Local People. Global Experience.

The Narrows

Technical Feasibility Study Report
Phase One

Final Revision Two

November 2015

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

A glossary of terms is given hereunder.

Term	Definition
ANCOLD	Australian National Committee on Large Dams
Abutment	That part of the valley side against which the dam is constructed
Annual Exceedance Probability (AEP)	Probability at which an event of specified magnitude will be equalled or exceeded in any year, normally used in relation to floods and earthquakes.
Annual Recurrence Interval (ARI)	A statistical estimate of the average period in years between the occurrence of a flood of a given size. For example, the 10 year ARI event will occur on average once every 10 years: this is equivalent to a 10 year ARI having a 10% probability (AEP) of occurring in any given year.
Catchment	The land surface area which drains to a specific point such as a reservoir
Consequence Category	Classification to categorise a dam for the potential consequences associated with failure. It is used to determine aspects such as the level and frequency of surveillance of a dam, and magnitudes of load cases to be used in the design and analysis of a dam.
Dam Crest Flood (DCF)	The flood which can be passed through the spillway with the reservoir level at the dam crest.
Design Flood	The flood for which the dam is designed to safely operate with appropriate freeboard.
Factor of Safety (FOS)	Ratio of acting to resisting loads - indicative of the level of safety
Failure	The uncontrolled release of the contents of the dam/weir through collapse of the dam/weir or some part of, or the inability of a dam to perform its design functions such as water supply
Flood Hazard	The potential loss of life, property and services which can be directly attributed to a flood.
Freeboard	The vertical distance between a stated water level and the top of the dam.
Foundation	The material of the valley floor and abutments on which the dam is constructed.
Full Supply Level, (FSL)	The maximum normal operating water surface level of a reservoir when not affected by flood
Height of Dam	Normally the maximum height from the lowest point of the general foundation area to the top of the dam
Gigalitre (GL)	A unit of volume equivalent to 10^9 litres
Left and Right hand direction	The left and right hand directions when looking downstream at the dam site.
Megalitre (ML)	A unit of volume equivalent to 10^6 (one million) litres
Minimum Operating Level (MOL)	The level in the reservoir where extraction of water will cease – typically the lowest level at which the pumps can operate
Outlet Works	The combination of intake structure, conduits, tunnels, flow controls and dissipation devices to allow the release of water from a dam
Population at Risk (PAR)	All people who would be directly exposed to floodwater assuming they take no action to evacuate

Term	Definition
Probable Maximum Flood, (PMF)	The flood hydrograph resulting from the probable maximum precipitation and, where applicable, snowmelt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.
Probable Maximum Precipitation (PMP)	The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin.
Relative Level (RL)	Elevation in Australian Height Datum
Storage	An artificial reservoir, lake or basin for storage, regulation and control of water
Spillway	A structure designed to permit discharges from the storage under normally flood or in anticipation of floods
Tailwater	The water at the downstream side of the dam
Toe of Dam	The junction of the downstream (or upstream) face of the dam/weir with ground surface (foundation)
Top (Crest) of Dam	The elevation of the uppermost surface of a dam/weir not taking into account any camber allowed for settlement, kerbs, parapets, crest walls, guardrails, or other structures that are not a part of the main water retaining structure. This elevation maybe a roadway, walkway or the non-overflow section of a dam/weir.
United States Army Corps of Engineers (USACE)	One of the world's leading dam authorities

1 INTRODUCTION

SMEC was engaged by Towong Shire Council (TSC) to undertake Phase One of The Narrows Project Feasibility Study, to assess the technical feasibility of constructing a water control structure across Lake Hume, on the Mitta Mitta arm, west of Tallangatta.

It is understood that the lower water level in the Mitta Mitta arm of Lake Hume, between the months of November and April, impacts on potential recreation and tourism opportunities for the township of Tallangatta. To this end it is envisaged that a water control structure would enable water levels to be maintained at a functional level during this period.

It is intended that The Narrows Project be undertaken in three phases as follows:

- Phase One – Literature review, identification of known physical constraints and preliminary cost estimate for the capital works
- Phase Two – Preliminary feasibility assessment; and
- Phase Three – Detailed option assessment.

This report details the outcomes of Phase One of this project and includes:

- Literature Review
- Project History
- Hydrological Assessment
- Development of Geological Model
- Legislation, Planning and Cultural Heritage
- Options Development and Concept Design
- Preliminary Cost Estimates for Capital Works

The recommended concept design would provide the technical definition of The Narrows Project. As such it should be highlighted that aspects including the economic benefits or social impacts resulting from The Narrows Project have not been considered.

2 AVAILABLE INFORMATION

The following details the list of documents and background information utilised by SMEC for the study:

- Photographs taken during site visit
- Harold Corey (2000) Summary of Project History document entitled “History”
- Woodward-Clyde (1995) Narrows Project Pre-feasibility Study
- National Institute of Economic & Industry Research (1987) The Impact of ‘Bad Seasons’ on Lake Hume on Tallangatta Expenditure Levels
- River Murray Commission (1985) Options for Maintaining Water Levels at Tallangatta for Recreation
- Loder and Bayly et al, (1979) Lake Hume Recreational Capacity Study
- State Rivers and Water Supply Commission (1949) Water Resources Investigation, Enlargement of Hume Reservoir, Effect on Township of Tallangatta
- GMW (2014), Upper Murray Groundwater Management Area: Local Management Plan, DM# 3747717, Goulburn Murray Water, Victoria.
- Stakeholder List and Business Contacts
- Hume Dam – Storage Capacity Table
- River Flow gauge data
- Flood Frequency Data document entitled “Hume & Dartmouth Dams – Flood Frequency Data for Narrows Preliminary”
- Various Document Extracts document entitled “Document Extracts”
- Survey
  - 5m LiDAR (2007)
  - Bathymetric data (2007)
  - 10m ARC GIS files
- Geological Survey of Victoria (1979), Hume: First Edition, 8325-IV Zone 55, Scale 1:50,000.
- Geological Survey of Victoria (1976), Tallangatta: First Edition, Sheet SJ 55-3, Scale 1:250,000.
- Geological Survey of Victoria (1997), Tallangatta: Second Edition, Sheet SJ 55-3, 1:250,000 Geological Map Series.
- O’Shea, PJ (1976), Explanatory Notes on the Hume 1:50,000 Geological Map, Geological Survey of Victoria Report 39 (1976/5), Department of Mines, Victoria.

3 PROJECT BACKGROUND

3.1 Project Site

The site of the proposed water control structure is located at a section of the Mitta Mitta River between the township of Tallangatta and Lake Hume. Colloquially this section of the Mitta Mitta River is known as the Narrows. A plan identifying the location of The Narrows is presented below in Figure 3.1

Figure 3.1: The Narrows – Locality Plan

Source: Department of Environment, Land, Water and Planning
http://services.land.vic.gov.au/maps/pmo.jsp

3.2 Project History

In the late 1940's a decision was made to increase the storage capacity of Hume Dam. As a direct result of this increase in capacity the township of Tallangatta would have been inundated and hence provision needed to be made to 'protect' the town. To this end it was agreed that the township would be relocated. Two locations were considered namely Toorak and Bolga.

It is understood that originally Toorak was the site preferred by Tallangatta residents but that authorities considered the move to Toorak undesirable due to the site being located at the extreme upstream end of Lake Hume. At this location the backwaters of the reservoir were known to recede significantly when irrigation commenced and would have resulted in the township of Tallangatta facing mud flats over the summer months.

In the early 1950's it was agreed that the township would be relocated to Bolga. This site was selected as Lake Hume was deeper at this location and it was expected that when the reservoir was drawn down the riverbed and mud flats would be observed less frequently. In 1952 the Victorian

Premier noted that the waters of Lake Hume would provide a great tourist attraction. It is understood that Tallangatta residents took this to mean that only rarely would the mud flats be seen in front of the new Tallangatta township.

In years that followed the relocation there were many occasions, namely at the end of February in the years 1956, 1957, 1958, 1962 and 1968, where the mud flats were visible and there was no water frontage for Tallangatta. A drought in 1968 resulted in the near emptying of Lake Hume by the end of the irrigation season. This prompted discussion about construction of a new dam upstream of Lake Hume (now known as Dartmouth Dam). It became apparent that construction of another dam would result in more frequent low water levels at Tallangatta.

In March 1968 local member T.W Mitchell raised with the Minister for Water Supply the possibility of the construction of an earth wall across "The Narrows" at a height sufficient to hold water for safe boating at Tallangatta. At this time the State Rivers and Water Supply Commission (SR&WSC) said that an earth wall would not be satisfactory, as it would need to sustain the full 'brunt' of floods in the Mitta Mitta River and that the cost of a rock wall substantial enough to withstand such floods would be out of all proportion to the benefits.

By 1970 a decision to build Dartmouth Dam seemed certain, and the SR&WSC wrote to the Shire of Tallangatta cautioning that an impact from the construction of Dartmouth Dam would be that the levels in Lake Hume would be 'lower than average'. Shire President Jim Harvey remarked that it appeared that after the completion of Dartmouth Dam there would be a fairly large area of mud flats in front of Tallangatta, and a lot earlier in the season than had previously been the case.

In 1974 during the construction of Dartmouth Dam the Shire requested that a minimum operating level for Hume Dam be set. Subsequently in 1978 the Chief Executive of the River Murray Commission (RMC) advised the Shire that the intention for Dartmouth Dam was to operate the dam as a backup dam with water only being released when it became apparent that there would be insufficient water in Lake Hume to last until the end of that particular irrigation season. In addition it was noted that to release water from Dartmouth earlier, or to use it to maintain water in Lake Hume for recreation, would impact on the quantity of water available for irrigation in future years.

In 1979, Loder & Bayly were commissioned by the Lake Hume Recreation Coordinating Committee to undertake a recreational study of Lake Hume. Some of the key findings of this report related to the feasibility of constructing a dam near Tallangatta and included the following:

- at a level of RL181.5m AHD there is no useable water off Tallangatta and the town ceases to become a viable centre for water-based recreation.
- the current operation of Dartmouth and Hume Dams conflicts with recreational activities within Lake Hume;
- alternative water operating policies for Dartmouth and Hume Dams to reduce fluctuations in water levels in Lake Hume during the recreational season would potentially increase the risk of irrigation shortfall, and potentially reduce hydropower generation at Dartmouth Dam.

In 1982 the idea of constructing a dam at "The Narrows" was revisited with the Tallangatta Shire Council and the Tallangatta District Promotions Committee proposing to the Hon. Lou Lieberman that an embankment ("Lock") be constructed to retain water at Tallangatta for boating during the Summer/Autumn recreation season. The Rural Water Commission (RWC) undertook a brief review of the proposed "Lock" in March 1982 and suggested that a rock-faced earth embankment about 11 metres in height and 430m long could be built within "The Narrows". The dam would hold back water at RL182mAHD or approximately 50% capacity of Hume Dam. The cost to construct the structure was estimated at around $3 million. Subsequently in 1983 Tallangatta Shire Council suggested that a structure at RL187mAHD should also be considered.

A severe drought struck the region in the summer of 1982/83 resulting in the water level in Lake Hume dropping to similar levels to those experienced during the 1968 drought. This level occurred in spite of the fact that water had been released from Dartmouth Dam at the maximum carrying capacity of the Mitta Mitta River.

In 1985 River Murray Commission (RMC) was commissioned to evaluate proposals for improving the availability of water for recreation in Lake Hume at Tallangatta. The objective of the study was to determine if enhanced recreational opportunities could be obtained with little or no effect on the existing primary users of the resources, namely irrigation and hydroelectricity generation. The three strategies that were investigated were:

- Strategy A: Releasing water from Dartmouth Reservoir to maintain water in Lake Hume at Tallangatta until the end of February.

  This strategy gave satisfactory conditions for recreation at Tallangatta in 74% of all years, an increase over current conditions of 19%.

- Strategy B: Releasing water from Dartmouth Reservoir to maintain water at Tallangatta but restricting Dartmouth releases to that water that had a 75% chance of spilling before the following November.

  This strategy gave satisfactory conditions for recreation at Tallangatta in 62% of all years, an increase over current conditions of 7%.

- Strategy C: Constructing an embankment with Full Supply Level (FSL) RL182mAHD across the Mitta Mitta Arm of Lake Hume to maintain water for recreation.

  This strategy gave satisfactory conditions for recreation at Tallangatta in 100% of all years.

The study indicated that the loss of irrigation supplies was small for all three strategies tested but that the losses to hydro electricity generation were significant. When these costs were taken into account it was concluded that the strategies involving modifications to the Dartmouth releases resulted in significant improvements in the number of "good" recreation years (good year classified as water levels above RL182mAHD) but at a cost of around $1.6 million for Strategy A and $2.3 million for Strategy B for every extra "good" year.

The proposal to construct an embankment at a capital cost of $3 million (RWC, 1983) was considered the most cost effective for the Tallangatta area. However if no provision was made for adequate outlet facilities in the embankment then the extra dead storage behind the dam would result in an average cost to irrigation industry of $90,000/year, and that the cost of each additional good year would be $0.63-0.90 million. In addition the cost to hydropower generation resulting from construction of a dam was estimated to be insignificant at about $1000/year. The report did not provide an economical assessment of whether or not constructing a dam was viable.

In 1987 the National Institute for Economic Research was engaged by the Shire of Tallangatta to investigate the impact of low levels in Lake Hume on tourism and income levels within Tallangatta. The results of the study showed that the economic loss to Tallangatta for a year where there is no water in summer for recreation was estimated at between $100,000 and $200,000.

Later in 1987 a recreation consultant, Carl Malmberg, was appointed to prepare a recreation study for the whole of the Tallangatta Shire, based on the premise that a weir across the Narrows was not economically viable. The outcomes of this study are not available.

In general the impact of the lack of guaranteed recreational facilities was seen as not only being limited to tourism at Tallangatta. The Albury-Wodonga growth centre also saw the lack of guaranteed facilities as a "major obstacle to their objectives". In 1988, in response to public agitation, Pak-Poy Kneebone were commissioned by the Murray Darling Basin Commission (MDBC) (formerly the River Murray Commission) to undertake an economic study. The study aimed to make a comparison between economic gain over the whole of Lake Hume, including Albury-Wodonga, in operating the two dams so as to ensure the maximum possible water availability for recreation, and the economic loss to irrigation and power generation of such an action.

The study found that if the two dams were operated such that Lake Hume never fell below 85% capacity (NOTE: At RL189.5mAHD Lake Hume is approximately at 85% capacity), there would be a possible economic gain to the whole region of $2.2 million. The economic loss would be:

- Irrigation $67 million
- Electricity generation $0.8 million
- Salinity $2.8 million

Following the release of this report it is understood that MDBC modified the operating regime of the two dams such that releases from Dartmouth commenced in the early summer months, rather than waiting to see if Lake Hume would be able to supply irrigation water for the prevailing season before commencing releases from Dartmouth dam.

In 1994 the Shires of Tallangatta and Upper Murray were amalgamated to form Towong Shire Council. Prior to election of the councillors for the amalgamated council, three interim Commissioners were appointed, and based on the sentiment that the economic future of the Tallangatta township was dependent on the construction of a weir at the Narrows, the interim Commissioners commissioned a prefeasibility study. To this end in 1995 Woodward Clyde were engaged to investigate the feasibility of constructing an embankment at The Narrows to provide constant upstream water level of RL192mAHD (100% capacity of Lake Hume). The key findings of this report were as follows:

- With Lake Hume at approximately RL182m AHD the boat ramp becomes unusable and water skiing and power boating activities decrease by 50%.
- When levels in Lake Hume drop from 100% to 85% capacity (NOTE: At RL189.5mAHD Lake Hume is approximately at 85% capacity), there appears to be no change in recreational use of Lake Hume. When the reservoir drops from 85% to 50% (NOTE: At RL183mAHD Lake Hume is approximately at 50% capacity), there is a fall of 10% in the recreational use of the reservoir.
- Storage volume of the dam at the Narrows (at Point Packer) with a FSL of RL192mAHD is about 2.75% of Lake Hume or 83.5GL
- Results of geotechnical investigations undertaken as part of the study indicated that the foundation of the dam is likely to be founded on silt and clay, with rock observed in the boreholes in the centre of the valley at around RL140mAHD (35m to 40m below natural surface).
- Investigations also identified possible suitable sources of earth and rockfill material in the abutments at the proposed site.
- The study concluded that to construct an armoured single zone embankment dam across the Narrows with a FSL of 192mAHD could be economically viable if the following assumptions were met:
    - A 4MW hydropower project was included in the project and power was sold in accordance with prices set out in co-generation agreement 1988;
    - Water supply authority contributed to the capital cost of the dam, an amount equivalent to the avoided capital cost of a new water treatment plant and associated works;
    - The State Government contributes to the capital cost of the wall an amount equivalent to the estimated rate revenue foregone which has been lost as a result of the historic Hume Dam expansion; and
    - Developer contributions from subdivision of lakeside real estate and increased rate revenue would be attributed directly to the project.

The scheme proposed by Woodward-Clyde was dependent on a subsidy being available for the power generated under a renewable energy incentive scheme. When it became apparent that the subsidy could not be obtained, the scheme was shelved at the end of 1996.

Since the prefeasibility study was undertaken a water treatment plant was built at Tallangatta to improve the quality of town's water supply, particularly when drawing off water from Lake Hume when the reservoir level is drawn down.

In 1998 Victorian Premier Jeff Kennett visited Tallangatta to meet Shire representatives and a community advocate for the Narrows Project to discuss the current proposed option. At this time the proposal had been scaled back following the 1995 study to comprise a weir of sufficient height to hold water at Tallangatta at a level equal to 76% of lake capacity. (NOTE: At RL188mAHD Lake Hume is approximately at 76% capacity). The cost of this structure was estimated to have been $5.2million. At the end of 1998, the Shire unsuccessfully applied under the Commonwealth and Federal Cultural and Heritage Project for $5.2 million to undertake construction of the weir. Subsequent to the 1998 funding rejection, the Shire has been advised that an application for public funding is unlikely to be successful unless an economic study accompanies the application, and unless such a study shows that the expenditure is justified.

It is understood that since 1998/99 no further investigation has been undertaken with regard to the Narrows project.

4 FUNCTIONAL REQUIREMENTS

4.1 General

In order to determine an appropriate weir arrangement for The Narrows a functional design criteria was developed to meet the project objectives. The Functional Design Criteria memo was prepared to confirm Towong Shire Council's (TSC), and the Project Steering Committee's (PSC) functional requirements for the structure. The criteria was based on SMEC's understanding of the project drivers from discussions with TSC and utilising information from previous studies. It was intended that any gaps in understanding be identified at an early stage and alignment be reached as to key functional requirements such that these requirements could be incorporated into concept design.

To this end the functional design criteria memo was prepared and issued to TSC and the PSC for comment. A copy of the functional design memo is presented in Appendix 4.1 along with a table summarising comments from TSC and the PSC, and associated SMEC response.

4.2 Functional Design Arrangements

4.2.1 General

Based on review of the previous reports and discussions with the TSC a list of the key functional objectives are summarised below in order of decreasing importance:

1. To maintain consistent water levels in Lake Hume at Tallangatta township over the peak tourist season (December to February) each year to encourage recreational water activities. It is noted that the following water activities need to be accommodated:
    - Boating (including power boats)
    - Water skiing
    - Fishing
2. To provide an alternative road access to the north side of the Mitta Mitta arm to the west of Tallangatta
3. To provide improved water frontage and amenity in vicinity of the township

4.2.2 Functional Criteria

The following functional design criteria requirements provided a basis for which the concept was to be developed:

1. Low maintenance

    It is intended that the structure essentially be an unregulated structure with no routine operational or maintenance requirements. Normal river flows would pass over the dam, rather than be regulated through an outlet.

    Consideration would also be given to aspects such as floating debris/rubbish control.
2. Flood Afflux

    Ensure minimal affect upstream of the weir as a result of the afflux caused by the construction of a weir across the river channel. The structure would be designed such that the flood afflux at the 1 in 100 year event would be nominally zero. The results of the afflux study are presented in Section 5.4.
3. Flooding

    The structure needs to be capable of passing flows generated by the upstream catchment as well as Dartmouth Dam releases and spill flows via overtopping of the weir. The structure will be designed to allow for overtopping in the upstream/downstream direction (Mitta

Mitta Flows). Consideration will also be given to a requirement to allow for overtopping flows from Hume Dam in the downstream/upstream direction, albeit scenarios for such a situation are difficult to contemplate.

4. Outlet

   The outlet would be designed to meet dam safety emergency drawdown requirements. The maximum transfer from Dartmouth to Hume is 10,000ML/day. It is also noted that during a flood, flows in the Mitta Mitta River may be greater than 10,000ML/day. It was not considered feasible to design the outlet to pass either the maximum transfer between Dartmouth and Hume or these 'run of river' flood flows as the outlet would need to be of considerable size to pass 10,000ML/d. As such it was judged that a smaller outlet would be suitable noting that once the storage is full inflows would be passed via the spillway increasing the overall discharge capacity of the structure.

   The durability of the outlet is an aspect that would be considered in the design, noting that the outlet would be submerged for all but infrequent periods.

5. Road Access

   As the structure is to be designed to be overtopped, road access across the weir would require construction of a bridge/culvert. The criteria proposed by TSC comprises two lane two way access, with access available when Hume Dam is at FSL. As such it is expected that the bridge would also need to pass flood flows, as for any similar TSC road bridge in the Shire.

6. Construction

   Sequence of construction was considered in terms of the requirement for passing of flows during construction and the timing of construction in general, with factors such as drawing down of Lake Hume (if possible) and construction in water considered.

7. Operation of the Narrows (impact on Lake Hume)

   The structure would be designed to that ensure that if required The Narrows could be dewatered and the storage drained. Dewatering of the storage would be undertaken via the outlet. However, it should be noted that the ability to dewater the storage is a function of the inflows and as discussed previously it is not considered feasible to design the outlet to pass either the maximum transfer between Dartmouth and Hume or 'run of river' flood flows.

   It is understood that for inflows into Lake Hume up to 600,000ML/day (in the order of a 1 in 60,000 year event) the storage level of Lake Hume is held around FSL by the spillway gate operation.

8. Recreational Use

   It is understood that the ski-able water level at Tallangatta is RL184.1mAHD (Lake Hume storage volume equal to 55%) and that this level is 1m above the bottom of the Tallangatta boat ramp.

   It is not proposed to incorporate a lock for boat transfer across the structure. However it is noted that depending on the height of the structure boat transfer across the structure would be possible given that the crest level of the dam could be several metres below the FSL of Lake Hume.

9. Other aspects that would need to be considered at a later stage of the overall project include:

   - Siltation
   - Water quality
   - Erosion protection works i.e. due to flow and wave action

- Signals, signage and barriers for road closure, access to the dam generally, and boat navigation in the vicinity of The Narrows weir

4.3 Consequence Category

In establishing the functional design criteria for the Narrows project consideration was given to the likely Consequence Category for the dam should it fail. Consequence Categorisation assists the dam owner in selection of design and operation criteria appropriate to the dam. Such criteria could include design flood capacity, seismic stability criteria, operation and maintenance requirements and surveillance requirements.

An initial assessment of the consequence category of the weir was undertaken using ANCOLD, 2012, Guidelines on the Consequence Categories for Dams. As the weir is upstream of Hume Dam, and within the water body of Lake Hume, the severity of damage and loss resulting from a dam failure is likely to be minor to medium, essentially associated with damage to The Narrows structure itself. The dambreak would only involve water flowing into the existing Hume Lake, and the main loss will be the loss of the recreational facility created by the Narrows dam. With regard to population at risk (PAR), it is judged that the only people potentially at risk during a dam failure are either water users within the reservoir or those users immediately downstream of the dam at the time of failure. As such, a conservative assumption of PAR between 1 and 10 is considered reasonable. Based on this initial assessment the weir would be classified as a ‘Significant’ consequence category dam.

5 HYDROLOGY

5.1 General

The construction of a weir within the Mitta Mitta arm of Lake Hume has the potential to alter the existing hydrological conditions upstream of the location of the structure. In order to assess the feasibility, of the project the possible changes to existing hydrological conditions needed to be assessed. To this end the following hydrological modelling was undertaken:

- Evaporation Loss – Water loss in the storage due to evaporation.
- Flood Afflux – The impact of the weir on flooding upstream.

In addition, storage relationships for the new storage created by The Narrows Weir were calculated for use in the evaporation loss study and for information in general.

Assessments of evaporation loss within the storage and the flood afflux resulting from construction of the new weir were undertaken for a number of weir heights and comprised the following weir crest elevations:

- EL 184 (8m below Hume FSL)
- EL 186 (6m below Hume FSL)
- EL 188 (4m below Hume FSL)
- EL 190 (2m below Hume FSL)

For the purposes of the hydrological investigations, the weir embankment was assumed to be located at the most constricted river section of The Narrows as indicated on Appendix 5.1.

The following sections detail the methodology and results of the hydrological assessment undertaken.

5.2 Storage Relationships

Storage relationships, comprising Elevation-Storage (Volume) and Elevation-Area curves, were developed for The Narrows Storage utilising available survey information. The survey data was imported into the 12d software package and the topography of the storage modelled such that volumes and surface areas could be estimated.

The storage relationships for The Narrows are presented below in Figures 5.1 and 5.2. Based on these curves and the Storage-Elevation Curve for Lake Hume, a table presenting water depth, weir height and details on storage capacity for both Lake Hume and The Narrows, for each weir crest elevation is presented in Table 5.1.

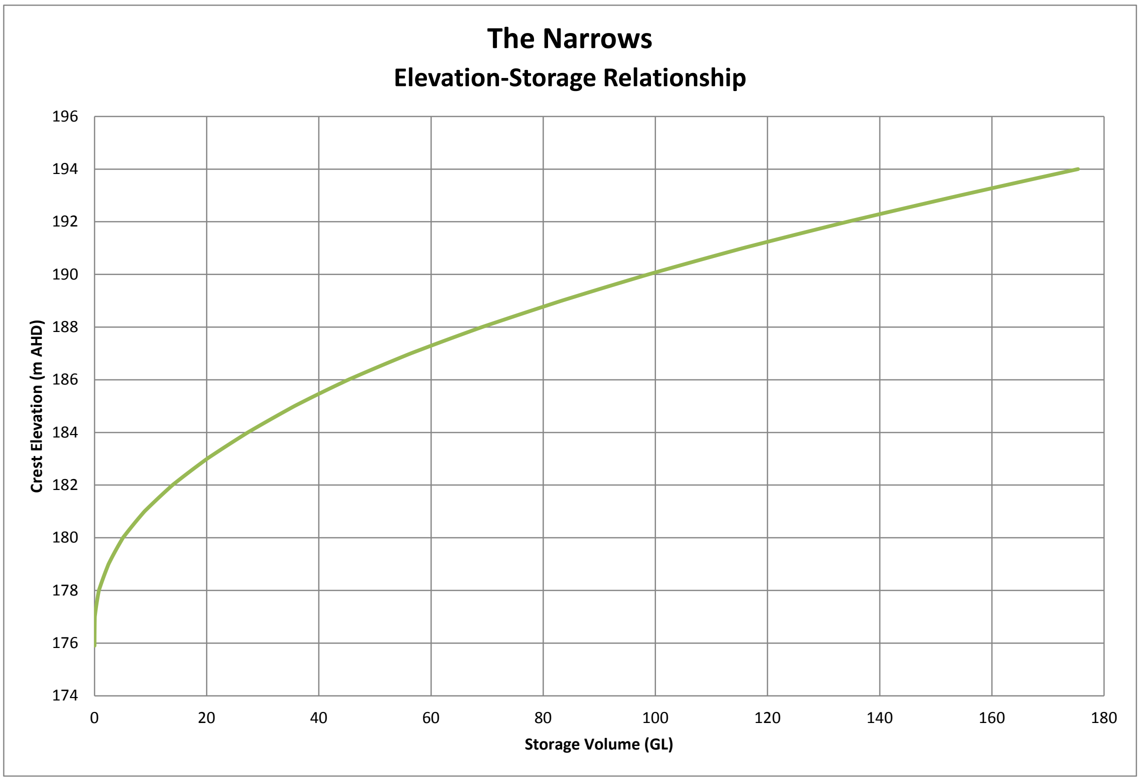

Figure 5.1: The Narrows – Elevation-Storage Volume

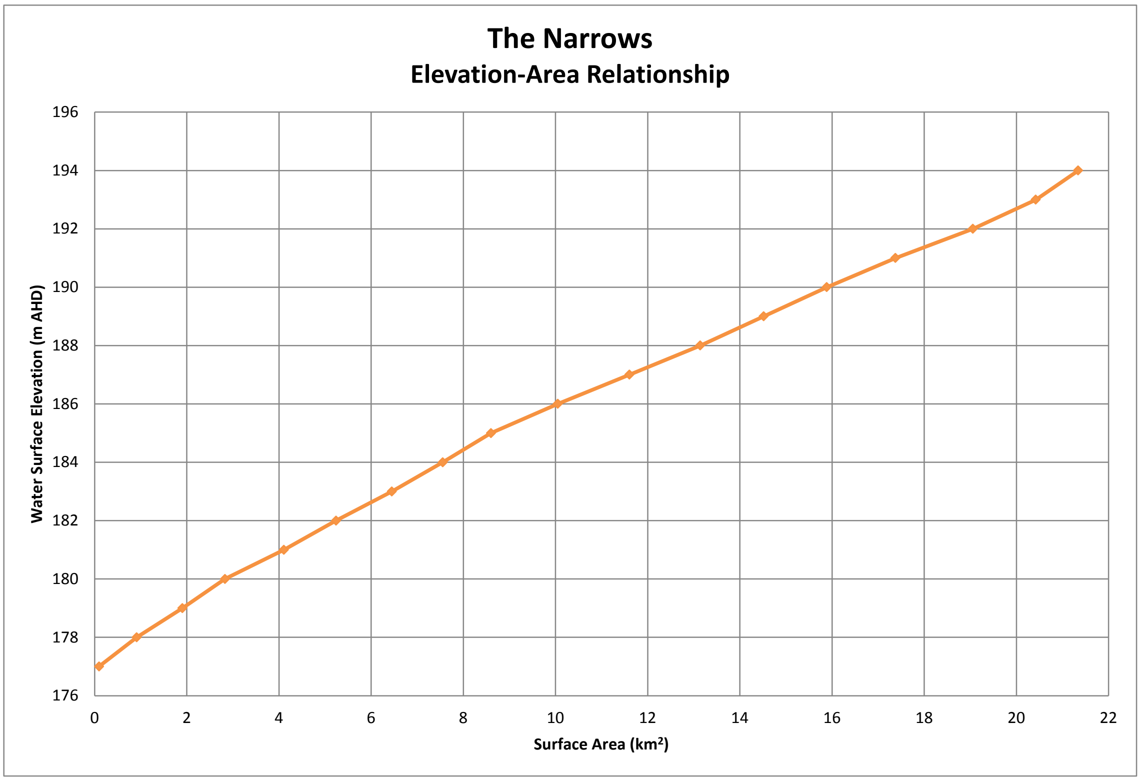

Figure 5.2: The Narrows – Elevation-Area Relationship

Table 5.1: Storage Relationships

Weir Crest Elevation	Depth below Hume FSL	Indicative Capacity of Lake Hume		Indicative Height of Weir	Capacity of The Narrows
(mAHD)	(m)	(GL)	(% FSL)	(m)	(GL)
EL184	8	1645	55	8	28
EL186	6	1940	65	10	45
EL188	4	2265	75	12	70
EL190	2	2620	87	14	100

(1) Assumed foundation level of EL176mAHD

5.3 Evaporation Loss Estimate

Evaporation loss is the volume of water within a storage that is lost due to evaporation and is a function of surface area and depth of water in storage. For the purposes of this study it has been assumed that water depths are sufficient such that depth does not materially impact on evaporation for the weir options modelled. As such the volume of evaporation loss from a water storage has been estimated based on the product of the surface area of the storage and the measured evaporation per unit area.

The construction of The Narrows Weir will create a new water storage in the Mitta Mitta arm of Lake Hume and will result in a higher water level in the arm for a longer period of time resulting in a greater surface area and hence greater evaporation loss, compared with historic water levels in the arm in late summer and autumn.

An increase in evaporation loss would only occur when the water level in Lake Hume drops below the crest elevation of the weir; this would be the point at which the weir begins to alter the surface area of Lake Hume. For the purposes of assessing the evaporation loss estimate, it was assumed that the water level within The Narrows Storage would be held at top water level with the water level in Lake Hume dropping independently of The Narrows Storage.

An estimate of the incremental evaporation loss that could be expected from The Narrows Storage was made utilising the daily evaporation data recorded by the 'Hume Reservoir Met Station'.

Average daily evaporation rates were calculated for each month and were multiplied by the number of days in the relevant month. The resulting average monthly evaporation rates are presented in Table 5.2.

Table 5.2: Average Monthly Evaporation for Lake Hume

Month Number	Month	Average Monthly Evaporation (mm)
1	January	245
2	February	195
3	March	160
4	April	90
5	May	45
6	June	30
7	July	35
8	August	50
9	September	75
10	October	120
11	November	170
12	December	215

Surface areas for The Narrows Storage for the various weir crest levels were obtained from the Elevation-Area chart presented in Figure 5.2. The surface areas were then used along with the average monthly evaporation rates given in Table 5.2 to determine the average monthly **total** volume losses due to evaporation for The Narrows storage. The results are presented in Figure 5.3. These **total** evaporation losses expressed as percentages of the storage volumes are presented in Figure 5.4.

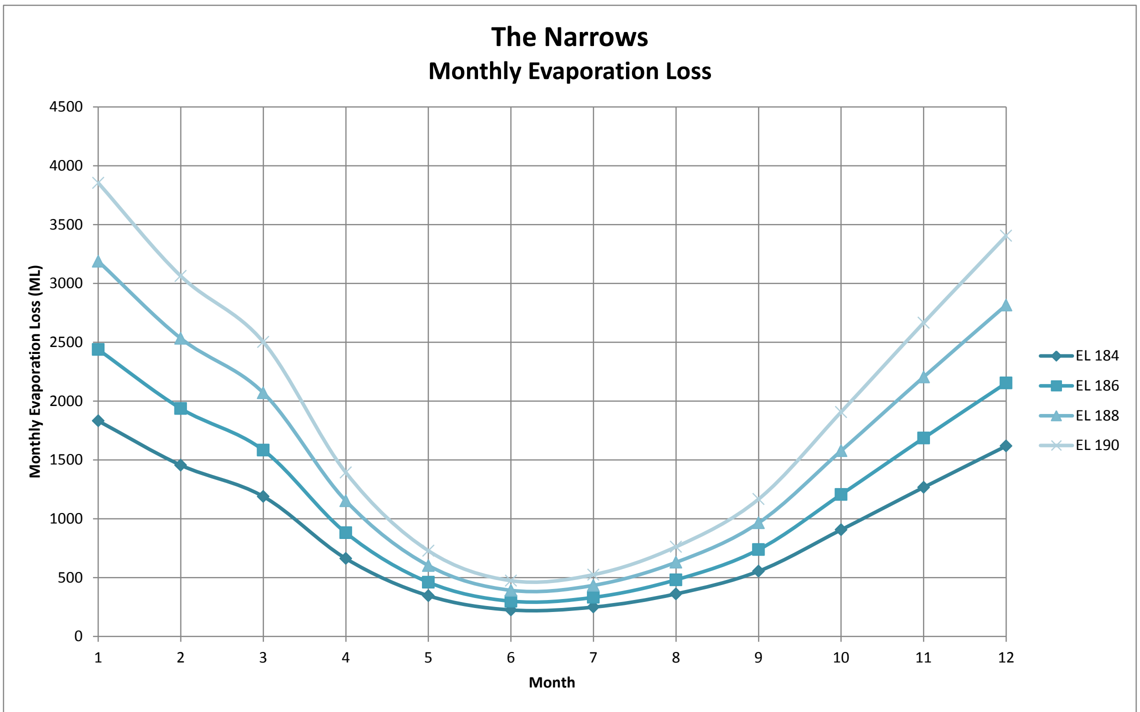

Figure 5.3: Evaporation Loss from The Narrows Storage

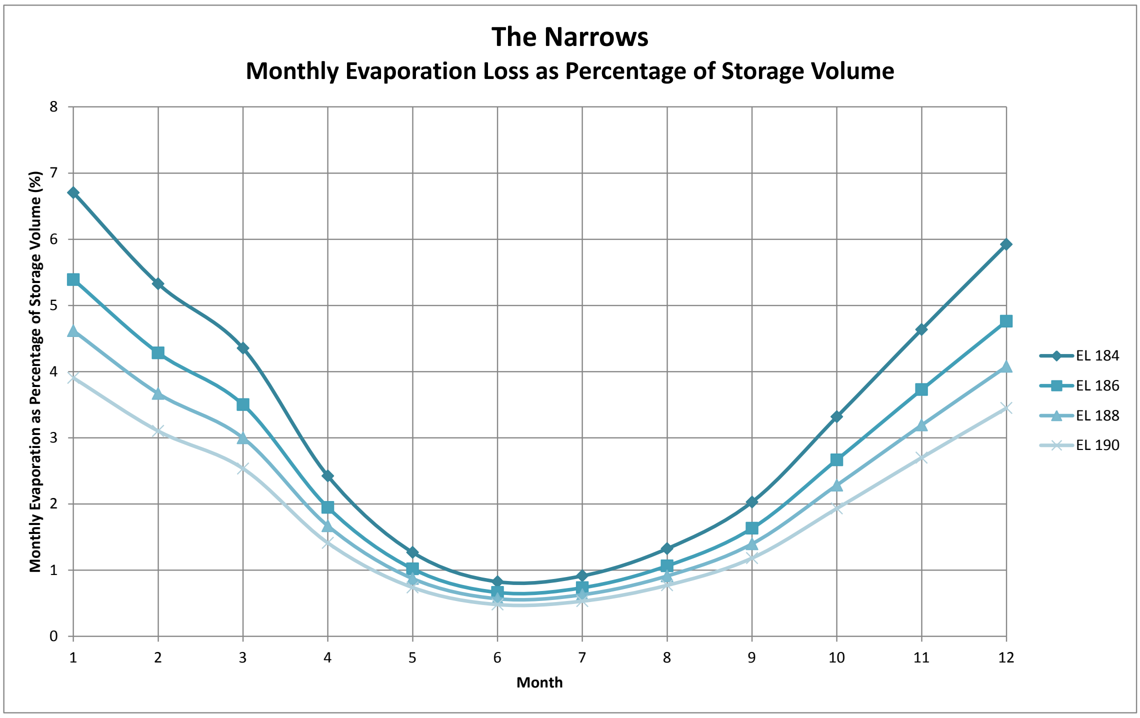

Figure 5.4: Percentage Evaporation Loss from The Narrows Storage

As seen in Figures 5.3 and 5.4 the **total** evaporation loss increases with weir crest elevation. Conversely, the percentage evaporation loss decreases with weir crest elevation.

However as discussed previously, an increase in evaporation loss will only occur when the water level in Lake Hume drops below the crest elevation of The Narrows weir. Figure 5.5 shows the percentage of time that the water level in Lake Hume has dropped below nominal weir elevation over the past 35 years (since the construction of Dartmouth Dam).

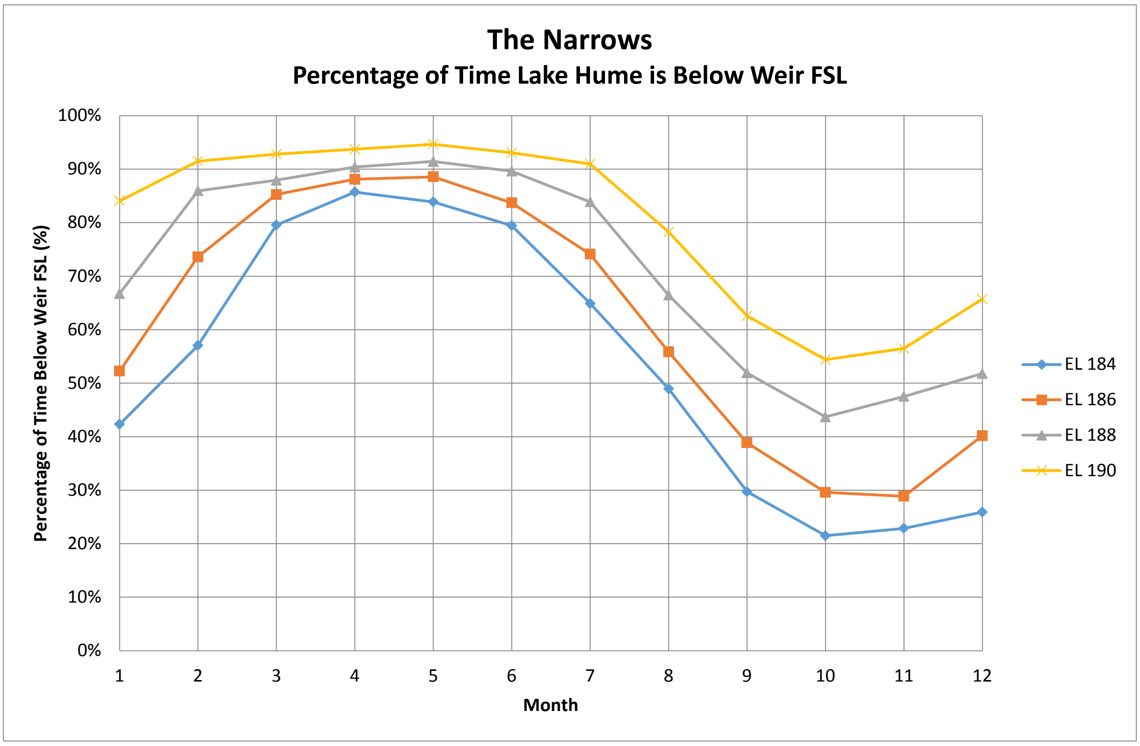

Figure 5.5: Percentage of Time the Water Level in Lake Hume is Below The Narrows Weir FSL

Figure 5.6 shows the estimated **incremental** increase in the volume of evaporation loss for each weir crest elevation based on the historic water levels in Lake Hume. It can be observed that the largest incremental increase in evaporation occurs over the months of November to April when the water level in Lake Hume are the lowest, The Narrows Weir is in operation (for a significant duration) and the differential water level between Lake Hume and The Narrows storage is the greatest.

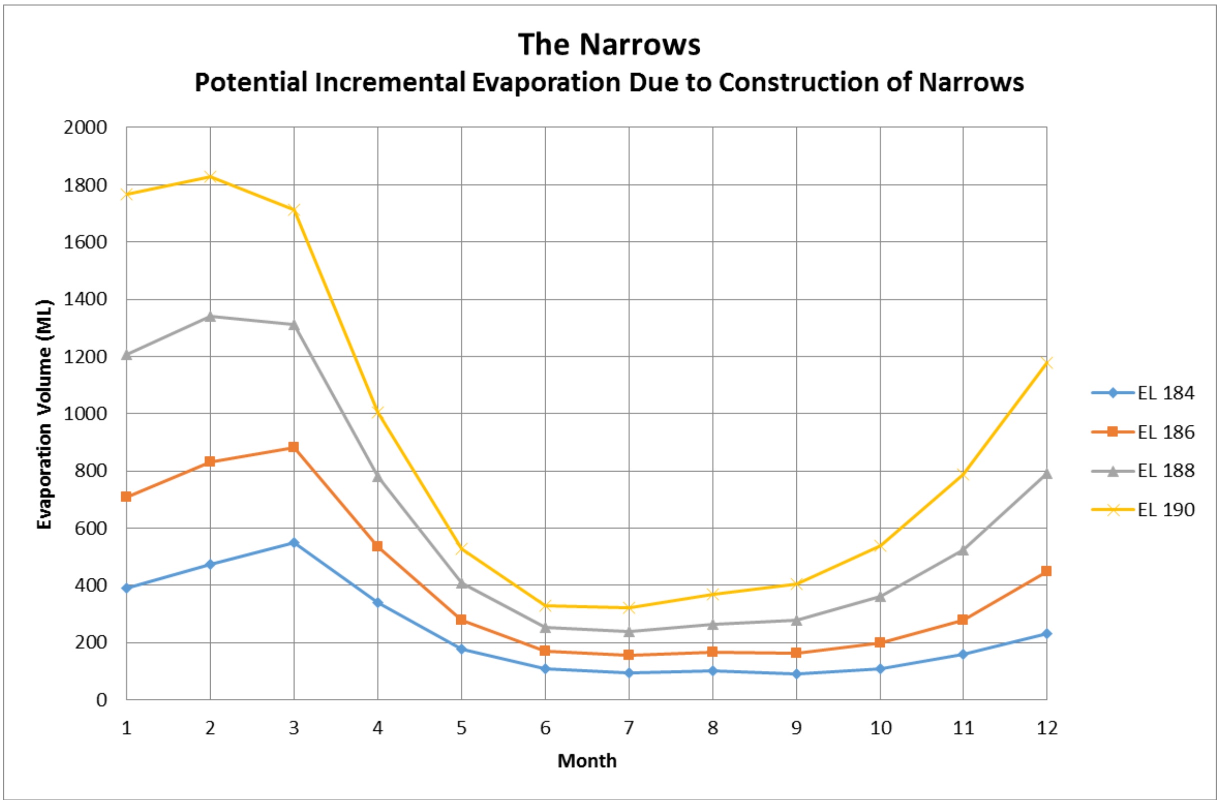

Figure 5.6: Potential Incremental Evaporation Due to Construction of The Narrows*

**Based on Historic Water levels for Lake Hume: Years in Data Set (1979 - 2015)*

The average total incremental evaporation summed over a 12 month period is detailed in Table 5.3 below.

Table 5.3: Volume of Annual Incremental Increase in Evaporation Loss for Different Weir Crest Levels

The Narrows Crest Level	Total Average Annual Incremental Evaporation	
(mAHD)	(ML)	(GL)
190	10800	10.8
188	7800	7.8
186	4800	4.8
184	2800	2.8

It should be noted that the amount of evaporation loss represents a volume of water 'lost' to the Murray-Darling system, hence has potential to impact on security of supply in the system.

5.4 Flood Afflux

5.4.1 General

The introduction of a weir at The Narrows has the potential to impact on the extent of flooding and inundation upstream of the new structure under moderate and potentially extreme flood flows in the Mitta Mitta catchment. In order to assess the potential upstream impact resulting from construction of the weir a hydraulic model was developed to estimate the incremental increase in flood depth above Hume Dam FSL, referred to as 'flood afflux'.

5.4.2 Model Setup

The Narrows hydraulic model encompasses sections of the Mitta Mitta River and Tallangatta Creek. The modelling was undertaken utilising the HEC-RAS (USACE HEC Version 4.1.0 January 2010) software program. This watercourse was divided further into three sections and denoted as follows:

- Lake Hume (section of the Mitta Mitta River downstream of the confluence with Tallangatta Creek)
- Mitta Mitta River (section of the Mitta Mitta River upstream of the confluence with Tallangatta Creek)
- Tallangatta Creek

A layout of the watercourse identifying these sections is presented in Appendix 5.1.

The HEC-RAS model requires a variety of inputs namely:

- water course geometry;
- hydraulic inputs; and
- boundary conditions.

A description of the input required and value of the parameter adopted are presented in Table 5.4.

Table 5.4: HEC-RAS model parameters

HEC-RAS Model Parameters	Value
Watercourse geometry	The lengths of the three river reaches in the watercourse are given below: ▪ Lake Hume – 13.3 km ▪ Mitta Mitta River – 6.6 km ▪ Tallangatta Creek – 7.1 km The weir is located 4.5 km upstream of the end of the Lake Hume river reach. Cross sections were generally placed at intervals of 500 m. The downstream cross section was placed at the confluence of the Mitta Mitta River and the Hume Reservoir. The layout of the watercourse and locations of cross sections are presented in Appendix 5.1.
Structure (Weir)	The Narrows Weir structure was modelled as a broad crested weir, with a 10 m wide crest and vertical upstream and downstream faces. A coefficient of discharge of 1.5 was adopted. A number of weir levels were modelled namely, with crest levels of EL184m, EL186m, EL188m and EL190m.
Manning's 'n' Roughness Coefficient	Manning's roughness coefficients (n) were adopted for the watercourse cross sections as follows: ▪ n = 0.035 – low flow channel and floodplain ▪ n = 0.04 – river banks
Downstream Boundary Condition	The downstream boundary of the model was set at a constant water level of EL192mAHD, the FSL of Hume Dam. It is understood that the Hume Dam spillway gates are operated such that the water level in Lake Hume is maintained at FSL up to a 1 in 60,000 AEP flood event. It is noted that a 1 in 60,000AEP event is approximately equal to an inflow to Hume Dam of 600,000 ML/day (total inflow from the Mitta Mitta, Murray and tributaries)
Upstream Boundary Conditions	Normal depth was adopted for the upstream boundary condition. In order to set this boundary condition the bed grade of the channel needed to be nominated. Based on the survey data average slopes (S) of the river reaches were adopted as follows: ▪ S = 0.001 Mitta Mitta River (1000H:1V) ▪ S = 0.002 Tallangatta Creek (500H:1V)

5.4.3 Model Inflows

A number of inflows to the proposed Narrows Storage were modelled. Based on the original data set a correlation between flow and return period was not able to be confirmed. As such a number of key flows were selected for modelling. These flows along with an explanation for the selection of the flows is presented in Table 5.5.

Table 5.5: Flows Modelled Down the Mitta Mitta River

Mitta Mitta River Flow (ML/day)	Explanation
10,000	The normal maximum transfer rate from Dartmouth Dam to Lake Hume
30,000	The flood of record on the Mitta Mitta River (since the construction of Dartmouth Dam)
100,000	The flood of record on the Mitta Mitta River (since the construction of Hume Dam) recorded at the Tallandoon river gauging station on the Mitta Mitta River
300,000	A flow equivalent to half the inflow to Lake Hume for the 1 in 60,000AEP event. As noted previously for events up to 1 in 60,000AEP the water level in Lake Hume is controlled by the spillway gates with FSL in the Lake maintained.

Historical streamflow records indicate that the flows down Tallangatta Creek are approximately equal to 5% of the flows down the Mitta Mitta River. As such the flows modelled down the Tallangatta Creek were taken to be equal to 5% of the flows down the Mitta Mitta River.

5.5 Results and Discussion

The HEC-RAS model was first run for the ‘no weir’ condition to assess the case for water levels in the watercourse based on the existing conditions. Subsequently modelling was undertaken for the various weir elevations being investigated. Flood affluxes were assessed based on the difference in water levels when compared to the existing conditions outputs.

Results from the HEC-RAS model are presented in Table 5.6.

Table 5.6: HEC-RAS Afflux Model Results (Incremental Depth of Water above the No-Weir Water Depth)

Model Location (River/Station)	Description	Weir EL 184mAHD	Weir EL 186mAHD	Weir EL 188mAHD	Weir EL 190mAHD
		10,000 ML/day Afflux (mm)			
All cross sections	n/a	0	0	0	0
		30,000 ML/day Afflux (mm)			
All cross sections	n/a	0	0	0	0
		100,000 ML/day Afflux (mm)			
Lake Hume/4500	At The Narrows	5	5	5	15
Lake Hume/8000	At Tallangatta	5	5	5	15
Lake Hume/13000	Downstream of River Junction	5	5	5	15
Mitta Mitta/14200	At Murray Valley Hwy Bridge	5	5	5	15
Mitta Mitta/15000	At Tallangatta East	5	5	5	15
Mitta Mitta/17500	At Spring Valley Rd Junction	5	5	5	14
Tallangatta/2462.13	At Old Tallangatta	5	5	5	15
Tallangatta/3987.13	South of George’s Creek	5	5	5	15
		300,000 ML/day Afflux (mm)			
Lake Hume/4500	At The Narrows	7	7	33	343
Lake Hume/8000	At Tallangatta	7	7	33	342
Lake Hume/13000	Downstream of River Junction	7	7	33	335
Mitta Mitta/14200	At Murray Valley Hwy Bridge	8	8	33	342
Mitta Mitta/15000	At Tallangatta East	7	7	30	313
Mitta Mitta/17500	At Spring Valley Rd Junction	5	5	24	254
Tallangatta/2462.13	At Old Tallangatta	7	7	34	345
Tallangatta/3987.13	South of George’s Creek	6	6	27	292

As detailed in Table 5.4, the downstream boundary condition for all models was set at the FSL of Hume Dam. This assumption relies on the premise that inflow equals outflow at the cross section at the downstream end of the model. This assumption is valid for all modelled inflows, however as inflow increases, the influence of the downstream boundary condition on the upstream water levels decreases. In essence, the watercourse itself begins to exhibit a backwater effect on the weir. This backwater effect indicates that the model is no longer controlled by the downstream boundary condition, with the inflows instead dictating the behaviour of the model. It is under this second scenario, with the upstream boundary condition controlling, that afflux occurs.

It can be seen from Table 5.6 that there was no afflux for the various weir elevations for the smaller flows of 10,000ML/day and 30,000ML/day. This result was due to the downstream condition controlling the water level far enough upstream for there to be no afflux.

The ‘no weir’ results for the larger floods of 100,000 ML/day and 300,000 ML/day showed water levels that were increasingly exhibiting backwater effects as the flows increased. Hence afflux occurs naturally, even without the weir.

The results for the 100,000 ML/day and 300,000 ML/day flows indicated affluxes for all weir elevations.

In summary the range of affluxes for each weir level for the flows modelled are presented in Table 5.7.

Table 5.7: Summary of Afflux Investigation.

Weir Elevation (mAHD)	Flood Afflux
184	0 to 10mm
186	0 to 10mm
188	0 to 35mm
190	0 to 345mm

Following the afflux investigation, SMEC received two flood frequency curves, namely:

- Inflow and outflow frequency curves for Dartmouth Dam; and
- Inflow frequency curve for Hume Dam.

A copy of these charts is presented in Appendix 5.2. The data was provided to assist in determining a relationship between the flows modelled and return period. However neither chart provided sufficient data for a rigorous relationship to be developed. The flood frequency curve for Dartmouth Dam was not used to correlate the modelled inflows for The Narrows to return period as the flow increase/decrease between Dartmouth Dam and The Narrows was not consistent. In some cases based on the flood gauge data there was a reduction in flows between Dartmouth Dam and The Narrows. It was therefore considered appropriate to utilise the inflow flood frequency curve for Hume Dam to estimate likely return periods for inflows to The Narrows. However, noting that the inflows to Hume Dam included flows from both the Mitta Mitta River and Murray River catchments, it was necessary to ascertain the percentage of flow that the Mitta Mitta tributaries contribute to the Hume Dam inflows. In order to estimate the percentage of flow the gauge flow data (post construction of Dartmouth Dam) in the Mitta Mitta River and Murray River was combined to give an estimate of the total inflows to Lake Hume. Utilising this data it was assessed that the Mitta Mitta River contributes on average 25% of the flow into Lake Hume. At high flows, the Mitta Mitta River's contribution decreases to 20%. However for the flood of record in the Mitta Mitta River it was assessed that the contribution from the Mitta Mitta River alone rose to 43%. In general terms it is judged that on average the Mitta Mitta River contributes between 25% and 45% of the inflows to Hume Dam during a regional storm event.

In generating an inflow flood frequency curve for The Narrows the peak storm event for Hume Dam was selected as it provides the most conservative estimate. As such for flows less than a 1 in 10,000AEP event the 72 hour storm was adopted. For flow greater than a 1 in 10,000AEP event the 24 hour storm was adopted. The peak inflows into the Mitta Mitta Arm were then calculated by multiplying the peak inflows from the Hume Dam flood frequency curve by the contribution percentage. Figure 5.7 presents an estimated flood frequency curve for The Narrows for a range of percentage contributions.

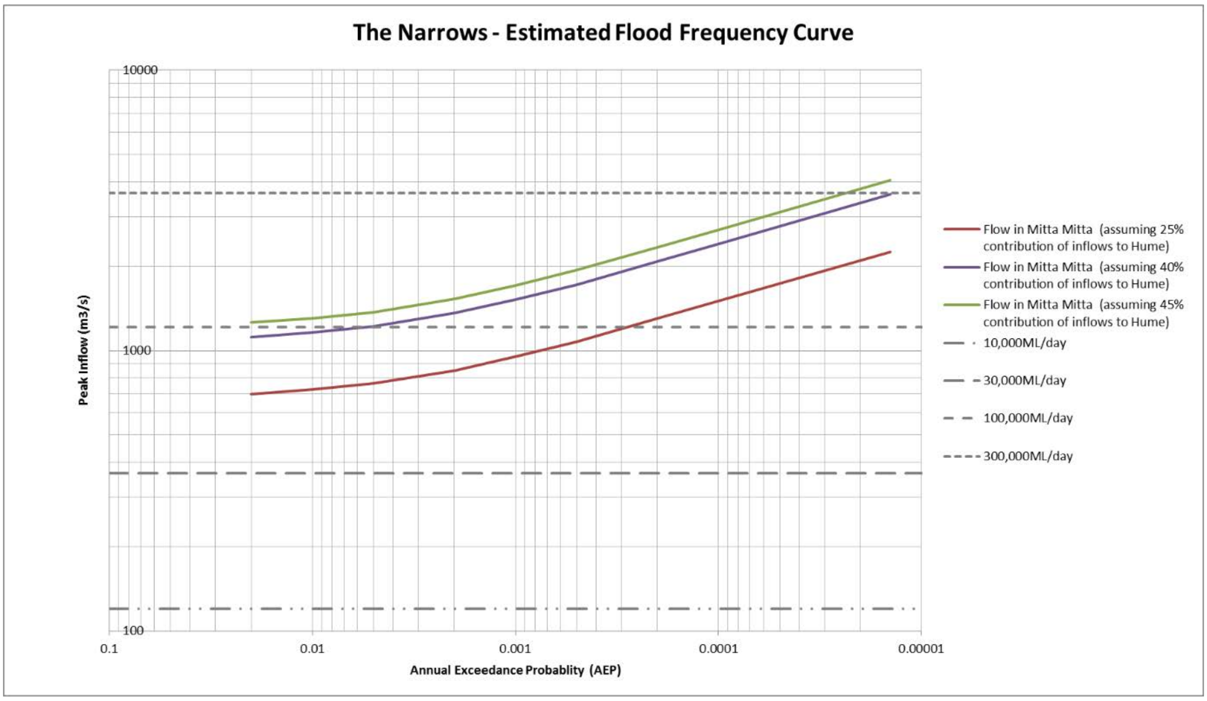

Figure 5.7: Estimated Flood Frequency Curves for The Narrows

It should also be noted that the inflows into Lake Hume do not exclusively comprise the Murray Arm and Mitta Mitta Arm inflows, as surface flows would also enter Lake Hume directly. Therefore the Mitta Mitta flows calculated from the flood frequency curve are likely to be conservative.

An estimate of approximate return period for the modelled flows based on The Narrows inflow flood frequency curve is presented in Table 5.8.

Table 5.8: Correlation of Modelled Flows to AEP Events and Corresponding Maximum Afflux

Mitta Mitta River Flow (ML/day)	Total Flow Modelled(1) (m^3/s)	Approximate Return Period (1 in AEP)	Afflux(2) (mm)
10,000	120	< 1 in 10	0
30,000	365	< 1 in 10 to 1 in 50	0
100,000	1,215	1 in 50 to 1 in 4000	5 – 15
300,000	3,650	> 1 in 10,000	5 – 345

(1) Mitta Mitta River + Tallangatta Creek Flows

(2) All weir heights

Overall it can be concluded from the results presented in Tables 5.8 and Table 5.9 that significant affluxes are not experienced for events less than a 1 in 10,000AEP flood event, with results indicating a maximum modelled afflux of 345mm for a weir crest level set at EL190mAHD. Should the weir height be set 2m lower at EL188mAHD the afflux would be less than 50mm.

Again, based on the estimated flood frequency curve for The Narrows, the results of the model predict that for the 1 in 100AEP flood event, the maximum afflux for all weir levels modelled is 15mm.

6 GEOLOGY

6.1 General

A geological review of the proposed site for the Narrows was undertaken to allow for a preliminary geological model to be developed. The review was undertaken utilising the following available information:

- Regional geological maps and associated explanatory notes
- Test pit investigations undertaken as part of Woodward-Clyde (1995) study
- Bore construction details and logs obtained from Department of Environment and Primary Industries (DEPI) Victoria investigations undertaken in vicinity of the site

6.2 Regional Geology

6.2.1 General

The Narrows is a slender section of the Mitta Mitta arm immediately upstream of Lake Hume, approximately 3km west of the town of Tallangatta. When the water level in Lake Hume is low, the site of The Narrows reveals the old Mitta Mitta River and floodplain. The Narrows extends approximately 4km in length and the river flats are on average approximately 500m wide.

6.2.2 Geological Setting

A number of Geological Survey of Victoria Maps were referenced in order to gain an appreciation for the geological setting. These included:

- Geological Survey of Victoria (1979), Hume: First Edition, 8325-IV Zone 55, Scale 1:50,000.
- Geological Survey of Victoria (1976), Tallangatta: First Edition, Sheet SJ 55-3, Scale 1:250,000.
- Geological Survey of Victoria (1997), Tallangatta: Second Edition, Sheet SJ 55-3, 1:250,000 Geological Map Series.

A copy of these Geological Maps along with the associated explanatory notes are attached in Appendix 6.1.

With reference to Tallangatta (1976) the river banks have been formed in alluvial flats described as clay, sand, sandy clay and gravel with swamp deposits of grey-black clay. These alluvial flats are reported as being of Recent Quaternary age and part of the Coonambidgal Formation. This material is likely underlain by gneiss described as 'gneissic pegmatite, minor schist'. The gneiss is documented as being of Upper Ordovician age. Reference to Tallangatta (1997) indicates that the river banks have a fluvial, lacustrine geology which is described as 'clay, sand and sandy clay' and part of the Coonambidgal Formation. The material is documented as being of Mostly Holocene- Quaternary age. The surrounding hills are shown to comprise gneiss of Lower Ordovician age and assigned as part of the Omeo Metamorphic Complex. The geology within Lake Hume itself is not specified however it is likely that the alluvial materials along the river banks extend into the river channel and overlies the metamorphic rocks at depth. The two maps indicate similar geology, although the Second Edition map is not as descriptive as its predecessor.

The Hume (1979) map is at a larger scale of 1:50,000 compared to the Tallangatta maps and provides more detail on the geology in the area surrounding Lake Hume. This map indicates that the site is likely underlain, at depth, by Rubyview Gneiss described as 'grey, fine to coarse-grained gneiss, banded or massive, poorly foliated, granitic in composition'. The Rubyview Gneiss is of Lower Ordovician to Silurian age and is shown on the map as abutting the Mitta Mitta arm of Lake Hume. The geology within the lake itself is not specifically documented. Along the banks of the river, the map indicates that there are deposits of colluvium described as 'hillwash and scree deposits, red to yellow silt, sand and gravel poorly sorted, red-brown soil'. The colluvium is of Pleistocene to Recent Quaternary age. The Shepparton Formation alluvials are documented along the creeks that flow into the Mitta Mitta arm of Lake Hume, including First Bay Creek, Washaway Creek and Jarvis Creek. These creeks are close to the site of The Narrows and the alluvial deposits are described as 'buff to yellow-brown clay, silt, sand and gravel, soil grey-buff to red-brown'. Given these Shepparton Formation alluvial deposits exist in the creeks it is likely that this same material is deposited in the Mitta Mitta River.

According to the explanatory notes on the Hume (1979) map (O'Shea, 1976), the area surrounding Lake Hume contains Ordovician gneisses and schists that are intruded by granites and overlain by Tertiary and Quaternary alluvium in the river valleys. The map area represents the northernmost part of the north-eastern metamorphic belt of Victoria. The major fault in the Lake Hume area shown on the geological map of Hume is the north-east trending Talgarno Fault that runs from Sandy Inlet in the south to the Murray River in the north. The broader view of the area indicates that regional faults tend to strike either northwest-southeast or southwest-northeast. Such a trend of smaller structures, such as foliation or local shears may occur throughout the metamorphic rocks. Other faults exist within Lake Hume and to the south of the Mitta Mitta arm of Lake Hume. Tallangatta (1976) indicates an inferred fault near the western end of the arm, trending southwest to northeast. It appears to follow the general direction of First Bay Creek but is shown to terminate in the upper reaches some 3-4 km from the reservoir shoreline at the Narrows. No other faults are documented within the Mitta Mitta arm itself. In general, the faults in the Hume area are likely to be quartz-filled and are generally aligned with creeks.

Based on the information gained from the Geological Survey of Victoria maps, the site of the proposed weir at The Narrows is likely to be founded on alluvium in the river channel and colluvium at the abutments. The adjacent hills are documented as comprising gneiss and it is likely that the alluvium and colluvium in the Mitta Mitta arm of Lake Hume is underlain by the same gneiss at depth. The geological maps also indicate that the immediate site does not intersect any known faults.

6.2.3 Hydrogeology

The site of The Narrows is located within the Upper Murray Catchment. GMW (2014) indicates that the groundwater resources in the catchment occur within two aquifer types. These include:

- Basement Bedrock (Highlands)
- Alluvial Aquifer (Sedimentary Plains)

The alluvial aquifers are located within the Coonambidgal Formation that is associated with the Murray and Mitta Mitta Rivers. The aquifers consist of gravel, sand and silt sediments that were deposited along the valley by the ancestral Murray and Mitta Mitta Rivers. The alluvial aquifer is typically 20m to 50m thick along the flood plain of the river and can produce bore yields of 5-10 L/sec due to the permeable, unconsolidated material that comprise the aquifer.

The sequence of groundwater flow within an alluvial aquifer is detailed in a Figure 6.1 below, sourced from GMW (2014).

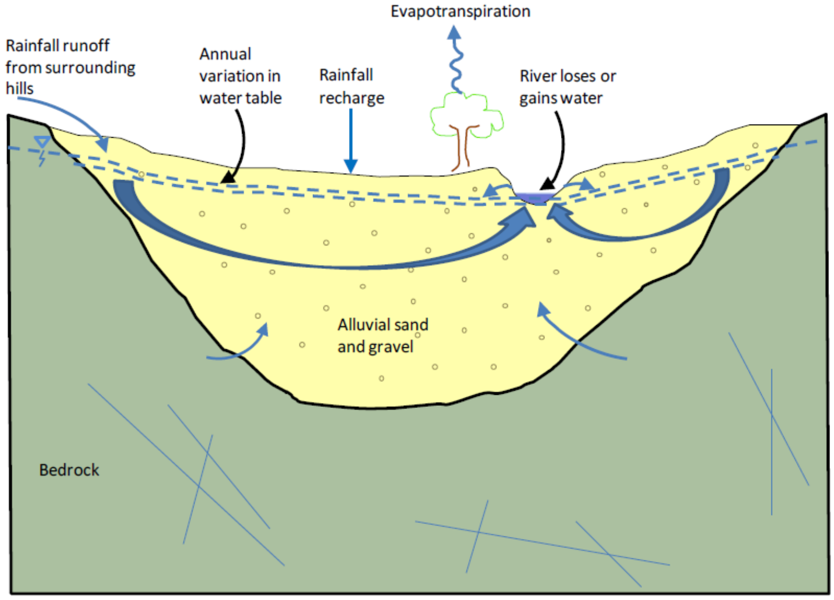

Figure 6.1: Groundwater Flow through an Alluvial Aquifer (Figure 6, GMW 2014).

6.3 Past Investigations

6.3.1 General

The extent of subsurface investigations undertaken in the vicinity of The Narrows site has been limited to the following:

- Drilling of 4 boreholes in 1992 and 1 borehole in 1995
- Excavation of 3 test pits and laboratory testing in 1995

The locations of these field investigations are presented in Appendix 6.2.

6.3.2 Drilling Investigations

It is understood that these drilling investigations were undertaken by Hydrotechnology (Rural Water Corporation) in relation to the assessment of groundwater reserves in the Tallangatta region. The results of these investigations are documented in reports entitled 'Tallangatta Township Water Supply Investigation of a Groundwater Source, Part 1', dated 1993 and 1995. These Hydrotechnology reports were not available for this review however bore construction details and logs were able to be sourced from the Water Measurement Information System operated by DEPI Victoria (now known as the Department of Environment, Land, Water and Planning). A copy of the raw data is attached in Appendix 6.3.

Overall, five boreholes were drilled, four (4) boreholes from 7th May to 4th June 1992 and a further (1) borehole on 17th June 1995. These boreholes were drilled upstream of The Narrows across the width of the floodplain. Information on the locations, elevations, depths and drilling techniques of the boreholes are documented in Table 6.1.

Table 6.1: Summary of Drilling Investigations

Location ID	Easting	Northing	Elevation (mAHD)	Depth (m)	Method of Investigation	Year of Investigation
111316	517445.4	5992768.3	188.53	11	Cable Tool	1992
111317	517475.4	5993036.3	181.37	44	Cable Tool	1992
112526	517509.4	5993213.3	185.18	31	Cable Tool	1992
112527	517395.4	5992976.3	182.8	40	Cable Tool	1992
125933	517490.4	5993032.3	181.4	41.5	Cable Tool	1995

The results of the borehole drilling generally indicate that the site comprises a mixture of silt with variable degrees of sand and clay near the surface, followed by gravels with variable amounts of sand and/or ligneous sand with seams of silt and ligneous silty clay. Depth to bedrock at the centre of the river channel appears to be approximately 40m, reducing in depth closer to the abutments.

An interpreted geological profile across the floodplain is presented in Appendix 6.4.

It can be seen from the profile that the reported ground elevations of the boreholes do not match the LiDAR survey of the area; in some cases there is a difference of several metres. According to information obtained from the Water Measurement Information System, the borehole ground elevations were surveyed in November 2011. The LiDAR survey was reportedly taken in 2007. The reason for the discrepancy in elevations has not been established. However for this level of study the discrepancy is not critical.

6.3.3 Testpit Investigations

6.3.3.1 General

Testpit investigations were completed as part of the 'Narrows Project – Pre Feasibility Study' undertaken by Woodward-Clyde. The investigations comprised excavation of three (3) test pits, test pit scrapings and laboratory testing. In addition, a 2-dimensional hydrogeological model was developed to investigate the potential for leakage beneath the proposed embankment.

6.3.3.2 Fieldwork

The tests pits were excavated over two days between the 31st May and 1st June 1995. At the time of the fieldwork, the water level in Lake Hume was approximately EL177 – 178mAHD.

The test pits were excavated at the proposed site of The Narrows embankment. The locations of these test pits investigations are presented in Appendix 6.2.

The test pits were logged by engineers from Woodward-Clyde. A copy of these logs are presented in Appendix 6.5. A summary the investigations is presented in Table 6.2

Table 6.2: Summary of Test Pit Investigation

Test Pit ID	Depth (m)	Material Encountered	Groundwater Inflow	Samples Taken	Method of Investigation
TP1	0 – 0.6m 0.6m – 3m	Sandy SILT Silty CLAY	At 3.0 m, rising slowly	-	Backhoe
TP2	0 – 0.03m 0.03 – 1.0m 1.0 – 2.0m 2 – 2.1m	SILT Sandy SILT SILT Silty SAND	At 1.6 m, rising slowly	0.05-0.2 m	Backhoe
TP3	0 – 2.4m 2.4 – 2.5m	SAND SILT	At 1.5 m, rising slowly	-	Backhoe

The test pits revealed a non-continuous sequence of silts with varying amounts of sand as well as silty clays and sand. TP3 towards the centre of the valley encountered 2.4 m of sand, indicating likely alluvial channels sediments. It was noted that both test pits near the middle of the river flats (TP2 and TP3) were terminated due 'cave in' likely due to groundwater inflow at depths of 1.5-2 m. The test pit near the right abutment, TP1, remained stable to a depth of 3m after which the test pit was terminated due to the limited reach of the backhoe.

A number of test pits (scrapings) were also excavated on the right abutment in the vicinity of the proposed embankment to ascertain the likely conditions at the abutment/embankment interface. It is understood that excavation was not undertaken on the left abutment due to access constraints. Two lines of test pits were excavated to effective refusal at an area of exposed bedrock up to the Hume FSL. Effective refusal was recorded between approximately 0.25 to 1m depths at slope distances of approximately 0 to 30m respectively below the estimated Hume FSL contour. The residual soil overlying the bedrock was observed to contain several less weathered rock fragments that increased in frequency with depth. The depth to effective refusal varied between the test pits and in some cases within the test pit. Effective refusal was encountered as a gradual change in material properties that increasingly hindered excavation, rather than as a discreet change in properties.

6.3.3.3 Laboratory Testing

One representative sample was taken during the fieldwork for geotechnical laboratory testing of dispersion characteristics. The Emerson test was carried in accordance with AS1289.C8.1-1980.

The sample selected for testing was taken from TP2 logged as a sandy silt. The test pit log indicates that the sample material was moist, with low plasticity, dark brown and with fine-grained dark brown sand. Reportedly, the purpose of the Emerson test was to 'determine the potential dispersiveness of the upper alluvial material once subject to inundation after dam construction'.

The results of the laboratory test classified the sample as Emerson Class 7 – 'the air-dried crumbs of soil shall remain coherent in water and shall swell'. The result indicated that the sample of sandy silt was not dispersive. In addition Woodward-Clyde concluded that it is unlikely that suspended soils that affect water colour and turbidity would be generated by the immersion of these surface soils.

6.3.3.4 Hydrogeological Model

A 2-dimensional hydrogeological numerical model of the proposed embankment was prepared by Woodward-Clyde to assess the potential for leakage beneath the dam.

Input sources for the model included existing topographic information, the conceptual design cross section, lithological and hydrogeological information from Hydrotechnology investigations, in addition to estimated or assumed parameters.

The embankment was modelled as being founded on a layer of silt which is underlain by sands and gravels and finally bedrock. A depth to bedrock of 40m was adopted. A constant flow was modelled as entering the sand/gravel aquifer. The hydraulic conductivity of the sand/gravel aquifer was specified on the results of the testing undertaken by Hydrotechnology as part of the assessment of groundwater reserves in the Tallangatta region.

The initial modelling indicated significant leakage through the sand/gravel aquifer due to its considerable thickness in the paleo valley. Subsequently a second embankment was modelled that included a partially penetrating cutoff wall aimed at decreasing the leakage beneath the embankment. The results of this modelling under steady state conditions indicated the following:

- Seepage in the order of $0.2m^3$/day (per metre width of embankment) would occur from the new reservoir through the silt layer and into the sand/gravel aquifer.
- A partially penetrating cutoff wall would reduce the amount of leakage by less than 1%.
- There would be no significant reduction in leakage unless the cutoff wall is fully penetrating (i.e. keyed into the bedrock).
- The total depth of sand/gravel in the model would be unlikely to influence the leakage from the impounded water body.

6.4 Interpretation of Subsurface Conditions

The soil profiles encountered during the previous geotechnical investigations are generally consistent with the published geological information for the area.

Although the borehole investigations were undertaken approximately 4km upstream of the site of The Narrows, it is judged to be representative of materials likely to be encountered at The Narrows site. The regional geology identifies that the bed of the Mitta Mitta arm of Lake Hume comprises alluvial materials underlain by the bedrock into which the ancestral Mitta Mitta River was cut. This was supported by the results of the drilling investigations. Furthermore, the materials encountered in the test pits are consistent with the materials logged during the drilling investigations.

In general, the subsurface conditions at the weir site are likely to comprise an upper layer of silt, with variable amounts of sand and/or clay to a depth of approximately 3-5m. This layer is likely to be underlain by gravel and sand mixtures, with some intermittent seams of silty clay, down to bedrock. The materials overlaying the bedrock are likely to be Shepparton Formation alluvials. The depth to bedrock is judged to be in the order of 40m near the centre of the river channel, decreasing closer to the abutments to meet the exposed rock at the hillsides. The regional geology indicates that the bedrock is gneiss of Upper Ordovician age and is described as gneiss with a ‘granitic composition’.

The geological profile of the river channel as attached in Appendix 6.4 is consistent with the description of the alluvial aquifer systems that are common in the Upper Murray Catchment, as reported in GMW (2014) and shown in Figure 6.1. The groundwater inflows experienced during the test pit investigations further support the existence of an alluvial aquifer in the Mitta Mitta valley.

7 ENVIRONMENTAL AND CULTURAL ANALYSIS

7.1 General

This section of the report sets out the legislation and approvals that may be applicable to the project and informs the need for specialist investigations that would be required. The town planning approvals for the various project components have been reviewed, as well as a desktop review to identify areas of Aboriginal Cultural Heritage Sensitivity and Heritage Overlays, and the associated requirements.

7.2 Relevant Legislation

The legislation and associated approvals that may apply to the project are summarised in Table 7.1. The specific approvals and their requirements would be informed by specialist investigations required for the project. The various project components that have been considered include:

- Development of a dam across The Narrows;
- A new road to access the dam to the south of The Narrows (although not across the dam);
- Drilling investigations (locations yet to be determined); and
- Disposal of excess material in the dam or elsewhere in the study area (locations yet to be determined).

A map of the indicative project components are shown in Figure 7.1.

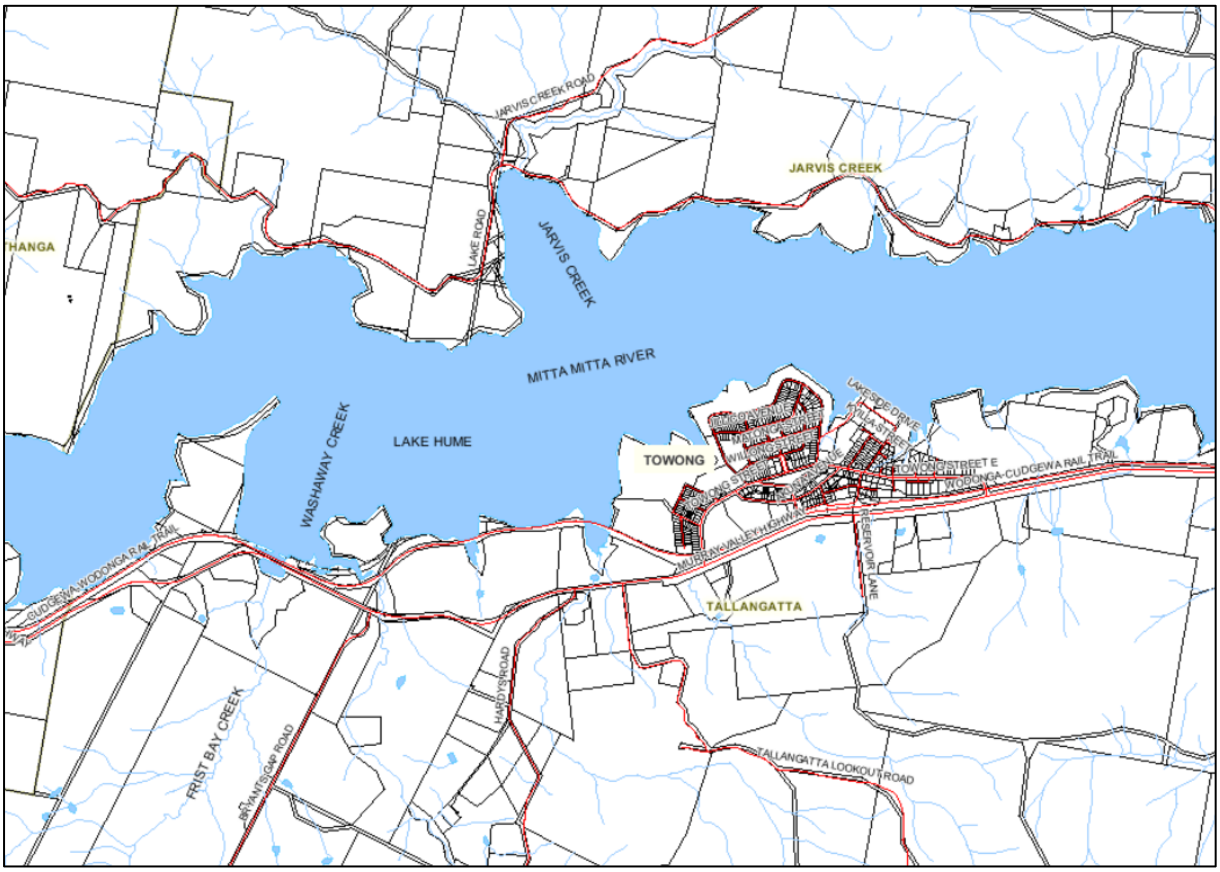

Figure 7.1: Project Area

Source: Department of Environment, Land, Water and Planning
http://services.land.vic.gov.au/maps/pmo.jsp

Table 7.1: Legislation and Associated Approvals

Act	Approval Agency	Statutory Approval (if required)	Requirement/Trigger	Reviews/Assessments Required
Land Use and Development				
Planning and Environment Act 1987 (Towong Planning Scheme)	Towong Shire Council	Planning permit Planning scheme amendment	Permit triggers are outlined in Section **7.3.2** of this report. Determine whether a Public Acquisition Overlay will need to implemented for the purposes of the access road through a planning scheme amendment, in addition a number of planning approval exemptions could be sought by amending the schedules (further investigation would be required for this)	Planning assessment report to support planning permit application Flora and fauna assessment, including any offset requirements in accordance with Permitted clearing of native vegetation – Biodiversity assessment guidelines Traffic Impact Assessment and Traffic Management Plan Historic Heritage Assessment Cultural Heritage Assessment Cultural Heritage Management Plan Environmental Management Plan Dam Operations Aquatic and Waterway Assessment
Native Title Act 1993	Department of Environment, Land, Water and Planning (DELWP)	Native Title Future Acts	Determine whether the works are on Crown land and whether Native Title may exist on the land. If required, determine whether the future acts are permissible under the Native Title Act.	Identification of land tenure within the project area
Land Act 1958 *Crown Land (Reserves) Act 1978*	DELWP	Application for lease and cancellation of existing licences that may be affected by the project	Determine whether the works are on Crown land. Identify whether there are any existing licences that may be affected by the project.	Identification of land tenure within the project area

Act	Approval Agency	Statutory Approval (if required)	Requirement/Trigger	Reviews/Assessments Required
Environmental				
Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Commonwealth)	Department of Environment	EPBC referral, if required	Determine whether there are potential impacts on a matter of national environmental significance.	Flora and Fauna Assessment
Environment Effects Act 1978	DELWP	Environmental effects referral	Determine whether there are potential impacts on the environment of a regional or State significance as listed in the referral criteria of the Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978; there is a need for an integrated assessment; and normal statutory processes are not considered sufficient for the project.	Various information should to be submitted, if applicable, as part of an environmental effects referral, including project description, land tenure, alternative project designs/locations, known or potential approvals, project implementation, preliminary environmental information (potential effects and mitigation measures), study program and consultation plan. The Minister may require the proponent to provide additional information. Various studies may be required, including Flora and Fauna Assessment, Aquatic Assessment, Waterways Assessment, Social Impact Assessment, Traffic Impact Assessment, Cultural Heritage Assessment, Cultural Heritage Management Plan, Historic Heritage Assessment, Geotechnical investigations
Flora and Fauna Guarantee (FFG) Act 1988	DELWP	FFG Act Permit	Impacts on threatened species or listed communities or undertaking a potentially threatening process.	Flora and Fauna Assessment Aquatic Assessment Waterway Assessment

Act	Approval Agency	Statutory Approval (if required)	Requirement/Trigger	Reviews/Assessments Required
Wildlife Act 1975	DELWP	Authorisation	Determine whether native fauna will need to be captured and relocated.	Flora and Fauna Assessment
Fisheries Act 1995	DELWP	Permit	Determine whether native fish will need to be captured and relocated.	Aquatic Assessment
Catchment and Land Protection Act 1994	DELWP North East Catchment Management Authority		Determine whether noxious weeds need to be removed and whether the construction vehicles travel through areas of noxious weeds.	Identification of land tenure within the project area Review of zones to determine whether it is a public use Flora and Fauna Assessment
Conservation, Forests and Lands Act 1995	DELWP	Referral for comment pursuant to a planning permit application to removal, destroy or lop native vegetation defined as a high risk-based pathway or on Crown land which is occupied or managed by the Responsible Authority.	Determine whether construction of the dam potentially interferes with the passage of fish.	Flora and Fauna Assessment Waterway Assessment Aquatic Assessment
Water Act 1989	Goulburn-Murray Water	Licence to construct works, including bores	The works will be within the bed and banks of the waterway.	Waterway Assessment
Water Act 2007 (Murray-Darling Basin Agreement and *Basin Plan) (Commonwealth)*	Murray Darling Basin Authority	Murray Darling Basin Authority are to be informed of new proposals.	The public authority shall inform the Authority of the proposal and provide all necessary information to permit it to assess the anticipated effects of the proposal on flow, use, control or quality of water in the upper River Murray.	Impacts Assessment Study

Act	Approval Agency	Statutory Approval (if required)	Requirement/Trigger	Reviews/Assessments Required
Cultural Heritage				
Aboriginal Heritage Act 2006	Aboriginal Affairs Victoria/ Registered Aboriginal Party	Cultural Heritage Management Plan/Cultural Heritage Permit	Determine whether there are high impact activities within areas of aboriginal cultural heritage significance. Refer to Section **7.4.2** for findings from the desktop review.	Due diligence assessment, Standard and Complex Assessments, Cultural Heritage Management Plan
Heritage Act 1995	Heritage Victoria	Permit to disturb a heritage object	Determine whether works impact on objects or places of post-contact heritage that are listed on the Victorian Heritage Register. Refer to Section **7.4.3** for findings from the desktop review.	Historic Heritage Assessment
Other				
Road Management Act	VicRoads/Towong Shire Council	Consent	Determine whether works are required within a road reserve Determine whether a road will need to be opened	Traffic Impact Assessment
Local Government Act 1989	Towong Shire Council	Declaration of a road Permit for drilling on Council land	Determine whether works would be on Council owned land Determine whether the access road would be handed over to Council	Identification of land tenure within the project area
Land Acquisition and Compensation Act 1986	Acquiring Agency	Purchase of land or creation of easement	Determine whether the works require purchase of land or creation of an easement	Identification of land tenure within the project area Review of construction footprint

Act	Approval Agency	Statutory Approval (if required)	Requirement/Trigger	Reviews/Assessments Required
Drilling investigations				
Local Government Act 1989	Towong Shire Council	Permit for drilling on Council land	Determine whether drillings would be on Council owned land	Identification of land tenure within the project area
-	VicRoads	Permit for drilling	Determine whether drillings would be on land within a VicRoads Road reserve	Identification of land tenure within the project area
-	Relevant water authority	Approval for drilling on land managed by the water authority	Determine whether drillings would be on land managed by a water authority	Identification of land tenure within the project area
Water Act 1989	Goulburn-Murray Water	Licence to construct a bore	Determine whether this is applicable to the project	Identify whether bores are required for investigating the potential to access groundwater

7.2.1 Land Use and Development Legislation

The legislation associated with land use and development includes the following:

- *Planning and Environment Act 1987*
- *Native Title Act 1993*
- *Land Act 1958*
- *Crown Land (Reserves) Act 1978*

The potential planning permit triggers are identified in Section 7.3.2 of this report. A planning permit application would need to be supported by a number of specialist reports, including a Flora and Fauna Assessment, and any offset requirements in accordance with Permitted clearing of native vegetation – Biodiversity assessment guidelines, Traffic Impact Assessment, Historic Heritage Assessment and Cultural Heritage (assessment and/or Cultural Heritage Management Plan).

The land tenure of the project area would also need to be identified to determine whether Crown land will need to be developed and if Native title is present on this land.

7.2.2 Cultural Heritage

The legislation associated with cultural heritage includes:

- *Aboriginal Heritage Act 2006*
- *Aboriginal Heritage Regulations 2007*
- *Heritage Act 1995*

The cultural heritage legislation and requirements are detailed in Section 6.4 of this report.

7.2.3 Other legislation

Legislation to be considered associated with the construction of the road access includes the following:

- *Road Management Act*
- *Local Government Act 1989*
- *Land Acquisition and Compensation Act 1986*

The land tenure of the proposed road access alignment would need to be determined and whether the land would be acquired or an easement created.

7.3 Planning Controls

A desktop planning review of zones, overlays and particular provisions has been undertaken of the study area to identify the planning approvals that may be required for:

- Development of a dam across The Narrows;
- A new road to access the dam (but not across the dam);
- Drilling investigations (locations yet to be determined); and
- Disposal of excess material in the dam or elsewhere in the study area (locations yet to be determined).

The following websites were used to identify the zones, overlays and areas of Aboriginal Cultural Heritage Sensitivity within the study area, as well as the need for a Cultural Heritage Management Plan (CHMP) associated with the various project components:

- The Department of Transport, Planning and Local Infrastructure 'Planning Maps Online'; and

- The Department of Premier and Cabinet Aboriginal Heritage Planning Tool to generate a report regarding the need to undertake a CHMP.

The Towong Planning Scheme applies to the Narrows and the associated study area. The zones and overlays that apply, or may apply (depending on the project footprint), to the proposed location of the dam, new road and wider study area are shown Figure 7.2 and Figure 7.3, and are outlined in Table 7.2. Particular provisions that may apply to the project are also listed in this table.

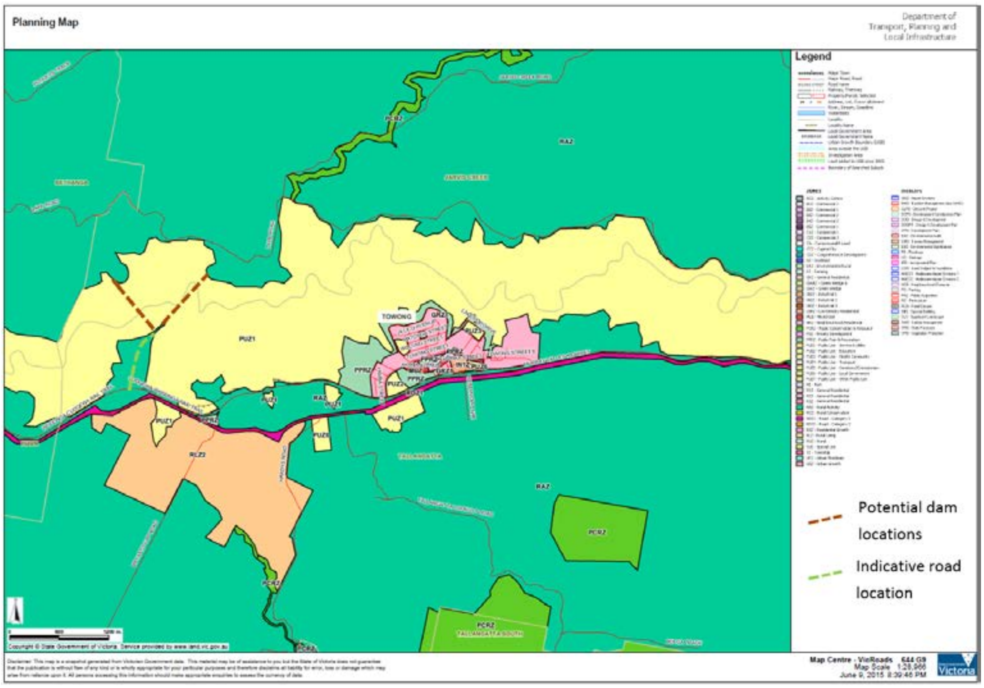

Figure 7.2: Zoning Map

Source: Department of Transport, Planning and Local Infrastructure, Planning Maps Online, http://services.land.vic.gov.au/maps/pmo.jsp

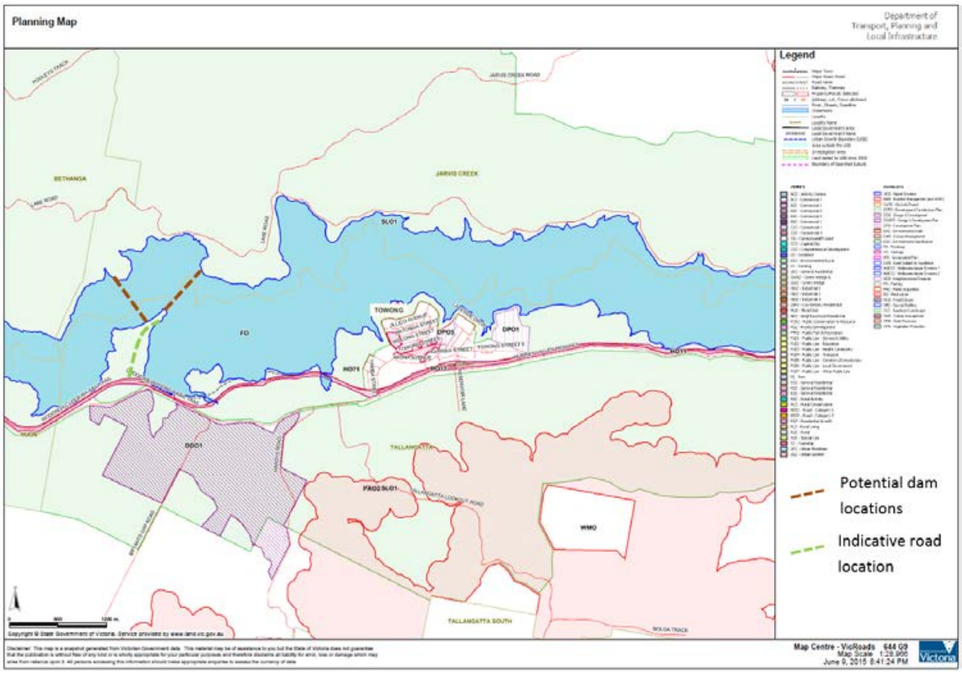

Figure 7.3: Overlays Map

Source: Department of Transport, Planning and Local Infrastructure, Planning Maps Online, http://services.land.vic.gov.au/maps/pmo.jsp

Table 7.2: Applicable Zones, Overlays and Particular Provisions

Project Area	Zones, Overlays & Particular Provisions	Locations
Dam	Public Use Zone 1 (PUZ1) – Service and Utility	Applies to the waterbody
	Rural Activity Zone (RAZ)	Applies to areas abutting the Public Use Zone 1 to the north and south (further investigation would be required to determine whether the dam would be located in areas of the Rural Activity Zone)
	Significant Landscape Overlay - Schedule 1 (SLO1) – Lake Hume and Environs	Applies to the waterbody and to land north and south of the waterbody
	Flood Overlay (FO)	Applies to the waterbody
	Clause 52.17 Native Vegetation	Applies if native vegetation removal is required
Access road	Rural Activity Zone (RAZ)	Applies to land south of the waterbody
	Road Zone Category 1 (RDZ1)	Applies to the Murray Valley Highway (a connection from the proposed access road to the highway may be required)
	Significant Landscape Overlay - Schedule 1 (SLO1) – Lake Hume and Environs	Applies to the waterbody and to land north and south of the waterbody
	Heritage Overlay - Schedule 11 (HO11) and Schedule 70 (HO70)	HO11 - Applies to the Cudgewa-Wodonga Rail Trail, located to the south of the waterbody and north of Murray Valley Highway HO70 - Applies to two Canary Island Date Palms at the Lakelands Caravan Park
	Clause 52.17 Native Vegetation	Applies if native vegetation removal or destruction is required.
	Clause 52.29 Land Adjacent To A Road Zone, Category 1, Or A Public Acquisition Overlay For A Category 1 Road	Applies if a new access or alterations to an existing point of access to the Murray Valley Highway is required.

7.3.1 Land use definition

A dam is defined as 'utility installation' pursuant to the Towong Planning Scheme. A utility installation is *'land used:*

> *a) for telecommunications;*
>
> *b) to transmit or distribute gas, oil, or power;*
>
> *c) to collect, treat, transmit, store, or distribute water; or*
>
> *d) to collect, treat, or dispose of storm or flood water, sewage, or sullage.*

It includes any associated flow measurement device or a structure to gauge waterway flow.'

A 'road' is not defined in the Towong Planning Scheme. A common definition of a 'road' has been sourced from the Oxford dictionary. A road is *'A wide way leading from one place to another, especially one with a specially prepared surface which vehicles can use'.*

Disposing of excess fill in the study area, land forming and revegetating the land would be considered as 'earthworks'. The definition of earthworks in the Towong Planning Scheme is *'Land forming, laser grading, levee banks, raised access roads and tracks, building pads, storage embankments, channel banks and drain banks and associated structures.'*

Drillings for the purposes of geotechnical investigations is not considered to be a use or works, therefore no further discussion is included in this section.

7.3.2 Planning permit exemptions

Clause 62 of the Towong Planning Scheme provides the following exemptions:

- The use of land for a Road except within the Urban Flood Zone and a Public Conservation and Resource Zone.
- Buildings & works associated with a dam if a license is required to construct the dam or to take and use water from the dam under the Water Act 1989.
- Buildings or works with an estimated cost of $1,000,000 or less carried out by or on behalf of a municipality.

The planning permit triggers for each project component are identified below and summarised in Table 7.3.

7.3.3 Environmental Legislation

The legislation associated with environment aspects of the project include:

- *Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Commonwealth)*
- *Environment Effects Act 1978*
- *Flora and Fauna Guarantee (FFG) Act 1988*
- *Wildlife Act 1975*
- *Fisheries Act 1995*
- *Catchment and Land Protection Act 1994*
- *Conservation, Forests and Lands Act 1995*
- *Water Act 1989 (including Murray-Darling Basin Agreement and Basin Plan)*

A Flora and Fauna Assessment would be required to determine whether a referral is required pursuant to the EPBC Act for matters of national environmental significance or whether a permit is required pursuant to the FFG Act for impacts on threatened species or listed community or undertaking a potentially threatening process.

As part of the specialist investigations undertaken for the project, it is recommended further consideration is given to whether an environment effects referral is required. The Ministerial guidelines for assessment of environmental effects under the Environment Effects Act 1978 (2006) sets out the referral criteria.

The FFG Act identifies potentially threatening processes (the Processes List), which included the following:

- Alteration to the natural flow regimes of rivers and streams; and
- Prevention of passage of aquatic biota as a result of the presence of instream structures.

It is recommended that further investigations are undertaken for the above processes.

Other environmental impacts that would need to be considered, includes thermal changes to water temperature. This aspect is particularly relevant for The Narrows due to variability of inflows associated with releases from Dartmouth Dam. Temperature of water in rivers is an important factor in determining habitat quality. Alternation to stream temperature regimes can have adverse effects on instream biota and native freshwater fishes.[1]

In addition, pursuant to the *Fisheries Act 1995*, Section 119 ‘Passage of fish not to be blocked’ states:

> *(1) A person must not, except as permitted by or under this or any other Act, set a net, netting or other material or otherwise create an obstruction across or within a bay, inlet, river or creek or across or around an inter-tidal flat so that—*
>
> > *(a) fish will or could be blocked and left stranded; or*
> >
> > *(b) immature fish will or could be destroyed; or*
> >
> > *(c) the free passage of fish will or could be obstructed.*

The above must be considered in the design of the dam. It would need to be determined whether there are any exemptions that may apply for fishways when there is a dam located further downstream that ultimately prevents the movement of fish.

[1] Source: Department of Sustainability and Environment, Action Statement: Flora and Fauna Guarantee Act 1988, No. 178, webpage: http://www.depi.vic.gov.au/__data/assets/pdf_file/0006/249954/Alteration_to_the_natrual_temperature_regimes_of_rivers_and_streams.pdf

Specific sections to note from the Water Act 1989 include Section 51 'Licence to take and use water'

> *(1) A person may apply to the Minister for the issue of a licence to take and use—*
>
> > *(a) water from a waterway (including the River Murray); or*
> >
> > *(b) groundwater; or*
> >
> > *(c) water from a spring or soak or water from a dam (to the extent that it is not rainwater supplied to the dam from the roof of a building or water supplied to the dam from a waterway or a bore), for a use other than domestic and stock use; or*
> >
> > *(d) water, other than recycled water, from any works of an Authority; or*
> >
> > *(e) water, other than recycled water, from any works of a person holding a water licence, a water and sewerage licence or a water headworks licence issued under Division 1 of Part 2 of the Water Industry Act 1994.*

Section 67 'Licence to construct works etc.' outlines:

> *(1) An Authority or any other person may apply to the Minister for the issue of a licence to construct, alter, operate, remove or decommission—*
>
> > *(a) any works on a waterway (including the River Murray), including works to deviate (temporarily or permanently) a waterway; or*
> >
> > *(b) a bore.*

The Murray Darling 'Basin Plan' is developed and enacted under the Water Act 2007. The plans intent is to provide a coordinated approach to managing the Murray-Darling Basin's water resources. The Basin Plan requires that consideration to be given to matters such as water availability, evaporation and drought response etc.

7.3.4 Planning approvals

7.3.4.1 *Dam*

The following identifies the planning permit triggers for the development of the dam, including changes to the topography of land (e.g. the earthworks within the dam).

<u>Use</u>

The dam would be primarily located in the Public Use Zone 1. If the use of the dam is for 'Service & Utility' and is carried out by or on behalf of the public land manager, a planning permit would not be required.

An application for a permit by a person other than the relevant public land manager requires written approval by the public land manager.

If the dam structure is partially located in the Rural Activity Zone, a planning permit would be required for the dam in that zone.

<u>Buildings and works</u>

If a licence has been sought for the dam under the *Water Act 1989*, a planning permit for buildings and works would not be required for the dam. The *Planning and Environment Act 1987* provides a definition of works, which *'includes any change to the natural or existing condition or topography of land including the removal, destruction or lopping of trees and the removal of vegetation or topsoil.'* The placement of excess fill within the dam is considered to be associated with 'works', by changing the existing condition or topography of the land. If the placement of excess fill in the dam is associated with constructing the dam, a planning permit would not be required if a licence has been sought under the *Water Act 1989*.

If earthworks are required in the Rural Activity Zone that changes the rate of flow or the discharge point of water across a property boundary, or increase discharge of saline groundwater, a planning permit would be required for earthworks. Earthworks are defined as *'Land forming, laser grading, levee banks, raised access roads and tracks, building pads, storage embankments, channel banks and drain banks and associated structures.'*

Vegetation removal

Pursuant to the Significant Landscape Overlay, a planning permit is required for vegetation removal. Pursuant to Clause 52.17 'Native Vegetation, a planning permit is required for native vegetation removal or destruction. There are unlikely to be any applicable permit exemptions.

A flora and fauna assessment could identify the approval requirements relating to the inundation of native vegetation.

7.3.4.2 *Road*

Use

A planning permit is not required for the use of land for a road.

Buildings and works

Pursuant to the Significant Landscape Overlay and Heritage Overlay, a planning permit is required for building and works to construct a road.

The Significant Landscape Overlay requires all applications for use and development 200 metres of the full supply level of Lake Hume to prepare an Environmental Management Plan that contains details of land management principles and actions relevant to the site and water quality of Lake Hume.

Vegetation removal

Pursuant to the Significant Landscape Overlay, a planning permit is required for vegetation removal or destruction. Pursuant to Clause 52.17 'Native Vegetation, a planning permit is required for native vegetation removal or destruction. There are unlikely to be any applicable permit exemptions.

Further investigation would be required to determine whether the two Canary Island Date Palms at the Lakelands Caravan Park would be impacted by the proposal. Pursuant to the HO70, tree controls apply to these palms.

7.3.4.3 *Summary*

Table 7.3 provides a summary of planning approvals that may be applicable to the proposed dam, road and drilling.

Table 7.3: Summary of Planning Permit Triggers

	Permit Triggers				
	Use	Buildings & Works	Earthworks	Vegetation removal/destruction	Access to a Road Zone Category 1
Dam					
PUZ1	No[2]	Exempt[3]	-	-	-
RAZ	Yes	Exempt[3]	Yes[4]	-	-
SLO1	-	Exempt[3] [5]	-	Veg removal/destruction[6]	-
FO	-	Exempt[3]	-	-	-
Road					
RAZ	Exempt	No	Yes[4]	-	-
RDZ1	Exempt	No	-	-	-
SLO1	-	Yes[5]	-	Veg removal/destruction[6]	-
HO11	-	Yes	-	No	-
52.29	-	-	-	-	Yes
All					
52.17	-	-	-	Native veg removal/destruction[7]	

[2] If the dam is for the purposes of *Service & Utility* and is carried out by or on behalf of the public land manager. An application for a permit by a person other than the relevant public land manager requires written approval by the public land manager.

[3] Buildings and works associated with a dam are exempt from a planning permit if a licence has been sought under the *Water Act 1989,* otherwise a planning permit would be required.

[4] If earthworks are proposed that changes the rate of flow or the discharge point of water across a property boundary, or increase discharge of saline groundwater.

[5] A permit application for use and development within 200m of the full supply level of Lake Hume will be required to prepare an Environmental Management Plan (Clause 5.0 of Schedule to SLO1).

[6] Unless a specific permit exemption applies under Clause 42.03-3.

[7] Unless a specific permit exemption applies under Clause 52.17-7. Any native vegetation will need to be assessed and offset in accordance with the *Permitted clearing of native vegetation – Biodiversity assessment guidelines* (Department of Primary Industries, September 2014).

7.4 Cultural Heritage

7.4.1 Legislation

Aboriginal Heritage Act 2006

The Aboriginal Heritage Act 2006 provides for the protection and management of Victoria's Aboriginal heritage with processes linked to the Victorian planning system. The Act provides for a system of Registered Aboriginal Parties that allows for Aboriginal groups with connections to areas of land to be involved in decision making processes around cultural heritage. The Act establishes the requirements for Cultural Heritage Management Plans (CHMP) and Cultural Heritage Permit processes to manage activities that may harm Aboriginal cultural heritage.

Aboriginal Heritage Regulations 2007

The Aboriginal Heritage Regulations 2007 sets out the circumstances in which a CHMP is required for an activity or class of activity. Regulation 6 sets out that a CHMP is required for an activity if:

(a) all or part of the activity area for the activity is an area of cultural heritage sensitivity; and

(b) all or part of the activity is a high impact activity.

Regulation 23 outlines areas of cultural heritage sensitivity include, but are not limited to, the following:

- A registered cultural heritage place is an area of cultural heritage sensitivity;
- Land within 50m of a registered cultural heritage place is an area of cultural heritage sensitivity;
- A waterway or land within 200m of a waterway is an area of cultural heritage sensitivity;
- A prior waterway or land within 200m of a prior waterway is an area of cultural heritage sensitivity.

Regulation 43 'Buildings and works for specified uses' outlines:

The construction of a building or the construction or carrying out of works on land is a high impact activity if the construction of the building or the construction or carrying out of the works—

(a) would result in significant ground disturbance; and

(b) is for or associated with the use of the land for any one or more of the following purposes—

(xxiii) a utility installation, other than a telecommunications facility, if—

(A) the works are a linear project that is the construction of an overhead power line with a length exceeding one kilometre or for which more than 10 power poles are erected; or

(B) the works are a linear project that is the construction of a pipeline with a length exceeding 500 metres; or

(C) the works are a linear project with a length exceeding 100 metres (other than the construction of an overhead power line or a pipeline with a pipe diameter not exceeding 150 millimetres); or

(D) the works affect an area exceeding 25 square metres.

The above regulation may apply to the dam, as construction of the dam would affect an area exceeding 25 square metres.

Regulation 4 identifies that *Significant ground disturbance means disturbance of—*

(a) the topsoil or surface rock layer of the ground; or

(b) a waterway— by machinery in the course of grading, excavating, digging, dredging or deep ripping, but does not include ploughing other than deep ripping;

Regulation 44 'Constructing specified items of infrastructure' outlines:

(1) The construction of any one or more of the following is a high impact activity if the construction would result in significant ground disturbance—

(e) a road with a length exceeding 100 metres;

As the proposed road would be greater than 100 metres in length, it would be considered a high impact activity.

Regulation 49 'Extraction or removal of sand or sandstone'

(1) The extraction or removal of sand or sandstone (other than extraction or removal that requires an earth resource authorisation) is a high impact activity if the extraction or removal would result in significant ground disturbance.

(2) Sub-regulation (1) does not apply to the extraction or removal of sand or sandstone—

(e) if the primary purpose of the excavation or removal is for the construction of the footings or foundations of a building or structure.

The above exemption may not specifically apply to the drilling investigations, as the intent is for the construction of footing or foundations, whereas the drillings is primarily for investigation purposes.

Regulation 53 'Dams' outlines:

The construction or alteration of a private dam, other than on a waterway, is a high impact activity if a licence is required under section 67(1A) of the Water Act 1989 for the construction or alteration of the private dam.

It is considered that the above regulation does not apply to the proposed dam across the Narrows, as it would be a public dam on a waterway.

Heritage Act 1995

The Heritage Act 1995 provides for the protection and conservation of places and objects of cultural heritage (non-Indigenous) significance. Heritage places and objects that are of significance in Victoria include historic archaeological sites and artefacts, historic archaeological sites and artefacts, cultural landscapes and significant objects. The Act also establishes a Heritage Council and the Victorian Heritage Register.

7.4.2 Aboriginal Cultural Heritage

Areas of Aboriginal Cultural Heritage Sensitivity have been identified within the study area using Planning Maps Online. Refer to Figure 7.4 for areas of Aboriginal Cultural Heritage Sensitivity.

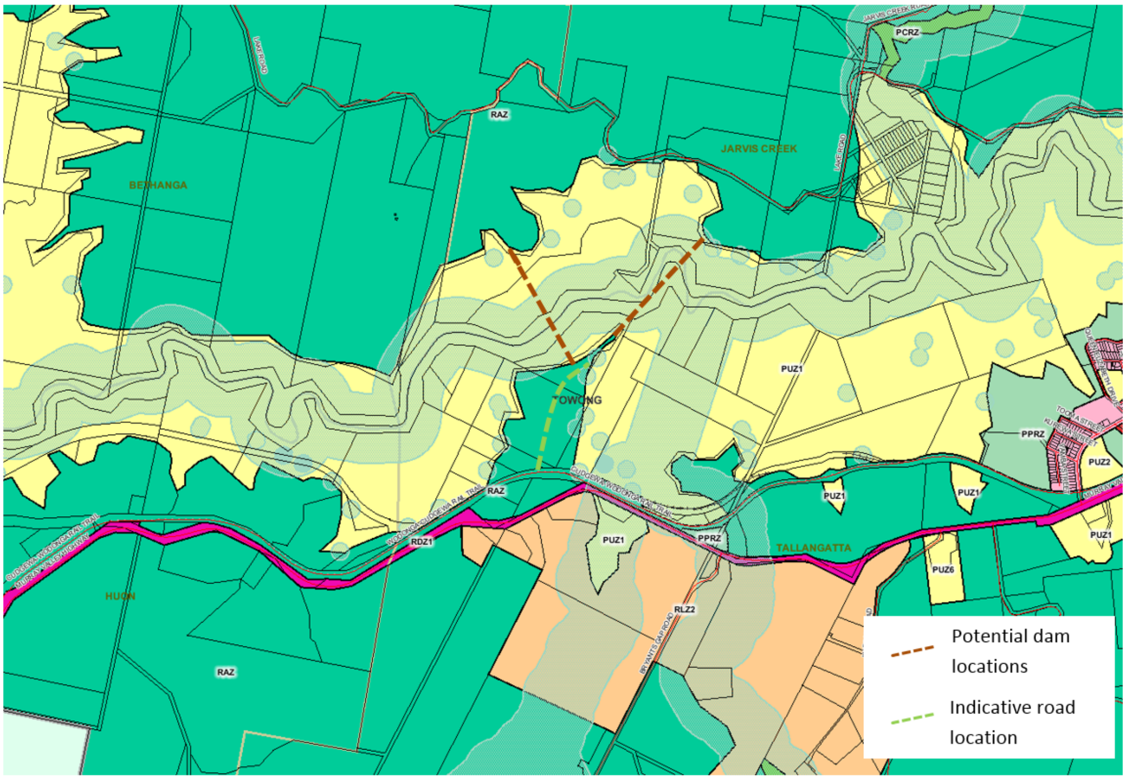

Figure 7.4: Areas of Aboriginal Cultural Heritage Sensitivity

Source: Department of Transport, Planning and Local Infrastructure, Planning Maps Online, http://services.land.vic.gov.au/maps/pmo.jsp

Areas of Aboriginal cultural heritage significance are identified at the Lake Hume water body, as well as smaller areas, which presumably would relate to registered cultural heritage places and land within 50m of a registered cultural heritage place. A review using the Aboriginal Heritage Planning Tool has been undertaken to determine whether further cultural heritage investigations are required.

Dam

Regulation 53 only applies to the construction of a private dam not on a waterway, and is considered to be a high impact activity. As the proposed dam would be a public dam and located on a waterway, it may not be considered a high impact activity. If this is the case, a review using the Aboriginal Heritage Planning Tool identifies that a CHMP is not required, although it is suggested that a voluntary CHMP could be undertaken. This would minimise risks associated with finding cultural heritage material during construction and potentially delaying works.

Alternatively, the dam could be considered as a utility installation, as the works will affect an area exceeding 25 square metres. A review using the Aboriginal Heritage Planning Tool identifies that a CHMP is required for the utility installation.

Additional investigations undertaken by an archaeological and cultural heritage advisor is recommended.

Road (greater than 100m in length)

The road is likely to traverse one or two areas of Aboriginal Cultural Heritage Sensitivity. A review using the Aboriginal Heritage Planning Tool identifies that a CHMP is required to construct a road greater than 100m in length and within areas of Aboriginal Cultural Heritage Sensitivity.

Drilling investigations

A review using the Aboriginal Heritage Planning Tool identifies that a mandatory CHMP is not required.

7.4.3 Post – Contact Cultural Heritage

There are two Heritage Overlays within the study area that may be affected by the proposal, which area HO11 and HO 70, refer to Figure 7.5.

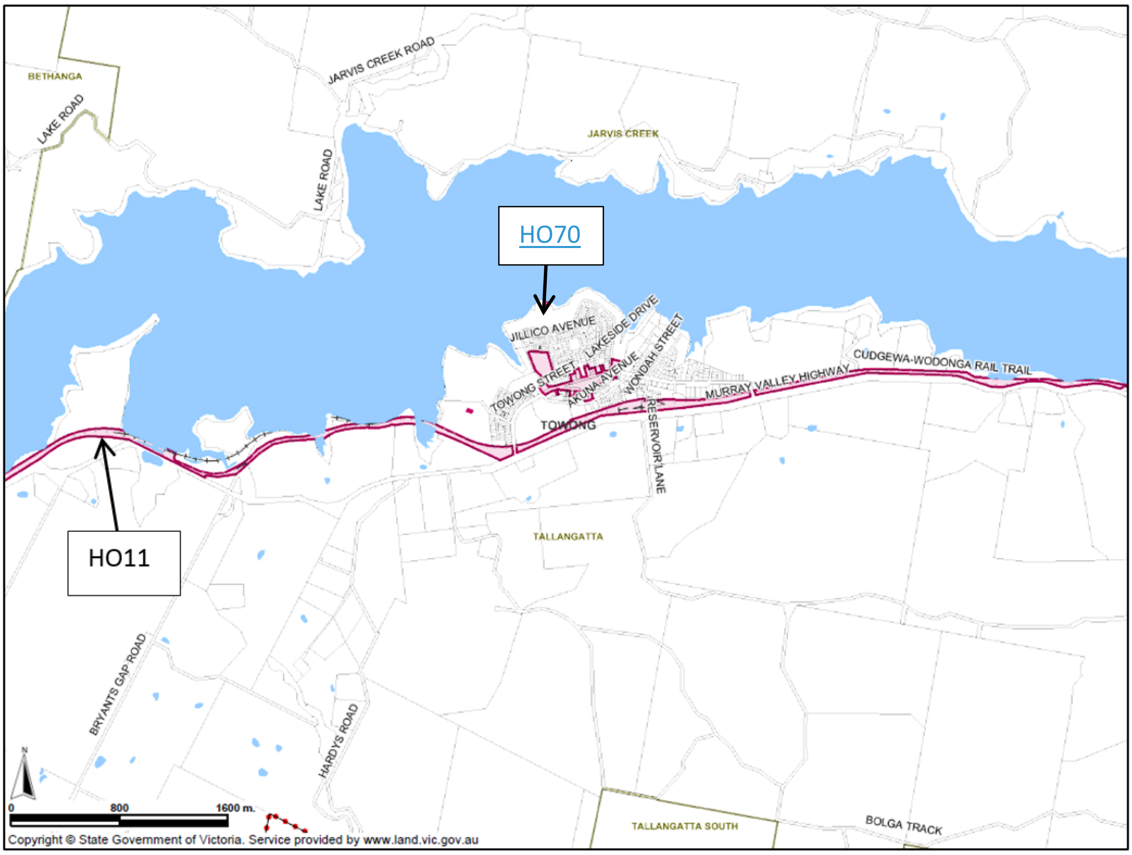

Figure 7.5: Heritage Overlay – Schedule 11 and Schedule 70

Source: Department of Transport, Planning and Local Infrastructure, Planning Maps Online, http://services.land.vic.gov.au/maps/pmo.jsp

Heritage Overlay Schedule 11 (HO11) is for the purposes of protecting the 'Railway Reserve Precinct (part of former Wodonga-Cudgewa Railway)' and applies to the Cudgewa-Wodonga Rail Trail, which abuts the Murray Valley Highway to the north. The HO11 will need to be crossed to develop the proposed road. The Schedule to the Heritage Overlay notes that the Railway Reserve Precinct is not included on the Victorian Heritage Register under the *Heritage Act 1995*. As identified in Section 7.3.2 of this report, a planning permit would be required for buildings and works within the HO11.

Heritage Overlay Schedule 70 (HO70) is for the purposes of protecting two Canary Island Date Palms at the Lakelands Caravan Park. Pursuant to the HO70, tree controls applies. Further investigations would be required to determine whether the project through the inundation of water impacts on these palms.

Decision guidelines

Before the responsible authority makes a decision on an application, they must consider the following, as appropriate:

- The significance of the heritage place and whether the proposal will adversely affect the natural or cultural significance of the place.
- Any applicable statement of significance, heritage study and any applicable conservation policy.
- Whether the location, bulk, form or appearance of the proposed building will adversely affect the significance of the heritage place.
- Whether the location, bulk, form and appearance of the proposed building is in keeping with the character and appearance of adjacent buildings and the heritage place.
- Whether the demolition, removal or external alteration will adversely affect the significance of the heritage place.
- Whether the proposed works will adversely affect the significance, character or appearance of the heritage place.

It is recommended that a study is undertaken by a cultural heritage advisor to address the above and the study would be submitted as part a planning permit application or other applicable approvals process.

There are no heritage listed places on the Victorian Heritage Register in the vicinity of the project area. There are a number of historical places that are recorded on the Victorian War Heritage Inventory in the vicinity of the site, however they are located within the Tallangatta Township and would not be affected by the proposal, refer to Figure 7.6. They are as follows:

- Tallangatta Memorial Hall;
- Tallangatta Volunteer Air Observers Corps Memorial; and
- Tallangatta War Memorial.

Figure 7.6: Sites Listed on the Victorian War Heritage Inventory

Source: Heritage Council Victoria, Victorian Heritage Database
http://vhd.heritagecouncil.vic.gov.au/

8 OPTIONS DEVELOPMENT

8.1 General

The location of the proposed site for The Narrows was investigated prior to comment of options development. Consideration was given to the following aspects:

- Minimising the overall volume of water in storage. This could be achieved by locating the weir as far upstream as possible.
- Limiting the overall length of the structure and hence volume of earthworks required.
- Outlet location and alignment. It was considered preferable to excavate the outlet structure through 'rock' rather than through alluvial foundation and also to align the outlet structure such that is suits the alignment of the existing water course
- Grade of the abutments. 'Flatter' abutments would allow easier access to the site for construction and ultimately if judged to be feasible improve the approaches for vehicle access across the weir.

On this basis the location as noted on Sketch 1 in Appendix 8.1 was selected, being the upstream entry to The Narrows.

In order to identify the appropriate weir arrangement for The Narrows a number of options were considered and a preliminary options assessment undertaken.

The following options were considered.

- Option 1 – Rockfill structure with a core/cutoff

  This option would comprise a weir with rockfill shoulders and a nominally centrally located low permeability core and cutoff extending into the foundation.
- Option 2 – Zoned earth and rockfill structure with a core/cutoff

  This option would comprise an earthfill structure with a centrally located low permeability core and cutoff extending into the foundation, filter/transition zone and rockfill beaching on the upstream and downstream shoulders for erosion protection.
- Option 3 – Concrete Structure

  This option would comprise a mass roller compacted concrete (RCC) gravity structure.
- Option 4 – Twin Walled Sheet Pile with Plunge Pool

  This option would comprise two parallel walls of sheet piles driven into the foundation, offset at least 5m, and backfilled above foundation level with conventional concrete. The plunge pool would be constructed from conventional reinforced concrete.

These options were evaluated in terms of a set criteria as well as benefits and limitations identified to determine the preferred option to be progressed. A tiered approach was adopted:

- Constructability (i.e. can it be constructed in water)
- Technical
- Design

8.2 Constructability

A key aspect of the functional design requires that the weir be constructed in water. For construction in water to be feasible it would be necessary to ensure that flows including daily transfers between Dartmouth Dam and Hume Dam could be passed through the site during the construction period.

A typical approach would be to allow the flows to pass around the 'end' of the weir as the embankment is gradually extended out into the water course. However 'closure' of the embankment would be difficult to undertake whilst still ensuring flows are passed through the site. As such, in order to manage flows during construction it is envisaged that the first task undertaken would comprise excavation of a trench through the left abutment for the outlet structure. It is proposed that this 'trench' be utilised for diverting flows during construction. It would be necessary to temporarily limit the maximum transfer between Dartmouth Dam and Hume Dam to less than 5,000ML/day during the period that the diversion is in place. Once construction of the embankment is completed the 'trench' would be cofferdammed to allow for construction of the outlet. Flows would then be passed over the dam as for the proposed normal operation of The Narrows weir. Once the outlet is commissioned the cofferdams would be removed.

On the basis that the outlet 'trench' would adequately pass flow, two approaches were considered for constructing a structure in water:

- A – Design of a weir arrangement and selection of materials such that the weir can be constructed under water
- B – Construction of cofferdam(s) and installation of a dewatering and river diversion systems to allow for placement of materials in the dry.

For construction in the dry to be a realistic option it was judged that from both a practicality and an economic perspective, the cofferdams should be no more than 3m in height. A review of the historic water levels in Lake Hume (post-Dartmouth, 1979-2015) was then undertaken to ascertain the frequency at which the water levels at The Narrows were up to 3m above foundation level (RL175mAHD). This level equated to RL178mAHD.

The results of the review of the historic water levels in Lake Hume since the construction of Dartmouth Dam is presented in Table 8.1

Table 8.1: Summary of Historic Water Levels in Lake Hume (post 1979)

Elevation	RL175mAHD	RL178mAHD
Number of Occasions Below XXmAHD	20	20
Average Consecutive Days Below XXmAHD	129	199
Max. Consecutive Days Below XXmAHD	377	902
Min. Consecutive Days Below XXmAHD	23	47
Percentage of Days Below XXmAHD	20%	31%

The results of this review indicate that there is likely to be a sufficient length of time over a three to five year period at which the water levels in Lake Hume will be below RL175mAHD. This would allow for access to the dam foundation and hence construction of 3m cofferdams and commencement of construction of the weir. Figures 8.1 and 8.2 show the duration and frequency at which water levels in Lake Hume are at or below RL175mAHD and RL178mAHD respectively. It can be observed from Figure 8.2 that typically at least once in a five year period there is a 3 to 4 month construction window between the months of April to July where construction of the weir could commence. It is envisaged that although construction of the weir may not be completed within this period of time it would be reasonable to assume that the weir could be constructed to a level above RL178mAHD and hence allowing for construction of the dam to continue as the water levels in Lake Hume rise without impacting on the works in progress. It should however be noted that with this approach it would be necessary to schedule the works to fit within this construction window.

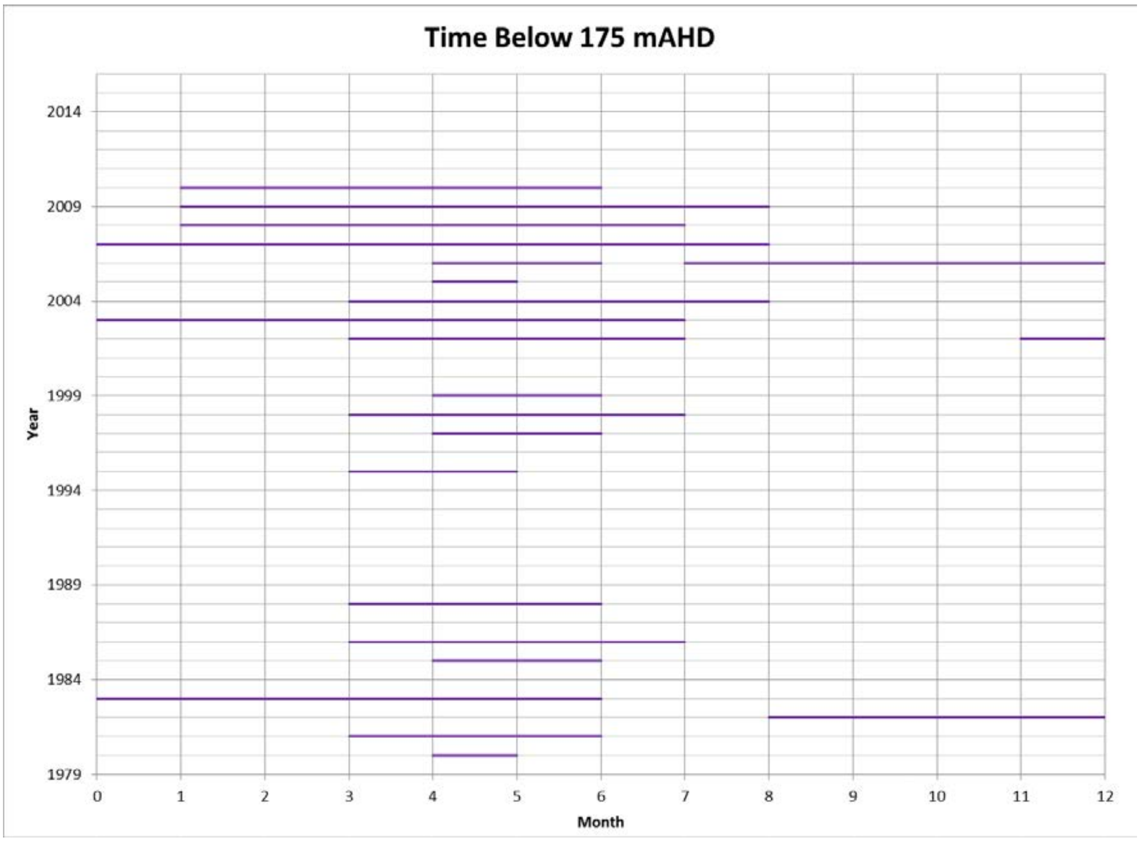

Figure 8.1: Frequency and Duration of Water Levels in Lake Hume to be below RL175mAHD (foundation level)

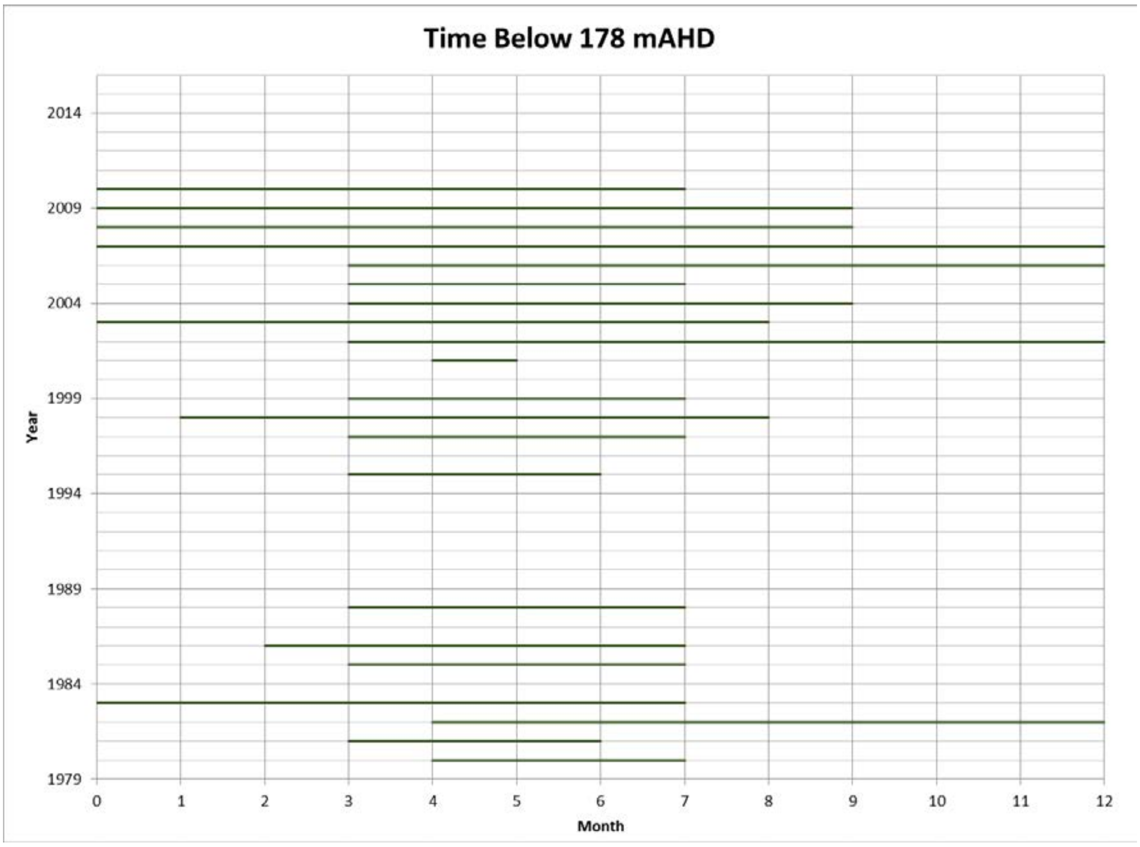

Figure 8.2: Frequency and Duration of Water Levels in Lake Hume to be below RL178mAHD (crest level of cofferdam)

On the basis that both approach A and B would be acceptable, each option was assessed in terms of the requirement to be constructed in water. Aspects relating to each option are discussed below.

- Option 1 could be constructed in water. Depending on the core/cutoff arrangement the rockfill could be placed first with the core/cutoff to follow by excavation through the rockfill, or alternatively the core/cutoff could be installed first from a barge and once in place the rockfill material could be placed either side. A number of different core/cutoff arrangements could be considered including:
  - A: Sheet pile
  - B: Twin walled sheet pile backfilled with concrete
  - C: Reinforced concrete placed by secant pile techniques
  - D: Reinforced concrete placed by slurry trench techniques
  - E: Jet grout

  Conclude: OPTION 1 is Feasible

- Construction of Option 2 would need to be undertaken in the dry as neither earthfill nor filters can be adequately placed and compacted in water. In order to make the site ‘dry’ two cofferdams, one upstream and one downstream would need to be constructed, a dewatering system would need to be installed and a diversion pipe constructed to allow for flows to pass through the site during construction.

  Conclude: OPTION 2 is Feasible

- Option 3 would need to be constructed in the dry as it is not practicable to construct a concrete gravity weir in water. As for Option 2, to make the site 'dry', installation of cofferdams, dewatering system and a diversion pipe would be required.

  Conclude: OPTION 3 is Feasible

- Option 4, the twin-walled sheet pile structure could be constructed either under water or in the dry. For underwater construction the sheet piles would first be driven from a barge and sealed at either end. The void between the sheet piles would be pumped dry, the silt removed and the unreinforced concrete would be pumped into the 'dry' void providing mass for stability. Unlike the other options a plunge pool would be required for energy dissipation (upstream to downstream only). The reinforced concrete plunge pool would be constructed against the twin-walled sheet pile weir. It is envisaged that a sheet pile cofferdam to the full height of the weir would be constructed around the perimeter of the plunge pool to allow dewatering of the pool area for placement of the concrete. The sheet piles above the concrete would then be cut and removed, leaving only the sheet pile cut off around the perimeter of the plunge pool.

  Conclude: OPTION 4 is Not Feasible – Cost Prohibitive

In summary it was assessed that although a construction methodology could be developed for all four options to allow for construction under water, it was judged that Option 4 would be cost prohibitive and for this reason was discounted from further consideration.

8.3 Technical

Following the constructability review a technical assessment of each option was undertaken. Primarily this assessment entailed evaluating the suitability and long term integrity of each option based on the foundation conditions of the site. As discussed in Section 6 the interpreted geological profile of the lake bed comprises several metres of silt overlying 30 to 40m of alluvials before bedrock is encountered.

A rock foundation is not considered realistic based on the depth of alluvials overlying bedrock. Founding the structure on the alluvials is considered acceptable but it is noted that this type of foundation is flexible and settlement of the structure are inevitable. A rigid structure founded on alluvials would not be suitable as movement in the foundation could result in unpredictable performance of the structure. In order to ensure integrity of a rigid structure such as the RCC gravity weir proposed for Option 3, it would be necessary to found the weir on structural piles to ensure predictable behaviour and manage settlement.

It was assessed that Option 3 is cost prohibitive and hence the RCC weir was discounted from further consideration.

Conclude: OPTION 3 is Not Feasible – Cost Prohibitive

8.4 Design

8.4.1 General

Options 1 and 2 were then compared taking into consideration the merits of each option with respect to the following aspects:

- Serviceability – Durability and ability to meet the design intent.
- Dam and Public Safety – Aspects which influence the safety of the structure or the safety of maintenance personnel or public.
- Construction Duration, Risk and Constructability – The expected length of time associated with construction of the works, the possibility that the duration would exceed initial estimates and the risks associated with the construction duration being extended. In addition the difficulties associated with the construction, safety risks during construction, constraints and limitations associated with construction.
- Environmental Risk – Associated with construction activities such as noise, dust, contamination of waterways and on-going environmental risk.
- Operation and Maintenance – Frequency and cost of on-going maintenance and operation difficulties (in particular safety) associated with maintenance and operation.
- Cost* – Concept cost estimates have been prepared. These estimates should be used only to provide a comparison of relative costs between options and should not be used for budgeting purposes.

  * The unit rates adopted are based as far as possible upon recent experience with relevant similar works. Such rates can, however, vary significantly depending upon the prevailing business conditions at the time of construction. The actual unit rates for any particular task will be affected by many aspects such as perceived risks, availability of supplies, economic climate, competition etc.

  Cost estimates do not include an allowance for the following:

  - owner costs
  - land acquisition
  - water costs associated with incremental evaporation loss that could be expected from The Narrows Storage
  - traffic management and control
  - any restrictions on construction activities including hours of operation, truck movements, noise levels, etc.
  - delays in construction
  - on-going maintenance
  - architectural features

A discussion on the details of the options and their evaluation is outlined below. It should be noted that the geometry presented for each option is only that required for structural performance. Each option can be modified to address public safety and amenity, essentially 'architectural' features, the cost of which has not been included in the evaluation. Sketches showing the site layout and weir structure plan are presented in Sketches 1 and 2 in Appendix 8.1

8.4.2 Option 1 – Rockfill Dam with core/cutoff (See Sketch 3 – Appendix 8.1)

This option has been developed on the basis that the water level at The Narrows would be above foundation level for duration of the works. That is, the construction of the weir would be undertaken in-part under the water. The construction sequence would be as follows:

1. Construct outlet structure. Assume 2m diameter, concrete encased, mild steel cement lined (MSCL) pipe with hydraulically actuated 2m x 2m vertical lift gate. The outlet would likely be excavated into the south (left) abutment of the weir, largely in the dry. An intake structure would be constructed to mount the gate and trash racks. A discharge structure would also be constructed to provide a means for dissipating energy should The Narrows need to be dewatered and the storage drained with minimal tailwater level (Lake Hume at low level).
2. Incrementally place Zone 3B rockfill downstream bund, sufficient width to cover the footprint of the downstream shoulder and for trucks to operate safely. Assume angle of repose of dumped rock of 1.5H:1V.
3. Incrementally place Zone 3A rockfill central core, width dictated by position of corewall within Zone 3A, and for trucks to operate safely. Assume angle of repose of dumped rock of 1.5H:1V.
4. Excavate downstream Zone 3B batter to flatten slope to 5H:1V to allow for overtopping of the weir. The excavated rock would be placed on the upstream shoulder against the Zone 3A. The upstream Zone 3B material would be placed on a slope of 3H:1V.
5. Place Zone 4 rip rap for erosion protection on the upstream and downstream faces with a long-reach excavator.
6. Install corewall and cutoff. Cutoff would be required to extend to a nominal depth equal to the dam height into the alluvial foundation to form the foundation cutoff (actual depth to be determined in design phase).
7. Place Zone 4 along crest of weir.

8.4.3 Option 2 – Zoned Earth and Rockfill Dam core/cutoff (See Sketch 4 – Appendix 8.1)

This option has been developed on the assumption that the zoned earth and rockfill dam could be constructed in the dry. This would require the construction of the weir to be timed to suit a 'dry' sequence in terms of water levels in Lake Hume, and would also require construction of sacrificial upstream and downstream cofferdams. The construction sequence would be as follows:

1. Construct outlet structure. The outlet for Option 2 would be as for Option 1. Noting that for this option the outlet structure would be required to pass flows during construction of the weir. Spoil from the excavation for the outlet would be used for upstream and downstream cofferdams and the weir generally.
2. Construct Zone 1 core trench. Assume a nominal 2m depth or equivalent to penetrate depth of silt in the foundation.
3. Install cutoff. Cutoff would be required to extend to a nominal depth equal to the dam height into the alluvial foundation to form the foundation cutoff.
4. Progressively place in layers and compact Zone 1 earthfill core, Zone 2A and 2B blanket filters.
5. Following completion of the blanket filter, progressively build the Zones 1, 2A, 2B, 3A and 3B materials up in layers to the top of the core. Zones 1, 2A and 2B placed on a slope of 0.5H:1V. The Zone 3A material would be placed based on an assumed angle of repose of dumped rock of 1.5H:1V. Placement slopes of the Zone 3B zones would be 3H:1V upstream and 5H:1V downstream.
6. Progressively place Zone 4 for erosion protection on the upstream and downstream faces with a long-reach excavator.
7. Cap the Zone 1 earthfill core with Zone 2A, 2B, 3A, 3B and Zone 4.

8.4.4 Options Assessment

8.4.4.1 *Serviceability*

- Both options meet the design intent
- Option 2 is a typical standards based design and hence is more robust with lower long term risk, whereas the arrangement for Option 1 is less typical with uncompacted rockfill and zone thickness determined primarily on constructability rather than technical requirements
- As the dam is constructed on an alluvial, and hence potentially permeable, foundation, both options incorporate protection measures against foundation piping. Option 1 provides for a 'deep' cutoff, increasing the length of the seepage path whilst Option 2 provides a core trench through the silt layer, a 'deep' cutoff, and provides protection against piping through the foundation via a blanket filter. It should be noted that it is not practicable to provide a foundation cutoff that extends to rock due to the depth of alluvials.

8.4.4.2 *Dam and Public Safety*

- Dam safety requirements would be similar for both options. Both options would require routine inspection in accordance with the ANCOLD Dam Safety Management Guidelines. Noting that inspection would be possible when the water level in Lake Hume is below The Narrows weir crest level.
- The risks to public safety would be equal for both options.

8.4.4.3 *Duration, Risk and Constructability*

- There is a risk associated with both options relating to exposure to flood during construction. It is envisaged that the risk could be reduced by programming the works during the 'dry' season. However it is noted that an extreme flood during construction would have considerably less impact on the exposed weir for Option 1 than it would Option 2. It is considered that should a flood occur during construction of Option 2 significant recovery and repair works could be required.
- The total construction duration is expected to be longer for Option 2, noting the additional requirement to construct cofferdams and placement of earthfill and filter zones.
- As discussed in Section 8.2 for Option 2 it would be necessary to time the works to fit within a specific construction window. As such it could be several years before Option 2 could be constructed. Construction of Option 1 could commence at any time that the water level is nominally 1m below weir crest level.
- Option 1 in general is less weather dependent as there are fewer constraints on placement of rockfill compared to earthfill.

8.4.4.4 *Environmental Risk*

- The footprint of both weir arrangements are nominally the same and hence any environmental impact on the watercourse or floodplain would be equal for both.
- In terms of water security the impacts to MDBA are considered equal for all options.
- It is considered likely that Option 2 would require a greater works area as material would need to be stockpiled on site for conditioning prior to placement
- Risk to the environment in terms of noise, dust, contamination of waterways etc. are considered equal for all options.
- In terms of aesthetics both options once constructed would be similar in appearance.

8.4.4.5 *Operation and Maintenance (O&M)*

- Both options require routine inspect and removal of debris and periodic inspection and operation of the outlet.
- On the basis that the weir is assigned a consequence category of 'significant' an estimate of the net present value (NPV) over 50 years at 6% was estimated at $1.25M. This amount is equivalent to an $80K annual budget.

8.4.4.6 *Cost*

- It has been assumed that the earthfill, filters and rockfill could be sourced locally.
- Concept cost estimates have been prepared to provide a comparison in relative costs. The estimates are provided in Appendix 8.2. The estimated capital works cost for each option with crest level of The Narrows weir at RL184mAD, inclusive of ancillary works and contingency costs, is as follows:
  - Option 1 = $64.7M
  - Option 2 = $52.7M

8.5 Additional considerations

8.5.1 Weir Crest Elevation

In addition to dam type, consideration was also given to selection of a weir height. Two options were considered:

- Lowest crest elevation (RL184mAHD)

  It was considered that the lowest crest elevation would provide the most cost effective solution. However it was necessary to ensure that at this level the viability of recreational use would not be affected. RL184mAHD was selected as it is understood that this is the minimum water level that could still be 'ski-able'.
- Maximum water level (RL188mAHD)

  The maximum water level was judged to be the level that allowed for the deepest pool at The Narrows whilst ensuring the afflux for this level was acceptable.

  The results of the afflux study indicated that for weir height RL188mAHD the afflux would be no more than 35mm. However beyond RL188mAHD the afflux increased to 345mm at RL190mAHD. As such it was judged that a weir at RL188mAHD would provide the maximum benefit at The Narrows site with a lesser impact upstream.

The estimated benefit during the months November to April of a weir at the Narrows for both crest elevations is presented in Table 8.2 below, based on historic Lake Hume water levels post Dartmouth (1979 to 2015).

Table 8.2: Estimated Benefit of The Narrows Weir for Nominated Elevations

	RL184mAHD	RL188mAHD
Total Days (Nov - Apr)*	6356	6356
Total Days Below XXmAHD (Nov - Apr)	3300	4557
Percentage Below XXmAHD (Nov - Apr)	52%	72%

**Years in Data Set (1979 - 2015) = 35.26years*

In summary it can be seen that historically the water level in Lake Hume was below RL184mAHD 52% of the time during the months of November to April and below RL188mAHD 72% of the time. This means that a weir at The Narrows at RL184mAHD would have been providing a pool level at The Narrows 52% of the time since the construction of Dartmouth Dam. The other 48% of the time the weir would have been submerged with Hume Dam controlling the water level at The Narrows regardless. If instead the weir at The Narrows had a crest elevation of RL188mAHD the weir would have been providing a pool level at the Narrows 72% of the time since the construction of Dartmouth Dam. The weir would have been submerged for the other 28% of the time.

It was considered that the increase in benefit during the months of November and April resulting from construction of a taller weir warranted further investigation. To this end a cost estimate was prepared for a rockfill weir (Option 1) for the purposes of assessing whether the additional benefit in constructing a taller weir could justify the increased cost. The capital works cost associated with constructing a rockfill weir (including ancillary works) at RL188mAHD was estimated at $99.6M. The capital works cost associated with construction of weir (excluding ancillary works) at RL188mAHD is almost double the capital cost of construction of a weir at RL184mAHD.

In addition it should be noted that in terms of storage capacity the taller weir height at RL188mAHD holds 2.5 times the volume of water as compared to RL184mAHD. These volumes amount to 28GL for RL184mAHD and 70GL for RL188mAHD. It is also noted that the amount of water in storage represents a volume of water 'lost' to the Murray-Darling system, hence has potential to impact on security of supply in the system.

8.5.2 Road Access

Consideration was given to providing vehicle access from one side of the weir to the other and providing a connection between Murray-Valley Highway and Tallangatta-Bethanga Road. It is noted that TSC required two lane, two way access across the weir when Lake Hume is at FSL. For both weir options and crest elevations the weir would be underwater when Lake Hume is at FSL. As such in order to provide access a road bridge would be required. The bridge could be constructed either over the weir with the piers embedded within the weir or as a completely independent structure.

The bridge would be constructed on piles. This work would be undertaken primarily from a barge.

An estimate of cost to construct a bridge meeting the requirements of TSC has been prepared based on the following:

- Two 3.5m wide lanes
- 0.6m shoulders
- No emergency lane
- No provision for pedestrians or cyclists

On this basis the estimated cost for the construction of the bridge would be in the order of $25M.

8.5.3 Fishway

It is noted that the results of future flora and fauna and/or aquatic assessments may identify the requirement for fish passage. Should a fishway be required it is envisaged that based on the likely head differential a vertical slot arrangement would be most suitable. A typical arrangement for a weir with crest level at EL184mAHD would comprise the following:

- Concrete channel (slope 1V:25H) with baffles
- 2.5m wide x 200m long

On this basis the estimated cost for the construction of a vertical slot fishway would be in the order of $5M.

9 REFERENCES

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APPENDIX 4.1 FUNCTIONAL DESIGN CRITERIA MEMO AND PSC COMMENTS TABLE

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Memorandum

Organisation:	**Towong Shire Council (TSC)**
To:	**Alicia Power (Vivid Consulting)**
Copy:	**Lauren Elvin (TSC)**
From:	**SMEC**
Subject	**The Narrows Project – Stage 1 – Functional Design Criteria**
Version	**Draft Rev 1**
Date:	**24/03/2015**
No. Pages:	**4**

INTRODUCTION:

The Narrows Project Feasibility Study is to be undertaken to assess the feasibility of constructing a water control structure across Lake Hume, on the Mitta Mitta arm, west of Tallangatta. It is understood that the lower water level in the Mitta Mitta tributary of Lake Hume, between the months of November and April, impacts on potential recreation and tourism opportunities for the township of Tallangatta. To this end it is envisaged that a water control structure would enable water levels to be maintained during this period.

This Functional Design Criteria memo has been prepared to confirm Towong Shire Council's (TSC), and the Project Steering Committee's (PSC) functional requirements for the structure. The criteria are based on SMEC's understanding of the project drivers from discussions with TSC and utilising information from previous studies. It is intended that any gaps in understanding be identified at this early stage and alignment is reached as to key functional requirements such that these requirements are incorporated into concept design.

OBJECTIVE:

Based on our review of the previous reports and discussions with the TSC a list of key functional objectives are summarised in order of decreasing importance, namely:

- To maintain consistent water levels in Lake Hume at Tallangatta township over the peak tourist season (December to February) each year to encourage recreational water activities. It is noted that the following water activities need to be accommodated:

    - Boating (including power boats)
    - Water skiing
    - Fishing
- To provide an alternative road access to the north side of the Mitta Mitta arm to the west of Tallangatta
- To provide improved water frontage and amenity in vicinity of the township

FUNCTIONAL CRITERIA

Historical Review

In developing the functional criteria a review of previous studies was undertaken. Key aspects associated with these studies are listed below:

- Loder and Bayly et al, 1979
    - When Lake Hume is at RL 181.5m AHD there is 'no useable water' off Tallangatta
- River Murray Commission (RMC), 1985
    - A brief review into maintaining water levels at Tallangatta was undertaken, including the construction of an embankment across the Mitta Mitta Arm. Top Water Level (TWL) was set at RL182mAHD. The report stated that a water level of RL182mAHD would provide sufficient water for recreation at Tallangatta in all years.
    - In regard to hydropower generation a dam with a TWL of RL182mAHD, was expected to reduce hydropower revenue by less than 0.5%.
- Woodward-Clyde, 1995
    - This report documents that in November 1983 the Tallangatta Shire Council put forward ideas for a 'Lock' at RL187mAHD. No reason for the change in TWL from RL182mAHD as previously suggested by the Rural Water Commission to RL187mAHD was provided.
    - A feasibility study into constructing a dam with a TWL at RL192mAHD was undertaken. It is noted that this arrangement included road access across the dam and included hydroelectricity generation.
    - This report documents that at approximate RL182mAHD the boat ramp becomes unusable and water skiing and power boating activities decrease 50%.
    - When levels in Lake Hume drop from 100% to 85% of full capacity there appeared to be no change in recreational use of Lake Hume. When the reservoir dropped from 85% to 50% there was a fall of 10% in the recreational use of the reservoir
    - Storage volume of the dam with a TWL of RL192mAHD was about 2.75% of Lake Hume or 84GL if constructed at 'Point Packer'.
- In an abstract of the history of the Narrows Project, it was recorded that by May 1998 the council proposal for a weir at Tallangatta had been scaled back to comprise a weir of sufficient height to hold back water at Tallangatta at a level of RL188mAHD. At RL188mAHD Lake Hume is approximately at 76% capacity.

It can be seen that in the previous studies various water levels for the dam have been investigated ranging from RL182mAHD to RL192mAHD. In determining an appropriate TWL for the Narrows Dam it was assessed that the water level should be set to allow the enjoyment of recreational activities including boating and water skiing without the potential dangerous hazard of trees and stumps discouraging or hindering the recreational activities.

Functional Design Arrangements

The key function design requirements are detailed below:

- Low maintenance

  It is proposed that the structure be an unregulated structure with no routine operational requirements. It is intended that the only operational 'rule' would involve release of the Narrows storage via the outlet on request from the operators of Hume Dam. It is envisaged that this release of the storage would be triggered at a particular water level in Lake Hume.

- Flood Afflux

  Ensure minimal affect upstream of the weir as a result of the afflux caused by the construction of a weir across the river channel.

- Flooding

  Structure needs to be capable of passing flows generated by the upstream catchment as well as Dartmouth dam spill flows via overtopping of the weir.

- Outlet

  The outlet would be designed to meet dam safety emergency drawdown requirements. It is noted that it is not intended that the outlet be operated for run of river flows.

- Fishway

  Upstream and downstream fish migration requirements would be assessed as part of options development to determine if there is any requirement for a fishway.

- Road Access

  As the structure is to be designed to be overtopped, road access across the weir would require construction of a bridge/culvert. It is noted that TSC requires two-lane, two way access. SMEC require input from the PSC on this aspect in regard to access requirements, including:

  - confirmation of road width i.e. assume 3.5m width lanes with shoulder and pedestrian/maintenance access on either side
  - access requirements i.e. how often is the road likely to be used? Would it be acceptable for the road to be closed when Lake Hume is at 100% or 75% of 50% capacity?

- Other aspects that would need to be considered at a later stage of the overall project include:

  - Siltation
  - Water quality

With consideration of the above requirements SMEC has developed two alternative functional design criteria for consideration. Following PSC review it is envisaged that agreement would be reached on the preferred criteria before the options development phase commences. It is recognised that the criteria may require amendment to incorporate any comments received from the PSC. In particular, relating to the water depth requirements for the various recreational activities.

The alternate functional design criteria are summarised below and in Table 1:

- Option 1 – TWL = RL188mAHD

  This option has been nominated to further investigate the option proposed by the council in 1998. At this elevation it is expected that a suitable water level can be provided for recreational use whilst minimising the height of the weir required.

  It is noted that this at RL188mAHD the weir would be 4m below the FSL of Hume Dam and hence fully submerged. Requirements of road access would need to be confirmed.

- Option 2 – TWL = RL 191mAHD

  This option has been proposed to maximise the water level at Tallangatta, whilst ensuring that the recorded inflows down the Mitta Mitta arm can be safely passed over the weir without exceeding the FSL of Hume Dam.

  It is noted that at RL91mAHD the weir would be 1m below the FSL of Hume Dam and hence fully submerged. Requirements of road access would need to be confirmed.

Table 1: Functional Design Criteria

	Option 1	**Option 2**
Weir Crest Level	RL188mAHD	RL191mAHD
TWL	RL188mAHD (average water depth 12m)	RL191mAHD (average water depth 15m)
Foundation Level	RL176mAHD (nominal)	RL176mAHD (nominal)
Outlet Invert Level	RL176mAHD (nominal)	RL176mAHD (nominal)

In addition, in establishing the functional design criteria for the Narrows project consideration was given to the likely Consequence Category for the dam. An initial assessment of the consequence category of the weir was undertaken using ANCOLD, 2012, Guidelines on the Consequence Categories for Dams. As the weir is upstream of Hume Dam, and within the water body of Lake Hume, the severity of damage and loss resulting from a dam failure is likely to be minor to medium. The dambreak would only involve water flowing into the existing Hume Lake, and the main loss will be the loss of a local or possibly regional recreational facility. With regard to population at risk (PAR) it is judged that the only people potentially at risk during a dam failure are either water users within the reservoir or those users immediately downstream of the dam at the time of failure. As such, a conservative assumption of PAR between 1 and 10 is considered reasonable. Based on this initial assessment the weir would be classified as a 'Significant' consequence category dam

On the assumption that the weir has a Consequence Category of Significant the following design loadings as suggested by ANCOLD would be considered.

Load Case	**Usual**	**Unusual**		**Extreme**	
		Flood	Earthquake (OBE)	Flood	Earthquake (MDE)
Very low to Significant Consequence Category Dams	1:50 AEP Flood but with FSL as a minimum case	1:500 AEP	1:475 AEP	1:1000 AEP to 1:10,000 AEP	1:1000 AEP

Note: OBE – Operating Basis Earthquake

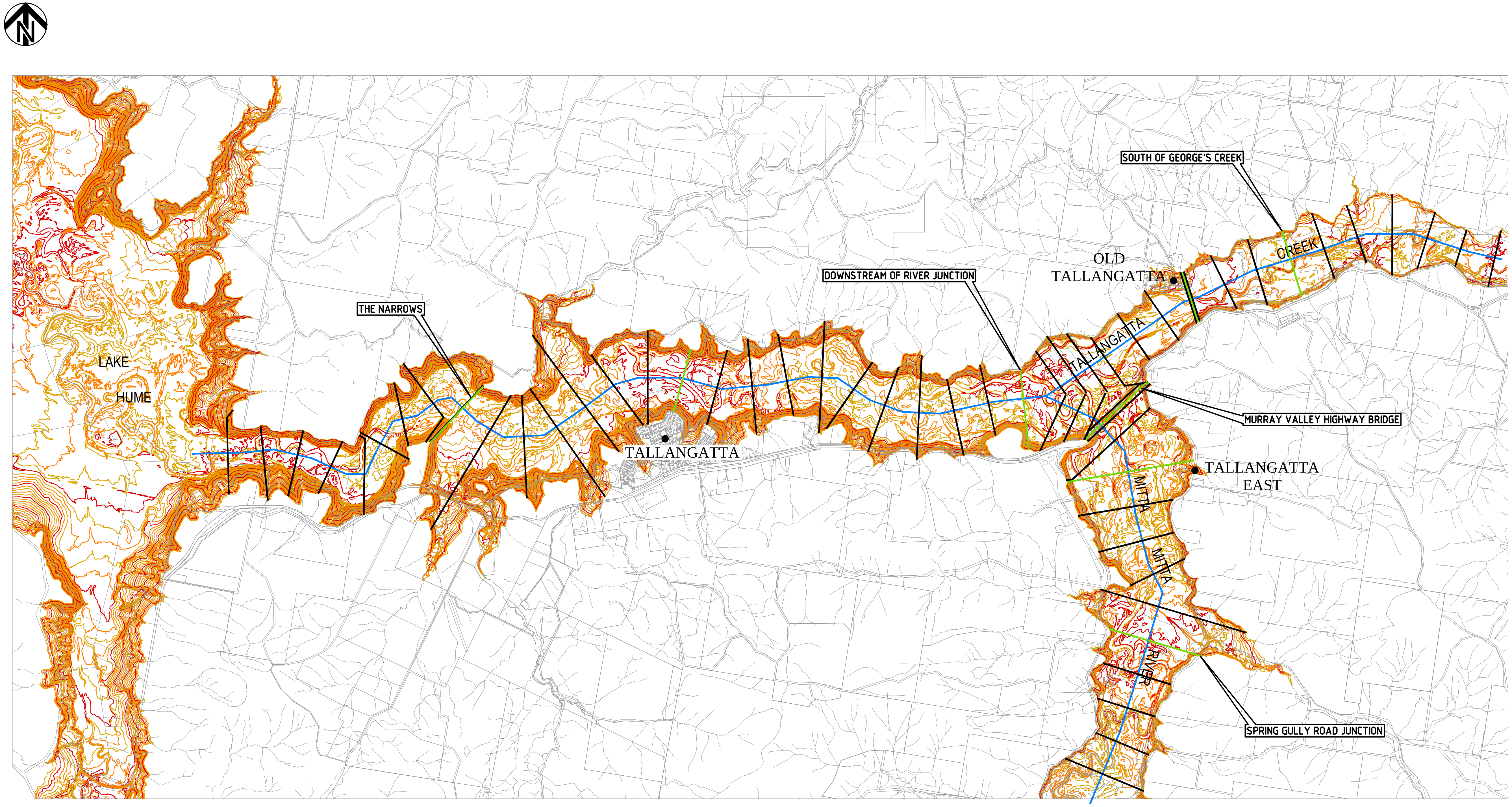
MDE – Maximum Design Earthquake

Functional Design Criteria Requirement	TSC/PSC Comments	Organisation	SMEC Comment/Action
Low Maintenance	None	n/a	n/a
Flood Afflux	The flood afflux at 1:100 year event should be zero or close to as agreed with TSC	G-MW (Graeme Hannan)	The predicted inflow to the Narrows for the 1:100 event is not known. An estimated correlation has been made based on inflow/outflow data for Dartmouth and Hume Dams provided by MDBA. More detailed assessment can be undertaken should project progress to the next phase
	The flood afflux should be estimated and reported for the other flood cases (1:50, 1:1000, 1:10,000)	G-MW	An exact correlation between inflow to the Narrows and return period could not be determined based on data provided. Flood afflux was estimated for a number of meaningful flows. An estimated correlation has been made between these flows and return period. More detailed assessment can be undertaken should project progress to the next phase
Flooding	While an unlikely scenario, consideration should be given to downstream water level exceeding upstream in the event of a large Murray flood that is not matched by a flow on the Mitta Mitta. This would be possible if the adopted TWL is less than the FSL for Lake Hume	MDBA (Andrew Reynolds)	Noted – albeit consider that this Murray flood is an 'extreme' event and hence the weir does not require the same level of design as necessary for flows travelling in the upstream to downstream (Mitta Mitta flow) direction. Intended operation for The Narrows would be that The Narrows is at top water level on all occasions except for when there are extreme low levels in Lake Hume. As such a high Murray inflow would be absorbed into Lake Hume downstream of The Narrows.
Outlet	Do not understand the statement "run of river flows"	G-MW	The statement run of river flows was intended to convey that the outlet would not be designed to release flood flows on the Mitta Mitta River.
	The low level outlet will have capacity to meet the maximum transfer rate from Dartmouth to Hume, say 10,000ML/d The outlet would need to pass the maximum transfer from Dartmouth to Hume (say 10,000ML/d) with both the upstream and downstream pools drawn down to near empty. This is necessary to protect downstream entitlements in severe drought.	G-MW MDBA	Disagree – The size of the outlet would need to be considerable to pass 10,000ML/d. Consider that a smaller outlet would be suitable noting that once the storage is full inflows would be passed via the spillway increasing the overall discharge capacity of the structure

Functional Design Criteria Requirement	TSC/PSC Comments	Organisation	SMEC Comment/Action
	Maintenance access/dewatering capability must be provided with consideration that water levels may stay high for an extended period (in particular a low level outlet may be submerged for many years)	MDBA	Agreed – dewatering capability would be considered as part of establishing the size of the outlet, however not under high river flow scenario. Should planned maintenance be required it is expected that releases from Dartmouth would facilitate this. Agreed – durability of the outlet would an aspect considered as part of the concept design, albeit considered most relevant for detailed design
Fishway	None	n/a	n/a
Road Access	If there is a road structure it will be available when Lake Hume is at FSL	G-MW	Noted – Based on this requirement a road bridge (similar to the Murray Valley Hwy bridge) would be required. The elevation of the road bridge would be set such that the road would be accessible up to a 1 in 100 event and permit recreational craft to safely navigate the lake.
	A means to close the road when lake levels are high is needed	MDBA	Agreed – However consider that this a requirement for Detailed Design
	Two lane, two way access is required	TSC	Noted
Siltation	None	n/a	n/a
Water Quality	Consider that water quality is a consideration for Phase One. Three items that would need addressing are: Increase in BGA counts Increase in turbidity Increase in Pathogen risk	NEW	Disagree – not in current scope. Requirement is to provide technical definition only. Agree that Water Quality is a factor that should be considered albeit at a later phase of the project
Boat Access	G-MW opinion is that a lock for boat transfer should not be provided	G-MW	Agreed – Although boat access will be available subject to Lake Hume water levels, as The Narrows weir would be below the FSL of Lake Hume
	If the embankment is to be submerged at higher lake levels then appropriate navigation warning infrastructure be provided	MDBA	Agreed – However consider that this a requirement for Detailed Design
Operation of the Narrows	As project progresses O&M requirements of the owner (as yet defined) need to be defined	G-MW	Agreed – Consider appropriate for a later phase
	Provision for removal of debris from road bridge piers or culverts	G-MW	Agreed – However consider that this a requirement for Detailed Design

Functional Design Criteria Requirement	TSC/PSC Comments	Organisation	SMEC Comment/Action
	Within reason, the design should consider potential rates of rise and fall in the upstream pool noting that an 88GL storage could fill very quickly under flood scenarios, and depending on the operating protocols, could need to be drawndown quite rapidly in a dry sequence	MDBA	Agreed – The necessity for rapid drawdown for operational purposes needs to be explored in detailed design. Regardless, rapid drawdown would be a consideration when developing the weir arrangement. Albeit that analysis of the weir for this load case would be undertaken as part of detailed design
Crest Level	Design Pool Level of 184mAHD for a cost effective solution	G-MW	A range of levels will be considered with 184mAHD the lowest height option
Recreational Use	Ski-able water level is 184.1mAHD and equates to 1m above the bottom of the boat ramp	G-MW	Noted
Land Ownership/Acquisition	Land ownership to be identified at the selected site and an estimate of land acquisition costs provided in the design	G-MW	Agree that Land Ownership is a factor that should be considered albeit at a later phase of the project. However, not in current scope. Requirement is to provide technical definition only.
	SMEC will need to evaluate the land impacts/acquisition including consideration of land below FSL that G-MW currently leases to adjacent landowners. This will become less productive if it is inundated for long periods	MDBA	Agree that Land Ownership is a factor that should be considered, albeit at a later phase of the project. However, not in current scope. Requirement is to provide technical definition only.
Construction	Construction method to be provided and suitable for inundation of the works	G-MW	Agreed
	Construction method must be sequenced such that flows pass the structure are not impeded and the upstream water could be accessed should it be necessary to meet entitlements	MDBA	Agreed
Erosion Protection	The design of all works will minimise erosion at all site subject to flow and wave action	G-MW	Agreed – However consider that this a requirement for Detailed Design
Impacts on hydro-generation	Impacts on downstream pool level as a result of operations will need to be assessed with consideration of impact on hydro generation at the existing Hume Power station. Impact needs to be assessed noting that Hume power station is privately owned	MDBA	Agree that impact on hydro generation is a factor that should be considered, albeit at a later phase of the project. However, not in current scope. Requirement is to provide technical definition only.

APPENDIX 5.1 WATERCOURSE LAYOUT



LEGEND:

- RIVER STRING
- SOURCE STRING
- SOURCE STRING DOCUMENTED IN REPORT

SMEC AUSTRALIA PTY LTD
© ACN 065 475 149
LEVEL 10, 71 QUEENS ROAD
MELBOURNE VIC. 3004
PH 03 9514-1500 FAX 03 9514-1502

THE NARROWS PROJECT FEASIBILITY - STAGE 1

AFFLUX INVESTIGATION
HEC-RAS MODEL
WATERWAY LAYOUT

job no. 30041148
rev no. A

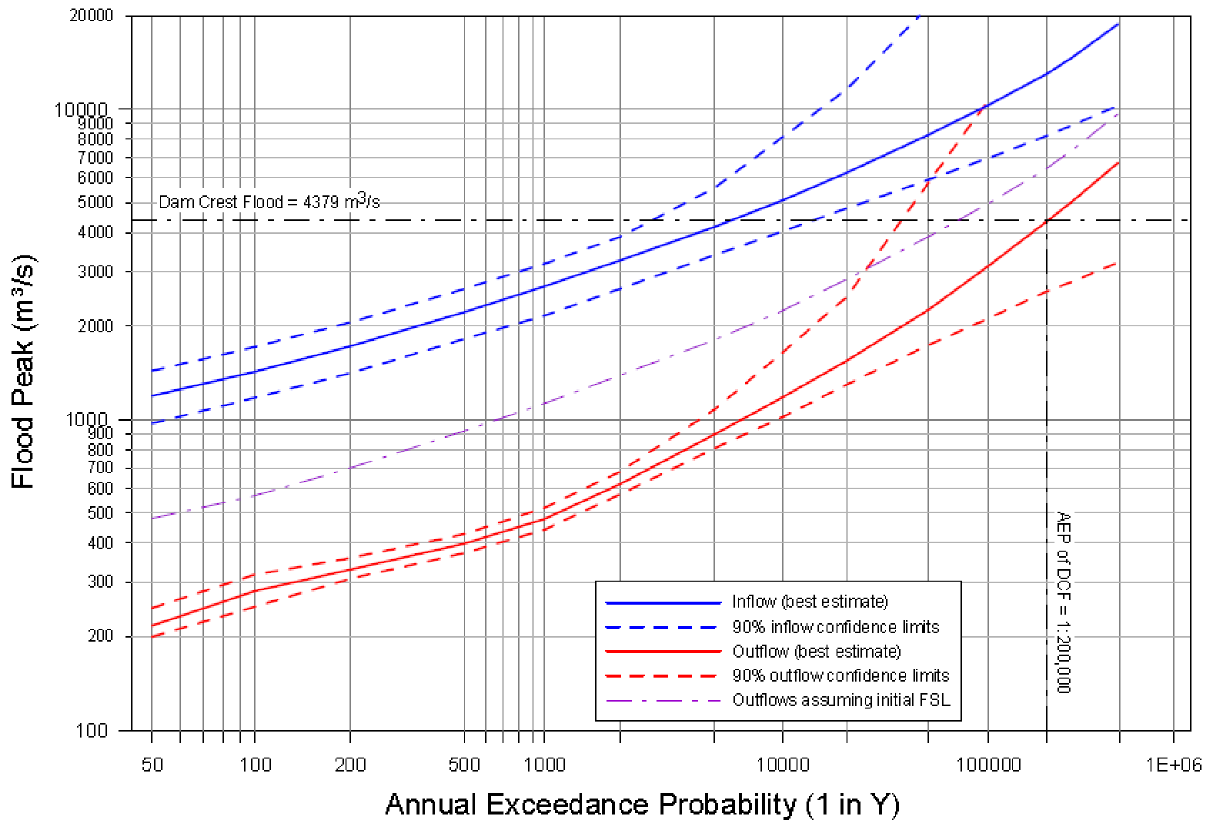
scale 1:60000 date JULY 2015

FIG-1

APPENDIX 5.2 FLOOD FREQUENCY CURVES FOR DARTMOUTH AND HUME DAMS

Extract from 'Dartmouth Dam Spillway Adequacy Review' report prepared by SKM for Goulburn-Murray Water (Final 2 – 29 January 2010)

SKM



- **Figure 6-1 Inflow and outflow frequency curves for Dartmouth Dam.**

NB: This information is provided for use in preliminary studies on the Narrows project only and is not to be distributed or used for any other purpose.

Extract from ‘Hume Dam Assessment of Hydrologic Risk – Stages 4 and 5 – Derivation of Inflows and Outflows’ report by State Water NSW & SKM (Final April 2010)

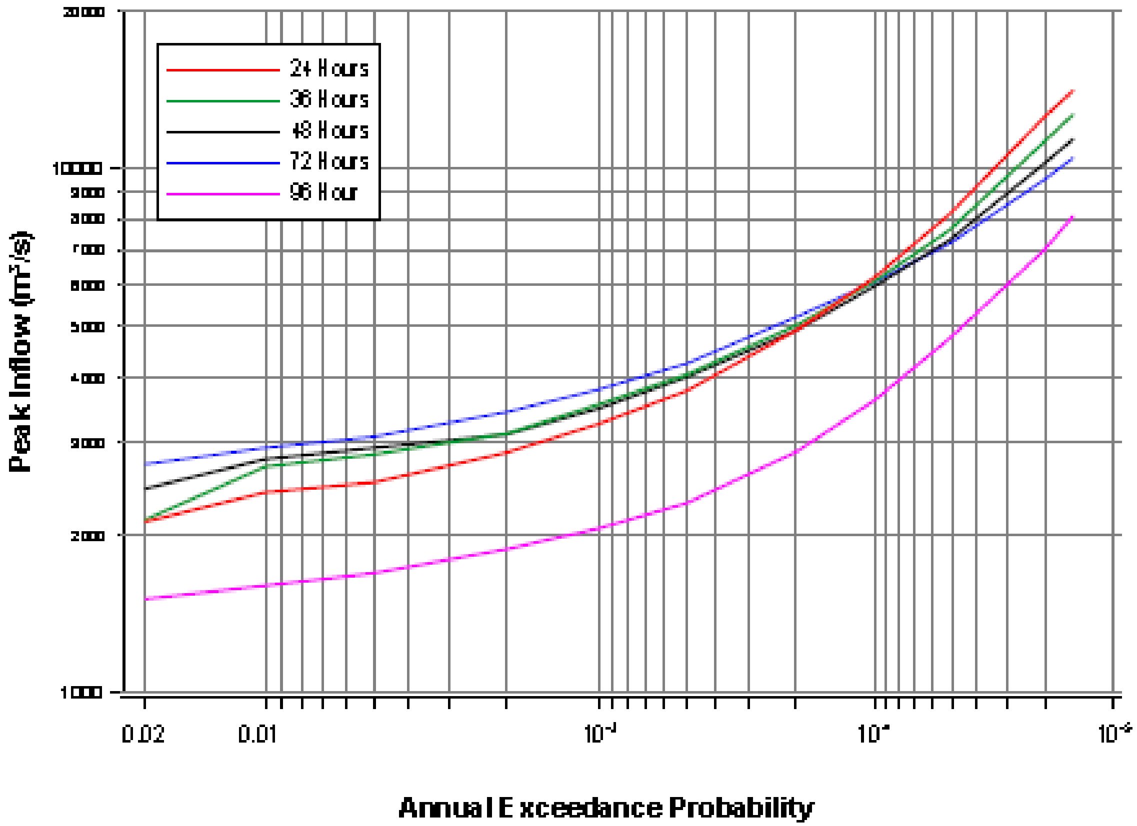


Figure 6.1 – Hume Dam inflow frequency curves.

NB: This information is provided for use in preliminary studies on the Narrows project only and is not to be distributed or used for any other purpose.

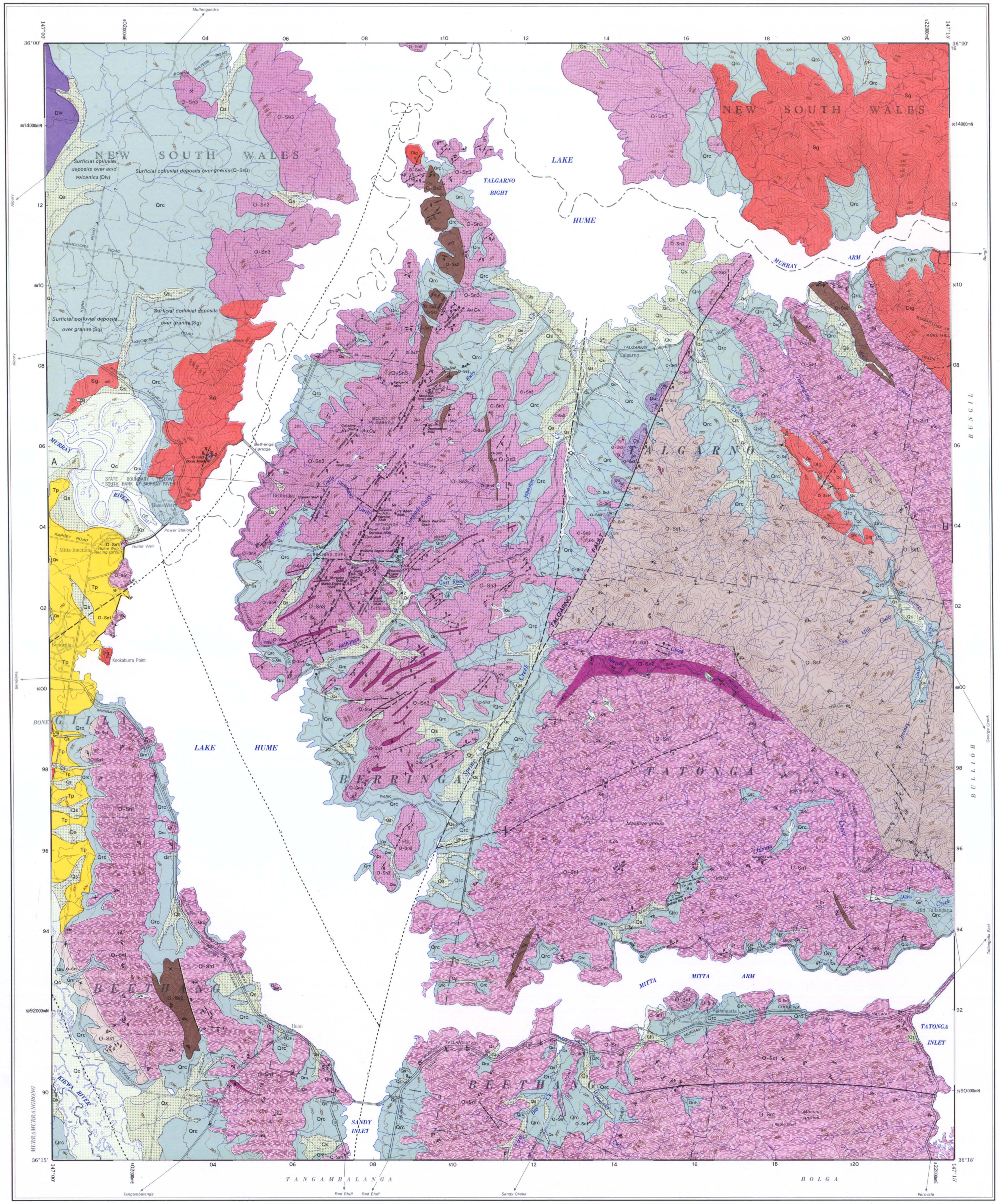
APPENDIX 6.1 GEOLOGICAL MAPS AND EXPLANATORY NOTES

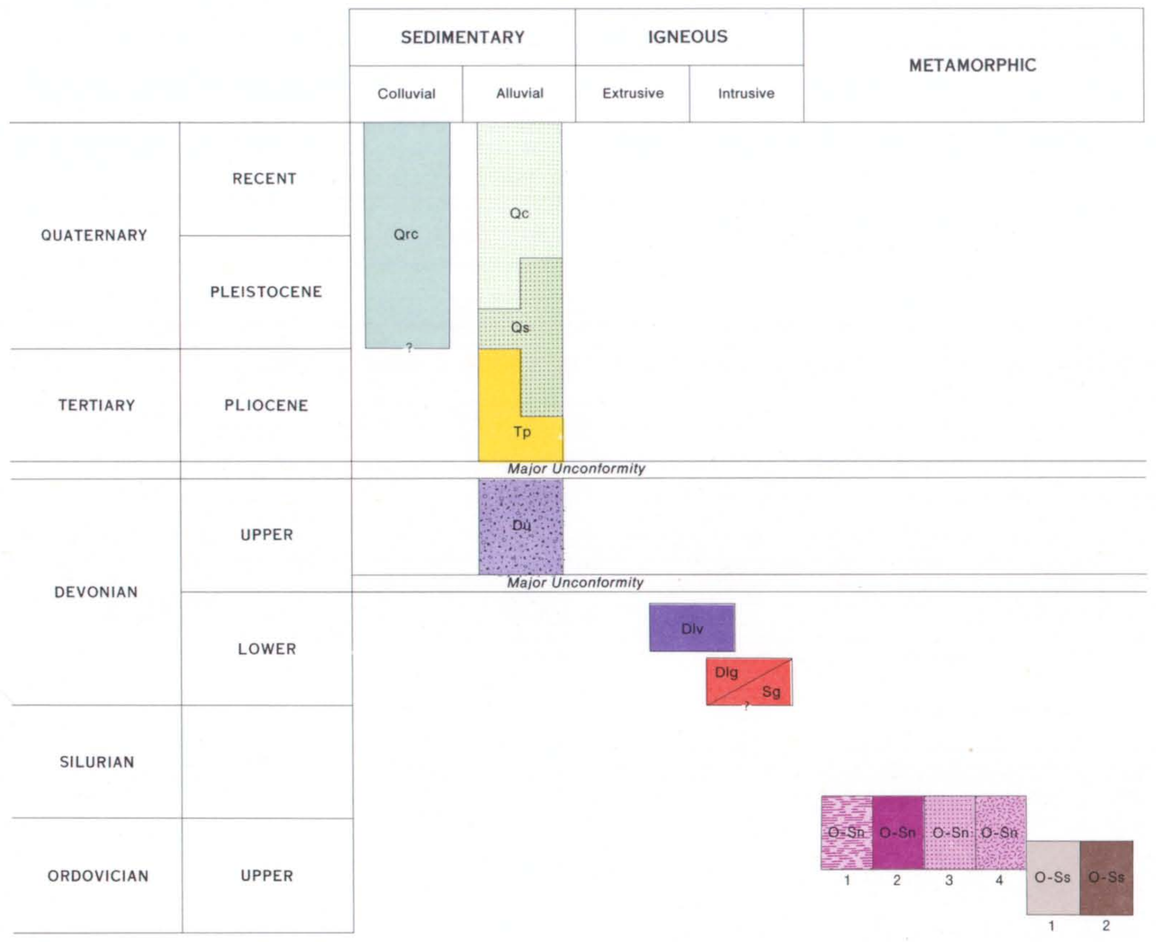
AUSTRALIA 1:50 000

HUME

GEOLOGICAL SURVEY OF VICTORIA

8325 - IV ZONE 55



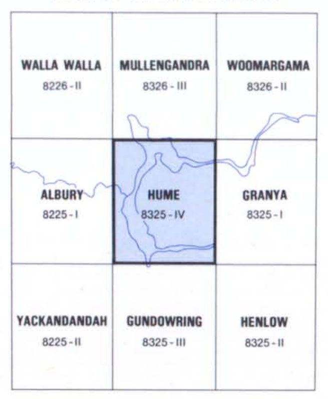


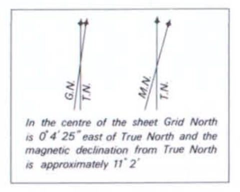
Coonambidgal Formation	Qc	*Grey clay, sandy clay and silt, poorly developed dark grey soil*
Shepparton Formation	Qs	*Buff to yellow-brown clay, silt, sand and gravel, soil grey-buff to red brown*
	Qrc	Colluvium: *hillwash and scree deposits; red to yellow silt, sand and gravel poorly sorted. Red-brown soil*
	Tp	*Red-brown well sorted sand and gravel overlying buff silt and sand Red-brown soil. (This formation is split into two units on the adjoining* Albury 1:50 000 sheet*)*
	Du	*Red to purple conglomerate, minor sandstone and siltstone*
	Dlv	*Quartz-feldspar porphyry, rhyolite, tuff, quartzite*
Koetong, Hawkesview and Yackandandah Granite	Dlg, Sg	*Fine to medium grained granite, includes* Yackandandah Porphyritic Granite
	O-Sn	Gneiss: 1. Rubyview Gneiss: *grey, fine to coarse grained gneiss. Banded, or massive, poorly foliated, granitic in composition* 2. Bethgarno Gneiss: *grey, finely banded gneiss. Amphibole and biotite-rich bands alternating with quartz-feldspar rich bands* 3. Bethanga Gneiss: *medium to coarse grained biotite-rich gneiss, strongly contorted with sedimentary xenoliths. Frequent garnet, grades into foliated medium to coarse grained gneiss.* 4. Bellbridge Gneiss: *medium to coarse grained, poorly foliated to well foliated gneiss with abundant feldspar porphyroblasts.*
	O-Ss	Schist: 1. Tarrangatta Schist: *silver-grey to buff schist, in places, knotted with staurolite, andalusite and sillimanite* 2. Talgarno Schist: *fine to medium grained grey and white banded schist, variably micaceous. Minor grey quartzites.*

Geological boundary	*Basic dyke*	*Highway with route marker*
Geological boundary inferred	*Pegmatite dyke*	*Main connecting road*
Fault	*Granite or aplite dyke*	*Other road*
Fault inferred	*Diorite dyke*	*Track*
Fault concealed	*Shaft*	*Railway line with station*
Fault concealed and inferred	*Adit*	*Abandoned railway line*
Dip and strike of bedding	*Government bore*	*State boundary*
Dip and strike of foliation	*Gold; Copper* — Au; Cu	*Parish boundary*
Vertical foliation	*Watercourse*	*Parish name* — BUNGIL
Quartz vein	*Swamp*	*Bridge*
Quartz vein significantly mineralized	*Contours (20 metre interval)*	*Power transmission line*
Quarry, abandoned quarry	*Depression contour*	*Trig. station*

INDEX TO ADJOINING SHEETS

WALLA WALLA 8226 - II	MULLENGANDRA 8326 - III	WOOMARGAMA 8326 - II
ALBURY 8225 - I	HUME 8325 - IV	GRANYA 8325 - I
YACKANDANDAH 8225 - II	GUNDOWRING 8325 - III	HENLOW 8325 - II





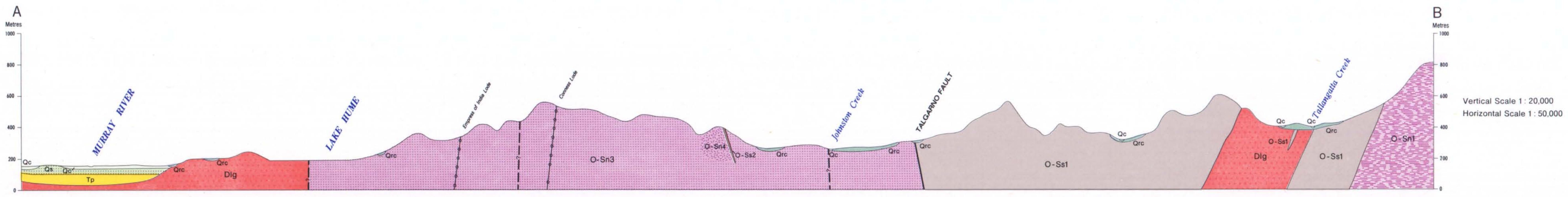
Scale 1:50,000

METRES 1000 500 0 1 2 3 4 5 6 KILOMETRES

CONTOUR INTERVAL 20 METRES
VERTICAL DATUM IS BASED ON LOW WATER, HOBSONS BAY

AUSTRALIAN MAP GRID - TRANSVERSE MERCATOR PROJECTION
HORIZONTAL DATUM - AUSTRALIAN GEODETIC DATUM 1966

NUMBERED TICKS INDICATE THE 2,000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 55, AUSTRALIAN NATIONAL SPHEROID
THE LAST THREE DIGITS OF THE GRID NUMBERS ARE OMITTED



Geology compiled and resurveyed by P J O'Shea MSc, incorporating previous work by J G Easton, J P L Kenny, N Williams and R L King New South Wales geology by courtesy of the Geological Survey of New South Wales

J G Douglas, MSc, PhD, Supervising Geologist, Regional Geology
J L Knight, BSc, DPA, Director of Geological Survey

Drawn for reproduction in the Department of Minerals and Energy Melb., by G M Short,
W J Bennett, MAIC, Chief Draughtsman, 1979

Base prepared from information supplied by the Department of Crown Lands and Survey

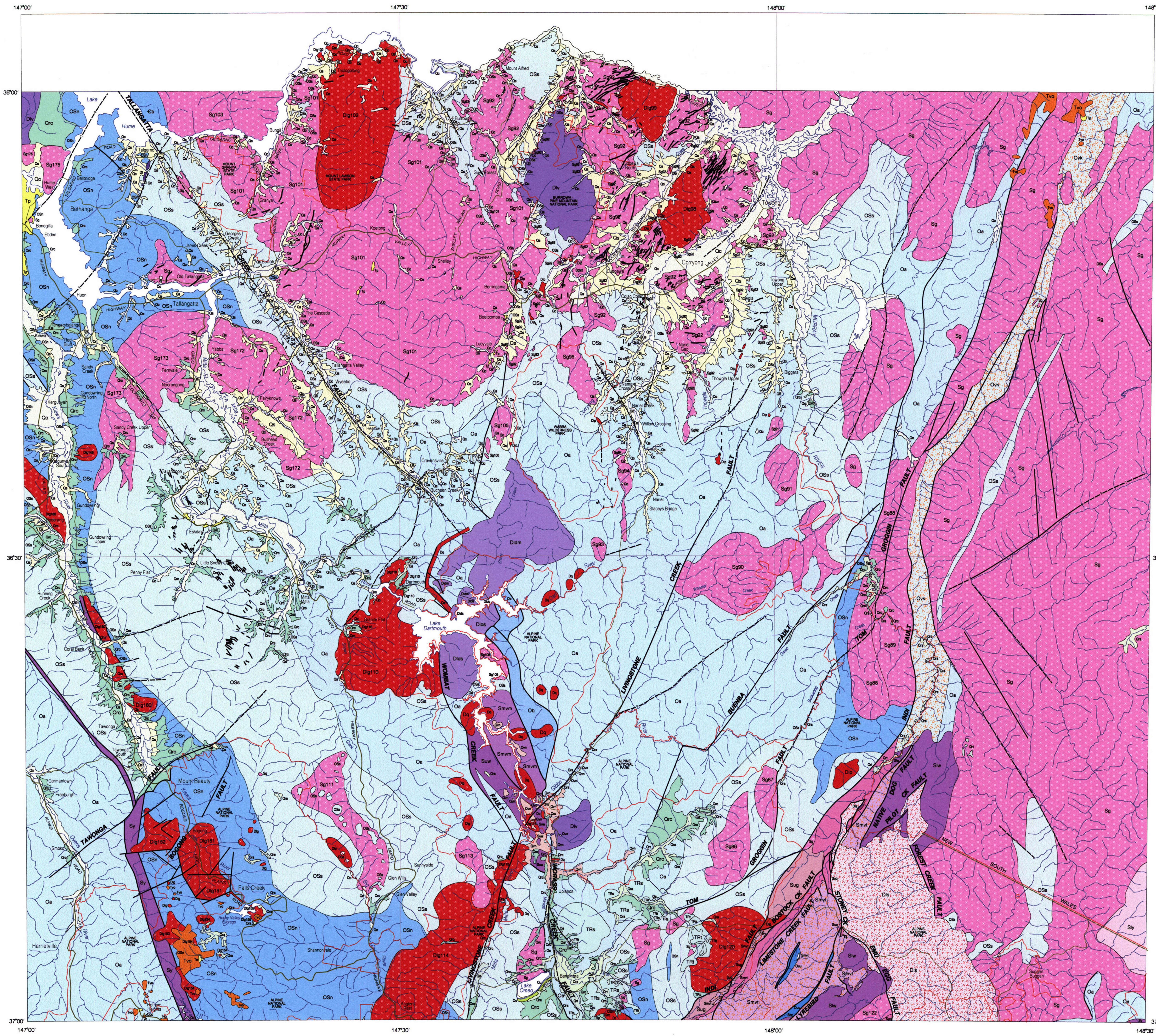
Issued by B W Court, Secretary for Minerals and Energy, under the authority of the Honourable J C M Balfour, MLA, Minister for Minerals and Energy

F D Atkinson, Government Printer, 1979

FIRST EDITION 1979

HUME

8325 - IV ZONE 55



Period	Epoch	Symbol	Group	Formation / Unit	Description
QUATERNARY	MOSTLY HOLOCENE	Qra			Qra *Fluvial: alluvium, gravel, sand, silt*
		Qrc			Qrc *Fluvial: "gully" alluvium, colluvium: gravel, sand, silt*
		Qrt			Qrt *Fluvial: alluvial terraces: gravel, sand, silt*
		Qc		Coonambidgal Formation	Qc *Fluvial, lacustrine: clay, sand, sandy clay*
	HOLOCENE TO PLEISTOCENE	Qu			Qu *Aeolian: lunette deposits: sand, silt, clay*
	PLEISTOCENE	Qpc			Qpc *Fluvial: "gully" alluvium, colluvium: gravel, sand, silt*
		Qs		Shepparton Formation	Qs *Fluvial: silt, sand, minor gravel*
TERTIARY	PLIOCENE	Qvn	NEWER VOLCANICS		Qvn *Extrusive: tholeiitic to alkaline basalts, minor scoria and ash*
	PLIOCENE TO MIOCENE	Tp		undifferentiated	Tp *Fluvial: gravel, sand, silt*
	EOCENE TO OLIGOCENE	Tvo	OLDER VOLCANICS		Tvo *Extrusive: tholeiitic and minor alkaline basalts*
	EOCENE	Te		undifferentiated	Te *Fluvial: gravel, sand*
TRIASSIC	MIDDLE	TRp		Mount Leinster Igneous Complex	TRp *Intrusive: granite porphyry*
		TRs			TRs *Intrusive: syenites, syenite porphyry*
		TRt			TRt *Extrusive: trachyte, sediments*
DEVONIAN	UPPER	Dl		unnamed	Dl *Fluvial: conglomerate, sandstone, mudstone*
	LOWER	Dla	BUCHAN GROUP	Buchan Caves Limestone	Dla *Marine: limestone, dolomite, well-bedded dark grey recrystallized*
		Dls	SNOWY RIVER VOLCANICS		Dls *undifferentiated volcanics, sediments, intrusives*
		Dlp		ring dyke	Dlp *Intrusive: granite/granodiorite porphyry*
		Dlv			Dlv *Extrusive/fluvial: rhyolitic ignimbrite, lava, quartzite*
		Dlds	DARTELLA VOLCANICS	Sheevers Spur Rhyodacite	Dlds *Extrusive: felsic ignimbrite, minor andesite*
		Dldm		Murtagh Creek Rhyolite	Dldm *Extrusive, fluvial: felsic ignimbrite, agglomerate, minor siltstone*
		Dldc		Dart River Volcanic Breccia	Dldc *Fluvial, lacustrine? : black siltstone, volcanogenic sandstone, slate breccia*
		Dt	MOUNT TAMBO GROUP		Dt *Fluvial, marine, extrusive: conglomerate sandstone, mudstone, ignimbrite*
		Dq			Dq *Intrusive: porphyry*
		Dlg			Dlg *Intrusive: granite quartz monzodiorite quartz diorite*
SILURIAN	UPPER	Suq	ENANO GROUP	Cowombat Siltstone	Suq *Marine: siltstone, laminated, minor sandstone, limestone lenses*
		Sug		Gibsons Folly Formation	Sug *Marine, extrusive, intrusive: siltstone, andesite*
		Suw	WOMBAT CREEK GROUP		Suw *Marine: conglomerate, sandstone, siltstone, limestone*
	LOWER	Smvt	THORKIDAAN VOLCANICS		Smvt *Marine, intrusive, extrusive: felsic lava, ignimbrite, porphyry, minor sediments*
		Smvm			Smvm *Marine, extrusive, intrusive: rhyolite, lava ash*
		Sg			Sg *Intrusive: granite*
		Slw		Towanga Sandstone	Slw *Marine: sandstone, thick to thin bedded, siltstone, minor conglomerate*
		Sy			Sy *mylonite, fault rock*
		Sly	YALMY GROUP		Sly *Marine: sandstone, thick to thin bedded, siltstone*
ORDOVICIAN	UPPER	Ouu		Blueys Creek Formation	Ouu *Marine: chert, volcaniclastic sandstone*
		Ob	BENDOC GROUP		Ob *Marine: black shale, cherty shale, stripy thin-bedded sandstone and siltstone, laminated siltstone*
	LOWER	Ovk	KIANDRA GROUP		Ovk *Marine: basalt lava, agglomerate, sandstone, chert*
		OSn		Omeo Metamorphic Complex	OSn *Metamorphic: gneiss*
		OSs			OSs *Metamorphic: schist, spotted schist, phyllite*
		Oa	ADAMINABY GROUP	Pinnak Sandstone	Oa *Marine: sandstone, mudstone, siltstone, minor chert*

Dlg

G98	Mount Mittamatite
G99	Pine Mountain
G102	Thologolong
G110	Bannimboola Quartz Diorite
G114	Anglers Rest Granite
G115	Taylors Crossing Tonalite
G116	Lower Tableland Granite
G120	Marengo
G148	Gundowring
G151	Spion Kopje
G152	Big Hill Quartz Diorite
G153	Niggerheads
G154	Pretty Valley
G155	Rocky Valley
G180	Kergunyah Granite

Sg

G86	Mount Misery
G87	Buckwong (Mount Murphy)
G88	Butchers Block
G89	Tom Groggin
G90	Boebuck Adamellite
G91	Bunroy Hut
G92	Corryong Granite
G93	Glendart
G94	Nariel
G95	Wabba Granodiorite
G101	Koetong Granodiorite
G103	Granya
G105	Beetomba
G108	Eustace Creek Granodiorite
G111	Mount Willis
G113	Post Office Granite
G122	Forlorn Hope Granite
G172	Yabba
G173	Lockhart Adamellite
G175	Bethanga Gneiss

WARNING! - DATUM

Incorrect description or usage of datums can cause errors. This affects the use of maps, map co-ordinates and spatial data.

What you should do:

- Always check carefully and specify explicitly the datums of all data, maps and map references that you use, supply and/or receive.
- If you are unsure or unaware about datums then immediately seek and use expert assistance.
- Note in particular that wrong use of GDA94 and AGD66 datums can in Victoria displace positions by about 200m to the NE or SW, or both.

Further information:
http://anzlic.org.au/geodesy/datums/datums.htm

DATUM NOTES

Horizontal datum: Australian Geodetic Datum (1966).

Vertical datum: Australian Height Datum (1971).

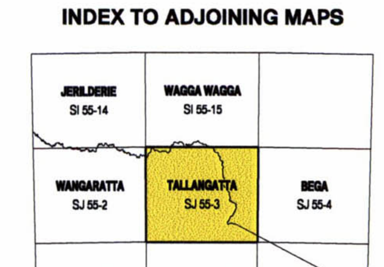
MAP SCALE 1:250 000

metres 5000 2500 0 5 10 15 20 25 kilometres

PROJECTION NOTES

Albers Conical Equal Area Projection.
Australian National Spheroid.
Standard parallels 35°S, 38°S.

INDEX TO ADJOINING MAPS



SYMBOL LEGEND

GEOLOGY

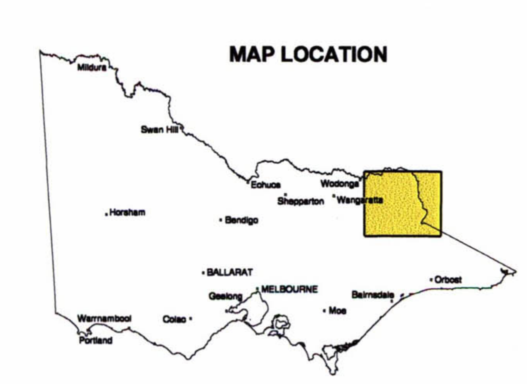
- Geological boundary
- Fault, position accurate/approximate/inferred
- Thrust fault, triangle on upthrown side
- Strike-slip fault, showing relative displacement
- Normal fault, tick on downthrown side
- Monocline crest, arrows point to downthrown side, position accurate/approximate
- Anticline, position accurate/approximate
- Syncline, position accurate/approximate
- Dyke

TOPOGRAPHY

- Main road
- Other road
- Track
- Railway track; operating, dismantled
- Trig station, peak — STAUGHTON HILL, DIAMOND HILL
- Watercourse
- Channel, drain
- Park boundary. Area may not be available for mining

Not all structure shown in the above legend necessarily appears on this sheet

MAP LOCATION



Natural Resources and Environment
AGRICULTURE
RESOURCES
CONSERVATION
LAND MANAGEMENT

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Manager Geological Survey: T. W. Dickson.

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Publishing process: G. A. Callaway, K. Dodd
Manager Draughting: J. P. Kinder.

In this hardcopy edition, the geology has been updated with respect to the AUSLIG hydrographic base used.

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It should be noted that large hydrographic features shown, such as lakes and coastline, may not be part of the AUSLIG data set.

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GEOLOGICAL SURVEY OF VICTORIA

1:250 000 Geological Map Series

TALLANGATTA

SJ 55-3

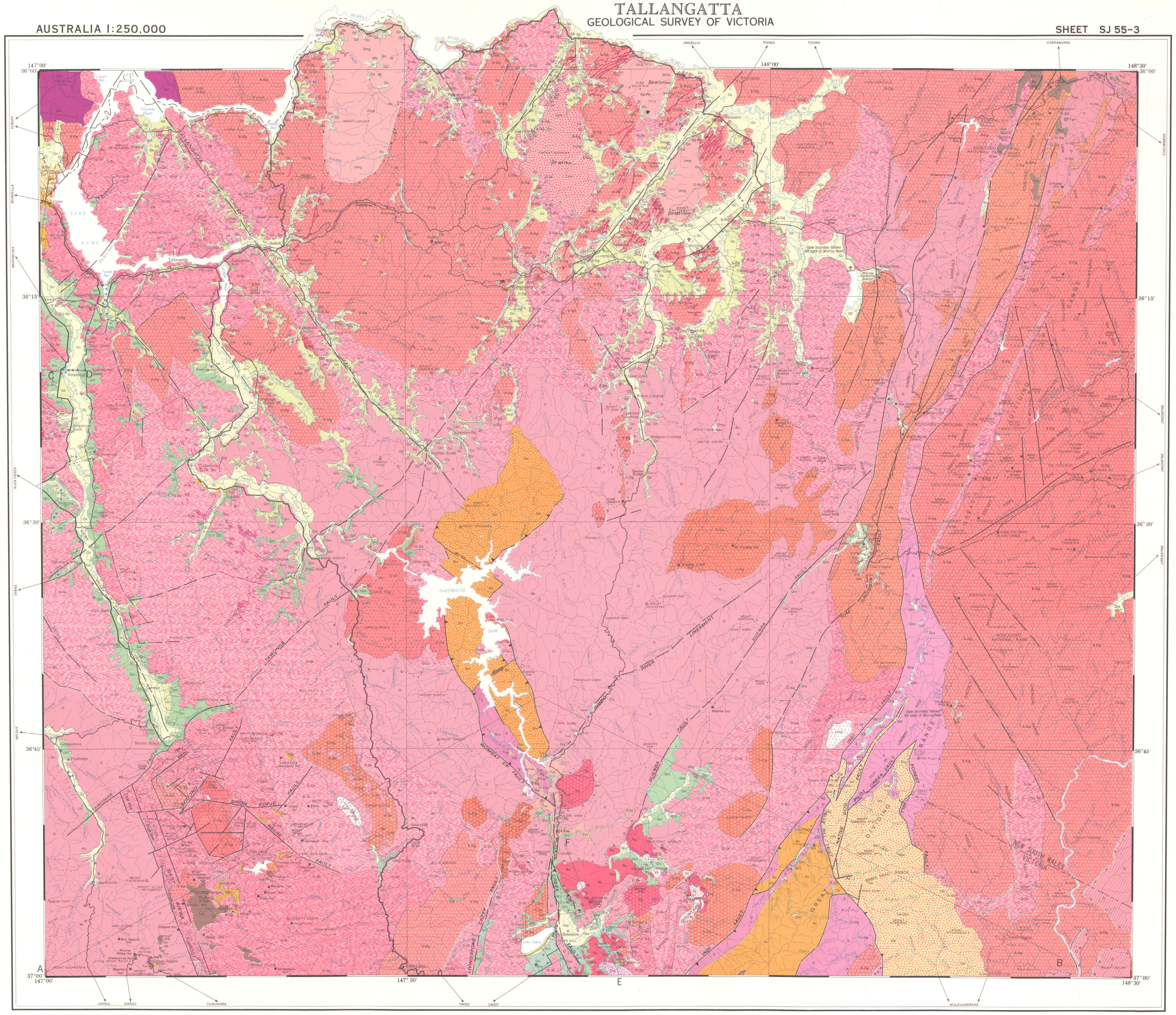
Edition 2
May 1997

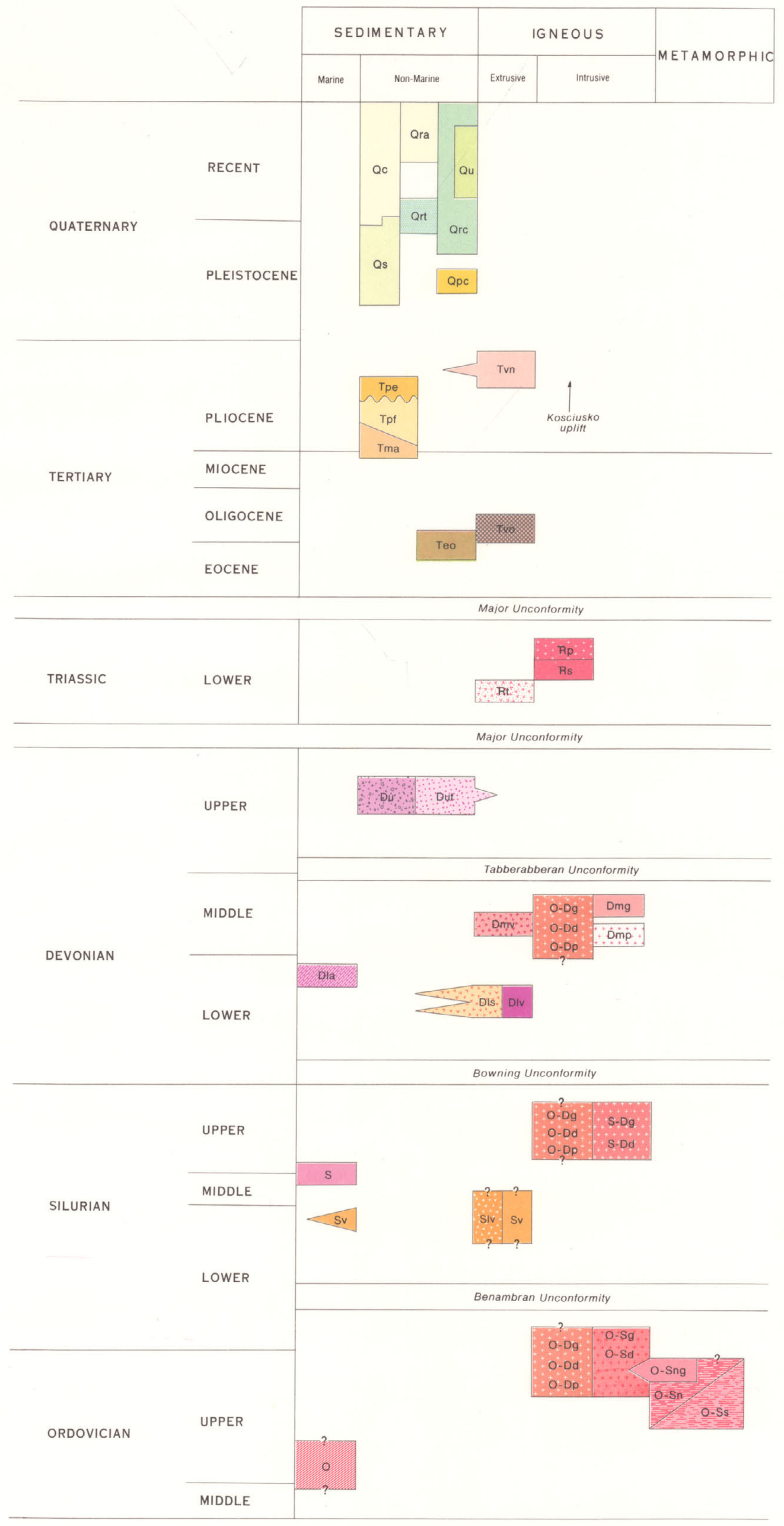
TALLANGATTA

GEOLOGICAL SURVEY OF VICTORIA

AUSTRALIA 1:250,000

SHEET SJ 55-3



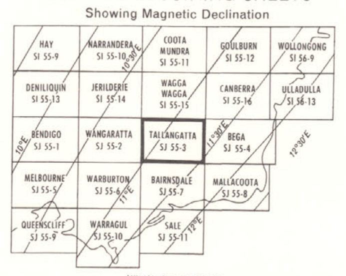


	Coonambidgal Formation	Qra	Alluvial flats; sand, gravel, silt, minor clay
		Qc	Alluvial flats; clay, sand, sandy clay, gravel, slight soil development, grey in colour; surface with channels and scroll patterns; swamp deposits grey-black clay. Subject to inundation
		Qrc	Hillwash, scree, rock debris, more extensive deposits along major valleys, often red
		Qu	Lunette; silt, sand, contains diprotodont remains
		Qrt	Alluvial terraces; sand, silt, minor clay
	Shepparton Formation	Qs	River terraces not subject to inundation; clay, sand, silt, gravel. Soil red brown earth
		Qpc	Periglacial rock-rivers; large angular blocks of basalt (Mt Hotham area) and rhyodacite (Mt Cobberas area) with little or no matrix
	Morass Creek Basalt	Tvn	Olivine and olivine-iddingsite basalt, minor gravel, sand, clay
		Tpe	High alluvial terrace; conglomerate, gravel, sand, minor clay, consolidated, cross bedded, deep red colour
		Tpf	Alluvial deposit; laminated silt, sand, light brown colour
	Calivil Sand	Tma	Alluvial deposit; conglomerate, gravel, sand, subsurface only
Older Volcanics		Tvo	Olivine basalt, minor limburgite, phonolite, tuff, associated dolerite, alkaline dykes, interbedded sediment
		Teo	Gravel, sand, clay, tuff, brown coal
Mount Leinster Complex		Rp	Quartz-feldspar porphyry
		Rs	Soda syenite, soda granite, monzonite, adamellite; porphyritic to equigranular
		Rt	Trachyte, agglomerate, tuff
	Mount Tambo Beds	Du	Coarse conglomerate, red to purple
		Dut	Shale, sandstone, conglomerate, in part red to purple, minor interbedded rhyolite
		Dmg	Leucocratic granite (includes Pine Mountain, Mt Mittamatite, Thologolong Granites)
	Jemba Rhyolite	Dmv	Rhyolite, rhyodacite, welded tuff
		Dmp	Generally small pods of quartz and feldspar porphyry. Smaller bodies of quartz and feldspar porphyry, diorite and granite shown as dykes
Buchan Group	Buchan Caves Limestone	Dla	Calcarenite, calcilutite, dolomite, thick bedded, dark grey
		Dlv	Quartz-feldspar porphyry, rhyolite, tuff, micaceous quartzite
Snowy River Volcanics		Dls	Complex sequence of ignimbrite, rhyodacite, rhyolite, minor andesitic tuff, conglomerate, siltstone, tuffaceous sandstone
		O-Dg	Granite, granodiorite (Age uncertain)
		O-Dd	Diorite, granodiorite (Age uncertain)
		O-Dp	Quartz porphyry, quartz-feldspar porphyry (Age uncertain)
		S-Dg	Granite, granodiorite (includes Corryong Granite, Kosciusko Granite)
		S-Dd	Quartz diorite
Wombat Creek Group and Cowombat Group		S	Conglomerate, sandstone, siltstone, shale, slate, limestone, marble, tuff
	Mitta Mitta Volcanics	Slv	Rhyodacite, rhyolite, quartz porphyry, volcanic breccia, tuff, ignimbrite
		Sv	Andesitic tuff, lava, minor interbedded sediment
		O-Sg	Granite, granodiorite
		O-Sd	Granodiorite, diorite (Banimboola Diorite)
		O-Sng	Gneissic granodiorite
		O-Sn	Gneiss, gneissic pegmatite, minor schist
		O-Ss	Schist, spotted phyllite, lit-par-lit schist-gneiss complexes
		O	Sandstone, shale, siltstone, rhythmically interbedded; metamorphosed to slate, low grade phyllite, hornfels and quartzite in places

Symbol	Meaning
	Geological boundary
	Fault (teeth on down thrown side)
	Fault inferred, lineament
	Trend lines metamorphic, bedding
d	Dyke; g, granite, d, dolerite, p, porphyry, pg, pegmatite. Symbol omitted where dyke undifferentiated
m m m m	Zone of contact metamorphism
2.3 my	Isotopic date in millions of years K/Ar method
βtr 427±32 my	Isotopic date in millions of years-Rb/Sr method (total rock analysis)
β 430±8 my	Isotopic date in millions of years-Rb/Sr method (from total rock, biotite, muscovite and feldspar analysis)
Ag/Pb	Silver/lead
As	Arsenic
Au	Gold
Bi	Bismuth
Cr	Chromium
Cu	Copper
F	Fluorine
16	Highway with route marker
	Main connecting road
	Other roads
	Track
	Railway line and siding
	Landing ground
	Trigonometrical station
	Power transmission line
	Watercourse
	Water Tunnel
	Deep water bore
ls	Limestone
Mo	Molybdenum
Sb	Antimony
Sn	Tin
U	Uranium
W	Wolfram

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination



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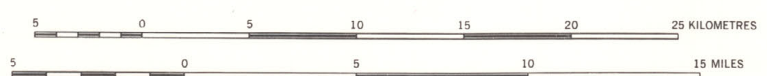
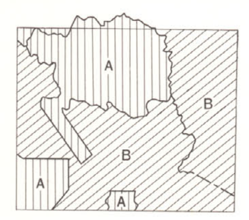
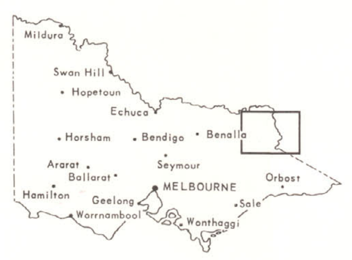


GEOLOGICAL RELIABILITY DIAGRAM

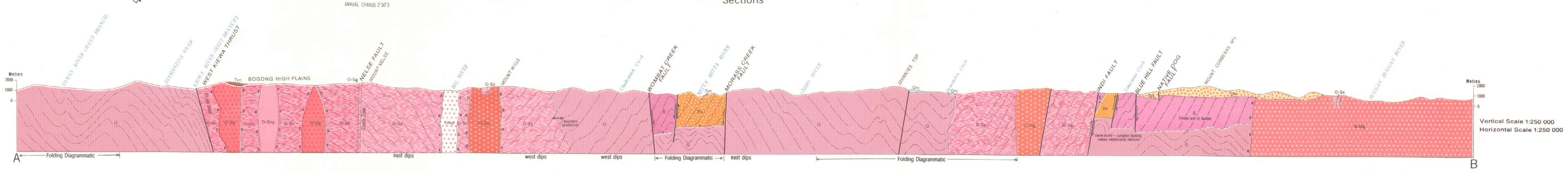


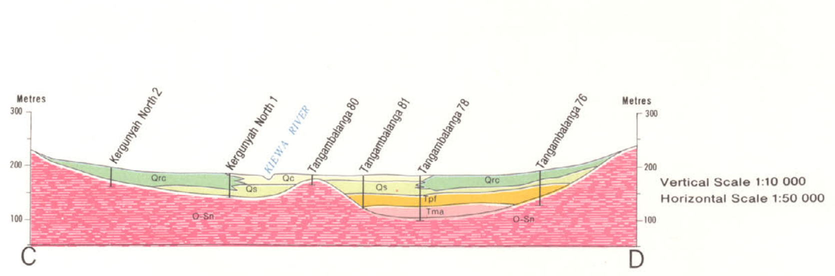
A Detailed ground survey.

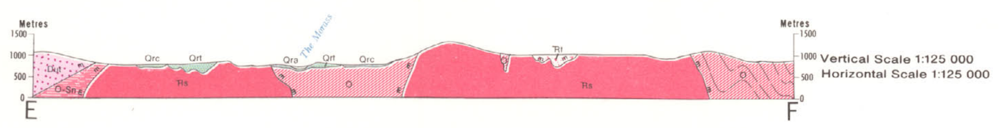
B Reconnaissance ground survey with aerial photo interpretation.



Sections







Compilation and Survey by P F Bolger and R L King

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Geology of N.S.W. portion by courtesy of Geological Survey of N.S.W and Snowy Mountain Authority

Isotopic Dates: C Brooks, M D Leggo, I Mc Dougall, P Wellman

J G Douglas, MSc, PhD, Supervising Geologist, Regional Geology
D Spencer-Jones, BSc, PhD, Director of Geological Survey

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Albers' Equal Area Projection

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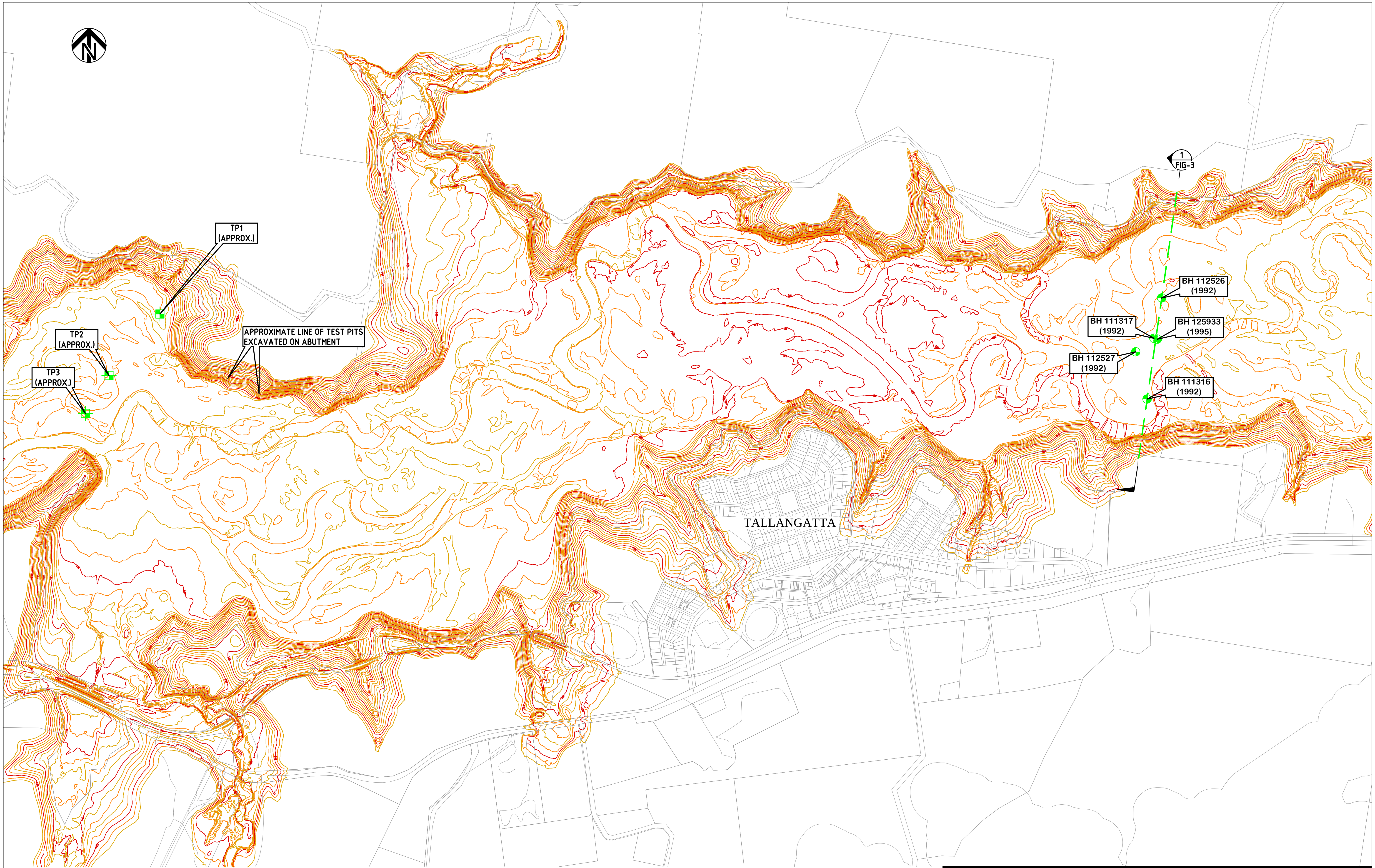
C H Rixon, Government Printer

FIRST EDITION 1976

TALLANGATTA

SJ 55-3

APPENDIX 6.2 LOCALITY PLAN – FIELD INVESTIGATIONS



LEGEND:

BOREHOLE

TEST PIT

SECTION LINE

SMEC
SMEC AUSTRALIA PTY LTD
© ACN 065 475 149
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MELBOURNE VIC. 3004
PH 03 9514-1500 FAX 03 9514-1502

THE NARROWS PROJECT FEASIBILITY - STAGE 1

LOCALITY PLAN
HISTORICAL FIELD INVESTIGATIONS

job no. 30041148
rev no. A

scale 1: 15000 date JULY 2015

FIG-2

APPENDIX 6.3 RAW GEOTECHNICAL INVESTIGATION DATA FROM DEPI

Bore ID	Type	Latitude	Longitude	Easting	Northing	Zone	Distance to nominated point (m)	Area	Date commenced	Date completed	Use	Total depth (m)	Elevation top of casing (mAHD)	Elevation ground level (mAHD)	Date surveyed	Survey desc	Surveyor name	Screen top (m)	Screen bottom (m)	Artesian y/n
111316	DRILLED BORE	-36.20976009	147.1940789	517445.4	5992768.3	55	277	Parish=BOLGA	7/05/1992	13/05/1992	GROUNDWATER INVESTIGATION	11	188.53	188.53	9/11/2011	DEM10	DSE-C/O SKM TATURA	6	9	N
111317	DRILLED BORE	-36.20734308	147.1944068	517475.4	5993036.3	55	58	Parish=BOLGA	13/05/1992	28/05/1992	GROUNDWATER INVESTIGATION	44	181.37	181.37	9/11/2011	DEM10	DSE-C/O SKM TATURA	21	33	N
112526	DRILLED BORE	-36.20574606	147.1947808	517509.4	5993213.3	55	193	Parish=BOLGA	21/05/1992	27/05/1992	GROUNDWATER INVESTIGATION	31	185.18	185.18	9/11/2011	DEM10	DSE-C/O SKM TATURA	14	19	N
112527	DRILLED BORE	-36.20788509	147.1935178	517395.4	5992976.3	55	70	Parish=BOLGA	29/05/1992	4/06/1992	GROUNDWATER INVESTIGATION	40	182.8	182.8	9/11/2011	DEM10	DSE-C/O SKM TATURA	22	31	N
125933	DRILLED BORE	-36.20737907	147.1945738	517490.4	5993032.3	55	73	RWC=GOULBURN-MURRAY WATER,Parish=BOLGA	17/05/1995	17/06/1995	GROUNDWATER INVESTIGATION	41.5	181.4	181.4	9/11/2011	DEM10	DSE-C/O SKM TATURA	30	36	N

Bore ID	Date	Interval from (m)	Interval to (m)	Description
111316	13/05/1992	0	5	SILT
111316	13/05/1992	5	8.5	LARGE GRAVELS
111316	13/05/1992	8.5	10	COARSE SAND LARGE GRAVELS(DIRTY)
111316	13/05/1992	10	10.5	WEATHERED GRANITE
111316	13/05/1992	10.5	11	FRESH GRANITE
111317	28/05/1992	0	3.5	SILT
111317	28/05/1992	3.5	7	LARGE GRAVELS DIRTY
111317	28/05/1992	7	8.5	SANDY GRAVELS DIRTY
111317	28/05/1992	8.5	9	GREY SILTY, SANDY CLAY
111317	28/05/1992	9	11.5	LARGE GRAVELS & MIXED SANMD
111317	28/05/1992	11.5	13.5	GREY SILTY CLAY
111317	28/05/1992	13.5	21	COURSE TO FINE SAND (GRAVEL) WOOD
111317	28/05/1992	21	21.5	LIGNIOUS SILTY CLAY
111317	28/05/1992	21.5	32	LARGE GRAVELS & MIXED SAND WOOD
111317	28/05/1992	32	32.5	SILTY CLAY
111317	28/05/1992	32.5	35	LARGE GRAVELS & MIXED SAND
111317	28/05/1992	35	36	LIGNIOUS SILTY CLAY
111317	28/05/1992	36	41	LARGE GRAVELS & MIXED SAND BANDS OF CLAY
111317	28/05/1992	41	44	WEATHERED GRANITE
112526	27/05/1992	0	2	BROWN SILTY CLAY
112526	27/05/1992	2	4	BROWN SILT
112526	27/05/1992	4	8	LARGE WASHED ROCK & GRAVELS
112526	27/05/1992	8	10	SMALL GRAVELS & ROCK
112526	27/05/1992	10	13	COARSE GREY SAND
112526	27/05/1992	13	14	DARK GREY SILTY CLAY & SAND
112526	27/05/1992	14	19	MEDIUM GREY SAND
112526	27/05/1992	19	28	BROWN, GREEN , WHITE SILT SILVER FLAKES
112526	27/05/1992	28	31	GRANITE
112527	4/06/1992	0	3.5	BROWN SILT
112527	4/06/1992	3.5	7	LARGE DIRY GRAVELS
112527	4/06/1992	7	8.5	DIRTY SANDY GRAVELS
112527	4/06/1992	8.5	9	GREY SILTY SANDY CLAY
112527	4/06/1992	9	11.5	LARGE GRAVELS MIXED SAND
112527	4/06/1992	11.5	13.5	GREY SILTY CLAY
112527	4/06/1992	13.5	21	COARSE TO FINE SAND GRAVEL WOOD
112527	4/06/1992	21	21.5	LIGNEOUS CLAY
112527	4/06/1992	21.5	32	GRAVELS MIXED SAND & WOOD
112527	4/06/1992	32	32.5	GREY SILTY CLAY
112527	4/06/1992	32.5	35	LARGE GRAVELS MIXED SAND
112527	4/06/1992	35	36	SILTY LIGNEOUS CLAY
112527	4/06/1992	36	40	BEDROCK
125933	17/06/1995	0	1	BROWN & GREY SILTY CLAY
125933	17/06/1995	1	2.5	BROWN SILTY SAND
125933	17/06/1995	2.5	4	GREY SILTY SAND
125933	17/06/1995	4	8	SAND, COARSE GRAVEL & STONES
125933	17/06/1995	8	8.5	COARSE GRAVEL & CLAY
125933	17/06/1995	8.5	13	COARSE GRAVEL & STONES
125933	17/06/1995	13	27	FINE SAND, COARSE GRAVEL
125933	17/06/1995	27	39.5	FINE SAND, COARSE GRAVEL & STONES
125933	17/06/1995	39.5	41	COARSE GRAVEL & ROCKS
125933	17/06/1995	41	41.5	BEDROCK

Bore Construction

Bore ID	Start date	Component	Material	Interval from (m)	Interval to (m)	Construction method	Out.Diam. (mm)	Ins.Diam. (mm)
111316	13/05/1992	Hole		0	11	CABLE TOOL	152	
111316	13/05/1992	Casing	PVC	0	6			100
111316	13/05/1992	Screen	PVC	6	9		114	100
111316	13/05/1992	Casing	PVC	9	11			100
111317	28/05/1992	Hole		0	44	CABLE TOOL	152	
111317	28/05/1992	Outer Lining	CEMENT	0	2			
111317	28/05/1992	Outer Lining	SEAL	8.5	0		152	
111317	28/05/1992	Casing	PVC	0.5	21			100
111317	28/05/1992	Screen	PVC	21	33		114	100
111317	28/05/1992	Casing	PVC	33	44			100
112526	27/05/1992	Hole		0	7	CABLE TOOL	203	
112526	27/05/1992	Hole		7	31	CABLE TOOL	152	
112526	27/05/1992	Outer Lining	CEMENT	0	0			
112526	27/05/1992	Casing	PVC CLASS 12	0	31			101
112526	27/05/1992	Screen	PVC CLASS 12	14	19			100
112527	4/06/1992	Hole		0	14	CABLE TOOL	203	
112527	4/06/1992	Hole		14	40	CABLE TOOL	152	
112527	4/06/1992	Outer Lining	CEMENT	0	0			
112527	4/06/1992	Casing	PVC	0	40			101
112527	4/06/1992	Screen	PVC	22	31			100
112527	4/06/1992	Screen	SLOTTED PVC	33	36			100
125933	17/06/1995	Hole		0	41.5	CABLE TOOL	305	
125933	17/06/1995	Casing	PVC	-1	30			203
125933	17/06/1995	Screen	PVC	30	36			200
125933	17/06/1995	Casing	PVC	36	41			203

Bore ID	Start date	Time	Interval from (m)	Interval to (m)	Extraction method	Draw down (m)	Pumping rate (m3/day)	Pumping time (hours)	Recovery time (min)	Yield (L/s)	Pump level (m)	Water sample taken	Final level (m)
111316	13/05/1992	14:00:00	6	9	NKN							FALSE	
111317	28/05/1992	14:00:00	21	33	BAL							TRUE	
112526	27/05/1992	14:00:00	14	19	BAL							FALSE	
112527	4/06/1992	14:00:00	22	36	NKN							FALSE	
125933	17/06/1995	13:00:00	30	36	PUM	8		2		2	30	TRUE	1.5
125933	17/06/1995	14:00:00	30	36	AIR	20				2		TRUE	

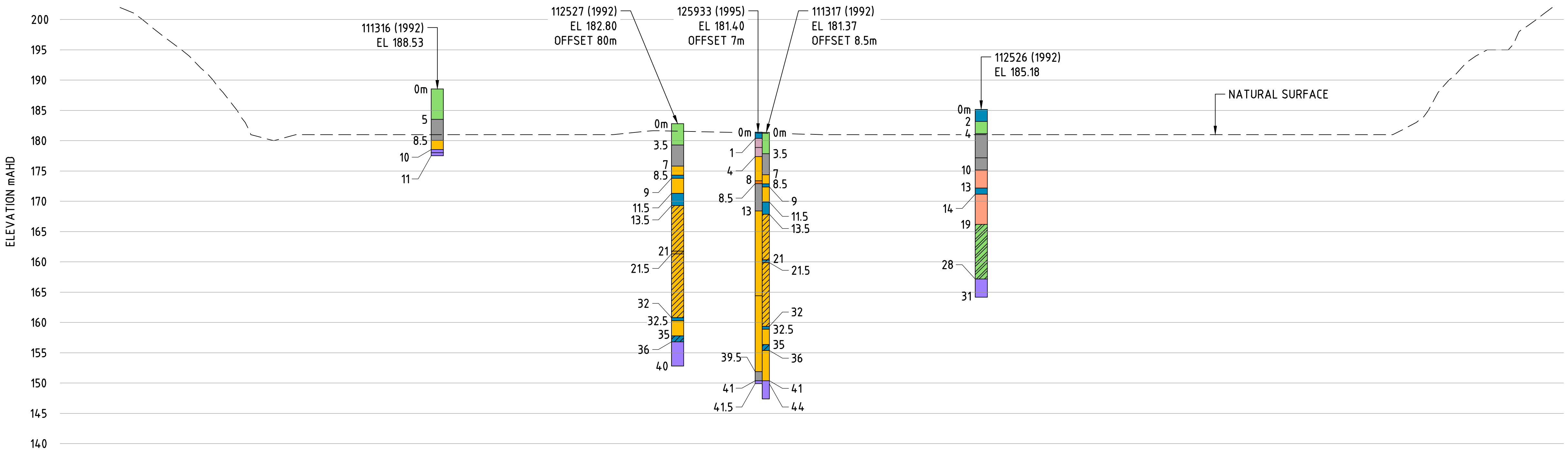
Field Chemistry

Bore ID	Date	Time	Interval from	Interval to	Collection method	Volume of water purged (L)	pH	Temperature (C)	EC (uS/cm)	Dissolved Oxygen (mg/L)	Redox potential (mV)	Comment
111317	1899-12-30	0:00:00	21	33	NOT KNOWN		6.9					
112526	1899-12-30	0:00:00	14	19	NOT KNOWN		7.1					

Laboratory Chemistry

Bore ID	Reading date	Reading time	Interval from (m)	Interval to (m)	Collection method	Parameter name	Parameter value	Unit of measure	Comment
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Conductivity (µS/cm)	290	µS/cm @ 25°C	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Total Alkalinity, as CaCO3	140	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Calcium, as Ca	18	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Chloride, as Cl	9	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Hardness, as CaCO3 (calc.)	91	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Potassium, as K	5.2	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Sodium, as Na	28	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Nitrate & Nitrite, as N(0.15de	0.05	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Silica, total as SiO2	27	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Sulphate, as SO4	4.7	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Iron (Undigested), as Fe	5.2	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Magnesium, as Mg	11	mg/L	
111317	1899-12-30	0:00:00	21	33	NOT KNOWN	Total Soluble Salts (Summation	247	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Conductivity (µS/cm)	230	µS/cm @ 25°C	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Total Alkalinity, as CaCO3	110	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Calcium, as Ca	18	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Chloride, as Cl	4	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Hardness, as CaCO3 (calc.)	73	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Potassium, as K	2.3	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Sodium, as Na	23	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Nitrate & Nitrite, as N(0.15de	0.05	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Silica, total as SiO2	34	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Sulphate, as SO4	2.3	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Iron (Undigested), as Fe	6.7	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Magnesium, as Mg	6.8	mg/L	
112526	1899-12-30	0:00:00	14	19	NOT KNOWN	Total Soluble Salts (Summation	191	mg/L	

APPENDIX 6.4 GEOLOGICAL PROFILE



SECTION 1 FIG-2
HORIZ. SCALE 1:4000
VERT. SCALE 1:20000

LEGEND:

SILT	BEDROCK, GRANITE	GRAVEL/SAND	SILTY CLAY (LIGNIOUS)
SAND	SILTY CLAY	GRAVEL/SAND WITH WOOD	GRAVEL/CLAY
GRAVEL, ROCKS	SILTY SAND	CLAY (LIGNIOUS)	SILT WITH SILVER FLAKES

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LEVEL 10, 71 QUEENS ROAD
MELBOURNE VIC. 3004
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THE NARROWS PROJECT FEASIBILITY - STAGE 1

GEOLOGICAL PROFILE

job no. 30041148
rev no. A

scale AS SHOWN date JULY 2015

FIG-3

APPENDIX 6.5 TP LOGS

Excavation
ENGINEERING FIELD LOG

Woodward-Clyde

Excavation No: TP1

Sheet: 1 of 1

CLIENT:	**Shire of Towong**	JOB NUMBER:	**A3100037/1001**
PROJECT:	**Narrows Weir**	DATE EXCAVATED:	**1 June 95**
LOCATION:	**Tallangatta**		
CONTRACTOR:	**Shire JCB**	LOGGED BY:	**GWC**

Equipment:	**Backhoe (JCB 3CX)**	Width:	**N/A**	Exc. Depth:	**3.0**	RL:	**N/A**
Bucket Size:	**600mm**	Length:	**N/A**	Co-ords:	**N/A**	N	**N/A**

Method	Support	Excavation (no resistance / refusal)	Water	Depth (m)	Graphic Log	Classification	Material Description (type, plasticity/particle size, colour, secondary/minor components)	Moisture Condition	Consistency Rel. Density	Scale	Sampling	Testing	Field Records/Comments (insitu testing, soil structure, soil origin, additional observations)
Backhoe		▨	No Groundwater Encountered	0–0.15		ML	Sandy SILT, low plasticity, dark brown, with medium to coarse grained quartz sand.	M	S				
				0.15–0.2			Sandy SILT, as above except black.	M	S				
				0.2–0.58		CL	Silty CLAY, low to medium plasticity, orange/light brown, with medium to coarse grained quartz sand.						
				0.58–1			Silty CLAY, as above with less sand	M	F				
				1–3				M	F/St				
				3			Test Pit Terminated at 3.0m.						Groundwater Inflow at 3.0m; rising slowly.

Depth scale: 0.15, 0.2, .5, 0.58, 1, 1.5, 2, 2.5, 3, 3.5

Produced By: GP
Checked By: GWC

Document No: A31/00037/1001/LOGS/TP1:GC

Excavation
ENGINEERING FIELD LOG

Woodward-Clyde

Excavation No: **TP2**

Sheet: 1 of 1

CLIENT:	**Shire of Towong**	JOB NUMBER:	**A3100037/1001**
PROJECT:	**Narrows Weir**	DATE EXCAVATED:	**1 June 95**
LOCATION:	**Tallangatta**		
CONTRACTOR:	**Shire JCB**	LOGGED BY:	**GWC**

Equipment:	**Backhoe (JCB 3CX)**	Width:	**N/A**	Exc. Depth:	**2.1**	RL:	**N/A**
Bucket Size:	**600mm**	Length:	**N/A**	Co-ords:	**N/A**	N	**N/A**

Method	Support	Excavation (no resistance / refusal)	Water	Depth (m)	Graphic Log	Classification	Material Description (type, plasticity/particle size, colour, secondary/minor components)	Moisture Condition	Consistency Rel. Density	Scale	Sampling	Testing	Field Records/Comments (insitu testing, soil structure, soil origin, additional observations)
Backhoe			No Groundwater Encountered	0.03		SM/ML	Silt, black, with minor sand.	M	S				
							Sandy SILT (to Silty SAND), low plasticity, dark brown, with fine grained, dark brown sand.				Bulk		Bulk Sample (0.05m - 0.20m)
				0.25			Sandy SILT (to Silty SAND), as above, except sand is brown.						
				1		ML	Silt, low plasticity, light brown/orange.	M	S				
								W	S				Groundwater Inflow at 1.6m, rising slowly.
				2		SM	Silty SAND, fine grained, orange/light brown.	W	S				
				2.1			Test Pit Terminated at 2.1m due to cave in.						

Depth scale: 0.5, 1, 1.5, 2, 2.5, 3, 3.5

Produced By: GP
Checked By: GWC

Document No: A31/00037/1001/LOGS/TP2:GC

Excavation
ENGINEERING FIELD LOG

Woodward-Clyde

Excavation No: **TP3**

Sheet: 1 of 1

CLIENT:	**Shire of Towong**	JOB NUMBER:	**A3100037/1001**
PROJECT:	**Narrows Weir**	DATE EXCAVATED:	**1 June 95**
LOCATION:	**Tallangatta**		
CONTRACTOR:	**Shire JCB**	LOGGED BY:	**GWC**

Equipment:	**Backhoe (JCB 3CX)**	Width:	**N/A**	Exc. Depth:	**1.5**	RL:	**N/A**
Bucket Size:	**600mm**	Length:	**N/A**	Co-ords:	**N/A**	N	**N/A**

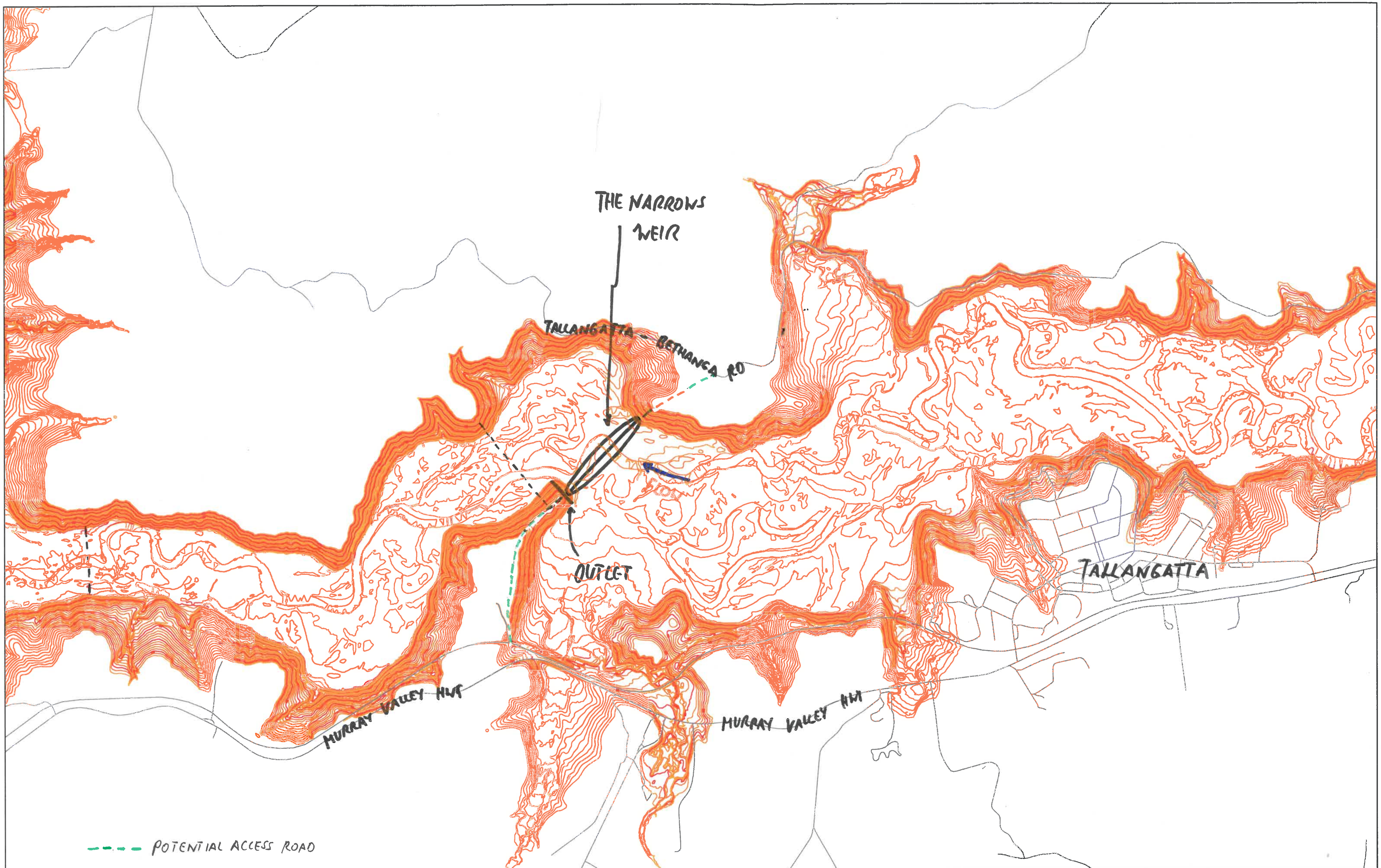
Excavation Info.					Material Properties					Additional Information			
Method	Support	Excavation (no resistance / refusal)	Water	Depth (m)	Graphic Log	Classification	**Material Description** type, plasticity/particle size, colour, secondary/minor components	Moisture Condition	Consistency Rel. Density	Scale	Sampling	Testing	**Field Records/Comments** insitu testing, soil structure, soil origin, additional observations
Backhoe			No Groundwater Encountered	0–2.4		SP	Sand, fine grained, light brown layered to dark brown, with some quartz, feldspar and mica present, and minor low plasticity Silt.	M	VL				
				1.5				W	VL				Groundwater Inflow at 1.5m, rising slowly.
				2									PIT COLLAPSE from 1.5m to 2.4m.
				2.4–2.5		ML	Silt, low plasticity, black.	W	VS				
				2.5			Test Pit Terminated at approximately 2.5m due to cave in.						

Depth scale: .5, 1, 1.5, 2, 2.4, 2.5, 3, 3.5

Produced By: GP
Checked By: GWC

Document No: A31/00037/1001/LOGS/TP3:GC

APPENDIX 8.1 SKETCHES



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THE NARROWS PROJECT FEASIBILITY - STAGE 1

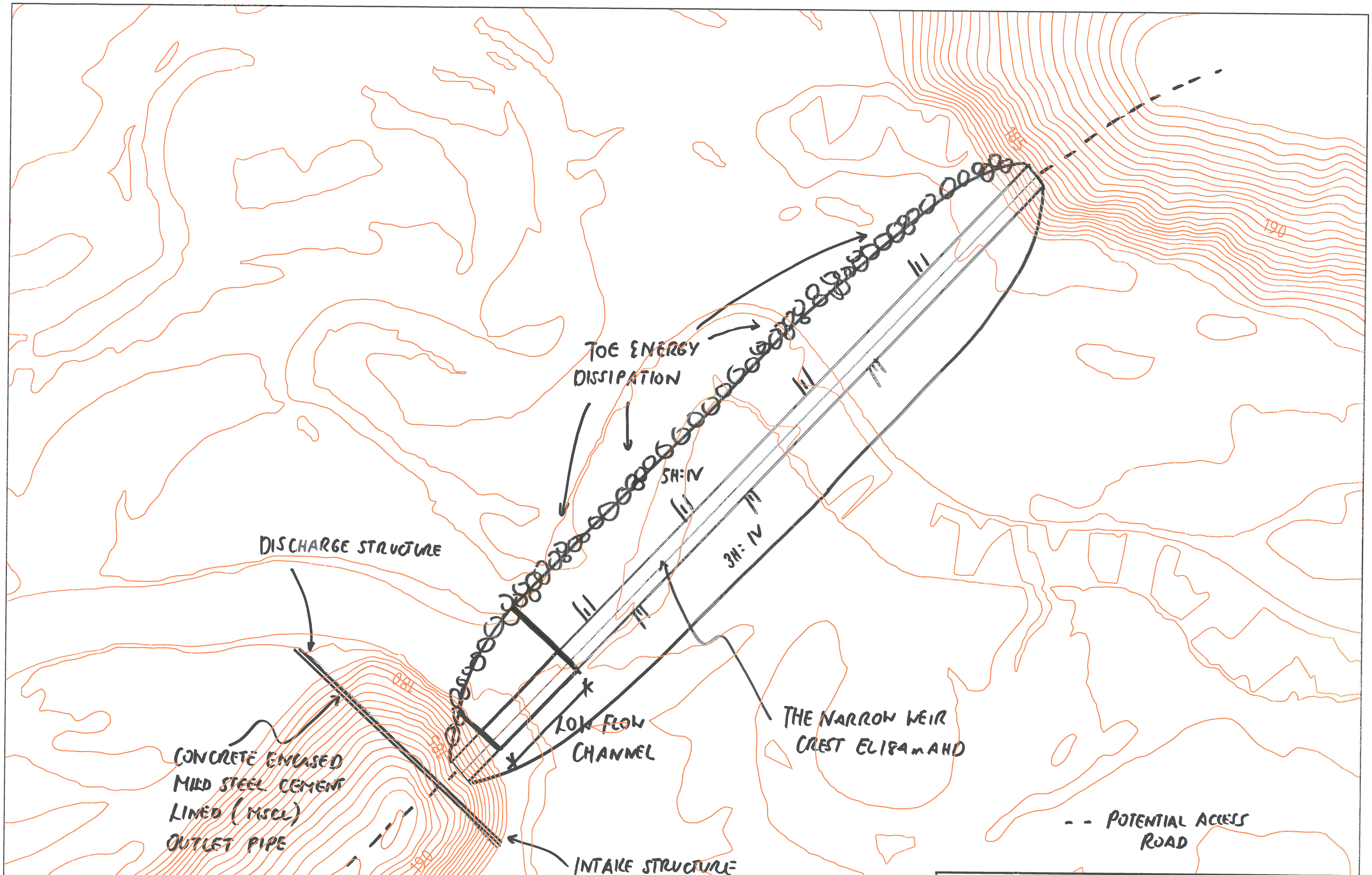
THE NARROWS WEIR
SITE LAYOUT

job no.	30041148
rev no.	A

scale | 1:20000 date | JULY 2015

FIG-1

I:\Projects\30041148\2.4 2.5 Concept and Preliminary Design\ Plan.dwg 31 July, 2015 - 12:26 PM



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THE NARROWS PROJECT FEASIBILITY - STAGE 1

THE NARROWS WEIR
WEIR STRUCTURE PLAN

job no. | 30041148
rev no. | A

scale | 1:2000
date | JULY 2015

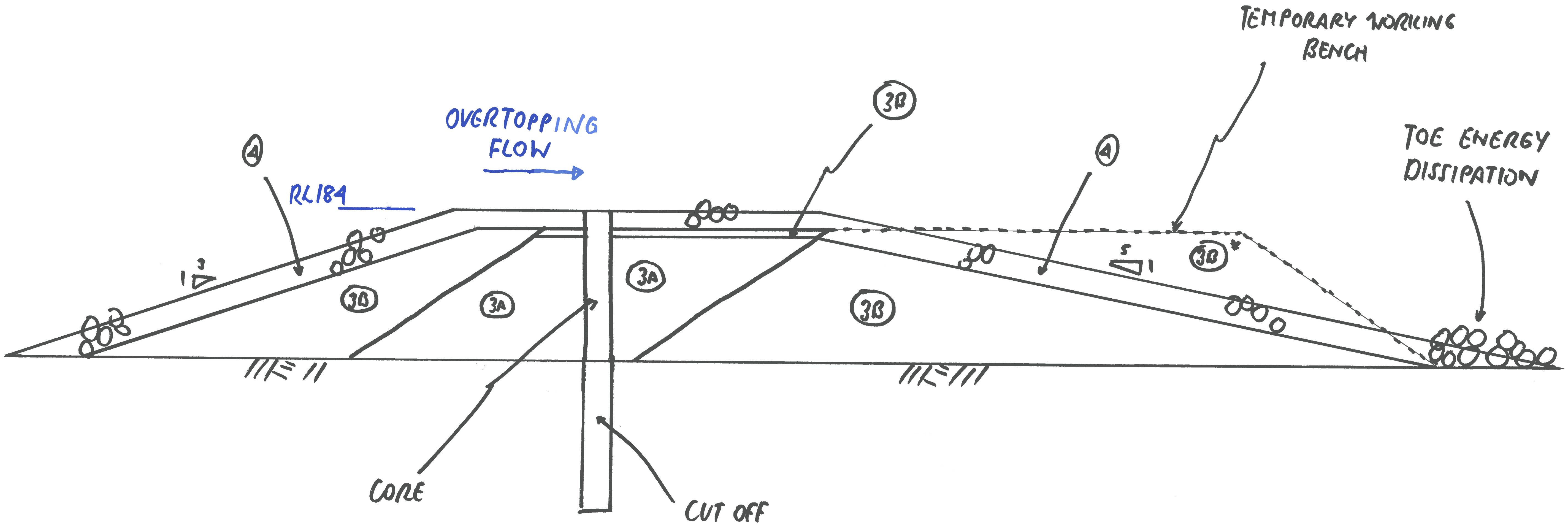
FIG-1

I:\Projects\30041148\2.4 2.5 Concept and Preliminary Design\ Plan.dwg

31 July, 2015 - 12:33 PM

OPTION 1.

ROCKFILL WEIR WITH A CORE / CUTOFF



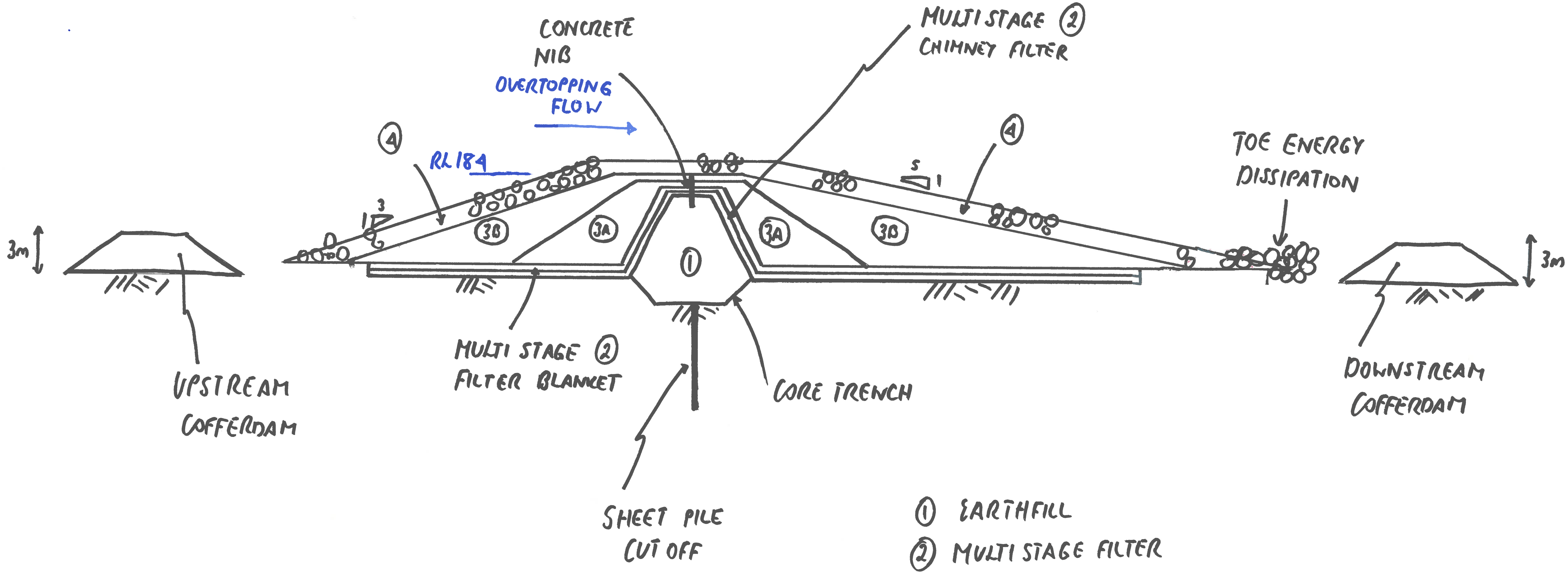
3A FINE ROCKFILL

3B COARSE ROCKFILL

4 RIP RAP

OPTION 2

ZONED EARTH AND ROCKFILL WEIR WITH CORE / CUTOFF



① EARTHFILL
② MULTI STAGE FILTER
3A FINE ROCKFILL
3B COARSE ROCKFILL
④ RIP RAP

APPENDIX 8.2 COST ESTIMATE

The Narrows Project

Option 1 - Rockfill Weir (FSL 184mAHD)

Rockfill Weir with Cut off constructed in the wet

Compiled:	LJB	**File:**	30041148
Checked:	RJW	**Date:**	16-Nov-15

Item	Description of Works	Quantity	Unit	Rate $	Cost $	
1	**ESTABLISHMENT**					
1.01	Establishment	1	L.S.	1000000	1,000,000	
						1,000,000
2	**TEMPORARY WORKS**					
2.01	none	0	m^3	0	0	
						-
3	**WEIR**					
3.01	3A - Supply and Place	72,900	m^3	40	2,916,000	
3.02	3B - Supply and Place	171,200	m^3	40	6,848,000	
3.03	4 - Supply and Place	72,800	m^3	120	8,736,000	
3.04	Cutoff	9,500	m^2	1000	9,500,000	
						28,000,000
4	**OUTLET**					
4.01	Pipe (diameter 2m)	200	m	7200	1,440,000	
4.02	Concrete encasement	1,200	m^3	1500	1,800,000	
4.03	Gate/Valve (2m x 2m)	2	tonne	45000	90,000	
						3,330,000
	DIRECT COST (DC)					**32,330,000**
	Minor Items			20%	of DC	**6,466,000**
	Procurement and Construction Risk			10%	of DC	**3,233,000**
	PRIME COST (PC)					**42,029,000**
	Contingencies			40%	of PC	**16,811,600**
	CONTINGENT COST (CC)					**58,840,600**
5	**MANAGEMENT**					
5.01	Investigation and Design	10%	of DC	L.S.	3,233,000	
5.02	Studies, Planning and Approvals	1		L.S.	1,000,000	
5.03	Construction Management	5%	of DC	L.S.	1,616,500	**5,849,500**
	TOTAL DESIGN AND CONSTRUCTION COST (TCC) for					**64,690,100**
					say	**$ 64,700,000**

Notes:

Cost estimates do not include an allowance for the following:

- road bridge (if required)
- fish passage (if required)
- owner costs
- land acquisition
- water costs associated with incremental evaporation loss that could be expected from The Narrows Storage
- traffic management and control
- any restrictions on construction activities including hours of operation, truck movements, noise levels, etc.
- delays in construction
- on-going maintenance
- architectural features

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The Narrows Project

Option 2 - Zoned Earth and Rockfill Weir (FSL 184mAHD)

Earth and Rockfill Embankment constructed in the dry with u/s and d/s cofferdams

Compiled:	LJB	**File:**	30041148
Checked:	RJW	**Date:**	16-Nov-15

Item	Description of Works	Quantity	Unit	Rate $	Cost $	
1	**ESTABLISHMENT**					
1.01	Establishment	1	L.S.	1000000	1,000,000	
						1,000,000
2	**TEMPORARY WORKS**					
2.01	Cofferdams	32,000	m^3	15	480,000	
						480,000
3	**WEIR**					
3.01	1 - Supply and Place	31,600	m^3	25	790,000	
3.02	2A - Supply and Place	26,900	m^3	60	1,614,000	
3.03	2B - Supply and Place	26,700	m^3	60	1,602,000	
3.04	3A - Supply and Place	41,300	m^3	40	1,652,000	
3.05	3B - Supply and Place	85,600	m^3	40	3,424,000	
3.06	4 - Supply and Place	68,200	m^3	120	8,184,000	
3.07	Nib Wall	500	m^4	1500	750,000	
3.08	Sheet Pile	500,000	m^3	5	2,500,000	
						20,516,000
4	**OUTLET**					
4.01	Pipe (diameter 2m)	200	m	7200	1,440,000	
4.02	Concrete encasement	1,200	m^3	1500	1,800,000	
4.03	Gate/Valve (2m x 2m)	2	tonne	45000	90,000	
						3,330,000
	DIRECT COST (DC)					**25,326,000**
	Minor Items			20%	of DC	**5,065,200**
	Procurement and Construction Risk			15%	of DC	**3,798,900**
	PRIME COST (PC)					**34,190,100**
	Contingencies			40%	of PC	**13,676,040**
	CONTINGENT COST (CC)					**47,866,140**
5	**MANAGEMENT**					
5.01	Investigation and Design	10%	of DC	L.S.	2,532,600	
5.02	Studies, Planning and Approvals	1		L.S.	1,000,000	
5.03	Construction Management	5%	of DC	L.S.	1,266,300	**4,798,900**
	TOTAL DESIGN AND CONSTRUCTION COST (TCC) for					**52,665,040**
					say	**$ 52,700,000**

Notes:

Cost estimates do not include an allowance for the following:

- road bridge (if required)
- fish passage (if required)
- owner costs
- land acquisition
- water costs associated with incremental evaporation loss that could be expected from The Narrows Storage
- traffic management and control
- any restrictions on construction activities including hours of operation, truck movements, noise levels, etc.
- delays in construction
- on-going maintenance
- architectural features

APPENDIX 8.3 OPTIONS EVALUATION MATRIX

Options Comparison Matrix

Option	Serviceability	Dam and Public Safety	Duration, Risk and Constructability	Environmental	Operation and Maintenance	Cost
Weighting	3	1	2	0.5	1	2.5
1 - Rockfill Weir	• Design intent meet • Weir arrangement is driven by construtability aspects rather than a standards based design • To reduce and control seepage a cut off has been incorporated into the design	• Routine inspections would be required in accodance with the ANCOLD Guidelines on Dam Safety Management when the water level in Lake Hume is below The Narrows weir crest level. • Risks to public safety minimal, it is envisaged that navigation warning system would be required • Elevation of bridge would be set such that road would be accessible up to a 1 in 100 event. A means of closing the road if required would also be provided.	• Risk associated with potential exposure to flood during construction • A flood during construction would have less impact than Option 2 • Construction duration expected to be less than Option 2 as cofferdams are not required • As weir can be constructed in water, construction of the weir could commence anytime that the water level is nominally 1m below weir crest level • Less weather dependent than Option 2 as less contraints required for placement of rockfill	• Environmental impact on the watercourse or floodplain similar for both options • Risk to environment in terms of noise, dust, contamination of waterways similar for both options • In terms of aethetics, once constructed both weirs would be similar in appearance	• Routine inspections would be required in accodance with the ANCOLD Guidelines on Dam Safety Management • Routine removal of debris would be required • Periodic testing/operation of the outlet required	$64.7M
2 - Zoned Earth and Rockfill Weir	• Design intent meet • Zoned earth and rockfill dam is a standards based weir arrangement • To reduce and control seepage a core trench, cut off and filter blanket has been incoporated into the design	• Routine inspections would be required in accodance with the ANCOLD Guidelines on Dam Safety Management when the water level in Lake Hume is below The Narrows weir crest level. • Risks to public safety minimal, it is envisaged that navigation warning system would be required • Elevation of bridge would be set such that road would be accessible up to a 1 in 100 event. A means of closing the road if required would also be provided.	• Risk associated with potential exposure to flood during construction • A flood during construction would have greater impact than Option 1 • Construction duration expected to be greater than Option 1 as cofferdams are required • Timing of works needs to fit within a specific construction window to ensure works can (as much as can be planned) be completed in the dry • More weather dependent than Option 1 as increased requirements in terms of placement and conditoning of earthfill	• Environmental impact on the watercourse or floodplain similar for both options • Risk to environment in terms of noise, dust, contamination of waterways similar for both options • In terms of aethetics, once constructed both weirs would be similar in appearance • Larger hardstand area required for stockpiling of earthfill on site for conditioning prior to placement	• Routine inspections would be required in accodance with the ANCOLD Guidelines on Dam Safety Management • Routine removal of debris would be required • Periodic testing/operation of the outlet required	$52.7M

DOCUMENT / REPORT CONTROL FORM

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Project Number:	30041148
Revision Number:	Final Rev 3

Revision History

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