Edithvale and Bonbeach
Level Crossing removal project

Report of Groundwater

1. Introduction

1. My firm AECOM-GHD Joint Venture (**the JV**) prepared the technical report titled **Groundwater Impact Assessment** (**Technical Report**) which is included as Technical Report **A** to the Environment Effects Statement (**EES**) for the Edithvale and Bonbeach Level Crossing Removal Project (**Project**).
2. The role that I had in preparing the Technical Report was **author**. Rikito Gresswell of the JV designed and constructed the numerical groundwater model and the saltwater intrusion model, and prepared the associated modelling reports. Chris Nicol of Groundwater Logic undertook predictive uncertainty analysis on the numerical groundwater model. Michael Finger (previously of the JV) designed and constructed the surface water balance model of the Edithvale component of the Edithvale-Seaford Wetlands and prepared the associated wetland hydrological modelling report. Jeffery Morgan of the JV was the technical checker for the Technical Report inclusive of all appendices. The Technical Report, inclusive of all appended reports, was independently reviewed by Dr Tony Smith of firm CDM Smith.
3. I adopt the Technical Report, in combination with this document, as my written expert evidence for the purposes of the Project Inquiry and Advisory Committee's review of the EES and draft planning scheme amendment.

2. Qualifications and experience

1. Appendix A contains a statement setting out my qualifications and experience, and the other matters raised by Planning Panels Victoria 'Guide to Expert Evidence'.
2. A copy of my curriculum vitae is provided in Appendix B.

3. Further work since preparation of the Technical Report

1. Since the Technical Report was finalised, I have undertaken further work to inform the Edithvale and Bonbeach Level Crossing Removal Project in relation to the groundwater impact assessment. This work is described in the following sections.

3.1 Literature review to identify comparable precedents

1. I undertook a literature search in March 2018, with the aim of identifying:
    - existing subsurface infrastructure projects that considered the potential for groundwater impedance
    - existing construction designs that have been implemented to minimise predicted groundwater impedance
    - existing projects that effectively managed groundwater through passive drainage designs
2. The literature review was focussed upon publicly available technical journals, manuscripts, academic publishers, online repositories, and other cited literature, but was not intended to be exhaustive. A summary of findings in relation to this further work is provided below:
    - In summary, the review did not identify any existing project examples where a long, linear subsurface drain was implemented in a construction project, for the purpose of minimising project induced changes to groundwater levels and/or quality. Some examples of passive subsurface

drainage were identified however, which typically related to small scale projects associated with foundations of proposed commercial developments.

- Since undertaking this literature review, additional examples have been brought to my attention through the peer review report provided by Kim Chan of the JV, which is described further in Section 3.3 of this report. The examples cited therein, particularly that relating to the Tokyo Gaikan Expressway project in Japan, confirm the application of passive horizontal drains (or similar perforated pipes in granular bedding) to reduce project impacts on groundwater level and flow in a linear, urban infrastructure project.

3. This further work has not caused me to materially change my opinions, which correlate with the findings of EES Technical Report A *Groundwater*. In other words, I believe that the passive horizontal drain is one engineering option, likely of many, that could effectively reduce groundwater level changes associated with the proposed project at Edithvale. This is because the literature review and the subsequent peer review report (refer to Section 3.3) identified numerous examples that further support the application of passive horizontal drains to maintain existing groundwater levels in subsurface infrastructure projects.

3.2 Assessment of the sensitivity of the passive horizontal drain

1. An additional assessment was undertaken in April and May 2018 by Rikito Gresswell of the JV and Chris Nicol of Groundwater Logic, which is documented in a currently unreleased technical memorandum entitled *Edithvale Passive Horizontal Drain – Model Sensitivity Testing* (Reference: LXRA-LX31-00-GE-MEM-0014). The additional work was undertaken to:

    - Assess the sensitivity of the passive horizontal drain diameter proposed at the Edithvale level crossing removal site. Previously, pipe diameters were only tested for 225 mm and 450 mm. In this study, a 100 mm was tested as narrower diameters may provide a broader range of construction opportunities.
    - Assess the effectiveness of the passive horizontal drain through a range of blockage scenarios.

2. A summary of findings in relation to this further work is provided below:

    - A 100 mm diameter passive horizontal drain pipe provides an almost identical level of water table mounding mitigation on the inland side of the alignment but generates a slightly broader area of greater than 0.1 m drawdown on the coastal side. A comparison of transient effectiveness of the 100 mm and 250 mm diameter pipes shows near identical predictions, which leads to the conclusion that a 100 mm diameter passive horizontal drain pipe is suitable for consideration as a construction option.
    - A single discrete blockage at one end of the drain is not predicted to appreciably change mitigation effectiveness.
    - Concurrent discrete blockages at either ends of the drain are predicted to reduce mitigation effectiveness more so than a single discrete blockage.
    - Blockage of flow along a significant length of the drain would result in a decrease in mitigation effectiveness, with greater impact predicted along the southern half of the inland side of the drain.
    - Modelling of low and high aquifer hydraulic conductivity sensitivity indicates that the area affected by water table mounding on the inland side of the rail trench is greater under a high water table aquifer hydraulic conductivity scenario. To a lesser extent, the area affected by water table drawdown on the coastal side of the rail trench is also greater under a high water table aquifer hydraulic conductivity scenario. In the context of transient effectiveness however, the passive horizontal drain is similarly very effective under either a low or high aquifer hydraulic conductivity scenario.

3. This further work has not caused me to materially change my opinions, which correlate with the findings of EES Technical Report A *Groundwater*. In other words, I maintain my view that the passive horizontal drain is one engineering option, likely of many, that could effectively reduce groundwater level changes associated with the proposed project at Edithvale. The sensitivity testing undertaken through this further work has confirmed that the passive horizontal drain would maintain effectiveness

under most blockage scenarios tested. However, consideration should be made during detailed design for:

- Developing the understanding of local variation in lithology along the trench. This would help to inform the system specifications, including the design elevation of the passive horizontal drain and construction materials (size of drain aperture, filter pack configuration)
- Developing the understanding of variability in local groundwater chemistry and the potential for chemical clogging or precipitation, to inform the system specifications
- The installation technique, which the EES confirms could be installed through horizontal direction drilling methods, however consideration of alternative methods (such as 'one-pass trenching') is suggested in light of the additional site specific data collection
- The incorporation of redundancy measures. A potential example of this is cross trench pipes, installed through the base slab and piled walls, at regular intervals across the rail trench. The intention of redundancy measures would be to provide numerous outlets to facilitate groundwater throughflow across the trench, reducing the reliance on the two cross-trench pipes at the project's extremities.

3.3 Independent peer review

1. A review of selected EES documentation was undertaken by industry leading specialists in April and May 2018. Kim Chan and Richard Murphy, both of the JV provided technical opinion regarding the likely effectiveness of the proposed passive horizontal drain to reduce changes to groundwater levels as a result of the construction of the rail trench at Edithvale.
2. Kim Chan's review confirmed that the passive horizontal drain option would be an effective engineering solution to reduce potential impacts predicted to occur due to the proposed rail trench. Kim cited four existing project examples, two of which he has cited from personal professional experience, that revealed some similarities to the proposed Edithvale project, most notably in relation to the use of passive horizontal drains (or similar perforated pipes in granular bedding) to redirect groundwater and reduce predicted impacts to groundwater levels as a result of the installation of essential subsurface infrastructure.
3. The passive horizontal drain installation depth noted in the EES was queried by Kim and he suggested a shallower installation depth to simplify installation, minimise maintenance/replacement costs and avoid low permeability lithology such as the Pleistocene Clay. In response to this comment, I note that the passive horizontal drain installation depth of -2 metres Australian Height Datum was nominally suggested in the EES and that the assessment of the passive horizontal drain provided therein was undertaken for the purpose of 'proof of concept'. It is expected that the passive horizontal drain installation depth is assessed further as part of detailed design.
4. Richard Murphy's review confirmed that the passive horizontal drain option could be an effective engineering solution to reduce potential project induced changes to groundwater levels at Edithvale. Richard's review also notes that remaining considerations could be suitably addressed through the normal process of detailed design and the implementation of maintenance and monitoring programs. The Environmental Performance Requirements (EPRs) outlined in Section 8 of EES Technical Report A *Groundwater* provide the overarching guidance for such considerations to be addressed during detailed design, construction or operation, as required.
5. Richard concludes that the proposed engineering solution is a simple adaptation of common measures for subsurface water management that he is familiar with or has been involved with professionally.
6. This further work has not caused me to materially change my opinions as expressed in the Technical Report, as Kim and Richard's reviews further confirm that the proposed passive horizontal drain is in many respects, similar to proven subsurface water management approaches that are commonly applied in infrastructure projects.

4. Written Submissions

4.1 Submissions Received

1. I have read the public submissions to the EES and identified those that are relevant to the Technical Report and my area of expertise. These include the following submissions:

   1, 2, 8, 25, 28, 121, 147, 207, 213, 216, 226, 235, 242 and 248.

4.2 Summary of Issues Raised

1. The submissions have raised the following issues relevant to my area of expertise:
   - Potential impacts to the beneficial use of groundwater, in terms of both groundwater quality and available yield
   - Potential impacts to Edithvale Wetland
   - Potential impacts to vegetation, including vegetation along the foreshore and rail corridor
   - Contingency for the Passive Horizontal Drain is not clearly stated in the EES
   - Potential impacts of climate change
   - Preference for an alternative construction approach

4.3 Response to Issues Raised

1. Set out below are my comments and responses to the issues raised by the written submissions relevant to the area of my expertise. These responses have been arranged initially to provide direct responses to the concerns of relevant agencies.

4.3.1 Response to the Environment Protection Authority (EPA) and other submissions concerning groundwater quality

1. An issue raised in the written submission provided by EPA (submission number 207) pertained to the proposed project potentially changing groundwater salinity beyond a segment classification as defined in the State Environment Protection Policy (SEPP) *Groundwaters of Victoria 1997*.
2. In response, I refer to the Groundwater Performance Outcomes (EPR_GW2), which are proposed in the EES with the intention of minimising changes to groundwater levels as a result of the projects, such that groundwater quality would be maintained as close as practicable to background levels. I support EPR_GW2 since it incorporates all the important elements of assessing groundwater performance in the context of the projects, namely groundwater level and quality changes, which would be monitored through the cross-referenced Groundwater Management and Monitoring Plan (EPR_GW3).
3. In my opinion, EPR_GW2 appropriately addresses the types of changes to groundwater levels, quality and flow that are not acceptable as a result of the project. Since EPR_GW2 does not specify the design of the rail trench, the type of rail trench design adopted, and any subsequent contingency options implemented, are considered implicitly within EPR_GW2.
4. The Groundwater Management and Monitoring Plan (EPR_GW3) would form the basis of groundwater level and quality monitoring. In my opinion, EPR_GW3 is appropriate in establishing the type of monitoring that would be undertaken to meet the groundwater performance outcomes established through EPR_GW2. It is my understanding and recommendation that the specifics of EPR_GW3 (e.g. monitoring locations, frequencies, durations, trigger definitions) would be developed in consultation with relevant agencies (including City of Kingston and EPA) and that the plan would provide a list of stakeholders that would need to be consulted and/or approve a final decision under various relevant impact scenarios.
5. With respect to EPR_GW3, consideration should be given to the collection of pre-construction groundwater data and the development of baseline groundwater level and quality conditions. Baseline data is required to develop an understanding of existing or background conditions with respect to groundwater, prior to the introduction of project activities (for example, the pile wall

installation or trench excavations) that may change these conditions. The baseline condition established would be used for comparison and assessment of groundwater conditions during construction and for an agreed period during project operation, and in the assessment of potential project impacts. If necessary, the timing of the baseline data collection period could be specified to be implemented 'prior to project construction' (i.e. prior to installation of the project pile walls).

6. It is my understanding that groundwater level data monitoring is currently ongoing across the existing groundwater monitoring network, but that an understanding of seasonal variability in groundwater quality is to be determined. While the duration of baseline data collection can be subjective (no local technical guidance on this topic exists) and is often determined by construction timelines, consideration should be given to the baseline groundwater data collection objective of 'developing an understanding of seasonal variations in groundwater levels and quality across the project area, prior to project construction'.
7. If project induced changes (i.e. degradation) to groundwater salinity are identified (which are distinct from potential groundwater salinisation caused by other factors such as climate change during the project life) during project operation, additional monitoring would be undertaken through EPR_CL5 (Acidic and/or contaminated groundwater (operation)) to provide measures to maintain or manage potential project impacts on beneficial use. Such an assessment would consider the baseline groundwater data collected (as suggested in the previously).
8. The EPRs (for example EPR_GW2 and/or EPR_GW3), should identify the need for engineering contingency measures to be investigated as part of the detailed design. The aim of the contingency measures would be impact avoidance or restoration of project induced changes to groundwater quality.

4.3.2 Response to the Mordialloc Beaumaris Conservation League Inc.

1. An issue raised in the written submission provided by the Mordialloc Beaumaris Conservation League Inc. (submission number 248) pertained to the maintenance of water quality of Edithvale Wetland.
2. Specifically, submission number 248 expressed concern that discharge from the Brighton-Fyansford Aquifers (referred to as the Upper Tertiary Aquifer and Upper-Middle Tertiary Aquitard respectively in the EES), could impact on water quality at Edithvale Wetland.
3. As described in Section 5.9 of EES Technical Report A *Groundwater*, under existing conditions, surface water within the Edithvale Wetland is hydraulically connected to the water table aquifer (Quaternary Aquifer). The underlying natural impermeable layer separating the Quaternary Aquifer from the Brighton Group Aquifer (Upper Tertiary Aquifer) was historically breached (refer to Sections 3.6.3 and 5.4.6 of Technical Report A *Groundwater*). Therefore, since the 1980s, which is when the breach occurred, local water quality in the Edithvale Wetland surface water has been affected by saline groundwater. This aspect would not change as a result of the proposed projects, as the EES concludes that changes to the water regime at Edithvale Wetland are not predicted to occur as a result of the projects.
4. Submission number 248 makes reference to the broad area of known groundwater contamination in Dingley, situated some 6 kilometres north of Edithvale Wetland. The landfill area surrounding Dingley has been an existing condition for some decades, and is located a significant distance (up hydraulic gradient) from the proposed rail trenches (over 7 kilometres). With these factors in mind, the proposed projects are unlikely to interact with or affect groundwater in the Dingley area, and its relevance to this EES is questionable.
5. Submission number 248 quotes several passages from a report prepared by AECOM-GHD JV (2017) entitled '*Groundwater Preliminary Impacts – Ecological Assessment – Rail Under Road*' (LXRA-LX31-00-PA-RPT-0029 Rev 0). It should be noted that the quoted report, finalised in February 2017, preceded the EES and in fact, informed the EES Referral. The AECOM-GHD JV (2017) report was prepared prior to undertaking site specific intrusive investigations and prior to the development of a calibrated numerical groundwater model. As such, the assessment therein should be considered, as the title suggests, preliminary in nature. In other words, the technical assessments therein provide a preliminary indication of potential impacts as they were understood based on information and data available at the time. For these reasons, I suggest that

the Mordialloc Beaumaris Conservation League Inc. refers to EES Technical Report A *Groundwater* in considering groundwater impacts assessment.

4.3.3 Response to the City of Kingston and other submissions concerning contingency for the Passive Horizontal Drain.

1. An issue raised in the written submission provided by the City of Kingston (submission number 226) as well as other submissions from individuals (submission numbers 2 and 147) raised concerns that the passive horizontal drain proposed in the reference design for the Edithvale level crossing removal, was not proven technology and that contingency measures were not proposed for implementation if the passive horizontal drain was found to be ineffective or if identified impacts were different to the model predictions.
2. It is important to note that several engineering options were identified and discussed with LXRA and technical and construction specialists. These engineering options included:
    - Active abstraction and recharge system
    - Passive groundwater equalisation approach – (in-slab pipework)
    - Passive groundwater equalisation approach – directional bore (through retaining wall piles)
    - Passive groundwater equalisation approach – (under retaining wall piles)
    - Passive horizontal drain
    - Swale drains
    - Limited soldier piles (beyond extents of tanking slab)
    - Passive recharge using potable / recycled water
3. Through an assessment of feasible options, the passive horizontal drain option was highlighted as the most favourable in terms of design opportunities, limitations and constructability considerations. As such, this is the engineering option presented in the EES as one potential engineering solution that could manage groundwater levels and flow at Edithvale, with the project in place.
4. While an exact precedent has not been identified, the literature review and peer reviews undertaken (refer to Section 3 of this report) suggest that numerous existing projects bear similarities to the proposed passive horizontal drain. The application of new solutions and the adaptation of existing solutions are standard and expected activities in engineering practice, however it is recognised that there are risks and technical challenges with the passive horizontal drain that would need to be addressed in detailed design. Design of the rail trenches at Edithvale and Bonbeach would need to comply with EPR_GW1, which requires compliance of the other EPRs developed under the project Environmental Management Framework. As mentioned previously, consideration could be given to addressing potential engineering contingency options explicitly or expressly within the EPRs, for example, within EPR_GW2 and/or EPR_GW3.
5. The modelling undertaken to predict the potential impacts to groundwater with the passive horizontal drain in place is comprehensive. The model has been calibrated to site specific data and has been subjected to a thorough predictive uncertainty analysis and independent peer review (refer to Appendix I of EES Technical Report A: Groundwater). In other words, I have confidence in the model predictions, which include realistic upper and lower statistical ranges of potential groundwater level changes and indicative effectiveness in light of hydrogeological parameter uncertainty / variability. In this regard, I reference the comments I make in Section 3.2 of this report with respect to the additional considerations that should be made in due course to inform the detailed design.
6. A Groundwater Management and Monitoring Plan (EPR_GW3) is included in the EES to monitor performance of the installed rail trench and confirm that it is not having an impact on groundwater levels and quality beyond those outlined in the Groundwater Performance Outcomes (EPR_GW2).

7. I reiterate that the passive horizontal drain is presented in the EES as 'one potential engineering solution' that could be implemented to achieve the outcome of groundwater level control (as defined by EPR_GW2) across the rail trench at Edithvale. Variations of this engineering solution, or different solutions altogether, may be proposed during detailed design or during project operation, so long as the requirements of EPR_GW2 are met.
8. Since implementation of the passive horizontal drain is subject to detailed design, specific engineering contingency options have not been developed for the passive horizontal drain at this stage. As mentioned previously, the adoption of engineering contingency options is implicit in EPR_GW2. Consideration could be given to stating potential engineering contingency options explicitly or expressly within the EPRs, for example, within EPR_GW2 and/or EPR_GW3.
9. It is my understanding that the required Groundwater Management and Monitoring Plan (EPR_GW3), once it is developed, will identify:
    - A suite of potentially feasible mitigation measures that may be considered in the event that defined trigger levels are exceeded. This would likely be a list of potentially feasible measures, which may include other engineering options that were previously identified and discussed with LXRA and technical and construction specialists, as mentioned previously
    - A list of stakeholders that would need to be consulted and/or approve a final decision under various relevant impact scenarios
    - The process by which a preferred measure will be identified and agreed with stakeholders
10. I consider EPR_GW3 suitable in monitoring potential project induced groundwater changes since it specifically requires for the relevant hydrogeological parameters to be monitored, including groundwater levels, quality and for the location, frequency and duration of monitoring to be stipulated. In addition, the requirement for the Plan to be prepared to the satisfaction of relevant authorities including EPA, and to undergo independent peer review (by way of EPR_GW4), provides me with confidence that all relevant aspects would be considered in the Plan and that subjective elements of the Plan, such as the development of 'trigger levels', would be reviewed and approved through a multiple-agency approach.

4.3.4 Response to the Chelsea Bonbeach Train Station Group

1. An issue raised in the written submission provided by the Chelsea Bonbeach Train Station Group (submission number 1) pertained to flooding in the area and the potential impacts of declining groundwater levels on dependent vegetation in the rail corridor. Similarly, submission number 121 raised concerns about 'water flow issues' with a rail under road construction approach.
2. I am a little unclear on the concern at hand here; that is, whether the concern is around surface flooding – an urban drainage issue that is not my area of knowledge, or whether the concern is around water logging at the ground surface, that could be exacerbated by the project. In response to the latter, I reiterate that the study area is naturally prone to shallow groundwater levels and at times, water logging (refer to Section 5.8.7 of EES Technical Report A *Groundwater*). The 'initial assessment' undertaken in the EES indicated a Moderate project risk in relation to water logging at Edithvale. This risk was the primary motivator to undertake the 'mitigated assessment' (refer to Section 7.2.1.3 of EES Technical Report A *Groundwater*), which included the changed design to incorporate a passive horizontal drain for the Edithvale project. Based on this 'mitigated assessment', a reduction in the magnitude and extent of project induced groundwater level change is predicted. In other words, the risk of exacerbating the existing risk of waterlogging has been addressed through the Groundwater Performance Outcomes (EPR_GW2) and the residual risk is ranked Negligible.
3. A further issue raised in the written submission provided by the Chelsea Bonbeach Train Station Group (submission number 1) pertained to maintaining the health of groundwater dependent vegetation in the rail corridor. It is my understanding that a significant portion of the existing rail corridor vegetation, which is distinct from the foreshore vegetation, would need to be removed to facilitate the rail trench excavations.

4. Written submission number 216 presents comments around surface water quality impacting Port Phillip Bay, however I perceive this to relate to surface water and urban drainage rather than groundwater, and for that reason, have not commented on that aspect. Submission number 216 also comments on existing urbanisation impacting groundwater levels and flows, which is confirmed in Section 5.9.3 of EES Technical Report A *Groundwater.* I note that the very undertaking of this EES specifically addresses the concern for *"careful assessment of whether the LXRA projects will exacerbate pre-existing adverse impacts"*.
5. While the dependence of the foreshore vegetation on groundwater remains uncertain, groundwater levels on the coastal side of the rail trench would be managed through EPR_GW2 by way of the requirement that changes to groundwater that would impact on dependent ecosystems are minimised. The foreshore vegetation would be monitored indirectly through the Groundwater Management and Monitoring Plan (EPR_GW3). If groundwater level changes caused by the project are inferred to occur along the foreshore, additional monitoring of ecological health would be implemented through a Groundwater Dependent Ecosystem Monitoring and Mitigation Plan (Coastal Native Vegetation) (EPR_FF7).

4.3.5 Response to the Kingston Conservation and Environment Coalition and the Kingston Residents Association concerns regarding climate change

1. An issue raised in the written submission provided by the Kingston Conservation and Environment Coalition (submission number 28) and the Kingston Residents Association (submission number 242) pertained to the likelihood of a rise in sea levels.
2. Future rise in sea levels will occur regardless of the project or the construction option selected and predicted climate change would typically result in less recharge to groundwater and consequentially, deeper groundwater levels.
3. EES Technical Report A Groundwater included model scenarios incorporating climate change predictions obtained from Victorian Government guidelines (DELWP, 2016) and sea level rise predictions obtained from Melbourne Water (Melbourne Water, 2016). Each of the climate change scenarios run in the numerical groundwater model indicated no predicted impact to Edithvale Wetland. Similarly, the 'predictive uncertainty analysis' undertaken as part of the modelling included a plausible range of values for each relevant model parameter, to gauge a 'worst case' scenario. The predictions from the uncertainty analysis undertaken confirmed that even for the year of greatest modelled impact, groundwater mounding would not occur at Edithvale Wetland.
4. The quantum of sea level rise predicted during the project life (around 0.8 metres) would generally not affect the project area (rail alignment), which occurs at around 5 metres above sea level. In other words, the project area would remain above sea level for the duration of the project life.
5. An issue raised by the Kingston Conservation and Environment Coalition (submission number 28) pertained to existing 'high groundwater levels' in the context of climate change and sea level rise. In response, with the proposed mitigation designs, the water table is predicted to broadly remain within historic ranges. In some areas at Edithvale, the water table is already 'very high' (i.e. close to ground surface). As mentioned previously, future rise in sea levels would typically result in deeper groundwater levels, which is contrary to the initial concern raised. An additional relevant response that addresses similar concerns around shallow groundwater levels and water logging is provided in the above response to the Chelsea Bonbeach Train Station Group.

4.3.6 Response to the Friends of Edithvale-Seaford Wetlands Incorporated, Port Phillip Conservation Council Inc. and the Kingston Residents Association

1. With respect to the concerns raised in written submissions 235 and 242 regarding the AECOM-GHD JV (2017) report, I refer the reader to my response above to the Mordialloc Beaumaris Conservation League Inc. and emphasise that the quoted report, finalised in February 2017, preceded the EES and is no longer a current source of information on the proposed projects.
2. Concerns expressed through written submission numbers 213, 235 and 242 regarding contingency for the Passive Horizontal Drain are addressed in the above response to City of Kingston.

3. With respect to the concerns raised in written submission numbers 213 and 235 regarding the lack of independent review of the groundwater modelling and the mitigation measures proposed, please refer to Appendix I of Technical Report A Groundwater, which includes an independent peer review assessment of all technical groundwater assessments, including all modelling undertaken, and refer to Section 3.3 of this report, which summarises the peer reviews focussed on the passive horizontal drain.
4. In response to the Port Phillip Conservation Council Inc. concern regarding flood events, sewerage and waterways (submission number 235), I note that surface flooding and waterways is not my area of knowledge. Since this comment may be perceived to relate to groundwater, I note that if Melbourne Water sends sewerage into waterways, this wastewater would outlet to Port Phillip Bay via Centre Main Drain (i.e. via surface water features). The subsurface piled walls would unlikely affect emergency releases of surface water during flood events as the relatively low permeability (and already saturated nature) of the subsurface sediments (i.e. the aquifers) mean that to a large extent, additional water cannot seep in. Under existing conditions, there is only a small portion of the water table aquifer that is unsaturated.
5. In response to the Friends of Edithvale-Seaford Wetlands Inc. concerns regarding impacts shown in Figure 24 of EES Technical Report B Ecology (submission number 213), it appears to me that Figure 24 has been misunderstood. Figure 24 does not show a predicted shift in groundwater catchments relative to the wetlands. Figure 24 shows the area of groundwater level change (depicted by the radial contour lines to the east of the rail line) predicted to result from the initial assessment (unmitigated project). Groundwater levels would likely be shallower across the contoured area compared to existing conditions. For comparison, Figure 25 (overleaf in EES Technical Report B Ecology) shows the comparatively smaller area of groundwater level change (depicted by the radial contour lines to the east of the rail line) predicted to result from the mitigated assessment (i.e. with the passive horizontal drain).
6. In response to the Friends of Edithvale-Seaford Wetlands Inc. concern that the “initial model suggested that a lot of water would be redirected away from the wetlands and move towards the coast” (submission number 213), it appears to me that the model predictions outlined in the EES have been misunderstood. The initial model (initial assessment of the unmitigated project) does not suggest that water would be redirected from the wetlands, but rather it predicts that some areas between the wetland and the rail line would experience shallower groundwater levels. Based on the mitigated assessment (i.e. the passive horizontal drain), groundwater mounding of 0.1 metres is predicted to occur no closer than 855 metres west of Edithvale Common and over 1,000 metres west of Edithvale Wetland (refer to Figure 25 within EES Technical Report B Ecology).

4.3.7 Responses relating to the available yield of groundwater

1. An issue raised in one written submission (submission number 147) pertained to the potential impact of the proposed projects on the available yield for existing groundwater users. In response, as outlined in the EES, I confirm that drawdown on the coastal side of the trench could impact groundwater availability for groundwater users, particularly at Bonbeach where this is considered a minor risk (defined as generally ‘low level impact’ or ‘high level impact’ for a small number of individuals).
2. The EES considered all 'registered' groundwater bores listed on DELWP's Water Measurement Information System database. The EES could not consider the likely numerous unregistered groundwater users, since their location, construction and use is not registered with DELWP, as required under Section 67 of the *Water Act 1989*. The ability for existing (unregistered) users to extract groundwater with the project in place is dependent on the location of the bore (with respect to the area of groundwater drawdown), the depth of the bore (deeper bores are less likely to be affected) and the actual groundwater level drawdown impact (which would vary depending on climatic conditions).
3. The predicted areas of groundwater drawdown impact at both Edithvale and Bonbeach, as presented in the EES, indicate that the broadest areas where groundwater availability could be affected would experience groundwater drawdown in the order of 0.1 metres. Typically, groundwater bores would be installed with a total depth well below the water table, to provide an

appreciable volume of groundwater in the well, to account for seasonal declines in groundwater during dry periods and to ensure that pumps do not 'run dry'. With these factors in mind and in light of the model results, which indicate predictions for the 'greatest period of impact during the model period', it is unlikely that existing unregistered groundwater users would be permanently affected from using existing low yielding bores. Alternative supplies of water are also available by way of the reticulated water supply available across metropolitan Melbourne.

4.3.8 Responses relating to the preference for a different construction approach

1. An underlying issue raised in written submission number 8 and 25 pertained to the preference for a different approach to the rail under road construction approach considered in this EES, either because of personal opinion or perceived risk.
2. If even a remote risk of impact to Edithvale Wetland was predicted, then a revised 'rail over road' construction option should be considered. The EES was requested to assess the environmental effects of a 'rail under road' (rail trench) construction option and EPR_GW1 (Rail trench design) has been developed to address this. Furthermore, there is risk in every activity or inactivity, and a level of risk acceptability in any infrastructure project. In practice, it can be difficult or even impossible to reduce project risk to zero, due to factors such as cost (which would become unfavourably high) and residual risk (which may result from risk mitigation).
3. The risk assessment approach adopted in the EES is consistent with International Standard AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines. It provides a transparent outline of risk definitions, quantification and where required, risk reduction through the implementation of proposed EPRs.
4. Following the EES inquiry, the Minister for Planning will ultimately make an assessment that will conclude whether the project will have an acceptable level of environmental effects.

5. Declaration

I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance which I regard as relevant have to my knowledge been withheld from the Inquiry and Advisory Committee.

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Signed

Date: 28 May 2018

Appendix A Matters Raised by PPV Guide to Expert Evidence

(a) the name and address of the expert;

Tony Cauchi
AECOM Australia Pty Ltd
C/O AECOM-GHD Joint Venture
Level 10, Tower Two 727 Collins Street
Melbourne VIC 3008

(b) the expert's qualifications and experience;

Tony Cauchi obtained a Bachelor of Engineering (Geological) (Hons) from RMIT University, Melbourne Australia in 2005. Tony is a Chartered Professional Engineer (MIEAust CPEng NER), and is employed as a Senior Hydrogeologist and Project Manager with GHD, with over 12 years' consulting experience working directly with water industry clients in the various Australian state governments, the Australian Federal Government, as well as private industry in the mining and infrastructure sectors. These projects have involved groundwater resource studies, environmental impact assessment, urban infrastructure, mineral exploration and environmental site assessment and contaminant remediation.

(c) a statement identifying the expert's area of expertise to make the report;

As detailed in the CV attached in Appendix B, Tony is the Hydrogeology Lead for the LXRA Technical Advisor (AECOM-GHD JV) and has led every aspect relating to groundwater assessment for both the Edithvale and Bonbeach level crossing removal projects. Tony was involved in these studies prior to the EES and also undertook the preliminary groundwater impacts assessment that formed the basis of the EES referral. Tony has led the groundwater component of the EES, which involved coordinating the onsite hydrogeological drilling program and ongoing monitoring, coordinating data analysis, management and transfer, development of the regional numerical groundwater model, hydrological modelling, saltwater intrusion modelling, spatial analysis, impact assessment and risk assessment.

Tony has presented to stakeholders throughout this process, including to the Technical Reference Group (TRG) and to commonwealth representatives, community interest groups and has provided media releases relating to the EES.

(d) a statement identifying all other significant contributors to the report and where necessary outlining their expertise;

Rikito Gresswell
Rikito Gresswell obtained a Master in Science in Geology in 2004 and a Master of Science in Hydrogeology in 2005, from University College, London. Rikito is a Fellow of the Geological Society of London and a Committee Member of the International Association of Hydrogeologists (Victorian Branch). Rikito is employed as a Senior Hydrogeologist with GHD, with over 11 years' consulting experience in hydrogeological and groundwater modelling studies in Australia and the United Kingdom for clients in the mining, oil and gas, water resources, civil infrastructure and contaminated land industries.

Rikito was the Lead Groundwater Modeller for this EES and has successfully undertaken this role for numerous large projects including the Latrobe Valley Regional Groundwater Model, Hazelwood Mine Closure and Rehabilitation and the North-East Link project.

Michael Finger
Michael Finger obtained a Bachelor of Engineering (Civil) (Hons) and a Bachelor of Science from the University of Melbourne in 2007. Michael has over 11 years of water resource experience, most notably in hydrological analyses, water resource modelling and hydraulic investigations related to water rights, water supply, environmental management and

environmental impact assessment. Michael's experience includes the set up and application of several water resource models, which relates to his involvement in this EES.

Jeffery Morgan
Jeff Morgan obtained a Bachelor of Engineering (Geological) (Hons) from RMIT University, Melbourne Australia in 1992. Jeff is employed as a Principal Hydrogeologist, Project Manager and Team Leader with GHD, with over 18 years' consulting experience in groundwater resource investigations and development, salinity investigation and environmental impact assessments, including a number of key large-scale urban and industrial water supply projects.

Jeff has a detailed understanding of the hydrogeological issues associated with water management systems, and is familiar with the requirements of Victoria's regulatory authorities and has presented at EES panel hearings.

Chris Nicol
Chris Nicol obtained a Bachelor of Science (Hons) from Monash University, Melbourne Australia in 2001. Chris has over 15 years' experience in Australia and the UK and is Director of firm Groundwater Logic. Chris has a strong background in conceptual hydrogeological model development, as well as data analysis and modelling highly complex systems. Chris has developed methodologies and tools for assessing and managing the risks of groundwater use and land use change to water resources, including groundwater dependent ecosystems. Chris has experience in hydrogeological mapping, GIS, data management and was key to several landmark studies undertaken across Victoria in recent years, including the SAFE project (VAF) and the Ensym ecoMarkets models.

Chris oversaw the numerical groundwater modelling undertaken for this EES, and undertook predictive uncertainty analysis on the model to provide probabilistic outputs to inform risks.

Tony Smith
Tony Smith has a PhD in groundwater and surface interaction and 20 years of experience in research and consulting on a diverse range of groundwater projects. Tony is employed by firm CDM Smith, where he applies his strong background in quantitative analysis and simulation and has led and contributed to projects involving mine dewatering and water supply, coal seam gas development, managed aquifer recharge, aquifer sustainable yield assessment, water logging and salinisation in irrigated areas, seawater intrusion and density-coupled groundwater simulation, and submarine groundwater discharge.

Tony Smith performed the role of independent peer reviewer for the groundwater impact assessment component of this EES.

(e) all instructions that define the scope of the report (original and supplementary and whether in writing or oral);

	Groundwater
Study objectives	▪ To predict the potential impacts of the projects on the local and regional groundwater regime ▪ To assess the risk of project related groundwater impacts on the local and regional groundwater regime and identify management and/or mitigation measures to reduce risk relating to potential groundwater impacts
Legislation	*Water Act 1989* *Environment Protection Act 1970* SEPP (Groundwaters of Victoria) 1997 SEPP (Waters of Victoria) 2003 SEPP (Prevention and Management of Contamination of Land) 2002

Consultant Engaged	AECOM-GHD Joint Venture
Methodology	▪ Characterise the existing local and regional geological and hydrogeological conditions, through o desktop literature review o design and development of a geotechnical and hydrogeological drilling investigation program o development of a groundwater monitoring network and program o periodic groundwater monitoring o characterisation of beneficial uses ▪ Develop a conceptual hydrogeological model to summarise the current conceptual understanding as it relates to local and regional groundwater systems and to form the basis for development of the numerical groundwater model. ▪ Develop a three-dimensional numerical groundwater model capable of: o simulating existing local and regional (cumulative) groundwater condition as they are currently understood (baseline conditions) o predicting groundwater levels and flow systems over key stages of the project life to inform impacts over the short term (during construction) and long term (during operation). ▪ Calibrate the model with data collected from literature and the geotechnical drilling and groundwater monitoring programs. The model would be calibrated using historic data from 1997 – 2017. ▪ Simulate the level crossing removal works at Edithvale and Bonbeach. ▪ Undertake uncertainty analysis on the modelling results. This will help to Improve the definition of likelihood rankings, using the modelled magnitude and probability of impact(s). ▪ Undertake an impact assessment to assess the local and regional (cumulative) groundwater impacts during construction and operation. Including: o potential for impacts on existing groundwater quality, resulting from acid sulfate soil activation, saline intrusion and migration of existing contaminated soil and groundwater o potential for impacts on existing hydrogeological/hydrological conditions (fluxes) at the Ramsar listed Edithvale-Seaford Wetlands (specifically, the Edithvale Wetlands situated north of Patterson River). o potential for impacts on existing ecological conditions at the Ramsar listed Edithvale-Seaford Wetlands (specifically, Edithvale Wetlands). ▪ Identify appropriate avoidance, mitigation and management measures to minimise the cumulative impacts of the projects on local and regional groundwater systems would be identified ▪ Identify appropriate methods to manage and, if necessary, dispose of groundwater during construction ▪ Saline intrusion assessment using a 2D density couple flow and mass transport model developed using FEFLOW. The model will be calibrated to equivalent freshwater heads and salinity measured in monitoring bores. The assessment will be presented in a memorandum summarising the findings, to be appended to the Groundwater Impact Assessment report for the EES. A series of figures showing the location and movement of concentration (salinity) contours over time will be produced for the memo.

Type of investigation	▪ Site investigations (geotechnical drilling program, site characterisation and groundwater monitoring) ▪ Regional groundwater modelling ▪ Desktop assessment ▪ Groundwater boreholes in the wetlands ▪ Bathymetry Survey
Groundwater Boreholes in the Wetlands	**The groundwater bore and monitoring program is required to fill gaps in information required for the assessment of the Edithvale Wetlands.** • Local surface water level trends within individual wetland cells • Temporal reliance of identified ecological vegetation classes (EVCs)1 to surface water and groundwater, to inform the ecological assessment • Local groundwater level trends locally within the wetland area • Local fluxes between the shallow QA sediments and the underlying UTAF sediments, particularly in relation to the vertical pressure gradients • Confirmation of the local groundwater-surface water interaction at Edithvale Wetlands (e.g. gaining or losing systems, and temporal variations) **A number of bore holes were be installed at the Edithvale Wetlands with a mixture of hand-augured and drilled bores.**
Bathymetry Survey	The bathymetric study will determine the depths of the cells in the Edithvale Wetlands. The data is collected by a 'z boat' using sonar to determine depth profiles of the wetlands. It is an unmanned craft 1.8m in length and roughly 50kg that is transported to and from site on a trailer towed by a 4WD Utility vehicle. Boat movement will be controlled by remote and GPS. To gather data, the boat will move in a systematic basis back and forth and transect intervals of between 10 and 20 metres

[1] An ecological vegetation class (EVC) is a component of the vegetation classification system developed and used by the State of Victoria

(f) the identity of the person who carried out any tests or experiments upon which the expert relied in making this report and the qualifications of that person;

All laboratory analytical services of surface water and groundwater samples were subcontracted to either Eurofins or ALS Environmental. These laboratories are National Association of Testing Authorities (NATA) accredited for the testing program conducted.

Laboratory permeability tests were undertaken on two core samples of the Pleistocene Clay from Edithvale Wetland. These tests were undertaken by GHD Traralgon Laboratory, which is NATA accredited for the testing program conducted.

(g) a statement setting out the key assumptions made in preparing the report;

The key assumptions relevant to my statement herein are consistent with the assumptions and limitations outlined throughout EES Technical Report A *Groundwater*.

I have reviewed all written submissions received that are relevant to groundwater, specifically those written submission numbers outlined in Section 4.1 of this report.

(h) a statement setting out any questions falling outside the expert's expertise and also a statement indicating whether the report is incomplete or inaccurate in any respect.

In preparing this Groundwater Expert Report, it was my intention to focus and discuss only those received written submissions that in my opinion, pertained in some way to groundwater and were relevant to the EES. Numerous written submissions were received in relation to 'other' water related issues, such as plumbing, surface flooding and management of sewerage by Melbourne Water. Since these issues are beyond my area of knowledge, I have not provided a response in relation to these issues.

Appendix B CV

Curriculum Vitae

Tony Cauchi
Senior Hydrogeologist

Qualified. RMIT University. BEng (Geological) (Hons). 2005.
Chartered Professional Engineer (MIEAust CPEng NER)

Relevance to project. Tony has over 12 years of experience managing, designing and undertaking hydrogeological studies at both the desktop and field investigation levels.

Tony is a Chartered Professional Engineer and a project manager with years of experience in delivering small projects and coordinating larger multidisciplinary teams.

Project Hydrogeologist
Level Crossings Removal Authority | Victoria

As the Groundwater Lead in this government advisory role, Tony undertook desktop hydrogeological assessments for each level crossing site, and designed and installed groundwater monitoring networks, coordinated groundwater quality sampling and aquifer testing as well as long term groundwater level monitoring. Tony also coordinated data management and reporting aspects, and liaised with local, state and commonwealth stakeholders as required. This project required diligent planning throughout, in light of short project timeframes, complex approvals processes relating to undertaking works in the rail reserve and the busy setting, which required a dynamic approach that accommodated changes in project priorities.

Environmental Effects Statement (EES) for Edithvale and Bonbeach level crossing removal projects
Level Crossings Removal Authority | Victoria

Tony scoped and led the groundwater component of the Environmental Effects Statement (EES) for the Edithvale and Bonbeach level crossing removal projects, which was required due to predicted changes to groundwater resulting from the proposed projects. Tony coordinated the development of a regional numerical groundwater model, hydrological modelling, saltwater intrusion modelling, spatial analysis, impact assessment and risk assessment, to improve the understanding of groundwater impacts on environmental features. Tony presented to stakeholders throughout this process, including to the state and commonwealth representatives within the Technical Reference Group, community interest groups, media releases and was an expert witness for groundwater during the Panel Hearing / Inquiry process.

Groundwater Storage Reporting
Department of Environment, Land, Water and Planning (DELWP) | Victoria

Tony was Project Hydrogeologist and Manager of this innovative project to develop a new statewide groundwater resource reporting approach that considers abstractive development and the environmental requirements of an aquifer. Through collaboration with industry, academia and research stakeholders and literature reviews, Tony developed conceptual approaches to facilitate reporting on the condition of aquifers across the state. The method was applied to a selection of confined and unconfined aquifers to test its veracity and practical application.

Assessing Groundwater Responses to Climate Change and Bushfire Risk
Melbourne Water | Victoria

Tony was technical lead and project manager for this study, which involved the assessment and conceptualisation of groundwater systems and potential Groundwater Dependent Ecosystems (GDE) in Melbourne's protected water supply catchments. The focus was understanding the potential impacts of climate change and increased bushfire risk on groundwater quality and availability. The project involved the review, prioritisation and selection of sites and the development of numerous surface water and groundwater monitoring networks and development of monitoring plans.

SEPP (Waters) Review

EPA Victoria | Victoria

Tony was Project Hydrogeologist and Manager of this project which required a review of the State Environment Protection Policy (SEPP) clauses regarding the management of interactions between freshwater, estuarine, marine and groundwater systems. The SEPP (Waters) policy is new and encompasses each of these water systems, which were previously governed by two separate policies. Tony undertook a review of: overlapping clauses between the two previous SEPPs; scenarios where interactions between water systems are not currently explored, and where current clauses should apply; and coordinated a technical workshop involving EPA, DELWP and numerous Environmental Auditors.

Groundwater Dependent Ecosystems Monitoring

Melbourne Water | Victoria

Tony was Project Hydrogeologist and Manager and coordinated the review, prioritisation and selection of priority sites from an extensive database, for further monitoring in this Groundwater Dependent Ecosystems (GDE) project.

Tony assisted Ecology specialists in selecting and adopting relevant attributes on which to base the shortlisting of five GDEs and undertook hydrogeological desktop assessments for each GDE site (including Boneo Swamp, Seaford Swamp, Truganina Swamp, Westernport Bay and Deep Creek). Tony coordinated stakeholder engagement, project workshops and site access preliminaries as well as drilling and installation of groundwater monitoring bores, deployment of dataloggers and surface water gauges.

Wetlands Feasibility Study

DELWP | Victoria

Tony was Project Manager and Hydrogeologist for this study, which related to the rising groundwater levels issue around Bendigo, VIC. Specifically this project assessed the feasibility of utilising wetlands to treat groundwater discharges that are high in arsenic. This study involved a literature review, development of scenarios on which risk assessments were undertaken and engineering design options were evaluated and costed.

Approaches to Achieve Sustainable Use and Management of Groundwater Resources

Murray Darling Basin Authority

Tony was Project Hydrogeologist for this study, which required the identification of the types of rules and resource condition limits (RCLs) that could be included in water resource plans. These plans require consistency with the Basin Plan requirements in order to be accredited or adopted under the Water Act 2007. Tony undertook an internationally focused literature review to identify the key rules and RCLs that could be incorporated into water resource plans to manage the local impacts of groundwater take.

Business Case Development for Bore Completion Report process

DELWP

Tony project managed and led the development of a technical study and subsequent business case development on behalf of DELWP, which was issued to the Department of Treasury and Finance for consideration. To identify issues with the bore reporting process and potential options to resolve / improve the system, a series of interviews and surveys were held with various stakeholders engaged in the bore completion reporting process. The business case outlined the drivers for identified issues and explored potential options for improvement. The preferred option best addressed the problems, while delivering high benefits, mid-range costs and an acceptable level of risk and dis-benefit, compared to other options considered.

Groundwater Salinity Assessment

Delfin Lend Lease, Pakenham | Victoria

As Project Hydrogeologist and Project Manager, Tony designed and installed a groundwater monitoring bore network based on information obtained from a desktop study, to facilitate the assessment of potential salinity impacts of soil and groundwater to an urban development site. Tony developed potential engineering strategies to manage salinity issues that may arise post-development. Tony used ArcGIS tools to display and analyse data obtained and to estimate direct recharge to the site using the Hydrus-1D code. Tony also undertook a cost-benefit assessment of groundwater control options for the site. Tony managed on-going groundwater level and quality assessments for two further years, developing

trigger levels that would prompt the implementation of salinity mitigation measures.

Future Water Resource Management
Alinytjara Wilurara NRM Board | South Australia

Tony was project manager and Hydrogeologist for this long term assessment of water resources in this remote NRM region, for the future allocation of water resources. Tony developed an understanding of legislative requirements, collected and collated available data, and was involved in data management/interpretation for the development of a conceptual model. Tony also undertook stakeholder and community consultation, along with cultural heritage professionals, primarily involving remote Indigenous communities. Tony undertook rainfall-recharge-runoff modelling using a GIS platform and the numerical code PERFECT. Model outputs were used along with remote sensing outputs to assess potential monitoring locations in terms of climate, surface water and groundwater.

Medium and Long Term Mine Planning
Yeniköy Kemerköy | Turkey

Tony was Project Hydrogeologist for this coal exploration project, which involved a significant onsite hydrogeological investigation. Tony was onsite to coordinate initiation of the investigations, and successfully trained local Turkish consultants, contractors and drillers in the undertaking of vibrating wire piezometer (VWP) installations, packer testing, groundwater bore installation and sampling, pump testing, slug testing and data management.

Drill Site Supervisor and Project Hydrogeologist
Linking Melbourne Authority | Victoria

As project hydrogeologist and drill site supervisor, Tony designed, coordinated and undertook the drilling, core logging, installation and test pumping of several groundwater bores for one of Melbourne's most significant infrastructure projects. Tony engaged and managed several subcontractors and provided effective on-going client liaison during onsite and office based activities. Diligent planning was required throughout this process in light of short project timeframes, protestor disruption and the busy setting, which required irregular and long work hours and a dynamic approach that accommodated changes in project priorities.

Groundwater Management Plan reviews
Department of Sustainability and Environment | Victoria

Tony carried out a review of several groundwater management strategies/plans for water supply protection areas around Victoria. The review was conducted in order to assess in particular, the technical basis for environmental considerations (in particular, GDE protection and management) in current groundwater management plans. The reviews helped develop a methodology for establishing Environmental Water Reserves, consistent with holistic water management approaches, which form the basis of the current groundwater management framework.

Groundwater Management Review, Western Sustainable Water Strategy
Department of Sustainability and Environment / Wimmera CMA | Victoria

As project Hydrogeologist and Project Manager, Tony detailed the current groundwater management arrangements for three case study Water Supply Protection Areas in southwest Victoria. The adequacy of current monitoring in protecting GDEs and groundwater / surface water (GW / SW) interactions was assessed. The project identified the level of knowledge of GW / SW connectivity to enable waterway and groundwater management to be implemented in the interest of stakeholders, including the environment. Such information was required in order to provide a direction for policy development in relation to the identification, protection and management of GDEs and input to the Western Sustainable Water Strategy.

Bore Deterioration Assessment |
National Water Commission

Tony played a major role in the collation of information and data obtained through stakeholder consultation as well as established reference material, relating to the causes and effects of bore deterioration throughout Australia. This information was used by the NWC to direct future monetary funding and to gain an appreciation of the extent and severity of bore deterioration impacts around Australia.

Project Hydrogeologist and Manager
Shenhua Watermark Coal | New South Wales

For three years, Tony was project Hydrogeologist, coordinator and one of the Project Managers for this large scale, long-term coal exploration program. Responsible for the supervision of simultaneous drilling operations, collecting and assessing groundwater levels, quality and quantity data through the design, rationalisation and conduct of monitoring programmes, management of artesian groundwater flow, conduct and analysis of pumping tests, slug tests, packer tests and vibrating wire piezometer installations. Tony characterised complex fractured rock and alluvial aquifers and flow systems through conceptual hydrological models in this major energy resource development project.

Peer Review of Salinity Report
Wagga Wagga City Council | New South Wales

Tony undertook an independent technical peer review for Council in relation to the proposed urban development at the Lloyd precinct, Wagga Wagga. Salinity risks owing to shallow groundwater levels and saline groundwater required appraisal in the context of the proposed urban development is required, including an assessment of the potential impacts both at the development site and regionally in the Wagga Wagga area. Tony reviewed salinity risk assessment reports and numerical model inputs, assumptions and outputs and considered the limitations of the reports' outcomes. In a Council and stakeholder workshop, Tony suggested a number of activities to help achieve sustainable development of the Lloyd subdivision.

Albert Park Lake MAR Feasibility Study
Parks Victoria | Victoria

Tony undertook pre-feasibility study for this Managed Aquifer Recharge project to use aquifers in an urban parkland for storage of stormwater runoff. This involved a detailed investigation of previous drilling, undertaking exploratory drilling, assessment of lithology, and undertaking of pumping tests to assess aquifer potential.

Goorambat Water Supply Investigations
North East Water | Victoria

Tony undertook a desktop assessment to gather background information including site geology, hydrogeology, and an assessment of MAR potential through conducting an entry level assessment consistent with the National Water Quality Management Strategy Guidelines 2009 and assessment of the potential impacts of MAR. Tony undertook detailed investigation of previous drilling, undertaking exploratory drilling, assessment of lithology, and undertaking of pumping tests to assess aquifer potential.

Drill Site Supervisor and Field Hydrogeologist
Adani Mining | Queensland

For the Carmichael Coal drilling and environmental assessment program, Tony managed drilling contractors on- and off-site, supervised borehole drilling and groundwater bore installations, undertook packer testing and technically difficult vibrating wire piezometer installations (to depths of 500 m) and pumping tests.

Groundwater Suitability Assessment and Production Bore Installation
Melbourne Water | Victoria

Groundwater Suitability Assessment and Bore Installation – Tony undertook a desktop study to assess the feasibility of stock watering through utilising local groundwater resources at the Werribee Western Treatment Plant. This involved assessing legislation and approvals processes, site geology and hydrogeological conceptualisation, and assessment of aquifer potential for intended use. GIS was used during the analytical stages and for data presentation purposes. Subsequently, GHD designed, installed, sampled (for screen design), geophysical logged and test pumped a production bore, which ultimately developed the Werribee Formation and produced rates of 6 L/sec.

Hydrogeological Reviews, Unity Mining | VIC

Tony undertook several hydrogeological reviews for an evaporation pond site, required to fulfil the conditions of a discharge mine water licence. Tony's tasks included the interpretation of aquifer stratigraphy and geological structure by developing and interpreting digitised geological cross-sections; hydrograph development and review of temporal groundwater levels; review of groundwater chemistry from multiple aquifers using graphical techniques such as Piper diagrams of groundwater quality data and comparison with the chemistry of pond waters; and consideration of the groundwater beneficial uses of the aquifers in the vicinity of the site.

The project was related to the potential impact of the evaporation ponds on regional aquifers, as well as groundwater resources in the Upper Loddon basin.

Water Sensitive Urban Design, City of Port Phillip, | VIC

Tony conducted borehole permeability tests using the Talsma Permeameter technique at several sites, to assess soil infiltration rates and other permeability parameters in development of water sensitive urban design projects such as rain gardens.

Groundwater Monitoring Network; Review and Monitoring, Spotless Services Australia RAAF/DSTO Edinburgh | SA –

Project management and assessment of over 20 years of laboratory analytical results from over 300 groundwater monitoring bores in multiple aquifers. Assessment of groundwater flow systems and potential for cross-contamination between aquifers. Considerations also had to be made to groundwater discharge to receiving environments (groundwater receptors). Tony also devised an optimised groundwater monitoring programme for the site and prepared the final reports for this study.

Port Wakefield P&EE Stage 2 Assessment, Department of Defence | SA

Numerous groundwater monitoring bore installations, shallow soil investigations and delineation of contamination in an operating proof and experimental establishment. Tony conducted permeability tests, created groundwater elevation contours and subsequently interpreted data to yield inferred hydraulic conductivity parameters for the site. Assessments of groundwater flow systems were paramount as several sites were located nearby to Defence site boundaries. Tony managed the field team during these works and was independent in preparing the final reports for these works.

RAAF Edinburgh Stage 2 Assessments, Department of Defence| SA

Numerous groundwater monitoring bore installations and shallow soil investigations in airside locations of this operating air force base, as well as other parts of the Defence site. This included delineation of contamination evident from historic activities and assessment of groundwater flow systems. Assessment sites included subsurface waste dumps, firefighting areas, burn-off areas, airplane washdown facilities and bulk fuel stores. Potential contaminants included hydrocarbons, radionuclides and AFFF compounds. Tony conducted permeability tests and interpreted hydraulic conductivity parameters. Tony managed field works and the field team during these works and was independent in preparing the final reports for these works.

Land capability and risk assessment, Koorlong Wastewater Treatment Plant, Lower Murray Water | VIC

Tony assessed the risks and impacts associated with the disposal of treated wastewater from the Koorlong WWTP to land (the swale). This included a review of existing information, site inspection, characterisation of hydrogeology and land condition, water and nutrient balances and impact/risk assessment.

Assessment of seepage from lagoon TSF-4, St Ives Gold Mining Company | WA

Tony undertook a review of historical groundwater levels and development of a water balance in order to estimate the potential proportion of groundwater rise that could possibly be attributable to seepage of discharged tailings at TSF 4. This resulted in the development of a Seepage Recovery Plan.

Moe GMA groundwater investigation Department of Sustainability and Environment | Victoria

Tony supervised the Installation of 14 observation bores to depths up to 300 m as part of the government's State Observation Bore Network (SOBN). An in-depth knowledge of the groundwater system was required to manage potential issues, such as artesian groundwater flow, which occurred at a number of bore sites.

Other related areas of interest

- **Conceptual Modelling**. Specialises in developing conceptual hydrogeological and eco-hydrological models.
- **Community Engagement.** Experience in sensitive projects requiring community engagement.
- **Aquifer Testing.** Completed numerous pump tests and analysis.
- **Victorian Hydrogeology.** Thorough understanding of hydrogeology throughout Victoria.
- **Salinity.** Experienced with assessing and managing groundwater salinity issues.
- **Geophysics.** Experienced with downhole geophysical techniques and interpretation.
- **Membership.** Chartered Member, Institute of Engineers Australia (MIEAust CPEng NER).

Published.

Cauchi, T & Ibrahimi, F (2015) *Development of an Audit Framework for Management of Groundwater Assets of the Victorian State Observation Bore Network (SOBN).* AWA Water Journal, May 2015

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Anderson, T., Cauchi, T., Hamstead, M., Merrick, N. and Phillipson, K. (2014) *Approaches to achieve sustainable use and management of groundwater resources in the Murray-Darling basin using rules and resource condition limits*.

Anderson T, Cauchi T, Ibrahimi F, Llewellyn B, Mozina M and Ray E (2010) Waterlines report No. 32, *Groundwater bore deterioration: schemes to alleviate rehabilitation costs*, for the National Water Commission, Canberra.

Bolger P, Tilling A, Cauchi T, Pemberton F (2010) *Future water resource management – Alinytjara Wilurara NRM Region, South Australia*. Presented at Groundwater 2010 Conference

Presented.

Assessing groundwater responses to climate change in the context of water supply catchment management. Climate Adaptation Conference 2018, Melbourne: 8 to 10 May 2018

Concepts for Groundwater Storage Condition Reporting on a State-wide Scale. Australasian Groundwater Conference 2017, Sydney: 11 to 13 Jul 2017

Groundwater dependent ecosystems monitoring in Urban Settings. Australian Groundwater Conference 2015, Canberra: 3 to 5 Nov 2015

Groundwater dependent ecosystems monitoring – an Australian perspective. Presented at Groundwater Resources Association (GRA) of California conference, Sacramento: 6 to 7 Oct 2015

Development of an Audit Framework for Management of Groundwater Assets. Presented at GRA of California conference, Sacramento: 6 to 7 Oct 2015

Groundwater Dependent Ecosystems Management in Urban Settings. Presented at Oz Water 2015 Conference, Adelaide: 12 to 14 May, 2015