REPORT

WAIMEA WATER AUGMENTATION COMMITTEE/TASMAN DISTRICT COUNCIL

Assessment of Two Alternative Water Storage Options - Upper Lee and Left (Eastern) Branch Wairoa Rivers - Waimea Catchment

Report prepared for:

WAIMEA WATER AUGMENTATION COMMITTEE/TASMAN DISTRICT COUNCIL

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EXECUTIVE SUMMARY

This report sets out the results of preliminary and comparative investigations for Site 11 (Upper Lee River) and Site 15 (Left (eastern) Branch Wairoa River), as a basis for the Waimea Water Augmentation Committee (WWAC) choosing a preferred option as the second milestone for the feasibility study of water storage in the upper parts of the Wairoa/Lee catchments in Tasman District. The report focuses on those aspects that contribute to a *comparative* assessment.

The report is based on work undertaken to June 2006. It firstly presents those aspects that are common to both Site 11 and 15, but which influence the comparative assessment. These are water demand and required storage (including irrigation, community/industrial demand, groundwater requirements, and instream requirements), and the cultural impact assessment.

Sections 5 and 6 respectively address Site 11 and Site 15, focussing on comparative issues as determined from the currently available preliminary information.

Section 7 focusses on the key comparative issues. These are summarised in tabular form below.

Feature	**Site 11 - Lee**	**Site 15 – Left Branch Wairoa**
Water demand	No difference	No difference
Storage capacity	No difference	No difference
Reservoir area (hectares)	Larger	Smaller
Materials availability	Majority available on-site	Expect most to be imported
Construction access issues	Effects less apparent	Effects more apparent
Operating regime	Effects more apparent	Effects less apparent (Right Branch Wairoa provides buffering)
Sedimentation potential	No significant difference	No significant difference
Downstream hazard potential	Lower	Higher
Required design standard	No difference	No difference
Comparative cost (base price)	No significant difference (within current order of accuracy)	No significant difference (within current order of accuracy)
Cost (piped delivery)	Lower cost	Higher cost
Land tenure	More owners (7)	Fewer owners (4)
Land administered by DOC	Less	More
Potential electricity generation	Little difference (1.2 MW; 6.8 GWh/annum)	Little difference (1.7 MW; 9.8 GWh/annum)
Aquatic ecology	Little difference	Little difference
Water quality (effect of ultramafic geology in catchment)	No issue	Potentially an issue

Feature	Site 11 - Lee	Site 15 – Left Branch Wairoa
Indigenous vegetation	More significant	Less significant
Blue duck (whio)	No difference	No difference
Cultural impact	Difference not known at this stage	Difference not known at this stage
Trout fishing	Little difference	Little difference
Informal recreation	Little difference	Little difference
Kayaking	No issues	An issue – development would be opposed
Access to Richmond Forest Park	Lesser effect	Greater effect
Archaeology/heritage values	No difference apparent at this stage	No difference apparent at this stage
Community preference	Not gauged	Not gauged
Enhancement opportunities	No difference apparent at this stage	No difference apparent at this stage

It appears from the above table (without weightings being applied to any criteria) that the Lee may have more positive points than the Wairoa.

This report was presented as a Draft Discussion Document to WWAC at its meeting on 19 July 2006. Following that meeting, WWAC undertook further consultation with various components of the community, and considered the issues further at a second WWAC meeting on 21 August 2006. At that second meeting, WWAC took the decision to focus further investigations on Site 11 Lee River as the preferred option for possible storage.

1 Introduction

In November 2004, Tonkin and Taylor was commissioned by the Waimea Water Augmentation Committee (WWAC) and Tasman District Council (TDC) to undertake a feasibility study of water storage in the upper parts of the Wairoa/Lee catchments in Tasman District. The specific brief was to address the recurrent water shortages experienced on the Waimea Plains and to investigate enhancing water availability for consumptive and environmental/community/aesthetic benefits downstream on the Waimea Plains and surrounds.

The project is multi-disciplinary and covers a three year period. It has four main components:

1. water availability analysis
2. site storage options, and water delivery methods and costs
3. environmental and economic analysis of scenarios with and without augmentation
4. water allocation for optimisation of water use, environmental/community benefits/funding.

Tonkin and Taylor is undertaking this project in a staged way. The overall project stages are generally described as follows:

- identify potential water demand
- identify range of potential storage sites
- work with ESR to assist them to identify community values of Waimea Catchment
- assess broad-scale physical, engineering, and environmental constraints to refine list to small number of practical storage sites
- refine hydrological, physical, engineering, and environmental issues and conduct Workshop with WWAC to determine up to three possible storage options
- develop hydrological model of Wairoa and Lee Catchments including relationship between surface and groundwater resources in the Waimea Basin
- identify opportunities to enhance surface and groundwater resources from management of storage scenarios
- undertake initial dambreak and environmental assessment studies of (up to) three scenarios
- work with ESR for them to assess community response to (up to) three scenarios
- determine appropriate water allocation and distribution parameters
- consider community feedback, water demand, distribution requirements etc and determine preferred option(s)
- undertake geotechnical investigations, and dambreak analysis for feasibility of preferred option
- develop overall solution (or scenario) including distribution and allocation.

This report outlines the work undertaken to June 2006, leading to the second milestone for the overall project of determining the preferred option for possible storage.

Clarification Note: The NZMS topographic map names the branches of the Wairoa River as follows:

- Left Branch – this is the eastern branch
- Right Branch – this is the western branch

This naming is opposite to the usual convention of referring to right and left branches (or banks) to reflect the orientation when facing **down**stream. To avoid confusion in this report we have endeavoured to make it clear by including reference to the east or west in our descriptions.

2 Preliminary Work

In December 2004 Tonkin and Taylor completed a preliminary scan of possible storage (and infill) options in and adjacent to the study area, but excluding those below about 5 Mm^3 size. Identification of options was essentially desk-based, but involved inspection from public vantage points of those sites able to be accessed by specialist members of the team. We identified 18 possibilities and provided these to WWAC's project manager for advice on any which should be excluded.

WWAC's technical team discussed the options, and requested the removal of seven sites. The remaining sites were:

- Sites 1A and 1B – Pigeon Valley South
- Site 2 – Pigeon Valley North
- Site 3 – Unnamed tributary of the Wai-iti River
- Site 4 – Teapot Valley
- Site 10A – Lower Lee
- Site 10A – Middle Lee
- Site 11 – Upper Lee
- Site 13 – Wairoa Forks
- Site 14 – Right Branch Wairoa (western)
- Site 15 – Left Branch Wairoa (eastern)

Tonkin and Taylor's technical team undertook a ranking exercise of the above sites, based on a range of initial technical and environmental criteria. These included:

- storage characteristics
- geological/seismic risk
- reservoir filling
- constructability
- hazard potential
- power generation potential
- flexibility for staging
- cultural acceptability
- land use
- effect on infrastructure
- aquatic ecology
- terrestrial ecology
- recreation
- archaeology

The following five sites ranked highest:

- Site 2 – Pigeon Valley North
- Site 10A – Middle Lee
- Site 11 – Upper Lee
- Site 13 – Wairoa Forks
- Site 15 – Left (eastern) Branch Wairoa

On 5 April 2005, a report setting out the characteristics of the above sites was discussed during two workshop sessions, firstly with a Technical Group of the Waimea Water Augmentation Committee, and secondly with the formal Committee that evening.

A broad ranking exercise was undertaken by the Technical Group and was subsequently endorsed by the Committee. The ranking process assessed each of the five sites according to general criteria covering environmental, engineering, and consentability/public acceptance issues. The outcome was as follows:

- Site 11 (Upper Lee) – highest (best) ranking
- Site 2 (Pigeon Valley)
- Site 15 (Left Branch) eastern) Wairoa
- Site 10B (Middle Lee) and Site 13 (Wairoa Forks) – lowest equal ranking

There was little difference between Sites 2 and 15 in terms of their relative ranking.

Accordingly, Sites 11, 2, and 15 were selected for ongoing investigation.

Site 2 was then investigated further to determine relative costs, and WWAC representatives also met with Pigeon Valley residents to gauge community response. On the basis of the results of both those processes, Site 2 was eliminated from further investigation at this stage. Accordingly Tonkin and Taylor was instructed by WWAC to continue a comparative assessment of Site 11 (Upper Lee) and Site 15 (Left (eastern) Branch Wairoa.

This report sets out the results of the preliminary and comparative investigations for Sites 11 and 15, as a basis for WWAC choosing a preferred option to continue pre-feasibility investigations for. The report focuses on those aspects that contribute to a *comparative* assessment. However, as a basis for comparison, the key aspects that drive the comparison are also set out, as well as providing comments on those issues where no comparative assessment has yet been undertaken (eg cultural impact).

The work that has contributed to this phase of the study is:

- Assessment of water demand (irrigation, community/industry) – undertaken by AgFirst, in conjunction with Tasman District Council
- Determination of instream residual flow requirements at Appleby Bridge – undertaken by Cawthron Institute
- Modelling of groundwater system to determine requirements for surface water provision to meet water demand, groundwater and instream demands – undertaken by GNS
- Modelling of surface water system (incorporating groundwater requirements as above) to determine reservoir storage requirements – undertaken by Tonkin and Taylor
- Preliminary determination of operating regime – undertaken by Tonkin and Taylor

- Preliminary geological mapping – undertaken by Tonkin and Taylor
- Determination of dam type – undertaken by Tonkin and Taylor
- Preliminary layout determination – undertaken by Tonkin and Taylor
- Preliminary dambreak assessment – undertaken by Tonkin and Taylor
- Preliminary costing – undertaken by Tonkin and Taylor
- Assessment of land tenure – information provided by Tasman District Council
- Comparative assessment of indigenous vegetation – undertaken by Uruwhenua Botanicals (Dr Philip Simpson)
- Blue duck survey – undertaken in November 2005 by Dave Barker
- Cultural impact study – undertaken by Motueka Iwi Resource Management Advisory Komiti (MIRMAK)
- Consultation to determine recreational preferences (kayaking) – undertaken by Tonkin and Taylor
- One community meeting with residents of Lee and Wairoa Valleys – arranged by WWAC

These aspects are addressed in the following sections. The report firstly presents those aspects that are common to both Site 11 and 15, but which influence the comparative assessment. These are water demand and required storage (including irrigation, community/industrial demand, groundwater requirements, and instream requirements), and the cultural impact assessment.

The following sections address Site 11 and Site 15 separately, focussing on comparative issues. The final section summarises the key comparative issues.

3 Water Demand and Required Storage

3.1 Introduction

A required storage capacity of between 15 to 20 million m^3 was previously estimated (Tonkin and Taylor April 2005 report) based on a simple and approximate analysis. The demand associated with this estimate was equivalent to full irrigation of 4055 hectares of pasture at the rate of 35 mm/ha/week at 100% plant ground cover over a continuous 15 week period. Included in this figure was an urban and industrial demand allowance (within the Waimea Basin) equivalent to 380 ha of pasture. As an initial and conservative estimate, and based on the information available at that stage of the project, this storage estimate did not allow for the existing recharge and storage available in the Waimea groundwater aquifers or any incident rainfall during the irrigation season which may offset some of the demand.

A technical workshop on water demand was held on 8 February 2006 attended by Joseph Thomas (TDC), John Bealing (AgFirst), Timothy Hong (GNS), and Sally Marx and David Leong (Tonkin and Taylor). The purpose of this workshop was to refine and agree the demand assumptions on which to base the live storage requirement for the proposed dam and, critically, the detailed input requirements for the complex groundwater model. Among other things, the workshop covered the following:

- Overview of the overall process to determine live storage, and thus dam height
- Overview of the groundwater model, its geographical coverage, including its upstream and downstream boundaries, its layering system and the format of input required in terms of demand data
- Clarification of the area served by the Waimea East Irrigation Scheme (WEIS) (river intake) and that by groundwater takes, both as conceptualised in the groundwater model and in reality
- Limitations of the historical groundwater pumping and WEIS take data in the groundwater model
- Agreement of the assumptions and approach for estimating future irrigation and urban and industrial water demand
- Discussion of the effect of incident rainfall during irrigation season in moderating irrigation demand, and selection of an appropriate design drought year for groundwater modelling
- Agreement of timeframes and responsibilities for preparation of modelling datasets

A summary of the outcomes from the workshop was advised to WWAC representatives on the evening of 8 February 2006.

Details of the demand assumptions, particularly the assumed geographical distribution and seasonal pattern of take for different soil and crop types, will be provided as an appendix in our final report to WWAC. A summary covering both consumptive and in-stream water demand and the dam storage modelling is provided in the following sub-sections. Data on consumptive demand is based on information provided by AgFirst, TDC and GNS.

3.2 Consumptive Water Demand

The equivalent net irrigable area in the Waimea Basin, including areas yet to be irrigated (1500 ha), has been assessed at approximately 5300 ha. Note that the original area was assessed at 6,582 ha, and reduced to 5,306 ha when urban areas, road reserves, river reserves and other such areas were excluded. Allowing for a further 481 ha (181 ha existing plus 300 ha new) in the lower Wai-iti from Wakefield to Aldourie Rd brings the total to about 5800 ha. Table 3.1 presents the approximate areas and corresponding demand. Additional work following the water demand workshop has refined these figures, i.e. the tabulated figures will be updated in the final report.

Table 3.1: Irrigation Areas & Demand by Water Zones

Zone	Net Area Ha	Approx. Demand (Peak Daily Flow) l/s
Upper Catchments	Minimal	5
Reservoir	580	288
Waimea West	385	191
Hope & Eastern Hills (includes Upper and Lower Confined)	2,170	1,256
Golden Hills	300	149
Delta	1,246	556
Redwood	625	258
TOTAL	**5,306**	**2,703**
Wai-iti: Aldourie Rd to Wakefield	Up to 1180 ha irrigable. Current allocation sufficient for 181 ha.	105
	300 ha extra allowed for in this Design	174
TOTALS	**5,787 ha**	**2982 l/s**

Note: In this table, the demand figures are based on in which zone the land needing to be irrigated actually lies. The demand has been based on the predominant soil type making up that zone.

An urban and industrial demand within the Waimea Basin corresponding with an average supply rate from the aquifer of 227 l/s is additional to the above.

The actual irrigation usage depends heavily on the actual rainfall pattern over the season, and to a lesser extent on other climatic variables (wind, solar radiation, etc.) Clearly, the total volume of water required will be greater when in a drought situation. It is reasonable to assume that high irrigation usage will often coincide with lower than average river flows over an irrigation season. This is because both variables are driven by rainfall patterns to a large extent – low rainfall generally equates to low flows and high usage. In terms of reservoir storage utilisation, low inflows to the reservoir and high irrigation usage are compounding factors, and so must be captured appropriately in the reservoir simulation. Otherwise the result would be unconservative. Thus, an irrigation usage pattern which corresponds with a drought year must be used.

Complete datasets of soil moisture and aquifer recharge for groundwater modelling are only available for the following years: 1982/83, 1991/92 and 2000/01. Of these, the 1982/83 year plots at about the 90th percentile mark in terms of theoretical irrigation usage, and as such may be interpreted as being the 1 in 10 highest usage year. Thus, the 1982/83 year has been selected as the design drought year. The 2000/01 year is more severe and likely to be too conservative (see Section 3.6) while the 1990/91 year appears to be an average year (i.e. not a high usage year).

Figure 3.1 shows the theoretical demand pattern adopted for subsequent groundwater modelling and reservoir storage simulations. The WEIS intake (red), which is abstracted directly from the Wairoa River downstream of the Irvines flow recorder, is shown separately from the combined groundwater take from the Waimea Basin (dark blue). The actual takes for the 1982/83 season (pink for groundwater take and light blue for WEIS abstraction) are also shown for comparison.

In summary, over the full season from 1 July 1982 to 30 June 1983:

- total theoretical water usage for the future assumed allocations is about 32 million m^3
- the total actual water usage was about 22 million m^3
- the theoretical peak daily demand is about 3300 l/s or 280,000 m^3/day, inclusive of WEIS abstraction.

Note that these demand figures exclude additional allowance for any "future regional need". The additional demand for this future regional need (based on regional figures and provided to us by TDC) is approximately 22,000m^3/day. This equates to a constant year round take of 254 l/s, and an annual take volume of about 8 million m^3. In our modelling, for simplicity (and to be on the conservative side) the supply for such a need is assumed to be a surface water take above the Waimea aquifers rather than a groundwater take from the Waimea Basin.

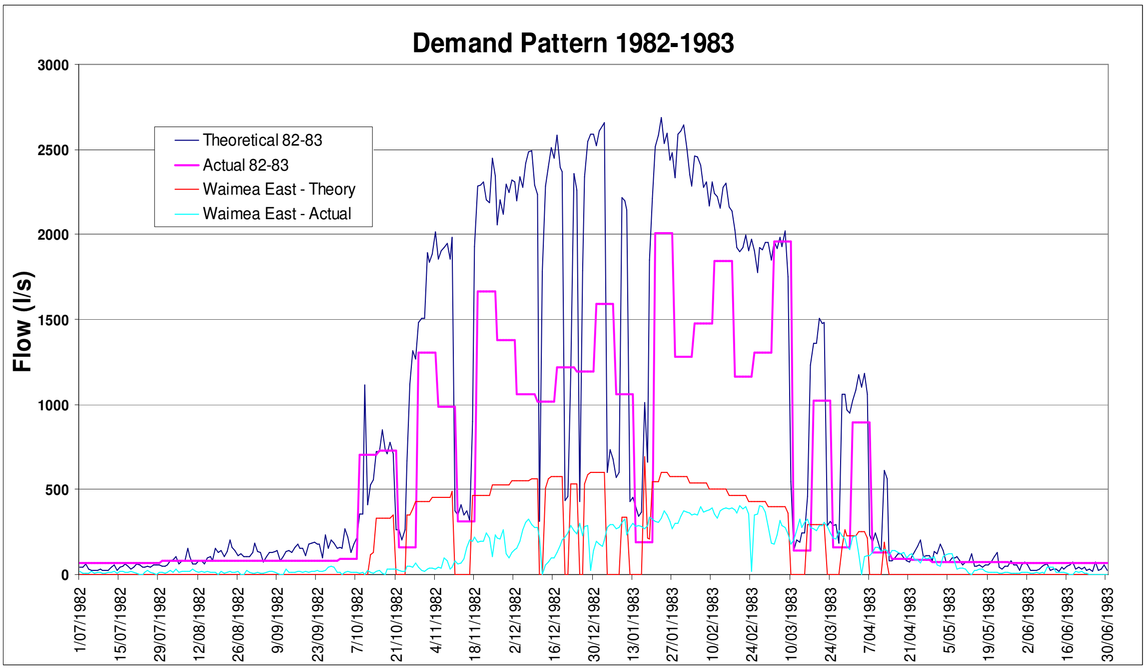


Figure 3.1 Assumed demand pattern for consumptive use

3.3 In-Stream Requirements

Cawthron has undertaken an assessment of the minimum flows required to provide instream habitat in the Waimea River and immediately below the two potential dam sites (Sites 11 and 15). Three different minimum flows were identified to span a range from an "environmental benchmark" minimum flow that would be conservative in terms of environmental protection, to a minimum flow that would be weighted towards out-of-stream values.

The results were:

1. instream residual flow requirements at Appleby
   - 1300 l/s (environmental benchmark)
   - 800 l/s (minimum flow retaining 80% of the adult brown trout habitat)
   - 500 l/s (minimum flow retaining 70% of the adult brown trout habitat).
2. instream residual flow requirements immediately below the two potential dam sites:
   - existing MALF (environmental benchmark)
   - 1 in 5 year low flow
   - 1 in 10 year low flow

WWAC subsequently took a decision to assess the live storage requirements necessary to maintain flows covering much of this range, specifically requesting T&T to assess two scenarios for flows at Appleby:

- 600 l/sec
- 1100 l/sec

At each of the dam sites, a residual flow immediately below the dam equal to the mean annual low flow (MALF) has been conservatively assumed.

3.4 Groundwater Modelling

The main objective of the groundwater modelling by GNS is to determine the flow releases required from a storage reservoir in either the Upper Lee River or Upper Wairoa River in order to sustain a pre-determined residual flow at Appleby Bridge while meeting unrestricted abstractive demands from the Waimea aquifers. This entailed multiple runs of the existing Waimea Plains groundwater model (which has been developed and calibrated by GNS in collaboration with TDC over the past few years) using the future allocation regime based on the 1982/83 theoretical demand profile and soil moisture (drainage) data.

Results from the groundwater modelling were then analysed to develop a relationship between the level of irrigation demand and the minimum flow required at Irvines to maintain a particular residual flow at Appleby Bridge.

An important part of the groundwater model is the representation of the river – aquifer interaction and recharge process. While the groundwater model has been well calibrated based on observed groundwater level and river level data, there remains a level of uncertainty in the results. In particular, the sensitivity of the aquifer recharge to riverbed level changes and potential for seawater intrusion in certain areas would need further assessment in subsequent study phases.

Details of the groundwater modelling will be provided as an appendix to our final report to WWAC.

3.5 Dam Storage Modelling

The required live storage required at a dam is dependent on the following factors:

- water demand – this has been discussed in Section 3.2 earlier
- environmental or residual flows for protection of instream values – this has been discussed in Section 3.3 earlier
- flow variability and the level of drought security desired - in the current system, year to year flow variability has been represented by the long-term record of Wairoa River flows at Irvines from 1958 to 2005; drought security is discussed in Section 3.6.
- system characteristics and behaviour – these revolve around drainage pattern of the catchment, its rainfall-runoff response, the groundwater-aquifer interaction and other processes

A simulation method which takes into the account the parameters and characteristics above has been used to model the dam storage behaviour at each dam site over the period of the Wairoa River flow record (1958 to 2005). The key to this spreadsheet based model, which operates on a daily timestep, is the maintenance of a threshold minimum flow at Irvines whereby predicted shortfalls in the remaining natural river flow must be met by controlled dam releases. The same water demand pattern, based on the theoretical usage for the 1982/83 drought year (Section 3.2), has been assumed for each year of record.

3.6 Drought Definition and Security of Supply

For a given amount of live storage, the level of service provided by the reservoir is expressed as the level of security with regard to a drought with a particular return period, viz. the "drought return period". This drought return period has been assessed from the simulated storage inflow-outflow behaviour described in Section 3.5.

By using a standard approach similar to that applied to estimating floods or low flows, an analysis of the magnitude of the storage fluctuations over time (specifically the minimum level attained in each year of record) produces a relationship between the minimum storage and the expected recurrence frequency or return period. The required live storage, or "storage drawdown" is equal to the full storage less this minimum storage.

Figure 5.3 in Section 5.2.4 provides an example of the simulated storage behaviour from 1958 to 2005. This shows what the magnitude of the drawdown (shown as inverted "spikes") would have been in each year of record. Figure 5.3 shows that the greatest "need" would have been in the 2000/01 season where a storage capacity in the order of 13 million m^3 would have been required. Figure 5.5 is an example of a frequency plot of the storage drawdown from which the live storage required versus drought return period is determined. Using the 2000/01 season again as an example, this shows that the 2000/01 drought had a return period in the order of 80 years.

Note that there is an important and fundamental difference in the drought definition for a river system with controlled storage and one without (i.e. a run-of-river system). To elaborate: when required, storage is released from the reservoir to supplement natural river flows according to downstream requirements, typically under low flow conditions. In general, the highest flow releases occur when periods of high demand coincide with very low natural flows.

While the maximum rate of release is related to the magnitude of this shortfall on an instantaneous (or daily) basis, the level to which storage in the reservoir is drawn down depends on the sum of all the preceding releases made. That is, the storage drawdown is a reflection of the accumulated shortfall over time. Thus, for a storage reservoir, the critical situation is one in which the total volume of shortfall over an entire season (or longer if the dam was not full at the start of the season) is a maximum. The magnitude of any one short-lived shortfall episode rarely governs the storage requirement.

For a run-of-river system, such as the Wairoa River currently, the return period of a drought event is typically determined from an analysis of short-term low flow events, such as the instantaneous low flow, the mean daily low flow, or the mean 7-day low flow. So, what may be a significant drought event in a run-of-river system may not necessarily have the same level of significance in terms of the security of supply from a reservoir, due to the different timeframes being considered.

3.7 Total Water Demand/Storage Requirement

The modelling for the determination of storage volume requirements, based on AgFirst's water demand and GNS's groundwater modelling was completed and peer reviewed by Andrew Fenemor of Landcare Research. The outcome was that the required storage volume to meet the identified target drought security (1 in 10 years) was found to be lower than the initial assessment of 15 million m^3 (which had been based purely on water demand). Key results are summarised in Tables 3.2 and 3.3 below for scenarios which do and do not allow for a future regional supply of 22,000m^3/day respectively. Accordingly Tonkin and Taylor sought instructions from WWAC on whether to:

- Retain the original drought security (1 in 10 years) with consequential savings in cost and (potentially) effects OR
- Provide additional storage to increase the drought security (but potentially still within the original cost estimate range)

The decision also needed to include:

- Which downstream residual flow scenario to adopt (for instream habitat purposes)
- Whether the reservoir is to perform any function additional to irrigation water supply; eg recreational resource, habitat provision, cultural purposes etc (incorporating provision for dead storage)

WWAC considered these issues at a meeting on 8 June 2006 (based on memos from Tonkin and Taylor setting out the storage volumes associated with various scenarios). WWAC's decision was to determine a total storage volume that was large enough to provide flexibility to respond to certain events, take into account the uncertainties in modelling and climate change, and to manage the storage in response to those events.

The volume chosen by WWAC for further study was:

- 12 million m^3 live storage
- Plus provision for an additional 1 million m^3 dead storage (allowing for 0.6 million m^3 for 100 years of sediment infill).
- Total of 13 million m^3 storage capacity

This volume was considered sufficient to provide storage to allow for the equivalent of approximately a drought security of 1 in 50 years plus provision for a residual instream flow at Appleby of 1100 l/s, as well as supply a potential future regional need of in the order of 22,000m^3/day. Alternatively, the volume could be managed to provide a higher security of supply under drought conditions with a lower residual instream flow at Appleby, but still within environmental guidelines.

Table 3.2
Storage Drawdown Frequency Analysis - No Future Regional Supply

Return Period (years)	Maximum Drawdown in million m^3			
	1100 l/s Appleby Residual		600 l/s Appleby Residual	
	Lee - Site 11	Wairoa - Site 15	Lee - Site 11	Wairoa - Site 15
10	4.4	4.3	2.6	2.6
20	6.3	6.2	3.9	3.8
35	8.0	8.0	5.1	5.1
50	9.2	9.2	6.1	6.0
100	11.8	11.8	8.1	8.0
simulated 82/83	7.4	7.3	5.2	5.1
simulated 00/01	11.3	11.2	7.7	7.6

Table 3.3
Storage Drawdown Frequency Analysis, With Future Regional Supply

Return Period (years)	Maximum Drawdown in million m^3			
	1100 l/s Appleby Residual		600 l/s Appleby Residual	
	Lee - Site 11	Wairoa - Site 15	Lee - Site 11	Wairoa - Site 15
10	5.8	5.6	3.7	3.6
20	7.9	7.8	5.2	5.2
35	9.8	9.7	6.6	6.5
50	11.1	11.0	7.6	7.5
100	13.9	13.7	9.6	9.6
simulated 82/83	9.3	8.9	6.2	6.2
simulated 00/01	13.0	13.0	9.3	9.2

Key points and inferences from the tabulated results above are as follows:

- storage requirements are virtually identical at the two dam sites (within 0.15 million m^3) for all scenarios considered
- based on storage utilisation and in descending order, the three worst droughts on record are the 2000/01, 1972/73 and 1982/83 seasons, with estimated drought return periods of about 80 years, 40 years and 30 years respectively (for the case including provision for future regional need)
- to maintain the higher residual flow at Appleby Bridge (i.e. 1100 l/s rather than 600 l/s), the additional storage required is between about 2 and 3 million m^3 depending on the drought standard adopted
- to provide for a future regional supply of 22,000 m^3/day, the additional storage capacity required is between about 1 and 2 million m^3 depending on the drought standard adopted
- the rate of increase in the required storage for higher drought standards is surprisingly steep – for example, the storage requirement for a 50 year drought standard is double that for a 10 year drought standard. One implication of this characteristic is that it would be very challenging to manage the resulting shortfall if a drought event significantly greater than the adopted design drought were to occur.
- natural river flows and groundwater storage appears to meet the bulk of the demand, which stands at about 32 million m^3 per annum (or 40 million m^3 per annum with future regional supply), with only occasional flow boosts from the reservoir to maintain the minimum flow at Appleby Bridge.

4 Cultural Impact Assessment

The Motueka Iwi Resource Management Advisory Komiti (MIRMAK) has commenced a cultural impact assessment for the project. The report (May 2006) of the work for this phase of the investigations addresses generic issues facing a potential development in either the Lee or the Wairoa catchments. It does not focus on any differences between the sites. As such, at this stage of the project therefore, there is no guidance available as to which site may be preferred or opposed by Tangata Whenua.

Tangata Whenua have advised WWAC in their report that the process of cultural impact assessment will continue at least until such time as the issues raised by Tangata Whenua have been fully addressed.

Thirteen recommendations were made by Tangata Whenua in their report. Those that have the potential to influence the decision on a preferred site are summarised below.

1. Recommendation 6.1 – Carry out risk assessment of ultramafic sediments to determine potential for effect on water quality.

   Response: The geological maps of the Lee and Wairoa Catchments show that the ultramafic belt crosses the two rivers *downstream* of the two potential dam sites. There is however a small portion of the upper Wairoa left branch catchment that drains ultramafic sediments, but none of the Lee. While any influence of the ultramafic sediments on water quality for the Wairoa site is expected to be small, this is an issue that is addressed later in this report.

2. Recommendation 6.2 – Develop wetlands in dam bounds, for the mitigation of biodiversity losses as well as protect the dam from siltation.

   Response: The storage volumes chosen for ongoing study are sufficiently large to be able to easily accommodate this recommendation, with no discernible difference between the two sites in design issues (including cost, and operating regime).

3. Recommendation 6.3 – Develop fish and waterfowl passage.

   Response: No difference between the two sites, but may influence design (especially cost).

4. Recommendation 6.8 – Carry out 'taonga survey' once final site chosen.

   Response: To be included in second phase of investigations as part of specific effects assessment. There is the potential for identification of taonga to influence design aspects in later stages. The map in the CIA report to date shows no specific taonga in the areas that would be directly affected by either dam or reservoir.

5. Recommendation 6.9 – Promote or require the protection of native vegetation, particularly within the footprint area.

   Response: See sections later in this report assessing indigenous vegetation.

5 Site 11 – Upper Lee River

5.1 Location/Site Topography

This site is within the main stem of the Lee River, approximately 700m downstream from the confluence with Anslow Creek (see Figure 5.1).

The storage dam would be an instream dam. The head of the reservoir would extend upstream for approximately 3.5 km, and would incorporate the lower reaches of Anslow Creek and Waterfall Creek. Initial delivery would be by release into the river.

5.2 Engineering

5.2.1 Dam/reservoir characteristics

Following closer inspection of the site, zoned earthfill dam construction is now considered better suited to the site, rather than the concrete faced rockfill assumed consistently for most sites in the earlier stages of the project.

Preliminary geotechnical investigation of Site 11 has been undertaken by agreement with WWAC and the results of this work have been incorporated in engineering assessment. Relevant geotechnical information is summarised and incorporated into the preliminary layout described in the next section. Investigation detail will be included as an Appendix in our final report to WWAC.

Based on the 20 m contour data currently available, the indicated top water level is RL 183 m to store 13 million m^3 of water. However, more accurate survey data could result in a modest change in normal top water level. About 3.5 m extra height will be required to enable passage of floods and provide safety freeboard to the dam. Thus the dam crest will be at about RL 186.5m. The inferred stream level is at around RL 138m, thus giving a total height for the dam of some 48.5m. Nelson City's Maitai dam, by comparison, is about 40 m high.

After allowing for flood rise and a potential riparian/reservoir access margin, the plan area of the reservoir will cover around 90 hectares. Vegetation below normal top water level will need to be cleared plus a small margin, prior to inundation, for water quality reasons.

Figure 5.1 illustrates the reservoir at normal top water level along with anticipated new roading to maintain access up valley and connections to existing main forestry tracks. The existing bridge near the head of the reservoir will need to be replaced (it looks too difficult to take roading around the head of the reservoir) and some 4.5km of new roads/tracks are required.

With earthfill dam construction and (as outlined in the next section) the occurrence of gravels at the damsite, nearly all construction materials (other than for concrete work) will be able to be obtained from closely adjacent to the damsite, but mainly above reservoir level.

5.2.2 Preliminary layout

Figure 5.2 illustrates the preliminary layout that appears at this stage to be best suited to the site. Prior to commencing site investigation work, it was judged that a dam crest location some 350m upstream would produce a better layout, but remnant gravel terrace materials of reasonably extensive depth were encountered in test pits on the true right (eastern) abutment, whereas the depth of gravel terrace materials reduces in the area presently selected.

In summary, siltstones form the dominant local geological unit. These siltstones have a relatively thin weathered layer (0.5 to 1.0 m) of clayey silt.

Overlying the siltstone basement unit, is a veneer of colluvium (ranging from 1.0m to 2.0m thick) in the form of gravelly clay/clayey gravel or a silty clay. Slip debris materials in the form of a silty gravel up to approximately 3m thick were identified within part of the footprint of the dam.

Somewhat unexpectedly, investigation work revealed old elevated terrace deposits on the right abutment, dominantly comprising gravel sized particles, but ranging from coarse sand through to cobbles and boulders up to 1m size. These terrace deposits were found below RL 180 m and upstream of the dam footprint as shown. These gravels extended below practical digger pit depth and caused rapid water inflows into the test pits, illustrating high permeability.

The other relevant finding was that in the riverbed, there is a shallow veneer of cobbles and boulders up to 1m deep over the siltstone basement rock. This could provide a source for riprap armour.

The terrace gravels and shallow localised slip debris would need to be subexcavated in the dam footprint area. The gravels will provide an on-site source for filter and drainage materials. We estimate that there are sufficient quantities of fully weathered rock and fine grained colluvium at or near the damsite for construction of a core zone to control leakage through the dam. The bulk of the embankment material is expected to come from excavation of the left abutment to provide a channel or auxiliary spillway to help take extreme flood flows past the dam.

The preliminary general layout is similar to that adopted for Nelson City's Maitai Dam which may be known to members of the Committee. Diversion and flood flows for the Lee site are similar to those at Maitai. One point of difference is the capacity of the supply release (consumptive plus environmental) which at around $2m^3/s$ for the Lee, is higher than at the Maitai Dam. It should be noted that the preliminary layout (and associated costing) does not provide for any additional large controlled release, which may possibly be required for the likes of flushing macrophytes from the riverbed in prolonged dry spells.

Principal components of the dam works are:

- a diversion culvert of around 2.6m wide x 3.9m high on the right bank terrace, founded on rock after subexcavation, initially to pass diversion flows during construction, and later carrying controlled discharges
- an intake tower with entry ports at about 8-10 m vertical intervals to allow highest quality water to be selected for controlled discharges
- the zoned embankment dam structure, including internal filters and drainage and wave armour or riprap over higher levels on the upstream face
- a right abutment concrete-lined chute spillway with terminal bucket, directing flow back into the river via an armoured plunge pool and taking flow from up to about a 200 year flood event prior to calling on the auxiliary spillway

- a left abutment auxiliary spillway channel with fuse plug embankments excavated at 1.25:1 slope up the ridge line ((matching steepest natural slopes locally), the excavation going into the embankment.

5.2.3 Preliminary costing

The same approach as outlined in Tonkin and Taylor's earlier report has been adopted but recognising site-specific features.

The raw capital cost is estimated at around $17.0M. This provides for:

- Access road upgrade and contractors' working area
- Power supply/communications to site
- Stripping to waste/stockpile, dam footprint and borrow areas
- Rehabilitation of exposed borrow areas and dam surrounds
- Dam fill, drainage and armour (six sub-items)
- Extra allowance for special drainage zones adjacent
- Clearing of reservoir area
- Reservoir access road upgrading
- New bridge at head of reservoir
- Cofferdams/dewatering and flood risk allowance
- Plunge pool armouring
- Diversion/conveyance structure
- Diversion structure headwalls, furniture
- Temporary energy dissipation during construction
- Spillway works
- Access bridge over spillway
- Extra for spillway chute anchoring/drainage
- Dam instrumentation
- Intake tower
- Pipework valving, ventilation, screens and ancillaries (2m^3/s max discharge)
- Miscellaneous small items allowance
- Contractor establishment, engineering and 20% contingency/uncertainty allowance.

Total costs will need to allow for financing costs, legal and developer administration. Furthermore, the cost excludes:

- land acquisition
- RMA process
- any hydro add-on costs
- extra flow release requirements

We were requested to provide an indicative cost for piping the abstractable flow (approximately 1 m^3/s excluding environmental and groundwater component), from the dam to the existing WEIS pump station at the end of the gorge. The purpose is to put this possibility into perspective, relative to releasing all flow into the river at the dam and then recovering that part of the demand not delivered through the groundwater system. With a lowest drawoff level at about RL 155m and the delivery point at about RL 25m there is some 130m static head available. Assuming that the pipeline substantially remains in the road reserve and to keep the pipeline below the hydraulic grade line, the controlling friction gradient for the pipeline would be about 1 in 88 over the upstream 5 km of pipeline. Thus for 1 m^3/s, a pipeline of about 750mm diameter is required for the first 5 km, reducing then to 600mm diameter. Allowing for more difficult river edge alignment near the old cement works where the road is locally high, and the end river crossing, a cost of about $6.5M is indicated (from the dam to the existing WEIS pump station at the end of the gorge).

5.2.4 Preliminary operating regime

Key hydrological parameters for this dam site are as follows:

- Catchment area to dam site = 84 km^2
- Estimated mean flow ≈ 3.6 m^3/s, equivalent to 113 million m^3 per annum
- Estimated mean annual low flow (MALF) ≈ 470 l/s , which is also set as the minimum residual flow at the foot of the dam
- Estimated 7-day 5-year low flow ≈ 360 l/s
- Maximum controlled dam release = 2070 l/s, based on 1100 l/s Appleby Bridge residual, full future allocations and 22,000 m^3/day future regional supply

Figure 5.3 is a time-series plot of the simulated storage behaviour (volume) from 1958 to 2005 for a dam at Site 11 Lee with a gross storage capacity of 13 million m^3 and releases for maintaining a residual flow of 1100 l/s at Appleby Bridge and for meeting future allocations corresponding with the 1982/83 theoretical demand profile. The demand includes provision for a future regional need of 22,000 m^3/day.

Figure 5.4 shows the same data but plots simulated reservoir levels instead of reservoir volume.

Figure 5.5 below shows the frequency distribution fitted to time-series of storage drawdowns from which the quantity of live storage versus drought return period has been ascertained.

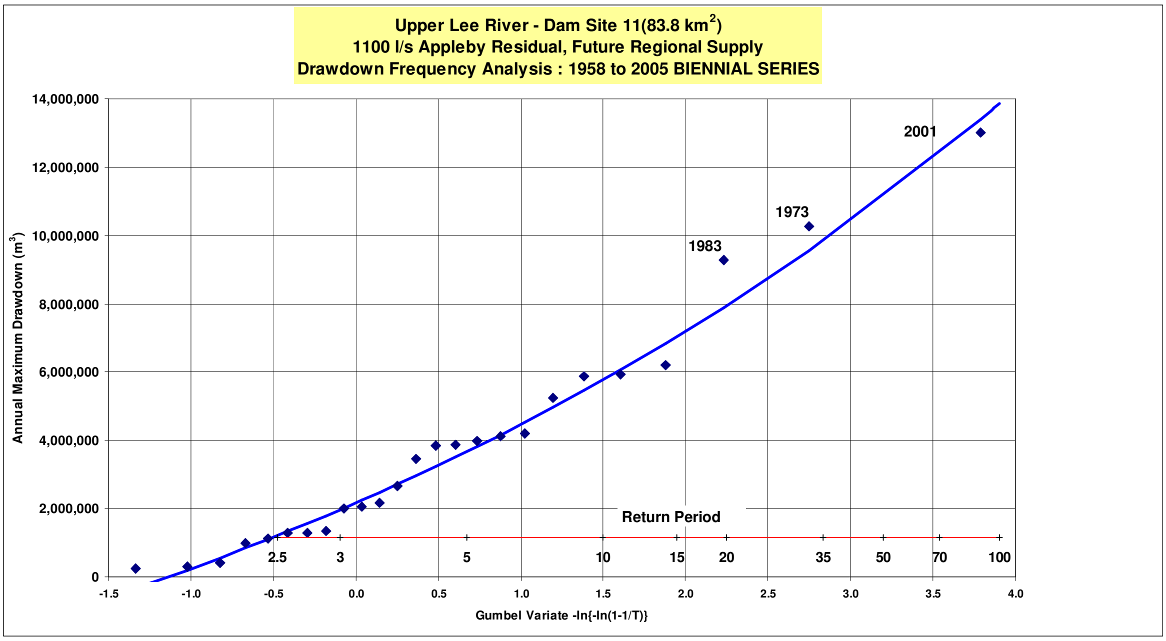


Figure 5.5 Upper Lee River Dam Site: Storage Drawdown Versus Return Period

Figure 5.6, which is a drawdown duration curve, provides an indication of the proportion of time the Lee reservoir would be full and the proportion of time for which the reservoir is at a particular level range. In effect, this plot is a condensed form of the time-series data contained in Figure 5.4. Figure 5.6 shows that the Lee reservoir would be virtually full about 85% of the time, within 1 m of full about 91% of the time and within 5 m of full for about 97% of the time on long-term average assuming fully allocated supply.

Figure 5.7 compares the flows immediately below the Lee dam before and after dam construction for a sample period (1 July 1981 to 30 June 1983). The 1982/83 season is a drought year with a return period of about 30 years, whereas the 1981/82 season is a more typical year in terms of flows. Note that the pre-construction flows are represented by (and are the same as) the reservoir inflows. Figure 5.8 compares the flows in the Wairoa River at Irvines before and after construction of a dam at Site 11 Lee.

As can be seen from Figure 5.7, the reservoir inflows or natural flows (blue) match the reservoir outflows (pink) for the majority of the time (i.e. the pink line plots on the blue line). Periods of flow augmentation provided by the reservoir are indicated by the reservoir outflow plotting higher than the reservoir inflow. In 1982, this occurs between late January and early April, while in the 1983 drought year, flow augmentation was provided from early November (1982) to mid April (1983). Reservoir refilling is indicated by periods where the reservoir inflow plots higher than the reservoir outflow. A clear example of this is seen in mid January 1983 where a fresh, peaking at about 10,000 l/s, is captured entirely to reservoir storage.

A similar interpretation can be drawn from Figure 5.8 in terms of flow augmentation. That is, Wairoa River flows at Irvines before and after Lee dam construction are almost identical most of the time, except over summer low flow periods during which the flow augmentation can be clearly seen (pink line plotting higher than the blue line between late January and early April 1982, and from November 1982 to April 1983). However, there is a notable difference between Irvines and the dam site in terms of flow regime changes. That is, the impact of the reservoir refilling is far less obvious at Irvines. For example, the fresh that occurred in mid January 1983 and the series of smaller freshes that preceded it are mostly preserved at Irvines albeit with a slight reduction in the peak flows (15% or so less). This is not unexpected and is attributed to the natural inflows from the tributaries below the dam continuing to contribute to the overall river flow. At the dam site, these freshes were absorbed entirely into the reservoir.

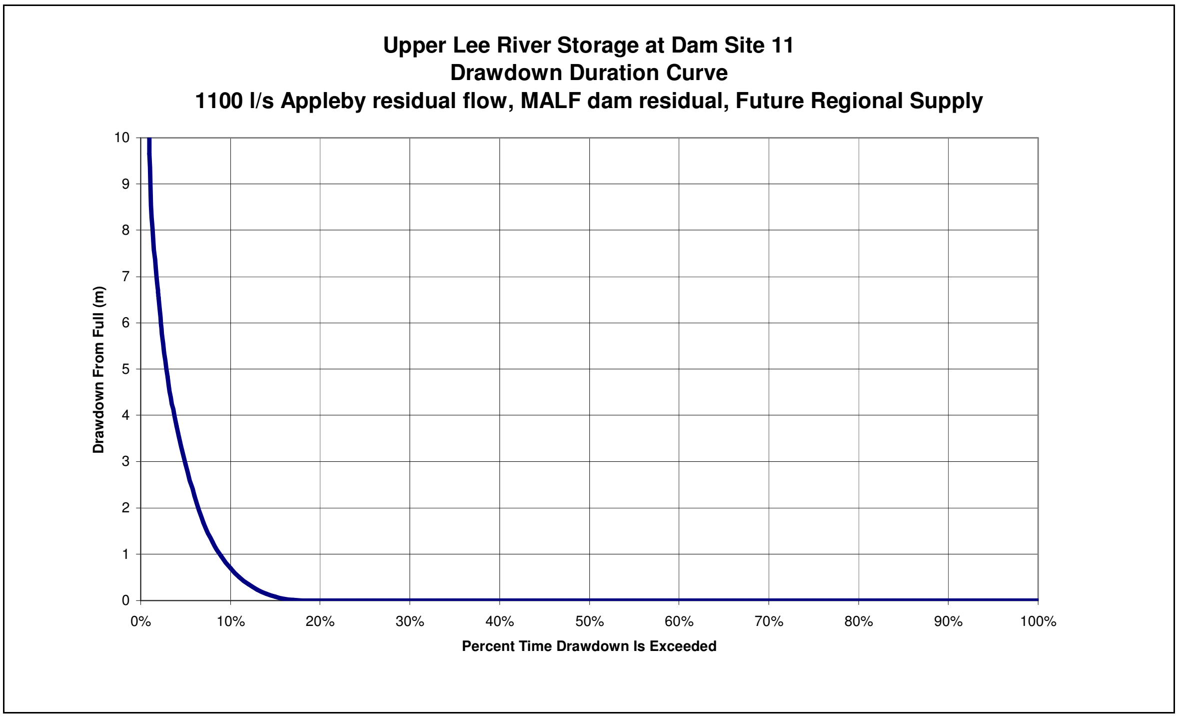


Figure 5.6 Upper Lee River Dam Site: Storage Drawdown Versus Duration

Figure 5.3

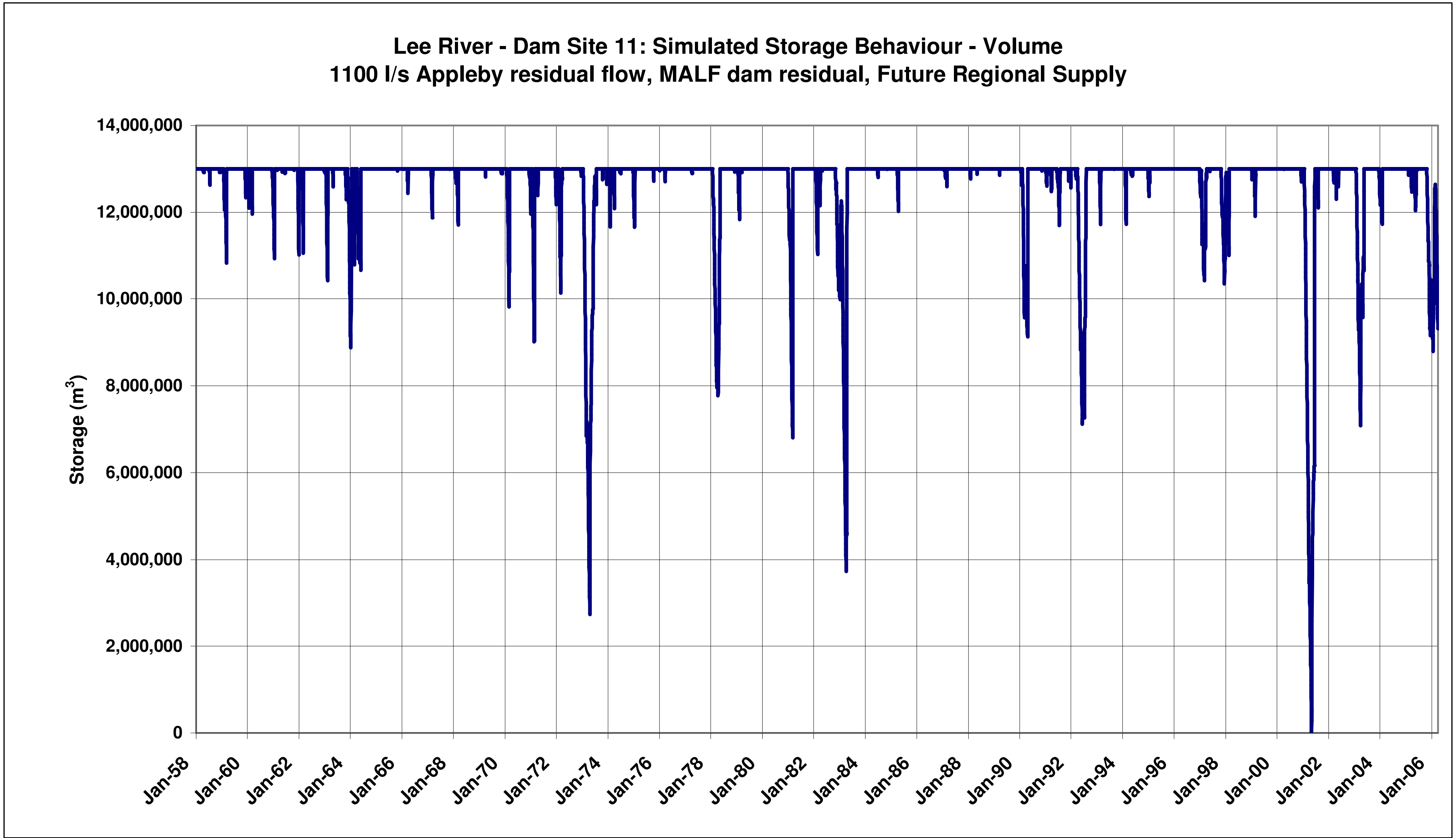

Lee River - Dam Site 11: Simulated Storage Behaviour - Volume
1100 l/s Appleby residual flow, MALF dam residual, Future Regional Supply
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
Storage (m3)
Jan-58
Jan-60
Jan-62
Jan-64
Jan-66
Jan-68
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06

Figure 5.4

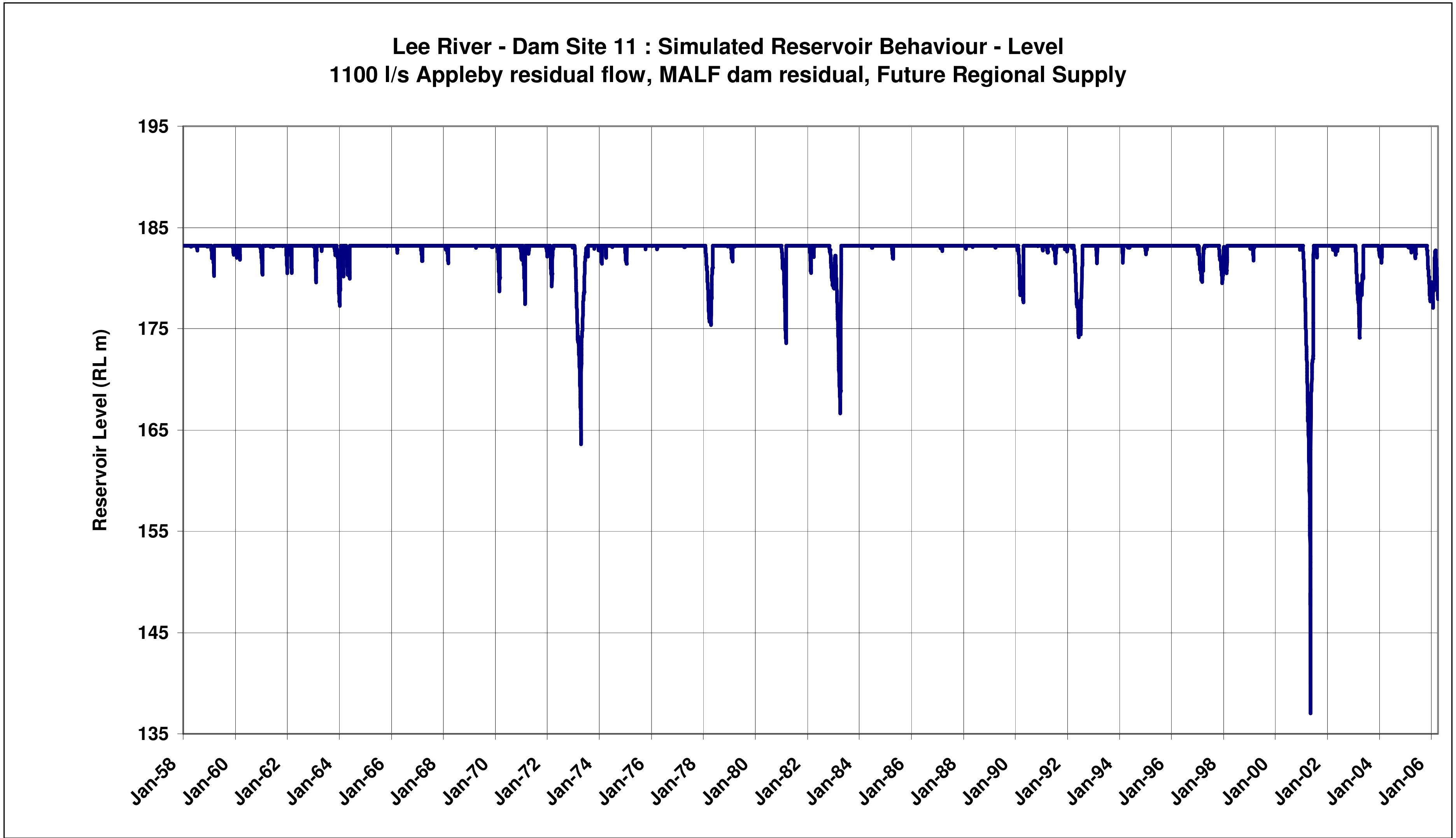

Lee River - Dam Site 11 : Simulated Reservoir Behaviour - Level
1100 l/s Appleby residual flow, MALF dam residual, Future Regional Supply
Reservoir Level (RL m)
195
185
175
165
155
145
135
Jan-58
Jan-60
Jan-62
Jan-64
Jan-66
Jan-68
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06

Figure 5.7

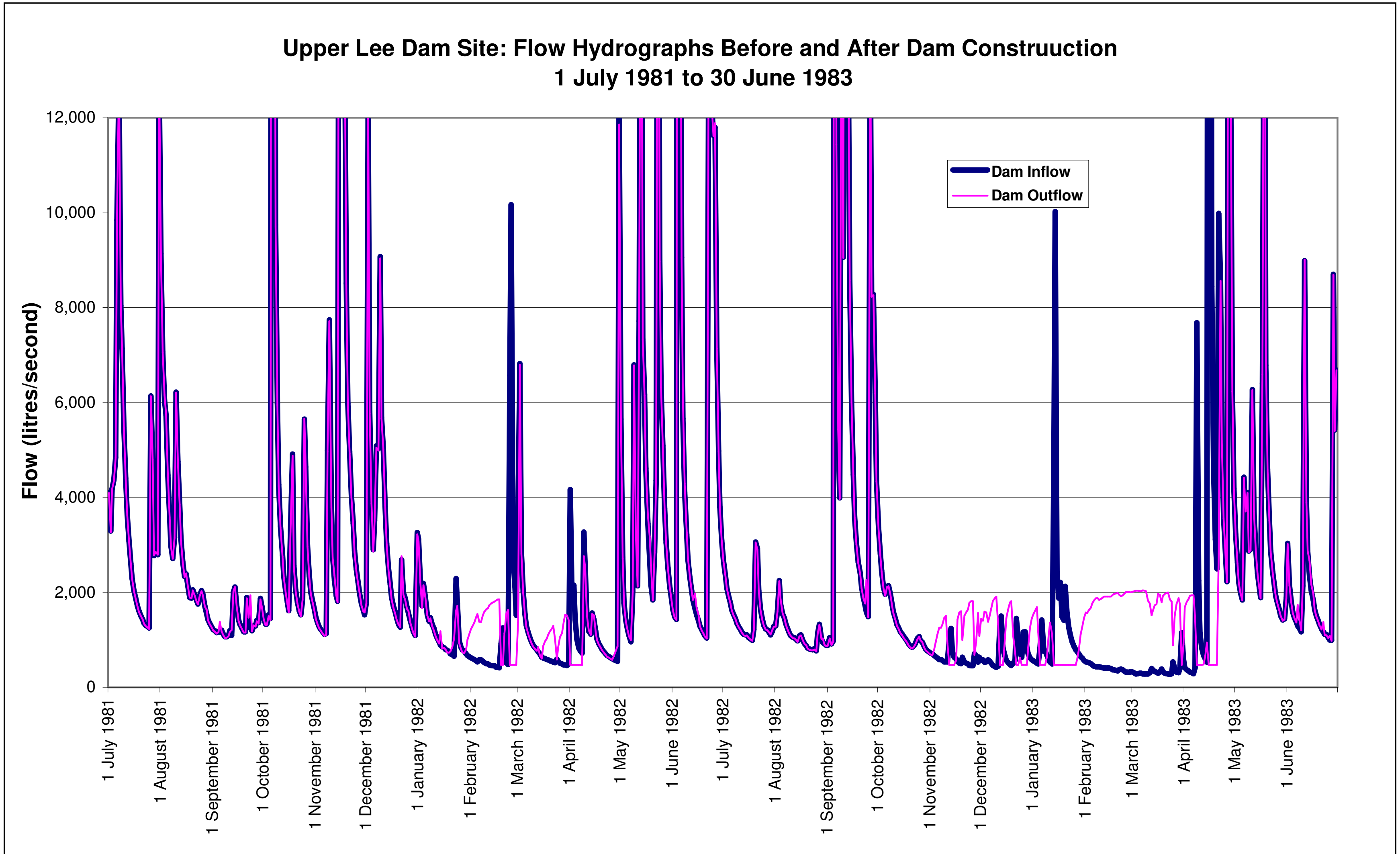
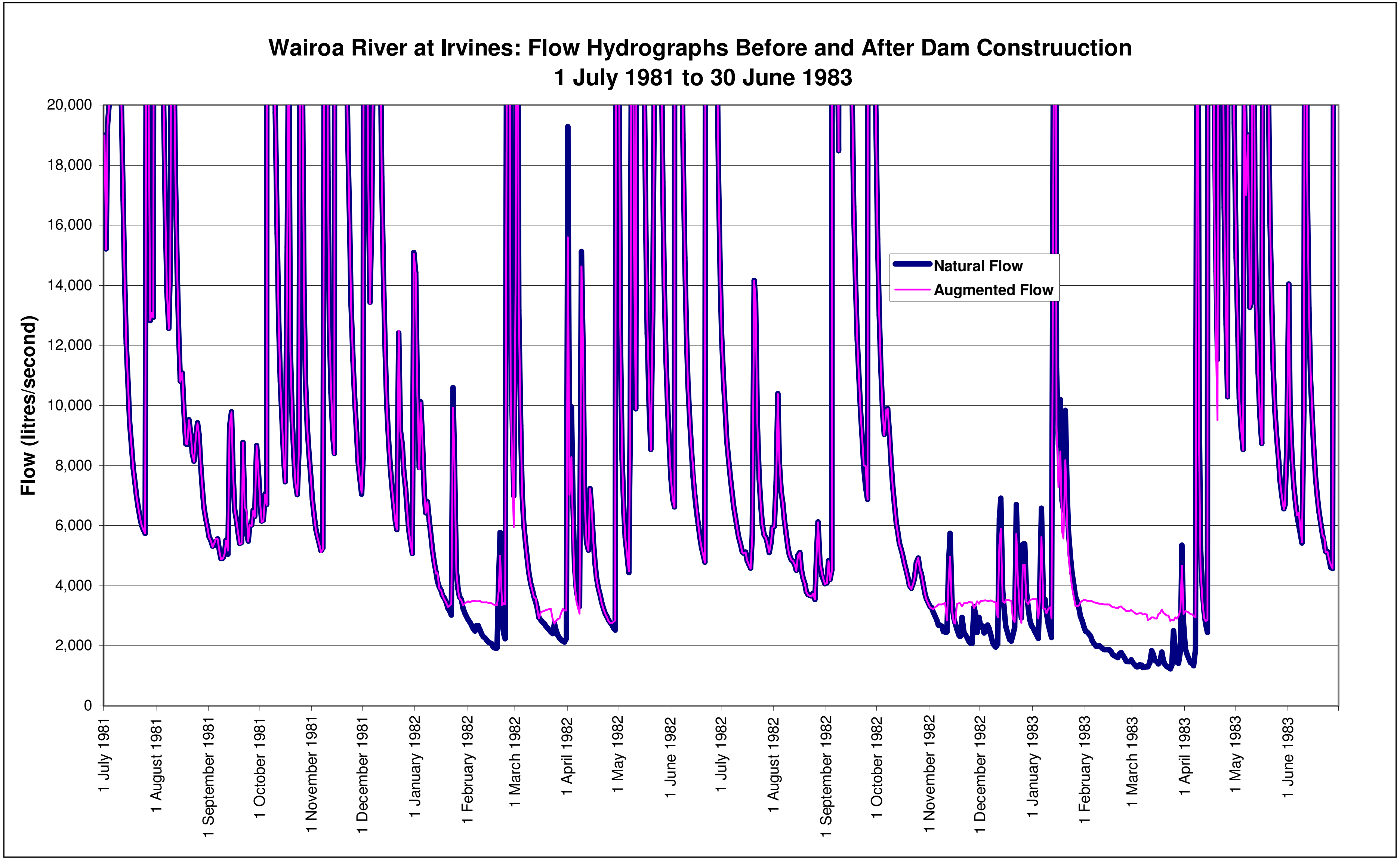

Upper Lee Dam Site: Flow Hydrographs Before and After Dam Construuction
1 July 1981 to 30 June 1983
Flow (litres/second)
12,000
10,000
8,000
6,000
4,000
2,000
0
Dam Inflow
Dam Outflow
1 July 1981
1 August 1981
1 September 1981
1 October 1981
1 November 1981
1 December 1981
1 January 1982
1 February 1982
1 March 1982
1 April 1982
1 May 1982
1 June 1982
1 July 1982
1 August 1982
1 September 1982
1 October 1982
1 November 1982
1 December 1982
1 January 1983
1 February 1983
1 March 1983
1 April 1983
1 May 1983
1 June 1983

Figure 5.8


Wairoa River at Irvines: Flow Hydrographs Before and After Dam Construuction
1 July 1981 to 30 June 1983
Flow (litres/second)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Natural Flow
Augmented Flow
1 July 1981
1 August 1981
1 September 1981
1 October 1981
1 November 1981
1 December 1981
1 January 1982
1 February 1982
1 March 1982
1 April 1982
1 May 1982
1 June 1982
1 July 1982
1 August 1982
1 September 1982
1 October 1982
1 November 1982
1 December 1982
1 January 1983
1 February 1983
1 March 1983
1 April 1983
1 May 1983
1 June 1983

5.2.5 Sedimentation potential

The Wairoa River overall (as measured at Irvines) has a relatively low to moderate sediment load in comparison with other comparable rivers in New Zealand. The river transports the great majority of its sediment load during flood events. Flows below mean flow are virtually free of suspended sediment.

Over a 100 year period, the amount of sediment that would be trapped within a Lee reservoir has been estimated at about 600,000 m^3. This estimate uses a relationship between river flow and suspended sediment concentration which was developed from a series of suspended sediment gaugings carried out at the Wairoa River at Irvines between 1976 and 1992.

Implicitly, the estimate assumes that the factors which control sediment generation, notably land-use, currently or in the future, are not significantly different from those in the gauging period. In this regard, it is noted that (uncontrolled) forestry operations have the potential to generate a substantially increased sediment load, from the time of harvest until a closed canopy with the new crop has established. The very steep hillslopes of the catchment afford limited opportunity for mitigation, i.e. it would be very difficult to implement effective erosion and sediment controls. This factor should be taken into account in selection of dam site, i.e. the site would be more favourable from a sedimentation point of view if there is less forestry coverage within its catchment. Conversion to exotic forestry from bush or pasture also has the potential to reduce water yield of the catchment.

5.2.6 Potential for electricity generation

The potential for generating electricity still exists but based on investigations to date this will be at a reduced level compared with the earlier estimates (due to the reduced height of dam from initial indications). The indicative economic potential is 1.2 MW capacity and 6.8 GWh/annum average.

5.3 Land Ownership

Information in this section is taken from a report from TDC's Manager Property dated 3 April 2006. It is based on an affected area to RL 195m, slightly higher than the current provisionally assessed affected area to RL 190m.

Owner	**Approximate area affected by dam/reservoir (hectares)**
David Leigh Irvine	0.87
Alexander Grant Irvine	7.98
Stanley Mitchell Irvine	28.61
JWJ Forestry Ltd	4.46
Land Information NZ	0.49
Forest Manager Crown	25.90
Department of Conservation	6.22

There appear to be no residences in the affected area.

5.4 Potential Effects on Existing Infrastructure

Site access up the Lee Valley is relatively straightforward and should present few difficulties for safe operation of construction traffic. Some upgrading of the final 3km of private access roading may be required.

TDC's Manager Property reports (April 2006) that there is legal road reserve extending on both sides of the river along the extent of the reservoir, including the main tributaries of Anslow Creek and Waterfall Creek. These roads would need to be stopped and would become esplanade reserve, provided that agreement could be reached with the affected parties. However legal access to several properties would disappear and the practicalities of obtaining alternative access would need to be investigated in later stages of the project.

Based on current information the following formed roads would potentially be affected by the proposed storage:

- Approximately 4-5km of formed road on the true left side of the river. However this road is largely private access to forest land, with public access being restricted by locked gate.
- Anslow Road - approximately 500m of this forestry road would be potentially affected by the reservoir. This road provides access to forestry land, and to Bush Road. The latter potentially provides access to Richmond Forest Park.
- Ford and forestry access road upstream of Waterfall Creek

5.5 Hazard Potential

A brief qualitative assessment is provided here with regard to dambreak hazard focussing on the differences between the two dam sites. A more detailed dambreak analysis and hazard assessment will be provided for the selected dam site in the final report.

As noted earlier, a zoned earthfill dam approximately 50m high is proposed. Based on the storage volume (13 million m^3) and height of the reservoir above river level (46 m), a rapid breach of the embankment dam has the potential to generate a peak dambreak outflow of between 4000 and 7000 m^3/s. Given the generally narrow and steep sided river valley and relatively steep river gradient below the dam there would be only modest attenuation of the flood wave before it exits the Wairoa gorge. This means that the river valley between the dam site and the Wairoa gorge would be exposed to risk of very high dambreak flows (say 3000 to 5000 m^3/s – to be refined in subsequent analysis if this option is chosen). Depending on the location on the river (specifically the catchment area), such flows could be up to an order of magnitude greater than the natural 100 year flood flow.

Subject to refinement in subsequent analysis, the maximum height of inundation could be between 10 m and 15 m above normal river level, depending on the valley width and gradient and other hydraulic controls at any particular location. Downstream of the Wairoa gorge, the floodplain opens out abruptly, and inundation depths and flow velocities would be significantly lower.

There are a few dwellings beside the Lee River on both banks mainly in the lower reach between the quarry and the confluence with the Wairoa River. While the buildings are generally located well above the river level, some may still be within the potential inundation extent from a dambreak. There is a girl guide camp located on the left bank about 1 km downstream from the confluence with the Roding River which could be at risk. The floor level of the main accommodation building is some 13 m above the river level. Therefore, this building could be near or just within the margin of inundation.

Accordingly, and also considering the effects in the more populated area downstream of the Wairoa gorge, a dam on the Lee should be assigned a High Potential Impact Category classification (in terms of the NZ Dam Safety Guidelines).

5.6 Potential Environmental Issues

5.6.1 Indigenous Vegetation

Context:

- The assessment examined the indigenous values of the footprint of the potential dam and reservoir, and downstream values likely to be affected by changed flow regime
- The assessment was based on an assumed top water level of RL 195m (based on original assumed required storage volume of 15 million m^3)
- The focus of the work was on a comparative assessment between the two sites (Lee and Wairoa). It is not a detailed botanical survey, and has made no attempt to put the significance of the vegetation into a regional context (ie whether eventual loss is likely overall to be a significant issue)
- The survey involved identifying areas of natural vegetation within the catchment. Those that were of a reasonable size and significance were mapped. Many other smaller areas may also exist.

Findings relevant to Site 11 Lee River:

- The Lee Catchment has a generally lower altitude, more gentle, even slopes, and greater tendency to create river flats.
- The Lee may offer a more favourable environment for ecological diversity and vegetation development.
- Of the total Lee Catchment, only approximately 12% has been cleared.
- Natural areas in the Lee are scattered along the valley in small areas.
- The mineral belt band of ultramafic rocks crosses the catchment downstream from the proposed dam site. The vegetation associated with this band has largely been disturbed by fire.
- The catchment is very weedy in its lower reaches.

Significant sites:

- Immediately downstream of dam site: High quality native vegetation begins a few hundred metres below the proposed dam site and extends upriver; eg at confluence of Lucy Creek and Lee River. This area may not be influenced by the dam but could be damaged by construction activities.
- Site 1 – dam site and upstream: 3-4 ha. Overall significance = medium (including high rank for rarity). Extends from the dam site upstream for 1 km on both sides of river. Variety of original and secondary riparian flat forest and rocky gorge habitat. All would be inundated.

- Site 2: 3-4 ha. Overall significance = medium to high (including high representativeness). Is riparian as well as hill slope. All but the mid to upper part of the gully at the southern end would be inundated.
- Site 3: 4 ha – Waterfall Creek flat and riparian forest. Overall significance = high (including high representativeness, high rarity, high diversity and pattern, high distinctiveness/special ecological characteristics, and high sustainability). High ecological value – is a remnant of regenerating kahikatea forest with a unique understorey. All will be inundated.
- Site 4: 4 ha. Riparian forest zone of beech and kahikatea. Overall significance = medium to high (including high connectivity and sustainability). All but the upper left bank slope will be inundated.
- Site 5: Extensive area at head of reservoir, grading to continuous original forest. Overall significance = high (including high representativeness, high diversity and pattern, high size and shape, high connectivity, and high sustainability). The potential reservoir would form a narrow, shallow waterway that would inundate the immediate riparian zone for approximately 1km but will have little overall impact on the forest.
- Downstream impacts: At issue is whether a changed flow regime will alter the habitat of species which require regular flooding to keep the site open from colonisation by exotic weeds. Low flow periods may be extended but it is doubtful that the river flowing over bedrock will influence the water regime along its bank. Plants growing on rock in the flood zone are regularly exposed to dry conditions and are adapted to them. The reservoir may alter the flooding pattern and will halt downstream movement of rocks and logs. It is probable that the bed-rock nature of the river will minimise changes in the riverbed and adjacent riparian zone.

5.6.2 Blue duck (whio)

A survey in the area of the Lee Catchment likely to be affected by the potential reservoir was undertaken in November 2005.

A section of the Lee River was surveyed, beginning at grid ref 233713 upstream to grid ref 237693 where the river became gorged and impassable. Waterfall Creek, a tributary on the true right was surveyed up to the waterfall at grid ref 244705 (approx). No blue duck or sign of blue duck was found.

Waterfall Creek is very narrow with a small flow and is modified by pine plantations in the lower reach. The small size of Waterfall Creek, would not offer any secure habitat for blue duck when considering the threat of stoats.

5.6.3 Water Quality and Aquatic Ecology

Cawthron's 2005 review of aquatic ecology showed that native fish species recorded in the Lee River are:

- koura (freshwater crayfish) - in upper Lee River. Koura are listed by DOC as one of the aquatic values of this area.
- Koaro
- bluegill bully
- redfin bully (upper and mid Lee)
- shortfin eel

- longfin eel

All of the fish species recorded are diadromous (ie they spend part of their life cycle in the sea and part in freshwater). They therefore require access to the sea at some stage of their life cycle, and conversely must be able to negotiate any obstacle to their upstream passage if they are to reach habitat higher in the catchment.

Brown trout are present in the Lee River. Recent drift diving by Fish and Game recorded 26.3 medium and large trout per kilometre of river (Cawthron report).

5.6.4 Archaeology/Heritage Values

- TDC records show no specific sites of significance in the potentially affected area.
- the "Inventory and Maps of Important Geological Sites and Landforms in the Nelson and Marlborough Regions, including the Kaikoura District" shows no sites in the area potentially affected by the storage system

5.6.5 Potential Effects on Recreation

The lower Lee Valley is a popular recreational resource. However this part of the upper Lee Valley appears to be of lower value, largely due to its lack of access (a locked gate exists at the Cement Works).

Specific comments are as follows:

Informal recreation

- it is unlikely that there are any picnic sites within the stretch of river that would be directly affected by the storage reservoir.
- there are several picnic areas in the lower Lee Valley, as well as the Regional Girl Guide Lodge.

Kayaking (Ron Wastney, Training and Conservation Officer Nelson Canoe Club, pers. comm.)

- the stretch of river that would be directly affected by the storage reservoir is of low value for kayaking. The stretch from the Cement Works downstream is of medium value for kayaking (Class 2-3 rapids when the river is high).
- Parts of it are used by beginners, but it is not high value to serious kayakers.
- Above the Cement Works the river is mostly gorge and access is difficult. Even at relatively easy river flows it is dangerous (Class 4-5 rapids during a fresh – is a very technical paddle)
- Creation of a dam on the Lee River is unlikely to draw much (if any) opposition from kayakers.

Trout fishing

- the Lee is not as significant a trout fishing river as the Wairoa, due largely to difficult access. It is smaller than the Wairoa and is perceived to hold fewer fish, although the fish are of good size (Grant Irvine, local angler, pers. comm. as reported by Cawthron).
- It is expected that lack of access to the upper reaches restricts fishing in the reach potentially affected by the storage system. It is not known how far trout move up the system (Neil Deans, F&G pers. comm.).

Richmond Forest Park access

- Anslow Road and Bush Road provide some access to Richmond Forest Park. Legal access to the Park exists up the true right bank of the Lee River, although few people either know this or use the access. The valley provides an emergency exit point from the Park. (Neil Deans, F&G pers. comm.).
- the NZMS 260 topographic map also shows a track on the eastern side of the river and "Waterfall Creek Hut" . The significance of this to trampers and hunters would need to be determined during further investigations, although we understand the hut may no longer exist.

5.6.6 Community Issues

ESR's earlier community survey work provided feedback on the values of the Lee River Valley. These are repeated below. However many of these comments were made generally about the Lee and/or Wairoa Rivers and may not necessarily be specific to Site 11. In general we expect it is fair to conclude that most comments would apply to the middle or lower Lee, rather than the upper, which is not generally accessible, and is unpopulated.

- intrinsic values of the river itself
- significant recreational asset
- habitat values (instream and terrestrial)
- sense of identity (for valley residents)
- easy access and proximity
- contrast to urban environment

Other significant community issues can be expected to arise as a result of the dambreak potential. ESR's work with Lee Valley residents showed a perception that any water storage system large enough for power generation would pose an additional risk to downstream residents.

The most important stretch of the river for Lee Valley residents was expressed as being the area up to the Cement Works (Ann Winstanley pers. comm.). ESR's work also showed that Lee Valley residents who did not want to see storage options detracting from their enjoyment of the area, also stated that they appreciated that water is needed on the Waimea Plains (ESR report).

The most important stretch of the river for other general residents (expressed to ESR via the family survey) is from the Mead Road bridge down to the Wairoa confluence (ie the lower Lee).

5.7 Planning Issues

- the storage site is mainly zoned Rural 2, apart from top end of reservoir which is zoned Conservation (Mt Richmond Forest Park)
- there are no denotations on the TRMP Area Maps.
- there appear to be no obvious inconsistencies with the objectives and policies for the Zones. Special attention will however need to be paid to the following objectives:
    - maintenance of public access to and along margins of rivers which are of recreational value (objective 8.1.0)

- protection and enhancement of biological diversity and integrity of terrestrial, freshwater and coastal ecosystems, communities and species (objective 10.1A.0)

- Site 11 is within the Upper Catchments Water Management Zone
- a range of consents will be required, mainly for discretionary activities, with exception as below.
- to be a Discretionary Activity, the total amount of water taken (between November and April each year) either by the scheme or in combination with other takes, must not exceed 3 l/s. Takes above this limit are non-complying (ie the resource consent process will need to pass a higher threshold test).
- Water management objectives for the Lee River (TRMP Schedule 30.1):
  - provide for protection of instream values including fisheries and natural values
  - provide for recreation in the Lee (and Roding) River
  - maintain contribution to Waimea River flows
  - protect landscape, cultural and spiritual values
  - maintain or improve existing users' security of supply to acceptable level

5.8 Potential for Mitigation of Effects

The following mitigation measures could be considered (excluding land acquisition issues):

- provision of replacement road to upper Lee Valley and Richmond Forest Park
- provision of alternative road access to forestry land
- dambreak warning system
- provision of system to allow native fish passage

5.9 Potential Opportunities for Enhancement

The following potential opportunities exist for enhancement (in addition to those arising from augmenting flows in the lower catchment for water supply, protection of instream values, and enhancement of the values of the Waimea Estuary):

- Generation of electricity
- Public access to upper catchment by provision of road network
- Self-sustaining (lake) trout fishery above dam
- Recreational use of 'lake' (reservoir) environment (picnic areas, swimming, boating, fishing)
- Creation of wetland habitat at reservoir margins
- Development of walkway system around reservoir (utilising land in public ownership (marginal strip)
- Improved access to Richmond Forest Park, and development of linking tracks to main track system.

6 Site 15 – Upper Wairoa River – Left Branch (Eastern)

6.1 Location/Site Topography

This site is within the Left (eastern) Branch of the Wairoa River, approximately 3km upstream from the confluence of the Right and Left Branches (see Figure 6.1).

The storage dam would be an instream dam. The head of the reservoir would extend upstream for approximately 3.5km. Controlled releases would again be directly into the river.

6.2 Engineering

6.2.1 Dam/reservoir characteristics

The Wairoa site is steep sided with a relatively narrow riverbed, and rock with little weathering profile exposed on the abutments and in the riverbed. No detailed geological mapping or investigation work has been undertaken at this stage. Given the general geology of the site (indurated and very strong, steeply inclined, interbedded, thin to thick layers of grey sandstone, siltstone and mudstone) and the site characteristics, a gravity concrete dam appears best suited to the site.

Again, based on 20m contour data, the indicated normal top water level for 13 million m^3 of storage is RL 237m, giving a height to the overflow crest of approximately 56m. With the reservoir margin allowances as outlined for the Lee site, the controlled reservoir area would be some 70 hectares. Figure 6.1 illustrates the reservoir and an indicative replacement road (approximately 3 km) on the western side to provide ongoing access beyond the head of the reservoir.

Mass concrete dam construction requires substantial quantities of aggregate along with cement, but relatively modest amounts of reinforcing steel. Cement clearly has to be transported to the site, but aggregates of suitable quality may be winnable within the reservoir or near the dam site. Rock exposed in cuttings near the site does not appear able to provide high quality aggregate for conventional concrete. Roller compacted concrete uses lower quality aggregates which may be winnable entirely within alluvial deposits, as mapped near the head of the reservoir, or in association with local quarrying and crushing. Given information available at the present level of study, it is assumed so as to have greater certainty on costing, that aggregate is imported from established quarries, such as that near the bottom end of the Wairoa Gorge.

6.2.2 Preliminary layout

Figure 6.2 shows the preliminary layout adopted for costing. The arrangements recognise the narrow and confined nature of the riverbed, which influences construction diversion and sequencing and how concentrated flood spills over the dam crest are returned to the river without eroding the riverbed area at the downstream toe of the dam. Gravity dams include internal galleries to collect and monitor seepage and provide access for foundation grouting before reservoir filling and repeat grouting later should the need arise. Thus arrangements need to provide for access to galleries and to the control/release systems for managed outflows.

Key features of the preliminary arrangements are as follows:

- twin diversion/flows release conduits built in two stages with a separating sheet piled wall, enabling half of the river to remain open while the other half of the dam base is raised about 6m high, then the other half raised to the same height (concrete dam blocks can be overtopped in large floods without causing significant damage).
- dam block with a base width approximately equal to the dam height to account for the potential high level of earthquake shaking.
- a control overflow section at the dam crest assumed 50m wide (flood rise in the order of 2.5m in maximum flood conditions) with downstream guide wall narrowing the flow to about 15m width (streambed width) at the base of the dam, along with a concave floor section to help energy dissipation by promoting a reverse roller.
- in association with the above, a slotted weir some 8 to 10m high to assure adequate tail water depth in large floods, along with concreting of the riverbed floor and sides against erosion between the weir and the toe of the dam.
- a bridge over the dam crest to access a service shaft for the galleries and with a raised crest wall beyond the 50m wide spill zone to contain flood rise.
- an intake system on the upstream face of the dam with intakes at intervals as for the Lee site.

6.2.3 Preliminary costing

The same approach as adopted for the Lee has been employed and the same inclusions and exclusions apply.

The preliminary estimate for the Wairoa dam is $16.5M, closely matching that for the Lee option.

For a piped delivery down the valley as described for the Lee, there is a total head available of 177m, but the length of line is longer than the Lee. However, the gradient of the road is reasonably consistent with no obvious high points. The indicated pipe diameter is 675mm and the indicative cost is $9.1M (from the dam to the existing WEIS pump station at the end of the gorge).

6.2.4 Preliminary operating regime

Key hydrological parameters for this dam site are as follows:

- Catchment area to dam site = 92 km^2
- Estimated mean flow ≈ 4.0 m^3/s, equivalent to 126 million m^3 per annum
- Estimated mean annual low flow (MALF) ≈ 520 l/s , which is also set as the minimum residual flow at the foot of the dam
- Estimated 7-day 5-year low flow ≈ 400 l/s
- Maximum controlled dam release = 2110 l/s, based on 1100 l/s Appleby Bridge residual, full future allocations and 22,000 m^3/day future regional supply

Figure 6.3 is a time-series plot of the simulated storage behaviour (volume) from 1958 to 2005 for a dam at Site 15 Wairoa Left Branch with a gross storage capacity of 13 million m^3 and reservoir releases for maintaining a residual flow of 1100 l/s at Appleby Bridge and for meeting future allocations corresponding with the 1982/83 theoretical demand profile. The demand includes future regional supply 22,000 m^3/day.

Figure 6.4 shows the same data but plots simulated reservoir levels instead of reservoir volume.

Figure 6.5 below shows the frequency distribution fitted to time-series of storage drawdowns from which the quantity of live storage versus drought return period has been ascertained.

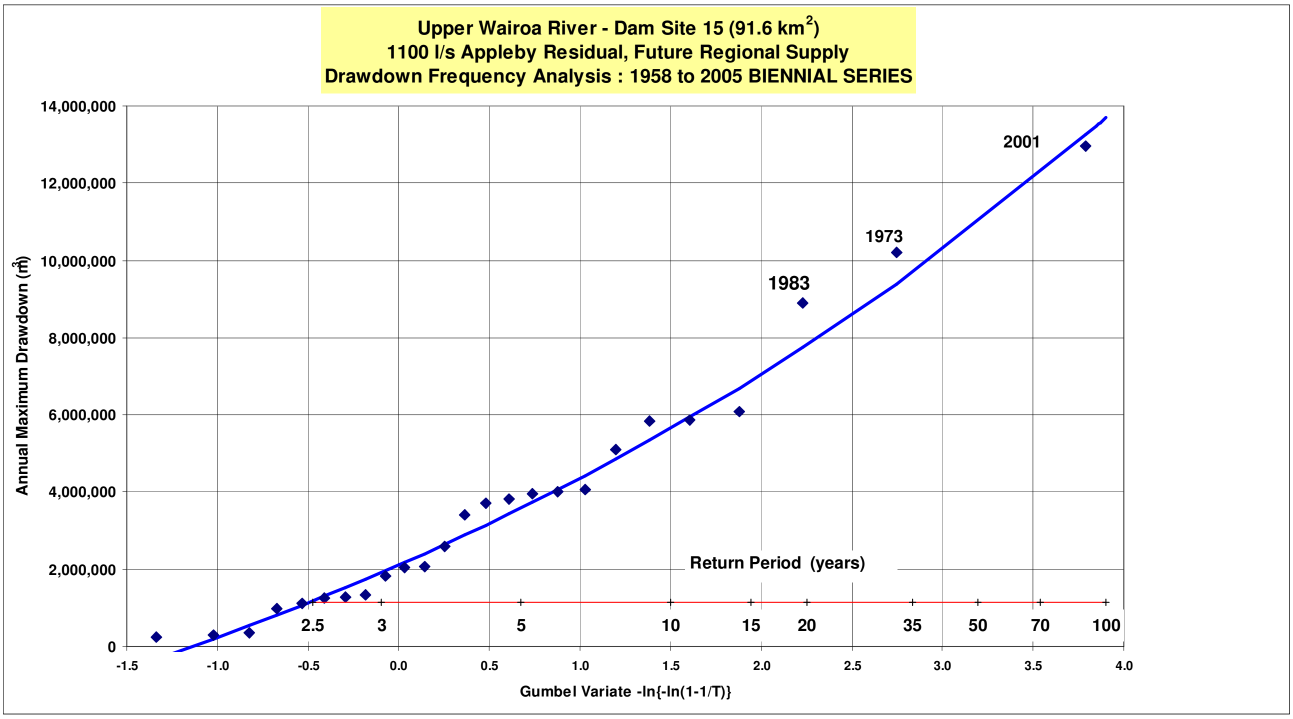


Figure 6.5 Upper Wairoa River Dam Site: Storage Drawdown Versus Return Period

Figure 6.6 below, which is a drawdown duration curve, provides an indication of the proportion of time the reservoir would be full and the proportion of time for which the reservoir is at a particular level range. In effect, this plot is a condensed form of the time-series data contained in Figure 6.4. Figure 6.6 shows that the Wairoa reservoir would be virtually full about 85% of the time, within 1 m of full about 91% of the time and within 5 m of full for about 97% of the time on long-term average assuming fully allocated supply.

Figure 6.7 compares the flows immediately below the Wairoa dam site before and after dam construction for a sample period (1 July 1981 to 30 June 1983). The 1982/83 season is a drought year with a return period of about 30 years, whereas the 1981/82 season is a more typical year in terms of flows. Note that the pre-construction flows are represented by (and are the same as) the reservoir inflows. Figure 6.8 compares the flows in the Wairoa River at Irvines before and after construction of a dam at Site 15 Wairoa. This plot is virtually identical to that for the Upper Lee dam site (Figure 5.8).

As can be seen from Figure 6.7, the reservoir inflows or natural flows(blue) match the reservoir outflows (pink) for the majority of the time (i.e. the pink line plots on the blue line). Periods of flow augmentation provided by the reservoir are indicated by the reservoir outflow plotting higher than the reservoir inflow. In 1982, this occurs between late January and early April, while in the 1983 drought year, flow augmentation was provided from early November (1982) to mid April (1983). Reservoir refilling is indicated by periods where the reservoir inflow plots higher than the reservoir outflow. A clear example of this is seen in mid January 1983 where a fresh peaking at about 11,000 l/s is captured entirely to reservoir storage.

A similar interpretation can be drawn from Figure 6.8 in terms of flow augmentation. That is. Wairoa River flows at Irvines before and after dam construction are almost identical most of the time, except over summer low flow periods during which the flow augmentation can be clearly seen (pink line plotting above blue line between late January and early April 1982, and from November 1982 to April 1983). However, there is a notable difference between Irvines and the dam site in terms of flow regime changes. That is, the impact of the reservoir refilling is far less obvious at Irvines. For example, the fresh that occurred in mid January 1983 and the series of smaller freshes that preceded it are mostly preserved at Irvines albeit with a slight reduction in the peak flows (15% or so less). This is not unexpected and is attributed to the natural inflows from the tributaries below the dam continuing to contribute to the overall river flow. At the dam site, these freshes were absorbed entirely into the reservoir.

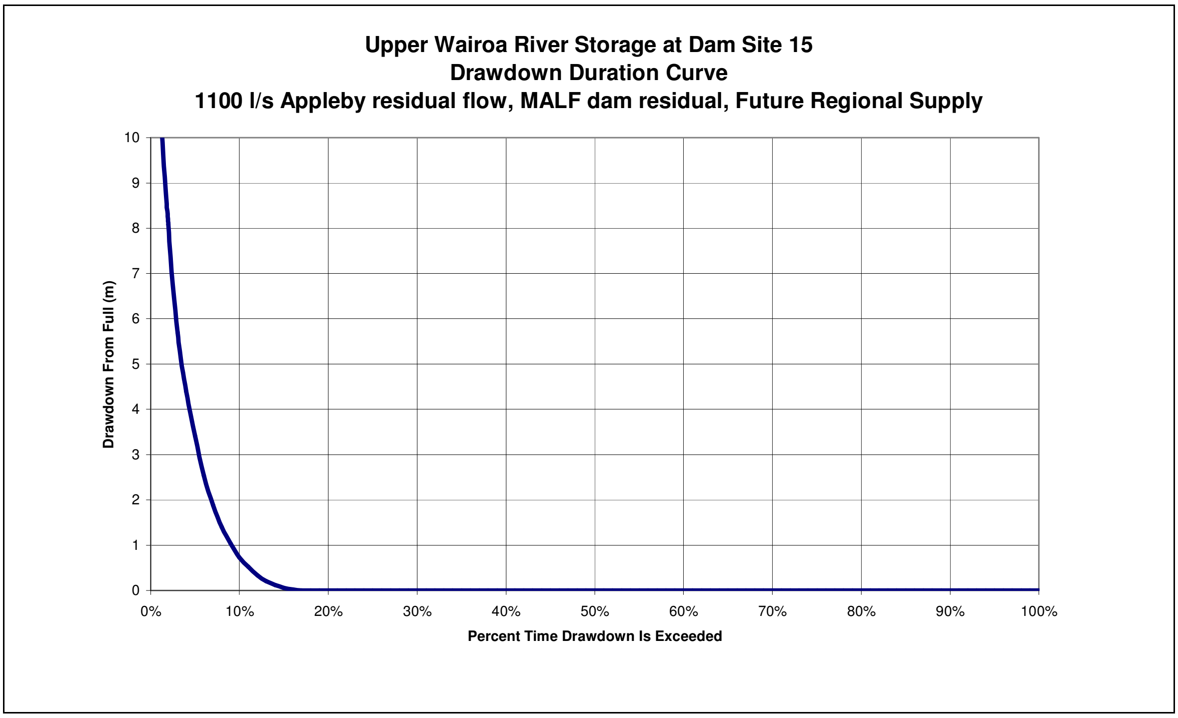


Figure 6.6 Upper Wairoa River Dam Site: Storage Drawdown Versus Duration

Figure 6.3

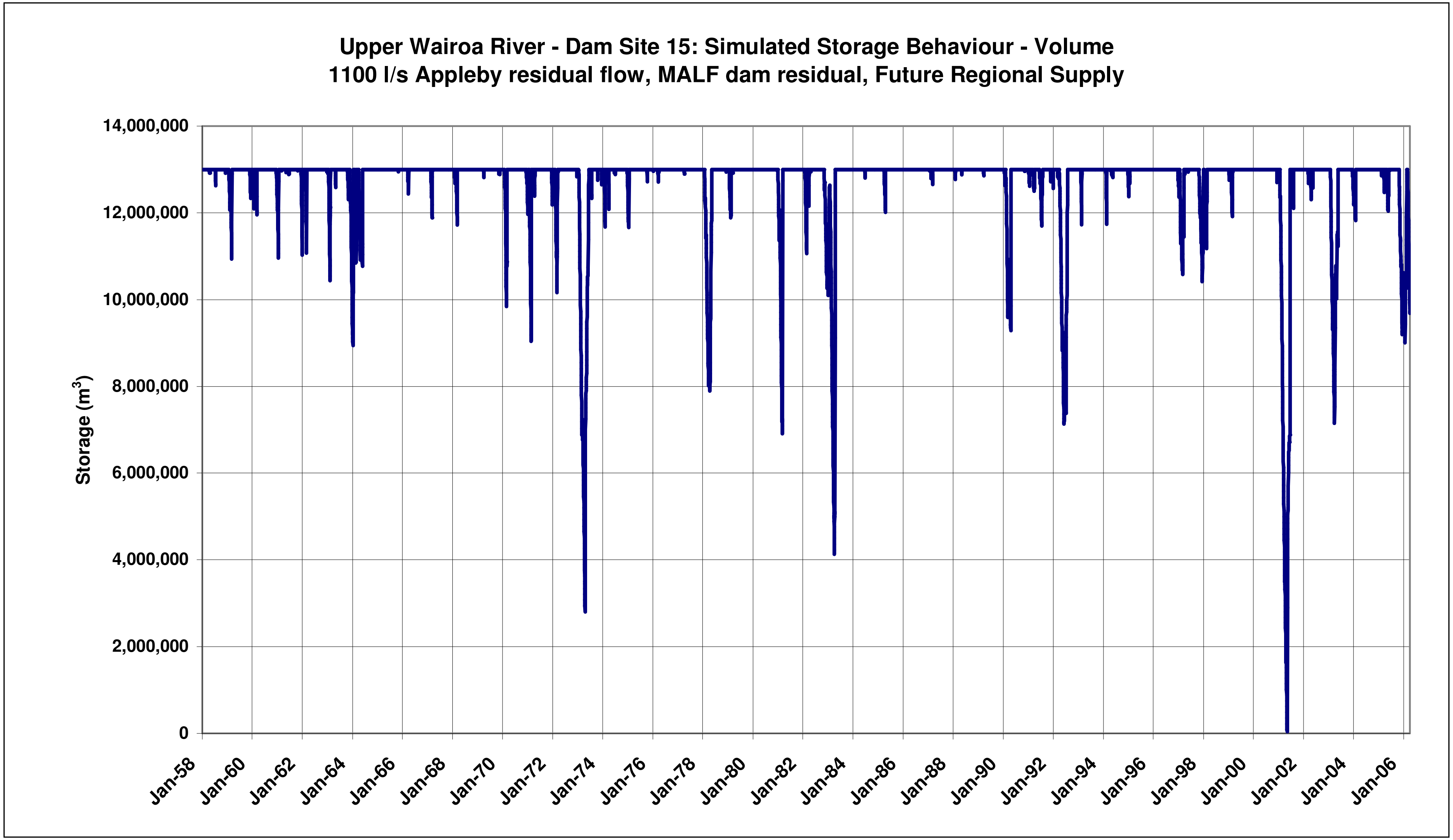

Upper Wairoa River - Dam Site 15: Simulated Storage Behaviour - Volume
1100 l/s Appleby residual flow, MALF dam residual, Future Regional Supply
Storage (m3)
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
Jan-58
Jan-60
Jan-62
Jan-64
Jan-66
Jan-68
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06

Figure 6.4

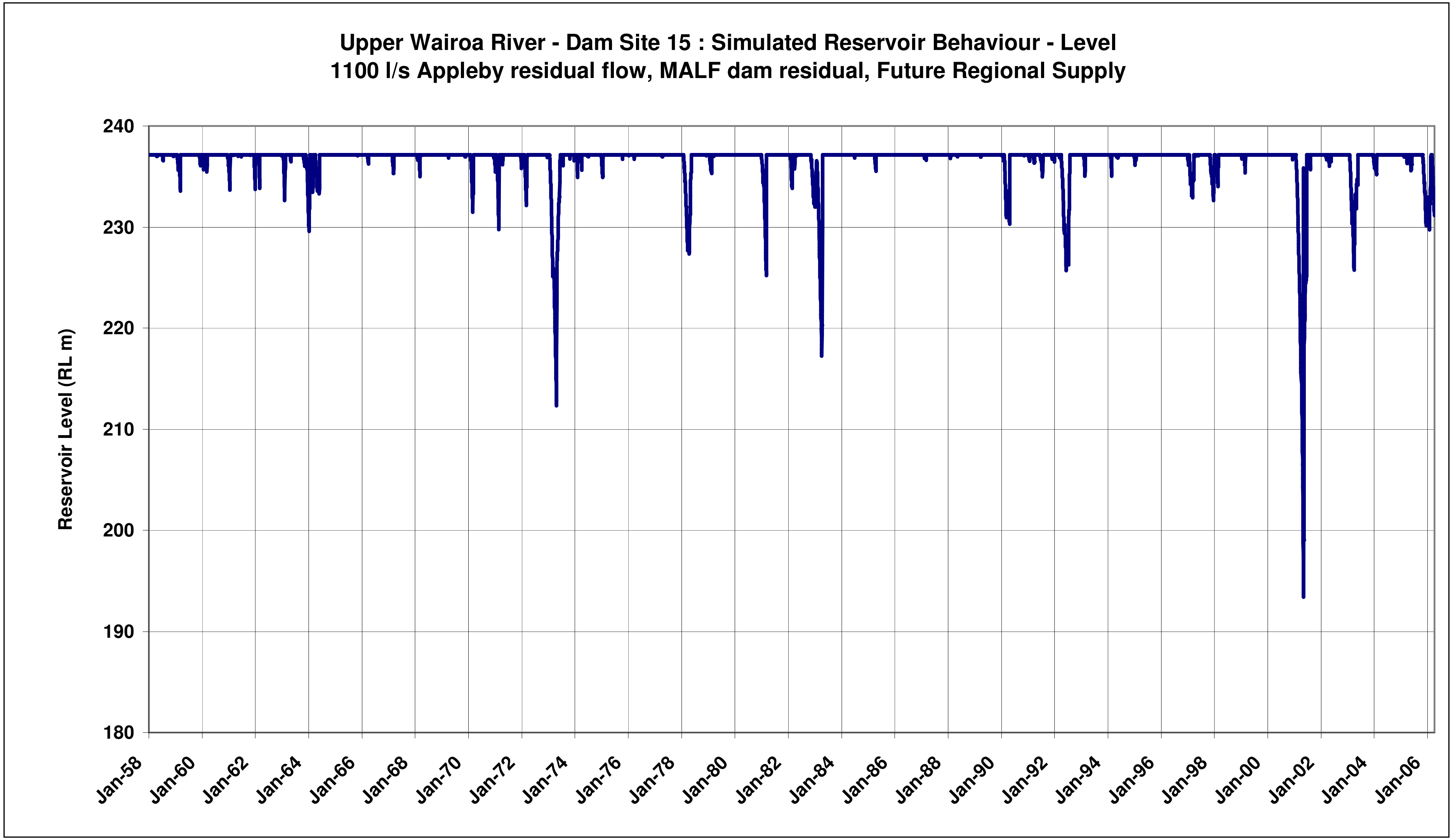

Upper Wairoa River - Dam Site 15 : Simulated Reservoir Behaviour - Level
1100 l/s Appleby residual flow, MALF dam residual, Future Regional Supply
Reservoir Level (RL m)
240
230
220
210
200
190
180
Jan-58
Jan-60
Jan-62
Jan-64
Jan-66
Jan-68
Jan-70
Jan-72
Jan-74
Jan-76
Jan-78
Jan-80
Jan-82
Jan-84
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Jan-00
Jan-02
Jan-04
Jan-06

Figure 6.7

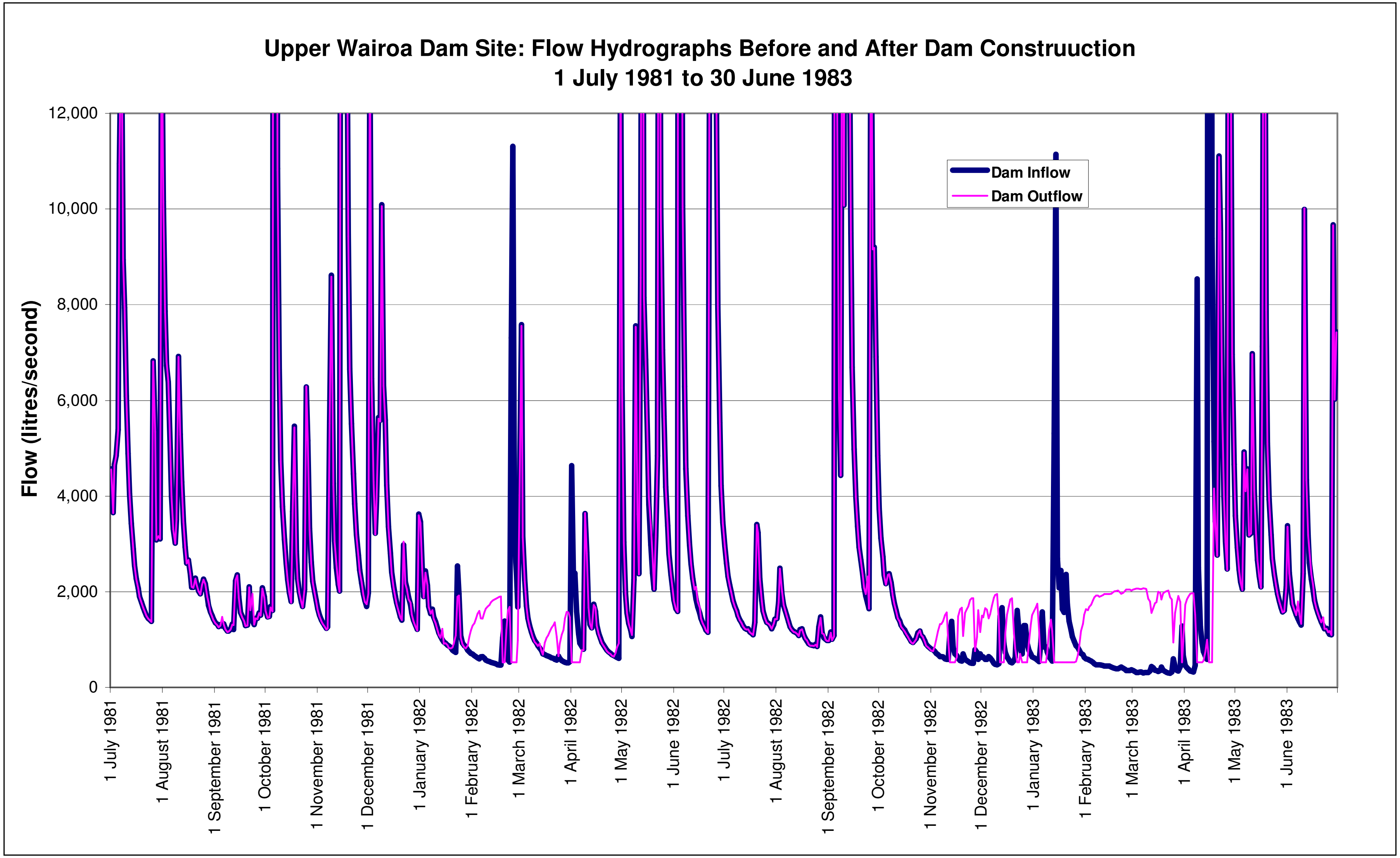
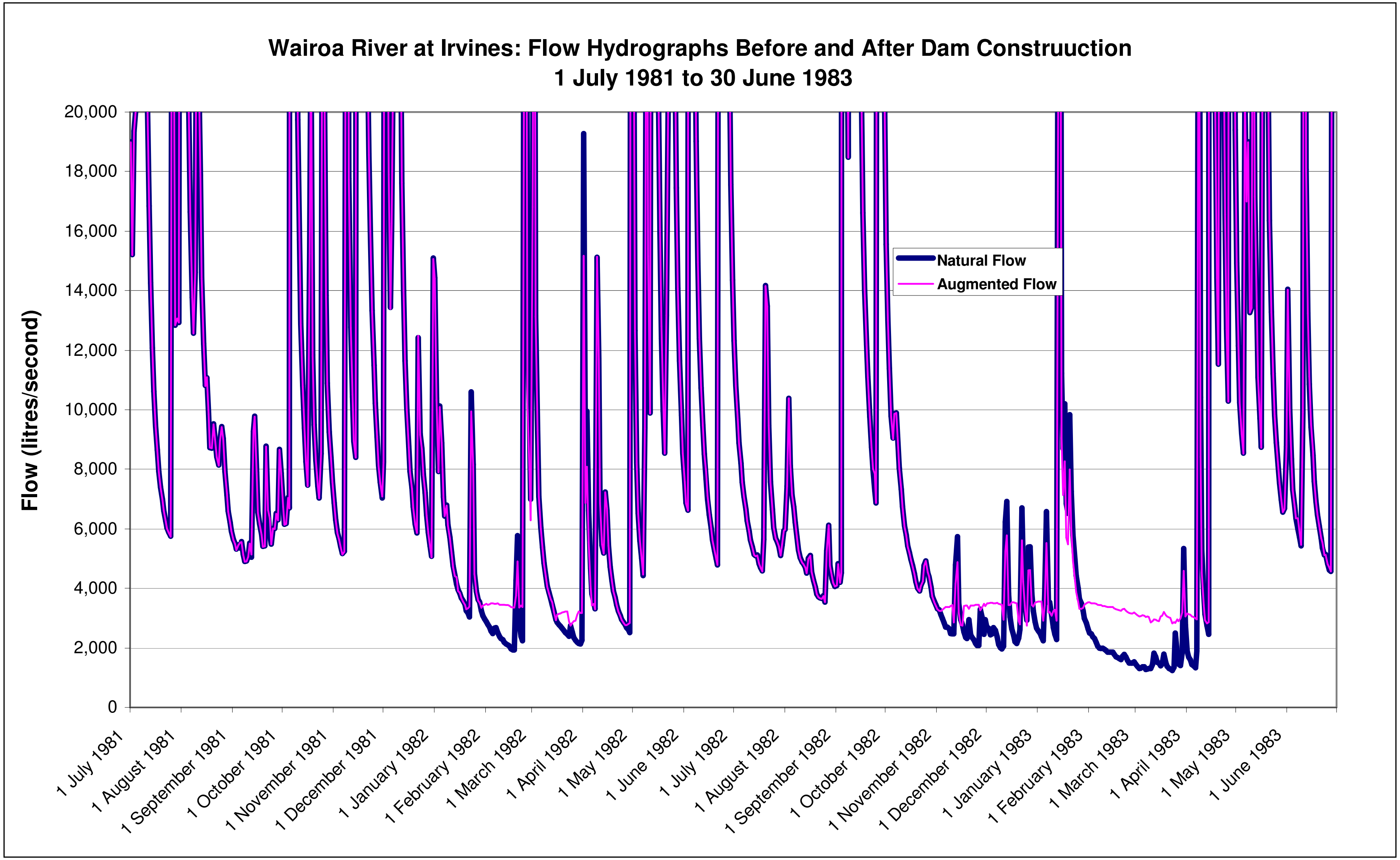

Upper Wairoa Dam Site: Flow Hydrographs Before and After Dam Construuction
1 July 1981 to 30 June 1983
Flow (litres/second)
12,000
10,000
8,000
6,000
4,000
2,000
0
Dam Inflow
Dam Outflow
1 July 1981
1 August 1981
1 September 1981
1 October 1981
1 November 1981
1 December 1981
1 January 1982
1 February 1982
1 March 1982
1 April 1982
1 May 1982
1 June 1982
1 July 1982
1 August 1982
1 September 1982
1 October 1982
1 November 1982
1 December 1982
1 January 1983
1 February 1983
1 March 1983
1 April 1983
1 May 1983
1 June 1983

Figure 6.8


Wairoa River at Irvines: Flow Hydrographs Before and After Dam Construuction
1 July 1981 to 30 June 1983
Flow (litres/second)
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Natural Flow
Augmented Flow
1 July 1981
1 August 1981
1 September 1981
1 October 1981
1 November 1981
1 December 1981
1 January 1982
1 February 1982
1 March 1982
1 April 1982
1 May 1982
1 June 1982
1 July 1982
1 August 1982
1 September 1982
1 October 1982
1 November 1982
1 December 1982
1 January 1983
1 February 1983
1 March 1983
1 April 1983
1 May 1983
1 June 1983

6.2.5 Sedimentation potential

The Wairoa River overall (as measured at Irvines) has a relatively low to moderate sediment load in comparison with other comparable rivers in New Zealand. The river transports the great majority of its sediment load during flood events. Flows below mean flow are virtually free of suspended sediment.

Over a 100 year period, the amount of sediment that would be trapped within the dam reservoir has been estimated at about 600,000 m^3. This estimate uses a relationship between river flow and suspended sediment concentration which was developed from a series of suspended sediment gaugings carried out at the Wairoa River at Irvines between 1976 and 1992.

Implicitly, the estimate assumes that the factors which control sediment generation, notably land-use, currently or in the future, are not significantly different to those over the gauging period. In this regard, it is noted that (uncontrolled) forestry operations have the potential to generate a substantially increased sediment load, from the time of harvest until a closed canopy with the new crop has established. The very steep hillslopes of the catchment afford limited opportunity for mitigation, i.e. it would be very difficult to implement effective erosion and sediment controls. This factor should be taken into account in selection of dam site, i.e. the site would be more favourable from a sedimentation point of view if there is less forestry coverage within its catchment. Conversion to exotic forestry from bush or pasture also has the potential to reduce water yield of the catchment.

6.2.6 Potential for electricity generation

Similar to the Lee Dam, the output potential is less than that indicated in the earlier report. The relevant comparative figures are 1.7MW and 9.8 GWh/annum average.

6.3 Land Ownership

Information in this section is largely taken from a report from TDC's Manager Property dated 3 April 2006. It is based on an affected area to RL 249m, slightly higher than the current provisionally assessed affected area to RL 245m, and assumed the downstream location.

Owner	**Approximate area affected by dam/reservoir (hectares)**
Richard Raynor Bolt	6.58
Alexander Grant Irvine	27.78
Forest Manager Crown	13.12
Department of Conservation	22.29*

* Area now likely to be less with dam site moved to upstream of lowermost tributary (near Anslow Road)

There are no residences in the affected area.

6.4 Potential Effects on Existing Infrastructure

Site access would presumably be via the existing Wairoa Gorge Road system, which contains areas which narrow and have poor sight distances. There could be substantial heavy vehicle movements for a Wairoa dam of the type appearing most suited to the site and for safe traffic operation, some road upgrading and possible special traffic control measures are likely to be required.

There is legal road reserve extending on both sides of the river along the extent of the reservoir. TDC's Property Manager has reported that these legal roads would need to be stopped and vested as esplanade reserves. It is noted that these roads extend beyond the potential reservoir until they reach Department of Conservation estate. TDC does not allow road stopping which leaves legal road isolated, and as such there may be an argument to leave the existing legal road system as it is. However there would be an issue of having to provide for access to the Irvine property at the top of the reservoir (true right bank).

Approximately 5km of Old Mill Road adjacent to the river (true left bank) would be potentially directly affected by the reservoir. It is used as access to forestry land and roads, and access to Richmond Forest Park.

6.5 Hazard Potential

A brief qualitative assessment is provided here with regard to dambreak hazard focussing on the differences between the two dam sites. A more detailed dambreak analysis and hazard assessment will be provided for the selected dam site in the final report.

As noted earlier, a concrete gravity dam approximately 56m high, is proposed. Unlike earth embankment dams, there are no general guidelines for estimating the peak dambreak outflow from a concrete gravity dam.

The potential failure mechanism of a concrete dam, whether it is overturning or cracking and sliding, would always result in a group of remnant monoliths (from the failed dam) in the river valley, which would obstruct the flow. Depending on the extent and pattern of toppling and speed of failure, the peak dambreak flow is likely to be smaller compared with an equivalent earth dam. A further possible scenario is severe cracking and outward rotation of concrete monoliths which would lead to massive leakage through the opened out cracks. Again, the leakage rate is unlikely to be as great as the peak dambreak flow from an earth dam of similar height.

As for the Lee River, the upper Wairoa River has a narrow and steep sided river valley (even more so than the Lee) and a relatively steep river gradient. Thus, there would be only modest attenuation of any flood wave before it exits the Wairoa gorge. There is a greater length of river exposed to high dambreak flows compared with the Lee since the upper Wairoa site is considerably further from the Wairoa gorge compared with the Lee dam site. There are possibly two or three times as many riverside dwellings in the upper Wairoa compared with the Lee. As in the Lee, the habitable buildings appear to be generally located well above river level. However, several dwellings could still be within the potential dambreak floodpath.

Accordingly, and also considering the effects in the more populated area downstream of the Wairoa gorge, a dam on the upper Wairoa should be assigned a High Potential Impact Category classification (in terms of the NZ Dam Safety Guidelines).

6.6 Potential Environmental Issues

6.6.1 Indigenous Vegetation

Context:

- The assessment examined the indigenous values of the footprint of the potential dam and reservoir, and downstream values likely to be affected by changed flow regime
- The assessment was based on an assumed top water level of RL 250m for the Wairoa (based on original assumed required storage volume of 15 million m^3)
- The focus of the work was on a comparative assessment between the two sites (Wairoa and Lee). It is not a detailed botanical survey, and has made no attempt to put the significance of the vegetation into a regional context (ie whether eventual loss is likely overall to be a significant issue)
- The survey involved identifying areas of natural vegetation within the catchment. Those that were of a reasonable size and significance were mapped. Many other smaller areas may also exist.

Findings relevant to Site 15 Wairoa River:

- The Wairoa Catchment has a generally higher altitude, steeper slopes, numerous bluff systems, more hard rock gorges, and fewer alluvial river flats
- Of the total Wairoa Catchment, only approximately 10% has been cleared.
- Natural areas in the lower part of the Wairoa tend to remain in larger blocks.
- The mineral belt band of ultramafic rocks crosses the catchment downstream from the proposed dam site. The vegetation associated with this band has largely been disturbed by fire.
- The catchment is very weedy in its lower reaches.

Significant sites:

- Downstream of dam site: Areas of threatened species occur on a river terrace; however any change in flooding regime will not influence these populations. One area of Department of Conservation reserve where a patch of threatened species (*Teucridium parvifolium*) grows close to the river and potentially may be influenced by increased flooding.
- Site 1 - dam site: extensive. Overall significance = high (for all criteria). Most of the natural values occur on right bank. Lower slopes and riparian zones would be inundated, although the mid-slope and upper part of the key matai forest would remain.
- Site 2: <1 ha. Overall significance = low to medium. Is a moist gentle river slope, leading to flats on both sides of the river. Is one of the few flats along the river with any natural values (logging has destroyed most of the others). All would be inundated.
- Site 3: 20 ha – below Gibbs Creek, connected to a much larger natural area to the east. Riparian and hill slope. Overall significance = medium (including high representativeness). Only the lower slope and riparian zone would be inundated.

- Site 4: 2-3 ha. Extensive area of regenerating lemonwood and gully of black beech. Contains one of the only surviving forest-covered river flats. Overall significance = medium. The gully would remain but the riparian zone would be inundated.
- Site 5: Extensive area at head of reservoir, grading to continuous original forest. Overall significance = high (for all criteria). The potential reservoir would form a shallow waterway along approximately 1km of river and would inundate the gorge sides and some low-lying flats and shaded rocky areas. Effect on this site may be minimal.
- Downstream impacts: At issue is whether a changed flow regime will alter the habitat of species which require regular flooding to keep the site open from colonisation by exotic weeds. Low flow periods may be extended but it is doubtful that the river flowing over bedrock will influence the water regime along its bank. Plants growing on rock in the flood zone are regularly exposed to dry conditions and are adapted to them. The reservoir may alter the flooding pattern and will halt downstream movement of rocks and logs. It is probable that the bed-rock nature of the river will minimise changes in the riverbed and adjacent riparian zone.

6.6.2 Blue duck (whio)

A survey in the area of the eastern branch of the Wairoa Catchment likely to be affected by the potential reservoir was undertaken in November 2005. The survey commenced at the road end grid ref 187643 and proceeded to the mid Wairoa Hut. From mid Wairoa Hut the area upstream to a major fork in the river at grid ref 198583 was surveyed.

No blue duck or sign of blue duck was found. This was not a surprise to the surveyor as the river is not of any size that would offer blue duck substantial protection from attention by stoats.

6.6.3 Water Quality and Aquatic Ecology

Consistently good water quality appears to occur in the Wairoa Gorge area, indicated by an invertebrate community typical of clean water (Cawthron’s 2005 report). Species richness is very good in the Wairoa River.

The fish community of the Wairoa River is described by DOC as a “diverse fauna of regional importance” (M Rutledge, DOC pers. comm. reported by Cawthron). Native fish species recorded in the Wairoa River are:

- koaro (both Branches)
- upland bully - in the Left (eastern) Branch
- longfin eel - in the Left (eastern) Branch and Right (western) Branch
- common smelt (Wairoa Gorge)

All of the fish species recorded, except upland bullies, are diadromous (ie they spend part of their life cycle in the sea and part in freshwater). They therefore require access to the sea at some stage of their life cycle, and conversely must be able to negotiate any obstacle to their upstream passage if they are to reach habitat higher in the catchment.

Brown trout are present in the Wairoa River. Recent drift diving by Fish and Game recorded 23.6 and 11.5 medium and large trout per kilometre in the Left (eastern) Branch and in the Wairoa upstream of Pig Valley.

A small portion of the upper catchment (in the order of 7%) drains ultramafic geology that could potentially contribute toxic sediment and potentially adversely affect water quality. The actual significance of this would need to be assessed in subsequent stages of the project.

6.6.4 Archaeology/Heritage Values

- TDC records show no specific sites of significance in the potentially affected area.
- the "Inventory and Maps of Important Geological Sites and Landforms in the Nelson and Marlborough Regions, including the Kaikoura District" shows no sites in the area potentially affected by the storage system

6.6.5 Potential Effects on Recreation

The mid and lower Wairoa River and Valley are a popular recreational resource.

Richmond Forest Park access

- Old Mill Road extends as a gravel road to the area that would be directly affected by the dam and reservoir footprint. The road provides a significant access point to Richmond Forest Park via a track system to Ben Nevis.

Informal recreation

- there are presently two formal picnic sites within the downstream stretch of river near the Forks area, as well as the Forks area itself at the bridge (off the rock formation).
- we note that in relation to the three DOC recreation areas, the "Nelson/Marlborough Conservancy Recreation Opportunities Review" (October 2004) has reviewed the status of each of the formal picnic areas downstream as follows:
  - Mid Wairoa Gorge Amenity Area: maintain
  - Wairoa Left (eastern) Branch Amenity Area – cease to maintain

  If these recommendations are accepted, this will mean that only the site downstream of the Forks (mid Wairoa Gorge Amenity Area) would have been maintained and be likely to have significant ongoing use.
- the downstream river contains good swimming areas.
- However it is unlikely that these areas would be adversely affected.

Kayaking (Ron Wastney, Training and Conservation Officer, Nelson Canoe Club, pers. comm.).

- the stretch of river that would be directly affected by the storage reservoir is of high value for both white water and its scenic value. This value extends downstream to Stillwells Bridge (mid Gorge). Below this (from Stillwells Bridge to the Lee confluence) is of low value for white water but does have high scenic value).
- Kayakers generally enter the river at the ford approximately 1km upstream of the Gibbs Creek confluence (ie within what would be the reservoir footprint) and come out at either the Forks (and redo this section) or continue to Stillwells (approximately 5 hour run). This section is used (by approximately 10 'hard core' Nelson kayakers every time there is a fresh in the river; ie when the flow as

measured at Irvines reaches 40-50 m^3/s (equates to approximately 15 m^3/s at the top part of the river stretch).

- Little use is made of the river in summer unless there is a good fresh (which usually only lasts for a day).
- A proposal to dam the Wairoa Left (eastern) Branch would be opposed by kayakers.
- information previously obtained by ESR notes that members of the Nelson Canoe Club consider the Wairoa River, when in flood, to be one of the premium rivers. It may be used by up to 100 kayakers when the river is high.

Trout fishing

- the Wairoa is a good trout fishing river. Grant Irvine (a local angler) rates the Wairoa River highly and lists its proximity to Nelson and Richmond as a major attraction. However the river is not heavily fished and as a result the trout are relatively easy to catch. The aesthetic values of the river are also valued. (Grant Irvine, pers. comm. reported by Cawthron). It is not clear whether these comments apply to the upper Wairoa (Left Branch), especially given its difficult access. This aspect would need to be explored as part of further investigation.

6.6.6 Community Issues

ESR's previous community survey work provided feedback on the values of the Wairoa River and Valley. These are repeated below. However many of these comments were made generally about the Lee and/or Wairoa Rivers and may not necessarily be specific to Site 15.

- intrinsic values of the river itself
- significant recreational asset
- habitat values (instream and terrestrial)
- sense of identity (for valley residents)
- easy access and proximity
- contrast to urban environment

Comments specific to the Wairoa River included:

- clear water
- scenic beauty
- prefer a storage dam(s) out of the river

Other community issues may arise as a result of the dambreak potential.

6.7 Planning Issues

- the storage site is mainly zoned Rural 2, apart from two areas zoned Recreation (lower true right, and small area upper true right)
- there are no denotations on the TRMP Area Maps.
- there appear to be no obvious inconsistencies with the objectives and policies for the Zones. Special attention will however need to be paid to the following objectives:
    - maintenance of public access to and along margins of rivers which are of recreational value (objective 8.1.0)

- protection and enhancement of biological diversity and integrity of terrestrial, freshwater and coastal ecosystems, communities and species (objective 10.1A.0)

- Site 15 is within the Upper Catchments Water Management Zone
- a range of consents will be required, mainly for discretionary activities, with exception as below.
- to be a Discretionary Activity, the total amount of water taken (between November and April each year) either by the scheme or in combination with other takes, must not exceed 3 l/s. Takes above this limit are non-complying (ie the resource consent process will need to pass a higher threshold test).
- water management objectives for the Wairoa River (TRMP Schedule 30.1):
  - provide for protection of instream values including fisheries and natural values
  - maintain contribution to Waimea River flows
  - protect landscape, cultural and spiritual values
  - maintain or improve existing users' security of supply to acceptable level

6.8 Potential for Mitigation of Effects

The following mitigation measures could be considered (excluding land acquisition issues):

- replacement of forestry roads and access to Richmond Forest Park
- dambreak warning system
- provision of system to allow native fish passage
- flow harvesting such that high flows suitable for kayaking in the stretch of river downstream of the dam are retained for some times
- controlled flow releases to provide whitewater for specific events

6.9 Potential Opportunities for Enhancement

The following potential opportunities exist for enhancement (in addition to those arising from augmenting flows in the lower catchment for water supply, protection of instream values, and enhancement of the values of the Waimea Estuary):

- Generation of electricity
- Improved road system to mid catchment , including public access to upper catchment and Richmond Forest Park by provision of road network
- Self-sustaining (lake) trout fishery above dam
- Recreational use of 'lake' (reservoir) environment (picnic areas, swimming, boating, fishing)
- Creation of wetland habitat at reservoir margins
- Development of walkway system around reservoir (utilising land in public ownership (marginal strip)
- Improved access to Richmond Forest Park, and development of linking tracks to main track system.

7 Summary of Comparative Points

7.1 Introduction

The following sub-sections provide our objective comment on those aspects of the schemes for which some difference between sites appears to exist, based on the current preliminary information. The points are summarised in tabular form in Section 7.12.

We acknowledge that members of WWAC may interpret the information presented here differently, and may also be in possession of additional information due to their roles on WWAC which may alter our summary. These points will be discussed at the forthcoming WWAC meeting.

7.2 Engineering Attributes

- Site 11 Lee:
  - Top water level: RL 183m
  - Dam height to crest: 48.5m
  - Dam type: earthfill embankment
  - Area affected: approximately 90 hectares
  - New roads/tracks: approximately 4.5 km
  - Materials availability: mostly from within reservoir footprint and immediate dam surrounds
  - Construction access issues: as a greater proportion of construction materials may be available on-site, there would be reduced construction traffic issues vs Wairoa.
  - Downstream hazard potential: Earth embankment dam; fewer dwellings exposed to dambreak risk compared with Site 15 Wairoa
  - Required design standards: to High Potential Impact Classification standard
  - Electricity generation potential: 1.2MW (6.8 GWh/annum)
- Site 15 Left Branch Wairoa:
  - Top water level: RL 237m
  - Dam height to crest: 56m
  - Dam type: concrete gravity
  - Area affected: approximately 70 hectares
  - New roads/tracks: approximately 3km
  - Materials availability: concrete would likely be needed to be transported to site unless on-site quarry proven in later stages
  - Construction access issues: more construction traffic (safety and nuisance factors for other road users)

- Downstream hazard potential: Concrete gravity dam allows possibly lower dambreak flow compared with Site 11 Lee, but more dwellings exposed to dambreak risk - worse overall
- Required design standards: to High Potential Impact Classification standard
- Electricity generation potential: 1.7MW (9.8 GWh/annum)

7.3 Preliminary Indicative Cost

It needs to be recognised in both cases that the costing is not based on a high level of preliminary design, or detailed assessment of geological implications or close evaluation (e.g., with local contractors) of contract rates that might apply to the specific works. Having said that, the approach to costing has been consistent for both, and should give a fair reflection of relativity.

- Site 11 Lee:
  - Base price : $17.0M
  - Piped delivery option (to bottom of Wairoa Gorge): $6.5M (additional to base price)
- Site 15 Left Branch Wairoa:
  - Base price : $16.5M
  - Piped delivery option (to bottom of Wairoa Gorge): $9.1M (additional to base price)

In summary, within the order of cost accuracy, there is no significant base cost difference between the two sites.

7.4 Operating Regime

- Site 11 Lee: Greater extent and impact of reduced river flows below the dam as the next major tributary, the Roding, is far downstream (some 2 km from the confluence with the Wairoa)
- Site 15 Left Branch Wairoa: Impact of reduced flows below the dam buffered by inflows from Right Branch Wairoa River

7.5 Sedimentation Potential

- Site 11 Lee: No significant difference at this stage
- Site 15 Left Branch Wairoa: No significant difference at this stage

7.6 Land Tenure and Infrastructure

	Lee (potentially affected)	**Wairoa (potentially affected)**
Private ownership	Four landowners: 41.92 ha	Two landowners; 34.36 ha
Crown entity (excl DOC)	Two entities: 26.39 ha	One entity: 13.12 ha
DOC	6.22 ha	Approx 15 ha (subject to confirmation)
Formed roads*	5-6 km formed forest access road (private)	4-5 km of currently formed public road. Some forestry roads

* Indicative only - based on limited site visits and current aerial photography/mapping. Subject to change in response to forestry activity in the areas.

7.7 Aquatic Ecology and Water Quality

Ecologically the two sites are comparable – good water quality, healthy invertebrate communities, and reasonable diversity of fish (including moderate densities of large brown trout) (Roger Young, Cawthron, pers. comm.).

There is the potential for water quality in the Left Branch Wairoa to be affected to some degree by the accumulation of toxic sediments from ultramafic geology in the headwaters of the catchment.

7.8 Indigenous Vegetation

- Both footprint areas have a considerable degree of botanical significance.
- Comparative assessment depends in part on which criteria are regarded most highly. If large size and continuity of natural areas is paramount, then the Wairoa site is the more important. However if diversity and rarity are more highly valued, then the Lee is uppermost in value.
- Both rivers (sites) have exceptionally high values at what may be the head of the reservoir footprint areas. However there is a likelihood that depending on storage volume and reservoir extent, neither will be seriously damaged, if at all.
- Opportunities exist for mitigation of effects, such as pest control, weed control, separation of forestry areas from protected riparian areas, and ecological restoration (species establishment).

Conclusions reached by Dr Simpson:

- The Lee is botanically more significant than the Wairoa because it has a greater range of ecosystems, good populations of rare or distinctive species, and overall is in better condition than the Wairoa.
- The downstream impacts of the changed river system are difficult to judge but overall do not seem to be critically important, but more research is required.
- Weeds, animal pests and forestry activities are damaging the natural ecosystems.
- A mitigation package could focus on the above problems.

7.9 Blue Duck (whio)

No blue duck were found in either area. The Lee River looked more promising in the lower reach than the left branch of the Wairoa but the feeling on all of the survey was that both catchments would have seen substantial stoat numbers and the size of the rivers offer no long-term secure habitat for blue duck. The surveyor concluded that apart from the occasional lone bird, the catchments were no longer inhabited by blue duck.

The Department of Conservation (Peter Gaze) has commented on the above survey findings as follows:

"The findings presented in this report should be considered in the light of what we know about blue duck in the Richmond Range over recent times. Twenty years ago blue duck were regularly encountered in all of the major catchments – Pelorus, Wakamarina, Timms, Goulter, Motueka and Wairoa as well as minor catchments such as the Brook, Maitai, Lee and Roding. Whether they bred in all these catchments is not known. Over this period sightings have become less widespread and

less frequent. These observations are consistent with what is known of trends elsewhere in the country – breeding productivity is low because of egg predation and while adults may live to an old age, females are often killed on the nest.

During the last 20 years blue duck were occasionally recorded from the Lee and Wairoa, sometimes well downstream of the bush boundary (Hay & Young 2005). These were usually single birds and I am unaware of any breeding records.

Dam construction and loss of river habitat could only have an adverse effect on this relict population of blue duck in the Richmond Range. However the significance of this would be small given the continued decline of the population through predation. A predator control operation would not make these rivers safer for dispersing birds but would be beneficial if a pair chose to breed.

The expense of establishing and maintaining a predator control operation of sufficient size to benefit blue duck at this location could probably only be justified if it was supplemented by the introduction of captively raised young birds. Mitigation of this nature would be more effective if directed at supplementing blue duck conservation work currently undertaken elsewhere.

The Department of Conservation is focusing its work on eight sites throughout the country, each of which will be managed to support at least 50 pair of blue duck. The Wangapeka/Fyfe catchments is one of these sites and, although resources are only available to manage a small part at present, this work has seen numbers in the lower Wangapeka rise from three to almost thirty in less than four years.

The Wangapeka/Fyfe operation now has the infrastructure to ensure that any additional resources can immediately be used to extend the area of protected habitat and the size of this population."

7.10 Recreation

- Kayaking: the Lee has little value. The Left Branch Wairoa is highly valued and any development attempts would be opposed.
- Trout fishing: the Lee is currently not as significant as the Wairoa due largely to difficult access. Both rivers have good sized fish. Potential benefits arise from improving access and developing a lake fishery – no difference between sites.
- Access to Richmond Forest Park: public access exists through the Wairoa Left Branch. Little access via the Lee.
- Informal recreation: both rivers are well used. Development on either river is unlikely to significantly affect this use.

7.11 Summary Comparison of Attributes

Feature	Site 11 - Lee	Site 15 – Left Branch Wairoa
Water demand	No difference	No difference
Storage capacity	No difference	No difference
Reservoir area (hectares)	Larger	Smaller
Materials availability	Majority available on-site	Expect most to be imported
Construction access issues	Effects less apparent	Effects more apparent
Operating regime	Effects more apparent	Effects less apparent (Right Branch Wairoa provides buffering)
Sedimentation potential	No significant difference	No significant difference

Feature	Site 11 - Lee	Site 15 – Left Branch Wairoa
Downstream hazard potential	Lower	Higher
Required design standard	No difference	No difference
Comparative cost (base price)	No significant difference (within current order of accuracy)	No significant difference (within current order of accuracy)
Cost (piped delivery)	Lower cost	Higher cost
Land tenure	More owners (7)	Fewer owners (4)
Land administered by DOC	Less	More
Potential electricity generation	Little difference (1.2 MW; 6.8 GWh/annum)	Little difference (1.7 MW; 9.8 GWh/annum)
Aquatic ecology	Little difference	Little difference
Water quality (effect of ultramafic geology in catchment)	No issue	Potentially an issue
Indigenous vegetation	More significant	Less significant
Blue duck (whio)	No difference	No difference
Cultural impact	Difference not known at this stage	Difference not known at this stage
Trout fishing	Little difference	Little difference
Informal recreation	Little difference	Little difference
Kayaking	No issues	An issue – development would be opposed
Access to Richmond Forest Park	Lesser effect	Greater effect
Archaeology/heritage values	No difference apparent at this stage	No difference apparent at this stage
Community preference	Not gauged	Not gauged
Enhancement opportunities	No difference apparent at this stage	No difference apparent at this stage

It appears from the above table (without weightings being applied to any criteria) that the Lee may have more positive points than the Wairoa.

8 Applicability

This report has been prepared for the benefit of the Waimea Water Augmentation Committee/Tasman District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

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