DELWP

Assessment of Accuracy of Baseflow Estimates

Targeted ground-truthing of existing data

May 2016

Executive summary

Background

The Department of Environment, Land, Water and Planning (DELWP) previously undertook two projects to fill information gaps on priority Groundwater Dependent Ecosystems (GDE) – baseflow dependent rivers, and wetlands. These projects, completed by GHD (GHD 2013a; GHD 2013b), developed a methodology to:

- establish where groundwater interaction occurs with rivers and wetlands
- quantify the groundwater contribution to the waterway where interaction occurs
- identify associated high value environmental assets, and
- assess the risk to these environmental assets from groundwater extraction.

A discussion paper was prepared by GHD in 2012 to appraise methods for quantifying regional groundwater discharge to streams (as “baseflow”) throughout Victoria. The adopted baseflow estimation method involved digital baseflow filtering “trained” to environmental tracer data – primarily electrical conductivity.

A pilot project was undertaken by GHD in 2012/13 for characterising the baseflow contributions for five Victorian rivers (GHD, 2013a), including the lower Mitchell and lower Thomson-Macalister Rivers. This project was expanded in 2013 (GHD, 2013b) to a further eight Victorian rivers including the Latrobe River catchment, using the same method. As for the pilot method, the results were used to assess the risk of groundwater extraction to the environmental values that those rivers support.

A scientific review of both baseflow studies (GHD, 2013a; GHD, 2013b) made a number of recommendations to refine the method and quantification used to determine the risk of combined surface water and groundwater extractions to significant environmental values.

Project objectives

The **primary objective** of this project is to implement the recommendations from the scientific review of the method developed by GHD (GHD, 2013a; GHD, 2013b) to improve the accuracy and reliability of the baseflow estimates to three high value Gippsland river systems:

- Latrobe River (Latrobe River to Kilmany South)
- Thomson-Macalister River system (Thomson River from Cowwarr Weir to Bundalaguah; Macalister River from Lake Glenmaggie to the confluence with the Thomson River), and
- Mitchell River (Glenaladale to Rosehill).

The objective of this project is to improve understanding of the degree and nature of interaction between rivers and groundwater in the Gippsland region, and to help understand potential impacts of coal mining, coal seam gas developments and other water uses on water-dependent environmental assets. The outputs of the work will improve the accuracy of, and confidence in, estimates of the dependency of flows on groundwater and improve the technical basis on the likelihood of direct, indirect and cumulative impacts of water use on baseflows.

One of the key outcomes from this study is to provide a tiered framework for the application of the baseflow estimation method(s) most suitable for different types of reaches, such as losing, gaining and regulated reaches.

The project has been completed in two stages:

- Stage 1**:** Review groundwater contributions to rivers
- Stage 2: Targeted ground-truthing of existing data (data verification)

This report documents the Stage 2 assessment.

Scope of Work

Following on from the work completed in Stage 1 of this study (GHD, 2015), the scope of work for Stage 2 of the study includes:

- Develop a field work plan to undertake monitoring at targeted ground-truthing sites;
- Undertake proposed field work at targeted locations and monitoring periods, based on the field work plan;
- Refine the baseflow analysis and interstation analysis based on the ground-truthing data; and
- Undertake high level analysis to assess potential effects that coal seam gas extraction may have on groundwater – surface water interactions.

Previous Work

Findings from Stage 1 of the study (GHD, 2015) highlighted a number of data gaps which increase the uncertainty of baseflow estimates. The key data gaps include:

- Surface water flow and EC – gaps in concurrent flow and EC gauging data between upstream and downstream sites which reduce the ability to implement interstation analyses;
- Groundwater EC – limited groundwater monitoring bores in upland catchments to define groundwater EC end members;
- Surface Water Management – gaps in the surface water management data, in particular river diversions and returns; and
- Independent baseflow studies – limited relevant independent baseflow studies to assess the effects of the recommended changes and additions to the baseflow assessment method on the reliability of the baseflow estimates.

The table below summarises the data available for the interstation reaches in the Latrobe, Thomson-Macalister and Mitchell River catchments. The findings indicate that there are no concurrent surface water flow and EC recordings for the Latrobe River upstream of Thoms Bridge, and the Latrobe River between Thoms Bridge and Scarnes Bridge. Additionally, there is limited data available for the Thomson River between Cowwarr Weir and Heyfield, and the Macalister River between Glenmaggie and Riverslea.

Furthermore, the Mitchell River between Glenaladale and Rosehill is the only assessed reach with an independent data set suitable for assessing the reliability of the EC mass balance method of baseflow estimation: those of Hofmann (2011). Therefore, it was recommended that monitoring investigations conducted as part of Stage 2 are focused on providing additional data for the Latrobe or Thomson-Macalister River catchments.

Interstation Section	Interstation Gauge Pairs	Period of con-current flow and SW EC readings	Count of concurrent flow and SW EC readings	Count of GW EC Boreholes
Latrobe River upstream of Thoms Bridge	226216, 226021, 226408, 226005	NA	0	174
Latrobe River between Thoms Bridge and Scarnes Bridge	226005, 226007, 226415, 226033	NA	0	13
Latrobe River between Scarnes Bridge and Rosedale	226033, 226228	7/01/1997 - 5/05/2013	194	53
Latrobe River between Rosedale and Kilmany South	226228, 226227	18/05/1977 - 3/12/2014	222	93
Thomson River between Cowwarr Weir and Heyfield	225231, 225200, 225236	17/10/2007 8/04/2010	3	12
Thomson River between Heyfield and Wandocka	225200, 225236, 225212	10/08/2005 5/09/2012	73	10
Lower Thomson-Macalister River from Wandocka to Bundalaguah including Macalister River	225212, 225232, 225247	13/07/2005 22/05/2014	93	43
Macalister River between Glenmaggie and Riverslea	225204, 225247	5/03/2007 4/04/2012	9	69
Mitchell River between Glenaladale and Rosehill	224203, 224217	11/01/1977 15/12/2014	82	54

Field Work

A targeted field work plan to undertake flow and EC accretion profiling was developed in consultation with DELWP, WG-CMA and SRW, based on the key data gaps identified in Stage 1 (GHD, 2015) and tailored to the following key reaches of interest:

- Thomson River from Cowwarr to Wandocka, including Rainbow Creek (9 sampling locations);
- Moe Drain / Latrobe River upstream of Lake Narracan, including Tanjil River and Narracan Creek (12 sampling locations); and
- Macalister River between Glenmaggie and Maffra Weir (5 sampling locations).

Spot sampling was undertaken for three sampling rounds over the study period to collect data for different seasons and regulated influences (irrigation releases):

- Sampling Round 1: Spring 2015 (09/09/2015 – 28/09/2015). Capture flows at the start of the irrigation season.
- Sampling Round 2: Summer 2016 (12/01/2016 – 05/02/2016): Capture summer low flows.
- Sampling Round 3: Autumn 2016 (12/04/2016 – 17/05/2016): Capture flows at the end of the irrigation season.

During the sampling events important changes were noted by field staff. Each sampling event was conducted to avoid peak streamflow after high rainfall events and after large reservoir releases, when the flow rate was below the median flow for the month of year. Sampling was also avoided when the rainfall forecast for the work week was greater than 5 mm. At these times, the difference in streamflow between sites is relatively stable; i.e. there is not a pulse of runoff or reservoir release water travelling down the river, which would serve to complicate and undermine the field data analyses.

Revised Baseflow Estimates

Downstream flow and EC 'accretion profiles' were prepared based on the field observations to provide an indication of the changes in streamflow conditions along each river. These flow and EC accretion profiles can be used to infer baseflow contributions to the stream, with baseflow gains likely when EC is increasing between upstream and downstream sampling sites (i.e. within an 'interstation reach'). To further quantify the magnitude of baseflow gains, reach-scale mass balances were constructed using the field data, in the same manner as was applied by GHD (2015) using historical gauge data.

Results for all sampled reaches indicate that baseflow-conditions (i.e. gain from or loss to groundwater) are variable along the reach length and between seasons.

Thomson River

Across seasons, there are consistent baseflow gains exhibited along Rainbow Creek, which is more deeply incised into the landscape than the main channel of the Thomson River. Rainbow Creek likely forms a natural drain towards which groundwater from beneath the more elevated Thomson River will flow. Relatively consistent baseflow gains are exhibited in the reach downstream of Cowwarr Weir, particularly during high flows into and out of the weir. This is most likely due to the lower river bed and stage immediately downstream of the weir, effectively forming a drain towards which groundwater from beneath the weir is driven.

Baseflow conditions along the Thomson River between Stoney Creek and Wandocka vary between seasons, ranging from predominantly baseflow gaining conditions during spring to neutral conditions during summer and autumn. It is noted that baseflow conditions were uncertain along several reaches, where gains in EC could potentially be attributed to evaporation losses, rather than baseflow gains.

Macalister River

The only reaches exhibiting seasonally-consistent baseflow conditions are between US Newry Drain and US Maffra Weir, and DS Maffra Weir to Riverslea, where gains were observed across all sampling events. The seasonal neutral to losing behaviour concluded for the upstream reach (between DS Glenmaggie and US Newry Drain) makes sense conceptually due to the relatively elevated river bed, when compared to downstream reaches. The elevated river bed - in conjunction with high river flows (releases from Glenmaggie Weir in Summer (January 2016)) - create hydraulically losing conditions in this reach. Losing behaviour in basin margin reaches was also noted in earlier studies by GHD (2013a).

The observations are in broad agreement with the earlier work of GHD (2015). The broad picture of neutral to losing conditions downstream of Glenmaggie Weir, and generally gaining conditions downstream of Newry Drain (aside from around Maffra Weir) is consistent with the earlier work, noting that there are temporal differences.

Latrobe River

Moderately gaining baseflow conditions are consistently experienced across seasons for the upper reaches of the Latrobe River, Tanjil River and Narracan Creek; however, baseflow gains are generally reduced in summer. The data suggests relatively variable seasonal baseflow condtions along the Moe Drain, with predominantly gaining conditions exhibited during spring and relatively neutral conditions during summer and autumn.

Effect of Coal Seam Gas Extraction on Baseflow

A high level analysis was completed to assess potential effects that coal seam gas extraction may have on groundwater – surface water interactions, drawing on findings from relevant literature. It is noted that there is potential for onshore coal seam gas production to have significant impacts on baseflow in the Gippsland region, as reported in DELWP (2015). However, the magnitude of the impact depends on the location of the CSG development, the stratigraphy of the gas bearing formations and the scale of the CSG development.

Review of historical groundwater hydrographs in the region indicates that the historical impacts of groundwater depressurisation for coal mining in the region have had limited impacts on the shallow aquifer systems.

Conclusions and Recommendations

This study obtained targeted field data aimed at ground-truthing the baseflow estimates derived in Stage 1 of this study (GHD, 2015) for river reaches of interest to stakeholders. While highly localised studies and field data do not broadly inform the regional-scale conceptualisation and analysis of groundwater-surface water interactions, they do provide a valuable basis for constraining the estimates, thereby improving the confidence of more broad-scale approaches.

A key outcome of this study was the development of field sampling condition criteria to select conditions that will give the most accurate and representative results. It is recommended that future field investigation studies adopt similar sampling criteria. Another recommendation from this study is to obtain field results for major ions - in additional to EC - for sites downstream of known agricultural or industrial discharges. This will confirm whether EC is representative of Chloride, or if it represents some other solute such as nitrogen. It is also recommended that any offtakes and outfalls within the monitored reaches are also recorded as part of the field sampling program.

This study refined the method for estimating interstation baseflow for detailed sub-reach mass balances, compared to the broader mass balances implemented in Stage 1. The recommended revised method for further baseflow studies is to estimate the EC of diverted water based on a river chainage-based interpolation to the diversion location, from the two gauge locations at the upstream and downstream ends of each assessed reach, and adopting the revised reach scale mass balance equation. The refinement to the equation should result in the highest possible degree of consistency between detailed sub-reach scale mass balances and broader scale mass balances.

For specific river reaches of interest to water managers and other stakeholders, there would be value in implementing an ongoing annual program of spatially detailed field sampling and analyses, for which this study forms a guide. Based on sampling results, a database of baseflow gains and flow losses along these reaches could be developed. This 'baseflow conditions' database would form a sound basis for more broadly characterising and better understanding priority river reaches in terms of seasonal baseflow conditions; in addition to how those conditions may change under variable climatic conditions and in response to land, water and resource developments. These broad characteristics could then be applied in:

- More robustly assessing the significance and value of groundwater inputs to environmental flows under a range of conditions
- Assessing threats to groundwater-dependent components of environmental flows, and
- Evaluating ongoing water management needs and options, licensing decisions, and approvals for significant land, water and resource developments.

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1. Introduction

1.1 Project background

The Department of Environment, Land, Water and Planning (DELWP) previously undertook two projects to fill information gaps on priority Groundwater Dependent Ecosystems (GDE) – baseflow dependent rivers and wetlands. These projects, completed by GHD, developed a methodology to:

- establish where groundwater interaction occurs with rivers and wetlands;
- quantify the groundwater contribution to the waterway where interaction occurs;
- identify associated high value environmental assets; and
- assess the risk to these environmental assets from groundwater extraction.

A discussion paper was prepared by GHD in 2012 to appraise methods for quantifying regional groundwater discharge to streams (as “baseflow”) throughout Victoria. This paper formed the basis of a workshop to decide which method would best be suited to quantifying groundwater-surface water interactions for high-risk baseflow-dependent waterways throughout Victoria. The adopted baseflow estimation method involved digital baseflow filtering “trained” to environmental tracer data – primarily electrical conductivity. A series of recommendations for trialling and implementing the recommended method were provided at the end of the discussion paper.

A pilot project was undertaken by GHD in 2012 - 2013 for five Victorian rivers (GHD, 2013a). The year-long pilot established an innovative method that characterised groundwater contributions to the upper Loddon, upper Moorabool, lower Ovens, lower Mitchell and lower Thomson-Macalister Rivers. These results were used to assess the risk of groundwater extraction to the environmental values that those rivers support.

This project was expanded in 2013 (GHD, 2013b) to a further eight Victorian rivers using the same method. Rivers assessed were the Latrobe, Barwon, Gellibrand, Glenelg, Hopkins, Yea, Seven Creeks and Deep Creek. As for the pilot method, the results were used to assess the risk of groundwater extraction to the environmental values that those rivers support.

The results from these projects were incorporated into a state-wide tool (Victorian Water Asset Register – VWAR) that flags areas where environmental values are potentially at risk from groundwater extraction (both current and future). This will assist waterway and environmental managers to manage risks to high priority GDEs.

A scientific review of both baseflow studies (GHD, 2013a; GHD, 2013b) made a number of recommendations to refine the method and quantification used to determine the risk of combined surface water and groundwater extractions to significant environmental values. These recommendations are reviewed and incorporated into this current project.

GHD, in partnership with Groundwater Logic, has been contracted by DELWP to assess the accuracy of baseflow estimates for the Latrobe, Thomson-Macalister and Mitchell River catchments.

1.2 Project objectives

The **primary objective** of this project is to improve the accuracy and reliability of the baseflow estimates along the Latrobe, Thomson-Macalister and Mitchell Rivers.

The objective of this project is to improve understanding of the degree and nature of interaction between rivers and groundwater in the Gippsland region, and to help understand potential impacts of coal mining, coal seam gas developments and other water uses on water-dependent environmental assets. The outputs of the work will improve the accuracy of, and confidence in, analysis of the dependency of flows on groundwater and improve technical basis on the likelihood of direct, indirect and cumulative impacts of water use on baseflows.

The scope of this project is to implement the recommendations from the scientific review of the method developed by GHD (GHD, 2013a; GHD, 2013b) for characterising groundwater contributions to rivers.

One of the key outcomes from this study is to provide a tiered framework for the application of the baseflow estimation method(s) most suitable for difference classes of reaches, such as losing reaches, gaining reaches and regulated reaches.

The project will apply the refined method to three high value Gippsland river systems (Figure 1):

- Latrobe River (Latrobe River to Kilmany South);
- Thomson-Macalister River system (Thomson River from Cowwarr Weir to Bundalaguah; Macalister River from Lake Glenmaggie to the confluence with the Thomson River); and
- Mitchell River (Glenaladale to Rosehill).

The project has been completed in two stages:

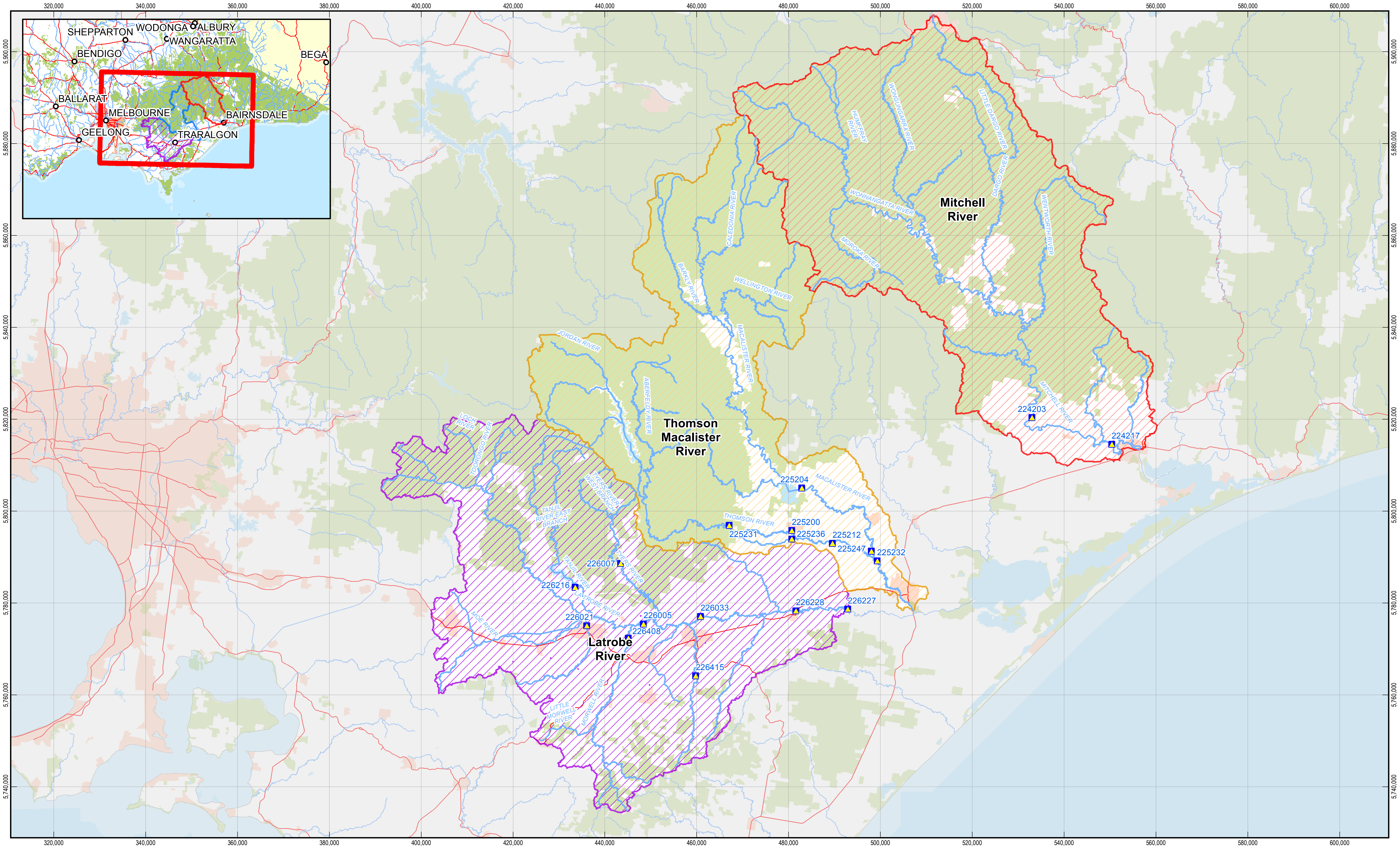
- Stage 1**:** Review groundwater contributions to rivers
- Stage 2: Targeted ground-truthing of existing data (data verification)

This report documents the Stage 2 assessment.

1.3 Project scope

Following on from the work completed in 2013 (GHD, 2013a; GHD, 2013b), the scope of work for Stage 2 of this project includes:

- Develop a field work plan to undertake monitoring at targeted ground-truthing sites;
- Undertake proposed field work at targeted locations and monitoring periods, based on the field work plan;
- Refine the baseflow analysis and interstation analysis based on the ground-truthing data; and
- Undertake high level analysis to assess potential effects that coal seam gas extraction may have on groundwater – surface water interactions.



Paper Size A3

0 4 8 16 24 32

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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- Major Water Course
- Latrobe River
- Mitchell River
- Thomson Macalister River
- Surface Water Gauges (Assessed)

State Government Victoria

GHD

Department of Environment, Land, Water & Planning
Gippsland River Baseflow Assessment

Catchment Overview
Baseflow Catchments

Job Number	31-32709
Revision	A
Date	27 May 2015

Figure 1

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Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015. Created by: adrummond

2. Field Work Plan

2.1 Background

It is recognised that while long-term data collection is the optimal approach for refining baseflow estimates, it is not possible to apply in this project given the short time-frame and budgetary constraints. Improved baseflow estimates are important for long-term groundwater-surface water management and provide valuable context in a range of water management issues, such as assessing the impact of groundwater extraction on environmental flows in priority reaches and groundwater dependent ecosystems. The field work plan developed for Stage 2 of this project focussed on activities that can be undertaken within the time and budget available, and could potentially achieve an improvement in the baseflow separation accuracy or uncertainty. The field sampling, analysis methods and interpretations applied in this study also form a useful template for ongoing monitoring and investigations. While highly localised studies and field data do not broadly inform the regional-scale conceptualisation and analysis of groundwater-surface water interactions, they do provide a valuable basis for constraining the more regional-scale estimates and thereby improving the approach to and confidence in more broad-scale approaches.

The targeted sites for field assessment were discussed between the relevant authorities (CMAs, SRW and DELWP) to prioritise the field assessments on reaches which will deliver most value to stakeholders, while meeting the requirements of the Gippsland CMAs and the Bioregional Assessment Program.

2.1.1 General Field Monitoring Options

The three main field activities proposed in this study include: flow and EC accretion profiling, EC and flow logging, and groundwater sampling. It is acknowledged that the project budget does not allow for all of these to be applied to all reaches; therefore a decision was made on the best use of resources and the preferred location of these activities.

The key field data collection options which could be implemented to assist in ground-truthing of the baseflow estimates are summarised below:

- *Flow and EC accretion profiling:* This activity consists of measuring streamflow and sampling EC at key points along the reach of interest, allowing a reach to be broken up into various sub-reaches. This method provides additional detail within a reach that has already been assessed using the baseflow estimation method, and may identify where the main discharges of baseflow occur spatially.
- *Groundwater potentiometry and EC sampling:* This activity would provide additional data to refine the groundwater EC end members used to estimate baseflow. The potentiometry data would provide qualitative information, indicating whether the river is gaining or losing at a particular location. However, there are large practical uncertainties with respect to accessing private bores and the time required to obtain groundwater samples. Consequently, there is potential for this to be an expensive activity relative to the benefit of the additional data.
- *Installation of temporary EC loggers at existing streamflow gauging locations:* This activity has a moderate cost and short to medium duration and would allow the collection of continuous EC data at sites that currently only have monthly or quarterly water quality sampling. This would provide significantly more data to calibrate the baseflow estimation method, particularly the reach-scale mass balance that requires EC data on the same day at multiple gauges.

- *Installation of temporary flow gauging stations with EC loggers:* This option would enable a greater spatial coverage of the baseflow estimation method; however, given the large installation costs, it is perhaps more appropriate that this be undertaken as part of a longer term program.

A targeted field work plan to undertake flow and EC accretion profiling was developed in consultation with DELWP, WGCMA and SRW, based on the key data gaps identified in Stage 1 (GHD, 2015), and the key reaches of interest. The key reaches include:

- Thomson River from Cowwarr to Wandocka;
- Moe Drain / Latrobe River upstream of Lake Narracan; and
- Macalister River between Glenmaggie and Maffra Weir.

Sampling locations were selected to monitor immediately upstream and downstream of key discharge points to the main reach (i.e. irrigation drains, tributaries, etc.), and where possible to promote site accessibility (i.e. close to roads and tracks, accessible via public land). They were also selected to avoid any site specific issues identified by Thiess (i.e. flooding of the Maffra Weir Pool during the irrigation season). It was decided that data would be collected for three sampling rounds over the study period, covering different seasons and regulated influences (irrigation releases):

- Sampling Round 1: Spring 2015 (09/09/2015 – 28/09/2015). Capture flows at the start of the irrigation season.
- Sampling Round 2: Summer 2016 (12/01/2016 – 05/02/2016): Capture summer low flows.
- Sampling Round 3: Autumn 2016 (12/04/2016 – 17/05/2016): Capture flows outside of irrigation season.

The sampling locations are outlined in the sections below.

2.2 Thomson River from Cowwarr to Wandocka

Anecdotal evidence suggests that the Thomson River between Cowwarr and Wandocka is a seasonal flow 'losing' reach. Surface water flow and EC accretion profiling will provide additional evidence to confirm whether or not this reach is in fact 'losing'. It was anticipated that further investigation could be useful to help assess future local water management plans for this region.

Nine sampling locations were initially selected along the Thomson River between Cowwarr and Wandocka, shown on Figure 2, and summarised below:

1. Thomson River U/S Cowwarr Weir (225231A)
2. Thomson River @ Timber Weir (225228A)
3. Rainbow Creek D/S Cowwarr Weir (225227A)
4. Rainbow Creek U/S Thomson River
5. Thomson River D/S Stoney Creek
6. Thomson River U/S Back Creek
7. Thomson River U/S Rainbow Creek
8. Thomson River D/S Rainbow Creek (225243A)
9. Thomson River at Wandocka (225212)

It is noted that the sampling locations were indicative, with minor adjustments made in the field to identify locations with adequate geomorphology for gauging and EC/temperature sampling.

2.3 Macalister River between Glenmaggie and Maffra Weir

Five indicative sampling locations were selected along the Macalister River between Glenmaggie and Maffra Weir, shown on Figure 3, and summarised below:

1. 225204D Macalister River D/S Glenmaggie T/G
2. Macalister River U/S Newry Drain (Banana Bridge)
3. Macalister River U/S Maffra Weir Pool (Bellbird Corner)
4. 225242A Macalister River D/S Maffra Weir T/G
5. 225247A Macalister River @ Riverslea

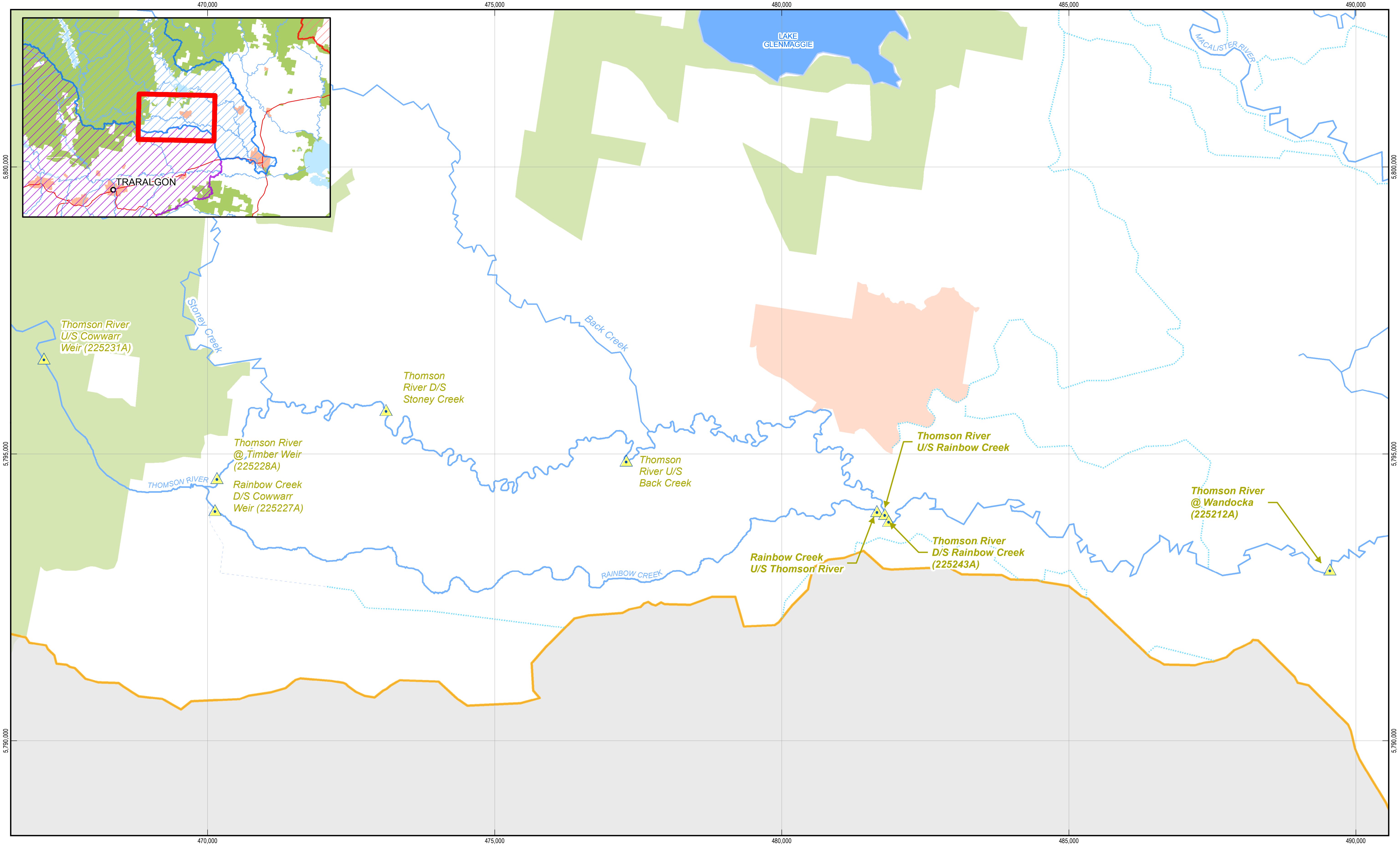
There is a high density of groundwater extractions within this region of the Macalister River, from the Wa De Lock GMA and the Rosedale GMA. It was anticipated that spot sampling along this reach would provide additional information to ground-truth existing baseflow estimates, and this information could be used to support future local water planning studies in this region.

2.4 Moe Drain / Latrobe River (upstream of Lake Narracan)

The WGCMA and SRW have expressed interest in investigating the interaction between groundwater and surface water within the Moe Groundwater Management Area. The baseflow separation method was not applied along the Moe River in previous studies due to data limitations. It was anticipated that targeted field work within this region would provide estimates of baseflow which can be used as a baseline for future assessments.

Twelve indicative sampling locations were selected along the Moe Drain / Latrobe River upstream of Lake Narracan, shown on Figure 4, and summarised below:

1. 226209B Moe River @ Darnum (Site 1)
2. Moe Drain Site 2 (Start of drain)
3. Moe Drain Site 3
4. 226402A Moe Drain @ Trafalgar East (Site 4)
5. Moe River U/S Latrobe River (Site 5)
6. 226204A Latrobe River @ Willow Grove
7. Latrobe River U/S Moe Drain
8. 226218A Narracan Creek @ Thorpdale
9. 226021A Narracan Creek @ Moe
10. 226216A Tanjil River @ Tanjil South
11. Tanjil River U/S Latrobe River
12. Latrobe River at U/S Lake Narracan (Becks Bridge)



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Kilometers

Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 55

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Major Water Area
Major Watercourse
Thomson Macalister River Catchment
Field Sampling Location

State Government Victoria

GHD

Department of Environment, Land, Water & Planning
Gippsland River Baseflow Assessment

Job Number 31-32709
Revision B
Date 01 Mar 2016

Field Monitoring Locations Thomson River

Figure 2

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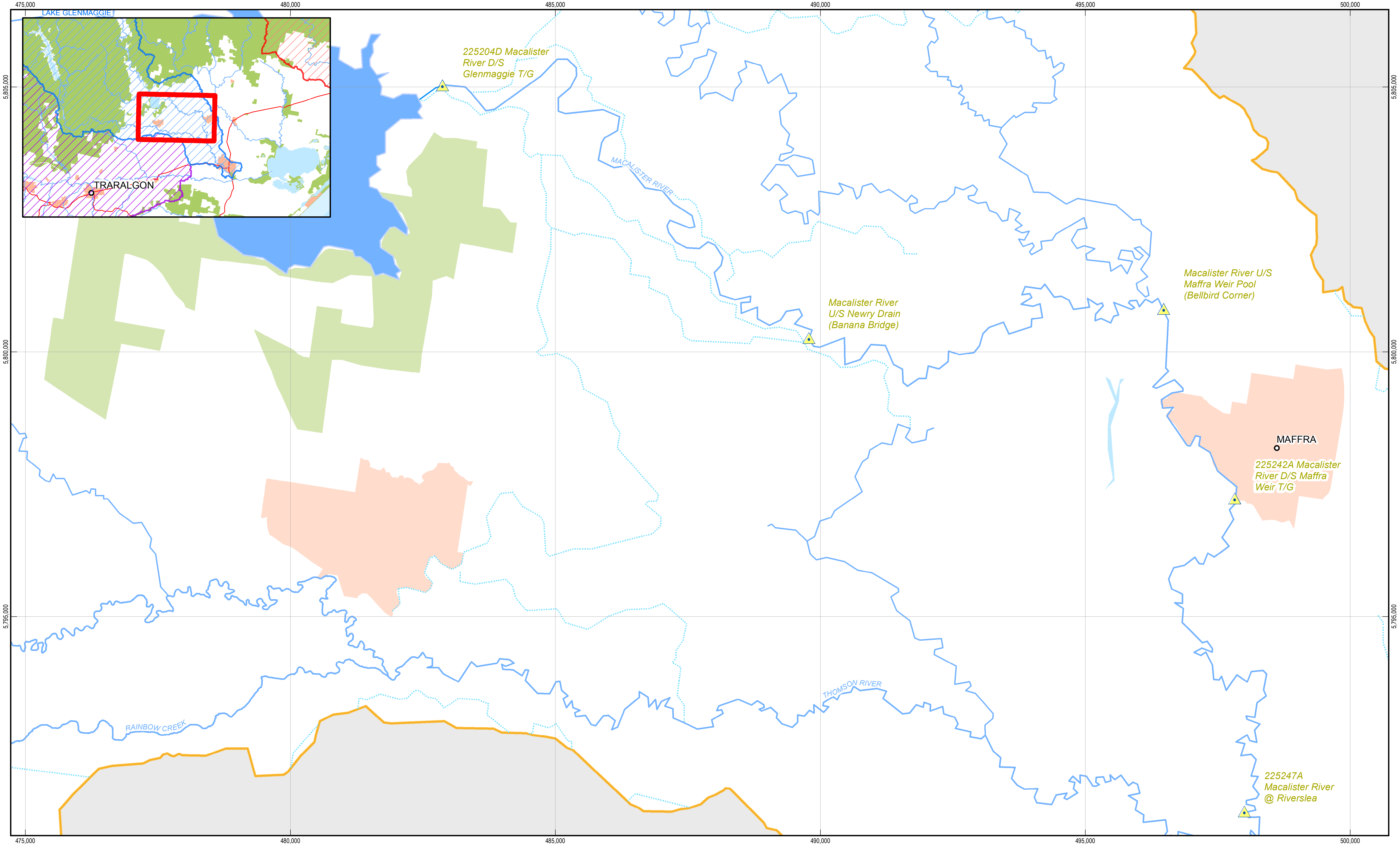
Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by: adrummond



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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
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Major Water Area
Major Watercourse
Thomson Macalister River Catchment
Field Sampling Location

Department of Environment, Land, Water & Planning
Gippsland River Baseflow Assessment

Job Number	31-32709
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Date	01 Mar 2016

Field Monitoring Locations Macalister River

Figure 3

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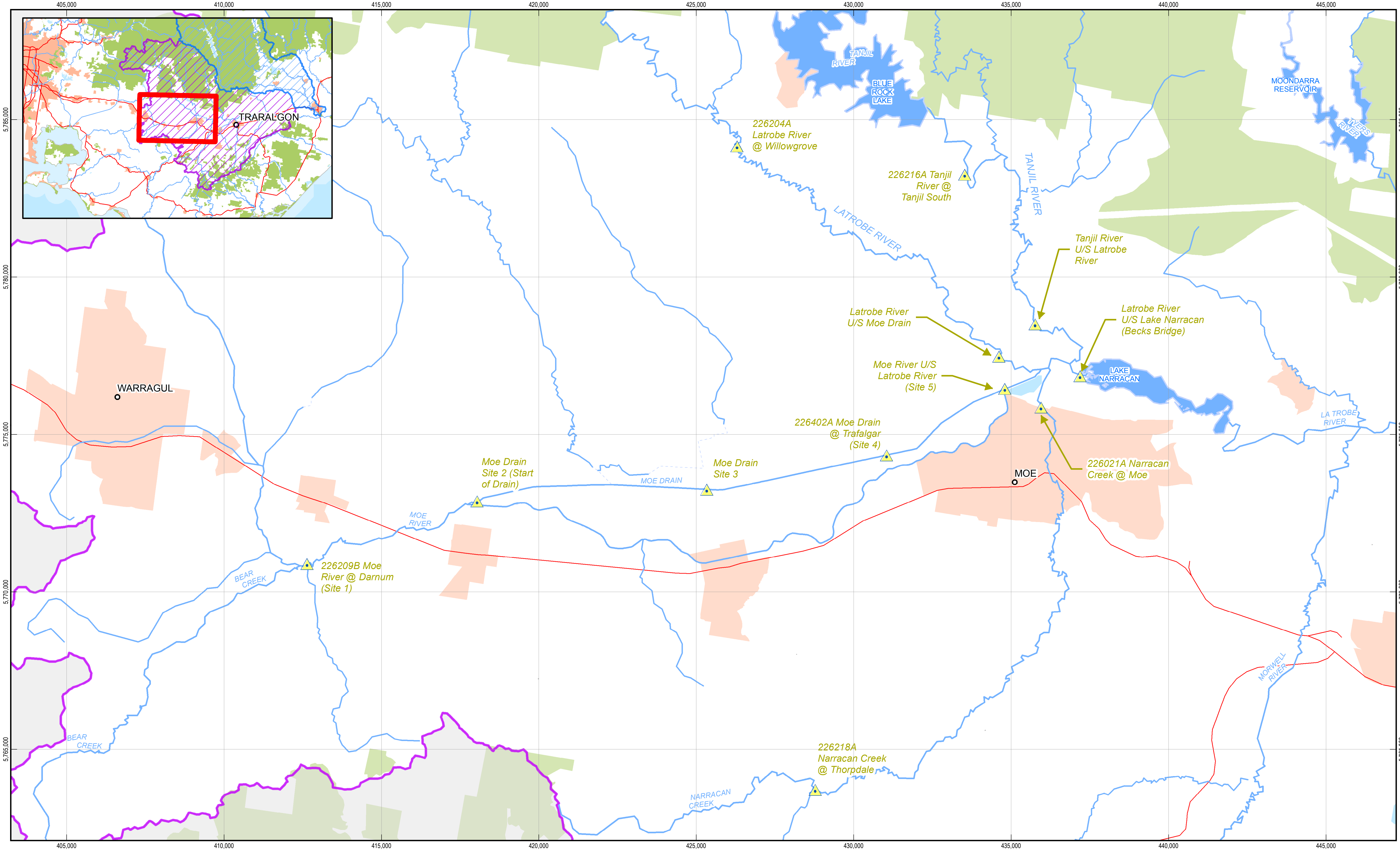

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0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Major Water Area
Major Watercourse
Latrobe River Catchment
Field Sampling Location

State Government Victoria

GHD

Department of Environment, Land, Water & Planning
Gippsland River Baseflow Assessment

Job Number 31-32709
Revision B
Date 01 Mar 2016

Field Monitoring Locations
Latrobe River

Figure 4

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by: adrummond

2.5 Field Sampling Condition Criteria

The objective of this study is to measure the groundwater contributions along river reaches by gauging flows and EC at key locations along the river. While it may be possible to measure these under almost all conditions, the constraint that sampling was limited to three rounds (designed to represent different seasons) meant that it was critical to select conditions that would give the most accurate and representative results. To identify suitable conditions for undertaking the streamflow gauging and EC sampling, a number of criteria were evaluated prior to commencing field investigations, and are outlined below.

Safety

The streamflow must be suitably low, to permit safe access to undertake flow gauging. The streamflow threshold varies depending on the site to be sampled. The hydrographer is able to make an assessment of the suitability for gauging. Other safety consideration may further limit field sampling.

River Operation

Periods associated with large reservoir releases (such as flood mitigation type releases) should be avoided, as these releases are likely to obscure the more subtle groundwater surface water interactions.

Streamflow Rate

As a generalisation, it is also possible to more accurately gauge streamflow at lower flow rates. While this depends on the hydraulic properties of the site, the absolute error is likely to grow as flow increases, where at high flows this error may exceed the interstation groundwater contribution. This study adopted a broad target to aim to undertake sampling when the flow rate was below the median flow for the month of year. However, it is important to note that other factors (such as regulation and recent rainfall) are likely to have a greater impact on the results.

Streamflow Trends

Sampling during peak streamflow following large rainfall events should be avoided for a number of reasons. The streamflow following rainfall events is likely to be high flows which have an associated higher uncertainty in the flow measurement, a relatively low proportion of groundwater contribution, first flush of salts, and high bank storage effects. It is desirable to undertake sampling as long after the peak as is practical so that these short term effects have reduced and groundwater has begun to more steadily contribute to flow.

Streamflow Profile (Longitudinal)

Field monitoring should be undertaken when the difference in streamflow between sites is relatively stable. If the streamflow is dropping rapidly as a peak of water travels down the river (from rainfall events or regulation) then it will not be possible to make a suitable comparison between sites.

Forecast Rainfall

Field monitoring should be undertaken when forecast rainfall over the proposed work period is 5 mm or less. This is especially important for the Thomson and Latrobe River catchments which require multiple days to complete sampling of the full suite of sites. However, it is noted that if another significant constraint is likely to more significantly impact the proposed work period, then a forecast of up to 10 mm may be acceptable. If the forecast is clear then it may be best to wait as long as possible, to allow other aspects to improve as necessary.

3. Field Work Results

To date, two of the three rounds of field sampling have been undertaken at the sampling locations as per the field work plan, discussed in Section 2. The first sampling round was undertaken in September (9th September until 28th September 2015) to capture the spring baseflows at the start of the irrigation season. The second sampling round was undertaken in mid-January to early February (12th January – 5th February 2016) to capture the summer baseflow conditions. The third round of field monitoring is scheduled to be completed in late May 2016 to capture the autumn base flow conditions following the end of the irrigation season.

Site photographs captured by Thiess during the spring sampling round showing the site conditions are contained in Appendix A.

3.1 Thomson River

Figure 5 summarises the streamflow and EC monitoring results for the Thomson River catchment (from Cowwarr to Wandocka), with the raw data obtained from Thiess contained in Appendix B.

Table 1 summarises the field results for the Thomson River taken for the first round of monitoring in spring. The following field notes were obtained when sampling:

1. Southern Rural Water commented that Cowwarr Channel was running at a constant rate of 67.2 ML/day (09/09/2015);
2. Logger at visit Cowwarr Head Gauge (HG): 64.927 ML/day and Tail Gauge (TG) 0.139 ML/day; and
3. Additional site information collected for the Stoney Creek Crossing and Syphon Outfall.

Table 1 Thomson Catchment Round 1 Field Results

Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
Thomson River U/S Cowwarr Weir (225231A)	9/09/2015	368.5	73	Overcast / Showers
Thomson River @ Timber Weir (225228A)	9/09/2015	262.3	73	Overcast / Showers
Thomson River D/S Stoney Creek	9/09/2015	293.0	77	Overcast / Showers
Rainbow Creek D/S Cowwarr Weir (225227A)	9/09/2015	56.7	74	Overcast / Showers
Thomson River U/S Back Creek	9/09/2015	290.4	78	Overcast / Showers
Stoney Creek Crossing	9/09/2015	3	142	Flow est.
Day 2				
Rainbow Creek @ U/S Thomson River	10/09/2015	67.4	101	Fine
Thomson River @ U/S of Rainbow Creek	10/09/2015	266.5	83	Fine
Thomson River @ U/S of Rainbow Creek	10/09/2015	269.3	83	Confirmation Meas.
Thomson River D/S Rainbow Creek (225243A)	10/09/2015	385.9	84	Fine
Thomson River @ Wandocka (225212A)	10/09/2015	404.2	92	Fine
Thomson River U/S Back Creek	10/09/2015	251.5	78	Fine

Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Syphon Outfall	10/09/2015	10 - 20	62	Flow est.

Table 2 summarises the field results for the Thomson River taken for the second round of monitoring in summer. The following field notes were obtained when sampling:

1. Southern Rural Water (D. Johnson) commented that Cowwarr Channel was running at a rate of 20 – 23 ML/day;
2. Logger at visit Cowwarr HG: 64.927 ML/day and TG 0.139 ML/day; and
3. Additional site information collected for the Stoney Creek Crossing and Syphon Outfall.

Table 2 Thomson Catchment Round 2 Field Results

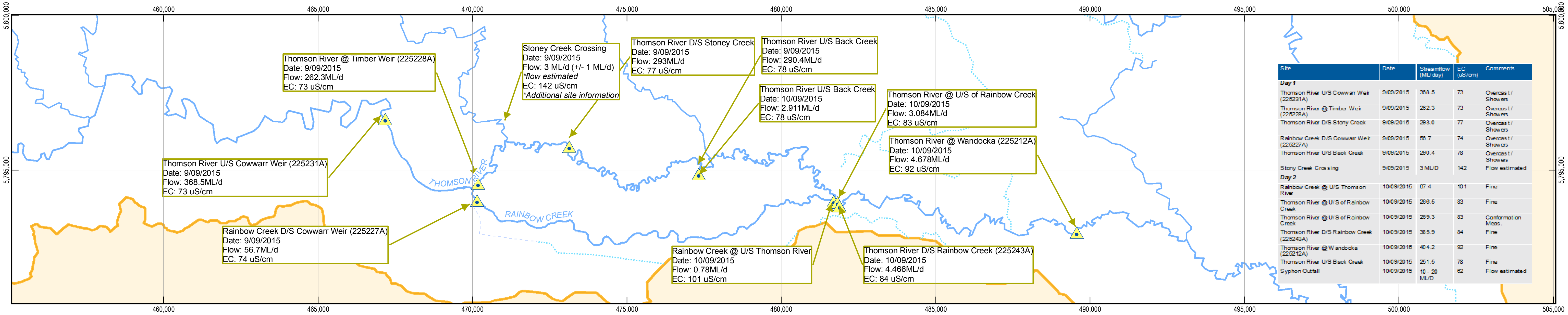
Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
Thomson River U/S Cowwarr Weir (225231A)	12/01/2016	231.6	83	Weather Fine
Thomson River @ Timber Weir (225228A)	12/01/2016	126.6	91	Weather Fine
Thomson River D/S Stoney Creek	12/01/2016	136.6	99	Weather Fine
Rainbow Creek D/S Cowwarr Weir (225227A)	12/01/2016	57.5	91	Weather Fine
Thomson River U/S Back Creek	12/01/2016	110.8	100	Weather Fine
Stoney Creek Crossing	12/01/2016	2		Flow est.
Day 2				
Rainbow Creek @ U/S Thomson River	13/01/2016	52.9	108	Weather Fine
Thomson River @ U/S of Rainbow Creek	13/01/2016	117.5	103	Weather Fine
Thomson River D/S Rainbow Creek (225243A)	13/01/2016	210.4	100	Weather Fine
Thomson River @ Wandocka (225212A)	13/01/2016	161.5	107	Weather Fine
Thomson River U/S Back Creek	13/01/2016	121.0	98	Weather Fine
Syphon Outfall	13/01/2016	40		Flow est.

Table 3 summarises the field results for the Thomson River taken for the third round of monitoring in summer. The following field notes were obtained when sampling:

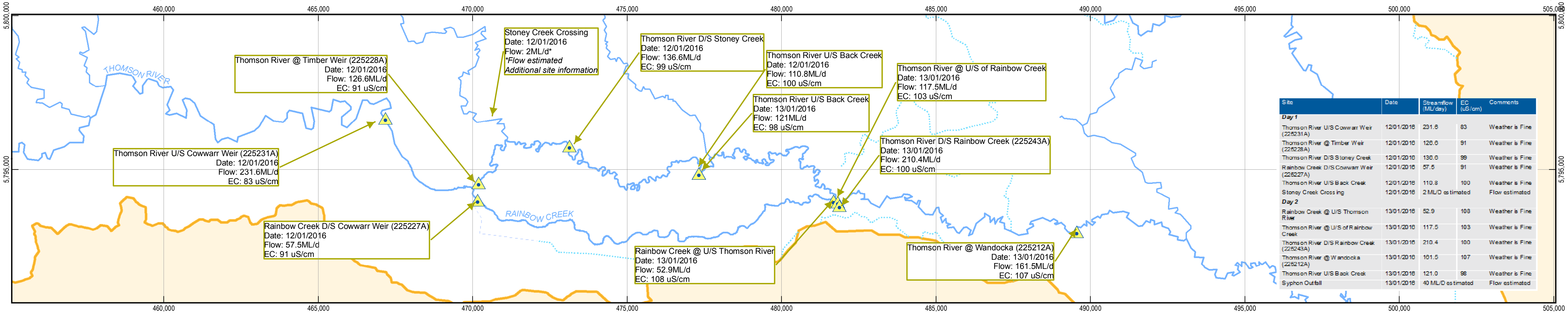
1. Southern Rural Water (D. Johnson) commented that 6 ML/day was being released down the Cowwarr Channel
2. Syphon Outfall was estimated to have a flow of 30 to 40 ML/day at 11:30 AM and 5 to 10 ML/day at 12:50 PM.

Table 3 Thomson Catchment Round 3 Field Results

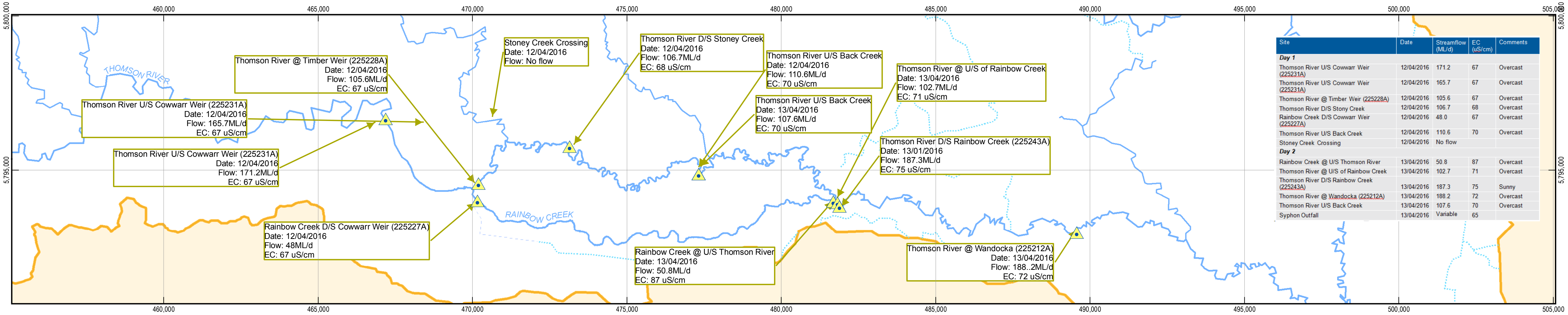
Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
Thomson River U/S Cowwarr Weir (225231A)	12/04/2016	171.2	67	Overcast
Thomson River U/S Cowwarr Weir (225231A)	12/04/2016	165.7	67	Overcast
Thomson River @ Timber Weir (225228A)	12/04/2016	105.6	67	Overcast
Thomson River D/S Stony Creek	12/04/2016	106.7	68	Overcast
Rainbow Creek D/S Cowwarr Weir (225227A)	12/04/2016	48.0	67	Overcast
Thomson River U/S Back Creek	12/04/2016	110.6	70	Overcast
Stoney Creek Crossing	12/04/2016	No flow		
Day 2				
Rainbow Creek @ U/S Thomson River	13/04/2016	50.8	87	Overcast
Thomson River @ U/S of Rainbow Creek	13/04/2016	102.7	71	Overcast
Thomson River D/S Rainbow Creek (225243A)	13/04/2016	187.3	75	Sunny
Thomson River @ Wandocka (225212A)	13/04/2016	188.2	72	Overcast
Thomson River U/S Back Creek	13/04/2016	107.6	70	Overcast
Syphon Outfall	13/04/2016	Variable	65	



Site	Date	Streamflow (ML/day)	EC (uS/cm)	Comments
Day 1				
Thomson River U/S Cowwarr Weir (225231A)	9/09/2015	368.5	73	Overcast / Showers
Thomson River @ Timber Weir (225228A)	9/09/2015	262.3	73	Overcast / Showers
Thomson River D/S Stony Creek	9/09/2015	293.0	77	Overcast / Showers
Rainbow Creek D/S Cowwarr Weir (225227A)	9/09/2015	56.7	74	Overcast / Showers
Thomson River U/S Back Creek	9/09/2015	290.4	78	Overcast / Showers
Stony Creek Crossing	9/09/2015	3 ML/D	142	Flow estimated
Day 2				
Rainbow Creek @ U/S Thomson River	10/09/2015	67.4	101	Fine
Thomson River @ U/S of Rainbow Creek	10/09/2015	266.5	83	Fine
Thomson River @ U/S of Rainbow Creek	10/09/2015	269.3	83	Conformation Meas.
Thomson River D/S Rainbow Creek (225243A)	10/09/2015	385.9	84	Fine
Thomson River @ Wandocka (225212A)	10/09/2015	404.2	92	Fine
Thomson River U/S Back Creek	10/09/2015	251.5	78	Fine
Syphon Outfall	10/09/2015	10 - 20 ML/D	62	Flow estimated



Site	Date	Streamflow (ML/day)	EC (uS/cm)	Comments
Day 1				
Thomson River U/S Cowwarr Weir (225231A)	12/01/2016	231.6	83	Weather is Fine
Thomson River @ Timber Weir (225228A)	12/01/2016	126.6	91	Weather is Fine
Thomson River D/S Stoney Creek	12/01/2016	136.6	99	Weather is Fine
Rainbow Creek D/S Cowwarr Weir (225227A)	12/01/2016	57.5	91	Weather is Fine
Thomson River U/S Back Creek	12/01/2016	110.8	100	Weather is Fine
Stoney Creek Crossing	12/01/2016	2 ML/D estimated		Flow estimated
Day 2				
Rainbow Creek @ U/S Thomson River	13/01/2016	52.9	108	Weather is Fine
Thomson River @ U/S of Rainbow Creek	13/01/2016	117.5	103	Weather is Fine
Thomson River D/S Rainbow Creek (225243A)	13/01/2016	210.4	100	Weather is Fine
Thomson River @ Wandocka (225212A)	13/01/2016	161.5	107	Weather is Fine
Thomson River U/S Back Creek	13/01/2016	121.0	98	Weather is Fine
Syphon Outfall	13/01/2016	40 ML/D estimated		Flow estimated



Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
Thomson River U/S Cowwarr Weir (225231A)	12/04/2016	171.2	67	Overcast
Thomson River U/S Cowwarr Weir (225231A)	12/04/2016	165.7	67	Overcast
Thomson River @ Timber Weir (225228A)	12/04/2016	105.6	67	Overcast
Thomson River D/S Stony Creek	12/04/2016	106.7	68	Overcast
Rainbow Creek D/S Cowwarr Weir (225227A)	12/04/2016	48.0	67	Overcast
Thomson River U/S Back Creek	12/04/2016	110.6	70	Overcast
Stoney Creek Crossing	12/04/2016	No flow		
Day 2				
Rainbow Creek @ U/S Thomson River	13/04/2016	50.8	87	Overcast
Thomson River @ U/S of Rainbow Creek	13/04/2016	102.7	71	Overcast
Thomson River D/S Rainbow Creek (225243A)	13/04/2016	187.3	75	Sunny
Thomson River @ Wandocka (225212A)	13/04/2016	188.2	72	Overcast
Thomson River U/S Back Creek	13/04/2016	107.6	70	Overcast
Syphon Outfall	13/04/2016	Variable	65	

Paper Size A3

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Field Sampling Location
Thomson Macalister River Catchment
Major Water Area
River
Stream
Channel
Drain/Channel/Ot...

Department of Environment Land Water and Planning
Gippsland Rivers Baseflow Assessment

Job Number 31-32709
Revision A
Date 31 May 2016

Field Monitoring Results Thomson River

Figure 5

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by:adrummond

3.2 Macalister River

Figure 6 summarises the streamflow and EC monitoring results for the Macalister River catchment (from Glenmaggie to Riverslea), with the raw data obtained from Thiess contained in Appendix B.

Table 4 summarises the field results for the Macalister River taken for the first round of monitoring in spring. The following field notes were obtained when sampling:

1. Small outflow into Macalister River at Maffra Weir D/S measurement section, estimated at 2-3 ML/d, EC recorded at 240 EC and Temperature 24.0 C;
2. Outflow from Lake Glenmaggie had been cut back 3 days prior to measurements;
3. SRW Estimate 60 ML/d flowing down the Eastern Channel from Maffra Weir; and
4. Possibly significant inflows into the Macalister River between Maffra Weir and Riverslea via the Serpentine Creek.

Table 4 Macalister Catchment Round 1 Field Results

Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
225204D Macalister River D/S Glenmaggie T/G	28/09/2015	108.5	49.3	Overcast
Macalister River U/S Newry Drain (Banana Bridge)	28/09/2015	123.1	63.9	Overcast
Macalister River U/S Maffra Weir Pool (Bellbird Corner)	28/09/2015	150.6	109.5	Overcast
225242A Macalister River D/S Maffra Weir T/G	28/09/2015	98.1	78.5	Overcast
225247A Macalister River @ Riverslea	28/09/2015	129.6	143.1	Overcast
225204D Macalister River D/S Glenmaggie T/G	28/09/2015	108.5	49.3	Overcast

Table 5 summarises the field results for the Macalister River taken for the second round of monitoring in spring. No additional field notes were made during monitoring.

Table 5 Macalister Catchment Round 2 Field Results

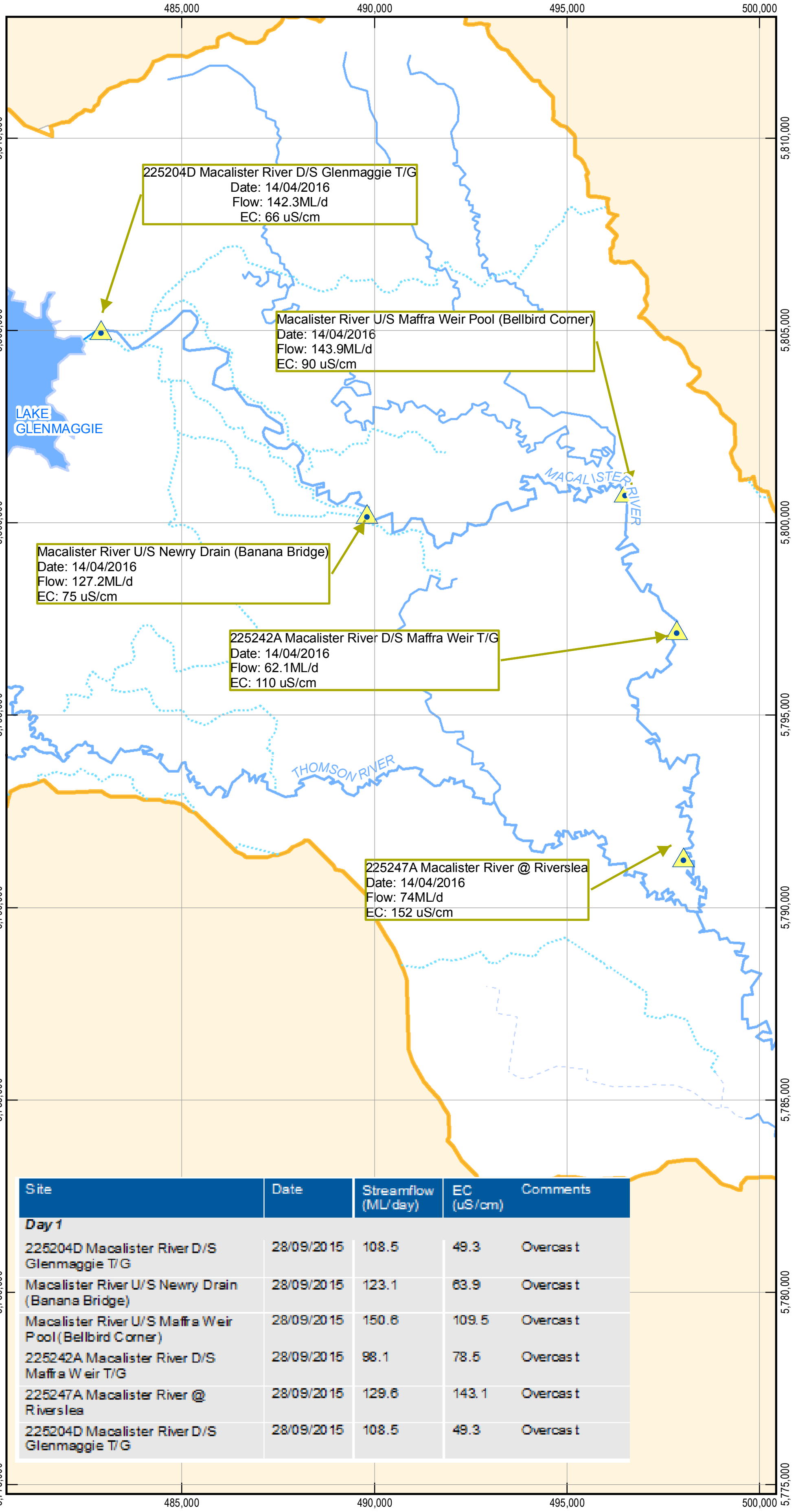
Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
225204D Macalister River D/S Glenmaggie T/G	14/01/2016	256.2	62	Weather is Fine
Macalister River U/S Newry Drain (Banana Bridge)	14/01/2016	244.7	60	Weather is Fine
Macalister River U/S Maffra Weir Pool (Bellbird Corner)	14/01/2016	258.2	80	Weather is Fine
225242A Macalister River D/S Maffra Weir T/G	14/01/2016	93.3	110	Weather is Fine
225247A Macalister River @ Riverslea	14/01/2016	129.1	209	Weather is Fine
225204D Macalister River D/S Glenmaggie T/G	14/01/2016	256.2	62	Weather is Fine

Table 6 summarises the field results for the Macalister River taken for the third round of monitoring in spring. The following field notes were obtained when sampling:

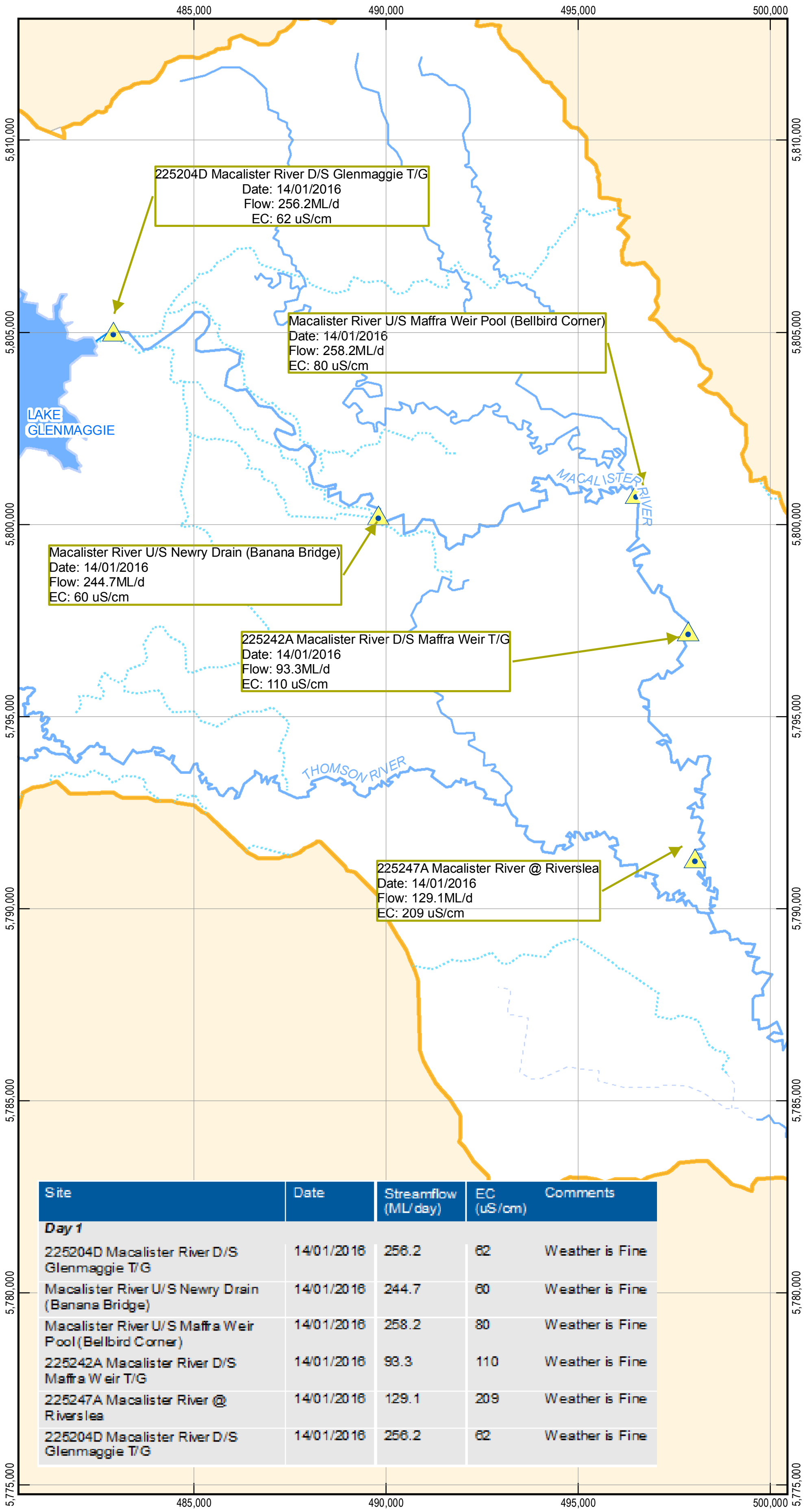
1. The pipe and gate 2 was closed at Maffra Weir
2. Small outflow into Macalister River at Maffra Weir D/S measurement section, estimated at 2-3 ML/d, EC recorded at 534 EC and Temperature 24.7°C
3. Flow in Serpentine Creek at Singletons was estimated between 3 and 5 ML/day, EC and temperature recorded was 374 and 18.3°C respectively.
4. Flow in Carter Creek (U/S Bellbird Corner) was estimated to be 2 ML/day, EC and temperature recorded was 560 and 16.5°C respectively.
5. SRW noted irrigation supply of 10 ML/day downstream of Banana Bridge.

Table 6 Macalister Catchment Round 3 Field Results

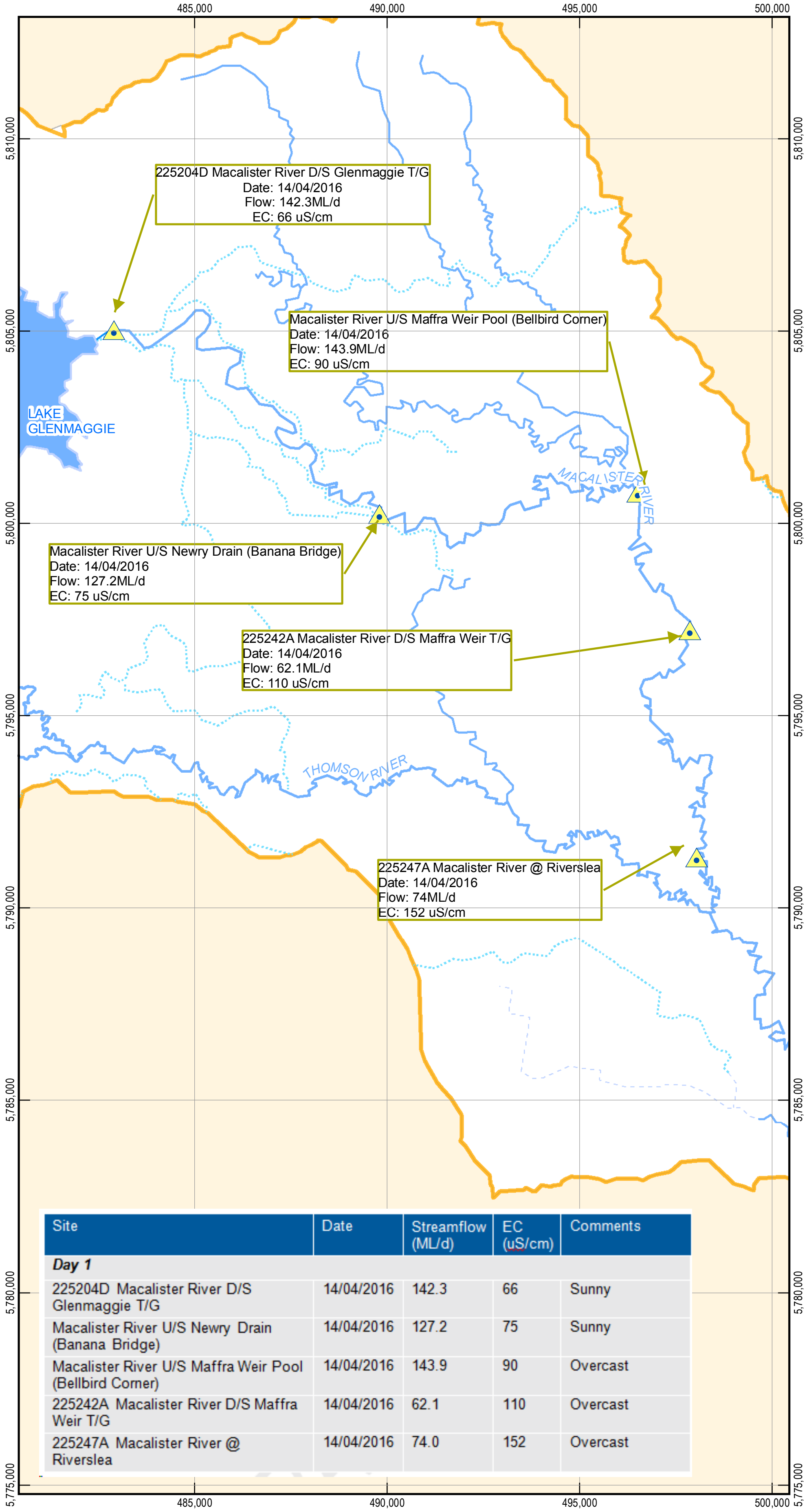
Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
225204D Macalister River D/S Glenmaggie T/G	14/04/2016	142.3	66	Sunny
Macalister River U/S Newry Drain (Banana Bridge)	14/04/2016	127.2	75	Sunny
Macalister River U/S Maffra Weir Pool (Bellbird Corner)	14/04/2016	143.9	90	Overcast
225242A Macalister River D/S Maffra Weir T/G	14/04/2016	62.1	110	Overcast
225247A Macalister River @ Riverslea	14/04/2016	74.0	152	Overcast



Site	Date	Streamflow (ML/day)	EC (uS/cm)	Comments
Day 1				
225204D Macalister River D/S Glenmaggie T/G	28/09/2015	108.5	49.3	Overcast
Macalister River U/S Newry Drain (Banana Bridge)	28/09/2015	123.1	63.9	Overcast
Macalister River U/S Maffra Weir Pool (Bellbird Corner)	28/09/2015	150.6	109.5	Overcast
225242A Macalister River D/S Maffra Weir T/G	28/09/2015	98.1	78.5	Overcast
225247A Macalister River @ Riverslea	28/09/2015	129.6	143.1	Overcast
225204D Macalister River D/S Glenmaggie T/G	28/09/2015	108.5	49.3	Overcast



Site	Date	Streamflow (ML/day)	EC (uS/cm)	Comments
Day 1				
225204D Macalister River D/S Glenmaggie T/G	14/01/2016	256.2	62	Weather is Fine
Macalister River U/S Newry Drain (Banana Bridge)	14/01/2016	244.7	60	Weather is Fine
Macalister River U/S Maffra Weir Pool (Bellbird Corner)	14/01/2016	258.2	80	Weather is Fine
225242A Macalister River D/S Maffra Weir T/G	14/01/2016	93.3	110	Weather is Fine
225247A Macalister River @ Riverslea	14/01/2016	129.1	209	Weather is Fine
225204D Macalister River D/S Glenmaggie T/G	14/01/2016	256.2	62	Weather is Fine



Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
225204D Macalister River D/S Glenmaggie T/G	14/04/2016	142.3	66	Sunny
Macalister River U/S Newry Drain (Banana Bridge)	14/04/2016	127.2	75	Sunny
Macalister River U/S Maffra Weir Pool (Bellbird Corner)	14/04/2016	143.9	90	Overcast
225242A Macalister River D/S Maffra Weir T/G	14/04/2016	62.1	110	Overcast
225247A Macalister River @ Riverslea	14/04/2016	74.0	152	Overcast

Paper Size A3

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Field Sampling Location
Thomson Macalister River Catchment
Major Water Area

River
Stream
Channel
Drain/Channel/Ot...

Department of Environment Land Water and Planning
Gippsland Rivers Baseflow Assessment

Job Number	31-32709
Revision	A
Date	31 May 2016

Field Monitoring Results
Macalister River

Figure 6

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Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by:adrummond

3.3 Latrobe River

Figure 7 summarises the streamflow and EC monitoring results for the Macalister River catchment (from Glenmaggie to Riverslea), with the raw data obtained from Thiess contained in Appendix B.

Table 7 summarises the field results for the Latrobe River taken for the first round of monitoring in spring. No additional field notes were made during monitoring.

Table 7 Latrobe River Catchment Round 1 Field Results

Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
226209B Moe River @ Darnum (Site 1)	23/09/2015	128.2	340.2	Overcast
Moe Drain Site 2 (Start of Drain)	23/09/2015	150.9	374.5	Overcast
Moe Drain Site 3	23/09/2015	231.4	447.1	Overcast
226402A Moe Drain @ Trafalgar (Site 4)	23/09/2015	234.7	493.2	Overcast
Day 2				
Moe River U/S Latrobe River (Site 5)	24/09/2015	240.5	488.6	Overcast
226204A Latrobe River @ Willowgrove	24/09/2015	437.9	92	Overcast
Latrobe River U/S Moe Drain	24/09/2015	482.9	118.5	Overcast
Latrobe River U/S Lake Narracan (Becks Bridge)	24/09/2015	1338.7	191.1	Overcast
226216A Tanjil River @ Tanjil South	24/09/2015	496.7	81	Overcast
Tanjil River U/S Latrobe River	24/09/2015	483.1	98.5	Overcast
226218A Narracan Creek @ Thorpdale	24/09/2015	65.9	124	Overcast
226021A Narracan Creek @ Moe	24/09/2015	88.8	219.2	Overcast

Table 8 summarises the field results for the Latrobe River taken for the second round of monitoring in spring. The following field notes were obtained when sampling:

1. Tanjil River rising/falling quickly due to unsteady outflows from Blue Rock; and
2. Estimated flows 10 -15 ML/d entering Moe Drain just upstream of site 226402A Moe Drain at Trafalgar East from small drain.

Table 8 Latrobe River Catchment Round 2 Field Results

Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
226209B Moe River @ Darnum (Site 1)	4/02/2016	14.7	359	Fine
Moe Drain Site 2 (Start of Drain)	4/02/2016	13.8	340	Fine
Moe Drain Site 3	4/02/2016	31.3	472	Fine
226402A Moe Drain @ Trafalgar (Site 4)	4/02/2016	38.6	570	Flows entering drain just upstream
Moe River U/S Latrobe River (Site 5)	4/02/2016	38.8	547	Fine
Day 2				
Moe River U/S Latrobe River (Site 5)	5/02/2016	35.4	576	Fine
226204A Latrobe River @ Willowgrove	5/02/2016	227.5	98	Fine
Latrobe River U/S Moe Drain	5/02/2016	276.6	111	Fine
Latrobe River U/S Lake Narracan (Becks Bridge)	5/02/2016	408.5	158	Fine
226216A Tanjil River @ Tanjil South	5/02/2016	111.9	88	Fine
Tanjil River U/S Latrobe River	5/02/2016	89.3	98	Fine
226218A Narracan Creek @ Thorpdale	5/02/2016	13.0	158	Fine
226021A Narracan Creek @ Moe	5/02/2016	17.8	283	Fine

Table 9 summarises the field results for the Latrobe River taken for the third round of monitoring in spring. The following field notes were obtained when sampling:

1. 226216A: Pumping from gauge pool at time of measurement, stage rising from 1.061 - 1.097 (m); and
2. Flow from Blue Rock dam increased during measurement.

Table 10 and Table 11 summarise additional water quality samples obtained at Moe Drain Site 3 and Site 4 to improve understanding of the relatively large gains in EC for modest gains in flow along this interstation reach. The results indicated that:

- Conductivity measured in situ was confirmed by the laboratory analysis;
- Water at both the Moe Site 3 and Trafalgar East sites are principally composed of sodium chloride hydrochemical facies;
- Nitrates and potassium concentrations increase downstream, potentially sourced from agricultural runoff identified increases are not of significant magnitude to account for the high rate of increase in electrical conductivity;
- It is possible that this reach receives baseflow from a more saline groundwater system at lower rates and that groundwater bores sampled and analysed to determine the groundwater end member EC do not monitor the same, or a connected, groundwater system;
- It is also possible that the flow measured is overestimated at the upstream site and/or underestimated at the downstream site. This would result in a lower reach inflow giving the impression of unusually high EC gains relative to the flow gain. The measurement error is likely to be less than 5%; therefore, while this may partially explain the observed phenomenon it would still indicate that groundwater discharge to the stream has a higher EC than expected.

Table 9 Latrobe River Catchment Round 3 Field Results

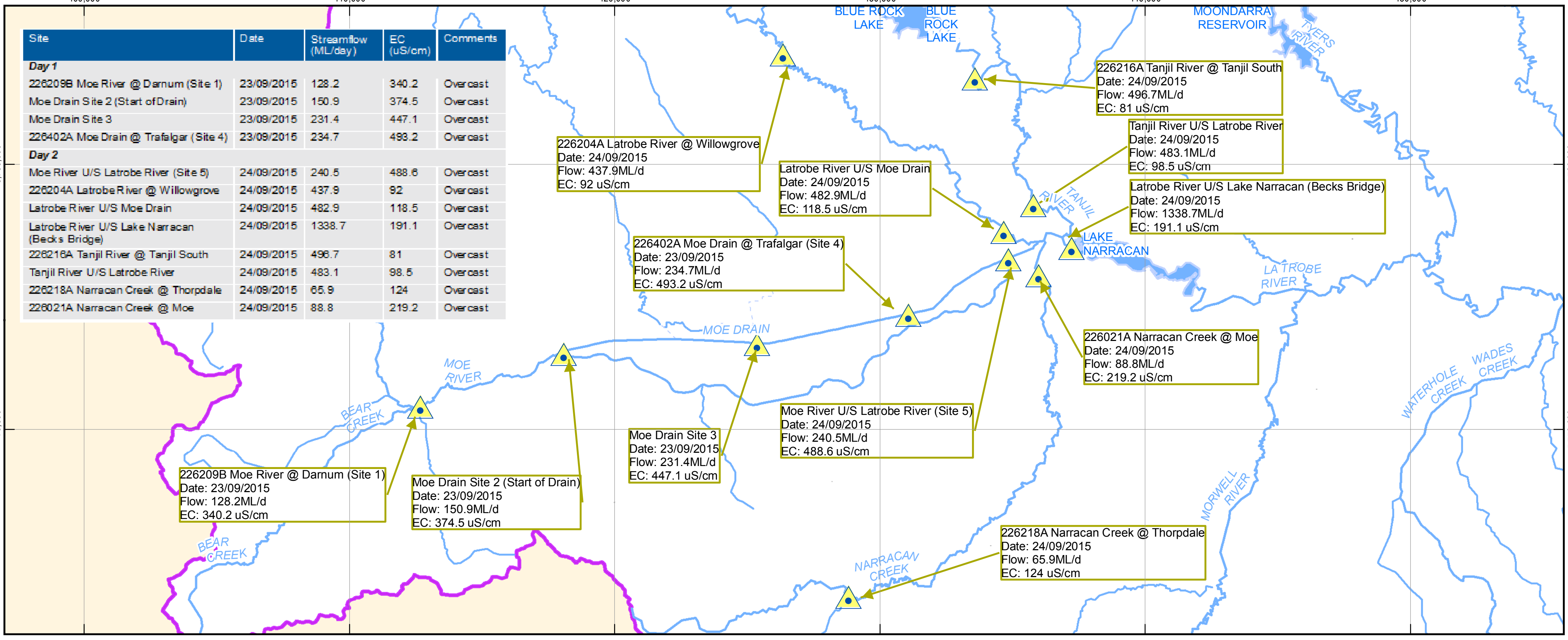
Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
226209B Moe River @ Darnum (Site 1)	16/05/2016	21.6	412	Windy / Overcast
Moe Drain Site 2 (Start of Drain)	16/05/2016	26.0	396	Windy / Overcast
Moe Drain Site 3	16/05/2016	38.4	484	Windy / Overcast
226402A Moe Drain @ Trafalgar (Site 4)	16/05/2016	48.8	577	Inflow upstream Est' 2-5ML/D
Moe River U/S Latrobe River (Site 5)	16/05/2016	44.9	574	Windy / Overcast
Day 2				
Moe River U/S Latrobe River (Site 5)	17/05/2016	43.0	573	Windy / Overcast
226204A Latrobe River @ Willowgrove	17/05/2016	161.2	99	Windy / Overcast
Latrobe River U/S Moe Drain	17/05/2016	173.8	136	Windy / Overcast
Latrobe River U/S Lake Narracan (Becks Bridge)	17/05/2016	365.0	195	Windy / Overcast
226216A Tanjil River @ Tanjil South	17/05/2016	109.9	81	Windy / Overcast
Tanjil River U/S Latrobe River	17/05/2016	107.7	103	Windy / Overcast
226218A Narracan Creek @ Thorpdale	17/05/2016	39.5	135	Windy / Overcast
226021A Narracan Creek @ Moe	17/05/2016	43.8	225	Windy / Overcast

Table 10 Moe Drain Site 3– Water Quality Results (Round 3 only)

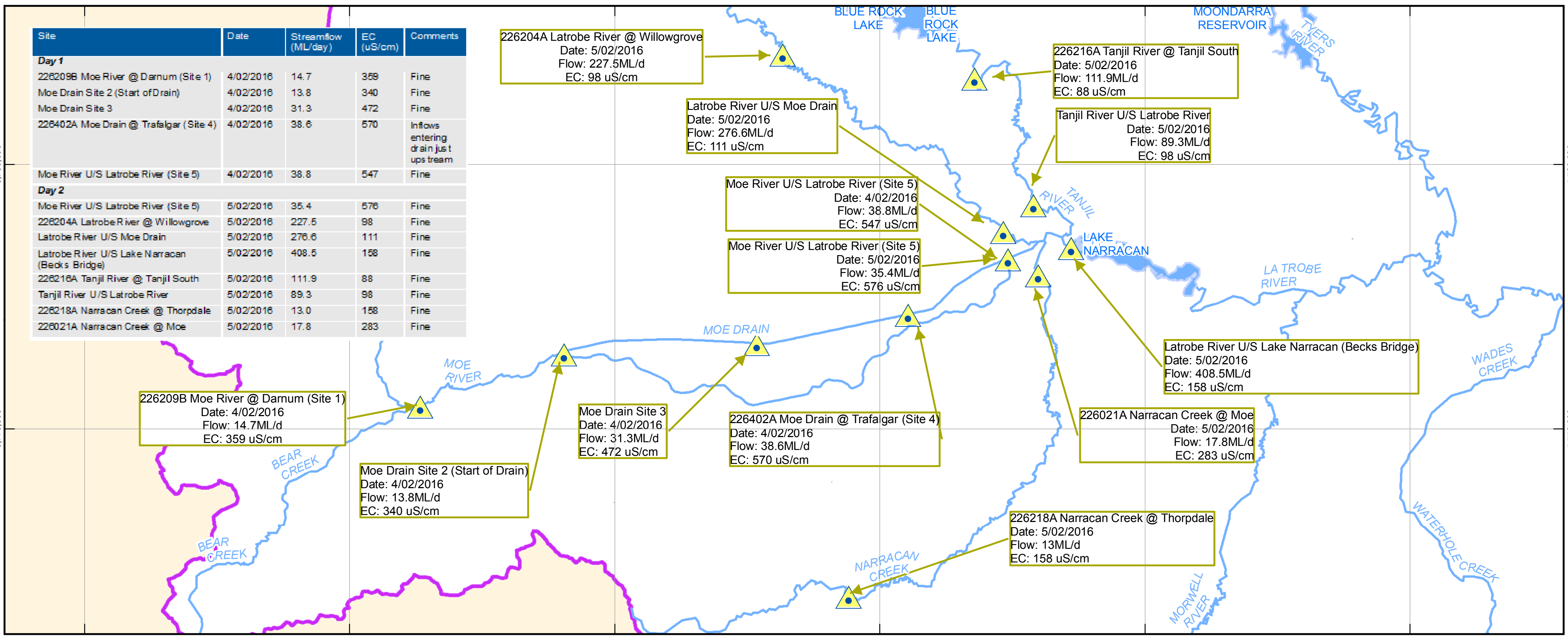
Constituent	Concentration	Sample Date
Alkalinity as Calcium Carbonate	31 mg/L	16/05/2016
Bicarbonate	38 mg/L	16/05/2016
Carbonate	0 mg/L	16/05/2016
Hydroxide	0 mg/L	16/05/2016
Ammonia as N	0.036 mg/L	16/05/2016
Calcium	11.1 mg/L	16/05/2016
Chloride	114 mg/L	16/05/2016
Conductivity	482 µScm	16/05/2016
Total Dissolved Solids (by EC)	260 mg/L	16/05/2016
Fluoride	0.1 mg/L	16/05/2016
Potassium	4.62 mg/L	16/05/2016
Magnesium	10.7 mg/L	16/05/2016
Sodium	57.3 mg/L	16/05/2016
Nitrite as Nitrogen	0.006 mg/L	16/05/2016
Nitrate + Nitrite as N	0.907 mg/L	16/05/2016
pH	7.1 pH units	16/05/2016
Silica - Reactive	11 mg/L	16/05/2016
Sulphate	13.2 mg/L	16/05/2016

Table 11 226402A Moe Drain @ Trafalgar (Site 4) – Water Quality Results (Round 3 only)

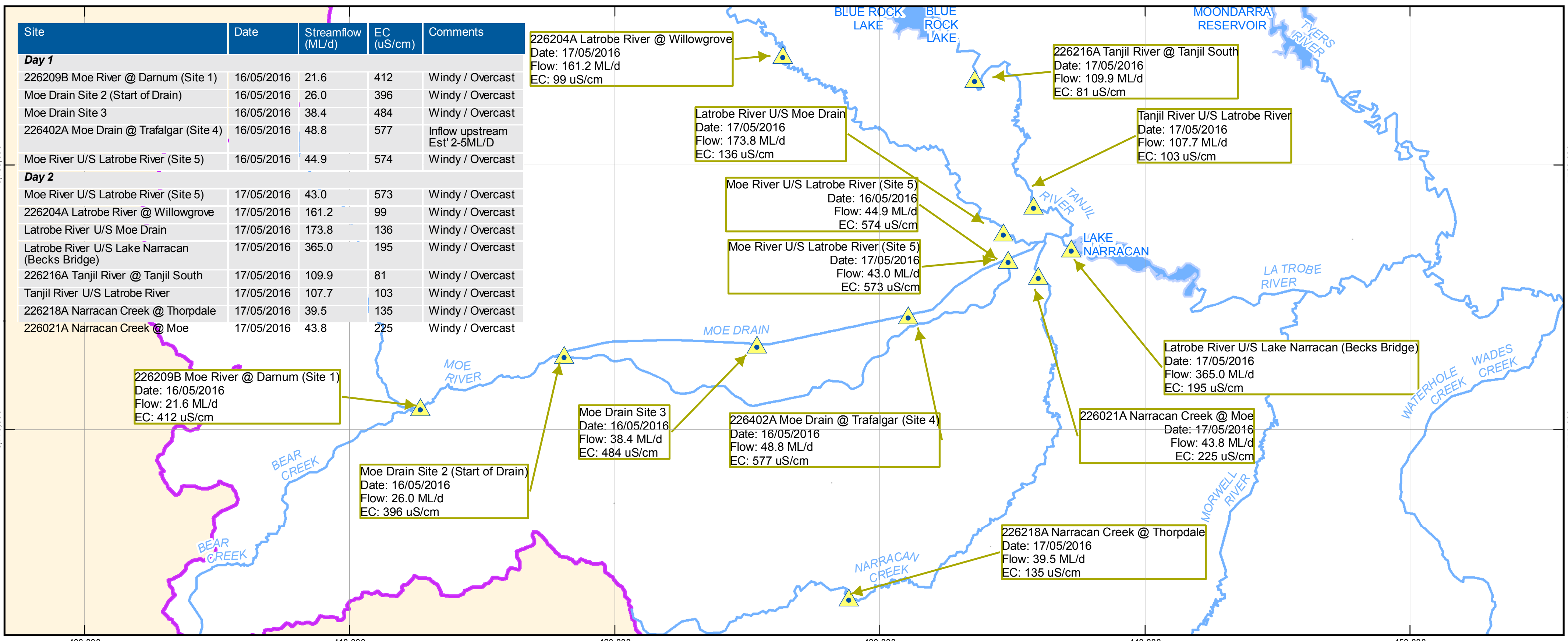
Constituent	Concentration	Sample Date
Alkalinity as Calcium Carbonate	28 mg/L	16/05/2016
Bicarbonate	34 mg/L	16/05/2016
Carbonate	0 mg/L	16/05/2016
Hydroxide	0 mg/L	16/05/2016
Ammonia as N	0.035 mg/L	16/05/2016
Calcium	10.7 mg/L	16/05/2016
Chloride	138 mg/L	16/05/2016
Conductivity	573 µScm	16/05/2016
Total Dissolved Solids (by EC)	310 mg/L	16/05/2016
Fluoride	<0.1 mg/L	16/05/2016
Potassium	5.09 mg/L	16/05/2016
Magnesium	12.1 mg/L	16/05/2016
Sodium	73.6 mg/L	16/05/2016
Nitrite as Nitrogen	0.005 mg/L	16/05/2016
Nitrate + Nitrite as N	1.06 mg/L	16/05/2016
pH	7.1 pH units	16/05/2016
Silica - Reactive	11 mg/L	16/05/2016
Sulphate	13.5 mg/L	16/05/2016



Site	Date	Streamflow (ML/day)	EC (uS/cm)	Comments
Day 1				
226209B Moe River @ Darnum (Site 1)	23/09/2015	128.2	340.2	Overcast
Moe Drain Site 2 (Start of Drain)	23/09/2015	150.9	374.5	Overcast
Moe Drain Site 3	23/09/2015	231.4	447.1	Overcast
226402A Moe Drain @ Trafalgar (Site 4)	23/09/2015	234.7	493.2	Overcast
Day 2				
Moe River U/S Latrobe River (Site 5)	24/09/2015	240.5	488.6	Overcast
226204A Latrobe River @ Willowgrove	24/09/2015	437.9	92	Overcast
Latrobe River U/S Moe Drain	24/09/2015	482.9	118.5	Overcast
Latrobe River U/S Lake Narracan (Becks Bridge)	24/09/2015	1338.7	191.1	Overcast
226216A Tanjil River @ Tanjil South	24/09/2015	496.7	81	Overcast
Tanjil River U/S Latrobe River	24/09/2015	483.1	98.5	Overcast
226218A Narracan Creek @ Thorpdale	24/09/2015	65.9	124	Overcast
226021A Narracan Creek @ Moe	24/09/2015	88.8	219.2	Overcast



Site	Date	Streamflow (ML/day)	EC (uS/cm)	Comments
Day 1				
226209B Moe River @ Darnum (Site 1)	4/02/2016	14.7	359	Fine
Moe Drain Site 2 (Start of Drain)	4/02/2016	13.8	340	Fine
Moe Drain Site 3	4/02/2016	31.3	472	Fine
226402A Moe Drain @ Trafalgar (Site 4)	4/02/2016	38.6	570	Inflows entering drain just upstream
Moe River U/S Latrobe River (Site 5)	4/02/2016	38.8	547	Fine
Day 2				
Moe River U/S Latrobe River (Site 5)	5/02/2016	35.4	576	Fine
226204A Latrobe River @ Willowgrove	5/02/2016	227.5	98	Fine
Latrobe River U/S Moe Drain	5/02/2016	276.6	111	Fine
Latrobe River U/S Lake Narracan (Becks Bridge)	5/02/2016	408.5	158	Fine
226216A Tanjil River @ Tanjil South	5/02/2016	111.9	88	Fine
Tanjil River U/S Latrobe River	5/02/2016	89.3	98	Fine
226218A Narracan Creek @ Thorpdale	5/02/2016	13.0	158	Fine
226021A Narracan Creek @ Moe	5/02/2016	17.8	283	Fine



Site	Date	Streamflow (ML/d)	EC (uS/cm)	Comments
Day 1				
226209B Moe River @ Darnum (Site 1)	16/05/2016	21.6	412	Windy / Overcast
Moe Drain Site 2 (Start of Drain)	16/05/2016	26.0	396	Windy / Overcast
Moe Drain Site 3	16/05/2016	38.4	484	Windy / Overcast
226402A Moe Drain @ Trafalgar (Site 4)	16/05/2016	48.8	577	Inflow upstream Est' 2-5ML/D
Moe River U/S Latrobe River (Site 5)	16/05/2016	44.9	574	Windy / Overcast
Day 2				
Moe River U/S Latrobe River (Site 5)	17/05/2016	43.0	573	Windy / Overcast
226204A Latrobe River @ Willowgrove	17/05/2016	161.2	99	Windy / Overcast
Latrobe River U/S Moe Drain	17/05/2016	173.8	136	Windy / Overcast
Latrobe River U/S Lake Narracan (Becks Bridge)	17/05/2016	365.0	195	Windy / Overcast
226216A Tanjil River @ Tanjil South	17/05/2016	109.9	81	Windy / Overcast
Tanjil River U/S Latrobe River	17/05/2016	107.7	103	Windy / Overcast
226218A Narracan Creek @ Thorpdale	17/05/2016	39.5	135	Windy / Overcast
226021A Narracan Creek @ Moe	17/05/2016	43.8	225	Windy / Overcast

Field Sampling Location
Major Water Area
River
Stream
Channel
Drain/Channel/Other
Latrobe River Catchment

Paper Size A3

0 1,000 2,000 4,000 6,000 8,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Department of Environment, Land, Water and Planning
Gippsland Rivers Baseflow Assessment

Job Number 31-32709
Revision A
Date 19 May 2016

Field Monitoring Results
Latrobe River

Figure 7

Hazelwood Drive (cnr Lignite Court) Morwell VIC 3840 Australia T 61 3 5136 5800 F 61 3 5136 5888 E mwlmail@ghd.com W www.ghd.com

Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by:adrummond

4. Revised Baseflow Estimates

4.1 Introduction

Downstream flow and EC ‘accretion profiles’ were prepared based on the field observations (Section 3) to show the changes in streamflow conditions along each river. These flow and EC accretion profiles can be used to infer baseflow contributions to the stream, with baseflow gains likely when EC is increasing between upstream and downstream sampling sites (i.e. within an ‘interstation reach’).

To further quantify the magnitude of baseflow gains, reach-scale mass balances were constructed using the field data, in the same manner as was applied by GHD (2015) using historical gauge data. As outlined by GHD (2015), the equation for this reach-scale EC mass balance for estimating baseflow fluxes to a given reach is:

$$\frac{Q_{Gr\quad h}}{Q_{Tr\quad h}} = \frac{(c_{S} - c_{S})}{(c_{Gr\quad h} - c_{S})}$$

Where: $Q_{Gr\quad h}$ is the groundwater-derived (baseflow) component of stream flow from within the reach only, excluding baseflow inputs from further upstream; $Q_{Tr\quad h}$ is the average stream flow across the reach (i.e. of upstream and downstream gauged flows); c_{S} is the tracer concentration in the stream at the downstream end of the reach, c_{S} is the tracer concentration in the stream at the upstream end, $c_{Gr\quad h}$ is the groundwater (baseflow) end member tracer concentration within the area thought to be contributing baseflow to the reach. Refer to Stage 1 of this study for further details on the reach-scale mass balance method (GHD, 2015).

In some reaches, there are other factors that complicate the analysis. These include:

- Water storages within the reach that are not in equilibrium (inflow and outflow not equal), or that are of a size such that the full mixing of the flow does not occur. Examples of this include:
  - Maffra Weir; and
  - Possibly Cowwarr Weir.
- Reaches with offtakes or inflows that are somewhat uncertain. Examples include:
  - Cowwarr Weir offtake (based on SRW operator comments);
  - Maffra Weir offtake (based on SRW operator comments); and
  - Thomson Syphon outfall (estimated in the field).
- Solute concentration through evapotranspiration along an interstation reach, which is a highly uncertain process. While in many cases the inferred baseflow gains are an order of magnitude greater than the likely effect (e.g. Macalister River), in other cases, depending on the assumptions adopted, evapotranspiration may be a reasonable explanation for the EC increases observed (e.g. some reaches of the Thomson River in summer).
- Other mechanisms that can affect EC. A very large EC increase was consistently observed in the Moe Drain reach upstream of Trafalgar East. This gain is difficult to explain solely as baseflow gains, as it would require a very saline groundwater contribution. *It is therefore recommended that major ions and nutrients be analysed on this reach to identify other possible causes for the increases in EC (e.g. agricultural or urban runoff)*.

4.2 Thomson River

Figure 8 presents the stream flow and EC accretion profiles for the Thomson River for all field sampling rounds. Annotations are provided to outline our interpretation of the data. Results for the Thomson River indicate that baseflow conditions (i.e. gain from or loss to groundwater) are variable along its length and between seasons.

In spring, the data suggest:

- Neutral or losing baseflow conditions between US Cowwarr and DS Cowwarr, and between Stoney Creek and Back Creek
- Rainbow Creek probably gains baseflow along its length, and
- Baseflow-gaining conditions along the remaining Thomson River reaches. The gains towards Wandocka may be indicative of irrigation returns from shallow groundwater drains.

In summer, the data suggest:

- Gaining baseflow conditions upstream of Cowwarr Weir
- Neutral to mildly gaining between Cowwarr Weir and Stoney Creek;
- Uncertainty in evapotranspiration effects on observed minor EC gains downstream of Stony Creek and along Rainbow Creek. No firm conclusions can be made for these reaches in this sampling round. At best, the minor EC gains suggest minimal, if any, baseflow gains in summer along these lower reaches.

In autumn, the data suggest:

- Neutral or losing baseflow conditions between Cowwarr Weir and Timber Weir
- Likely baseflow gains along Rainbow Creek
- Neutral to mildly gaining baseflow conditions between Cowwarr Weir and Back Creek
- Significant uncertainty in evapotranspiration effects on mild EC gains downstream of Back Creek, where no firm conclusion can be made in this sampling round, and very mild EC gains suggest these reaches are most likely neutral.

Across seasons, the only consistent areas of baseflow gain appear to be:

- Downstream of Cowwarr Weir, particularly during high river stage behind the weir. The consistent baseflow gains immediately downstream of the weir are likely due to the artificial maintenance of high upstream surface water levels behind the weir, with the downward grade in the river bed and stage immediately downstream of the weir effectively forming a drain towards which groundwater from beneath the weir is driven
- Along Rainbow Creek, which is more deeply incised into the landscape than the main channel of the Thomson River (see the topographic profile at the bottom of Figure 8), noting however that no firm conclusion could be made for the summer (January 2016) sampling round. Rainbow Creek probably forms a natural drain towards which groundwater from beneath the more elevated Thomson River will flow.

These observations are in broad agreement with the earlier work of GHD (2015). The identified neutral or losing reaches provide confirmation of anecdotal evidence of losses in the reaches of the lower Thomson towards/upstream of Cowwarr Weir (*Terry Flynn (SRW), pers. Comm., 2015*). The field data presented here provide significantly greater spatial resolution of baseflow gains and losses than the earlier work of GHD (2015), which only used data from the available permanent gauging stations. The detailed analysis presented here has also allowed for more thorough investigation of the effects of offtakes and evapotranspiration.

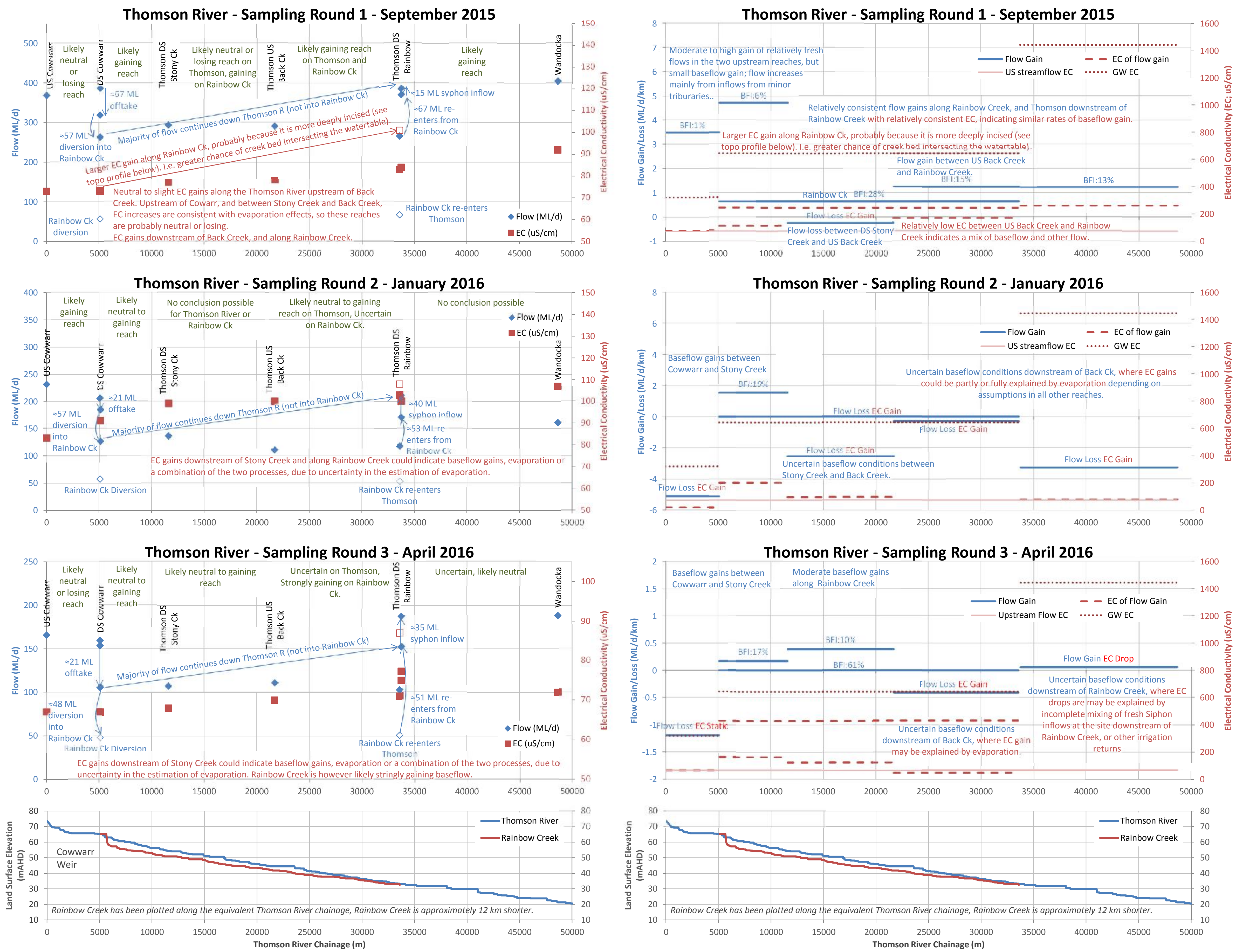
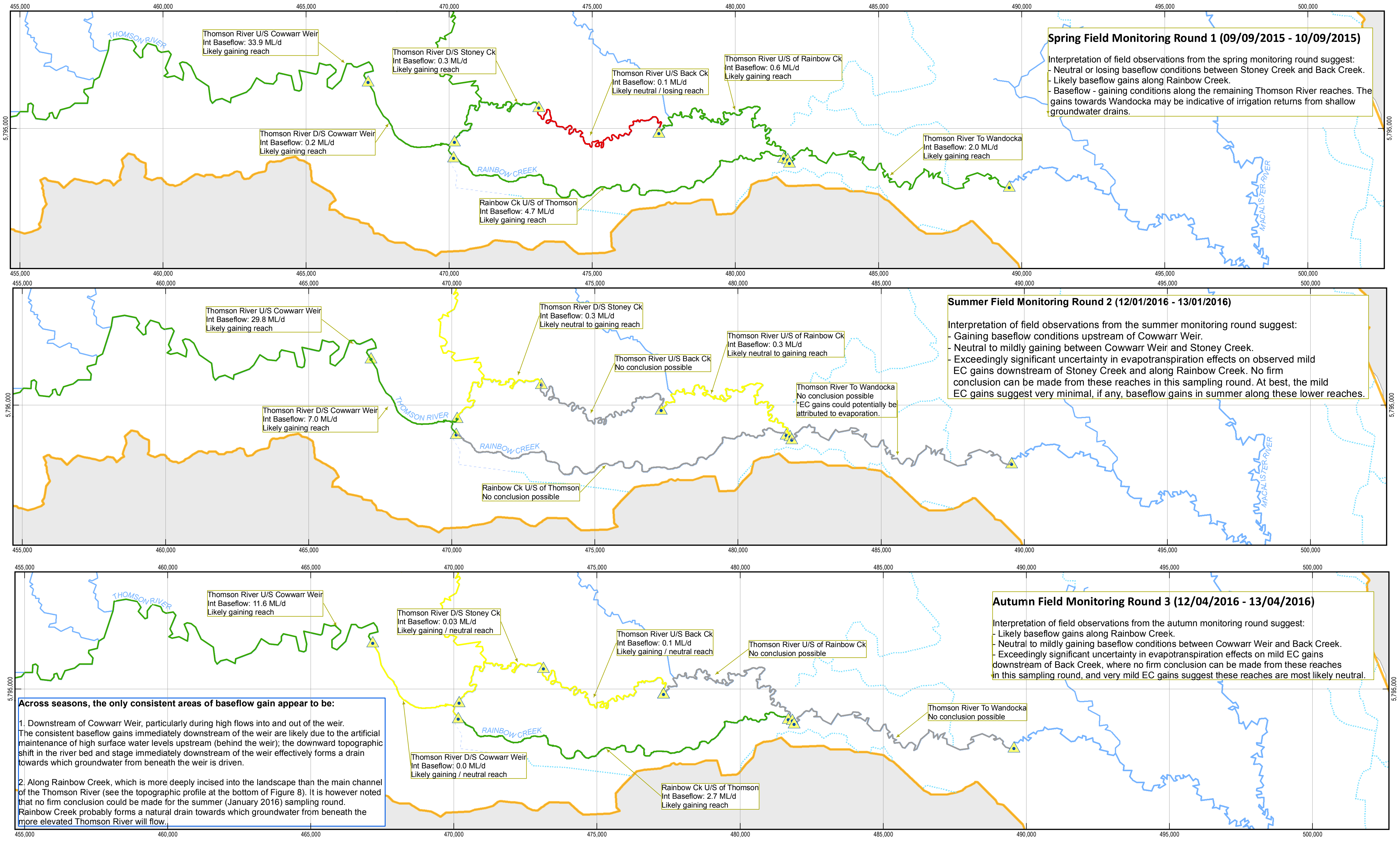


Figure 8 Flow and EC accretion profiles - Thomson River Catchment



Paper Size A3

0 0.5 1 2 3 4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Field Sampling Location

Thomson Macalister River Catchment

Major Water Area

River

Stream

Channel

Drain/Channel/Ot...

Baseflow Classification

Gaining

Gaining / Neutral

Neutral

Losing / Neutral

Unclassified

Department of Environment Land Water and Planning
Gippsland Rivers Baseflow Assessment

Job Number	31-32709
Revision	A
Date	19 May 2016

Baseflow Interstation Analysis
Thomson River

Figure 9

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by:adrummond

4.3 Macalister River

Figure 10 presents the stream flow and EC accretion profiles for the Macalister River for all field sampling rounds. Annotations are provided to outline our interpretation of the data. Figure 11 presents the inferences made regarding baseflow conditions along the Macalister River in map form to aid in interpretation. Results for the Macalister River indicate that the baseflow-conditions (i.e. gain from or loss to groundwater) vary along its length and between seasons.

In spring, the data suggest:

- Gaining baseflow conditions between D/S Glenmaggie through U/S Newry Drain, and to U/S Maffra Weir
- Gaining baseflow conditions D/S of Maffra Weir to Riverslea, and
- No conclusion can be made regarding baseflow conditions between U/S Maffra Weir and D/S Maffra Weir. This is due to the effect of storage and mixing (of stream EC) within the weir pool and disequilibrium between inflows to the weir and outflows from the weir on the day of sampling. Despite this uncertainty, this reach is likely to be either losing or neutral with regard to baseflow, given that water in the weir pool is artificially maintained at elevations above the watertable (refer to the DEM elevation profile in Figure 10).

In summer, the data suggest:

- Neutral or losing baseflow conditions between D/S Glenmaggie through U/S Newry Drain. This reach has switched from gaining to neutral or losing conditions in spring
- Gaining baseflow conditions D/S of Maffra Weir to Riverslea, exhibiting similar baseflow conditions as observed in spring, and
- No conclusion can be made regarding baseflow conditions between U/S Maffra Weir and D/S Maffra Weir for the same reasons as outlined for the spring data set. However, in summer, inferences for this reach become more uncertain as the potential effect of ET increases.

In autumn, the data suggest:

- Uncertain conditions between Glenmaggie and US Newry Drain, with flow loss and gaining EC, indicating that ET from the stream and riparian zone may be of significance;
- Gaining baseflow conditions between U/S Newry Drain and U/S Maffra Weir, and D/S of Maffra Weir to Riverslea, similar to the spring and summer round; and
- No conclusion can be made regarding the baseflow conditions between U/S Maffra Weir and D/S Maffra Weir for the same reasons as outlined in the spring.

The only reaches exhibiting seasonally-consistent baseflow conditions are between US Newry Drain and US Maffra Weir, and DS Maffra Weir to Riverslea, where gains were observed across all sampling events. The seasonal neutral to losing behaviour concluded for the upstream reach (between DS Glenmaggie and US Newry Drain) make sense conceptually due to the relatively elevated river bed, when compared to downstream reaches (see lower chart in Figure 10). The elevated river bed in conjunction with high river flows (releases from Glenmaggie Weir in Summer (January 2016)) create hydraulically losing conditions in this reach. Losing behaviour in basin margin reaches was also noted in earlier studies by GHD (2013a).

The observations are in broad agreement with the earlier work of GHD (2015), although there are some significant but unresolvable differences, as detailed in Section 5.1. The broad picture of neutral to losing conditions downstream of Glenmaggie Weir, and generally gaining conditions downstream of Newry Drain (aside from around Maffra Weir) is consistent with the earlier work, noting that there are temporal differences.

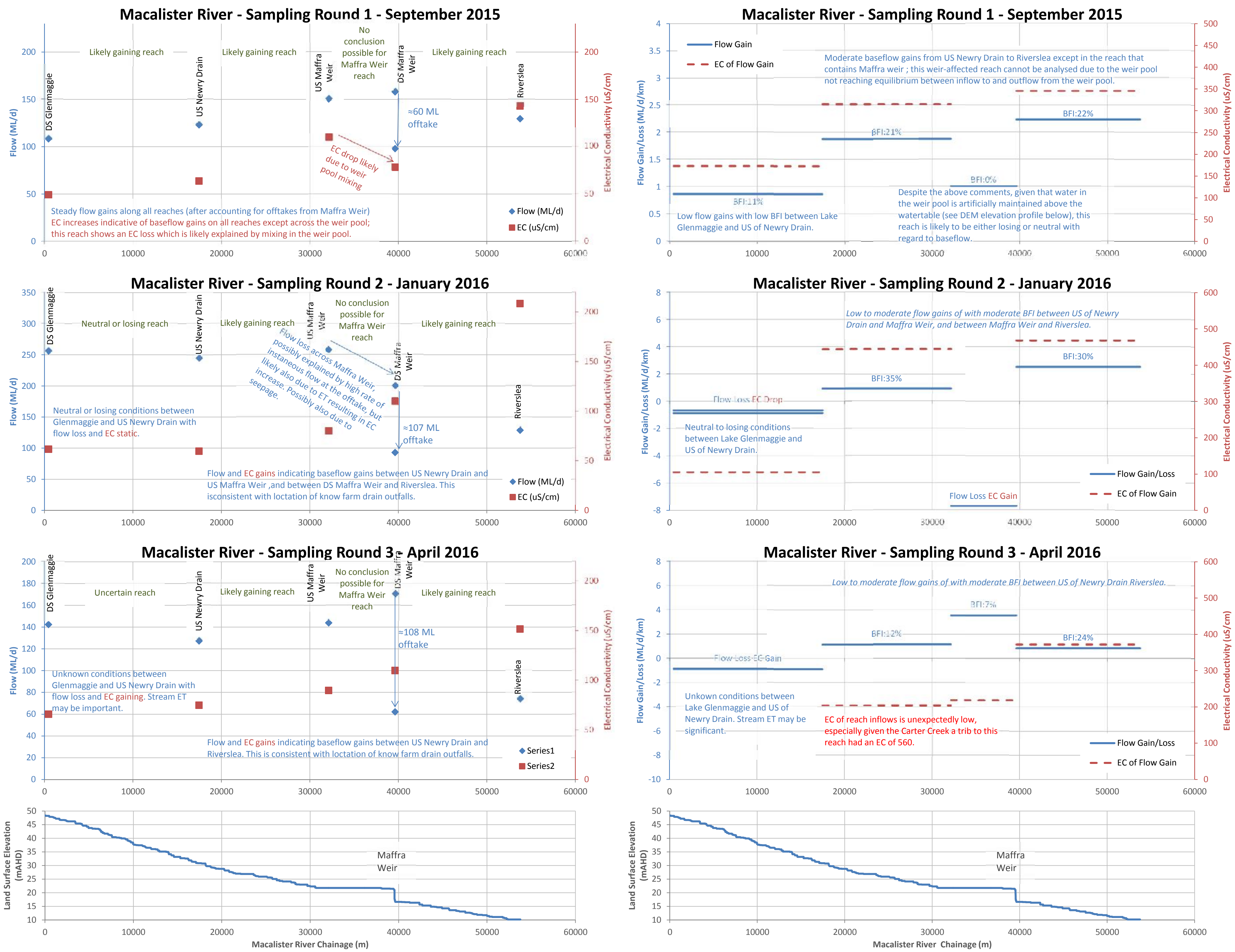
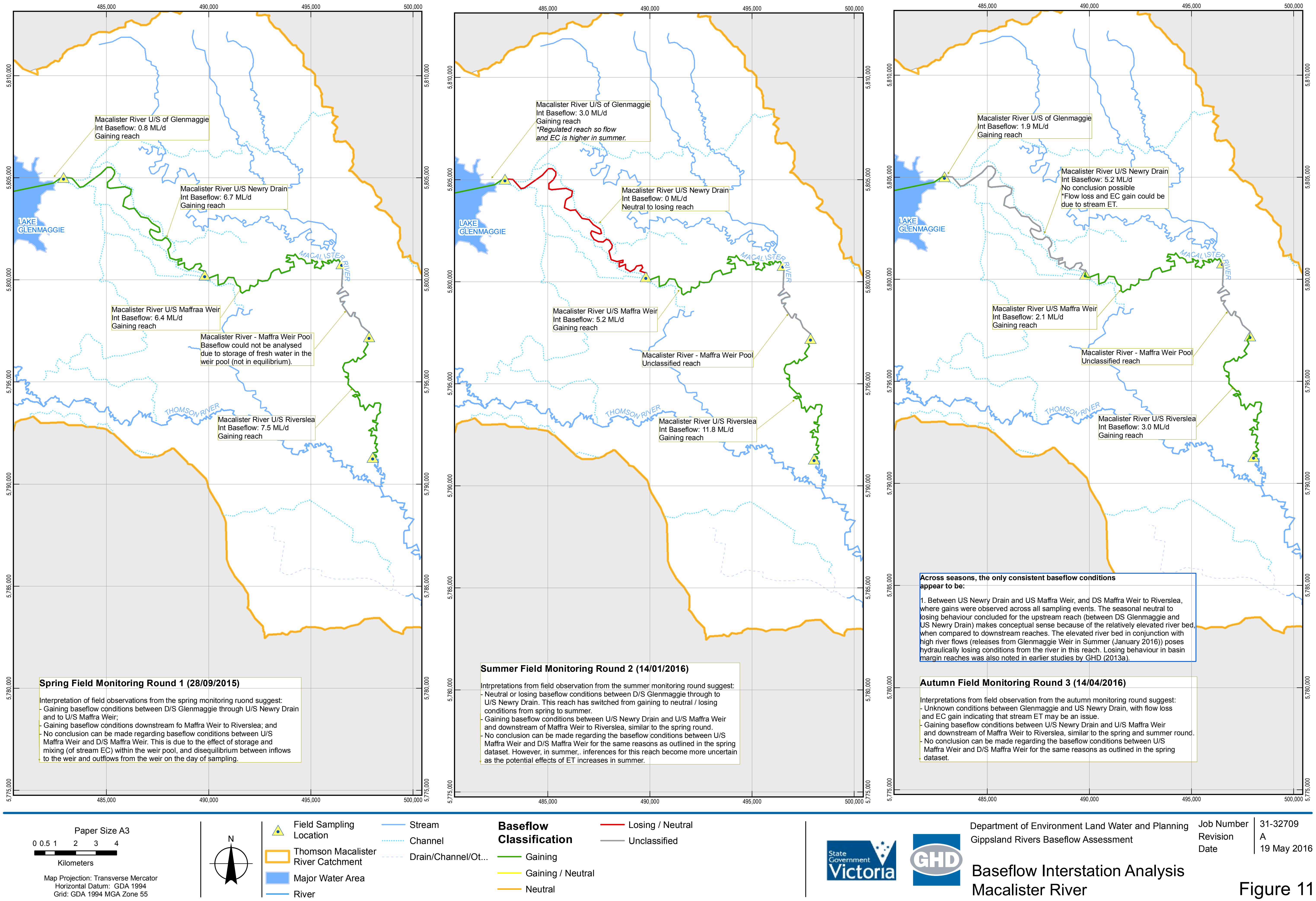


Figure 10 Flow and EC accretion profiles - Macalister River Catchment



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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by:adrummond

4.4 Latrobe River

Figure 12 presents the stream flow and EC accretion profiles for the Latrobe River for all field sampling rounds. Annotations are provided to outline our interpretation of the data. Figure 13 presents the inferences made regarding baseflow conditions along the Latrobe River in map form to aid in interpretation. The results for the Latrobe River indicate that baseflow conditions (i.e. gain from or loss to groundwater) are variable along its length and between seasons.

In spring, the data suggest:

- Gaining baseflow conditions along the length of the Latrobe River between Willowgrove and Lake Narracan, and
- Gaining baseflow conditions along the Moe River and Drain between Darnum and its confluence with the Latrobe River (upstream of Lake Narracan). However, this gaining condition is less clear in the Drain's lowers reaches towards the confluence, where neutral to slightly gaining baseflow conditions are inferred.

In summer, the data suggest:

- Gaining baseflow conditions along the length of the Latrobe River between Willowgrove and Lake Narracan, where there is no change from the inferred condition in spring, and
- Neutral baseflow conditions along much of then Moe River and Drain, with the exception of the sub-reach between Site No. 2 and Site No. 3, where gaining conditions are inferred. From spring to summer, the Moe River and Drain has become less baseflow dependent.

In autumn, the data suggests:

- Gaining baseflow conditions along the length of the Latrobe River between Willowgrove and upstream of Moe Drain, i.e. no change from the inferred conditions in spring and summer
- Neutral baseflow conditions along much of the Moe River and Drain, with the exception of the sub-reach between Site No. 2 and Site No. 3, where gaining conditions are inferred. From summer to autumn, the Moe River and Drain have become more baseflow dependent, and
- Inconclusive conditions in the Latrobe River downstream of the Moe Drain, where flow losses and gains in EC could partially be attributed to evaporation impacts.

Moderately gaining baseflow conditions are consistently experienced across seasons for the upper reaches of the Latrobe River, Tanjil River and Narracan Creek; however, baseflow gains are generally reduced in summer. The data suggests relatively variable seasonal baseflow conditions along the Moe Drain, with predominantly gaining conditions exhibited during spring and relatively neutral conditions during summer and autumn.

Analysis of baseflow gains in these upper reaches of the Latrobe River was not possible using existing gauging station data, as outlined by GHD (2015). Therefore, the sub-reach scale baseflow estimates provided from this study are a significant expansion of our understanding of baseflow conditions in this area. Importantly, the data suggest that a significant proportion of groundwater with the Moe Basin aquifers probably discharges up into the Moe River and Drain, and into the Latrobe River, upstream of its continuation eastward into the Latrobe Valley. These inferences are in agreement with GHD (2010a) and Brumley and Holdgate (1983). Importantly, whilst the Moe Drain appears to act as a groundwater discharge avenue from the Moe Basin aquifers around the Moe Groundwater Management Area, this is variable in time and space.

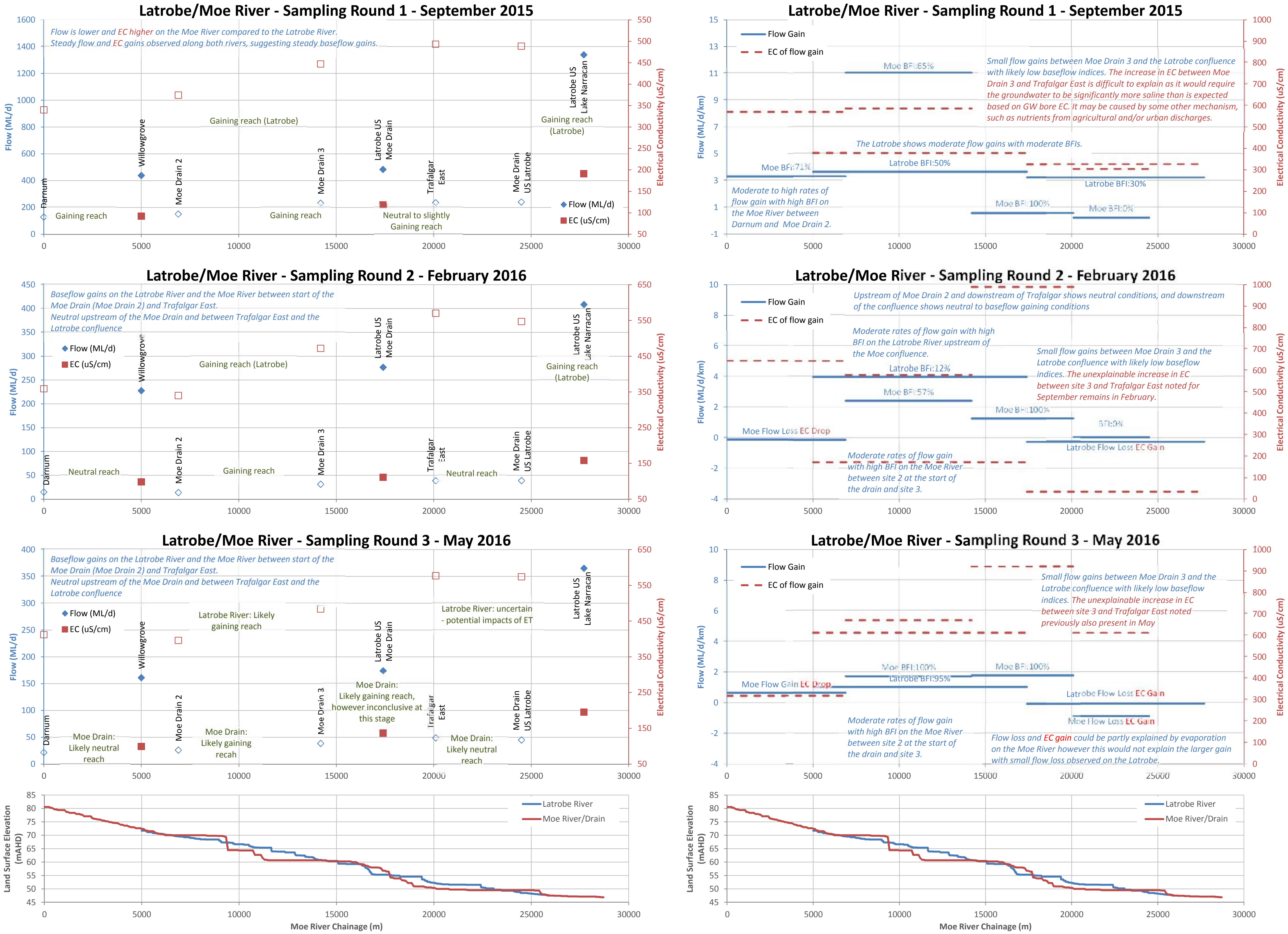
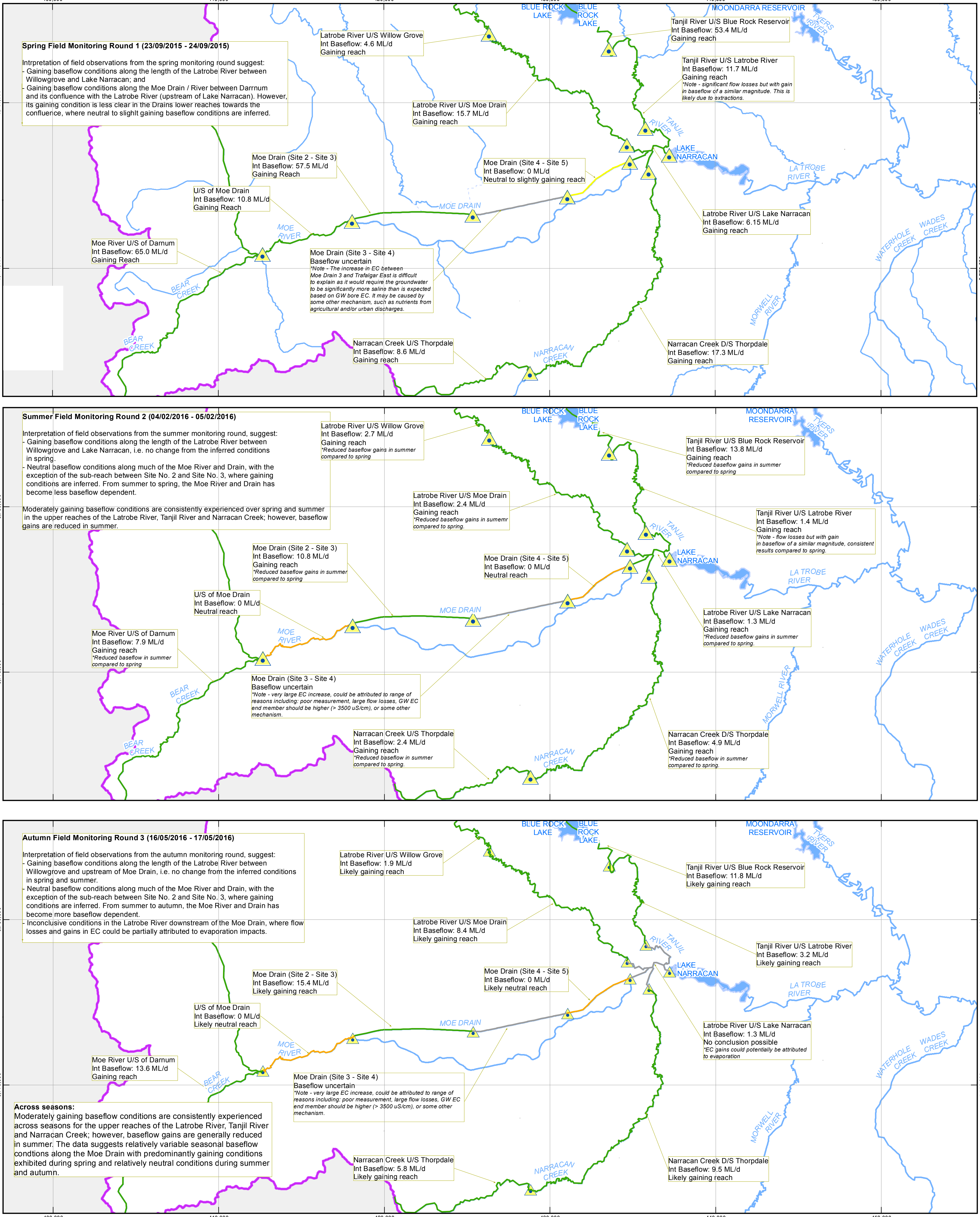


Figure 12 Flow and EC accretion profiles - Latrobe River Catchment



Field Sampling Location

Baseflow Classification

- Neutral / Gaining
- Neutral
- Neutral / Losing
- Gaining
- Unclassified
- Major Water Area
- River
- Stream
- Channel
- Drain/Chann...
- Latrobe River Catchment

Paper Size A3

0 1,000 2,000 4,000 6,000 8,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

GHD

State Government Victoria

Department of Environment, Land, Water and Planning
Gippsland Rivers Baseflow Assessment

Job Number 31-32709
Revision A
Date 20 May 2016

Baseflow Interstation Analysis
Latrobe River

Figure 13

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Hazelwood Drive (cnr Lignite Court) Morwell VIC 3840 Australia T 61 3 5136 5800 F 61 3 5136 5888 E mwlmail@ghd.com W www.ghd.com

Data source: DEWLP, VICMaps, 2015; GHD, Baseflow Catchments, 2015; DELWP, WMIS Surface and Groundwater Data, 2015; Thiess,Field monitoring locations, 2015 - 2016. Created by:adrummond

5. Validation of Previous Baseflow Estimates

5.1 Introduction

The spot flow and EC observations are snapshots of streamflow and baseflow conditions and as such cannot reliably be used to make conclusions about the average or even typical baseflow and streamflow conditions of a given river or river reach. Rivers and groundwater systems are both highly dynamic, spatially and temporally. Hence, making generalisations about gaining or losing conditions of a given river is generally not appropriate, unless a consistent story of baseflow conditions can be constructed using the available data, and the data are appropriate (spatially and temporally) to facilitate this.

That said, the observed streamflow and EC accretion data collected for this project provides a higher level of spatial resolution than does data from permanent gauging stations. The higher resolution ('spot') data can be used to investigate whether a more detailed understanding of the catchment can validate or contradict the baseflow estimates based on the broader reach scale mass balances, which only use data from permanent gauging station locations. Learnings from the analysis of the more spatially detailed field sampling data can be used to revise the broader methods and/or their application.

To evaluate and demonstrate this, baseflow estimates derived from the detailed sub-reach-scale mass balances (using the recently collected field data as outlined above in Section 4) were compared to the baseflow estimates derived from a reach scale mass balance of the broader reach (utilising only permanent gauging station locations). The latter was undertaken in Stage 1 of this project (GHD, 2015).The sum of baseflow gains based on detailed sub-reaches (i.e. those estimated using detailed field data) is different to that produced by the broader reach-scale mass balance results (i.e. using the less spatially detailed permanent gauging station data only). An example of this is observed by comparing Table 12 with Table 13 for the Macalister River.

Table 12 Broader Reach Scale EC Mass Balance Results for the Macalister River - using only sampling data from permanent gauging station locations (from Stage 1)

Upstream	Downstream	Qu (ML/d)	Qd (ML/d)	ECu (uS/cm)	ECd (uS/cm)	Diversion (ML/d)	Baseflow[1] (ML/d)
DS Glenmaggie	Riverslea	108.5	49.3	129.6	143.1	60.0[2]	12.9
						TOTAL	12.9

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2 EC of diversion estimated to be 143.1 uS/cm (same as downstream gauge) – NOTE: this is significantly higher than the estimate made possible by the more detailed field data shown in Table 13

Table 13 Sub-Reach Scale EC Mass Balance Results for the Macalister River - using recent field sampling data

Upstream	Downstream	Qu (ML/d)	Qd (ML/d)	ECu (uS/cm)	ECd (uS/cm	Diversion (ML/d)	Baseflow[1] (ML/d)
DS Glenmaggie	US Newry Drain	108.5	49.3	123.1	63.9		1.6
US Newry Drain	US Maffra Weir	123.1	63.9	150.6	109.5		5.9
US Maffra Weir	DS Maffra Weir	150.6	109.5	98.1	78.5	60.0[2]	0.0
DS Maffra Weir	Riverslea	98.1	78.5	129.6	143.1		7.0
						TOTAL	14.4

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2 EC of diversion estimated to be 78.5 uS/cm (same as downstream gauge)

There are two reasons for these differences:

1. The estimated EC of diverted water is improved when more spatially detailed data are available (i.e. a stream EC measurement immediately downstream of the offtake point); and
2. The equation adopted for the reach-scale mass balance includes a simplification equating the interstation runoff end member EC to the upstream gauge observed EC. This results in a different runoff end member EC used in the mass balance downstream along each sub-reach.

An improvement to the reach-scale mass balance method would be to estimate the EC of diverted water based on a river chainage-based interpolation to the diversion location, from the two gauge locations at the upstream and downstream ends of each assessed reach. Assuming no knowledge of the interstation (sub-reach) catchment nor direct measurement of the diversion EC, this is a reasonable assumption.

For the above example, the diverted water EC estimated based on this technique would be 118.2 uS/cm. This compares to the more accurate EC estimate of 78.5 uS/cm that was measured during the field sampling directly downstream of the diversion location (Table 13). Using the interpolated EC to adjust the downstream EC provides a revised broader reach-scale mass balance estimate for the Macalister River, as shown in Table 14.

Table 14 Broader Reach Scale EC Mass Balance Results for the Macalister River - using chainage-based interpolation of diverted water EC

Upstream	Downstream	Qu (ML/d)	Qd (ML/d)	ECu (uS/cm)	ECd (uS/cm	Diversion (ML/d)	Baseflow[1] (ML/d)
DS Glenmaggie	Riverslea	108.5	49.3	129.6	143.1	60.0[2]	11.9
						TOTAL	11.9

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2 EC of diversion estimated to be 118.2 uS/cm (using linear chainage-based interpolation). This results in an adjusted Qd of 109.3 ML/day and ECd of 135.2 uS/cm.

It is noted that the initial baseflow estimate of 12.9 ML/d (Table 12) appears to be closer than the revised baseflow estimate of 11.9 ML/d to the most accurate interstation baseflow estimate of 14.4 ML/d based on sub-reach observation (Table 13). However, this is because the second identified issue (the runoff end member assumption) has not yet been addressed. To address this second issue, the difference introduced by imperfect knowledge of the diversion end member will be removed as shown in Table 15.

Table 15 Broader Reach Scale EC Mass Balance Results for the Macalister River - using measured diverted water EC

Upstream	Downstream	Qu (ML/d)	Qd (ML/d)	ECu (uS/cm)	ECd (uS/cm	Diversion (ML/d)	Baseflow[1] (ML/d)
DS Glenmaggie	Riverslea	108.5	49.3	129.6	143.1	60.0[2]	10.1
						TOTAL	10.1

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2 EC of diversion estimated to be 78.5 uS/cm (based on field measurement immediately downstream of the diversion location). This results in an adjusted Qd of 109.3 ML/day and ECd of 122.6 uS/cm. NOTE: this measurement would not normally be available for this broader reach-scale mass balance, which in practice utilises only permanent gauging station data.

The reach-scale mass balance uses the equation, as outlined by GHD (2015):

$$\frac{Q_{Gr\quad n}}{Q_{Tr\quad n}} = \frac{(c_S \quad - c_S\ )}{(c_{Gr\quad n} - c_S\ )}$$

However, a more accurate representation of the mass balance based upon our detailed analysis of the detailed sub-reach field data is:

$$Q_d c_S \quad = Q_u c_S \ + Q_{Gr\quad n} c_{Gr\quad n} + Q_{Sr\quad n} c_S$$

Which can be written as:

$$Q_{Gr\quad n} = \frac{Q_d c_S \ - Q_u c_S \ _- (Q_d - Q_u) c_S}{(c_{Gr\quad n} - c_S)}$$

Diversions (and outfalls) can be incorporated explicitly, avoiding the need for adjustment of the downstream flow and EC as follows:

$$Q_{Gr\quad n} = \frac{Q_d c_S \ - Q_u c_S \ _- (Q_d - Q_u) c_S - Q_d \ \ C_d}{(c_{Gr\quad n} - c_S)}$$

Where:

Q_{div} and C_{div} are the flow rate and EC of diversions, respectively; and
C_S is the runoff end member EC, which should be defined using the 95th percentile gauge stream EC at the most upstream gauge assessed for a given river catchment, unless a more appropriate estimate can be made.

The key difference here, aside from explicit inclusion of diversions, is that the runoff end member has been redefined. Updated baseflow estimates for the above Macalister River example are shown in Table 16 and Table 17, based on the revised mass balance equation.

Table 16 Revised Equation Broader Reach Scale EC Mass Balance Results for the Macalister River - using only sampling data from permanent gauging station locations

Upstream	Downstream	Qu (ML/d)	Qd (ML/d)	ECu (uS/cm)	ECd (uS/cm	Diversion (ML/d)	Baseflow[1] (ML/d)
DS Glenmaggie	Riverslea	108.5	49.3	129.6	143.1	60.0[2]	16.5
						TOTAL	16.5

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2. Runoff end member of 44 uS/cm adopted

3 EC of diversion estimated to be 78.5 uS/cm. NOTE: this measurement would not normally be available for this broader reach-scale mass balance, which in practice utilises only permanent gauging station data. This has been adopted to separate the issue of imperfect knowledge of EC of diverted water from the issue of the reach scale EC mass equation.

Table 17 Revised Equation Sub-Reach Scale EC Mass Balance Results for the Macalister River - using recent field sampling data

Upstream	Downstream	Qu (ML/d)	Qd (ML/d)	ECu (uS/cm)	ECd (uS/cm	Diversion (ML/d)	Baseflow[1] (ML/d)
DS Glenmaggie	US Newry Drain	108.5	49.3	123.1	63.9		2.3
US Newry Drain	US Maffra Weir	123.1	63.9	150.6	109.5		7.9
US Maffra Weir	DS Maffra Weir	150.6	109.5	98.1	78.5	60.0[2]	0.0[3]
DS Maffra Weir	Riverslea	98.1	78.5	129.6	143.1		10.0
						TOTAL	20.2

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2. Runoff end member of 44 uS/cm adopted

3 EC of diversion estimated to be 78.5 uS/cm

4 Function gives a baseflow of -3.7 ML/day however the function cannot be used when EC is dropping as a baseflow loss does not result in a reduction in EC.

There remains a significant difference in baseflow estimates between the sub-reach and broad scale mass balances. However, this relates to the treatment of the EC drop across the Maffra Weir. While the spatially detailed sub-reach mass balance can isolate this anomaly, the broader reach mass balance cannot. The reach scale EC mass balance equation returns a negative baseflow of 3.7 ML/d for the sub reach between US Maffra Weir and DS Maffra Weir: in practice this is set to zero as the reach EC mass balance cannot be used to estimate baseflow losses which do not explain an EC reduction across a reach. However, if the value of this anomaly (3.7 ML/d) is added to the result for the broader reach scale mass balance (16.5 ML/day) the resultant baseflow (20.2 ML/d) is equal to the value for the detailed sub reach scale mass balance, demonstrating that the reach scale mass balance equation has been applied correctly (such that the sum of the sub reach baseflow contributions is equal to the broader reach baseflow contribution).

The recommended revised method for further baseflow studies is to estimate the EC of diverted water based on a river chainage-based interpolation to the diversion location, from the two gauge locations at the upstream and downstream ends of each assessed reach and adopting the revised reach scale mass balance equation. The results of the recommended revised method are shown in Table 18 and Table 19.

Table 18 Revised Equation Broader Reach Scale EC Mass Balance Results for the Macalister River - using only sampling data from permanent gauging station locations

Upstream	Downstream	Qu	Qd	ECu	ECd	Diversion	Baseflow[1]
DS Glenmaggie	Riverslea	108.5	49.3	129.6	143.1	60.0[2]	18.7
						TOTAL	18.7

1 Groundwater end member of 1129 uS/cm adopted - which is the interstation groundwater end member EC for the reach b/w Glenmaggie 225204 and Riverslea 225247 (refer table 16 of the Stage 1 report)

2. Runoff end member of 44 uS/cm adopted

3 EC of diversion estimated to be 118.2 uS/cm.

Table 19 Recommended Revised Method Results: Sub-Reach Scale EC Mass Balance Results for the Macalister River - using recent field sampling data

Upstream	Downstream	Qu	Qd	ECu	ECd	Diversion	Baseflow[1]
DS Glenmaggie	US Newry Drain	108.5	49.3	123.1	63.9		2.3
US Newry Drain	US Maffra Weir	123.1	63.9	150.6	109.5		7.9
US Maffra Weir	DS Maffra Weir	150.6	109.5	98.1	78.5	60.0[2]	0.0[3]
DS Maffra Weir	Riverslea	98.1	78.5	129.6	143.1		10.0
						TOTAL	20.2

1 Groundwater end member of 1129 uS/cm adopted, runoff end member of 44 uS/cm adopted

2 EC of diversion estimated to be 78.5 uS/cm

3 Function gives a baseflow of -3.7 ML/day however the function cannot be used when EC is dropping as a baseflow loss does not result in a reduction in EC.

Whilst there remain unresolvable differences between the detailed and broad-scale mass balances in this example, due to Maffra Weir, the baseflow estimates of both data sets can be considered very similar when the broader baseflow estimation uncertainties are considered – particularly those of the groundwater EC end member, as has been detailed in earlier work (GHD, 2014a, 2015). Table 20 illustrates that while the broader reach scale mass balance is not as precise as the detailed sub reach scale mass balance, the result is still well within the confidence interval based on uncertainty of the groundwater EC end member.

Table 20 Comparison of baseflow contribution best estimates and uncertainty range for the Macalister River

Best Estimate based on detailed field sampling data[1]	20.2
Best Estimate based on broader reach scale mass balance[1]	18.7
Lower bound estimate based on broader reach scale mass balance[2]	6.2
Upper bound estimate based on broader reach scale mass balance[3]	59.6

1 Groundwater end member of 1129 uS/cm adopted

2 Groundwater end member of 3319 uS/cm adopted

3 Groundwater end member of 384 uS/cm adopted

The analysis of higher spatial resolution field sampling data demonstrates that while the broader reach scale mass balance based on permanent gauging station locations gives a different best estimate result, the uncertainty ranges comfortably encompass the more accurate estimate.

5.2 Recommendations

Based upon the reach-scale mass balance analyses and validation of the broader mass balances presented in Section 5.1, the following recommendations are made:

- Seek data to estimate the EC of diversions and outfalls to adequately account for them in the reach-scale mass balance. In lieu of observed data it may be an improvement to our method to adopt a linear interpolation of EC based on the distance of the offtake point from the upstream and downstream gauge locations, and the stream EC gauged at those locations.

- Adopt a refined equation to better represent the reach scale mass balance:

$$Q_{Gr\quad h} = \frac{Q_d c_S \ - Q_u c_S \ - (Q_d - Q_u) c_S - Q_d \ \ C_d}{(c_{Gr\ \ ch} - c_S)}$$

Where: $Q_{Gr\quad h}$ is the groundwater-derived (baseflow) component of stream flow from within the reach only, excluding baseflow inputs from further upstream; Q_d and c_S are the gauged stream flow and EC at the downstream end of the reach; u and c_S are the gauged stream flow and EC at the upstream end; c_S is runoff end member concentration, which should be defined using the 95th percentile gauge stream EC at the most upstream gauge assessed for a given river, unless a more appropriate estimate can be made; c_S should be consistent across all sub-reaches assessed within a given broader river catchment unless information exist to substantiate that the runoff end member varies within the catchment; Q_{div} and C_{div} are the flow rate and EC of diversions, respectively; and $c_{Gr\quad h}$ is the groundwater (baseflow) end member tracer concentration within the area thought to be contributing baseflow to the reach.

This revised equation should result in the highest possible degree of consistency between detailed sub-reach scale mass balances and broader scale mass balances, however inconsistencies may remain in some cases as outlined in Section 5.1.

6. Effect of coal seam gas extraction on baseflow

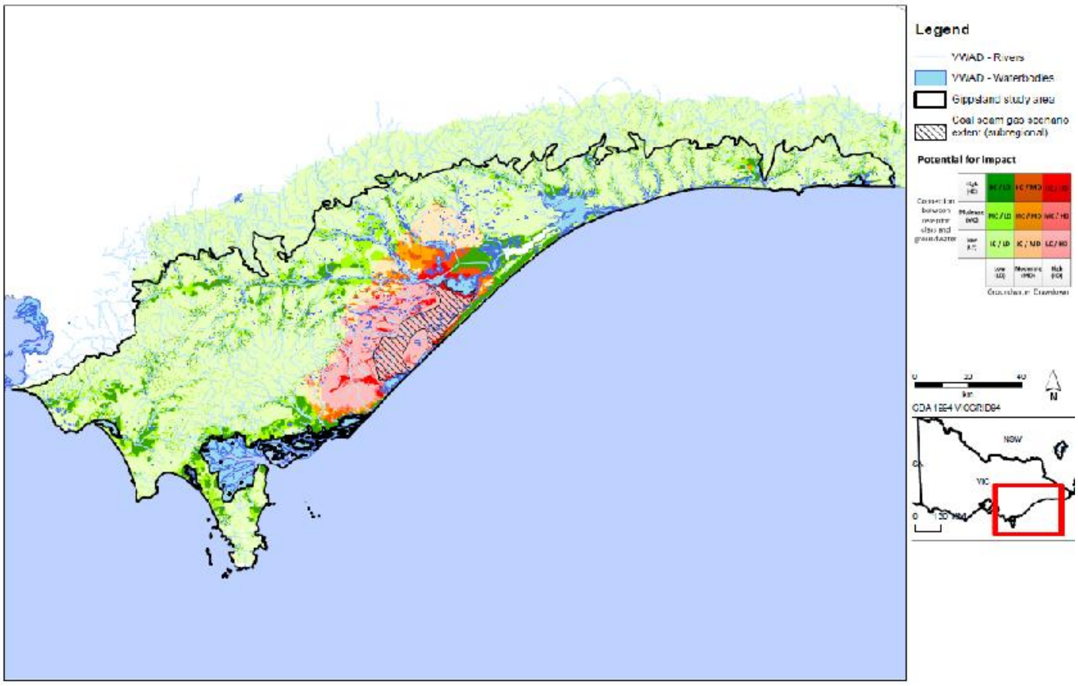
6.1 Background

One of the objectives of this project is the quantification of the potential risk of coal seam gas and coal mining development to groundwater-surface water interactions and groundwater-dependent environmental values of Gippsland's rivers. Coal seam gas extraction results in large scale aquifer depressurisation of the gas bearing formations, which has the potential to propagate up through the aquifer and result in declines in the water table aquifer. This in turn has the potential to reduce the hydraulic gradients to streams, reducing baseflow, and in some instances could lead to a change in hydrologic conditions from baseflow gaining to losing.

6.2 Coal Seam Gas studies

DELWP (2015) recently conducted a large series of studies investigating the potential impact of onshore natural gas extraction on groundwater and surface water users. The study concluded that potential impacts of depressurisation from coal seam gas in the Gippsland basin on surface water ecosystems are high in areas of close vicinity to the potential gas development and relatively low elsewhere (DELWP, 2015). Figure 14 shows the key results from DELWP (2015) indicating areas of potential impact to surface water ecosystems, where the high risk areas are near the coast, including the Gippsland Lakes and the lower reaches of the Thomson, Macalister and Latrobe Rivers. These reaches have significant baseflow contributions, as indicated in Stage 1 of this project (GHD, 2015). The results indicate that the upland areas are unlikely to be significantly impacted by coal seam gas extraction. It is important to note that this assessment assumed an extremely large production of Coal Seam Gas, of up to 510 GL/yr of additional extractions, compared to the current 100 GL/yr of extractions for offshore oil and gas production and 25 GL/yr of extractions from the Latrobe Valley coal mines.

Figure 14 Potential impacts on surface water ecosystems from possible coal seam gas development (Figure 45 of DELWP, 2015).



6.3 Historic groundwater extractions

Historically, groundwater has been extracted from the Gippsland basin for a range of uses, including:

- Offshore extractions for oil and gas production;
- Licenced groundwater extractions for dewatering coal mines;
- Other (non-mining) licenced groundwater extractions; and
- Stock and domestic groundwater extractions.

Figure 15 illustrates the increase in groundwater extraction from the Gippsland basin over the last 75 years, with around 200 GL/yr of groundwater currently extracted, predominantly for offshore oil and gas and mining purposes (Table 21). Offshore extraction volumes are source from DELWP (2015d) and groundwater extraction volumes for mining purposes are sourced from GHD (2015b). It is noted that the majority of groundwater extractions occur from the deep confined Traralgon and Morwell Formation Aquifer Systems.

Figure 15 Historic groundwater pumping from the Gippsland basin (Financial Year 1960 – 2015)

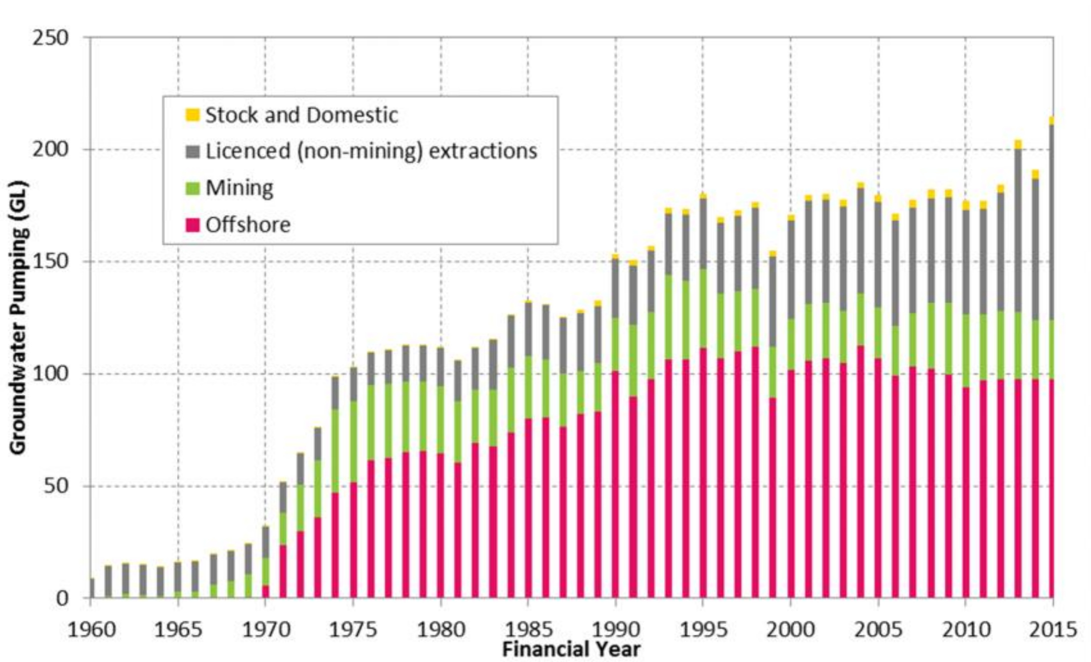


Table 21 Average and range in groundwater extraction from the Gippsland basin over the period 2000 – 2015

Groundwater Extraction (GL/yr)	Offshore extraction	Licenced extractions for mining	Stock and Domestic extractions	Licenced (non-mining) extractions
Average (2000 - 2015)	101	26	3	52
Range (2000 - 2015)	94 - 112	22 - 32	3 - 4	44 - 87

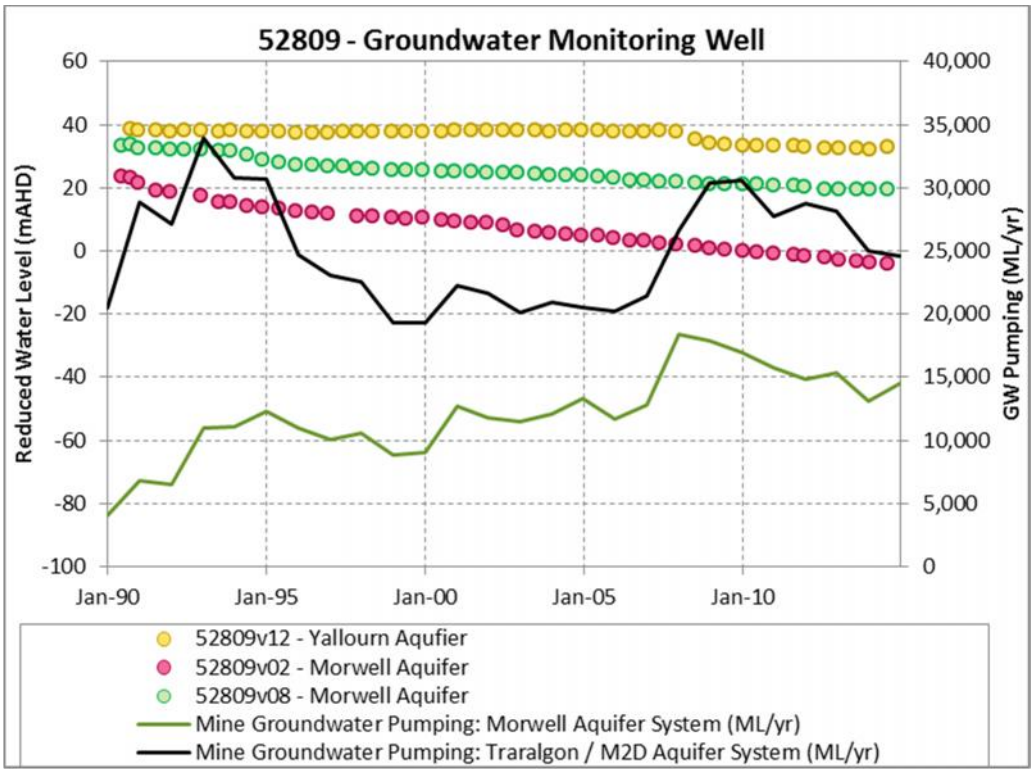
Review of historic groundwater trends from monitoring wells in proximity to the Latrobe Valley coal mines indicate that the potential effect of depressurisation of aquifers by the Latrobe Valley coal mines on shallow groundwater levels (and therefore groundwater-surface water interactions), is relatively insignificant in the (shallow) Haunted Hills and Yallourn Formations.

Figure 16 shows the groundwater hydrograph for monitoring well 52809, which is adjacent to Flynns Creek, in proximity to the Loy Yang mine. The groundwater hydrograph indicates that while relatively steep declines are experienced in the Traralgon and Morwell Aquifer Systems where the groundwater extraction occurs, only minor drawdowns are experienced in the shallow Yallourn Aquifer (with the exception of the period following 2005, which corresponds with the prolonged drought period). This is supported by the hydrograph of the State Observation Bore Network monitoring well 103811 (Figure 17) which is located away from the mines, and experiences similar drawdown trends in the shallow Haunted Hill Aquifer System in the prolonged drought period following 2005.

6.4 Conclusions

It is noted that there is potential for onshore coal seam gas production to have significant impacts on baseflow in the Gippsland region. However, the magnitude of the impact depends on the location of the CSG development, the stratigraphy of the gas bearing formations and the scale of the CSG development. It is noted that the scenarios presented in DELWP (2015) most likely reflect the upper limit of the potential CSG production across Gippsland.

Figure 16 Groundwater levels at 52809



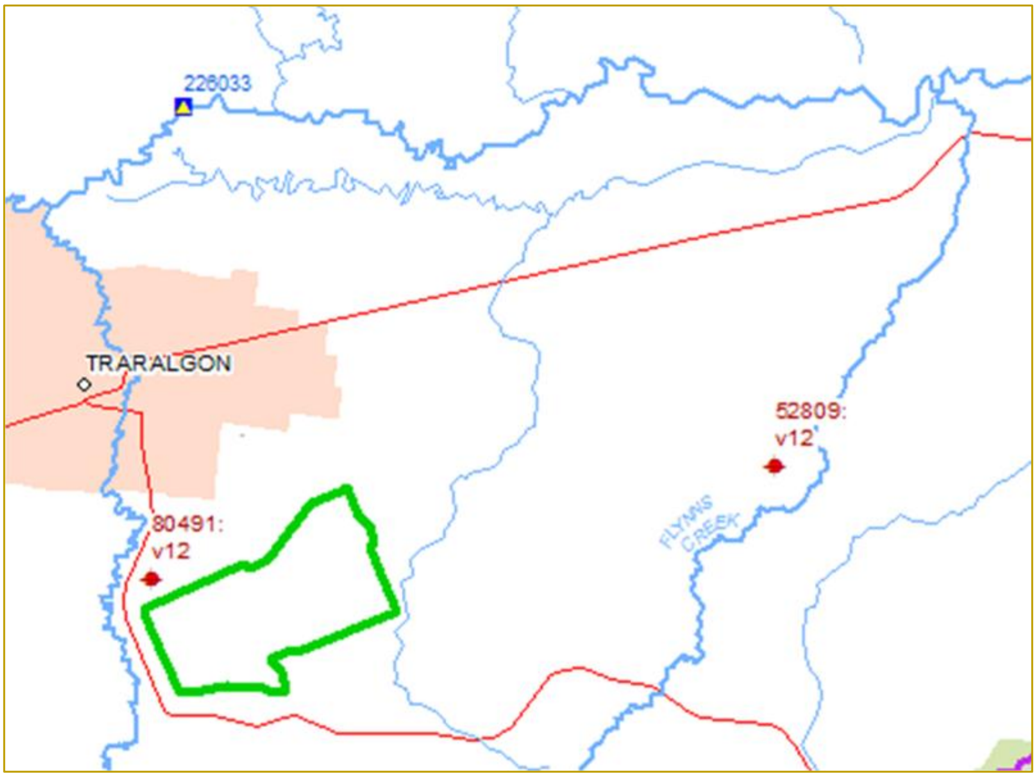
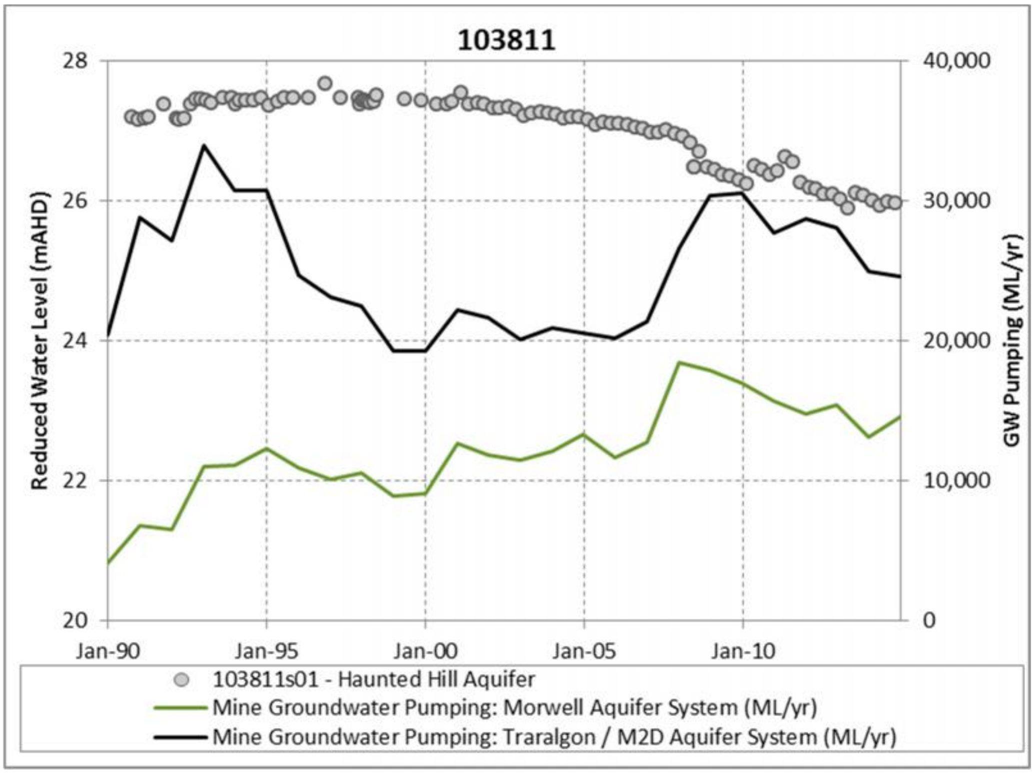
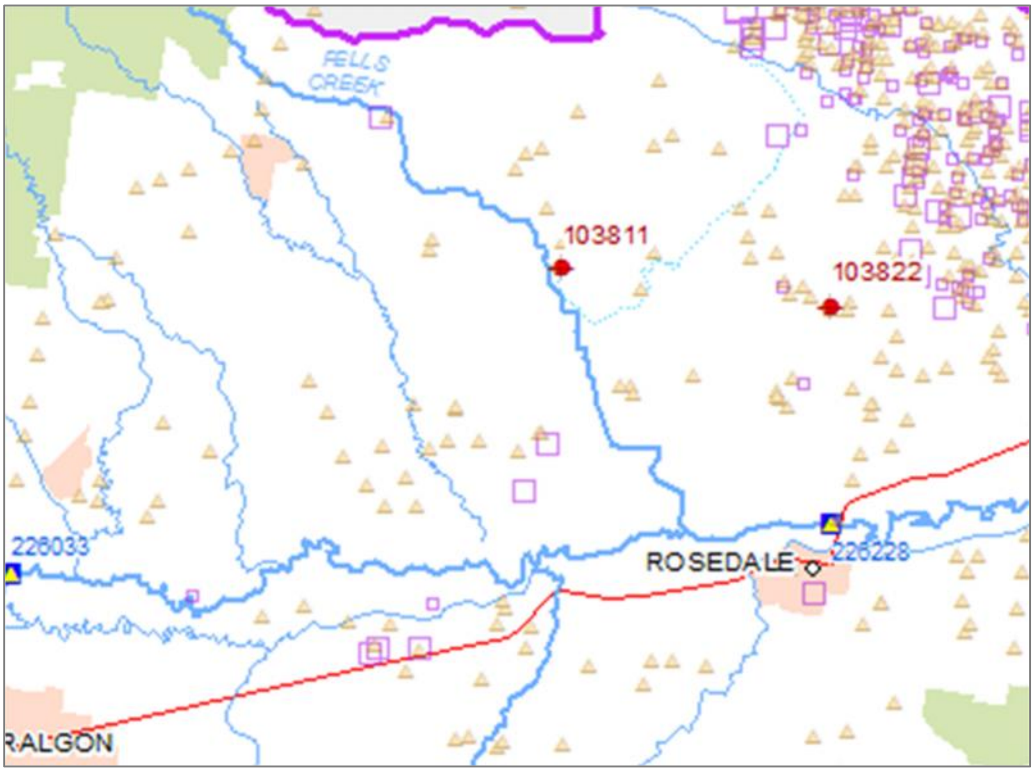


Figure 17 Groundwater levels at 103811





7. Conclusions and Recommendations

This study obtained targeted field data aimed at ground-truthing the baseflow estimates derived in Stage 1 of this study (GHD, 2015) for river reaches of interest to stakeholders. While highly localised studies and field data do not broadly inform the regional-scale conceptualisation and analysis of groundwater-surface water interactions, they do provide a valuable basis for constraining the estimates and thereby improving the confidence of more broad-scale approaches.

7.1 Field Sampling

Conclusions

A targeted field work plan to undertake flow and EC accretion profiling was developed in consultation with DELWP, WGCMA and SRW, based on the key data gaps identified in Stage 1 (GHD, 2015) and tailored to the following key reaches of interest:

- Thomson River from Cowwarr to Wandocka, including Rainbow Creek (9 sampling locations);
- Moe Drain / Latrobe River upstream of Lake Narracan, including Tanjil River and Narracan Creek (12 sampling locations); and
- Macalister River between Glenmaggie and Maffra Weir (5 sampling locations).

Spot sampling was undertaken for three sampling rounds over the study period to collect data for different seasons and regulated influences (irrigation releases):

- Sampling Round 1: Spring 2015 (09/09/2015 – 28/09/2015). Capture flows at the start of the irrigation season.
- Sampling Round 2: Summer 2016 (12/01/2016 – 05/02/2016): Capture summer low flows.
- Sampling Round 3: Autumn 2016 (12/04/2016 – 17/05/2016): Capture flows outside of irrigation season.

Recommendations

A key outcome of this study was the development of field sampling condition criteria to select conditions that will give the most accurate and representative results. It is recommended that future field investigation studies adopt similar sampling criteria developed in this study, where the key criteria are summarised below:

- Safety: the streamflow must be suitably low, to permit safe access to undertake flow gauging;
- River operation: periods associated with large reservoir releases (such as flood mitigation type releases) should be avoided;
- Streamflow rate: undertake sampling when the flow rate was below the median flow for the month of year to reduce flow gauging uncertainty associated with high flows;
- Streamflow trends: sampling during peak streamflow following large rainfall events should be avoided and the flow trend should be steady (neither rising nor falling);
- Streamflow profile (longitudinal): field monitoring should be undertaken when the difference in streamflow between sites is relatively stable;

- Forecast rainfall: sampling should be avoided when forecast rainfall over the proposed work period is greater than 5 mm.

Another recommendation from this study is to obtain field results for major ions in additional to EC for sites downstream of known agricultural or industrial discharges. This will confirm whether EC is representative of Chloride, or if it represents some other solute such as nitrogen. This has been conducted at key sampling locations along the Moe Drain as part of the third round of field investigations completed May 2016 (Section 3.3).

It is also recommended that any offtakes and outfalls occurring within the monitored reaches are also recorded as part of the field sampling program.

7.2 Revised baseflow estimates

Conclusions

The spot flow and EC observations are snapshots of streamflow and baseflow conditions, and as such cannot reliably be used to make conclusions about the average or even typical baseflow and streamflow conditions of a given river or river reach. Rivers and groundwater systems are both highly dynamic, spatially and temporally. Therefore, making generalisations about gaining or losing conditions of a given river is generally not appropriate, unless a consistent story of baseflow conditions can be constructed using the available data, and the data are sufficiently abundant to facilitate this.

That said, the observed stream flow and EC accretion data collected for this project provides a higher level of spatial resolution than data from permanent gauging stations. The higher resolution ('spot') data can be used to investigate whether a more detailed understanding of the catchment can validate or contradict the baseflow estimates based on the broader reach scale mass balances, which only use data from permanent gauging stations. Learnings from the analysis of the more spatially detailed field sampling data can then be used to revise the broader methods and/or their application.

Downstream flow and EC 'accretion profiles' were prepared based on the field observations to provide an indication of the changes in streamflow conditions along each river. These flow and EC accretion profiles can be used to infer baseflow contributions to the stream, with baseflow gains likely when EC is increasing between upstream and downstream sampling sites (i.e. within an 'interstation reach'). To further quantify the magnitude of baseflow gains, reach-scale mass balances were constructed using the field data, in the same manner as was applied by GHD (2015) using historical gauged data.

Results for all sampled reaches indicate that baseflow conditions (i.e. gain from or loss to groundwater) are variable along the reach length and between seasons.

Thomson River

Across seasons, there are consistent baseflow gains exhibited along Rainbow Creek, which is more deeply incised into the landscape than the main channel of the Thomson River. Rainbow Creek likely forms a natural drain towards which groundwater from beneath the more elevated Thomson River will flow. Relatively consistent baseflow gains are exhibited in the reach immediately downstream of Cowwarr Weir, particularly during high river stage behind the weir. This is most likely due to the lower river bed and stage immediately downstream of the weir, effectively forming a drain towards which groundwater from beneath the weir is driven.

Baseflow conditions along the Thomson River between Stoney Creek and Wandocka vary between seasons, ranging from predominantly baseflow gaining conditions during spring to neutral conditions during summer and autumn. It is noted that baseflow conditions were uncertain along several reaches, where gains in EC could potentially be attributed to evaporation losses, rather than baseflow gains.

Macalister River

The only reaches exhibiting seasonally-consistent baseflow conditions are between US Newry Drain and US Maffra Weir, and DS Maffra Weir to Riverslea, where gains were observed across all sampling events. The seasonal neutral to losing behaviour concluded for the upstream reach (between DS Glenmaggie and US Newry Drain) makes sense conceptually due to the relatively elevated river bed, when compared to downstream reaches. The elevated river bed - in conjunction with high river flows (releases from Glenmaggie Weir in Summer (January 2016)) - create hydraulically losing conditions in this reach. Losing behaviour in basin margin reaches was also noted in earlier studies by GHD (2013a).

The observations are in broad agreement with the earlier work of GHD (2015). The broad picture of neutral to losing conditions downstream of Glenmaggie Weir, and generally gaining conditions downstream of Newry Drain (aside from around Maffra Weir) is consistent with the earlier work, noting that there are temporal differences.

Latrobe River

Moderately gaining baseflow conditions are consistently experienced across seasons for the upper reaches of the Latrobe River, Tanjil River and Narracan Creek; however, baseflow gains are generally reduced in summer. The data suggests relatively variable seasonal baseflow conditions along the Moe Drain, with predominantly gaining conditions exhibited during spring and relatively neutral conditions during summer and autumn.

Recommendations

Refinement to the sub-reach scale mass balance

Based on the findings from the reach-scale mass balance analyses and validation of the broader mass balances, it is recommended that the following refinement to the method is adopted for subsequent baseflow assessments which are adopting the method trailed in this study:

$$Q_{Gr \quad h} = \frac{Q_d c_S \;\; - Q_u c_S \; _-(Q_d - Q_u) c_S - Q_d \;\; C_d}{(c_{Gr \quad h} - c_S)}$$

Refer to Section presented in 5.1 for full details of the refinement. This revised equation should result in the highest possible degree of consistency between detailed sub-reach scale mass balances and broader scale mass balances.

A key aspect of this refinement is to incorporate an accurate estimate of flow and EC major diversions within the reach as this can have a significant impact on the outcomes of the reach scale mass balance.

Application of the method

While application of the reach scale mass balance can provide a more accurate estimate of baseflows by removing some uncertainty associated with the runoff end member EC, there remains significant uncertainty in the baseflow estimates due to high uncertainty in the groundwater end member EC. The uncertainty may be reduced through undertaking EC and major ion sampling for a larger number of groundwater bores within the catchment; however, it is acknowledged that it could be a costly exercise. In cases where greater investment is justified, detailed transects that provide high resolution temporal information could be used to better separate the regional groundwater end member characteristics from the bank storage mixing zone water.

Ideally, temporary gauging stations would be installed to continuously record flow and EC for a period of time that encompasses a range of flow, groundwater and management conditions. This would provide sufficient data to estimate the uncertainty of the measurements in a robust manner, which is not possible with the very small number of spot measurements undertaken in this study.

The application of the detailed reach-scale mass balance method at a sub-reach scale successfully validated the findings from the broader mass balance approach applied in Stage 1 of this study (GHD, 2015), as well as previous applications of the method (GHD 2013a; 2013b; 2014a). This study can be used as a guide to the application of the reach-scale mass balance for future studies. This study also highlighted the importance of identifying a number of limiting factors which reduce the reliability of the method, and account for them accordingly, such as:

- Impacts of flow regulation on the baseflow estimates
- Impacts of water storages on the baseflow estimates
- Impacts of solute concentration through evapotranspiration along an interstation reach
- Impacts of diversions from the river and outfalls to the river in terms of flow and EC, and
- Scheduling of field work to increase applicability of results.

Baseflow database

For specific river reaches of interest to water managers and other stakeholders, there would be value in implementing an ongoing annual program of spatially detailed field sampling and analyses, for which this study forms a well-developed template. Based on sampling results, a database of baseflow gains and flow losses along these reaches could be developed. This 'baseflow conditions' database would form a sound basis for more broadly characterising and better understanding priority river reaches in terms of seasonal baseflow conditions; in addition to how those conditions may change under variable climatic conditions and in response to land, water and resource developments. These broad characteristics could then be applied in:

- More robustly assessing the significance and value of groundwater inputs to environmental flows under a range of conditions
- Assessing threats to groundwater-dependent components of environmental flows, and
- Evaluating ongoing water management needs and options, licensing decisions, and approvals for significant land, water and resource developments.

7.3 Coal seam gas impact assessment

Conclusions

This study completed a high level analysis to assess potential effects that coal seam gas extraction may have on groundwater – surface water interactions, drawing on finding from relevant literature. It is noted that there is potential for onshore coal seam gas production to have significant impacts on baseflow in the Gippsland region, as reported in DELWP (2015). However, the magnitude of the impact depends on the location of the CSG development, the stratigraphy of the gas bearing formations and the scale of the CSG development. It is noted that the scenarios presented in DELWP (2015b) most likely reflect the upper limit of the potential CSG production across Gippsland. Review of historic groundwater hydrographs in the region indicate the historic impacts of groundwater depressurisation for coal mining in the region have had limited impacts on the shallow aquifer systems.

8. References

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Appendices

Appendix A – Sampling Locations

Appendix A1 – Sampling Photos: Thomson River

Appendix A2 – Sampling Photos: Macalister River

Appendix A3 – Sampling Photos: Latrobe River

Appendix A1 – Field Photos Thomson River

 225212A – THOMSON RIVER WANDOCKA 20150910 DS	 225212A – THOMSON RIVER WANDOCKA 20150910 ME	 225212A – THOMSON RIVER WANDOCKA 20150910 US
 225227A RAINBOW CREEK DS COWWARR WEIR 20150909 DS	 225227A RAINBOW CREEK DS COWWARR WEIR 20150909 ME	 225227A RAINBOW CREEK DS COWWARR WEIR 20150909 US
 225228A THOMSON RIVER TIMBER WEIR 20150909 DS	 225228A THOMSON RIVER TIMBER WEIR 20150909 ME	 225228A THOMSON RIVER TIMBER WEIR 20150909 US
 225231A THOMSON RIVER US COWWARR WEIR 20150909 DS	 225231A THOMSON RIVER US COWWARR WEIR 20150909 ME	 225231A THOMSON RIVER US COWWARR WEIR 20150909 US

Appendix A1 – Field Photos Thomson River

 225243A THOMSON RIVER DS RAINBOW 20150910 DS	 225243A THOMSON RIVER DS RAINBOW 20150910 ME	 225243A THOMSON RIVER DS RAINBOW 20150910 US
 RAINBOW CREEK US OF THOMSON RIVER DS	 RAINBOW CREEK US OF THOMSON RIVER ME	 RAINBOW CREEK US OF THOMSON RIVER US
 THOMSON RIVER DS OF STONY CREEK DS	 THOMSON RIVER DS OF STONY CREEK ME	 THOMSON RIVER DS OF STONY CREEK US
 THOMSON RIVER US OF RAINBOW CREEK DS	 THOMSON RIVER US OF RAINBOW CREEK ME	 THOMSON RIVER US OF RAINBOW CREEK US

Appendix A1 – Field Photos Thomson River

 THOMSON RIVER US OF BACK CREEK DS	 THOMSON RIVER US OF BACK CREEK US	 THOMSON SYPHON OUTFALL TO RAINBOW CREEK
 THOMSON SYPHON OUTFALL	 STONY CREEK THOMSON TRIBUTARY 20150909	 COWWARR WEIR CHANNEL 20150909 67.2 MLD RATED

Appendix A2 – Field Photos Macalister River

 225204D MACALISTER DS GLENMAGGIE 20150928 DS	 225204D MACALISTER DS GLENMAGGIE 20150928 ME	 225204D MACALISTER DS GLENMAGGIE 20150928 US
 225242A MACALISTER RIVER DS MAFFRA WEIR 20150928 DS	 225242A MACALISTER RIVER DS MAFFRA WEIR 20150928 ME	 225242A MACALISTER RIVER DS MAFFRA WEIR 20150928 US
 225247A MACALISTER AT RIVERSLEA 20150928 DS	 225247A MACALISTER AT RIVERSLEA 20150928 ME	 225247A MACALISTER AT RIVERSLEA 20150928 US
 MACALISTER RIVER BELLBIRD CORNER 20150928 DS	 MACALISTER RIVER BELLBIRD CORNER 20150928 ME	 MACALISTER RIVER BELLBIRD CORNER 20150928 US
 MACALISTER RIVER US NEWRY DRAIN 20150928 DS	 MACALISTER RIVER US NEWRY DRAIN 20150928 ME	 MACALISTER RIVER US NEWRY DRAIN 20150928 US

Appendix A3 – Field Photos Latrobe River

 TANJIL RIVER US OF LATROBE RIVER ME	 26021A NARRACAN CREEK MOE 20150924 ME	 26021A NARRACAN CREEK MOE 20150924 DS
 226402A MOE DRAIN TRAFALGAR SITE 4 20150923	 MOE DRAIN SITE 3 20150923 ME	 MOE DRAIN SITE 2 START OF DRAIN 20150923 ME
 226209B MOE RIVER DARNUM SITE 1 20150923 ME	 226021A NARRACAN CREEK MOE 20150924 US	
 LATROBE US LAKE NARRACAN BECKS BRIDGE 20150924 DS	 LATROBE US LAKE NARRACAN BECKS BRIDGE 20150924 ME	 LATROBE US LAKE NARRACAN BECKS BRIDGE 20150924 US

Appendix A3 – Latrobe River

 226216A TANJIL RIVER TANJIL SOUTH 20150924 DS	 226216A TANJIL RIVER TANJIL SOUTH 20150924 US	
 226204A LATROBE RIVER WILLOWGROVE 20150924 DS	 226204A LATROBE RIVER WILLOWGROVE 20150924 ME	 226204A LATROBE RIVER WILLOWGROVE 20150924 US
 226218A NARRACAN CREEK THORPDALE 20150924 DS	 226218A NARRACAN CREEK THORPDALE 20150924 US	
 LATROBE RIVER US MOE DRAIN 20150924 DS	 LATROBE RIVER US MOE DRAIN 20150924 ME	 LATROBE RIVER US MOE DRAIN 20150924 US

Appendix A3 – Latrobe River

MOE RIVER US LATROBE SITE 5 20150924 DS

MOE RIVER US LATROBE SITE 5 20150924 ME

MOE RIVER US LATROBE SITE 5 20150924 US

226402A MOE DRAIN TRAFALGAR SITE 4 20150923 DS

226402A MOE DRAIN TRAFALGAR SITE 4 20150923 US

MOE DRAIN SITE 3 20150923 US

MOE DRAIN SITE 3 20150923 DS

MOE DRAIN SITE 2 START OF DRAIN 20150923 DS

MOE DRAIN SITE 2 START OF DRAIN 20150923 US

226209B MOE RIVER DARNUM SITE 1 20150923 DS

226209B MOE RIVER DARNUM SITE 1 20150923 US

Appendix B – Field Results

Appendix A1 – Field Results – Round 1

Appendix A2 – Field Results – Round 2

Appendix A3 – Field Results – Round 3

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Macalister River

Project No: 01106

Date: 28/09/2015

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
225204D Macalister River D/S Glenmaggie T/G	28/09/2015	9:45	0.428	1.2553	108.5	55H0483003	5800534	49.3	13.8	Overcast
Macalister River U/S Newry Drain (Banana Bridge)	28/09/2015	11:05	N/A	1.4253	123.1	55H0489788	5800257	63.9	15.4	Overcast
Macalister River U/S Maffra Weir Pool (Bellbird Corn	28/09/2015	13:27	N/A	1.743	150.6	55H0496495	5800814	109.5	15.1	Overcast
225242A Macalister River D/S Maffra Weir T/G	28/09/2015	14:50	0.145	1.1356	98.1	55H0497839	5797233	78.5	13.8	Overcast
225247A Macalister River @ Riverslea	28/09/2015	16:20	0.767	1.5003	129.6	55H0498013	5791320	143.1	15.4	Overcast

Note:

1. Small outflow into Macalister River at Maffra Weir D/S measurement section, estimated at 2-3 ML/D, EC recorded at 240 EC and Temperature 24.0 C
2. Outflow from lake Glenmaggie had been cut back 3 days prior to Measurements
3. SRW Estimate 60 ML/D flowing down the Eastern Channel from Maffra Weir.
4. Possibly significant inflows into the Macalister River between Maffra Weir and Riverslea via the Serpentine Creek.

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Latrobe River

Project No: 01106

Date: 23 & 24 /09/2015

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
Moe River/ Drain Sites										
226209B Moe River @ Darnum (Site 1)	23/09/2015	10:57	1.259	1.484	128.2	55H0412653	5770881	340.2	10.7	Overcast
Moe Drain Site 2 (Start of Drain)	23/09/2015	12:04	N/A	1.747	150.9	55H0418061	5772859	374.5	11.1	Overcast
Moe Drain Site 3	23/09/2015	14:00	N/A	2.678	231.4	55H0425348	5773247	447.1	12	Overcast
226402A Moe Drain @ Trafalgar (Site 4)	23/09/2015	15:50	0.608	2.716	234.7	55H0431054	5774340	493.2	12	Overcast
Moe River U/S Latrobe River (Site 5)	24/09/2015	9:04	N/A	2.783	240.5	55H0434822	5776437	488.6	9.48	Overcast
Latrobe River sites										
226204A Latrobe River @ Willowgrove	24/09/2015	12:15	1.216	5.068	437.9	55H0426324	5784168	92	8.85	Overcast
Latrobe River U/S Moe Drain	24/09/2015	10:20	N/A	5.589	482.9	55H0434644	5777471	118.5	8.78	Overcast
Latrobe River U/S Lake Narracan (Becks Bridge)	24/09/2015	13:50	N/A	15.494	1338.7	55H0437204	5776865	191.1	10.8	Overcast
Tanjil River sites										
226216A Tanjil River @ Tanjil South	24/09/2015	14:00	1.47	5.749	496.7	55H0433555	5783266	81	11.5	Overcast
Tanjil River U/S Latrobe River	24/09/2015	11:45	N/A	5.592	483.1	55H0435773	5778493	98.5	10.8	Overcast
Naracan Creek Sites										
226218A Narracan Creek @ Thorpdale	24/09/2015	10:45	0.77	0.7625	65.9	55H0428801	5763694	124	9.94	Overcast
226021A Narracan Creek @ Moe	24/09/2015	15:05	0.578	1.028	88.8	55H0435960	5775844	219.2	16.6	Overcast

Note:

1.:

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Thomson River

Project No: 01106

Date: 9 &10/09/2015

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
Day 1										
Thomson River U/S Cowwarr Weir (225231A)	9/09/2015	10:10	2.243	4.265	368.5	55H0467153	5796673	73	9.59	Ocast / Showers
Thomson River @ Timber Weir (225228A)	9/09/2015	11:40	0.406	3.036	262.3	55H0470165	5794579	73	9.92	Ocast / Showers
Thomson River D/S Stony Creek	9/09/2015	13:42	NA	3.391	293.0	55H0473116	5795775	77	10.5	Ocast / Showers
Rainbow Creek D/S Cowwarr Weir (225227A)	9/09/2015	12:15	0.142	0.6567	56.7	55H0470134	5794023	74	10.5	Ocast / Showers
Thomson River U/S Back Creek	9/09/2015	14:45	NA	3.361	290.4	55H0477306	5794882	78	10.8	Ocast / Showers
Stony Creek Crossing	9/09/2015	9:20	NA	3 ML/D est (+/-1 ML/D)		55H0470715	5796623	142	10	Flow estimated
Day 2										
Rainbow Creek @ U/S Thomson River	10/09/2015	12:20	NA	0.78	67.4	55H0481671	5794000	101	12.4	Fine
Thomson River @ U/S of Rainbow Creek	10/09/2015	11:00	NA	3.084	266.5	55H0481806	5793958	83	11	Fine
Thomson River @ U/S of Rainbow Creek	10/09/2015	11:45	NA	3.117	269.3	55H0481806	5793958	83	11	Conformation Meas.
Thomson River D/S Rainbow Creek (225243A)	10/09/2015	10:10	0.400	4.466	385.9	55H0481867	5793841	84	10.9	Fine
Thomson River @ Wandocka (225212A)	10/09/2015	15:45	1.408	4.678	404.2	55H0481672	5793999	92	11.7	Fine
Thomson River U/S Back Creek	10/09/2015	14:00	NA	2.911	251.5	55H0477306	5794882	78	11.5	Fine
Syphon Outfall	10/09/2015	13:00		10 to 20 ML est				62	12.7	Flow estimated

Note:

1. SRW commented Cowwarr Channel running @ 67.2mld 9/9/2015 All day no change
2. Logger @ visit Cowwarr HG 64.927 TG 0.139
3. Shaded lines indicate additional site information

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Thomson River

Project No: 01106

Date: 12 &13/01/2016

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
Day 1										
Thomson River U/S Cowwarr Weir (225231A)	12/01/2016	8:46	2.082	2.6806	231.6	55H0467153	5796673	83	22.9	Weather is Fine
Thomson River @ Timber Weir (225228A)	12/01/2016	10:59	0.277	1.465	126.6	55H0470165	5794579	91	24.2	Weather is Fine
Thomson River D/S Stony Creek	12/01/2016	12:32	NA	1.5806	136.6	55H0473116	5795775	99	24.3	Weather is Fine
Rainbow Creek D/S Cowwarr Weir (225227A)	12/01/2016	11:25	0.14	0.665	57.5	55H0470134	5794023	91	24.5	Weather is Fine
Thomson River U/S Back Creek	12/01/2016	13:38	NA	1.2824	110.8	55H0477306	5794882	100	24.2	Weather is Fine
Stony Creek Crossing	12/01/2016	8:20	NA	2ML/D estimated		55H0470715	5796623			Flow estimated
Day 2										
Rainbow Creek @ U/S Thomson River	13/01/2016	10:16	NA	0.6123	52.9	55H0481671	5794000	108	24	Weather is Fine
Thomson River @ U/S of Rainbow Creek	13/01/2016	9:19	NA	1.3604	117.5	55H0481806	5793958	103	22	Weather is Fine
Thomson River D/S Rainbow Creek (225243A)	13/01/2016	8:07	NA	2.4348	210.4	55H0481867	5793841	100	22.3	Weather is Fine
Thomson River @ Wandocka (225212A)	13/01/2016	13:07	1.081	1.8694	161.5	55H0481672	5793999	107	23.6	Weather is Fine
Thomson River U/S Back Creek	13/01/2016	12:05	NA	1.4005	121.0	55H0477306	5794882	98	23.7	Weather is Fine
Syphon Outfall	13/01/2016	0:00	NA	40ML/D estimated						Flow estimated

Note:

1. D Johnson from SRW provided there was 20-23ML/D being released down the Cowwarr Channel
2. Shaded areas indicate additional site information

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Macalister River

Project No: 01106

Date: 14/04/2016

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
225204D Macalister River D/S Glenmaggie T/G	14/04/2016	9:40	0.451	1.6475	142.3	55H0483003	5805034	66	17.7	Sunny
Macalister River U/S Newry Drain (Banana Bridge)	14/04/2016	10:40	NA	1.472	127.2	55H0489788	5800257	75	18.2	Sunny
Macalister River U/S Maffra Weir Pool (Bellbird Cor	14/04/2016	11:45	NA	1.665	143.9	55H0496495	5800814	90	17.6	Overcast
225242A Macalister River D/S Maffra Weir T/G	14/04/2016	13:45	0.110	0.719	62.1	55H0497839	5797233	110	17.6	Overcast
225247A Macalister River @ Riverslea	14/04/2016	15:25	0.650	0.8569	74.0	55H0498013	5791320	152	17.8	Overcast

Note:

1. Maffra Weir HG 20.868, Pipe Closed, Gate2 Closed, Sluice 0.182, TG 0.110. All steady during measurement -225242A.
2. Inflow from Murray Goulburn DS Maffra Weir TG est. 2-3mld EC 534 Temp 24.7
3. Sepentine Creek@Singletons est 3-5 mld EC 374 Temp 18.3. Sepentine Creek@Singletons est 3-5 mld EC 374 Temp 18.
4. Carter Ck (US Bellbird Corner) est 2 mld EC 560 Temp16.5
5. SRW Irrigation supply 10mld DS Banana Bridge

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Macalister River

Project No: 01106

Date: 14/01/2016

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
225204D Macalister River D/S Glenmaggie T/G	14/01/2016	8:16	0.525	2.9652	256.2	55H0483003	5800534	62	22.6	Weather is Fine
Macalister River U/S Newry Drain (Banana Bridge)	14/01/2016	10:27	NA	2.832	244.7	55H0489788	5800257	60	21.8	Weather is Fine
Macalister River U/S Maffra Weir Pool (Bellbird Corn	14/01/2016	11:44	NA	2.988	258.2	55H0496495	5800814	80	24.5	Weather is Fine
225242A Macalister River D/S Maffra Weir T/G	14/01/2016	12:29	0.145	1.0799	93.3	55H0497839	5797233	110	24.9	Weather is Fine
225247A Macalister River @ Riverslea	14/01/2016	14:18	0.777	1.494	129.1	55H0498013	5791320	209	23.7	Weather is Fine

Note:

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Latrobe River

Project No: 01106

Date: 4 & 5 /02/2016

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
Moe River/ Drain Sites										
226209B Moe River @ Darnum (Site 1)	4/02/2016	9:28	0.991	0.1704	14.7	55H0412653	5770881	359	18.5	Weather is Fine
Moe Drain Site 2 (Start of Drain)	4/02/2016	11:00	NA	0.1597	13.8	55H0418061	5772859	340	19.8	Weather is Fine
Moe Drain Site 3	4/02/2016	12:33	NA	0.362	31.3	55H0425348	5773247	472	20.1	Weather is Fine
226402A Moe Drain @ Trafalgar (Site 4)	4/02/2016	13:28	0.3	0.4471	38.6	55H0431054	5774340	570	21.4	Inflows entering drain just upstream
Moe River U/S Latrobe River (Site 5)	4/02/2016	14:52	NA	0.4489	38.8	55H0434822	5776437	547	22	Weather is Fine
Moe River U/S Latrobe River (Site 5)	5/02/2016	8:23	NA	0.41	35.4	55H0434822	5776437	576	19.5	Weather is Fine
Latrobe River sites										
226204A Latrobe River @ Willowgrove	5/02/2016	10:37	0.965	2.6334	227.5	55H0426324	5784168	98	18.5	Weather is Fine
Latrobe River U/S Moe Drain	5/02/2016	7:46	NA	3.2011	276.6	55H0434644	5777471	111	18.7	Weather is Fine
Latrobe River U/S Lake Narracan (Becks Bridge)	5/02/2016	10:50	NA	4.728	408.5	55H0437204	5776865	158	19.5	Weather is Fine
Tanjil River sites										
226216A Tanjil River @ Tanjil South	5/02/2016	12:23	1.075	1.295	111.9	55H0433555	5783266	88	18.2	Weather is Fine
Tanjil River U/S Latrobe River	5/02/2016	12:23	NA	1.034	89.3	55H0435773	5778493	98	19.8	Weather is Fine
Naracan Creek Sites										
226218A Narracan Creek @ Thorpdale	5/02/2016	9:25	0.42	0.1505	13.0	55H0428801	5763694	158	16.6	Weather is Fine
226021A Narracan Creek @ Moe	5/02/2016	9:37	0.391	0.206	17.8	55H0435960	5775844	283	18.2	Weather is Fine

Note:

1.: Tanjil River rising/falling quickly due to unsteady outflows from Blue Rock

2. Estimated flows 10 -15ML/D entering Moe Drain just upstream of site 226402A Moe Drain at Trafalgar East from small drain

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Thomson River

Project No: 01106

Date:12 &13/04/2016

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
Day 1										
Thomson River U/S Cowwarr Weir (225231A)	12/04/2016	11:30	1.974	1.9816	171.2	55H0467153	5796673	67	15.5	Ocast
Thomson River U/S Cowwarr Weir (225231A)	12/04/2016	12:10	1.975	1.9186	165.7	55H0467153	5796673	67	15.5	Ocast
Thomson River @ Timber Weir (225228A)	12/04/2016	13:00	0.259	1.2218	105.6	55H0470165	5794579	67	16.3	Ocast
Thomson River D/S Stony Creek	12/04/2016	13:50	NA	1.2346	106.7	55H0473116	5795775	68	16.3	Ocast
Rainbow Creek D/S Cowwarr Weir (225227A)	12/04/2016	13:55	0.117	0.553	48.0	55H0470134	5794023	67	16.4	Ocast
Thomson River U/S Back Creek	12/04/2016	15:40	NA	1.2804	110.6	55H0477306	5794882	70	16.4	Ocast
Stony Creek Crossing	12/04/2016	9:35	NA	No Flow		55H0470715	5796623			
Day 2										
Rainbow Creek @ U/S Thomson River	13/04/2016	14:00	NA	0.5882	50.8	55H0481671	5794000	87	18.1	Ocast
Thomson River @ U/S of Rainbow Creek	13/04/2016	13:05	NA	1.884	102.7	55H0481806	5793958	71	16.5	Ocast
Thomson River D/S Rainbow Creek (225243A)	13/04/2016	11:30	0.164-0.130	2.1678	187.3	55H0481867	5793841	75	17.2	Sunny
Thomson River @ Wandocka (225212A)	13/04/2016	15:10	1.110-1.130	2.1781	188.2	55H0489680	5793138	72	16.8	Ocast
Thomson River U/S Back Creek	13/04/2016	10:15	NA	1.2457	107.6	55H0477306	5794882	70	15.9	Ocast
Syphon Outfall	13/04/2016	14:30	NA	Variable		55H0481727	5793896	65	18.9	

Note:

1. D Johnson from SRW provided there was 6 ML/D being released down the Cowwarr Channel
2. Syphon Outflow est 30-40 mld @ 11:30 and est 5-10mld @ 12:50, Varying flows during measurement -225243A

THIESS

Gippsland Flow and EC Monitoring

Client: GHD

Catchment: Latrobe River

Project No: 01106

Date: 16/5/2016 - 17/5/2016

Site	Date	Time	GH	Discharge		GPS Coordinates		EC	Temp	Observations
				M^3/S	ML/D	Easting's	Northings	Temp ref 25C	oC	
Moe River/ Drain Sites										
226209B Moe River @ Darnum (Site 1)	16/05/2016	11:10	1.038	0.2496	21.6	55H0412653	5770881	412	10.8	Windy/Overcast
Moe Drain Site 2 (Start of Drain)	16/05/2016	12:15	-	0.3010	26.0	55H0418061	5772859	396	11.5	Windy/Overcast
Moe Drain Site 3	16/05/2016	13:43	-	0.4439	38.4	55H0425348	5773247	484	11.6	Windy/Overcast
226402A Moe Drain @ Trafalgar (Site 4)	16/05/2016	15:02	0.323	0.5648	48.8	55H0431054	5774340	577	12.2	Inflow upstream Est' 2-5ML/D
Moe River U/S Latrobe River (Site 5)	16/05/2016	16:01	-	0.5194	44.9	55H0434822	5776437	574	12.6	Windy/Overcast
Moe River U/S Latrobe River (Site 5)	17/05/2016	12:41	-	0.4980	43.0	55H0434822	5776437	573	12.7	Windy/Overcast
Latrobe River sites										
226204A Latrobe River @ Willowgrove	17/05/2016	10:06	0.871	1.8663	161.2	55H0426324	5784168	99	12.2	Windy/Overcast
Latrobe River U/S Moe Drain	17/05/2016	11:03	-	2.0121	173.8	55H0434644	5777471	136	12.4	Windy/Overcast
Latrobe River U/S Lake Narracan (Becks Bridge)	17/05/2016	09:01	-	4.2250	365.0	55H0437204	5776865	195	12.5	Windy/Overcast
Tanjil River sites										
226216A Tanjil River @ Tanjil South	17/05/2016	11:21	1.079	1.2723	109.9	55H0433555	5783266	81	14.2	Windy/Overcast
Tanjil River U/S Latrobe River	17/05/2016	12:45	-	1.2460	107.7	55H0435773	5778493	103	13.5	Windy/Overcast
Naracan Creek Sites										
226218A Narracan Creek @ Thorpdale	17/05/2016	08:44	0.622	0.4567	39.5	55H0428801	5763694	135	12.0	Windy/Overcast
226021A Narracan Creek @ Moe	17/05/2016	08:05	0.487	0.5070	43.8	55H0435960	5775844	225	12.3	Windy/Overcast

Note:

226216A - Pumping from gauge pool at time of measurement, stage rising from 1.061 - 1.097. Flow from Blue rock dam increased during n

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Australian Water Quality Centre

VENTIA PTY LIMITED
ATTN: Wayne Ross
13 Fulton Rd
Maffra
VIC 3862 AUSTRALIA

27/05/2016

Dear Wayne

Please find attached the Final Analytical Report for

Customer Service Request:	142829-2016-CSR-18
Account:	142829
Project:	AWQC-104028 Ventia - River/Ground Water Investigation - Non routine 15/6

This report has also been sent to: Wayne Ross

AWQC Sample Receipt hours are Monday and Tuesday 8:30am to 8pm and Wednesday, Thursday and Friday 8:30am to 4:30pm.

Yours sincerely,

Darren Seebohm
Customer Services Officer
Darren.Seebohm@sawater.com.au
+61 8 7424 2150

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Australian Water Quality Centre

FINAL REPORT: 183080

Report Information

Project Name	AWQC-104028
Customer	VENTIA PTY LIMITED
CSR_ID	142829-2016-CSR-18

Analytical Results

Customer Sample Description	Sample Location 1
Sampling Point	90641-VENTIA PTY LIMITED
Sampled Date	16/05/2016 1:45:00PM
Sample Received Date	17/05/2016 1:53:50PM
Sample ID	2016-003-2835
Status	Endorsed
Collection Type	Customer Collected

Inorganic Chemistry - Metals	LOR	Result
Sample temperature at time of receipt 2.9°C		
Calcium TIC-004 W09-023		
Calcium	0.1	11.1 mg/L
Magnesium TIC-004 W09-023		
Magnesium	0.05	10.7 mg/L
Potassium TIC-006 W09-023		
Potassium	0.040	4.62 mg/L
Sodium TIC-004 W09-023		
Sodium	0.1	57.3 mg/L
Sulphur TIC-004 W09-023		
Sulphate	1.5	13.2 mg/L

Inorganic Chemistry - Nutrients	LOR	Result
Sample temperature at time of receipt 2.9°C		
Ammonia as N T0100-01 W09-023		
Ammonia as N	0.005	0.036 mg/L
Chloride T0104-02 W09-023		
Chloride	4.0	114 mg/L
Fluoride T0105-01 W09-023		
Fluoride	0.10	0.10 mg/L
Nitrate + Nitrite as N T0161-01 W09-023		
Nitrate + Nitrite as N	0.003	0.907 mg/L
Nitrite as N T0107-01 W09-023		
Nitrite as Nitrogen	0.003	0.006 mg/L
Silica - Reactive T0111-01 W09-023		
Silica - Reactive	1	11 mg/L

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Notes

1. The last figure of the result value is a significant figure.
2. Samples are analysed as received.
3. # determination of the component is not covered by NATA Accreditation. Refer
4. ^ indicates result is out of specification according to the reference Guideline. Refer to Report footer.
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8. Where collection type is AWQC Collect, NATA has confirmed that due to a robust system in place for maintaining the temperature integrity for samples collected by AWQC's Field Laboratory Services, the recording of temperature when samples arrive at the AWQC is out of scope.
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FINAL REPORT: 183080

Analytical Results

Customer Sample Description	Sample Location 1
Sampling Point	90641-VENTIA PTY LIMITED
Sampled Date	16/05/2016 1:45:00PM
Sample Received Date	17/05/2016 1:53:50PM
Sample ID	2016-003-2835
Status	Endorsed
Collection Type	Customer Collected

Inorganic Chemistry - Physical	LOR	Result
Sample temperature at time of receipt 2.9°C		
Alkalinity Carbonate Bicarbonate and Hydroxide T0101-01 W09-023		
Alkalinity as Calcium Carbonate		31 mg/L
Bicarbonate		38 mg/L
Carbonate		0 mg/L
Hydroxide		0 mg/L
Conductivity & Total Dissolved Solids T0016-01 W09-023		
Conductivity	1	482 µScm
Total Dissolved Solids (by EC)	1.0	260 mg/L
pH T0010-01 W09-023		
pH		7.1 pH units

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Analytical Results

Customer Sample Description	Sample Location 2
Sampling Point	90641-VENTIA PTY LIMITED
Sampled Date	16/05/2016 3:25:00PM
Sample Received Date	17/05/2016 1:49:35PM
Sample ID	2016-003-2836
Status	Endorsed
Collection Type	Customer Collected

Inorganic Chemistry - Metals	LOR	Result
Sample temperature at time of receipt 2.9°C		
Calcium TIC-004 W09-023		
Calcium	0.1	10.7 mg/L
Magnesium TIC-004 W09-023		
Magnesium	0.05	12.1 mg/L
Potassium TIC-006 W09-023		
Potassium	0.040	5.09 mg/L
Sodium TIC-004 W09-023		
Sodium	0.1	73.6 mg/L
Sulphur TIC-004 W09-023		
Sulphate	1.5	13.5 mg/L

Inorganic Chemistry - Nutrients	LOR	Result
Sample temperature at time of receipt 2.9°C		
Ammonia as N T0100-01 W09-023		
Ammonia as N	0.005	0.035 mg/L
Chloride T0104-02 W09-023		
Chloride	4.0	138 mg/L
Fluoride T0105-01 W09-023		
Fluoride	0.10	<0.1 mg/L
Nitrate + Nitrite as N T0161-01 W09-023		
Nitrate + Nitrite as N	0.003	1.06 mg/L
Nitrite as N T0107-01 W09-023		
Nitrite as Nitrogen	0.003	0.005 mg/L
Silica - Reactive T0111-01 W09-023		
Silica - Reactive	1	11 mg/L

Inorganic Chemistry - Physical	LOR	Result
Sample temperature at time of receipt 2.9°C		
Alkalinity Carbonate Bicarbonate and Hydroxide T0101-01 W09-023		
Alkalinity as Calcium Carbonate		28 mg/L

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Customer Sample Description	Sample Location 2
Sampling Point	90641-VENTIA PTY LIMITED
Sampled Date	16/05/2016 3:25:00PM
Sample Received Date	17/05/2016 1:49:35PM
Sample ID	2016-003-2836
Status	Endorsed
Collection Type	Customer Collected

Alkalinity Carbonate Bicarbonate and Hydroxide T0101-01 W09-023

Bicarbonate		34 mg/L
Carbonate		0 mg/L
Hydroxide		0 mg/L

Conductivity & Total Dissolved Solids T0016-01 W09-023

Conductivity	1	573 µScm
Total Dissolved Solids (by EC)	1.0	310 mg/L

pH T0010-01 W09-023

pH		7.1 pH units

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AWQC Signatories

Roger Kennedy - Snr Technical Officer - Method Dev

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Analytical Method

Analytical Method Code	Description	Reference Method
T0010-01	Determination of pH	APHA 4500-H B
T0016-01	Determination of Conductivity	APHA 2510 B
T0100-01	Ammonia/Ammonium - Automated Flow Colorimetry	APHA 4500-NH3 G
T0101-01	Alkalinity - Automated Acidimetric Titration	APHA 2320 B
T0104-02	Chloride - Discrete Analyser	APHA 4500-Cl- E
T0105-01	Fluoride by ISE	APHA 4500-F- C
T0107-01	Nitrite - Automated Flow Colorimetry	APHA 4500-NO3-I
T0111-01	Silica by automated fow colorimetry	APHA 4500-Si02
T0161-01	Nitrate + Nitrate (NOx) - Automated Flow Colorimetry	APHA 4500-NO3-I
TIC-004	Determination of Metals - ICP Spectrometry by ICP2	APHA 3120
TIC-006	Elemental Analysis By ICP- MS	EPA method 200.8
W-052	Preparation of Samples for Metal Analysis	APHA 3030A to 3030D

Sampling Method

Sampling Method Code	Description
W09-023	Sampling Method for Chemical Analyses

Laboratory Information

Laboratory	NATA accreditation ID
Inorganic Chemistry - Metals	1115
Inorganic Chemistry - Nutrients	1115
Inorganic Chemistry - Physical	1115

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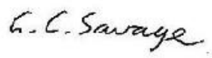
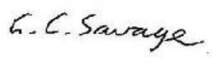
Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft A	Alice Drummond Michael Finger	Geoff Savage Chris Nicol		Geoff Savage		01/03/2016
Draft B	Alice Drummond Michael Finger	Geoff Savage Chris Nicol		Geoff Savage		20/05/2016
Rev 0	Alice Drummond Michael Finger	Geoff Savage Chris Nicol		Geoff Savage		31/05/2016

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