

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

✦ Prepared for:
Hurunui Water Project (HWP)

✦ September 2011



PATTLE DELAMORE PARTNERS LTD
40 Hammersmith Drive, Wigram, Christchurch
P O Box 389, Christchurch, New Zealand

Tel +3 363 3100 Fax +3 363 3101
Web Site <http://www.pdp.co.nz>
Auckland Wellington **Christchurch**



Quality Control Sheet

TITLE **Assessment of Environmental Effects: HWP Waitohi Irrigation and
Hydro Scheme**

CLIENT Hurunui Water Project

VERSION Final

DATE September 2011

JOB REFERENCE C02031406

SOURCE FILE(S) C020310406_R001_Stage 2_Final.doc

Prepared by

SIGNATURE



Bas Veendrick

Mark Pennington

Richard Brunton

Directed, reviewed and approved by

SIGNATURE



Peter Callander

Limitations:

This report has been prepared on the basis of information on potential future land use assumed by the Hurunui Water Project Ltd and environmental conditions determined by other parties.

The report describes a numerical modelling simulation of a natural hydrological regime. Due to the variability of natural processes, the modelling output cannot be guaranteed.

The report has been prepared for Hurunui Water Project, according to their instructions, for the particular objectives described in the report. The information contained in the report should not be used by anyone else or for any other purposes.

Executive Summary

In this report the effects of operating a large scale storage scheme in the Waitohi River to meet irrigation demand for a 58,500 hectare area in the Hurunui, Waipara and Kowai catchments are assessed. The scheme will also be used for hydro energy generation.

It is proposed that four storage reservoirs along the Waitohi River are constructed, with a combined total live storage volume of 220.7 million m³. The main storage reservoir is Hurricane Gully with an active storage capacity of 209.5 million m³. The Seven Hills and Inches Road storage reservoirs will have an active storage capacity of 7.3 million m³ and 3.9 million m³ respectively. The Lower Gorge 1 reservoir is not proposed to be used for meeting irrigation demands.

A total of three intakes in the Hurunui River will abstract water to meet irrigation demand or to refill the storage reservoirs. The upper intake will supply pumped water into the Waitohi catchment for irrigation storage and hydro-generation and the lower intakes will supply run-of-river supply to the distribution system.

The effects of the scheme were simulated over a 39 year period (1972-2011) using a model from which irrigation demand, run-of-river water availability (subject to the "post storage proposed Hurunui and Waiau River Regional Plan" flow regime) and water availability within the storage reservoirs are estimated. Hurricane Gully Reservoir is assumed to be the primary storage with Seven Hills Reservoir and Inches Road Reservoir providing supplementary irrigation supply in dry years. Water is harvested into storage from the Waitohi River catchment, and is also pumped into storage from the Hurunui River. An environmental flow at the outlet of the Lower Gorge 1 Storage Reservoir is also maintained.

The model is driven by a combination of inputs, primarily flows in the Hurunui River, inflows into the storage sites, and evapotranspiration and rainfall data. Modified flows were compared with natural/existing flows and reservoir levels were estimated to assess the effects of the scheme.

The most upstream intake on the Hurunui River mainly affects the flows outside the irrigation season due to the storage being refilled following drawdown in the reservoirs during the irrigation season. The main effect on Hurunui River flows downstream of the lower intakes (i.e. Hurunui River at Mandamus intake and Hurunui River Amuri Scheme intake) are within the irrigation season with the largest relative reduction in flows in the flow range between 20 and 70 m³/s. Downstream of the existing Balmoral Scheme modified flows are sometimes slightly higher than existing flows due to an increase in the A-block minimum flow in the "post storage proposed Hurunui and Waiau River Regional Plan" flow regime.

Effects on river flows are likely when irrigation abstraction is either ramped up or down. Investigation of the changes in water level associated with these changes in flow are required to enable environmental, ecological, aesthetic and other affects to be assessed.

The water level changes in response to flow ramping have been simulated using a hydraulic model, and the results indicate that water levels in downstream reaches may vary by up to half a metre. This fits well within the range of naturally occurring water levels in the relevant reaches.

The water levels in the proposed storage reservoirs are highly variable over the 39 year simulation period. In wet years the storage is hardly used whereas in dry years the live storage in the reservoirs may be used completely. Hurricane Gully, the main reservoir, has a mean lake level of 492.1 m RL, only 7.9 m below the maximum storage level of 500.0 m RL. Seasonally the lowest reservoir levels occur towards the end of the irrigation season (April).

Effects on the lower Waitohi River (i.e. downstream of the reservoirs) are characterised by long periods of stable river flows at the minimum environmental flow release of 250 L/s when water is harvested following the irrigation season. Flow variability is maintained when the reservoirs are full in the winter months. The minimum environmental flow of 250L/s generally results in reduced river flows except in the summer low flow period when flows naturally fall below 250 L/s. In order to reduce the risk of periphyton growth it is proposed that flushing flows be released from storage into the Waitohi River during the summer low flow period.

The reliability of the scheme described in this report is assessed based on the Soil Moisture Index (SMI). Soil moisture reliability considers the effects of the scheme on soil moisture content, and hence measures the real benefits of the scheme. Growth conditions are optimised when the soil moisture content is greater than 50 % of the PAW (Profile Available Water). A day is counted as reliable provided the SMI is greater than 50 %. In a good irrigation year the SMI is always greater than 50 %. The simulation suggests that for the vast majority of years (34 out of 39 years) the scheme has enough water for a complete irrigation season and is therefore highly reliable. In extremely dry years the SMI tends to drop off in the last 2 or 3 months of the irrigation season (i.e. from end of February onwards).

Table of Contents

| SECTION | PAGE |
|-----------------------------------------------------------------------|-----------|
| Executive Summary | ii |
| 1.0 Introduction | 1 |
| 2.0 Description of the Irrigation Scheme | 3 |
| 2.1 Physical Description | 3 |
| 2.2 Storage Reservoirs | 4 |
| 2.3 Water Take for Proposed Scheme | 5 |
| 2.4 Availability of Water | 6 |
| 2.4.1 Hurunui River | 6 |
| 2.4.2 Waitohi River | 8 |
| 2.5 Existing Water Takes | 8 |
| 3.0 Operating Rules for the Proposed Scheme | 8 |
| 3.1 Irrigation Season | 8 |
| 3.2 Off-Peak Pumping | 8 |
| 3.3 Attenuation of Hydro-Generation Flows at Seven Hills Reservoir | 8 |
| 3.4 Maximising Throughput for Hydro-Generation | 8 |
| 4.0 Description of the Environment | 8 |
| 4.1 Location | 8 |
| 4.2 Climate | 8 |
| 4.3 Climate Change | 8 |
| 4.4 Soils | 8 |
| 4.5 Hurunui Catchment | 8 |
| 4.5.1 General Catchment Description | 8 |
| 4.5.2 General Catchment Description: Waitohi River | 8 |
| 4.5.3 Sub-Catchments and Flow Characteristics | 8 |
| 4.5.4 Seasonal Flow Variability | 8 |
| 5.0 Model Methodology | 8 |
| 5.1 Modelling Approach—General Overview | 8 |
| 5.2 Simulation Period | 8 |
| 5.3 Irrigation Efficiency | 8 |
| 5.4 Hydraulic Assessment: Flow Ramping | 8 |

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation
and Hydro Scheme

| | | |
|------------|--------------------------------------------------|----------|
| 6.0 | Input Data | 8 |
| 6.1 | Introduction | 8 |
| 6.2 | Climate | 8 |
| 6.3 | Soils and Water Holding Capacities | 8 |
| 6.4 | Hydrological Inputs | 8 |
| 6.4.1 | Waitohi River Inflows | 8 |
| 6.4.2 | Hurunui River Flows | 8 |
| 6.5 | Natural Flow Characteristics | 8 |
| 6.6 | Hurunui Flow Regimes and Minimum Flow Conditions | 8 |
| 6.7 | Existing Balmoral Irrigation Scheme Intake | 8 |
| 7.0 | Reliability of Supply | 8 |
| 7.1 | Supply and Demand Reliability | 8 |
| 7.2 | Soil Moisture | 8 |
| 8.0 | Assessment of Environmental Effects | 8 |
| 8.1 | Introduction | 8 |
| 8.2 | Effects Based on Example Year | 8 |
| 8.2.1 | Effects Downstream of Intake 4 | 8 |
| 8.2.2 | Effects Between Intake 1 and 4 | 8 |
| 8.2.3 | Effects Between Intake 3 and 1 | 8 |
| 8.2.4 | Effects Downstream of Intake 5 | 8 |
| 8.3 | Effects for Full Simulation Period | 8 |
| 8.3.1 | Hurricane Gully Reservoir | 8 |
| 8.3.2 | Seven Hills Reservoir | 8 |
| 8.3.3 | Inches Road Reservoir | 8 |
| 8.3.4 | Lower Gorge 1 Reservoir | 8 |
| 8.4 | Effects on Hurunui River Flows | 8 |
| 8.4.1 | Effects Downstream of Intake 4 | 8 |
| 8.4.2 | Effects Between Intake 1 and 4 | 8 |
| 8.4.3 | Effects Between Intake 3 and 1 | 8 |
| 8.4.4 | Summary Statistics | 8 |
| 8.4.5 | Effects on Floods and Flooding | 8 |
| 8.5 | Effects on Waitohi River Flows | 8 |
| 8.5.1 | Effects Downstream of Intake 5 | 8 |

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation
and Hydro Scheme

| | | |
|-------------|-------------------------------------------------|----------|
| 8.5.2 | Summary Statistics | 8 |
| 8.6 | Environmental Considerations | 8 |
| 8.6.1 | Flushing Flows | 8 |
| 8.6.2 | Environmental Flow Releases from the Reservoirs | 8 |
| 8.6.3 | Reservoir Inundation and Wave Action | 8 |
| 9.0 | Reliability of Supply for the Scheme | 8 |
| 10.0 | Mitigation Measures and Monitoring | 8 |
| 10.1 | Mitigating Adverse Effects on the Environment | 8 |
| 10.1.1 | Minimum Environmental Flows | 8 |
| 10.1.2 | Environmental Flow Releases | 8 |
| 10.2 | Management and Operational Plans | 8 |
| 10.3 | Proposed Monitoring | 8 |
| 10.3.1 | Water Takes | 8 |
| 10.3.2 | Reservoir Levels | 8 |
| 10.3.3 | Environmental Monitoring | 8 |
| 11.0 | Conclusions | 8 |
| 12.0 | References | 8 |

Appendices:

| | |
|-------------|------------------------------------------------------------------|
| Appendix A: | Figures - Environmental |
| Appendix B: | Water Abstractions in the Hurunui Catchment |
| Appendix C: | Information on Recorder Sites |
| Appendix D: | Regression Waitohi River |
| Appendix E: | Lake Level Plots |
| Appendix F: | Hurunui River Hydrological Plots – Downstream of Intake 4 |
| Appendix G: | Hurunui River Hydrological Plots – Between Intake 1 and Intake 4 |
| Appendix H: | Hurunui River Hydrological Plots – Between Intake 3 and Intake 1 |
| Appendix I: | Waitohi River Hydrological Plots – Downstream of Intake 5 |
| Appendix J: | Reliability |

1.0 Introduction

Pattle Delamore Partners Ltd (PDP) has been engaged by the Hurunui Water Project (HWP) to assess the hydrological effects from the development of an irrigation scheme in the Hurunui, Waipara and Kowai catchments.

It has been determined through scoping and feasibility studies that the project will involve the taking of water from the Hurunui River and will deliver water through a system of water races. With adequate storage in place the proposed system will be able to irrigate an area of 58,500 ha, with a high level of reliability.

The key elements of the project as shown in Figures A1 and A2 include:

1) Intakes (points at which it is proposed that flow be taken/abstracted from each relevant river system)

- ✦ An intake on the Hurunui River at 383.5 m RL¹ to supply pumped water into the Waitohi catchment for irrigation storage and hydro-generation (Intake no. 3).
- ✦ An intake on the Hurunui River at 305.0 m RL or 280 m RL to supply run-of river water to the distribution system (Intake no. 1 on Figure A2).
- ✦ An upgrade of the existing Amuri Scheme intake (intake no. 4) on the Hurunui River.
- ✦ An intake on the Waitohi River at the Lower Gorge Dam (325.0 m RL and 340 m RL) to supply water to the main distribution and other areas from Waitohi Storage (Intake no. 5).

2) Dams

- ✦ A dam and consequent reservoir in the Waitohi River at Hurricane Gully to provide storage for irrigation and to generate electricity.
- ✦ A dam and consequent re-regulation reservoir in the Waitohi River at Seven Hills to attenuate hydro-generation flows in normal years. This reservoir will be used for irrigation and full draw down may occur in dry years.
- ✦ A dam and consequent reservoir in the Waitohi River at Inches Road. This reservoir will maintain a high reservoir level to maximise hydro-generation and will be used for irrigation and drawn down in dry years.
- ✦ A dam and consequent reservoir in the Waitohi River at the Lower Gorge. This dam will maintain a high reservoir level to maximise hydro-generation and will not be used for irrigation purposes.

A distribution network of water races across the plains will provide water to all shareholder properties in the scheme.

¹ Note that in this document all elevations are given as Reduced Levels (RL) above Mean Sea Level

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

The operation will involve delivering water to the supply area from run-of-river water via a race system when water is available in the rivers, with the shortfall in demand being drawn from storage. During periods when the water available for abstraction exceeds the demand, Hurunui River water is proposed to be pumped into the Hurricane Gully storage reservoirs if required.

This assessment of Environmental Effects report deals with hydrology and irrigation demand and has been produced to technically support the HWP resource consent application. The activities to which this report relates are:

- The storage for irrigation purposes of up to 209.5 million m³ of water in Hurricane Gully, up to 7.3 million m³ of water in Seven Hills and up to 3.9 million m³ of water in Inches Road. Water stored in the Lower Gorge 1 reservoir is not proposed to be used for meeting of irrigation demands.
- Use of water to irrigate 58,500 hectares within a command area of 72,100 hectares.

A high level hydro-optimisation has been included in this assessment of environmental effects but further optimisation will be included in the detailed design stage.

In this report the effects of the activities are assessed, and explanations of what changes may arise in the hydrology of the Hurunui and Waitohi Rivers as a result of these activities are given. The scale and significance of these effects are reflected in the level of detail provided within each section of the report. Measures to avoid, remedy or mitigate any potentially adverse effects of the project operation are also indicated.

2.0 Description of the Irrigation Scheme

2.1 Physical Description

The scheme area is defined as the area that will be serviced by water from the irrigation supply network. The total area covered (gross irrigable area) is approximately 72,100 ha as shown in Appendix A, Figure A1. Approximately 46,850 ha of this area is in the Hurunui Catchment with another 25,250 ha in the Waipara and Kowai catchments. Some of the farmland in this area will not be irrigated as the gross irrigable area will be larger than the net irrigable area.

Table 1 provides a summary of the irrigable areas as identified by a Project Team that was set up for the project. The gross and net irrigable areas reported in Table 1 are based on the District Scoping Report (Tonkin & Taylor, June 2004). In this report it was assumed that 20% of the gross area would not be irrigated to account for hardstand areas, shelter belts and other non-irrigable areas. For the existing Balmoral Scheme the numbers reported by Amuri Irrigation were used. Taking these considerations into account the net irrigable area will be 58,500 ha, and demands have been developed accordingly.

| Table 1: Gross and Net Irrigable Areas | | |
|-------------------------------------------------|---------------------------|-------------------------|
| Irrigation Area | Gross Irrigable Area (ha) | Net Irrigable Area (ha) |
| Existing Balmoral Scheme | 5,500 | 5,240 |
| Non-irrigated areas adjacent to Balmoral Scheme | 2,660 | 2,130 |
| Balmoral forest & adjacent area | 5,990 | 4,790 |
| Hawarden north of Waitohi River | 5,510 | 4,410 |
| Medbury Forest | 780 | 620 |
| Hawarden south of Waitohi River | 11,200 | 8,960 |
| Mid Hurunui Riparian | 2,730 | 2,180 |
| Scargill Valley | 5,880 | 4,700 |
| Greta Valley, Domett and lower Hurunui riparian | 6,600 | 5,280 |
| Total Hurunui Catchment | 46,850 | 38,310 |
| Upper Waipara/Mason's Flat | 6,640 | 5,310 |
| Pyramid Valley link | 250 | 200 |
| Omihi Valley north of Waipara River | 6,780 | 5,420 |
| Omihi Saddle link | 390 | 310 |
| Glasnevin Flats south of Waipara River | 5,380 | 4,300 |
| Amberley to Lower Branch of Kowai River | 5,810 | 4,650 |
| Total for the Waipara and Amberley area | 25,250 | 20,190 |
| Total Hurunui, Waipara and Kowai area | 72,100 | 58,500 |

For the purpose of this assessment it has been assumed that spray irrigation will be adopted throughout, and that all existing borderdyke irrigation will be converted to spray.

For this project it has been assumed that the area will be used for dairy farming, with demands calculated accordingly. This assumption is conservative and maintains the capacity to irrigate almost any other crop in the future.

2.2 Storage Reservoirs

As explained above storage for irrigation will be provided by a series of storage reservoirs in the Waitohi River. Table 2 provides details of the proposed dam sites.

| Table 2: Details of Proposed Dams | | | | | | | | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|------------------|----------------|-------------------|---------------------------|---------------------------------|---------------------------------------------------------------------------|---------------------------------------------|
| Dam | Crest RL (m) | Top Water RL (m) | Dam Height (m) | Draw-down (m) | Live Storage Volume (MCM) | Peak Inflow (m ³ /s) | Peak Generation Outflow ⁽²⁾ ⁽³⁾ (m ³ /s) | Peak Irrigation Outflow (m ³ /s) |
| Hurricane Gully | 505 | 500 | 105 | 50 | 209.5 | 17 ⁽¹⁾ | 35 | 42 |
| Seven Hills | 405 | 400 | 46 | 20 ⁽⁴⁾ | 7.3 | 42 | 8 | 42 |
| Inches Road | 375 | 370 | 31 | 20 | 3.9 | 42 | 8 | 42 |
| Lower Gorge 1 | 345 | 340 | 21 | 1 | 0.4 | 42 | 8 | 42 |
| Total | | | | | 221.1 | | | |
| <p>(1) Not including Waitohi natural inflows. (2) The difference between peak generation and irrigation flows is to maximise generation efficiency. During peak irrigation flows, generation will be at peak and the difference will be released via a bypass. (3) This is currently an estimated value and it may change, but it will not exceed peak irrigation outflow (4) Operating range for re-regulation will be up to 10 m. Full drawdown will occur in extreme dry years (5 to 10 years).</p> | | | | | | | | |

The main storage reservoir will be Hurricane Gully with an operating level in the range of 450-500 m RL, and a live storage of 209.5 million m³. Seven Hills dam will act as a re-regulation reservoir to attenuate generation flows in normal years, and will be used for irrigation and be drawn down in extreme dry years.

Inches Road reservoir will maintain a high reservoir level to maximise hydro-generation in normal years, and will be used for irrigation and be drawn down in dry years. The total available volume for irrigation is therefore 220.7 million m³.

The Lower Gorge 1 reservoir will maintain a high reservoir level to maximise hydro-generation. The available storage in this reservoir will not be used for irrigation purposes.

2.3 Water Take for Proposed Scheme

The water requirements for on-farm use are based on a peak daily water application rate of 0.58 L/s/ha. An allowance has been made in this assessment for 20% loss of flow to account for losses from the races and other on-farm losses. For 58,500 hectares of spray irrigation the total maximum demand is 42.4 m³/s.

The actual requirements for irrigation will depend upon the environmental conditions prevalent at the time and will vary between zero and the maximum value above of 42.4 m³/s. In Table 3 details of the proposed intakes are summarised.

| Table 3: Details of Proposed Intakes | | | | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------------|-------------------------------|------------------------------------------------------------------------------------------------|
| Intake | Intake No. | Intake RL (m) | Max. Flow (m ³ /s) | Comment |
| Hurunui River ⁽¹⁾ (at Mandamus) | 1 | 280.0 or 305.0 | 26.1 | To supply run-of river water to the distribution system. |
| First Stage Waitohi River | 2 | n/a | n/a | The Stage 1 intake at this location will be decommissioned. |
| Hurunui River (at pump station) | 3 | 383.5 | 17 | To supply pumped water into the Waitohi catchment for irrigation storage and hydro-generation. |
| Hurunui River ⁽²⁾ (Amuri Scheme) | 4 | unknown | 8.5 ⁽³⁾ | To supply run-of-river water to the existing Balmoral Scheme and Balmoral Forest. |
| Waitohi River at Lower Gorge Dam | 5 | 325.0 & 340.0 | 42.4 | To supply the main distribution canal and other areas from Waitohi storage. |
| (1) This intake will also act as a discharge point for stored Waitohi water. (2) The existing Amuri Scheme intake. (3) 3.8 m ³ /s to be abstracted from the mid- and lower-Hurunui River riparian area and Domett. | | | | |

The proposed scheme includes three main command areas which will be supplied from the intakes described in Table 3. The Hurunui River at Mandamus Intake (Intake 1) will supply water to areas south of the Hurunui River as shown in Appendix A, Figure A3. The Waitohi River at Lower Gorge Dam Intake (Intake 5) will supply water to areas south of the Waitohi River above the 305m RL (or 280 m RL) contour level as well as other areas south of the Hurunui River. The Hurunui River Amuri Scheme Intake (Intake 4) will supply water to the existing Balmoral Scheme and Balmoral Forest. Table 4 gives the areas, supplying intake and peak water abstraction for the three command areas. For the purpose of this assessment it is assumed that the canal will be at the 305.0 m RL contour.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

| Command Area | Description | Net Irrigable Area (ha) | Intake No. ⁽¹⁾ | Max. Demand for Area (m ³ /s) |
|--------------|------------------------------------------------------------------------------------------|-------------------------|---------------------------|------------------------------------------|
| Area 1 | West areas of Hawarden, Peaks, Upper Waipara/Masons Flat | 5,600 | 5 | 4.1 |
| Area 2A – 2B | Existing Balmoral Scheme, Balmoral Forest & adjacent area, Domett Lower Hurunui Riparian | 16,800 | 4 | 12.2 |
| Area 3A – 3C | Scargill, Omihi and east areas of Hawarden, Peaks, Upper Waipara/Masons Flat | 36,100 | 2 and 1 | 26.1 |

A more detailed description of the operation of the scheme and the estimated peak intake flow rates at each intake location is provided in section 3.0.

2.4 Availability of Water

2.4.1 Hurunui River

The rate at which run-of-river water can be abstracted is subject to the Hurunui River flow allocation rules. Currently there are three flow regimes (sets of rules) operative for the Hurunui River: the 1980 Plan Water Allocation regime (1980 regime), the Balmoral Irrigation Scheme regime and the modified Mosley Regime (Familton, July 2007). It is recognised by Environment Canterbury (ECan) that having three different flow regimes is not desirable and a new Hurunui River Flow Regime was notified by ECan (Variation 8) in 2008. Variation 8 was withdrawn and recently the proposed Hurunui and Waiau River Regional Plan was notified (1 October 2011) which proposes a new flow regime for the Hurunui River. This plan has a proposed pre- and post-storage flow regime. The pre-storage flow regime is applicable when the storage capacity is less than 20 million m³ and the post-storage flow regime applies when the storage capacity exceeds 20 million m³. The proposed post-storage flow regime is the relevant flow regime for stage 2 of this project since the proposed storage has a capacity greater than 20 million m³. Table 5 shows the minimum flows for each of the existing flow regimes (A-block) together with the "Proposed Regional Plan post storage flow regime".

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation
and Hydro Scheme

| Table 5: Minimum Flow for the 1980 Plan, Balmoral Irrigation Scheme, Modified Mosley and Regional Plan post-storage flow regimes. | | | | | | | | | | | | |
|-----------------------------------------------------------------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Flow Regime | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1980 Regime | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 13 | 17 | 16 | 11.5 |
| Balmoral Irrigation Scheme | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 13 | 15 | 19 | 18 | 13.5 |
| Modified Mosley | 15 | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 20 | 20 | 20 | 20 |
| Regional Plan post storage | 15 | 15 | 15 | 15 | 12 | 12 | 12 | 12 | 15 | 15 | 15 | 15 |

In addition to these minimum flows the 1980 flow regime has a 1:1 flow sharing provision which limits the proportion of the available flow that can be abstracted at flows above the minimum flow. All other flow regimes presented in Table 5 do not have a sharing regime above the minimum flow.

This AEE is based on the "Proposed Regional Plan post storage flow regime" since this is the most recent flow regime and is the one with which the proposed irrigation scheme will comply.

The "Proposed Regional Plan post storage flow regime" sets monthly variable A-and B- and C- block allocation limits for the Hurunui River. Table 6 shows the proposed flow regime as set out in the Proposed Regional Plan.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

| Table 6: Proposed Hurunui and Waiau Regional Plan “post storage” flow regime (m ³ /s) | | | | | | | | | | | |
|--------------------------------------------------------------------------------------------------|----------------------------|--------------------------------|------------------------------|---------------------|----------------------------|--------------------------------|------------------------------|----------------------------|--------------------------------|------------------------------|------------------|
| Month | Minimum flow for A permits | Allocation limit for A permits | Flow for 100% use of A water | Gap between A and B | Minimum flow for B permits | Allocation limit for B permits | Flow for 100% use of B water | Minimum flow for C permits | Allocation limit for C permits | Flow for 100% use of C water | Total Allocation |
| January | 15 | 6.2 | 21.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| February | 15 | 6.2 | 21.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| March | 15 | 6.2 | 21.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| April | 15 | 6.2 | 21.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| May | 12 | 6.2 | 18.2 | 0.8 | 19 | 10 | 29 | 29 | 33 | 62 | 49.2 |
| June | 12 | 6.2 | 18.2 | 0.8 | 19 | 10 | 29 | 29 | 33 | 62 | 49.2 |
| July | 12 | 6.2 | 18.2 | 0.8 | 19 | 10 | 29 | 29 | 33 | 62 | 49.2 |
| August | 12 | 6.2 | 18.2 | 0.8 | 19 | 10 | 29 | 29 | 33 | 62 | 49.2 |
| September | 15 | 6.2 | 18.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| October | 15 | 6.2 | 18.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| November | 15 | 6.2 | 18.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |
| December | 15 | 6.2 | 18.2 | 5.8 | 27 | 10 | 37 | 37 | 33 | 70 | 49.2 |

2.4.2 Waitohi River

The current minimum flow site for the Waitohi River is just above the Hurunui confluence and was set by the Hurunui River Water Management Plan (1980) at 350 L/s. In February 2008 Environment Canterbury reviewed the minimum flow and minimum flow site and in their '*Draft Flow and Allocation Regime: Waitohi River, Sheep Dip Creek and Washpen Stream report*' (Familton, 2008) they comment that '*the current minimum flow site is inappropriate because the flow is coming from surfacing groundwater sourced from the Hurunui not directly from the flow in the Waitohi River. A new minimum flow site is needed and the site identified, that would be useful for this purpose, is one above all the takes at Lake Sumner Road Bridge at NZMS 1 M33:713 166*'. To help improve the overall management of this water resource a permanent flow recorder site was installed at Lake Sumner Road Bridge in December 2007.

In summary the draft report mentioned above (Familton, 2008) recommends that the minimum flow site for the Waitohi River should be the Lake Sumner Road Bridge with a recommended minimum flow of 100 L/s in summer (1 October to 30 April) and 130 L/s in winter (1 May to 30 September).

The recommended summer minimum flow of 100L/s is based on the NIWA (2004) guidelines of 80% of the 7-day Mean Annual Low Flow (7D-MALF) whereas the winter minimum flow is based on the 7D-MALF. For a full discussion on Waitohi in-stream values and the considerations which lead to these minimum flow recommendations the reader is referred to the Hamilton (2008) ECan Draft Planning Report and the Gabites (2006) Low Flow Report.

For this application it is proposed to set a conservative minimum flow release of 250 L/s at the outlet of Lower Gorge 1 Reservoir (approximately 500 m upstream of Lake Sumner Road Bridge). This minimum flow is significantly higher than the estimated 7D-MALF (124 L/s, Gabbites, 2006). Based on the assumption that existing takes will become part of the scheme (see section 2.5) this will result in continuous flow in the naturally drying reach of the Waitohi River.

2.5 Existing Water Takes

Currently the natural hydrology of the Hurunui River has only been modified by abstractions below the Mandamus River confluence. Based on resource consent data supplied by Environment Canterbury the current abstractions in the Hurunui River catchment can be summarised as follows:

- There are currently 127 water permits that authorise the abstraction of surface water and hydraulically connected groundwater from the Hurunui River and its

tributaries. An additional 6 applications for water permits are in process as at August 2011. A list with all current abstractions is included in Appendix C.

- ✦ The sum of all surface water allocations for all surface water bodies in the Hurunui Catchment is approximately 11 m³/s.
- ✦ Apart from a small amount of domestic and stock water use, the demand for water from these existing takes is to provide an irrigation water supply.
- ✦ Current main stem allocation totals around 7.9 m³/s with the Amuri Irrigation Company Ltd taking 5.0 m³/s and other irrigators taking a sum total of 2.9 m³/s. A total of 6.2 m³/s is taken above the Pahau confluence and 1.7 m³/s downstream in the Domett Plains reach.
- ✦ The largest take is by the Amuri Irrigation Company Ltd which takes 5 m³/s from the Hurunui River just below the Mandamus River confluence.
- ✦ Current allocation in the Waitohi River totals 275 L/s, however only 3 takes have a minimum flow condition attached to the consent. These 3 takes have a total allocation of 102 L/s.

Currently irrigators rely on run-of-river water supply which does not have high reliability. The Amuri Company Ltd is a shareholder in the scheme and based on recent discussions between HWP and the Amuri Company it is assumed that the Amuri Irrigation Company Ltd will become part of the proposed scheme. It is further expected that other consent holders in the area will buy into the scheme as well since the project will provide a high degree of reliability of supply to irrigators. A large proportion of the existing irrigators are already shareholders in the scheme and based on discussions between HWP and shareholders (with existing consents) this is considered a reasonable assumption.

3.0 Operating Rules for the Proposed Scheme

In broad terms the storage scheme consists of four reservoirs (with three of them providing storage for irrigation) located in the Waitohi catchment (See Figure A2). Waitohi River water is harvested into the reservoirs subject to maintaining a minimum flow at the outlet of Lower Gorge 1 reservoir. Water is also pumped into the Hurricane Gully Reservoir via a pumped intake on the Hurunui River. The pump station, rising main and tunnel to convey the water into Hurricane Gully Reservoir is shown in Figure A2.

The natural flow regime of both rivers would be altered by pumping and harvesting water into storage. Water is released from the storage sites into the distribution network to supply water to the irrigation scheme.

Hurricane Gully Reservoir is used as the primary source of water with the Seven Hills Reservoir and Inches Road Reservoirs only being used for irrigation in extreme dry years.

For the modelled 58,500 ha scheme, the peak daily irrigation demand is up to 42.4 m³/s or 3.66 million m³ per day. Table 7 summarises the storage capacity of each reservoir together with the number of days each reservoir can meet the peak demand.

| Table 7: Storage Capacity | | |
|---------------------------|---------------------------------|-----------------------------------------------|
| Storage Reservoir | Storage capacity m ³ | Number of days reservoir can meet peak demand |
| Hurricane Gully | 209.5 million | 57 |
| Seven Hills | 7.3 million | 2 |
| Inches Road | 3.9 million | 1 |

Table 7 only provides an indication of the storage capacity and is a simplification of the supply-storage-demand situation when the scheme is operating.

The amount of storage available for irrigation will depend on the amount of inflow into the reservoirs which is highly variable as a result of dependence on both Waitohi River and Hurunui River flows.

The scheme is proposed to operate subject to the following rules:

- On days when there is an irrigation demand, water is first abstracted from the Hurunui River at Mandamus Intake (intake 1 on Figure A2) and Hurunui River Amuri Scheme Intake (intake 4 on Figure A2). These run-of-river abstractions are subject to the minimum flow and allocation conditions of the "Proposed Regional Plan post storage flow regime".
- During periods when the water supply from the Hurunui River exceeds the demand, and the storage reservoirs need replenishing, water will be pumped into storage at Hurricane Gully (intake 3 on Figure A2).

- When there is a deficit in run-of-river supply (i.e. demand cannot be met by run-of-river alone), water is released from the Hurricane Gully Reservoir to the irrigation network.

An exception to this is that areas above 305 m RL (or 280 m RL) that cannot be gravity fed from the Hurunui River at Mandamus (intake 1) will be supplied with water from storage only (at a higher level). This area is marked as Area 1 on Figure A3.

The Hurunui River at Mandamus Intake (Intake 1, Figure A3) will provide water to the irrigable area on the south side of the Hurunui River. For the purpose of this modelling exercise it is assumed that the canal will be at the 305 m RL contour and that it will be designed to convey flows in both directions to ensure that it can be used to supply the south side of the Hurunui River with run-of-river water but also to allow the irrigable area on the north side of the Hurunui River to be supplied with water from the Waitohi reservoirs during times of low river flows.

3.1 Irrigation Season

The irrigation season is taken to be 1 October through 1 May. However, if the soil moisture levels are low in September or May it is assumed that irrigators will want to irrigate and in these years the irrigation season is extended to include September and/or May. All graphs and associated statistics which refer to the irrigation season are based on an irrigation season of 1 October through to 1 May.

3.2 Off-Peak Pumping

For the operation of the scheme it is assumed that if the total storage volume in the reservoirs exceeds a calculated storage volume (indicatively 66 million m³, based on current assumptions) at the end of the irrigation season (1 June), the pumped intake will only refill off-peak.

To ensure that the reservoir is full again following an irrigation year where the drawdown in the reservoir results in a combined storage volume of less than the calculated volume at 1 June (indicatively 66 million m³, based on current assumptions) refill will occur at maximum pump rate throughout the day (i.e. not only off-peak).

It is also envisaged that, subject to off-peak/on-peak energy prices, the scheme would switch to a hydro-generation mode once the reservoir is at full capacity. This would enable additional revenue to be created when irrigation demands are met. The modelling of these scenarios has not been included at this stage. This would prolong the period of off peak pumping, as described in the previous paragraph, through months when the Hurricane Gully reservoir is full.

3.3 Attenuation of Hydro-Generation Flows at Seven Hills Reservoir

The proposed Seven Hills Reservoir is primarily used for re-regulation to attenuate hydro-generation flows generated by supplying electricity during peak demand periods. For the purpose of this simulation it is assumed that the reservoir will be drawn down in the weekends when the electricity demand is lower and therefore the release from Hurricane Gully is lower. This will result in a drawdown of up to 10 metres in the weekends. In reality the water level will fluctuate throughout the day depending on electricity prices. This may result in water level fluctuations of up to 5 metres within one 24 hr period.

3.4 Maximising Throughput for Hydro-Generation

The assessments in this AEE are based on the assumption that the scheme is predominantly operated for irrigation purposes. Hydro-generation is optimised for peak power generation from Hurricane Gully as explained in section 3.3 of this report, however depending on the variation of on and off peak power prices it may prove financially beneficial to maximise flow throughput through the hydro stations in the future. Maximising flow throughput through the scheme will result in effects on the hydrology in the Hurunui River. For example, when the scheme is being operated in this manner the pumped intake (intake 3) is likely to pump into storage more often when prices are low (i.e. off-peak pumping) and releases from storage back to the Hurunui River will increase. At this stage details of how flow throughput may be maximised is not modelled, but will depend on the prevailing power prices under certain electricity market conditions. When these conditions are met pumping at maximum rate could occur up to 24 hours a day provided there is water available.

4.0 Description of the Environment

4.1 Location

The gross irrigable area to which this application relates is approximately 72,100 ha as shown in Appendix A, Figure 1. Approximately 46,850 ha of this area is in the Hurunui Catchment with another 25,250 ha in the Waipara and Kowai catchments.

4.2 Climate

The climate in this area is similar to the Canterbury plains with a fairly consistent rainfall from month to month and a seasonal variation in temperature and evapotranspiration.

Table 8 shows the mean monthly rainfall, evapotranspiration and temperature for the command area.

| Table 8: Monthly Rainfall and Evapotranspiration Data for the Command Area | | | |
|------------------------------------------------------------------------------------------------------------|----------------------------|--------------------------------------|-------------------------------|
| Month | Rainfall ¹ (mm) | Evapotranspiration ¹ (mm) | Temperature ² (°C) |
| January | 37 | 135 | 17.25 |
| February | 41 | 104 | 16.89 |
| March | 49 | 84 | 14.66 |
| April | 45 | 49 | 11.68 |
| May | 46 | 30 | 8.36 |
| June | 53 | 21 | 5.75 |
| July | 60 | 21 | 5.27 |
| August | 57 | 35 | 6.80 |
| September | 47 | 59 | 9.32 |
| October | 50 | 90 | 11.34 |
| November | 43 | 111 | 13.05 |
| December | 43 | 130 | 15.86 |
| Average | 570 | 870 | 11.35 |
| (1) Based on synthetic daily rainfall and PET data from 1972 to 2011 produced by NIWA on a 5km x 5km grid. | | | |
| (2) Based on data from Culverden climate station from 1983-2011 (NIWA agent number 4527) | | | |

There is some variation in the rainfall and evapotranspiration within the command area as a result of the influences of the mountains and the sea. This is further detailed in section 6.2.

4.3 Climate Change

As recognised in the report '*Climate Change Effects and Impacts Assessments, A Guidance Manual for Local Government in New Zealand 2nd Edition*' (Ministry for the Environment, 2008) there is a lot of uncertainty associated with developing projections of future climate changes. However an indication of what is likely to happen in New Zealand and on a more regional scale has been described in the report mentioned above. A summary of this report with relevant information for the Hurunui Catchment has been given by Gareth Renowden in his evidence for the Hurunui Water Conservation Order (March 2008). In addition McKercher and Henderson (2003) researched shifts in flood and low flow regimes in New Zealand rivers associated with the shift in phase of the Interdecadal Pacific Oscillation (IPO). This section provides a summary of the available information on climate change relevant to the Hurunui Water Project and is primarily drawn from the three sources mentioned above.

Global warming and the climate change it brings are caused by the build-up of greenhouse gases in Earth's atmosphere. NIWA have recently modelled the expected temperature increase for New Zealand based on global climate models (GCMs). The projections for Canterbury are for an increase in average temperature of 0.9 °C by the 2040's and 2.0 °C by the 2090's. Rainfall is projected to decline only slightly at Christchurch and Hanmer, but increase by up to 8% at Tekapo. This reflects the trend towards increasing rainfall on the West Coast and at the Main Divide as a consequence of increasing westerly winds. The expectation is that flows in Canterbury rivers that have their catchments at or near the Main Divide will increase, and the incidence of drought will increase nearer to the coast. This would be in effect an intensification of the frequently observed pattern of "northwester" conditions in Canterbury: plenty of water in the rivers while surrounding farmland is dry.

Climate change associated with the Interdecadal Pacific Oscillation (IPO) however indicates a different trend. McKercher and Henderson (2003) have researched shifts in flood and low flow regimes in New Zealand rivers associated with the shift in phase of the IPO that occurred in 1977/1978. They found that flood and low flow regimes for many rivers were different in the periods 1947-1977, and 1978-1999, and that since 1999 there may have been a shift back to the 1947-1977 pattern.

The results of this study showed that there was no significant change in flood flows for the Hurunui River between the 1947- 1977 period and the 1978 – 1999 period. More importantly however the low flows in the Hurunui River were significantly higher over the 1978-1999 period (Increase of the order of 10 – 15 % in the medians of the low flow). At the time of writing this study, however, it is not clear whether the IPO moved to a state

similar to that which prevailed for 1947-1977. If the IPO does move back to this state then low flows in the Hurunui River may be more of a constraint on water supply in the coming decades.

In summary there are two processes which potentially affect future climate change in the project area. Climate change associated with global warming predicts a different effect on Hurunui River flows than climate change associated with the Interdecadal Pacific Oscillation. It is therefore difficult to predict the effect of climate change on flow in the Hurunui River and on the availability of run-of river water. However research does indicate that temperatures are expected to rise in the coming decades and that the incidence of droughts in the lower Hurunui catchment is likely to increase. This may warrant a conservative approach on required storage volumes.

4.4 Soils

Figure A4 shows a map with the soils in the command area. The majority of the soils in the Amuri Basin are identified as Balmoral, Glasnevin and Culverden silt and sandy loams, some of them stony (Sheet 6, Soil map of the South Island, DSIR, 1968).

The soils bordering the Pahau River consist of Templeton and Eyre-Paparua silt and sandy loams, and the soils bordering the Hurunui and Waitohi Rivers are Waimakariri and Waimakariri shallow sandy to silt loams. A small proportion of the area in the Amuri Basin consists of other soils (see Figure A4 and Table 9).

Soils in the Scargill and Omihi Valley mainly consist of Glenmark silt loams to sandy loams and Waipara silt loams.

Soils in the Amberley and Kowai area mainly consist of Mairaki silt loams, Waipara shallow silt loams and Waimakariri sandy to silt loams.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation
and Hydro Scheme

| Table 9: Soils Characteristics of the HWP Command Area | | |
|--------------------------------------------------------|-----------------------|----------------------------------------------------------|
| Id | Soil Name | Soil Description |
| 13a | Glasnevin | Stony sandy loams, silt loams and shallow silt loam |
| 13b | Balmoral | Mostly stony silt loams, some sandy loams |
| 14b | Culverden | Mostly silt loams, stony silt loams |
| 96a | Templeton | Silt loams, sandy loams, some stony loams |
| 96c | Eyre-Paparua | Mainly shallow silt loams, some sandy loams, often stony |
| 95 | Waimakariri | Sandy loams to silt loams |
| 95a | Waimakariri Shallow | Sandy loams to silt loams; shallow and stony loams |
| 95d | Willowbridge | Silt loams to sandy loams |
| 22 | Cheviot Soils | Mainly silt loams |
| 22H | Cheviot Hill Soils | Mainly silt and sandy loams |
| 22hH | Makerikeri Hill Soils | Mostly stony silt loams |
| 28a | Okuku | Mostly silt loam |
| 18d | Domett | Mainly silt loams |
| 15e | Waipara | Mainly silt loams, some shallow silt loams |
| 16H | Amberley Hill Soils | Fine sandy loams, stony loams, silt loams |
| 68b | Taumutu Soils | Stony sandy loams to stony loam |
| 18f | Wakanui Soils | Mostly silt and clay loams |
| 89 | Temuka | Silt loams to clay loams, some peaty loam topsoils |
| 71dH | Huihui Hill Soils | Mostly sandy loams |
| 71d | Huihui soils | Sandy loams to loams |
| 72 | Omihi | Mostly clay loams |
| 16fH | Tipapa Hill Soils | Mostly silt loams |
| 16b | Glenmark | Silt loams to sandy loam |

4.5 Hurunui Catchment

4.5.1 General Catchment Description

Several reports describe the hydrology of the Hurunui catchment in detail. The most notable reports include Mosley (January 2002), Facer (2003), Bowden (1977) and Morland (1994). This description of the Hurunui catchment draws on information from these reports and available flow data from recorder sites in the Hurunui catchment provided by ECan.

The total Hurunui River Catchment area is approximately 2,671 km² and is bounded by the Waiau catchment to the north and the Waimakariri, Ashley and Waipara catchments to the south. The catchment of the Hurunui River is shown in Figure A5.

The river has two main branches upstream of the Hurunui/Mandamus confluence, these being the North Branch including Lake Sumner and the Hurunui South Branch. Lake Sumner influences the magnitude and duration of flood flows moving down the North Branch. The peak of a flood is lowered as water passes into storage and the rate of recession decreases as water is released from storage after the peak has passed. Both branches have their headwaters in the Southern Alps but the North Branch has a significantly greater portion of its area in the Alps. There are numerous alpine, foothills and lowland tributaries. Both branches flow through dry, extensively grazed grass and shrublands before forming a single channel as far as the Amuri plains. There the river becomes braided, and with the exception of a gorge through the Lowry Peaks Range, remains so to the sea.

Some of the water balance in the Culverden area has been modified by existing irrigation schemes. Some formerly dry streams now carry water. The river enters the Pacific Ocean approximately 11 km south of Cheviot and the river mouth is narrow, having no delta or mudflats.

Elevations in the Hurunui catchment range from 0 m at the River mouth to 1980 m at its headwaters. The catchment has one extensive flat area, the Amuri Plains, formed by broad coalescing glacial outwash fans. The plains lie between the Main Divide and the coastal hills and vary in elevation from 150-275m. Some 44.5 percent of the catchment is at an elevation less than 400 metres and 8 percent of its headwater area is at elevations in excess of 1500 m.

Hydrologically the catchment contains three regions:

- The Eastern Alps region covers the upper reaches of the catchment, characterised by prevailing winds from the west and highest rainfall.
- The Canterbury Plains hydrological region covers the area of the Amuri plains. This is the area of lowest rainfall and small surface runoff especially in the summer months.
- The Hurunui hydrological region, which comprises the rolling hill country and includes some of the ranges just east of the main divide. Average annual precipitation is of the order of 800 - 2,000 mm.

Figure A6 is an isohyetal map which shows average annual rainfall totals within the Hurunui catchment sourced from NIWA. Rainfall ranges from around 6000 mm/year in the Southern Alps to around 700 mm in the Amuri Basin. Most of the rain in the catchment occurs with northwesterly rains resulting in heavy falls over and just east of the Divide. The isohyetal map indicates a rapid decrease in rainfall totals with distance further east of the divide.

4.5.2 General Catchment Description: Waitohi River

The Waitohi River is part of the Hurunui catchment and at the confluence with the Hurunui River it has a total catchment area of approximately 285 km². The catchment is bounded by the Hurunui River catchment to the north, Seaward River to the west and the Waipara catchment and Waikari catchment to the south (See Figure A5). The Waitohi River leaves the hills at Lake Sumner Road Bridge and is a braided shingle river where it flows through the Amuri Plains. Elevations in the Waitohi catchment range from approximately 190 m at the confluence with the Hurunui River to approximately 1300 m at its headwaters.

The isohyetal map of the Hurunui catchment (Figure A6) shows that rainfall in the Waitohi catchment ranges from around 1600 mm/year in the upper catchment to around 700 mm/year in the Amuri Basin.

The most recent hydrological report on the Waitohi River is the Facer (2006) report. This report reviews the low flows in the Waitohi River at several different locations. Figure A8 shows the estimated natural gains and losses at and downstream of Lake Sumner Road Bridge under 7D-MALF conditions (copy from Facer, 2006 report). The estimated 7D-MALF and mean flow for each location is summarised in Table 10 below.

| Waitohi River Site Name | Catchment Area above site (km ²) | 2006 estimate of 7D-MALF | Estimated Mean |
|-----------------------------------------|----------------------------------------------|--------------------------|----------------|
| Lake Sumner Road Bridge | 128.7 | 124 | 1310 |
| Powers Road Bridge | 139.4 | 103 | 1349 |
| Bakers Road Ford | 154.9 | 0 | 1330 |
| Medbury Road (Upstream) Bridge | 157.4 | 19 | 1242 |
| State Highway 7 | 256.8 | 182 | 1927 |
| 1.6km Upstream Hurunui River confluence | 268.1 | 338 | 1756 |

Figure A7 and Table 10 shows that during 7D-MALF conditions the main losing reach is between Powers Road Bridge and Bakers Road and that downstream of Bakers Road Ford the Waitohi River starts to gain flow again. The main gaining reach is between Medbury Road Bridge and State Highway 7. Even though Figure A8 only shows the natural losses and gains during 7D-MALF conditions the Facer (2006) report comments that the losses between Powers Road and Bakers Road are very similar in winter and summer. The gains for the main gaining reach (between Medbury Road Bridge and State Highway 7) are generally higher in winter months due to higher flows in winter forcing the average values higher.

The mean flows tend to increase with distance downstream of Lake Sumner Road Bridge, especially downstream of the confluence with Washpen Stream (see Figure A9).

In summary the relevant conclusions from this report are:

- ✦ The Waitohi River flow disappears subsurface through its middle reaches, and would have done naturally, pre irrigation. The flow emerges again between the Medbury Road Bridge and the State Highway 7 site.
- ✦ Assuming natural conditions, the flow at the Lake Sumner Road Bridge would have to be in the vicinity of 150 L/s for there to be a flow of about 25 L/s at Bakers Road.

4.5.3 Sub-Catchments and Flow Characteristics

There are a number of river flow recorder sites in the Hurunui catchment. The relevant sub-catchments with recorder sites relevant to this application are included in Table 11 together with their catchment areas, specific discharge and key flow statistics. The sub-catchment areas are shown in Appendix A, Figure A5. Comments on the record period and flow data for each of the recorder sites are included in Appendix C. The statistics provided in Table 11 provide an indication of the differences in flow characteristics between the sub-catchments of the Hurunui River. The Hurunui River at State Highway 1 flow recorder is downstream of most of the abstractions for irrigation, so flows will be modified and do not reflect the natural flows in the Hurunui River at this site.

It should be noted that the significantly differing record lengths for these sites means that comparisons are for indicative purposes only.

| Recorder Site | Catchment Area (km ²) | Specific Discharge (L/s/Km ²) | Flow (m ³ /s) | | | | | |
|------------------------------------|-----------------------------------|-------------------------------------------|--------------------------|-------------|------------|----------------|----------------|-------------------|
| | | | Mean Flow | Median Flow | 7-Day MALF | Lower Quartile | Upper Quartile | Mean Annual Flood |
| Hurunui at Mandamus | 1070 | 49.0 | 52.5 | 39.2 | 17.3 | 27.4 | 61.0 | 523.9 |
| Hurunui at State Highway 1 | 2518 | 28.7 | 72.2 | 55.7 | 21.4 | 37.4 | 83.6 | 756.2 |
| Mandamus at Tekoa Road Bridge | 160 | 25.6 | 4.1 | 1.80 | 0.49 | 0.87 | 4.00 | 156.67 |
| Waitohi at Lake Sumner Road Bridge | 122 | 11.4 | 1.390 | 0.396 | 0.076 | 0.150 | 1.416 | 59.776 |

With rainfall totals rapidly decreasing in the catchment area downstream of the Hurunui at Mandamus flow recorder (See Figure A6) the specific discharge decreases as well.

State Highway 1 has a specific discharge of 28.7 L/s/km² substantially lower than the Hurunui at Mandamus flow recorder. The Waitohi River at Lake Sumner Road Bridge only has a specific discharge of 11.4 L/s/km². The relatively low specific discharge (compared to the Hurunui River main stem recorder sites) is largely due to the Waitohi catchment not receiving spill-over rainfall during northwest storms. This is reflected in the mean annual rainfall totals for the catchment as shown in Figure A6.

4.5.4 Seasonal Flow Variability

As mentioned before most of the flow of the Hurunui River as it enters the scheme area is derived from precipitation in the upper catchment. In winter, much of this falls as snow, and this is not released to the river until spring. Therefore there is strong seasonality in the typical pattern of river flow, with higher flows from September to December. The summer and autumn months of February to April have the lowest flows. Table 12 summarises the mean monthly flows for the Hurunui at Mandamus recorder site.

| Month | Mean Monthly Flow Hurunui at Mandamus (m ³ /s) |
|-----------------------|-----------------------------------------------------------|
| January | 47 |
| February | 34 |
| March | 33 |
| April | 39 |
| May | 50 |
| June | 52 |
| July | 51 |
| August | 55 |
| September | 65 |
| October | 79 |
| November | 70 |
| December | 56 |
| Yearly average | 53 |

Flood flows can occur at any time of the year in response to heavy rainfall in the catchment but typically the months with the largest floods are August – December. February and March are least influenced by floods.

5.0 Model Methodology

5.1 Modelling Approach—General Overview

The water balance/irrigation demand model was coded in Matlab, a programming language used in scientific and engineering research and design. The model integrates hydrology and water balance with irrigation demand and is driven by hydrological input data and irrigation demand.

The immediate benefit of this integrated approach is that interaction between the hydrological and irrigation components occurs within model simulations avoiding the need for information transfer between different programmes, which is both computationally inefficient and limits output.

Figures A1 and A2 show the proposed scheme area with the proposed storage sites and intake locations. The principal hydrological input data are the inflows into the reservoirs.

To model irrigation demand it was assumed that the scheme area may be divided into 4 soil types with different water holding capacities. Representative evapotranspiration and rainfall data sets have been used to update daily soil moisture content.

All irrigation areas are assumed to be spray irrigated. The following irrigation rule has been assumed for areas which are spray irrigated: a sub-area has an irrigation demand when the soil moisture balance for that area falls below 55% of the PAW (profile available water), and the daily irrigation demand continues until the PAW is reached.

The way the hydrological routing has been coded is as follows: for a given reservoir and period when water is harvested to storage (from the Waitohi River), it has been assumed that all inflow into the storage reservoirs is harvested subject to maintaining an environmental flow condition at the outlet of Lower Gorge 1 reservoir. If the natural flow is less than the environmental flow (of 250 L/s) a release is made to meet the environmental flow condition. This modified flow is reflected in the Waitohi River downstream of the Lower Gorge 1 Reservoir.

If there is an irrigation demand, water is first abstracted from the Hurunui River flow. If there remains a deficit, water is released from the storage reservoir(s) into the distribution network to satisfy the irrigation demand.

It is important to recognise that the current model works on a daily timestep - all inputs are given as daily totals/averages. As a consequence it is not possible to simulate effects that occur on a much finer time scale, e.g. continuous time flow variability.

5.2 Simulation Period

Based on the availability of flow and environmental data, the simulation period was chosen to be 1972-2011. This was the longest period for which the flow record at the Hurunui at Mandamus flow recorder overlaps the environmental data (evapotranspiration and rainfall). The flow data includes extremely dry years (e.g. 1972, 2008), 'average' and 'wet' years, and therefore the effects of the scheme over a range of extreme and average conditions are able to be simulated.

The flow series for the Waitohi River are (partly) synthetic. The available historical flow record for the Waitohi River has been extended to the simulation period 1972-2011. Further details are given in section 6.4.1 and Appendix D on how the hydrological inputs were synthesised.

5.3 Irrigation Efficiency

The proposed scheme uses predominantly canals to convey water to the farms and then spray irrigation methods to apply the water to the farm paddocks. As the proposed scheme will have a canal distribution system and will consist of spray irrigation there are two main areas of losses within the system. The canal network will have some leakage of water to ground and evaporation from the water surface. Typically losses from open races can be expected to be around 10% (McIndoe 2002). The second area of losses will occur from the canal farm intake to the farm paddock. Again approximately 10% losses are expected due to leakage and evaporation within the farm distribution systems. Therefore a total loss of 20% has been adopted for this scheme.

5.4 Hydraulic Assessment: Flow Ramping

The proposed irrigation scheme will involve abstractions and flow releases in existing waterways (Hurunui and Waitohi Rivers). These changes in flow (termed "flow ramping") may occur within relatively short periods of time and could result in rapid changes in water level in downstream affected reaches.

The effects of flow ramping on water levels and cross sectional areas have been assessed by making use of a hydraulic model, developed using the HEC-RAS software. This model was built specifically for the purpose of these flow ramping assessments, and is not necessarily an appropriate tool for use for other assessments. As a result it lacks resolution in some areas, where deemed not necessary for the purpose of the flow ramping assessments.

The model was constructed from assessments of cross section, bed slope and channel roughness. A site visit was required to assess specific parameters at the assessment locations.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

Model runs were conducted at a range of flow rates, with ramping applied for various scenarios. These flow change locations (as shown in Figures A1 and A2 and as described in Table 3) are as follows:

- ✦ An intake on the Hurunui River at the 305.0 m RL or 280 m RL contour to supply run-of river water to the distribution system (Intake no. 1). A flow change of up to 26.1 m³/s may occur at this point.
- ✦ An intake on the Hurunui River at 383.5 m RL to supply pumped water into the Waitohi catchment for irrigation storage and hydro-generation (Intake no. 3). Proposed abstraction rate at this location is up to 17 m³/s, which is the change in flow that has been assessed against a range of flow rates in the Hurunui River.
- ✦ An upgrade of the existing Balmoral intake on the Hurunui River (Intake 4) just downstream of the Hurunui River at Mandamus Intake (Intake 1). As summarised in Table 3, a flow change of up to 8.5 m³/s may occur at this point.

While irrigation water is proposed to be taken from the Waitohi River system, this will occur immediately downstream of the proposed Lower Gorge 1 Dam and therefore no ramping in the river itself will occur as irrigation supply is started and stopped. No further assessment of flow ramping in the Waitohi River is therefore required.

For the sake of simplicity, the flow in the Hurunui River for all assessments was set at Mandamus, and was not increased with distance downstream (in reality this does occur due to tributary inflows), meaning that assessments at downstream locations are conservative in that the effects have been assessed against a smaller Hurunui River flow than would actually exist.

The sum of the maximum proposed abstraction rates is 51.6 m³/s (intakes 1, 3 and 4 at peak capacity). While the Regional Plan suggests a maximum allowable abstraction of 50 m³/s, assessments have been undertaken for full proposed abstraction rates and would thus be slightly conservative if all were in operation concurrently.

Assessment locations were selected based on likely positions for recreational use and accessibility, as well as those locations being most affected by the proposed changes (immediately downstream of abstraction locations). These assessment locations are detailed in Table 13 below.

| Location | Description | Model Chainage (m) |
|----------|-------------------------|--------------------|
| H1 | Downstream of Intake 3 | 39,000 |
| H2 | Between Intakes 3 and 1 | 31,008 |
| H3 | Between Intakes 1 and 4 | 23,715 |
| H4 | Downstream of Intake 4 | 23,513 |
| H5 | The Peaks | 18,420 |
| H6 | Downstream of SH7 | 1,360 |

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

According to the proposed Hurunui and Waiau River Regional Plan (see Table 6) the minimum flow in the Hurunui at Mandamus for a total take summing to 51.6 m³/s is 72.4 m³/s. This flow was therefore used against which to conduct effects of the proposed abstraction(s) on downstream water levels. In addition, assessments were conducted at the Hurunui River Mean Annual Flood flow of 523.9 m³/s.

Flow changes and assessment locations are summarised in Table 14. From this the maximum flow change that will result from the proposed scheme at each location is able to be identified (last column, highlighted). It is possible to undertake assessments at each location for all possible combinations of flow change, but for the purpose of this assessment of effects, the focus has been on the maximum potential effect. Therefore assessments have only been undertaken for those flow changes highlighted in the last column in the table below. The effects of each of these have been assessed for both the minimum flow for the sum of proposed abstractions (51.6 m³/s) and the Mean Annual Flood (523.9 m³/s).

| Assessed Location | Intake Number and Flow Change Assessed (m ³ /s) | | | | |
|-------------------|------------------------------------------------------------|------|-----|------|-------|
| | 3 | 1 | 4 | 3+1 | 3+1+4 |
| H1 | 17 | - | - | 17 | 17 |
| H2 | 17 | - | - | 17 | 17 |
| H3 | 17 | 26.1 | - | 43.1 | 43.1 |
| H4 | 17 | 26.1 | 8.5 | 43.1 | 51.6 |
| H5 | 17 | 26.1 | 8.5 | 43.1 | 51.6 |
| H6 | 17 | 26.1 | 8.5 | 43.1 | 51.6 |

6.0 Input Data

6.1 Introduction

This section provides a more detailed description of the required inputs for the demand and supply model. Some of this information given below will overlap with the information provided in Section 0 (Description of the Environment).

6.2 Climate

Limited Potential Evapotranspiration (PET) data exists from a climate station in Culverden and a more extensive series is available at Hanmer, 30 km outside the catchment (Site G22581 and G22582). Due to the distance from the project area and its geographical orientation the data from this site is considered unsuitable to represent potential evapotranspiration (PET) for the potentially irrigable area. The PET data at the Culverden climate station (Site H22783) is too short to be of any practical use.

Two rainfall sites with long term daily rainfall records are available close to the project area. These sites are Riverside (H22781), located close to Rotherham and Waipara, Wattle Grove (H32072) located in Waipara Township. Both records, however, have significant gaps in the data (several months) and are therefore considered unusable as a continuous input series for our model.

Synthetic daily rainfall and PET data is available from 1972 to date produced by NIWA on a 5km x 5km grid. This data has been produced by spline interpolation using all short and long term climate data available in the area and also takes into account other factors such as topography. These daily time series are considered the best available continuous long term dataset in the project area. Since the dataset from NIWA provides daily time series on a 5km x 5km grid, analysis on local variations in rainfall and evapotranspiration have been carried out within the command area. Table 15 provides a summary of the PET and rainfall variability within the different subareas of the command area. Between brackets representative average rainfall totals are shown for the areas which have relevant long term rainfall data available between 1972 and 2011.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

| Table 15: Average Yearly Rainfall and Potential Evapotranspiration for the Different Irrigation Areas (1972-2011) | | | |
|-------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------------------------------|--------------------------------------------------|
| Irrigation Area (ha) | Areas | Average Yearly Rainfall (mm) | Average Yearly Potential Evapotranspiration (mm) |
| Area 1 | West areas of Hawarden, Peaks, Upper Waipara/Masons Flat | 715 | 830 |
| Area 2A | Existing Balmoral Scheme, Balmoral Forest & adjacent area, Domett Lower Hurunui Riparian | 660 (690) ¹ | 850 |
| Area 2B | | 750 (780) ² | 920 |
| Area 3A | Scargill, Omihi and east areas of Hawarden, Peaks, Upper Waipara/Masons Flat | 642 (640) ³ | 830 |
| Area 3B | | 630 | 850 |
| Area 3C | | 730 | 900 |
| (1) Riverside (H22781), (2) Glenallen (H22961), (3) Ethelton (H22961) | | | |

The data indicates that the PET and rainfall variability within the project area is relatively small when comparing average yearly totals. Although the variability for average yearly totals is relatively small, the data does indicate that local rainfall and PET variability on a daily basis can vary significantly. Consequently six different sets of data were used to represent different areas within the project area. For this study one PET and rainfall series was used for areas above the 305 m RL contour including west areas of Hawarden, Peaks and Upper Waipara/Masons Flat. Two PET and rainfall series were used to represent the existing Balmoral Scheme, Balmoral Forest & adjacent area and Domett Lower Hurunui Riparian. Three sets of PET and rainfall series were used for Scargill, Omihi and east areas of Hawarden, Peaks and Upper Waipara/Masons Flat. All six data series consist of the average daily rainfall or PET from the NIWA 5km x 5km grid data located within one of the three identified areas mentioned above.

Immediately identifiable from Table 12 is that average yearly PET exceeds average yearly rainfall in all areas, reinforcing the need for irrigation.

6.3 Soils and Water Holding Capacities

Table 9 identifies the soils in the command area and their estimated water holding capacities (WHC) has been taken from the district scoping report (Tonkin and Taylor 2004). The soils have been classed into four different categories based on their estimated Soil Water Holding Capacities for the purpose of modelling irrigation water demand, namely 60, 90, 120 and 150 mm.

The spatial distribution and net areas for each irrigation area are shown in Appendix A, Figure A8 and Table 16.

| Table 16: Net Area in Each Soil Water Holding Capacity Category | | | | | |
|-----------------------------------------------------------------|-----------------------------------------|---------------|---------------|--------------|---------------|
| Irrigation Area (ha) | Net Area in Each Soil WHC Category (ha) | | | | |
| | 60 mm | 90 mm | 120 mm | 150 mm | Total |
| Area 1 | 1,342 | 2,455 | 1469 | 181 | 5,447 |
| Area 2A | 2,995 | 8,835 | 2,380 | 0 | 14,210 |
| Area 2B | 1,239 | 2,585 | 1044 | 405 | 5,273 |
| Area 3A | 4,019 | 7,372 | 1,637 | 675 | 13,703 |
| Area 3B | 2,833 | 6,544 | 3,886 | 534 | 13,797 |
| Area 3C | 1,855 | 2,192 | 2,084 | 0 | 6,131 |
| Total | 14,283 | 29,983 | 12,500 | 1,795 | 58,561 |

6.4 Hydrological Inputs

The hydrological inputs for the model are based on the long term flow series for the Hurunui at Mandamus Flow Recorder (1972 – 2011) and Waitohi at Lake Sumner Road Bridge flow recorder (2007-2011). A 39 year continuous flow series for the Waitohi River is required to enable modelling of the long-term reliability of the scheme and to assess the effects of the scheme over a range of climatic conditions (i.e. wet, average and dry years). Therefore a regression analysis was undertaken with two long-term flow recorder sites. Details of the regression are provided in Appendix D.

In order to determine inflow series for each of the storage reservoirs in the Waitohi River these synthesized long-term flow series were scaled to catchment size. For the Hurunui River two flow series were used to assess the effects of the proposed scheme on different reaches in the Hurunui River.

This section provides a description of the catchment scaling for the Hurunui River and Waitohi River.

6.4.1 Waitohi River Inflows

The synthesized long-term flow series for the Waitohi River was used to determine the inflow series for each of the storage reservoirs as shown in Appendix A, Figure A9. The sub-catchments flowing into each of the reservoirs is shown in Figure A9. A scaling factor for each sub-catchment was determined to account for the area of the Waitohi catchment contributing to each proposed dam site, tributaries downstream of the storage sites and the intake location (intake 2). Scaling factors were found by determining the percentage of catchment that contributes to each site and scaling the synthesised Waitohi River flow at Lake Sumner Road Bridge accordingly. Table 17 below shows the catchment scaling factors used for the Waitohi River inflow series;

| Table 17: Waitohi River Catchment Scaling Factors | | | |
|---------------------------------------------------|--------------------------------------|----------------|------------------------------------|
| | Catchment Area (km ²) | Scaling Factor | Mean Inflow (m ³ /s) |
| Hurricane Gully storage Inflow | 85.7 | 74% | 1.00 |
| Seven Hills storage Inflow | 14.8 | 11% | 0.14 |
| Inches Road storage Inflow | 16.6 | 12% | 0.16 |
| Lower Gorge 1 Inflow | 3.5 | 2% | 0.03 |
| Tributary below Lower Gorge 1 | 1.8 | 1% | 0.02 |
| Total | 122.4 | 100% | 1.35 |

The scaling factor was adjusted to account for higher rainfall in the upper parts of the Waitohi catchment and mean flows checked against the estimated mean flows from Gabites (2006) for several different locations in the Waitohi Catchment. For example the estimated mean flow at above Jacks Stream Confluence was estimated by Gabites (2006) at 1.15 m³/s. The Seven Hills storage reservoir is located just above Jacks Stream Confluence. The total estimated inflow into Hurricane Gully and Seven Hills storage reservoirs is 1.14 m³/s (i.e. 0.99 m³/s plus 0.15 m³/s as shown in Table 17). These very similar flow estimates provide confidence in the catchment scaling and estimated inflow in each of the reservoirs.

6.4.2 Hurunui River Flows

Measured flows for the Hurunui River are available at the NIWA recorder site "Hurunui at Mandamus" (site number 65104). The natural flows at this site were used to estimate the natural flows at the Hurunui River at pump station intake (intake 3) and the downstream intakes (intake 1 and 4). A scaling factor to determine the reduced or increased flow at the intake locations was determined based on catchment size while taking into account the higher rainfall in the upper parts of the Hurunui catchment. Flow statistics for the Mandamus River at the Tekoa Road Bridge recorder (ECan site 65102) were used to check the catchment scaling factor for intakes 1 and 4 (see isohyetal map Figure A6). The Mandamus River is the main tributary flowing into the Hurunui River between the Hurunui at Mandamus flow recorder (site 65104) and intakes 1 and 4. Table 18 below shows the catchment scaling factors used for the Hurunui intake sites.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

| | Catchment Area (km ²) | Scaling factor | Mean flow (m ³ /s) |
|----------------------------------------------------------------------------------------------|-----------------------------------|---------------------|-------------------------------|
| Hurunui at Mandamus (NIWA site 65104) | 1070 | 100% | 54.5 |
| Hurunui River at pump station (intake 3) | 905 | 93% ⁽¹⁾ | 50.8 |
| Hurunui River at Mandamus intake (Intake 1) and Hurunui River Amuri Scheme intake (intake 4) | 1230 | 108% ⁽¹⁾ | 58.6 |

(1) Scaling factor adjusted to account for higher rainfall in the upper parts of the Hurunui Catchment

6.5 Natural Flow Characteristics

Summary flow statistics for the modelling period between 1972 and 2011 are shown in Table 19. Note that these flow statistics are slightly different from the statistics provided in Table 11 since they are based on the modelling period of 39 years and not on the (much shorter or much longer) record period from the recorder sites in the catchment.

| Recorder Site | Catchment Area (km ²) | Specific Discharge (L/s/km ²) | Flow (m ³ /s) | | | | |
|------------------------------------|-----------------------------------|-------------------------------------------|--------------------------|-------------|------------|----------------|----------------|
| | | | Mean Flow | Median Flow | 7-day MALF | Lower Quartile | Upper Quartile |
| Hurunui at Mandamus | 1070 | 50.9 | 54.5 | 40.8 | 16.8 | 63.7 | 28.2 |
| State Highway 1 ⁽¹⁾ | 2518 | 28.7 | 72.2 | 55.7 | 21.4 | 37.4 | 83.6 |
| Waitohi at Lake Sumner Road Bridge | 122.4 | 10.9 | 1.34 | 0.61 | 0.12 | 0.23 | 1.41 |

(1) Flow statistics for State Highway 1 are based on actual record period since this data has not been synthesized for the 39 year modelling period.

Formatted: Bullets and Numbering

6.6 Hurunui Flow Regimes and Minimum Flow Conditions

It has been assumed that the flow allocation regime for the Hurunui River is given by the 'Proposed Hurunui and Waiau River Regional Plan' as shown in Table 6. For the Waitohi River a minimum flow of 250 L/s has been set downstream of the Lower Gorge 1 Reservoir. This minimum environmental flow of 250 L/s is maintained at all times except when the reservoirs are at its lowest operating level. When the reservoirs are low inflow equals outflow with modified flows being the same as natural flows.

6.7 Existing Balmoral Irrigation Scheme Intake

To estimate the existing flows in the Hurunui River downstream of Intake 4, an independent model was constructed to calculate the daily irrigation intake at the existing Balmoral irrigation Scheme (BIS) intake location. Measured intake data is available from NIWA (Balmoral Irrigation Intake Race 65103) from 1985 till 2011. Only the last few years of data represents the current irrigation practices with approximately 4200ha of spray irrigation and 1000 ha of borderdyke (pers. comm. Norm Williamson, Amuri Irrigation Company Ltd). Therefore it was necessary to create a long term irrigation demand series for the Amuri Scheme which represents the current irrigation practices.

The model assumed that the existing BIS scheme consists of approximately 4200 ha of spray and 1000 ha of border dyke irrigation. Higher losses (30% total losses) were assumed for this model compared to the HWP scheme to account for aged infrastructure and losses associated with border dyke irrigation. The existing BIS flow regime was used in the model with a maximum intake of 5m³/s. The modelled intake was then compared to the most recent measured intake data. Figure 1 below shows the modelled vs. measured intake at the existing BIS intake. As shown, the modelled and measured scheme has a maximum irrigation demand of approximately 5m³/s. The modelled intake shows bigger troughs compared to the measured data (e.g. October 2009). A possible reason for this is that the existing BIS scheme continues to take water when there is no demand. However, the measured and modelled intakes show the troughs occurring at similar times indicating that the modelled intake is a reasonable fit to the measured intake.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

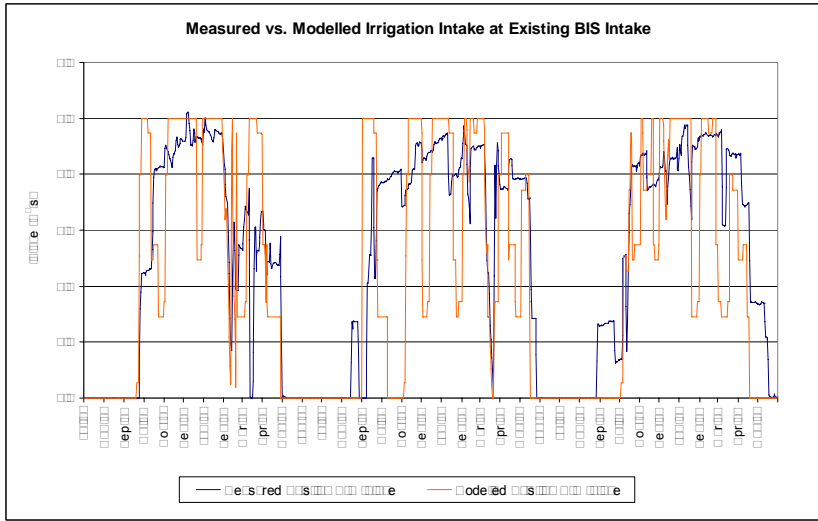


Figure 1: Measured vs. Modelled Existing BIS Intake

7.0 Reliability of Supply

In estimating the reliability of the proposed irrigation scheme and the corresponding storage volumes it is necessary to consider the physical reality. Flows are subject to considerable variability which results in variability in the availability of run-of-river water for irrigation. Very dry years like 1972 are infrequent, with occurrences in the period 1972-2011 about 10% of the time. During these years there can be significant water deficit and large storage requirements to meet demand. Any reasonable measure of reliability will identify these extreme events.

In a broad sense there are two kinds of storage: short term storage designed to meet demand in 'average' years and bulk storage to meet demand during extreme events. The proposed scheme is a bulk storage scheme designed to meet the majority of extreme hydrological conditions. This means that in non-extreme years the storage will not be drawn right down, with reservoir water levels being able to be maintained within a smaller range than during extreme dry years.

No bench mark measure of reliability has been used to infer required storage volume. Instead, the effects of a proposed scheme are analysed in terms of effects on flows and the environment, supply and demand reliability, and effects on soil moisture content and irrigation season duration.

7.1 Supply and Demand Reliability

The traditional approach to reliability is based on considering supply and demand: a day is counted as unreliable if there is an irrigation deficit on that day, i.e. supply does not meet demand, all other days are counted as reliable. Different measures of reliability are obtained by using different statistical summaries, some of which are given below:

Average Reliability: This is based on the proportion of days over each irrigation year when supply meets demand; average reliability is then defined to be the average over all the irrigation years. The drawback of this commonly used measure is that over a long simulation period, a few 'bad' years when there have been significant numbers of days when there is an irrigation deficit are averaged over, and these effects can be partially concealed.

Average Supply/Demand ratio: This is based on the number of days when supply does not meet demand divided over the number of days with a demand over each irrigation year; average supply/demand ratio is then defined as the average over all the irrigation years.

Full Reliability considers that an irrigation year is reliable if supply meets demand on all days during the irrigation season. Typically the scheme is said to be fully reliable if 9 out of 10 irrigation years are reliable.

Consecutive Reliability is based on counting the number of consecutive days in each irrigation season when supply is less than demand. Under the '10 consecutive day rule' a

scheme is said to be reliable if each irrigation year has no more than 10 consecutive days when supply is less than demand.

Average reliability and average supply/demand ratio corresponds to short term storage described in the previous section while full and consecutive reliability captures the effects of extreme years. While these measures can be helpful in summarising the effects of the scheme they are highly sensitive to the disparity between the occurrence of extreme years and average years. In addition, it is important to recognise that bulk storage schemes are fundamentally different to run-of-river schemes: for the former storage tends to run out towards the end of the irrigation season, while for the latter water deficits may be intermittent throughout the irrigation season, and provided the duration of restricted and/or no water supply is not too long it may be possible for pasture to grow throughout an irrigation season. Therefore 'run-of-river' measures of reliability, while they give indicative information about an irrigation scheme, are not really very useful in measuring the real benefits of a bulk storage scheme. For a bulk storage scheme a prolonged period of water deficit towards the end of the irrigation season will tend to result in a shortening of the irrigation season by a few months.

7.2 Soil Moisture

Soil moisture reliability considers the effects of the scheme on soil moisture content, and hence measures the real benefits of the scheme. Growth conditions are optimised when the soil moisture content is greater than 50 % of the PAW. The daily soil moisture index for a given soil type is the ratio of the moisture content to the PAW. This is averaged over the soil types to give a daily soil moisture index (SMI) for the scheme. A day is counted as reliable provided the SMI is greater than 50 %. In a good irrigation year the SMI is always greater than 50 %. In extreme years the SMI tends to drop off in the last 2 or 3 months of the irrigation season. It is therefore interesting to consider the duration for each irrigation season that the SMI is greater than 50 %. These durations are considered in Section 9.0.

8.0 Assessment of Environmental Effects

8.1 Introduction

This section contains an assessment of the environmental effects of operating the proposed scheme described in the previous sections over the 39 year simulation period. Assuming 20% losses the peak irrigation demand for the 58,500 ha scheme is approximately 42.4 m³/s.

The effects of the proposed scheme depend on the operating rules, the irrigation demand and the hydrological conditions. The suggested operating scenario which has been adopted for this modelling is described in Section 3.0. Due to the different storage volumes for each reservoir and the proposed operation of the scheme, the typical effects on each of the reservoirs are distinctly different.

This document contains an assessment of effects with respect to the following:

- ✦ Lake levels for all four reservoirs, outflows at the outlet of Lower Gorge 1 Reservoir;
- ✦ Hurunui River flows;
- ✦ Waitohi River Flows.

This assessment of effects is split into two parts. The first part will describe the operation of the scheme and associated effects based on an example year covering the 1981/1982 irrigation season. The second part contains a full description of the effects based on a wet, average, dry and large demand years together with overview statistics and graphs summarising the effects over the full 39 year simulation period. In this second part of the assessment, results are presented that show how the proposed system would have performed had it been in place during the past 39 years. These results are compared against measured parameters over this historic period.

8.2 Effects Based on Example Year

The effects of the scheme are highly variable depending on hydrological conditions and irrigation demand, and are best explained by example. The 1981/1982 irrigation year is considered an average year (i.e. not extremely dry or extremely wet) with Hurunui and Waitohi River Flows, irrigation demand and storage reservoir levels around average values.

8.2.1 Effects Downstream of Intake 4

Figure 2 shows the natural and modified flows in the Hurunui River downstream of the (upgraded) Amuri intake (intake 4 on Figure A2) together with irrigation demand, run-of-river take and total irrigation release from storage. The graph at the bottom of Figure 2 shows the Hurricane Gully lake levels over the same period.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

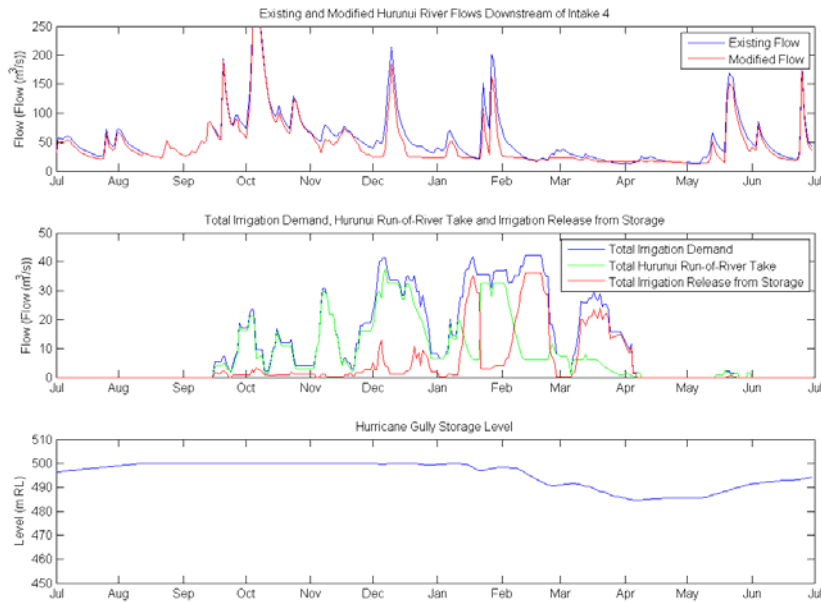


Figure 2: Natural and modified Hurunui River flows downstream of intake 4, Irrigation demand, run-of river take and storage release, and Hurricane Gully lake Levels for 1981/1982.

In this case, irrigation demand starts around mid-September and most of the irrigation demand is met from run-of river water without having to draw from storage. Only area 1, which is fully supplied from the storage reservoirs, draws water from storage. From the start of December the irrigation demand increases and the available run-of-river water still meets the majority of the demand. From mid-January through to the end of March river flows are relatively low and water needs to be drawn from storage to meet the irrigation demand. The reduction in water level in the reservoir corresponds to the releases from storage. From the beginning of April the Hurricane Gully Reservoir starts to refill due to inflows from the Waitohi River and pumping of run-of-river water from the Hurunui River (Figure A2, intake 3).

The points to note (for 1981/1982 as an example year) are:

- ✦ From July to mid-August flows are slightly lower than existing flows due to storage refill from intake 3 (Hurunui River at pump station).
- ✦ From mid-August to mid-September there is no change to the existing flows due to a full storage reservoir and no irrigation demand in this model.
- ✦ Mid- September through to December has sufficient run-of-river water available, and the majority of the demand is met from run-of-river supply. The modified flow is lower than the existing flow, however flow variability is maintained most of the time.
- ✦ From mid-January through to March the amount of run-of-river abstraction is reduced due to low flows in the Hurunui River and modified river flows are stable around 15 to 20 m³/s.

- ✦ End of March/beginning of April modified flows are slightly higher than existing flows due to a higher A-block minimum flow in the "proposed Hurunui and Waiau River Regional Plan" compared to the A-block minimum flow for the existing Amuri Scheme.
- ✦ By May, the Hurunui River flows have increased and modified flows are slightly lower than existing flows due to storage refill from the pumped Hurunui intake (Figure A2, intake 3).

In summary, taking 1981 as a typical year, but given that each year has different flow and irrigation demand patterns, the main conclusions are that:

- ✦ Modified flows are lower than existing flows.
- ✦ Flows are reduced to around 15 to 20 m³/s in months when the existing flows are low.
- ✦ The effects are not constant or similar from month to month.

Flow ramping assessment

In order to assess the changes in water level likely to accompany changes in flow when abstraction is either started or stopped, a flow ramping assessment has been deemed to be required. When considering the effects due to flow ramping, two design steady flows were used. As outlined in Section 5.4 these flows were (1) the minimum flow for the maximum total abstraction and (2) the Mean Annual Flood. The abstractions were applied individually but with times overlapping such that total and individual effects could be deduced. Effects were assessed in the reach downstream of Intake 4 (at "The Peaks") and also at State Highway 7.

Water level time series for The Peaks location are plotted in Figure 3 and Figure 4, and those for State Highway 7 are plotted in Figure 5 and Figure 6. In these figures the change in water level as the three proposed abstractions are started (i.e. flow drop in the river) and successively stopped is plotted with time.

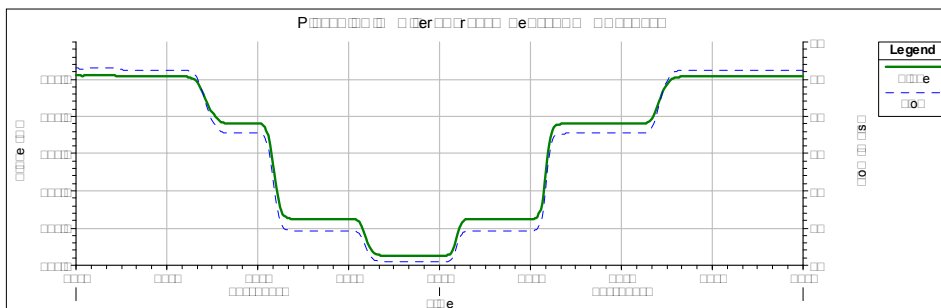


Figure 3: Flow Ramping Effects at The Peaks: Minimum Flow

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

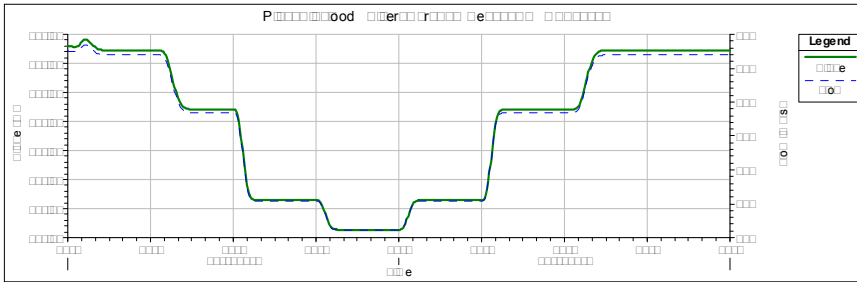


Figure 4: Flow Ramping Effects at The Peaks: Mean Annual Flood

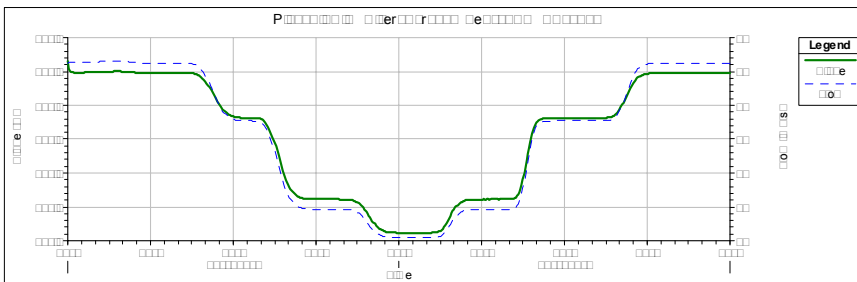


Figure 5: Flow Ramping Effects at State Highway 7: Minimum Flow

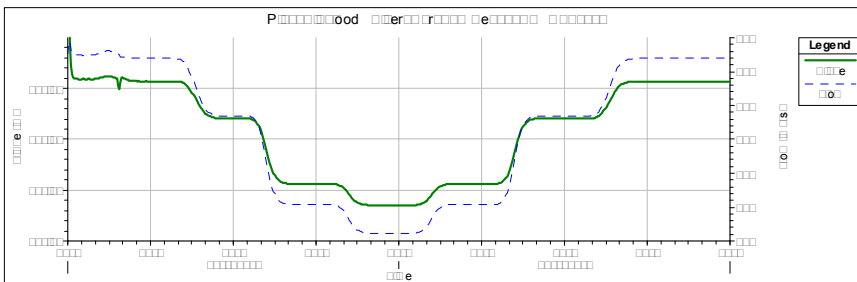


Figure 6: Flow Ramping Effects at State Highway 7: Mean Annual Flood

In Figure 5 it can be seen that water level downstream of SH7 starts at 190.9 m and then falls to 190.76 m (some 140mm) in response to the start of the 17m³/s abstraction at Intake 3 (Hurunui River Amuri Scheme Intake). After some 6 hours, the abstraction is increased by a further 26.1 m³/s which occurs at Intake 1 (Hurunui River at Mandamus Intake). A further drop in level to some 190.52 m occurs in response to this. Finally, abstraction at Intake 4 (Hurunui River Amuri Scheme Intake) of 8.5 m³/s begins, with a water level drop at this location to 190.42 m occurring in response. Thus a total water level drop of nearly 0.5 m is anticipated at this location and under these conditions a rise in water level of the same magnitude will occur at shut-down. This is shown in the cross section in Figure 7. In this figure it can be seen that the water level at this cross section changes as flow is changed, and the effects on flow cross sectional area and bank wetted perimeter can be seen.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

In Figure 6 it can be seen that water level starts at 192.70 m and then falls to 192.67 m (some 30mm) in response to the start of the 17m³/s abstraction at Intake 3 (Hurunui River at pump station). This is a much smaller water level change than under the minimum flow conditions due to the wide cross section under mean annual flood conditions. After some 6 hours, the abstraction is increased by a further 26.1 m³/s which occurs at Intake 1 (Hurunui River at Mandamus Intake) . A further drop in level to 192.61 m occurs in response to this (60mm drop). Finally, abstraction at Intake 4 (Hurunui River at Amuri Scheme Intake) of 8.5 m³/s begins, with a water level drop at this location to 192.59 m occurring in response. Thus a total water level drop of about 110mm is anticipated at this location and under these mean annual flood conditions. This is shown in the cross section in Figure 8.

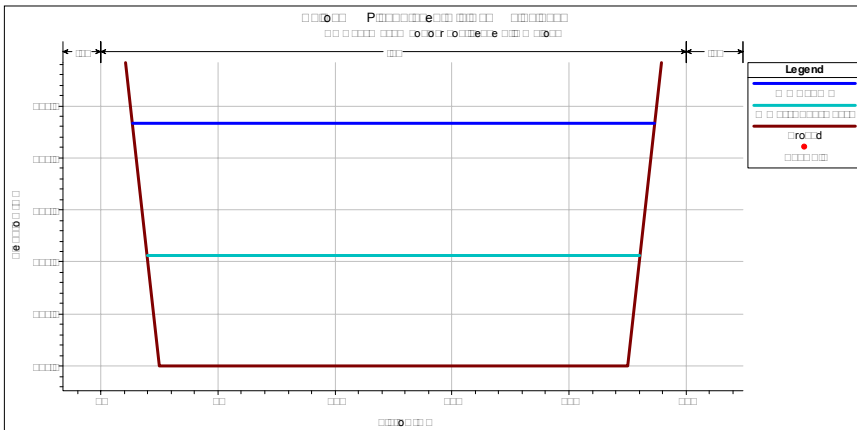


Figure 7: Schematic Cross Section at SH7: Minimum Flow Conditions

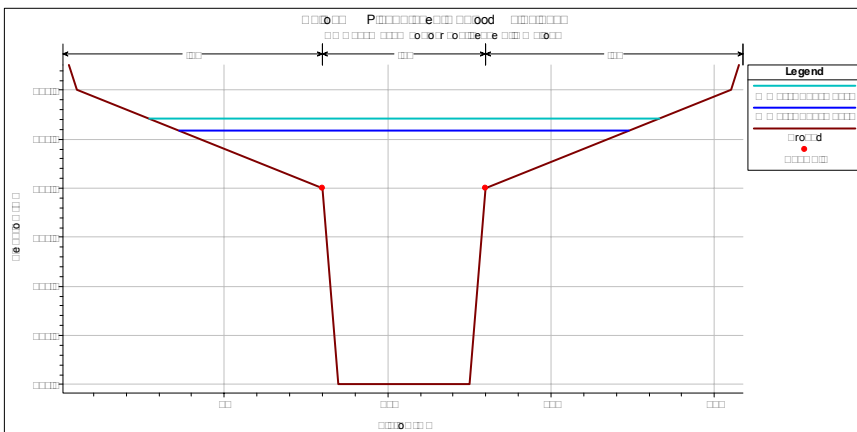


Figure 8: Schematic Cross Section at SH7: Mean Annual Flood

The rate of rise and fall in discharge and water level has been controlled by ramping over 30 minutes in each case.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

The above figures are anticipated to be useful for analyses relating to ecology, recreation and landscape. For example, the rate and magnitude of change in water level as flows are ramped up and down are likely to be required for assessments of safety for anglers using the river, or for available habitat for aquatic fauna.

8.2.2 Effects Between Intake 1 and 4

Figure 9 shows the natural and modified flows in the Hurunui River between the Hurunui River at Mandamus Intake (intake 1) and the existing Amuri Scheme intake (intake 4). For the purpose of this assessment it is assumed that intake 1 is located at 305 m RL (i.e. just upstream of the existing Amuri Scheme intake). This stretch of river is approximately 50 m long, however due to the two-way canal water is sometimes released from storage, conveyed by the canal, released into the Hurunui River (at intake 1) and taken out again further downstream at the existing Amuri intake (intake 4) on the north side of the river. Therefore the effects on Hurunui River flows in this short stretch of the Hurunui River are distinctly different to those at other locations in the Hurunui River.

Figure 9 also shows the total irrigation demand, take from run-of-river and irrigation release from storage for the 'Rest of the Scheme' (area 3) and for 'Balmoral Scheme, Balmoral Forest and the Hurunui Riparian area' (area 2).

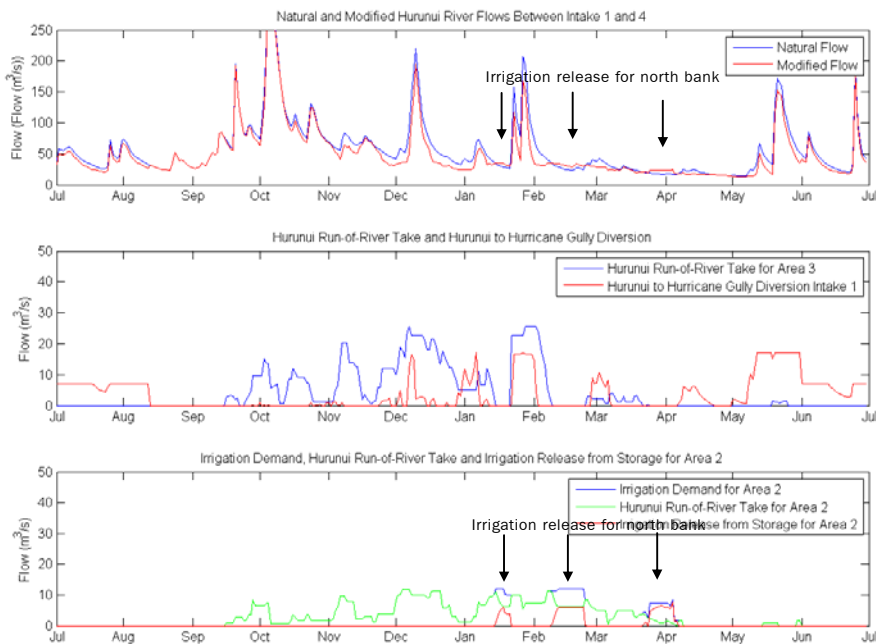


Figure 9: Natural and modified Hurunui River between intake 1 and intake 4, Irrigation demand, Run-of river take and storage release for area 3 and for area 2 for 1981/1982.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

For the example year 1981/1982 the modified flows in the Hurunui River between intake 1 and intake 4 are lower than natural flows due to run-of-river takes to supply area 3 and due to takes to storage from the upper Hurunui intake (intake 3 on Figure A2). Note that for the purpose of modelling it is assumed that the diversion rate for intake 3 is reduced from 17m³/s to 7m³/s from the beginning of June reflecting the off-peak pumping to refill the reservoir in the winter months (see section 8.2.3 for a more detailed explanation). As soon as river flows go down and the irrigation demand for irrigable area 2 cannot be met from run-of-river, a release is made from storage to supply this area with water. These releases are shown in red in the bottom figure and results in a higher modified flow in the Hurunui River (see Figure 2 above). This effect only occurs when natural flows in the Hurunui River fall below 34 m³/s and area 2 has an irrigation demand.

The points to note (for 1981/1982 as an example year) are:

- ✦ The effects in this stretch of the river are the same as for the downstream evaluation point (downstream of intake 4) for the period between July to mid-September.
- ✦ In September through to December the modified flow is lower than the natural flow due to run-of-river abstractions for Area 3. Flow variability is maintained most of the time.
- ✦ From January through to March modified flows are sometimes lower and sometimes higher than the natural flows due to run-of-river abstractions for area 3 (modified flow lower than natural flows) and releases from storage to supply area 2 (modified flows higher than natural flows).
- ✦ By May, there is no irrigation demand and the modified Hurunui River flows are slightly lower than natural flows due to storage refill from the pumped Hurunui intake (Figure A2, intake 3).

Flow ramping assessment

When considering the effects due to flow ramping, two design steady flows were used. As outlined in Section 5.4 these flows were (1) the minimum flow for the maximum total abstraction and (2) the Mean Annual Flood. The abstractions were applied individually but with times overlapping such that total and individual effects could be deduced. The simulated change in water level and discharge are plotted in Figure 10 and Figure 11.

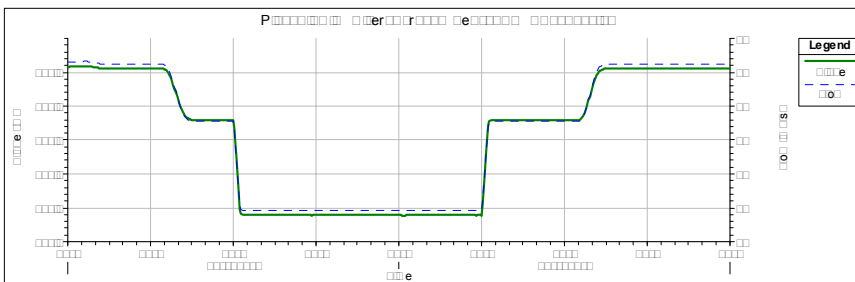


Figure 10: Flow Ramping Effects between Intakes 1 and 4: Minimum Flow

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

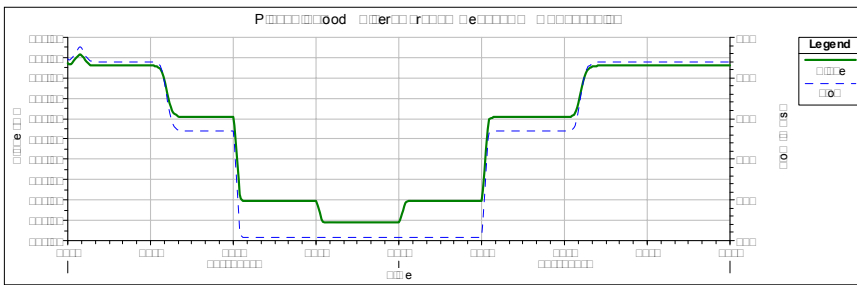


Figure 11: Flow Ramping Effects between Intakes 1 and 4: Mean Annual Flood

In Figure 10 it can be seen that water level starts at 305.41 m and then falls to 305.26 m (some 150mm) in response to the start of the 17m³/s abstraction at Intake 3 (Hurunui River at pump station). After some 6 hours, the abstraction is increased by a further 26.1 m³/s which occurs at Intake 1 (Hurunui River at Mandamus intake). A further drop in level to 304.98 m occurs in response to this. As Intake 4 (Hurunui River Amuri Scheme intake) is located downstream of this assessment point, no effects from the abstraction of 8.5 m³/s is experienced. Thus a total water level drop of some 430mm is anticipated at this location and under these conditions. This is shown in the cross section in Figure 12.

In Figure 11 it can be seen that water level starts at 307.45 m and then falls to 307.40 m (some 50mm) in response to the start of the 17m³/s abstraction at Intake 3 (Hurunui River at pump station). After 6 hours, the abstraction is increased by a further 26.1 m³/s which occurs at Intake 1 (Hurunui River at Mandamus intake) . A further drop in level to 307.32 m occurs in response to this. As Intake 4 (Hurunui River Amuri Scheme intake) is located downstream of this assessment point, effects from the abstraction of 8.5 m³/s are not expected. However, due to the flow conditions and to the assessment point being a short distance upstream of the abstraction location, a small effect (about 20mm) may be experienced. Thus a total water level drop of some 150mm is anticipated at this location and under these conditions. This is shown in the cross section in Figure 13.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

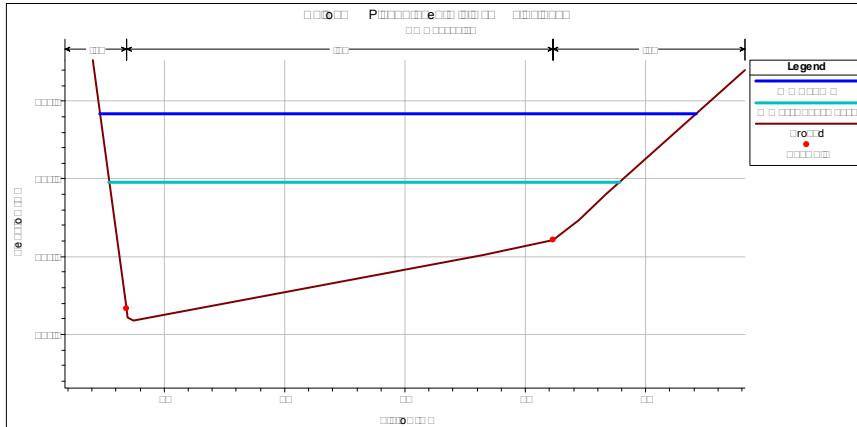


Figure 12: Schematic Cross Section between Intakes 1 and 4: Minimum Flow Conditions

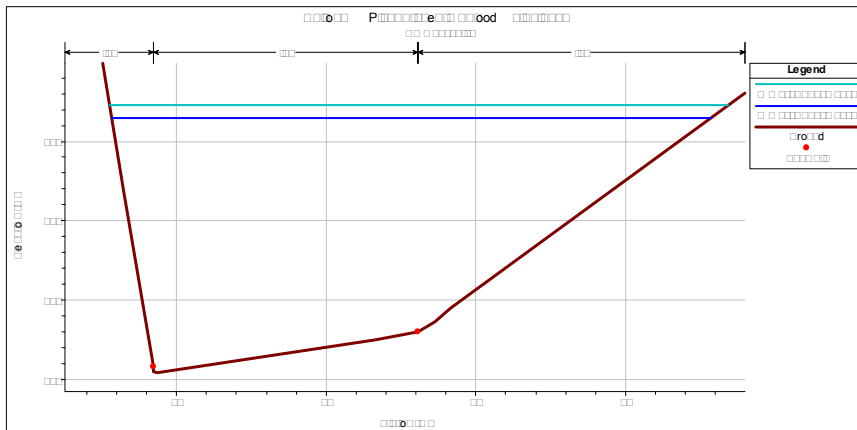


Figure 13: Schematic Cross Section between Intakes 1 and 4: Mean Annual Flood Conditions

8.2.3 Effects Between Intake 3 and 1

Figure 14 shows the natural and modified flows in the Hurunui River between the pumped intake and the main Hurunui River intake (i.e. between intake 3 and 1 on Figure A2) together with the diversion at the Pumped Hurunui Intake (Intake 3) and the water levels in Hurricane Gully Reservoir.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

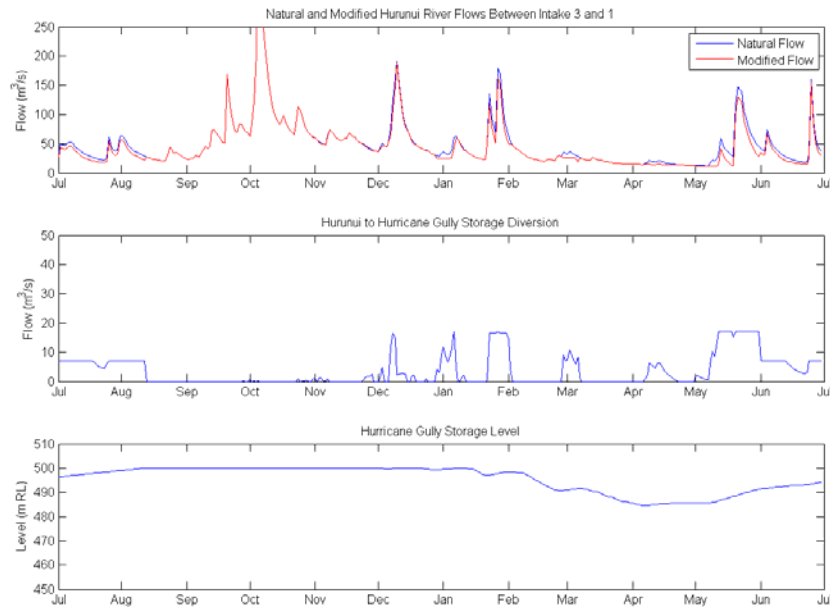


Figure 14: Natural and modified Hurunui River Flows between intake 3 and intake 1, Hurunui to Hurricane Gully storage diversion and Hurricane Gully storage reservoir levels for 1981/1982.

For the example year 1981/1982 the modified flows in the Hurunui River between intake 3 and intake 1 are lower than natural flows due to run-of-river takes replenishing the Hurricane Gully Storage Reservoir. The reduced flows in this stretch of the river correspond to the diversion to storage from intake 3 (Hurunui River at pump station) and an increase in Hurricane Gully storage reservoir levels.

As mentioned before for the purpose of modelling the diversion rate for intake 3 (Hurunui River at pump station) is reduced from 17 m³/s to 7 m³/s from the beginning of June reflecting the off-peak pumping in the winter months to refill the reservoir. For the operation of the scheme it is assumed that if the combined total storage volume in all three reservoirs exceeds a calculated storage volume (indicatively 66 million m³, based on current assumptions) at the end of the irrigation season (1 June) the pumped intake will only refill off-peak (i.e. assumed to be 10 hours, between 9 pm to 7am).

In this example year the total volume in all three storage reservoirs as at 1 June is 161 million m³, which is much higher than the threshold value of 66 million m³. The assumed operational rules of the model therefore ensure that replenishing of the reservoir will occur during off-peak hours only.

The points to note (for 1981/1982 as an example year) are:

- ✦ From July to mid-August flows are slightly lower than natural due to storage refill from intake 3 (Figure A2).

- ✦ From mid-August to end of November no or negligible change to the natural flows due to a full storage reservoir and a very small irrigation demand.
- ✦ In December through to June the modified flow is slightly lower than the natural flow during times when diversion to storage is occurring. Flow variability is maintained most of the time.
- ✦ From June the modified flows are slightly lower than the natural flows due to refill of the Hurricane Gully storage reservoir.
- ✦ By May, there is no irrigation demand and run-of-river water is available at intake 3 to refill the Hurricane from intake 3. The modified Hurunui River flows are slightly lower than natural flows.

Flow ramping assessment

When considering the effects due to flow ramping, two design steady flows were used. As outlined in Section 5.4 these flows were (1) the minimum flow for the maximum total abstraction and (2) the Mean Annual Flood. The abstractions were applied individually but with times overlapping such that total and individual effects could be deduced. The simulated change in water level and discharge are plotted in Figure 15 and Figure 16.

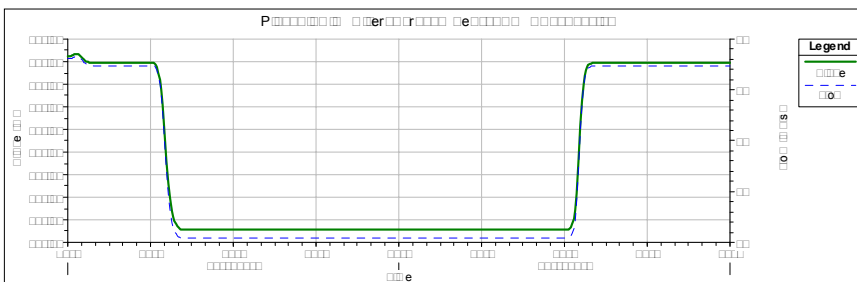


Figure 15: Flow Ramping Effects between Intakes 3 and 1: Minimum Flow

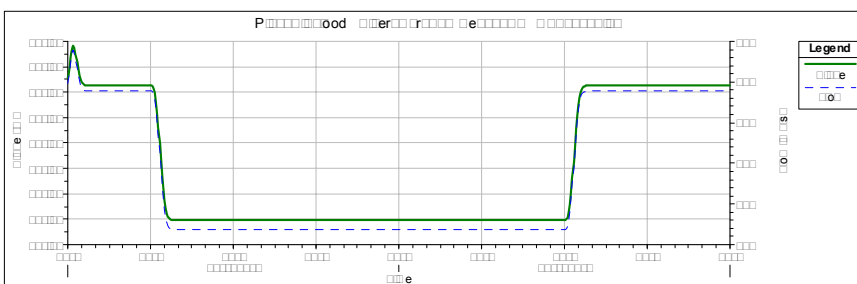


Figure 16: Flow Ramping Effects between Intakes 3 and 1: Mean Annual Flood

As there is only the Intake 3 (Hurunui River at pump station) abstraction upstream of this point, only the effects of the 17 m³/s change in flow can be experienced. A water level drop in this reach of some 130 mm is anticipated under the minimum flow conditions assumed (72.4 m³/s). Under flood flow conditions (Mean Annual Flood) a drop in water level of 50 mm would be expected through this reach as a result of the abstraction.

These changes in water level are shown in the cross section plots in Figure 17 and Figure 18.

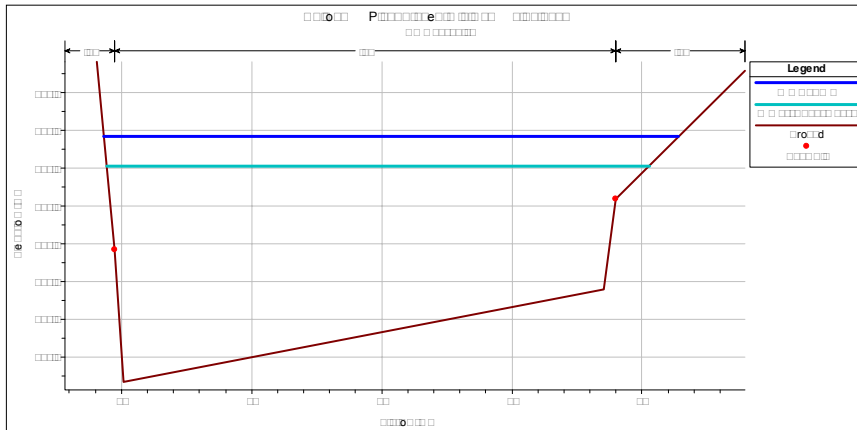


Figure 17: Schematic Cross Section between Intakes 3 and 1: Minimum Flow Conditions

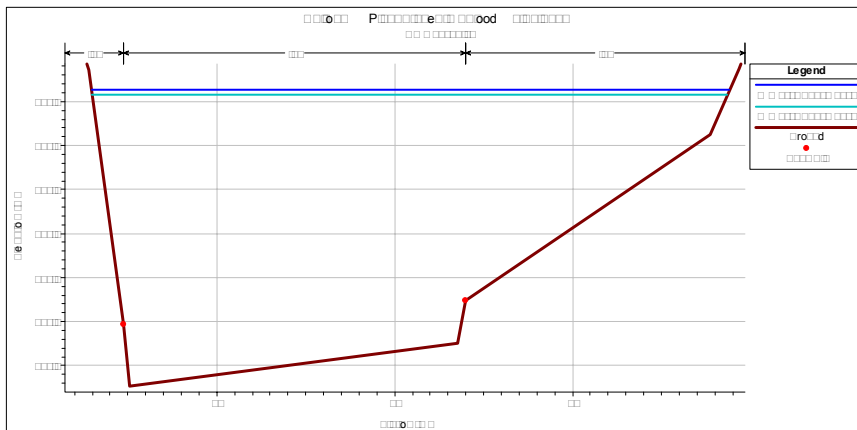


Figure 18: Schematic Cross Section between Intakes 3 and 1: Mean Annual Flood Conditions

8.2.4 Effects Downstream of Intake 5

Figure 19 shows the natural and modified flows in the Waitohi River downstream of Lower Gorge 1 Reservoir (i.e. downstream of Intake 5) together with the total irrigation demand and Hurricane Gully reservoir levels. Figure 19 also shows indicative flushing flows in December and March to keep the Waitohi River free of periphyton and algae in the summer low flow period. This proposed mitigation measure is further detailed in section 10.1.2.

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

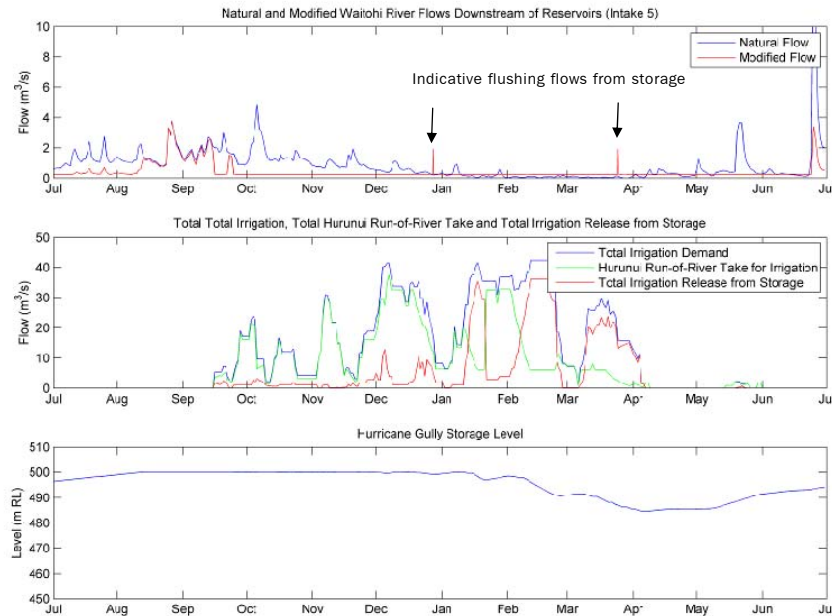


Figure 19: Natural and modified Waitohi River flows downstream of intake 2, Irrigation demand, run-of river take and storage release, and Hurricane Gully lake levels for 1981/1982.

Figure 19 shows that the modified Waitohi River flows are generally lower than the natural flows due to Waitohi River flows being harvested into storage when the storage reservoir needs replenishing. However, in the low flow summer months flows are higher than natural due to the minimum environmental flow release of 250 L/s at the outlet of the Lower Gorge 1 dam.

The points to note (for 1981/1982 as an example year) are:

- ✦ From July to mid-August Hurricane Gully Reservoir is being refilled and Waitohi River flows are harvested into storage resulting in lower than natural flows in the Waitohi River.
- ✦ From mid-August through to mid-September Hurricane Gully Reservoir is full and the flows are the same as the natural flows.
- ✦ From mid-September through to mid-January modified flows are stable at 250 L/s and generally lower than the natural flows.
- ✦ From mid-January through to the beginning of April modified flows are stable at 250 L/s and generally higher than the natural flows.
- ✦ From April through to June modified flows are stable at 250 L/s and generally lower than the natural flows.

In summary, taking 1981 as a typical year, but given that each year has different flow and irrigation demand patterns, the main conclusions are that:

- ✦ Modified flows are stable and lower than natural flows outside the summer low flow period.
- ✦ Flows are augmented to 250 L/s in the summer low flow period when Waitohi River flows are typically at their annual minima.

8.3 Effects for Full Simulation Period

This part of the assessment of environmental effects describes the effects of the scheme on lake levels, storage reservoir inflows and outflows and Hurunui and Waitohi River flows for the 39 years of simulation period.

8.3.1 Hurricane Gully Reservoir

Lake Levels

The proposed Hurricane Gully Dam is the main storage reservoir for irrigation and with an operating range of 50 m provides an estimated storage volume of 220.5 million m³. Over the simulation period there is considerable variability in storage reservoir levels. In wet years the storage is hardly used whereas in extreme dry years the Hurricane Gully Reservoir may use all the available live storage. Figure E1 shows the drawdown of the storage reservoir and Figure E2 and Figure E3 shows the lake level duration curve for the whole simulation period and for the irrigation season. Based on the simulation period of a past series of 39 years, the live storage would have been completely used in 6 of these years. Table 20 shows a summary of the lake levels, volumes and duration of time that a certain level is exceeded for the whole simulation period and for the irrigation season.

| Table 20: Hurricane Gully Lake Level Duration and Volumes (1972-2011) | | | |
|-----------------------------------------------------------------------|----------------------------------|---------------------------------------------------------|---------------------------------------------------|
| RL (m) | Volume (Million m ³) | % of time level exceeded (over whole simulation period) | % of time level exceeded (over irrigation season) |
| 500 | 210 | 31.0 | 27.1 |
| 490 | 140 | 72.8 | 70.5 |
| 480 | 87 | 88.4 | 87.3 |
| 470 | 47 | 94.0 | 93.1 |
| 460 | 19 | 96.3 | 95.6 |
| 450 | 0 | 98.0 | 97.4 |

Figure E1, Figure E2 and Table 20 shows that Hurricane Gully Reservoir is completely full for more than 31.0 % of the time and water level will be higher than 490 m RL for some 72.8 % of the time. Only the extreme dry years draw the lake down completely (to 450 m RL). There are considerable periods when the reservoir level is at the maximum of 500 m

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation and Hydro Scheme

RL. The mean lake level over the modelling period is 492.1 m RL, 7.9 m below the maximum storage level. The median lake level (equalled or exceeded 50% of the time) is 496.8 m RL, which is 3.2 m below the maximum storage level.

Figure E1, Figure E3 and Table 20 shows that when taking into account the irrigation season only Hurricane Gully Reservoir is completely full for more than 27.1 % of the time and water level will be higher than 490 m RL for some 70.5 % of the time. Only the extreme dry years draw the lake down completely (to 450 m RL). There are considerable periods when the reservoir level is at the maximum of 500 m RL. The mean lake level over the irrigation season is 491.4 m RL, 8.6 m below the maximum storage level. The median lake level (equalled or exceeded 50% of the time) over the irrigation season is 496.0 m RL, which is 4.0 m below the maximum storage level.

Table 21 shows the average monthly lake levels in the reservoir.

| Table 21: Hurricane Gully average monthly lake levels (1972-2011) | |
|-------------------------------------------------------------------|----------------|
| Month | Lake level (m) |
| January | 493.4 |
| February | 487.4 |
| March | 482.2 |
| April | 481.6 |
| May | 485.9 |
| June | 490.9 |
| July | 494.2 |
| August | 496.9 |
| September | 498.3 |
| October | 498.9 |
| November | 498.7 |
| December | 497.1 |
| Year | 492.1 |

Seasonally, the lowest water levels in the reservoir will be from February to the end of April which reflects the period where the reservoir is drawn down to meet irrigation demand. May through to August is the main refill period with average monthly lake levels recovering to near full at the beginning of September. On average the reservoir will be

near full from September to the end of December due to irrigation demand being met predominantly from Hurunui run-of-river flow without having to draw from storage.

Number of consecutive days at or below a specified lake level

There are considerable periods when the reservoir levels are at the maximum storage level as is clear from Figure E1. Table 22 summarises the number of consecutive days that the reservoir is at or below a certain lake level and also includes a column which shows the number of occurrences over the 39 year modelling period that the level is drawn down below that level.

| RL (m) | Volume (Million m ³) | Occurrences (during 39 year modelling period) | Number of consecutive days | | |
|--------|----------------------------------|-----------------------------------------------|----------------------------|---------|---------|
| | | | Average | Minimum | Maximum |
| 495 | 173 | 48 | 123 | 2 | 362 |
| 485 | 112 | 2 | 101 | 5 | 254 |
| 475 | 65 | 14 | 85 | 4 | 203 |
| 465 | 32 | 9 | 75 | 10 | 173 |
| 455 | 8 | 6 | 70 | 36 | 152 |

The average number of consecutive days that the lake is at or below a certain level provides an indication of the duration of time that the lake level is below a specified lake level before it recovers to that level. For example the lake level is drawn down to below 465 m RL on only 9 occasions. On average (over these 9 occurrences) the number of consecutive days that the level is at or below 465 m RL is 75 days.

8.3.2 Seven Hills Reservoir

The proposed Seven Hills Reservoir is primarily used for re-regulation to attenuate hydro-generation flows generated by supplying electricity during peak demand periods. For the purpose of this simulation it is assumed that the reservoir will be drawn down in the weekends when the electricity demand is lower and therefore the release from Hurricane Gully is lower. This will result in a drawdown of up to 10 metres in the weekends. In reality the water level will fluctuate throughout the day depending on electricity prices. This may result in water level fluctuations of up to 5 metres within one 24 hr period.

In extremely dry years this reservoir will be used for irrigation and will be able to be drawn down to 380m RL. With an operating range of 20 m it provides an estimated live storage volume of 7.3 million m³. Figure E1 shows the drawdown of the storage reservoir and Figure E4 and E5 shows the lake level duration curve for the whole simulation period and for the irrigation season. Based on the simulation period of 39 years, it is predicted that

the live storage would be completely used in 6 years out of 39 years. Table 23 shows a summary of the lake levels, volumes and duration of time that a certain level is exceeded for the whole simulation period and for the irrigation season.

| RL (m) | Volume (Million m ³) | % of time level exceeded (over whole year) | % of time level exceeded (over irrigation season) |
|--------|----------------------------------|--------------------------------------------|---------------------------------------------------|
| 400 | 7.3 | 41.9 | 22.5 |
| 395 | 4.5 | 95.8 | 94.4 |
| 390 | 2.3 | 97.8 | 97.4 |
| 385 | 0.9 | 98.1 | 97.7 |
| 380 | 0.0 | 98.3 | 97.8 |

Figure E4 and Table 23 shows that Seven Hills Reservoir is completely full for more than 41.9 % of the time and will be higher than 395 m RL for 95.8 % of the time. Only the extreme dry years draw on the storage in this reservoir.

Figure E5 and Table 23 shows that Seven Hills Reservoir is completely full for more than 22.5 % of the time over the irrigation season and will be higher than 395 m RL for 94.4 % of the time. Only the extreme dry years draw on the storage in this reservoir.

Seasonally, the lowest water levels in the reservoir will be from February to May which reflects the period where the reservoir is drawn down to meet irrigation demand and for the reservoir to recover. The lower 10 metre of the operating range is typically only used in extremely dry years towards the end of the irrigation season when Hurricane Gully reservoir is drawn down completely. The reservoir will be full or near full from June through to October due to low irrigation demand and high inflow into the reservoir.

8.3.3 Inches Road Reservoir

The proposed Inches Road Reservoir is primarily used for re-regulation to attenuate hydro-generation flows. However, in extremely dry years the reservoir will be used for irrigation and could be drawn down. With an operating range of 20 m it provides an estimated storage volume of 3.9 million m³. Figure E1 shows the drawdown of the storage reservoir and Figure E4 and E5 shows the lake level duration curve for the whole simulation period and for the irrigation season. Based on the simulation period of 39 years, it is predicted that the live storage would be completely used in 5 out of 39 years. Table 24 shows a summary of the lake levels, durations and volumes.

| RL (m) | Volume (Million m ³) | % of time level exceeded (over whole year) | % of time level exceeded (over irrigation season) |
|--------|-------------------------------------|-----------------------------------------------|------------------------------------------------------|
| 370 | 3.9 | 98.0 | 97.6 |
| 365 | 2.3 | 98.1 | 97.7 |
| 360 | 1.1 | 98.3 | 98.0 |
| 355 | 0.4 | 98.4 | 98.1 |
| 350 | 0.0 | 98.5 | 98.2 |

Figure E4 and Table 24 shows that Inches Road Reservoir is completely full for more than 98.0 % of the time and will be higher than 350 m RL for 98.5 % of the time. Only the extreme dry years draw the lake down completely.

Figure E5 and Table 24 shows that Inches Road Reservoir is completely full for more than 97.6 % of the time and will be higher than 350 m RL for 98.2% of the time over the irrigation season. Only the extreme dry years draw the lake down completely.

Seasonally, the lowest water levels in the reservoir will be from March to May which reflects the period where the reservoir is drawn down to meet irrigation demand and for the reservoir to recover. The reservoir is typically only used in extremely dry years towards the end of the irrigation season when Hurricane Gully reservoir is drawn down completely. The reservoir will be full from June to the end of February due to low irrigation demand and high inflow into the reservoir.

8.3.4 Lower Gorge 1 Reservoir

The proposed Lower Gorge 1 Reservoir will maintain a high reservoir level at all times to maximise hydro-generation. Some minor water level fluctuations are expected but the water level is expected to be at or around 340 m RL at all times.

8.4 Effects on Hurunui River Flows

8.4.1 Effects Downstream of Intake 4

Figure F1, F2 and F3 provide an overview of the modelled hydrological effects on Hurunui River flows downstream of intake 4 (Hurunui River Amuri Scheme Intake). Figure F1 shows overlay plots of the existing and modified flows during wet, average, dry and a large storage demand years. The modified flows at this location are compared to the existing flows (and not the natural flows) since the existing Balmoral Scheme currently abstracts water from the Hurunui River (intake 4) at a maximum flow rate of 5 m³/s . The

wet, average and dry years are based on Hurunui River flows at Hurunui at Mandamus with a dry year representing a 10th percentile dry year and a wet year representing a 10th percentile wet year. A large storage demand year is included to assess the effects of the scheme when the live storage in the reservoirs is fully used (which may be considered a 10th percentile dry year in terms of the storage reservoir levels).

The main points to note from Figure F1 are:

- In 1983 (example wet year) the summer low flow period is relatively short, flow variability is maintained (although slightly reduced) and storage is refilled by the end of May resulting in no change to the existing flows from May onwards.
- The periods of low flows in the Hurunui River are generally longer in dry years, however due to flow restrictions water is not abstracted from the river when flows are naturally low. In the low flow period modified flows are slightly higher than existing flows due to a higher A-block minimum flow in the "proposed Hurunui-Waiau River Regional Plan" compared to the A-block minimum flow for the existing Amuri Scheme. Natural flows below 15m³/s are unchanged in the summer low flow period (1973, February to mid-March).
- 1990 (example dry year) shows two low flow periods (November through to mid-December and February through to mid-April). Due to irrigation demand and storage refill modified flows are generally lower than existing flows.
- In average and dry years flows are relatively high through to the end of January with modified flows lower than existing flows. The higher flood flows are slightly reduced but still come through thereby maintaining flow variability.
- In a large storage demand year (i.e. extremely dry summer) flows are naturally low for a prolonged period of time with modified flows being slightly higher than existing flows (when the natural flow at the Hurunui at Mandamus flow recorder is between 12 and 15 m³/s) due to an increase in the A-block minimum flow from 12 m³/s to 15 m³/s. Natural flows below 15m³/s (abstractions must cease) are protected by the minimum flow conditions.
- During average and dry years the storage can be refilled by pumping off-peak only at a flow rate of 17 m³/s. In the model this is reflected by reducing the mean daily flows from 1 June to 7 m³/s. Following a large storage demand year (1972) the storage will need to be refilled throughout the day at the maximum pumping rate of 17m³/s to ensure that the storage is full at the start of the next irrigation season.

Figure F2 and F3 show comparative flow duration curves for the existing and modified flows over the whole year and over the irrigation season.

As can be seen, the existing flows are reduced and sometimes "flat lined" (especially in the irrigation season) at flows of around 15 m³/s and 20.8 m³/s. In other words flows can be drawn down to 15 m³/s when the natural flows at the Hurunui at Mandamus flow recorder are below 21.2 m³/s and can be drawn down to 20.8 m³/s when flows are between 27 m³/s and 70 m³/s (see Table 6).

8.4.2 Effects Between Intake 1 and 4

Figure G1, G2 and G3 provide an overview of the modelled hydrological effects on Hurunui River flows between intake 1 (Hurunui River at Mandamus intake) and 4 (Hurunui River Amuri Scheme intake). Figure G1 shows overlay plots of natural and modified flows during wet, average, dry and a large storage demand years. The effects outside the irrigation season (i.e. 1 June through to 1 September) are the same as described in section 8.4.1 (downstream of intake 4). The main differences with 'downstream of intake 4' are:

- The abstraction rate from the river is generally lower than downstream of intake 4 due to only intake 1 abstracting water for area 3 (total area of 36,100 ha, see section 2.3). Modified flows are generally lower than natural flows, however the effect is less pronounced than downstream of intake 4.
- During the summer low flow period natural flows are sometimes increased due to releases from storage. When run-of-river abstractions must cease due to flow restrictions (in accordance with the 'Regional Plan post-storage flow regime') water is released from the Waitohi storage reservoirs to supply the north side of the Hurunui River. Water from storage is released into the two-way canal at 305 m RL, released into the Hurunui River (at intake 1) and taken out again further downstream at the existing Amuri Scheme intake (intake 4) on the north side of the river. This effect is best seen during the 1973 irrigation year where flows in the Hurunui River are increased from February through to mid-March.

Figure G2 and G3 show comparative flow duration curves for the natural and modified flows over the whole year and over the irrigation season. As can be seen the natural flows are reduced however the effects are less pronounced than downstream of intake 4.

Figure G3 shows the increase in lower flows in the irrigation season when water is released from storage to supply the north side of the Hurunui River.

8.4.3 Effects Between Intake 3 and 1

Figure H1, H2 and H3 provide an overview of the modelled hydrological effects on Hurunui River flows between intake 3 (Hurunui River at pump station) and 1 (Hurunui River at Mandamus). Figure H1 shows overlay plots of natural and modified flows during wet, average, dry and a large storage demand years. The effects outside the irrigation season (i.e. 1 June through to 1 September) are the same as for the other two intakes. The main points to note from figure H1 are:

- The main changes in flow in this stretch of the river are outside the irrigation season when the storage reservoir is being refilled. As mentioned before during average and dry years the storage can be refilled by pumping off-peak only. In the model (and Figure H1) this is reflected by reducing the mean daily flows from 1 June to 7 m³/s. Following a large storage demand year (1972) the storage will need to be refilled throughout the day at the maximum pumping rate of 17m³/s to ensure that the storage is full at the start of the next irrigation season.

- Within the irrigation season the effects on river flows in this stretch of the river are much less pronounced than at the other two intakes. Modified flows are slightly lower than natural flows when run-of-river water is available. The main reason that this stretch is largely unaffected during the irrigation season is due to abstraction at the downstream intakes having priority over intake 3 in terms of run-of-river water. Intake 3 can only take water after irrigation demand from intake 1 and 4 is satisfied and water is available according to the flow regime.

In general terms it can be concluded that within the irrigation season flows are largely unaffected during wet, average, dry and large demand years and that the main effects are outside (or towards the end of the irrigation season) when flows are naturally high. The main summer low flow period (when the river ecology is naturally most vulnerable) is largely unaffected.

Figure H2 and H3 show comparative flow duration curves for the natural and modified flows over the whole year and over the irrigation season. As can be seen the natural flows are reduced however the effects are relatively small compared to the two intakes further downstream. For this stretch of the river the effects are more pronounced outside the irrigation season resulting in a bigger difference between the modified and natural flow duration curve when taking into account the whole year instead of just the flows in the irrigation season.

8.4.4 Summary Statistics

The following table shows summary statistics for natural and modified flows:

| Table 25: Summary Flow Statistics for Natural/Existing and Modified Flows (Period 1972-2011) | | | | | |
|----------------------------------------------------------------------------------------------|------|--------|---------|----------------|----------------|
| | Mean | Median | 7D-MALF | Upper Quartile | Lower Quartile |
| Hurunui River between intake 3 and 1 natural flows | 50.8 | 38.0 | 15.6 | 59.3 | 26.2 |
| Hurunui River between intake 3 and 1 modified flows | 45.9 | 33.3 | 13.0 | 53.8 | 21.7 |
| Hurunui River between intake 1 and 4 natural flows | 58.6 | 43.8 | 18.0 | 68.4 | 30.3 |
| Hurunui River between intake 1 and 4 modified flows | 50.3 | 35.1 | 15.9 | 56.4 | 26.2 |
| Hurunui River downstream intake 4 natural flows | 56.9 | 42.2 | 15.7 | 66.9 | 28.6 |
| Hurunui River downstream intake 4 modified flows | 46.7 | 28.0 | 15.1 | 54.6 | 22.9 |

As expected the summary statistics in Table 26 indicate reduced river flows in the Hurunui River as a result of the proposed scheme for low, average and high flows. The percentage decrease in mean flow in the following stretches of the river is estimated at:

- ✦ Downstream of intake 4: 18 %
- ✦ Between intake 1 and 4: 14 %
- ✦ Between intake 3 and 1: 10 %

As explained earlier the main effects of the proposed scheme are downstream of intakes 1 and 4 with intake 3 predominantly affecting the flows in the winter period when storage is being refilled.

8.4.5 Effects on Floods and Flooding

The flow duration curves downstream of intake 4 (Hurunui River Amuri Scheme) indicate that flows most affected by the takes are between 20 and 70 m³/s (Largest relative decrease in flows). The existing flood frequency or the duration of floods and larger freshes are largely unchanged. The proposed scheme will result in a small reduction of the magnitude of floods and flood frequency, however the impact on higher flows is expected to be relatively small. The impact of the proposed abstractions on smaller freshes is discussed in more detail in section 8.6.1.

8.5 Effects on Waitohi River Flows

8.5.1 Effects Downstream of Intake 5

Figures I1, I2 and I3 provide an overview of the modelled hydrological effects on Waitohi River flows downstream of intake 5 (Waitohi River at Lower Gorge Dam Intake). Figure I1 shows overlay plots of natural and modified flows during wet, average, dry and a large storage demand years. The main points to note from Figure I1 are:

- ✦ In all the example years flows are flat-lined at 250 L/s for the majority of the time.
- ✦ In dry, average and wet years flows are increased in the summer low flow period when natural flows are generally below 250 L/s. This flow ensures a continuous flow in the Waitohi River whereas it naturally goes dry.
- ✦ Natural flows are unchanged during periods when the reservoir is full and when there is no irrigation demand. These periods are confined to the high flow period in winter and/or the shoulders of the irrigation season.

Figure I2 and I3 show comparative flow duration curves for the natural and modified flows over the whole year and over the irrigation season. As can be seen the natural flows are reduced and flat-lined at 250 L/s for the majority of the time (especially in the irrigation season). The flow duration curve also shows the increase in flows over the summer low flow period. For the natural flows a flow of 250 L/s is exceeded 73 % of the time (using

the full year period), or in other words the flow is less than 250 L/s 22 % of the time. If assessing the record for just for the irrigation season (1 October through to 30 April) the flow is less than 250 L/s for 35 % of the time. For the modified situation the flows are only less than 250 L/s when the live storage is used completely (i.e. at or above 250 L/s for approximately 98 % of the time).

Section 8.6 addresses the environment implications of the modified flow regime and proposes mitigation measures how to prevent adverse effects on the Waitohi River as a result of reduced flow variability.

8.5.2 Summary Statistics

The following table shows summary statistics for natural and modified flows:

| | Mean | Median | 7D-MALF | Upper Quartile | Lower Quartile |
|---------------------------------------|------|--------|---------|----------------|----------------|
| Waitohi River intake 5 natural flows | 1.34 | 0.61 | 0.12 | 1.41 | 0.23 |
| Waitohi River intake 5 modified flows | 0.75 | 0.25 | 0.23 | 0.44 | 0.25 |

As expected the summary statistics in Table 26 indicate reduced Waitohi River flows for the median, mean and upper quartile. However, the lower quartile and 7D-MALF are increased due to the environmental flow release of 250 L/s.

During low flow conditions (see Table 10 for gains and losses during 7D-MALF conditions) the Waitohi River tends to loose flow between Lake Sumner Road Bridge and Bakers Road Ford and starts to gain flow again further downstream. A minimum flow of 250 L/s at the outlet of the storage reservoir will ensure a continuous flow in the reach of the river which naturally goes dry. With distance downstream of the Lower Gorge 1 reservoir it is expected that some flow variability is maintained due to contributing flows from the Lower Waitohi, Washpen Stream and Sheepdip Creek Catchments (see Figure A9). The increase in catchment area at several locations downstream of Lake Sumner Road Bridge and the increase in mean flow as estimated by Gabites (2006) is shown in Table 10.

8.6 Environmental Considerations

Boffa Miskell has provided input on environmental issues that may arise from operation of the scheme (i.e. minimum flows, flushing flow period, quantities etc).

8.6.1 Flushing Flows

The FRE3 statistic is a measure of the frequency at which flushing flows occur on an annual basis. Specifically, the FRE3 statistic is the mean annual frequency at which the

mean daily flow exceeds three times the median flow. The FRE3 statistic is closely linked with periphyton growth and invertebrate density. Flushing flows control periphyton biomass and a flow of around 3 times the median flow is generally required (substrate and flow pattern dependent) to disturb the bed of a river to such an extent that a substantial portion of the periphyton is lost from the reach due to abrasion, dislocation, and/or bed mobilisation. Clausen and Biggs (1977) found that periphyton biomass decreased with increasing FRE3, whereas invertebrate density had an increasing relationship.

Table 27 summarises the FRE3 statistic for natural and modified flows and provides an indication of the change in the frequency of flushing flows as a result of the proposed scheme. It is important to recognise that this reflects a particular set of operational rules.

| Table 27: FRE3 Statistic for Natural and Modified Flows (Period 1972-2011) | | | |
|----------------------------------------------------------------------------|--------------------------------------------------|-----------------------|---------------|
| | Median natural/existing flow (m ³ /s) | FRE3 | |
| | | Natural/Existing flow | Modified Flow |
| Hurunui between intake 3 and 1 | 38.0 | 6.9 | 6.3 |
| Hurunui between intake 1 and 4 | 43.9 | 6.7 | 6.1 |
| Hurunui downstream of intake 4 | 42.2 | 7.0 | 6.1 |
| Waitohi downstream of intake 2 | 0.61 | 11.4 | 6.4 |

As expected the frequency of flushing flows on an annual basis is reduced as a result of the proposed abstractions. Table 27 shows that there is a small decrease in flushing flows in the Hurunui River. The main decrease is downstream of all proposed abstractions (i.e. downstream of intake 4) with only a very small decrease in flushing flows between intakes 3 and 1.

The Waitohi River downstream of intake 5 (i.e. downstream of Lower Gorge 1 reservoir) shows a decrease from 11.4 to 6.4 in the annual frequency of flushing flows (i.e. instead of experiencing a flushing flow on average 11.4 times per year, the modified response would be for a flushing flow to occur on average 6.4 times per year). As detailed in section 8.6.2 it is proposed that additional flushing flow releases be made from storage to meet ecological and environmental requirements. It also has to be noted that in the typical low flow summer months (when periphyton growth can be an issue) low flows are generally augmented due to a minimum flow at the outlet of the Lower Gorge 1 dam of 250 L/s which may reduce the occurrence of periphyton growth.

8.6.2 Environmental Flow Releases from the Reservoirs

The main period of ecological stress in the river is in the summer low flow period between December and April. It is proposed that environmental flushing flows will be released from storage to meet ecological and environmental requirements. For example, if periphyton levels are observed to be too high an appropriate release can be made.

It is understood that a flushing flow of duration around 6 hours may be required at a flow rate of around 3 times the median flow to remove periphyton from the river bed. For the Waitohi River this would equate to a flow of around 2.0 m³/s. Indicative flushing flows are drawn on Figure 14.

These flows are negligible compared to the irrigation releases of up to 42.4 m³/s and it is therefore expected that these environmental releases do not impact on the reliability of the proposed irrigation scheme. The available volume of water can easily accommodate the required flushing of the Waitohi River system.

8.6.3 Reservoir Inundation and Wave Action

Prolonged inundation of the lake edge above the root zone has the potential to degrade lakeside vegetation. Waves have the potential to increase the inundation area /lake shore of the proposed reservoirs on top of the proposed maximum operating level. Wave amplitude (and hence wave run-up) is dependent on fetch and wind velocity. The fetch is the distance over which waves are generated by a wind that is nearly constant in direction and speed. In other words it is the effective distance which waves have travelled in open water, from their point of origin to the point where they break. Due to the small fetch for the Seven Hills, Inches Road and Lower Gorge 1 Reservoir it is not expected that wave action will inundate the lake edge appreciably above the proposed maximum operating level. However, due to the large area of the proposed Hurricane Gully reservoir the fetch of this lake is likely to induce wave action that will inundate the lake edge above the maximum operating level of 500 m RL. The slopes of the Hurricane Gully reservoir are relatively steep and the width and length of the lake inundation area is not expected to increase notably as a result of wave action.

9.0 Reliability of Supply for the Scheme

The upper plot in Figure J1 shows the total number of days that supply does not meet demand, and the lower plot shows the longest number of consecutive days that supply is less than demand. While there are 5 years in which supply does not meet demand throughout the irrigation season (*full reliability* of 87 % in the sense defined in section 7.0) there are only two irrigation seasons, namely 1972 (i.e. 1 October 1972 till 30 April 1973) and 2007 (i.e. 1 October 2007 till 30 April 2008) where the deficit may be regarded as significant, and corresponds to the live storage being used completely in all three reservoirs. In terms of *average supply/demand ratio* the scheme is 98 % reliable. In other words over the 39 year modelling period (on average) supply meets demand 98% of the time.

As noted in section 7.2 the *soil moisture index (SMI)* for a given soil is defined to be soil moisture balance divided by the PAW class. The SMI for the scheme is the average SMI over the soil types. Figure J2 shows the SMI by irrigation year. The green line shows the average SMI without irrigation and the blue line shows the SMI with the irrigation scheme in place. In all years except 1972/1973, 1997/1998, 2007/2008 and 2008/2009 the SMI is greater than 50 % (i.e. SMI greater than 0.5) throughout the irrigation season. During the irrigation year of 1997/1998 and 2008/2009 there was no actual water deficit, ET levels were uncommonly high in January through March 1998 and in January 2009, frequently greater than the irrigation application rate. Due to uncommonly low flows during the Summer of 1972/1973 the live storage in the reservoirs is completely used resulting in an SMI less than 50 % from the beginning of April onwards. 2007/2008 is more extreme and shows two periods when the SMI is less than 50%: Beginning of February and beginning of March onwards. Therefore in these years the irrigation season is shortened by up to 2 months.

The simulation suggests that for the vast majority of years the scheme has enough water for a complete irrigation season and is therefore highly reliable. For extreme years like 1972/1973 and 2007/2008 the irrigation season will be shortened.

Uncertainty rests with the frequency of hydrological conditions which lead to extreme years of the type discussed. Climate change and the Interdecadal Pacific Oscillation have been discussed in broad terms in section 4.3, and while it is not possible to quantify the level of uncertainty, it is prudent to assume that the incident of droughts in the lower Hurunui Catchment may increase and therefore years like 1972/1973 and 2007/2008 may increase in frequency.

10.0 Mitigation Measures and Monitoring

10.1 Mitigating Adverse Effects on the Environment

A large component of mitigation has already been built into the scheme operation and has been discussed in section 8.6 so that the effects of the modified regime do not stray significantly from the natural situation, and can comply with the allocation rules defined in the 'Regional Plan post storage flow regime'.

This section summarises the mitigation measures that have been proposed by the HWP, based on environmental requirements determined by Boffa Miskell.

10.1.1 Minimum Environmental Flows

A minimum environmental flow of 250 L/s at the outlet of Lower Gorge 1 reservoir has been set in consultation with Boffa Miskell. This will ensure a continuous flow in the Waitohi River during periods when the Waitohi River naturally goes dry. Flows during the summer low flow period (typically January through to April) are augmented except when the live storage in the reservoirs is completely used (see section 8.5.1)

10.1.2 Environmental Flow Releases

The frequency and occurrence of flat-lining in the Waitohi River has been discussed in section 8.5.1. For the Waitohi River it was noted that long periods of flat-lining for the modified scheme tends to coincide with refill periods of the reservoirs and irrigation takes. Even though flows are generally augmented in the summer low flow period, the lack of flow variability can induce periphyton growth. Periphyton levels are typically above nuisance levels during summer months (V. Keesing, Boffa Miskell).

The storage reservoirs provide an opportunity to release a fresh which under natural circumstances could not occur. To mitigate the effects of flat lining it is proposed to make flushing flows during the irrigation season if periphyton levels are high.

10.2 Management and Operational Plans

Plans will be prepared for the management of the scheme and operation of the dams. A draft of these plans will be submitted 6 months prior to the operation of the scheme.

Apart from maintaining environmental flows, the actual operation of the scheme can only be confirmed when operational, therefore this plan will need to be reviewed annually.

10.3 Proposed Monitoring

10.3.1 Water Takes

It is proposed that the rate at which water is abstracted from each of the intakes will be monitored on a continuous basis.

10.3.2 Reservoir Levels

It is proposed that water levels in all reservoirs will be monitored on a continuous basis.

10.3.3 Environmental Monitoring

As noted in section 6.2 there is an absence of reliable rainfall and evapotranspiration data in the command area. Consequently HWP is proposing to install weather stations to provide reliable rainfall, evapotranspiration and soil moisture data. This will provide information to shareholders so they can plan their irrigation and make the most efficient use of water.

With regard to flow monitoring it is proposed to monitor the flows at the outlet of Lower Gorge 1 reservoir.

11.0 Conclusions

The HWP Waitohi irrigation and hydro scheme proposes to abstract a maximum of 42.4 m³/s from the flow of the Hurunui River for the purpose of irrigating approximately 58,500 hectares of land and hydro-generation.

Effects on the Hurunui River

This assessment shows that the effects of the proposed abstraction on the Hurunui River flows downstream of each proposed intake location are distinctly different.

The effects immediately downstream of the pumped intake (i.e. between intake 3 and intake 1) are relatively small compared to the effect downstream of intake 1 and 4. In general terms it can be concluded that within the irrigation season flows are largely unaffected and the main effects are outside the irrigation season when flows are naturally high. This reach of the Hurunui River is largely unaffected during the summer low flow period.

The effects between intake 1 and intake 4 are characterised by a decrease in flows (especially in the irrigation season) when run-of-river water is abstracted to supply the irrigation area. During the summer low flow period flows are sometimes increased due to releases from storage supplying water to the north side of the Hurunui River. The mean flow in this stretch of the river is reduced by 14 %.

Downstream of intake 4 the existing flows are generally reduced and (in the irrigation season) sometimes "flat lined" at a flow of around 15 m³/s and 20.8 m³/s. During the summer low flow period flows are sometimes increased due to a higher A-block flow in the "post storage Regional Plan" flow regime compared to the A-block minimum flow for the existing Amuri Scheme. The largest relative reduction in flows is for the flow range between 20 and 70 m³/s. The mean flow in this stretch of the river is reduced by 18 %.

Storage reservoirs

This assessment of environmental effects shows that the total live storage of 220.5 million m³ in the proposed reservoirs will only be used in extremely dry years (i.e. 5 years out of the 39 years modelling period). In conclusion the effects on the storage reservoirs can be summarised as follows:

- Hurricane Gully is the main storage reservoir with an operating range of 50 metres. The mean lake level over the modelling period is only 7.9 m below the maximum storage level of 500 m RL and water levels being higher than 490 m RL for 73 % of the time. Lake levels are typically at the lowest towards the end of the irrigation season with the lowest mean monthly lake level being April at a level of 482 mRL. The full operating range of 50m is only used 6 years out of 39 years.
- Lake levels in the Seven Hills storage reservoir can fluctuate between 380 m RL and 400 m RL (operating range of 20 m). Water levels are generally high but will drawdown up to 10 metres in the weekends when electricity demand is lower

(increased release from Seven Hills and decreased release from Hurricane Gully over the weekend). The full operating range for this reservoir will only be used in extreme dry years when the water is being used to meet irrigation demand when the live storage in Hurricane Gully is completely used.

- Inches Road Reservoir is generally full and will only be drawn down to its lowest operating level of 350 m RL during extremely dry years when the upstream reservoirs have fully used their live storage (Hurricane Gully and Seven Hills)
- Lower Gorge 1 Reservoir will maintain a high level at all times to maximise hydro-generation.

Effects on Waitohi River Flows

The main effects on the Waitohi River are a decrease in flow variability downstream of the storage reservoirs. Due to harvesting water into storage subject to maintaining a minimum flow of 250 L/s flows are 'flat lined' for the majority of the time. However, during the summer low flow period flows are increased due to a conservatively high environmental flow release of 250 L/s at the outlet of Lower Gorge 1 reservoir. In order to prevent periphyton growth in the river it is proposed to release flushing flows from storage in the low flow period between December and April. It is not expected that these environmental releases will impact on the reliability of the scheme.

12.0 References

- Bowden, M J, The Water Resources of the Hurunui Catchment, North Canterbury Catchment Board and Regional Water Board, Christchurch, Reference No.3404, November 1977.
- Environment Canterbury, Variation 8, Proposed Natural Resources Regional Plan, Chapter 5: Water Quantity, Notified 25 August 2007, Report No. R07/22.
- Facer, S., Seven day mean annual low flow mapping in the Hurunui Catchment, Report No. U03/34, Environment Canterbury, July 2003.
- Familton, H., Planning Report Hurunui River and Tributaries: Environmental flow and water allocation. Report No. U07/60, Environment Canterbury, July 2007.
- Familton, H., Draft Flow and Allocation Regime: Waitohi River, Sheep Dip Creek and Washpen stream. Report No. U07/87, Environment Canterbury, February 2008.
- Gabites, S., Low flows in the Waitohi River, Report No. U06/5, Environment Canterbury, April 2006.
- McIndoe, I., Efficient and Reasonable Use of Water for Irrigation, Report No. U01/69, Environment Canterbury, May 2002.
- McKerchar, A.I., Henderson, R.D., Shifts in flood and low-flow regimes in new Zealand due to interdecadal climate variations. Hydrological Sciences-Journal des Sciences Hydrologiques, 48(4) August 2003.
- Mosley, Dr M P Hurunui River: Instream values and flow regime, Environment Canterbury, Report No. R02/1, ISBN 1-86937-437-1, January 2002.
- Morland, K., Water resources of the Canterbury region, An overview of values and resource management issues, Report No. U94/59, March 1994.
- Ministry for the Environment (2008), Climate Change Effects and Impacts Assessments: A Guidance Manual for local government in New Zealand. 2nd Edition. Mullan B; Wratt D, Dean S, Hollis M; Allan S; Williams T, Kenny G and MfE. Ministry for the Environment, Wellington. xvii + 149 p.
- Proposed Hurunui and Waiau River Regional Plan (Draft). Environment Canterbury, August 2011
- Tonkin & Taylor Ltd, Hurunui Community Water Development Project, Stage 1 District Scoping Report, June 2004.
- Department of Scientific and Industrial Research, General Survey of the Soils of South Island, New Zealand. Soil Bureau Bulletin 27, 1968

Assessment of Environmental Effects for Stage 2: HWP Waitohi Irrigation
and Hydro Scheme

Renowden, G., Statement of Evidence of Gareth Renowden on behalf of the Hurunui Water Project (26 March 2009). An application for a Water Conservation Order pursuant to s201 of the Resource Management Act 1991 by The new Zealand & North Canterbury Fish & Game Councils and the New Zealand Recreational Canoe Association.