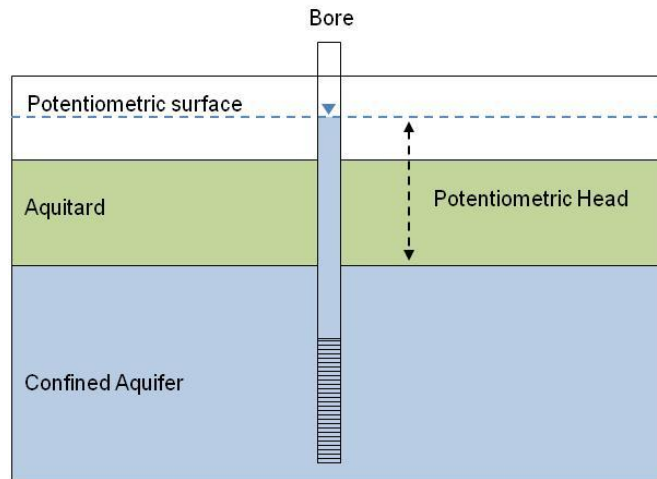
## Unconfined vs Confined Aquifers

Unconfined aquifers contain the water table (or *piezometric surface*) which reflects the transition from unsaturated to saturated conditions. The water table surface is free to move up and down as water fills or drains from individual pore spaces in response to the relative volumes of aquifer recharge (typically infiltration from rainfall or hydraulically connected surface water) and discharge (water draining to rivers and streams, throughflow into other aquifers or groundwater abstraction).

In contrast, confined aquifers are isolated from the land surface by overlying aquitards which restrict the ability of water to move vertically into or out of the aquifer. The RWP defines a confined aquifer as ‘*an aquifer which is overlain by a low permeability or impermeable layer where the water in the aquifer is under pressure*’. The key point in this definition is that in a confined aquifer the geological materials are fully saturated and the water is stored under pressure. This means the water level in a bore screened in a confined aquifer will rise above the lower surface of the overlying aquitard. The level to which water rises in a confined aquifer is termed the *potentiometric head*<sup>2</sup>. **Figure 1** shows a schematic illustration of a confined aquifer.

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<sup>2</sup> In the context of this report potentiometric head in a confined aquifer refers to the level above the base of the overlying aquitard layer to which water will rise in a bore screened in the aquifer. It is therefore a measure of the ‘pressure’ under which water is stored in the aquifer.



**Figure 1. Schematic representation of a confined aquifer**

In general, while aquitards restrict the vertical flow of water there are few hydrogeological settings where they completely prevent the movement of water into and out of confined aquifers. Aquifer systems therefore exist along a continuum between unconfined and more fully confined conditions depending on the hydraulic properties and physical distribution of aquitard materials. Although the term confined aquifer is generally applied to describe aquifers which are overlain by lower permeability sediments, and exhibit low storage and positive head, there are few aquifer systems that are completely isolated from surrounding water resources. As a result, most confined aquifers are more appropriately classified as *semi-confined*<sup>3</sup>, reflecting their incomplete hydraulic separation.

#### Confined Aquifer Response to Groundwater Abstraction

A key difference between unconfined and confined aquifers is the way they respond to pumping. In unconfined aquifers abstraction of groundwater causes water to physically drain from the pore spaces of the geological materials within the cone of depression. This results in appreciable volumes of water being released from storage by gravity drainage as the water level surrounding a pumping well is progressively drawn down. *Specific yield* is the term applied to describe the volume of water released from a unit volume of dewatered aquifer material in an unconfined aquifer. Typical specific yield values for coarse-grained (sand and gravel) aquifers ranges from 0.05 to 0.20<sup>4</sup>.

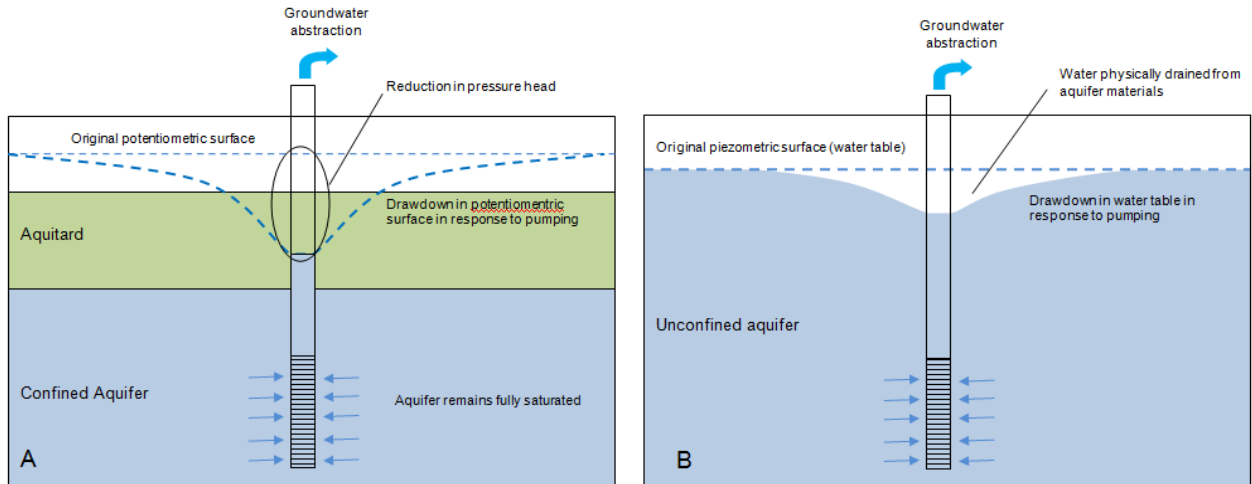
In contrast, in a confined aquifer the entire thickness of aquifer materials remains fully saturated and water stored under positive pressure (i.e. the water level in a bore screened in a confined aquifer rises above the base of the overlying aquitard). In this case abstraction of groundwater causes a reduction in the pressure head rather than physical drainage of water from the aquifer materials. This decrease in pressure allows the water to expand slightly and causes a slight compression of the aquifer matrix which yields a relatively limited volume of water per unit of drawdown. *Storativity* is the term applied

<sup>3</sup> In this report the term confined aquifer is applied in a generic sense to all aquifers which exhibit positive head and low storativity including those that may be more properly defined as semi-confined.

<sup>4</sup> A specific yield value of 0.2 means that 200 litres of water will be released per cubic metre reduction in the water table.

to describe the storage characteristics of confined aquifers which commonly lie in the range of 0.001 to 0.00001<sup>5</sup>.

The difference in aquifer response to abstraction in confined and unconfined aquifers is schematically illustrated in **Figure 2** below.



**Figure 2. Schematic illustration of drawdown in response to pumping in confined (A) and unconfined (B) aquifers. Note that in unconfined aquifer water is physically drained from the aquifer while in the confined aquifer pumping causes a reduction in pressure head around the point of abstraction (note the greater drawdown occurring in the confined aquifer).**

Under natural conditions it is not uncommon to observe differences in static water levels between confined aquifers and overlying unconfined confined aquifers reflecting the impendence of vertical flow by intervening aquitard layers. In this case the rate of vertical flow into and out of the confined aquifer is controlled by the hydraulic conductivity of the aquitard materials in combination with the hydraulic gradient. Drawdown resulting from abstraction in the confined aquifer will increase the hydraulic gradient thereby potentially increasing the rate of vertical flow through the aquitard. This increase in vertical flow into a confined aquifer in response to abstraction is termed *leakage*.

The restriction of vertical movement of water due to the presence of aquitard materials has the following implications for abstraction from confined aquifers:

- Groundwater abstraction will cause head changes in a confined aquifer to propagate further laterally than would be the case for equivalent abstraction from an unconfined aquifer due to different mechanisms of storage release (elastic storage in the confined aquifer versus physical drainage of the pore spaces in the unconfined aquifer).
- Pumping from a confined aquifer will result in changes in the piezometric level of overlying aquifers due to the leakage of water through the aquitard. The rate of leakage will be governed by the hydraulic properties of the aquitard and the changes in the natural hydraulic gradient induced by drawdown in the confined aquifer and occur across the entire cone of depression formed in the confined aquifer.

<sup>5</sup> A storativity value of 0.001 means the aquifer will yield 1 litre of water per cubic metre reduction in piezometric head.

## Fractured Rock Aquifers

Fractured rock aquifers are distinct from groundwater systems which are hosted in sedimentary deposits. While sedimentary aquifers store and transmit water through pore spaces between individual sediment granules, fractured rock aquifers store and transmit water through crevices, joints and fractures in an otherwise impervious rock mass. As a result, fractured rock aquifers exhibit hydraulic characteristics which are distinct from those observed in sedimentary aquifer systems with water availability (commonly observed in terms of bore yield) generally dependent on the nature (number, size and extent) of discontinuities in the rock mass and their degree of interconnection. This means the long-term yield available from bores screened in fractured rock aquifers is generally dependent on the localised extent and interconnection of discontinuities in the overall rock masses rather than permeability of the geological materials in the immediate vicinity of the abstraction point.

Fractured rock aquifers may also exhibit different recharge characteristics to other aquifer types, particularly unconfined aquifers. Fractured rock aquifers typically occur in rolling to steep topography where the percentage of rainfall contributing to surface water runoff is significantly higher than more flat-lying areas. In addition, due to the age of the geological units forming fractured rock aquifers (typically pre-Tertiary age) extensive weathering commonly occurs along the upper surface of the rock mass. This weathering commonly results in the alteration of the rock materials to form clay minerals which inhibit the vertical movement of water. Permeability in fractured rock aquifers may also reduce with depth due to the progressive reduction in open space along joints and fractures due to the weight of the overlying rock mass.

## Aquifer Sustainability

Sustainability is often a difficult concept to define in a precise manner and with universal applicability in terms of natural resource management. Section 5(2) of the Resource Management Act (1991) defines sustainable management in terms of:

*‘...managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural wellbeing and for their health and safety while:*

- a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonable foreseeable needs of future generations; and*
- b) Safeguarding the life-supporting capacity of air, water, soil and ecosystems; and*
- c) Avoiding, remedying or mitigating any adverse effects of activities in the environment.*

The USGS (Alley *et al*, 1999) define ground-water sustainability as the ‘*development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences*’. Similarly the Australian government National Water Initiative (NWI)<sup>6</sup> defines sustainable groundwater abstraction as ‘*the level of water extraction from a particular system which, if exceeded would compromise key environmental assets, or ecosystem functions and the productive base of the resource*’. Both definitions illustrate the degree of subjectivity inherent in defining an ‘acceptable’ level of abstraction that does adversely impact on the values associated with a particular groundwater resource.

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<sup>6</sup> <http://www.nwc.gov.au/www/html/180-sustainable-management.asp>

In the New Zealand context, aquifer sustainability typically relates to management of an individual aquifer system in a manner which maintains those values associated with the groundwater resource. These values depend on the physical characteristics and use associated with a particular groundwater resource and may relate to a combination of factors such as:

- Effects on existing groundwater users;
- Maintenance of aquifer storage to ensure continued access to the resource (i.e. the overall volume of water in the aquifer system is not depleted over time);
- Potential effects on hydraulically connected surface water bodies such as rivers, streams and wetlands; and
- Maintenance of groundwater quality suitable for a particular end use (e.g. drinking water).



## **2. Current Policy**

### **2.1 Background**

Development of a detailed framework for groundwater management in the Southland Region for the current Regional Water Plan is complicated by limited knowledge of regional hydrogeology and the comparatively short history of both resource development and environmental monitoring and investigations.

In response to a significant increase in the consumptive groundwater use, Environment Southland initiated Variation 2 to the Regional Water Plan in 2003 to develop a more robust framework for managing the regions groundwater resources. This variation adopted a staged approach to the allocation of groundwater within nominated management zones. Each individual management zone identified was classified according to 'aquifer type' and nominal allocation volumes for each aquifer type attributed varying activity status (e.g. restricted discretionary, discretionary and non-complying) according to the potential risk of adverse environmental effects associated with groundwater abstraction.

The basic premise of the management framework was the concept of adaptive management whereby the level of information and assessment required to support an individual resource consent application to take groundwater escalate as the level of allocation increases. As a consequence, the allocation framework does not establish definitive allocation limits, rather it recognises that the establishment of limits to consumptive groundwater use will, in a practical sense, only be determined through an iterative process involving further investigations, monitoring and resource development. The overall philosophy being to establish a management framework which enables information derived from progressive resource development to inform the resource consent decision-making process as a groundwater resource is progressively developed.

The Regional Water Plan (RWP) defines five basic aquifer types in the Southland Region (riparian, lowland, terrace, confined and fractured rock) and establishes preliminary allocation limits for riparian, lowland and terrace aquifers based on varying percentages of mean annual land surface recharge (LSR). Due to the limited knowledge of the spatial extent, hydrogeology and recharge characteristics at the time of plan development, such an approach was not considered appropriate for confined or fractured rock aquifers. As an alternative, criteria to manage allocation from confined aquifers were established on the basis of potential drawdown of groundwater levels in response to abstraction. No criteria were established to cover allocation from fractured rock aquifers

The following section provides a summary of current policy relating to groundwater allocation from confined and fractured rock aquifers and outlines some of the practical difficulties encountered implementing the current approach to management of confined aquifers through the resource consent process.

### **2.1 Policies and Objectives**

The policies and objectives outlined in the Regional Water Plan relevant to the management of confined aquifers include:

## **Objective 9 – Sustainable abstraction**

*To ensure that the total volume and rate of groundwater abstraction is sustainable*

## **Policy 28 - To Manage Groundwater Abstraction**

*To manage groundwater abstraction to avoid significant adverse effects on:*

- *long-term aquifer storage volumes*
- *existing water users*
- *surface water flows and aquatic ecosystems and habitats*
- *groundwater quality*

## **Policy 30 – Groundwater abstraction**

- a) *Use a staged management approach to allocate groundwater for abstraction in Southland to allow the knowledge gained by the progressive development of the region's groundwater resources to be built into its future management*
- b) *Recognise the different characteristics of the following aquifer types when managing groundwater abstraction:*
  - i. *riparian aquifers*
  - ii. *terrace aquifers*
  - iii. *lowland aquifers*
  - iv. *confined aquifers*
  - v. *fractured rock aquifers*
- c) *Provide for a level of permitted groundwater abstraction where there is a minimal risk of adverse effects*

## **Policy 31 - Interference Effects**

*Limit the interference effect of any new groundwater abstraction to no more than 20 percent of the available drawdown in any neighbouring bore provided the neighbouring bore is lawfully established and adequately penetrates the aquifer*

## **2.2 Regional Rules**

Rules defining the activity status of groundwater abstraction from confined aquifers are defined in:

### **Rule 23 – Abstraction and Use of Groundwater<sup>7</sup>**

- a) *In addition to takes authorised by Section 14(3) of the Act and the abstraction and use of groundwater permitted under Rule 23 (b), the abstraction and use of up to 20,000 litres of groundwater per landholding per day is a permitted activity provided the following conditions are met:*
  - (i) *The rate of abstraction does not exceed 2 litres per second, except where the abstraction is for the purpose of carrying out an aquifer test or hydrological study; and,*

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<sup>7</sup> It is noted that Rule 23 does not include provision for fractured rock aquifers.

- (ii) *The abstraction does not result in adverse effects on existing water users, surface water ecosystems or groundwater quality*
- c) *Except as provided for in Rules 23(a) and 23(b) and the takes authorised by Section 14(3) of the Act, the abstraction and use of groundwater from any of the following sources is a restricted discretionary activity, provided the rate of take is less than or equal to 2 litres per second*
  - (ii) *A confined aquifer where pumping of an individual bore results in a maximum reduction of less than 25 percent in the potentiometric head at a distance of 250 metres from the pumped bore*
- d) *Except as provided for in Rules 23 (a) and 23(b) and the takes authorised by Section 14(3) of the Act, the abstraction and use of groundwater from any of the following sources is a discretionary activity:*
  - (iii) *A confined aquifer where pumping of an individual bore results in a maximum reduction of between 25 and 50 percent in the potentiometric head at a distance of 250 metres from the pumped bore.*
- e) *Except as provided for in Rules 23 (a) and 23(b) and the takes authorised by Section 14(3) of the Act, the abstraction and use of groundwater from any of the following sources is a non-complying activity:*
  - (iii) *A confined aquifer where pumping of an individual bore results in a maximum reduction of between 25 and 50 percent in the potentiometric head at a distance of 250 metres from the pumped bore.*

Appendix A of the Regional Water Plan also outlines information required to be submitted to support applications for resource. These information requirements are of direct relevance to the assessment and management of potential environmental effects associated with groundwater abstraction and include:

*In the case of a groundwater take from a confined aquifer, the assessment of environmental effects outlined above shall include:*

- *appropriate bore construction standards*
- *an analysis of aquifer leakage*
- *interference effects*
- *radius of influence*
- *net use*
- *saltwater intrusion potential*
- *estimation of aquifer recharge/discharge characteristics*

*Where the take is a discretionary activity under Rule 23, the assessment shall also include:*

- *hydrochemical identification of recharge sources*
- *a detailed assessment of water balance*
- *an assessment of the impact of abstraction on adjacent water resources (throughflow, spring discharge, leakage)*

*Where the take is a non-complying activity under Rule 23, the assessment should also include (in addition to the matters outlined above):*

- *numerical modelling*

### **2.3 Application of Existing Policy Provisions to Management of Confined Aquifers**

As a result of groundwater development occurring since the early 2000's, at least four separate confined aquifer systems have been identified in the Southland Region. These include the Lumsden, North Range and Lintley aquifers in the Oreti Basin and the Garvie Aquifer underlying the Wendonside Terrace in the Mataura catchment. The Tertiary lignite measure deposits of the Eastern Southland Group which underlie Quaternary gravel deposits across the Southland Plains and Waimea Valley also host an extensive, but poorly defined, system of confined aquifers. Confined aquifers may also be present in other areas of Southland such as the Aparima Catchment and Te Anau Basin where to date there has been limited exploration of the groundwater resource potential below the shallow unconfined aquifers.

In many cases due to the limited data available to characterise aquifer hydrogeology, resource consent applications in confined aquifers have presented a challenge for groundwater resource management, particularly in terms of assessing aquifer sustainability and potential cumulative well interference effects. In order to provide a means of allocating water that addresses long-term aquifer sustainability and the potential effects of abstraction on the reliability of supply for existing users a majority of consents have been subject to conditions that include:

- A condition limiting the rate of abstraction to no more than 50 percent of the maximum consented rate if groundwater levels in a nominated monitoring bore reach an initial trigger level;
- A condition requiring abstraction to cease when groundwater levels in a nominated monitoring bore fall below a second trigger level (generally set at 1 metre lower than the initial trigger level); and
- A condition triggering a review of consent if seasonal recovery is inadequate (typically determined as either metre drop in groundwater levels between the commencement of consecutive irrigation seasons that exceeds a nominated figure or a larger decline in levels over three consecutive irrigation seasons).

These conditions have typically been intended to implement the intent Rule 23 c, d and e (in terms of aquifer drawdown). However, in reality, these conditions fail to effectively implement the policy intent of Rule 23, particularly in terms of activity status and provide little guidance as to the potential effect of further allocation on aquifer sustainability and reliability of supply for existing users. In addition these conditions have been implemented in a relatively ad hoc manner through the resource consent process so do not apply universally and equally to all relevant consents.

### **2.4 Application of Existing Policy Provisions to Management of Fractured Rock Aquifers**

Extensive fractured rock aquifer systems exist in the Southland Region, generally around the periphery of the Southland Plains and inland basins where Quaternary and/or Tertiary sediments are absent and basement rocks are exposed near the land surface. These geological units include:

- The Murihiku Terrane which forms the Catlins Block and Hokonui Hills and underlies much of the Southland Plains;
- The Dun Mountain-Matai and Caples Terrain exposed in hills and mountains in the Northern Southland area; and
- The Brooks Street Terrain which forms the Longwood Range and Takitimu Mountains; and
- The various schist and granitoid rocks forming Stewart Island and the Fiordland Mountains.

Fractured rock aquifers may also include groundwater resources hosted within limestone strata within the Tertiary sediments underlying the more Quaternary gravel deposits. These aquifer systems host a groundwater resource within jointing and fracturing within the rock mass and in places may also have developed secondary permeability within solution cavities (e.g. the upper portion of limestone deposits forming Winton Hill).

As described in **Section 1.2**, fractured rock aquifers commonly contain extensive groundwater resources hosted in discontinuities (jointing, fracturing and faulting) within the overall rock mass. Due to the irregular nature of the secondary permeability in these geological materials, aquifer hydraulic characteristics and available long-yield are generally highly location-specific. As a consequence, although different areas of an individual fractured rock aquifer may exhibit similar hydraulic characteristics, groundwater allocation cannot be managed on a global basis for these aquifers in the same way it can in sedimentary aquifers. For this reason, although recognised as a distinct aquifer type in the Regional Water Plan (Policy 30), fractured rock aquifers were not included in the stage management approach developed for other aquifer types (Rule 23). This means there are currently no allocation limits set for fractured rock aquifers which extend across a significant area of the Southland Region and no information requirements outlined in Appendix A.

## 2.5 Limitations of the Current Management Approach

Experience with the practical application of existing RWP provisions for the management of confined aquifers suggests that the current policies and rules are not particularly effective for a range of reasons including:

- Provisions of Rule 23 relating to establishing activity status on the basis of potential drawdown at a point 250 metres from the pumped bore do not provide an effective means of managing multiple abstractions from confined aquifers, particularly in terms of future allocation and overall aquifer sustainability;
- There is a lack of long-term groundwater level monitoring data which can be utilised to determine both natural seasonal variation in aquifer storage in relation to climate variability and to determine the long-term effects of existing levels of abstraction on aquifer sustainability. It is also difficult to determine overall aquifer sustainability when actual groundwater use is unknown or lower than consented volumes;
- In the absence of effective rules and policies to manage groundwater abstraction from confined aquifers, pumping regulation based on minimum groundwater level cut-offs and seasonal recovery have been implemented via consent conditions on a majority of groundwater takes. While these measures are able to provide a baseline to ensure aquifer sustainability they provide

limited guidance for future allocation and may result in equity issues for individual resource users;

- Current management provisions for interference effects are not particularly effective in terms of managing the cumulative drawdown effects resulting from abstraction on the reliability of supply for individual resource users;
- The limited ability to factor in the cumulative effects of abstraction on hydraulically connected water resources, particularly in regard to leakage induced by pumping and the need for integrated management of unconfined and underlying confined aquifers where appropriate; and
- The potential for localised drawdowns to impact on water levels in monitoring bores which are utilised as a minimum level reference site for a number of consents.

Due to their physical characteristics the absence of allocation limits for Fractured Rock aquifers is not generally an environmental issue for groundwater management. In this hydrogeological setting the typically low hydraulic conductivity and limited interconnection between waterbearing zones effectively limits aquifer sustainability and associated environmental effects (e.g. well interference and stream depletion) to a localised issue around individual pumping bores. However, the absence of allocation limits has the potential pose an issue for resource management in the case of large-scale or competing development groundwater development.

The lack of allocation limits for Fractured Rock aquifers may also be problematic if the Proposed National Standard on Ecological Flows and Water Levels were to become operative in its current form. The NES proposal would establish default allocation limits for aquifers where no equivalent measure is established in a Regional Plan based on 35 percent of average annual recharge. In an aquifer system as extensive as the Catlins groundwater zone such an allocation limit would essentially be meaningless due to the localised effects of groundwater abstraction.

In addition, to specific management issues related to Confined and Fractured Rock aquifers, there are a number of other resource management issues which, although not exclusively restricted to confined aquifers, reduce the ability of Environment Southland to effectively manage the regions groundwater resources. These issues are addressed in greater detail in the **Section 3** of this report and include:

- Common expiry dates;
- Supplementary allocation; and
- Situations of over-allocation.

## **2.6 Summary**

The existing framework for groundwater allocation was developed by Environment Southland in 2003 in response to rapidly increasing allocation of groundwater for consumptive use. This framework established a staged allocation system for unconfined aquifers based on the cumulative volume of allocation as a percentage of aquifer recharge. Due to the limited knowledge of the spatial extent and physical characteristics of confined aquifers at the time of plan development a similar water balance approach was not considered feasible for this aquifer type. As an alternative, the management framework for confined aquifers was based on ensuring drawdown resulting from abstraction did not exceed nominated thresholds.

However, difficulties have arisen with the application of the management framework for confined aquifers outlined in the RWP particularly with regard to ensuring the overall policy objective of aquifer sustainability, particularly with respect to management of the cumulative effects of abstraction from multiple bores. These issues include:

- Difficulties interpreting Rule 23 criteria in terms of establishing activity status and the overall sustainability of abstraction;
- Ensuring reliability of supply for existing groundwater users;
- Assessment of potential well interference effects;
- Arbitrary application of minimum water level controls; and
- Localised drawdown effects on monitoring bores linked to minimum level cut-offs.

In addition, the RWP currently does not establish allocation limits for fractured rock aquifers. While this has not been an issue to date, it could hinder effective management of these groundwater resources in the future if large scale development were to occur or the Proposed NES on Ecological Flows and Water Levels were to be adopted in its current form.

## 3. An Alternative Management Approach

### 3.1 Management of Confined Aquifers

#### 3.1.1 Classification

As described in **Section 1.2** aquifers exist along a continuum between unconfined and fully confined conditions with few, if any, aquifers exhibiting an 'ideal' confined aquifer response. In terms of groundwater management it is therefore difficult to define an exact point at which an aquifer system is best managed as an unconfined or confined aquifer system. Generally, the rate of leakage from other hydraulically connected groundwater resources in response to abstraction is the most important factor in determining whether a confined aquifer is best managed as a separate resource or as part of a larger groundwater flow system.

Issues associated with quantifying and managing potential leakage in response to abstraction from confined aquifer is discussed in some detail in a recent report (Lough and Williams, 2009) prepared for Environment Canterbury. This report concluded that within the context of the Canterbury Plains setting, pumping from any depth within alluvial gravel systems has the potential to result in a reduction in the water table equivalent to the volume of water pumped from the well but this response may occur over a long time interval and be partially offset by natural aquifer recharge.

In the context of groundwater resources in the Southland Region available data suggest the presence of three distinct confined aquifer systems that can, for the purposes of managing aquifer sustainability and overall environmental effects, effectively be managed separately from overlying unconfined aquifer systems. These include:

- The Lumsden Aquifer;
- The North Range Aquifer; and
- The Garvie Aquifer.

There are also likely to be other, as yet undefined, aquifer systems hosted in both the alluvial gravel basins and Tertiary deposits that are best managed as confined aquifers.

Elsewhere there may also be aquifer systems (such as the Lintley Aquifer near Lumsden) which exhibit hydraulic characteristics (i.e. sufficient leakage in response to pumping) which mean groundwater allocation and associated environmental effects are best managed as part of the allocation from overlying unconfined aquifer systems. In this case Environment Southland should include allocation from these aquifer systems within that calculated for overlying unconfined groundwater zones rather than managing allocation separately.

In many cases, the information available to establish the basis for sustainable management of confined aquifers only becomes available as a result of resource development as well as monitoring and investigations undertaken by Environment Southland. The quality and detail of this information (particularly with regard to the dynamic response of the aquifer to abstraction) increasing with ongoing use and development of the resource. It is therefore difficult to determine a set framework or criteria for management of aquifers in terms of a fixed 'degree' of confinement. This classification is best made by Environment Southland based on available information in a manner that initially adopts a



conservative approach to aquifer sustainability that can be subsequently modified to incorporate improved understanding of aquifer hydrogeology.

The requirement to classify aquifer confinement during the initial stages of resource development does however place a significant emphasis on ensuring high quality aquifer test data are available to support individual resource consent applications (this issue is further discussed in the following section).

### Recommendation

*That Environment Southland adopts an approach to classification of aquifer confinement for the purposes of sustainable resource management based on an assessment of available hydrogeological information on a case-by-case basis. Information used to support this determination should be included within information requirements outlined in Appendix A of the Regional Water Plan supplemented by investigations and monitoring undertaken by Council.*

*Where an aquifer is determined to be sufficiently confined to warrant management as a separate groundwater resource a preliminary allocation volume should be developed based on the proposed methodology detailed in **Section 3.1.3** below.*

*Where confined aquifer is considered sufficiently 'leaky' allocation should be managed in as part of that calculated for hydraulically connected groundwater or surface water resources (such as unconfined aquifers). In this situation Environment Southland should develop a methodology for including allocation from the 'leaky' aquifer within totals calculated for relevant hydraulically connected water resource (groundwater or surface water). It is noted anomalies may occur between the spatial extent of deeper 'leaky' waterbearing layers and groundwater management zones defined for overlying unconfined aquifers requiring allocation from deeper aquifers to be attributed to the relevant groundwater management zones on a pro-rata basis.*

*Once an aquifer is classified as confined (i.e. with allocation to be managed separately from other adjacent groundwater resources), Environment Southland should endeavour to document relevant hydrogeological information along with levels of existing information in a form that is accessible to potential resource consent applicants. This assessment should be updated on a regular basis as information becomes available to improve characterisation of aquifer hydrogeology.*

### **3.1.2 Information Requirements**

As described in the previous section, a critical step in assessing potential environmental effects associated with groundwater abstraction from confined aquifer systems is the development of a conceptual model of aquifer hydrogeology. This model includes consideration of the geometry and hydraulic characteristics of the aquifer system as well as the nature of potential interaction with hydraulically connected water resources in response to abstraction. A range of hydrogeological information required to support this assessment is outlined in Appendix A of the RWP. For confined aquifers these information requirements include:

*In the case of a groundwater take from a confined aquifer, the assessment of environmental effects ....shall include:*

- *appropriate bore construction standards*

- *an analysis of aquifer leakage*
- *interference effects*
- *radius of influence*
- *net use*
- *saltwater intrusion potential*
- *estimation of aquifer recharge / discharge characteristics*

*Where the take is a discretionary activity under Rule 23, the assessment shall also include:*

- *hydrochemical identification of recharge sources*
- *a detailed assessment of water balance*
- *an assessment of the impact of abstraction on adjacent water resources (throughflow, spring discharge leakage, stream depletion effects)*

*Where the take is a non-complying activity under Rule 23, the assessment shall also include (in addition to the matters outlined above):*

- *Numerical modelling*

Assessment of such information supplied with resource consent applications forms a critical component of the staged management approach which seeks to ensure information gained from resource development is utilised to inform decision-making in regard to future water allocation. However, experience suggests that that these information requirements are often not addressed in individual resource consent applications placing the onus on Environment Southland to collect and/or analyse available data in order to determine potential environmental effects associated with the proposed abstraction. This issue is of particular relevance when assessing resource consent applications for groundwater abstractions in confined aquifer systems where there are significant gaps in hydrogeological understanding.

#### Recommendation

Include a specific policy reference in the RWP requiring applications for resource consent to abstract water from confined aquifers to be supported by a conceptual hydrogeological model that is relevant to the level of resource development. Requirements for analysis to potential environmental effects of the proposed abstraction could be outlined in an amended Appendix A which requires:

*In the case of groundwater abstraction from a confined aquifer the application shall be accompanied by an assessment of environmental effects which addresses:*

- *Adequacy of bore construction and yield;*
- *Long-term aquifer sustainability;*
- *Cumulative well interference effects;*
- *Potential effects on hydraulically connected water resources;*
- *Seawater intrusion potential in coastal aquifers; and*
- *Land subsidence.*

*This assessment shall be informed by a conceptual hydrogeological model that is appropriate for the level of resource development.*

Where the application is classified as a restricted discretionary activity assessment of potential effect should include consideration of the following:

- An assessment of local geology to identify the lateral continuity of potential waterbearing and aquitard units within the lithological sequence;
- Aquifer test results which include observation bores screened at appropriate depths to identify potential recharge boundary/leakage response. Analysis of aquifer tests should be undertaken using appropriate assessment techniques to identify and characterise any leaky aquifer response observed;
- Analysis of relative water levels between the proposed confined aquifer and other adjacent aquifer systems including determination of relative groundwater levels to determine hydraulic gradients and flow directions; and
- Assessment of aquifer throughflow

Where the activity is classified as a discretionary activity assessment of potential effects should satisfy the information requirements for a restricted discretionary activity and also include:

- Assessment of temporal groundwater level variations to characterise potential aquifer recharge mechanisms;
- Analysis of water chemistry, including stable isotopes (e.g.  $^3\text{H}$  and  $\text{O}_{18}$ ) to identify potential difference in residence time; and
- A detailed assessment of aquifer water balance.

Where the application is for a non-complying activity assessment of potential effects should satisfy the information requirements for a discretionary activity and also include:

- Application of relevant analytical or numerical modelling techniques to quantify impacts of abstraction.

Although not necessarily forming part of the RWP Appendix A information requirements, it is recommended that Environment Southland establish guidelines for aquifer testing to support resource consent applications for groundwater abstraction from confined aquifers. While a degree of flexibility may be required to take account of site-specific factors, such a guideline would ensure that aquifer tests are undertaken to a consistent minimum standard. Suggested minimum aquifer test specifications for confined aquifers are outlined in **Table 1** below.

**Table 1. Minimum aquifer test requirements to support management of allocation from confined aquifers.**

Size of take (m <sup>3</sup> /day)	Minimum Aquifer Test Requirements
<250	Standard yield test – 2 hour pumping test at the required rate and measurement of recovery
250 to 750	<ol style="list-style-type: none"> <li>1. A step-drawdown aquifer test comprising a minimum of 3, 1 hour pumping steps followed by measurement of recovery. Maximum pumping rate should equal to required pumping rate.</li> <li>2. A 24-hour constant-rate aquifer test undertaken at the required pumping rate. Water level monitoring should include drawdown and recovery (to within 10% of initial static water level) in the pumped bore in at least one observation bore within the area of localised drawdown.</li> </ol>

>750	<ol style="list-style-type: none"> <li>1. A step-drawdown aquifer test comprising a minimum of 3, 1 hour pumping steps followed by measurement of recovery. Maximum pumping rate should equal to required pumping rate</li> <li>2. A 72-hour constant-rate aquifer test undertaken at the required pumping rate. Water level monitoring should include drawdown and recovery (to within 10% of initial static water level) in the pumped bore and at least two observation bores in the source aquifer and one observation bore in the overlying aquifer within the area of localised drawdown.</li> </ol>
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### 3.1.3 Establishing Sustainable Abstraction

SKM (2008) proposed an alternative method for establishing sustainability in confined aquifers intended to address some of the shortcomings in the current management approach including the need to establish allocation on the basis of overall water balance rather than localised aquifer response even when information available to characterise aquifer hydrogeology is limited. This method was based on the application of aquifer throughflow as a measure of the overall long-term water balance of the aquifer system.

Under natural conditions the volume of water flowing through a given cross section of an aquifer system (termed throughflow in this report) represents a balance between aquifer recharge and discharge. The storage of water within the aquifer system (represented by changes in groundwater levels) provides a buffer between variable climate-driven recharge processes and the relatively constant outflow the aquifer system occurring via spring discharge and more general leakage to other hydraulically connected water resources.

Following Darcy's Law, the volume of water flowing through a given cross section of an aquifer system is dependent on the permeability of the aquifer materials, the cross sectional area of the aquifer and the hydraulic gradient:

$$Q = K \times A \times \frac{dh}{dl}$$

where:

Q = flow through aquifer system

K = hydraulic conductivity of aquifer materials

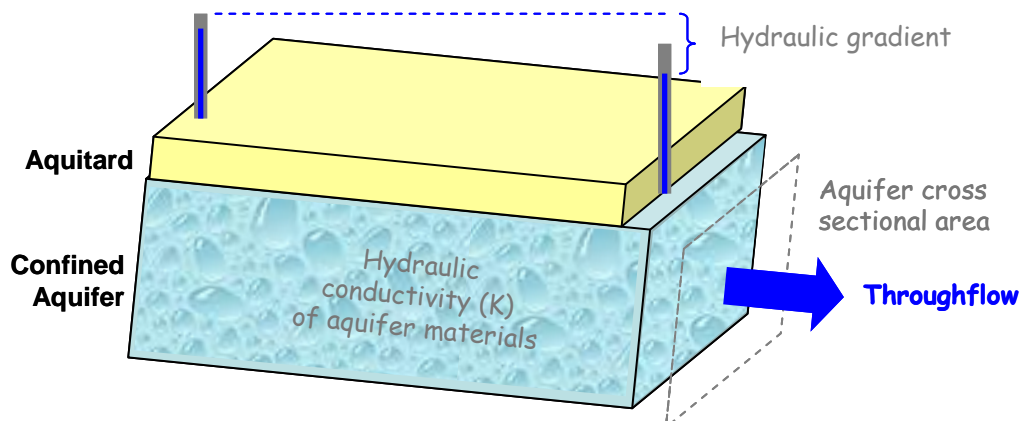
A = cross sectional area of aquifer system

$\frac{dh}{dl}$  = hydraulic gradient<sup>8</sup>

Given that aquifer properties and dimensions are effectively fixed, aquifer throughflow is therefore proportional to the hydraulic gradient in the aquifer system. **Figure 3** provides a schematic illustration of throughflow in a confined aquifer system.

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<sup>8</sup> This may also be referred to as the *piezometric gradient*



**Figure 3. Schematic illustration of throughflow in a confined aquifer.**

Calculation of aquifer throughflow can be undertaken by a variety of means ranging from simple estimates based on measured aquifer characteristics through to detailed numerical modelling studies. In its most basic application, throughflow can be estimated from relatively simple measurements of the physical characteristics of an aquifer system including:

- Aquifer permeability - derived from analysis of aquifer test results. Commonly expressed in terms of transmissivity (T) which is equivalent to hydraulic conductivity multiplied by aquifer thickness;
- Aquifer cross sectional area - given that aquifer thickness is inherent in calculation of transmissivity, estimation of aquifer throughflow requires an estimate of a representative aquifer width perpendicular to groundwater flow; and
- Hydraulic gradient - estimation of hydraulic gradient requires measurement of piezometric levels at a minimum of three points within an aquifer system. This allows identification of relative hydraulic gradient perpendicular to groundwater flow direction.

For example, a confined aquifer system with a measured aquifer transmissivity of 1000 m<sup>2</sup>/day, a width of 4000 m and a hydraulic gradient of 0.001 will have a calculated throughflow of 4,000 m<sup>3</sup>/day. On an annual basis this equates to a throughflow of 1,460,000 m<sup>3</sup>. This calculation may be suitable to establish basic aquifer sustainability criteria where the level of allocation is low compared to overall aquifer water budget.

During the initial stages of resource development throughflow estimates of aquifer throughflow made by Environment Southland should be based on conservative assumptions (in terms of aquifer transmissivity and dimensions) and place the onus on future resource consent applicants to prove that additional allocation is within a valid throughflow estimate which may be updated by additional hydrogeological information.

#### Recommendation

*That Environment Southland adopt aquifer throughflow as the primary measure of sustainability in confined aquifers.*

### 3.1.4 Staged Management Approach

The current staged management approach offers advantages in a region such as Southland where knowledge of the Regions aquifer systems is generally insufficient to establish reliable calculations of aquifer sustainability. The current approach allows knowledge gained by the initial stages of resource development to inform subsequent decision making on future water take applications.

Following the discussion outlined in **Section 3.1.3** it is suggested that the existing provisions of Rule 23 relating to confined aquifers should be replaced with an equivalent controls based on aquifer throughflow. Setting 25% of aquifer throughflow as a threshold for groundwater abstraction from confined aquifers as a restricted discretionary would enable the initial stages of resource development to proceed based on a relatively basic level of hydrogeological understanding, particularly if the 2 L/s threshold for the maximum size of take currently specified in Rule 23 is retained.

Applying an upper limit of 75% percent of aquifer throughflow for discretionary takes enables a relatively high level of resource development to occur in confined aquifers subject to assessment of potential effects based on available hydrogeological data. Classifying takes where allocation is in excess of 75% percent of throughflow as non-complying would ensure a high level of assessment is available to support granting of further consents for groundwater abstraction when total allocation is approaching the total aquifer water budget.

Classification of activity status for groundwater takes from confined aquifers should include consideration of the potential for throughflow estimates to change as additional or improved information becomes available. Initial estimates of aquifer throughflow made by Environment Southland should be based on conservative assumptions and place the onus on future resource consent applicants to prove that additional allocation is within a valid throughflow estimate. Such estimates, based either on water balance or numerical modelling, should be validated by appropriate resource monitoring including soil moisture, river flow, groundwater level and water use data.

#### Recommendation

*That the criteria currently utilised to establish activity status for groundwater abstraction from confined aquifers under Rule 23 of the Regional Water Plan be amended in line with the criteria outlined in **Table 2**.*

**Table 2. Proposed criteria for allocation from confined aquifers**

<b>Activity Status</b>	<b>Criteria</b>	<b>Information requirements<sup>9</sup></b>
Restricted Discretionary	Takes less than 2 L/s where allocation is up to 25 % of estimated aquifer throughflow	<ul style="list-style-type: none"> <li>▪ <i>An assessment of local geology</i></li> <li>▪ <i>Aquifer test results to identify potential recharge boundary/leakage response.</i></li> <li>▪ <i>Analysis of relative water levels between the proposed confined aquifer and other adjacent aquifer systems including determination of relative groundwater levels to determine hydraulic gradients and flow directions;</i></li> <li>▪ <i>Assessment of aquifer throughflow</i></li> </ul>

<sup>9</sup> Information requirements derived from proposed revisions to Appendix A requirements outlined in **Section 3.1.2**

Activity Status	Criteria	Information requirements <sup>9</sup>
Discretionary	Takes greater than 2 L/s where allocation is less than 75% of estimated aquifer throughflow	<ul style="list-style-type: none"> <li>▪ <i>Hydrochemical identification of recharge sources</i></li> <li>▪ <i>A detailed assessment of aquifer water balance</i></li> <li>▪ <i>An assessment of the impact of abstraction on adjacent water resources (throughflow, spring discharge leakage, stream depletion effects)</i></li> </ul>
Non-Complying	Allocation >75% of estimated throughflow	<ul style="list-style-type: none"> <li>▪ <i>Application of relevant analytical or numerical modelling techniques to quantify impacts of abstraction</i></li> </ul>

### 3.1.5 Application of Minimum Level Cut-offs and Seasonal Recovery Criteria

As described in **Section 2.3**, application of minimum level cut-back/cut-off and seasonal recovery conditions on individual resource consents provides a means of managing groundwater abstraction from confined aquifers to ensure maintenance of long-term aquifer storage volumes and security of supply for resource users.

It is noted however that establishing appropriate cut-off levels for individual resource consents can be a subjective process, particularly when aquifer response to existing levels of allocation has not been reliable established. As a guide it is suggested that minimum level cut-offs for initial groundwater takes from confined aquifers should be established to ensure drawdown (at any point within the aquifer system) does not exceed the available artesian potentiometric at any point in the aquifer (i.e. to ensure the aquifer remains confined). Subsequent consents may have progressively higher minimum levels established to protect the reliability of supply for first-in users based on observed drawdown in response to abstraction.

#### Recommendation

*That specific reference to minimum level cut-offs and seasonal recovery triggers as potential management tools to assist sustainable management of confined aquifers be included in Policy 30.*

### 3.1.6 Interference Effects

Policy 31 of the RWP establishes a limit for the allowable interference effect of any new groundwater abstraction as:

*'..no more than 20 percent of the available drawdown in any neighbouring bore providing the bore is lawfully established and adequately penetrates the aquifer'.*

The intent of the policy is further expanded in the explanation for the policy which states that:

*'This policy sets a figure of 20 percent of the available saturated thickness below the piezometric (or potentiometric in the case of confined aquifers) level that is exceeded 50 percent of the time.'*

In practice this policy has proved problematic to implement in confined aquifers for a number of reasons including:

- It does not adequately recognise differences in the nature of water level drawdown between confined and unconfined aquifers; and
- The policy explanation states that the allowable interference effect in confined aquifers is based on a percentage of the available saturated thickness rather than the potentiometric head in the aquifer.

The original background technical document<sup>10</sup> covering interference effects prepared to support Variation 2 to the Regional Water Plan proposed that the available drawdown in a confined aquifer be defined as the '*average potentiometric head above the top of the confining layer*'. The most critical part of this definition is that it established the top of the confining layer as the maximum drawdown available for the aquifer to remain confined (drawdown exceeding this figure will result in the aquifer becoming locally unconfined as water is physically drained from the aquifer materials).

It is also now recognised that establishing 20% of available drawdown as the maximum figure for well interference fails to adequately recognise difference in drawdown characteristics between unconfined and confined aquifers (as explained in **Section 1.2**) and does not include cumulative effects of multiple groundwater takes. It is therefore suggested that the maximum cumulative interference effect between neighbouring bores in confined aquifers be increased to 50 percent of the potentiometric head. This figure being more in line with potential cumulative drawdown for groundwater takes classified as discretionary activities under the proposed amendments to Rule 23 (see **Section 3.1.4**).

Another issue with the existing interference effects policy include potential subjectivity in interpretation of the policy as to whether the allowable drawdown relates to the drawdown resulting from an individual pumped bore or the cumulative interference effect where there are multiple bores pumping from the same aquifer.

Also, Policy 31 refers to the interference effect on bores which are '*lawfully established and adequately penetrate the aquifer*'. Some issues have arisen with regard to definition of adequate penetration in the case where existing bores and wells are of 'adequate' depth to access water under existing levels of allocation but may not remain so if additional allocation is granted. As a result, further clarity is required to establish that well interference effects will be assessed based on an assumption that bores fully penetrate the entire saturated thickness of the source aquifer.

#### Recommendation

That Policy 31 of the RWP be amended to clarify reference to the allowable drawdown in confined aquifers resulting from the cumulative effects of abstraction in the source aquifer.

*Limit the cumulative interference effect of any new groundwater abstraction (in conjunction with other lawfully established groundwater takes) to no more than 20 percent of the available drawdown in an unconfined aquifer or 50 percent of the potentiometric head in a confined aquifer, provided the neighbouring bore is lawfully established and fully penetrates the aquifer.*

#### *Explanation*

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<sup>10</sup> Appendix 5 *Interference Effects Between Bores to Variation 2 (Groundwater) to the Regional Water Plan for Southland* (P:\Policy\_Planning\Water Plan Development\Variation 2–Groundwater\Notified Variation & Report\Appendix 5.doc)



*Paragraph 3....This policy sets a figure of 20 percent of the available saturated thickness below the piezometric level (or 50 percent of potentiometric head in the case of a confined aquifer) that is exceeded 50 percent of the time*

*Paragraph 4....The interference effect of any new groundwater abstraction will be assessed as though all existing neighbouring bores and wells fully penetrate the aquifer.*

In developing policies to manage well interference effects it needs to be recognised that situations may arise where it may be appropriate to allow well interference effects to exceed the thresholds established in Policy 31. Such situations may include aquifer testing, construction activities or long-term dewatering to enable mining development. Such cases are best dealt with on an individual basis which ensures such activities are undertaken under controlled conditions where appropriate monitoring and environmental safeguards are established.

#### Recommendation

*Add comment regarding possible exceptions for activities including aquifer testing, construction dewatering and mining to the explanation for Policy 31.*

Given the importance of groundwater level monitoring to sustainable management of confined aquifers it is critical that monitoring sites are not significantly impacted by localised drawdown from individual groundwater takes. Such drawdown may have a significant impact on the quality of data available to characterise long-term trends in aquifer storage in response to the combined effects of groundwater abstraction and climate variability as well as reducing the reliability of supply for individual users who have pumping restrictions based on trigger levels in the monitoring bore. It is therefore suggested that the interference effect resulting from abstraction from any individual bore on a designated Environment Southland water level monitoring site be limited to less than 20 percent<sup>11</sup> of the potentiometric head in the monitoring bore.

#### Recommendation

*The reference be made in Policy 31 (or a separate policy) to limit the interference effect on any individual pumping well on any bore utilised for long-term monitoring of water levels in any confined aquifer to no more than 20 percent of the available potentiometric head that is exceeded 50 percent of the time.*

### **3.2 Fractured Rock Aquifers**

As described in **Section 1.2** fractured rock aquifers present a special case for management of groundwater allocation which is distinct from that utilised for sedimentary (i.e. gravel and sand) aquifers. In particular, due to the dependence of aquifer hydraulic properties (and consequent groundwater storage and recharge characteristics) on local geological conditions, allocation from these aquifer systems has to be managed on a localised rather than an aquifer-scale basis.

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<sup>11</sup> It is recognised that in a confined aquifer drawdown resulting from an individual groundwater take can extend over a relatively extensive area. It is proposed that well interference from any individual groundwater take should not exceed 20% of the potentiometric head to avoid water level monitoring records being significantly impacted by localised drawdown.

### 3.2.1 Establishing Sustainable Abstraction

In order to manage groundwater allocation from fractured rock aquifers it is suggested that Environment Southland adopt a simple methodology for establishing sustainability in fractured rock aquifers on a localised basis. The simplest approach would be to ensure that groundwater abstraction does not exceed a nominated percentage of local groundwater recharge. The most practical basis for such a methodology would be to compare groundwater allocation to recharge on a 'per landholding' basis similar to that utilised to define permitted use under Rule 23.

**Table 3** provides a possible staged framework for allocation of groundwater from fractured rock aquifers. Although the thresholds for determining activity status are somewhat arbitrary, they follow the principle utilised for other aquifer types whereby information requirements to support resource consent applications escalate as the level of allocation increase. Using this framework activity status can be established relatively simply based on existing estimates of groundwater recharge (e.g. Lincoln Environmental, 2003) and cadastral data.

#### Recommendation

*That Environment Southland add the following criteria for establishing activity status for groundwater abstraction from fractured rock aquifers to Rule 23 and Appendix A of the RWP:*

**Table 3. Proposed criteria for allocation from fractured rock aquifers**

Activity Status	Criteria	Information requirements <sup>12</sup>
Restricted Discretionary	Takes less than 2 L/s where allocation is up to 25 % of estimated groundwater recharge on the relevant landholding	<ul style="list-style-type: none"> <li>▪ Assessment of potential aquifer recharge on relevant landholding</li> <li>▪ Aquifer test results to identify local hydraulic characteristics.</li> </ul>
Discretionary	Takes greater than 2 L/s <u>or</u> where allocation is between 25% to 50% of estimated groundwater recharge on the relevant landholding	<ul style="list-style-type: none"> <li>▪ Assessment of cumulative effects of water abstraction on neighbouring landholdings</li> <li>▪ Aquifer test results adequate to characterise long-term aquifer response to abstraction</li> <li>▪ Assessment of potential effects of abstraction on hydraulically connected surface water</li> </ul>
Non-Complying	Allocation >50% of estimated groundwater recharge on the relevant landholding	<ul style="list-style-type: none"> <li>▪ Detailed assessment of local hydrogeological setting including aquifer recharge and discharge characteristics</li> <li>▪ Analytical or numerical modelling of long-term effects of abstraction</li> </ul>

The RWP currently establishes two groundwater management zones for fractured rock aquifers (Catlins and Hokonui). Due to the localised nature of resource management required for fractured rock aquifers these groundwater zones have little, if any practical application for management of

<sup>12</sup> Information requirements derived from proposed revisions to Appendix A requirements outlined in **Section 3.1.2**

groundwater allocation. In addition, there are also large areas where groundwater resources occur but which are not currently included within any defined groundwater zones. These areas may include fractured rock aquifers (i.e. in areas such as Stewart Island or Fiordland) as well as sedimentary aquifer systems (such as in the Nokomai Valley, upper Waikaia catchment and Eastern Bush areas).

In order to manage groundwater allocation from these areas it is suggested that the methodology proposed in Section 3.2.1 be applied to all areas (including the existing Catlins and Hokonui groundwater zones) outside of the groundwater management zones defined in Appendix H of the RWP. This approach would ensure all areas of Southland are included within a groundwater allocation framework which provides a conservative methodology for establishing aquifer sustainability.

As additional hydrogeological information becomes available, particularly in areas of sedimentary deposits not included within existing groundwater management zones, Environment Southland may wish to add additional groundwater management zones to Appendix H by way of a plan change to the RWP. However, in the interim, application of the allocation methodology proposed in Section 3.2.1 to these areas should ensure sustainable management of the groundwater resource in these areas.

#### Recommendation

*That Environment Southland remove reference to the Catlins and Hokonui groundwater zones from Appendix H of the RWP and identify that the proposed staged allocation framework proposed in Section 3.2.1 apply to all areas outside the groundwater zones identified in Appendix H.*

### **3.3 Sustainable Groundwater Management**

#### **3.3.1 Supplementary Allocation**

Compliance monitoring currently indicates that in a majority of aquifer systems (including confined aquifers) actual groundwater use is significantly lower than allocated volumes. This may occur where water is allocated to a high level of reliability (e.g. sufficient to meet water demand in a drought event that would occur very infrequently) meaning full allocations are rarely, if ever, fully utilised. This results in a situation where allocative efficiency is sub-optimal (i.e. a significant proportion of water allocated is never used)

Provided existing allocations are within sustainable limits the discrepancy between allocation and actual use may lead to situations where it is possible to allocate more water from an aquifer system (including confined aquifers) than is provided for within primary allocation limits established on the basis of average annual recharge (or throughflow in the case of confined aquifers). This potential for supplementary allocation may arise in situations where:

- Actual abstraction is consistently lower than seasonal allocation; and
- Groundwater level monitoring indicates that aquifer storage is sufficiently above levels required to maintain ongoing aquifer sustainability either on an inter-annual or long-term basis; and
- Where recharge to aquifer systems is enhanced by artificial means.

Supplementary groundwater allocation would be analogous to that provided for surface water in RWP Policy 15(g)(iii) which enables water in excess of the primary allocation to be abstracted from rivers and streams when flows are sufficiently high. This allocation is typically available only at restricted

times meaning it has a relatively low reliability of supply which may be suitable for storage or out-of-season uses. A similar provision applying to groundwater would enable Environment Southland to allocate additional water from confined aquifers if aquifer storage (due to low levels of actual use or above average (or artificial) recharge) is more than that required to ensure the ongoing sustainability of primary allocation (i.e. allocation made under the criteria proposed in Section 3.1.4). Such supplementary allocation would have to be subject to appropriate minimum level cut-offs appropriate to maintain reliability of supply for existing users and ensure long-term aquifer sustainability and may have a low supply reliability.

#### Recommendation

*That Environment Southland include a provision under Policy 30 that would enable supplementary allocation of groundwater subject to appropriate controls to ensure aquifer sustainability and reliability of supply for existing users.*

### **3.3.2 Common Expiry Dates**

Common consent expiry dates provide a potential mechanism to assist sustainable management of groundwater allocation from confined aquifers. Such a process would enable cumulative effects from all takes to be considered at the same time and avoid the need for individual consents applications to be assessed as and when they expire. This would enable Environment Southland to evaluate cumulative effects and apply appropriate management controls in a consistent and transparent manner to all consents at the same time rather than in a relatively ad-hoc manner through the resource consent process. Such a process would also reduce costs for consent applicants where replacement applications for a number of consents from the same aquifer are processed concurrently.

Provision for common expiry dates is included within Proposed Plan Change 3 (Community Water Supplies) to the RWP currently being notified by Environment Southland. Application of common expiry date provisions contained in this variation to management of confined aquifers would potentially offer a number of benefits in terms of efficient and consistent management of the groundwater resource.

### **3.3.4 Realigning Over-Allocation**

Where monitoring suggests that current levels of abstraction from a confined aquifer are not sustainable (i.e. are resulting in an ongoing decline in groundwater storage that is inconsistent with Policy 28), Environment Southland may be required to implement a range of measures to ensure that allocation does not adversely impact on the sustainability of the resource. Such measures may include:

- Establishment of an aquifer users groups. Such groups can be utilised as a means to inform consent holders in regard potential concerns regarding sustainability of the resource and to investigate voluntary methods to reduce groundwater usage to more sustainable levels;
- Initiatives to ensure efficient utilisation of water including the provision of soil moisture data to inform management of pasture irrigation;

- Where voluntary means are not sufficient to ensure sustainability of the resource, implementation of pro-rata reductions in seasonal allocation through consent reviews or at the time of consent renewal;
- As an alternative to regulatory review, enabling variable seasonal allocation to be determined on a 'resource share' basis. This would enable Environment Southland to establish the volume of allocation available in any given year on the basis of aquifer storage (or other hydrogeological criteria) at a pre-determined time with the available allocation shared on a pro-rate basis between existing resource users. Allocation on this basis may also enable establishment of different 'classes' of consent differentiated on the basis of supply reliability (i.e. consents that are restricted when water availability is limited).

#### Recommendation

*That Environment Southland continue to develop and support aquifer user groups as a primary means to engage with resource users with regard measures ensure sustainable resource management and investigate options for alternative methods of water allocation where issues arise with regard the long-term sustainability of abstraction.*

## **4. Summary**

Recent experience with management of confined aquifers in the Northern Southland area has highlighted shortcomings in the current management framework for groundwater allocation from confined aquifers outlined in the Regional Water Plan for Southland (RWP). Other issues such as the management of cumulative well interference effects are also complicated by current provisions of the RWP.

This report provides a series of recommendations to improve the efficacy of RWP provisions relating to the management of fractured rock and confined aquifers. These recommendations suggest a number of amendments to the existing RWP provisions, the most significant being the replacement of the existing criteria for establishing activity status in confined aquifers on the basis of drawdown in response to abstraction with equivalent criteria based on estimated aquifer throughflow. In order to support these amended criteria, amendments are also recommended to RWP Appendix A information requirements as well as existing policies relating to groundwater allocation (Policy 30) and well interference effects (Policy 31).

At the current time fractured rock aquifers are not included in the staged management framework for groundwater allocation established in the RWP. This omission was due to a requirement to manage allocation from these aquifers at a localised rather than aquifer-scale. In order to ensure that fractured rock aquifers are included within the overall groundwater allocation framework for the Southland Region, the report proposes a simple methodology for establishing activity status based on a simple estimate of local aquifer recharge.

The report also provides a number of recommendations that may assist efficient management of groundwater resources in the Southland Region including improved alignment between allocated volumes and actual use, supplementary allocation, common expiry dates for resource consents and management actions that can be adopted where monitoring results indicate groundwater abstraction in excess of sustainable limits.

## **5. References**

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