Barwon Downs Monitoring Program

MONITORING REVIEW

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- 2012

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1. Terminology

CCMA - Corangamite Catchment Management Authority

DEPI - Department of the Environment and Primary Industries

SRW - Southern Rural Water

2. Introduction

The existing licence for the Barwon Downs bore field was granted in 2004 which focused largely on resource availability and reliability of supply of the aquifer. Potential risks to the environment were identified, and, as a result, conditions in the licence were put in place to mitigate any unacceptable impacts known at that time. The current groundwater licence for the Barwon Downs bore field expires in 2019.

A review of flora and groundwater levels completed under existing licence conditions (SKM and EA, 2008/09) recommended that a long term vegetation and hydrogeological monitoring program be designed and implemented to better understand a range of factors (such as groundwater extraction, drought and land use changes) that could be contributing to the drying of the catchment. A review of the existing groundwater monitoring program has also been driven by the community, who are concerned about any potential impacts that groundwater extraction may have caused.

Barwon Water has commissioned SKM in conjunction with Ecology Australia and Latrobe University to develop a revised monitoring program to:

- Better understand the environmental impacts of groundwater extraction;
- Determine the cause and relative contribution of groundwater variability (for example, groundwater extraction, drought and land use changes) in contributing to environmental impacts; and
- Provide additional monitoring data and subsequent analysis required to support the licence renewal process.

This project will identify the:

- basis and/or drivers for the revised program;
- activities (and timeframes) to be included in the revised program;
- preliminary estimate of costs to establish and undertake the revised program;
- risks of program being unable to reliably predict impacts and having perceived gaps/weaknesses by the community and regulators;
- residual risk if the revised program is implemented; and
- schedule for revised program.

Cost estimates for the program will be preliminary and based on the consultants experience with similar projects. Contractor costs (e.g. drilling) will be estimates only (i.e. quotes for this report will not be obtained).

3. Background

Drought in 1967-1968 identified a need to supplement the existing drinking water supply to Geelong and the surrounding area. In response to this need Barwon Water developed the Barwon Downs bore field, which comprises of:

- four production bores,
- four pump stations,
- a groundwater treatment plant; and
- a transfer pump station and pipelines.

The bore field was completed in the early 1980s. In 2000, two new production bores and pump stations were installed so maintenance on the existing four production bores could occur.

The bore field has provided successful drought relief for Geelong and district in 1982-1983, 1997-1998, and 2006 to 2011. Use of the borefield has been in accordance with the 2004 licence conditions, which clearly states that the most efficient use of the resource dictates that Barwon Water only extracts groundwater during dry periods when surface water supplies are falling.

Current licence conditions require monitoring of groundwater water levels and water quality subsidence, flow in Boundary Creek, protection of riparian vegetation (floral survey undertaken every five years), protection of stock and domestic use and protection of flows in the Barwon River and tributaries. This data is provided in an annual report to Southern Rural Water (SRW) who administers and regulates groundwater licences on behalf of the Water Minister. Conditions of the licence also take into account mitigation of any unacceptable impacts. This licence is due for renewal in 2019.

A review of flora and groundwater levels completed under licence conditions(SKM and EA, 2008/09) recommended that a long term vegetation and hydrogeological monitoring program be designed and implemented to better understand a range of factors (such as groundwater extraction, drought and land use changes) that could be contributing to the drying of the catchment. A review of the existing groundwater monitoring program has also been driven by the community, who are concerned about any potential impacts that groundwater extraction may have caused.

To address community interest adequately and be prepared for licence renewal come 2019, Barwon Water commissioned SKM in conjunction with Ecology Australia and Latrobe University to develop a revised monitoring program to:

- Better understand the environmental impacts of groundwater extraction;

- Determine the cause and relative contribution of groundwater variability (for example, groundwater extraction, drought and land use changes) in contributing to environmental impacts; and
- Provide additional monitoring data and subsequent analysis required to support the licence renewal process.

4. Drivers for Monitoring Program

4.1. Regulatory Requirements

The requirements in the Water Act (1989), as listed in Section 40 and 53 of the Act, that were applied to the current licence will again apply during the licence renewal process.

In addition to the specific requirements of the Water Act the Ministerial Guidelines for Licensing Groundwater for Urban Water Supply (Appendix A) state that the licence must develop and implement management programs as follows:

- A water level monitoring program;
- A groundwater extraction monitoring program;
- A groundwater salinity protection program; and
- A surface water and riverine environment protection program.

The Guidelines provide additional detail on how monitoring data should be presented as well as reporting frequencies. Although the Guidelines were established for new licences the same principles apply for the renewal of licences.

4.2. Community Concerns

The primary issues that drive community concerns can be related to environmental impacts (both perceived and real). The main concerns are as follows:

- The extent of stream flow reduction and any ecological impacts at various points along Boundary Creek,
- The potential to increase existing acid sulphate soil risks in the Yeodene peat swamp,
- The potential to increase the existing fire risk at the Yeodene peat swamp, and
- Groundwater extraction limits and whether they are sustainable under climate change projections.

Addressing community interests around potential environmental impacts is a key driver of the revised groundwater monitoring program. The revised monitoring program will need to collect sufficient data so that community concerns can be evaluated to a satisfactory standard.

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4.3. Water Security for Barwon Water

The Barwon Downs borefield plays a crucial role in providing Geelong and surrounds with water security during times of drought. Water supply modelling undertaken for the 2012 Barwon region *Water Supply Demand Strategy* confirmed that Barwon Downs best serves Geelong as a drought response water source.

This modelling also indicated that using Barwon Downs as the first drought response in drier years provides the least price impact to customers. The cost of water from Barwon Downs is almost twenty times less expensive than water from the Melbourne Geelong Pipeline (MGP). In terms of variable cost per million litres, Barwon Downs water costs $100 whereas water via the MGP costs $1914 (2013/14 price).

4.4. Water Security for Existing Users

There are very few, if any existing groundwater users in the region. Although it is unlikely to be an issue, it is recommended that a database search be conducted. Anxiety about water security (supply) by existing surface water users is currently expressed as an environmental concern. Impact to water security is likely to be raised by land holders in the region, with some already claiming that Barwon Downs pumping having caused their dams to become dry.

The current monitoring program includes:

- spot monitoring of flow along a three kilometre reach of the Baron River East Branch to identify change in flow,
- measurement of Barwon Water supplementary flow in Boundary Creek,
- monitoring of total Boundary Creek flow, and
- spot sampling of water quality at the Yeodene State Network stream gauge on Boundary Creek.

However, existing monitoring is unlikely to enable reduced yield from farm dams to be assessed.

4.5. Subsidence

Ongoing subsidence monitoring will be of value for further developing our understanding of how the groundwater system responds to groundwater extraction, particularly in the area where the aquifer is confined.

4.6. Summary

Both regulatory requirements and community concerns highlight the importance of enhancing the scope of the current monitoring program.

Although the current licence incorporates conditions specific to certain environmental assets such as Boundary Creek, management responses (in the form of trigger levels) was based on what was understood at that time. Additional data is now required to better understand the relationship between aquatic ecology and terrestrial vegetation. The degree to which the current monitoring program needs to be modified and/or expanded depends on:

- the adequacy of our understanding of the environmental processes that are triggered when there are changes to the groundwater system,
- the degree to which these processes will respond to changes in groundwater, and
- the sensitivity of the environment to the response to these processes.

Other issues such as security of supply for Barwon Water and existing water users (particularly farm dams) will also need to be addressed.

The following section identifies the environmental processes that occur in response to changes in the groundwater system and the impacts that may occur.

It is recommended that Barwon Water engage with stakeholders and the community prior to implementation of the revised monitoring to ensure that any potential issues are addressed.

5. Groundwater Variability, Processes and Impacts

5.1. Introduction

Groundwater variability triggers a range of groundwater processes (e.g. decline in groundwater levels, change in groundwater flow directions, etc) which may affect users that are connected to the groundwater system (i.e. people and/or ecological systems). If this is detrimental to the beneficial use, then that variability will have caused an (unacceptable) impact. The following sections describe:

- the types of groundwater variability,
- the processes triggered by these changes, and
- potential impacts caused by variability which the monitoring program may need to address.

5.2. Groundwater Variability

Variability in a groundwater system can occur when the volume of groundwater stored increases or declines (e.g. due to extraction or drought conditions), or a water quality concern where a contaminant is introduced into the groundwater (e.g. chemical spill or leaching of fertilisers). Contaminants that are unrelated (e.g. nutrients leaching into groundwater from cattle or application of fertilisers) are not relevant to the monitoring program and are, therefore, not considered any further.

Hydraulic variability in an aquifer is most commonly caused by a reduction (or sometimes an increase) of water stored in the groundwater system. This includes:

- Groundwater extraction or drainage (increasing groundwater discharge),
- Drought (reducing groundwater recharge), and
- Land use change (increasing and/or decreasing recharge)

The effect these changes have on groundwater processes are the same, and they can often occur simultaneously (e.g. groundwater extraction often occurs in times of drought). Ideally the monitoring program will aim to differentiate the effects of one variability from another (i.e. differentiate the effects of drought from land use change, and extraction).

Note: Hydraulic variability can also occur when there is a change in groundwater pressure but no change in the volume of groundwater stored. This is usually called a loading effect and occurs when an external load is applied to the groundwater system (e.g. construction of large structures such as dams, filling of artificial lakes, wide scale flooding) or removed (unloading such as open

cut mining, draining of lakes, flood recession). These types of hydraulic variability are unlikely to occur in the project area and are usually short term and therefore not considered relevant to this project.

5.3. Environmental Processes

When there is variability in a groundwater system, a number of processes respond to this change - some immediately, and others lag by days, months or even years after initiation of the change. The lag is the same when the change is removed (e.g. when extraction stops) with some processes continuing to respond to the change long after it has been removed. The lag in response to this change depends on the location and the hydraulic properties of the groundwater system (e.g. hydraulic conductivity).

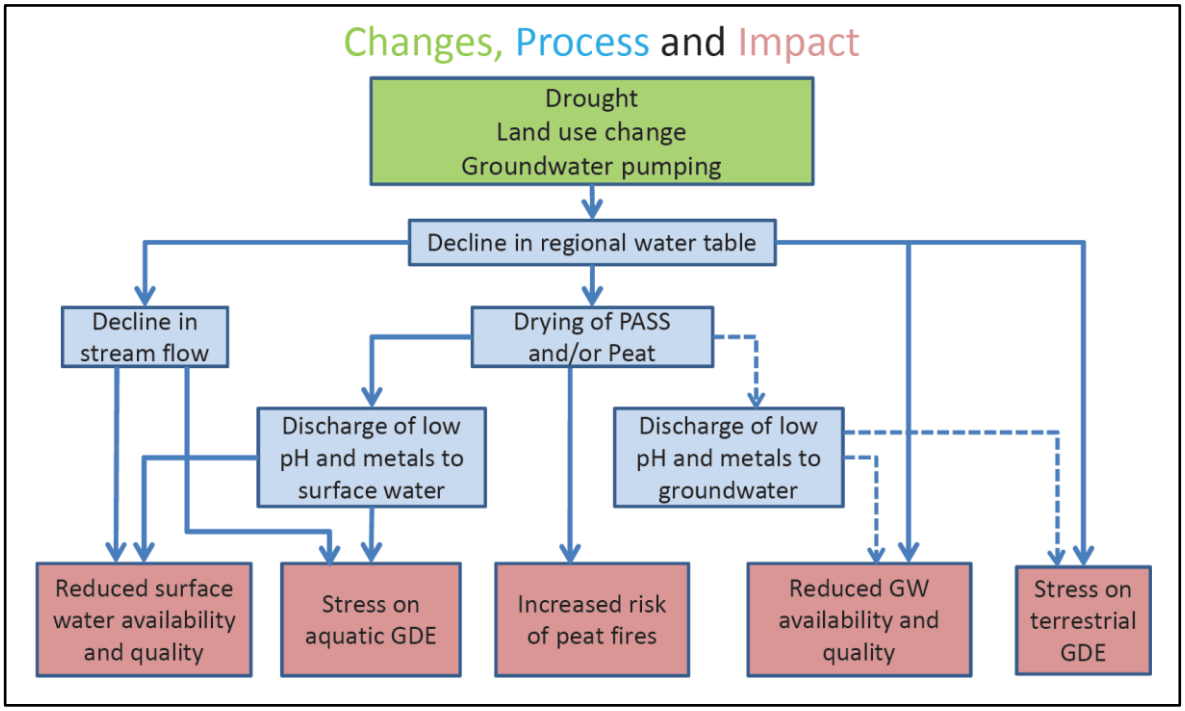
The first process to respond to such changes is groundwater levels (e.g. aquifer being extracted or reduced rainfall). The change in groundwater levels can alter the direction of groundwater movement. This can then trigger other processes including:

- compression of aquifers and aquitards (leading to subsidence),
- decline in water table levels (leading to the drying of wetlands including those that contain peat),
- drying of acid sulphate soils, and
- the decline in stream flow (Figure 1)

The drying of peat and acid sulphate soils can also lead to processes that release metals and acidic water (Figure 1). Subsidence can lead to changes in drainage patterns that can affect sediment transport (including erosion) which can affect water quality. The processes and potential impacts are shown in the blue and red boxes respectively in Figure 1.

The monitoring program will need to focus on the processes that lead to impacts that are relevant to renewal of the existing groundwater licence. As shown in Figure 1 the decline in groundwater levels affects all other processes and impacts, therefore making it crucial to the monitoring program. All other processes affect a smaller number of impacts but in most instances impacts are dependent on more than one process. As a result it likely that most, if not all, of the processes shown in Figure 1 will need to be addressed by the monitoring program.

- **Figure 1 Changes and processes that lead to environmental impacts**



5.4. Potential Impacts

Hydraulic changes to a groundwater system will always impact the environment that interacts with groundwater. These only become unacceptable impacts if the level of change exceeds legislated or agreed criteria (limits) including limits that reflect community concerns (both real and perceived). Given that the potential impacts (Figure 1 and Table 1) are all related to the key issues affecting the scope of monitoring (in Section 3), the monitoring program will need to identify criteria that define when an unacceptable impact occurs.

Criteria are currently available for most of the potential impacts but those that affect ecosystems are unlikely to have been developed using sufficiently rigorous data and methods to be acceptable to the community and the regulators. The data required to develop suitable criteria will need to be included in the revised monitoring program.

Given that all of the potential impacts identified in Table 1 are related to the key issues identified in Section 3, it is likely that that monitoring program will need to identify acceptable limits for each of these potential impacts where they are not currently specified. Potential sources of existing limits are indicated in Table 1.

Recommended activities in the revised monitoring program may need to involve studies to clarify important thresholds/limits to verify change and any possible effect and/or impact.

On the basis of current understanding of hydrogeological processes in the Barwon Downs region, the impacts that are likely to require the greatest level of effort in determining suitable limits are the effects on aquatic and terrestrial ecosystems (Table 1). This is due to the high variability of ecosystems and the likelihood that there is very little detailed information available on the sensitivity of ecosystems in the Barwon Downs region to changes in the groundwater regime.

The current level of understanding of the processes that lead to these impacts and the groundwater changes that need to be considered will also directly influence the design of the monitoring program.

- **Table 1: Likelihood of unacceptable impacts occurring, and availability of suitable impact criteria**

Potential Impact	Likelihood of Impact Occurring	Likelihood Impact is Unacceptable	Impact Criteria Available?	Potential Sources for Impact Criteria	Is a review of criteria required?
Reduced surface water availability for existing diverters	Mod to High	Mod to Low	No	SRW may have diversion limits for streams in the project area	Yes
Reduced surface water quality for existing diverters	Low to Mod	Low to Mod	Partial (for ecosystems only, not for water users)	Unlikely that limits have been defined for surface water diversion	No
Reduced groundwater availability for existing users	Low to Mod	Low	Yes	SRW have rules that define the maximum drawdown groundwater pumping can impact on existing bores not related to licence	No
Reduced groundwater quality for existing users	Low	Low	Yes	These limits are based on current beneficial use categories for groundwater as defined by the EPA	No
Pressure on aquatic ecosystem	Mod to High	Low	Yes	EPA has general guidelines for water quality changes but these are not specific to the ecology in individual streams.	Yes

Potential Impact	Likelihood of Impact Occurring	Likelihood Impact is Unacceptable	Impact Criteria Available?	Potential Sources for Impact Criteria	Is a review of criteria required?
Pressure on terrestrial ecosystem	Mod to High	Low	No	Sensitivity of vegetation to changes in groundwater level is not defined. Unlikely that any drawdown limits based on vegetation impacts will have been defined.	Yes
Increased risk of peat fires	Mod	Mod	No	Unknown	Yes

5.5. Summary

1. There are three types of changes to a groundwater system that could lead to similar impacts in the Barwon Downs area, of which groundwater extraction is one. As a result:

   The monitoring program will need to identify the relative contribution of each change to each impact (e.g. is drought contributing to impacts more than pumping?).

2. All of the potential impacts are likely to influence the renewal of the groundwater licence. Criteria are currently available for some of the potential impacts. Of those that are available, some are unlikely to be suitable, particularly those related to impacts on ecosystems. As a result:

   The monitoring program will need to collect data to ensure impact criteria are not exceeded and to develop new or refine existing criteria, particularly for impacts on ecosystems.

3. In most instances the potential impacts are dependent on all groundwater processes that respond to hydraulic variability. As a result:

   The monitoring program will need to characterise all groundwater processes to a sufficient standard that will enable impacts to be estimated to a reasonable level of accuracy.

The monitoring program will be required to differentiate between groundwater changes, characterise groundwater processes that lead to impacts, and identify criteria that define when unacceptable impacts occur. The following sections provide details on the proposed monitoring program to meet these requirements.

6. Gap Analysis of Data Requirements

6.1. Groundwater Change

Identifying the groundwater chnages that contributes the most to the potential impacts will require the changes to be characterised (e.g. pumping rates or rainfall patterns). The data needed to characterise each change is shown in Table 2.

Groundwater Extraction
Detailed information on pumping rates and the location of pumping has been collected since the commencement of the bore field operation. Likely future pumping rates can be determined relatively simply using existing demand predictions. No change to current data collection on pumping rate is required for the proposed monitoring program.

Drought
Historical rainfall records have been collected and continue to be collected at several locations in the project area and are readily available. The monitoring program should identify which rain gauge best represents rainfall in the groundwater recharge areas. Predictions of future rainfall are also readily available for various future climate scenarios.

Land Use Change
Data on historical land used change including vegetation cover and type, and modifications to drainage patterns since the bore field came into operation is unlikely to be available. This could be compiled from various sources such as aerial and satellite imagery from DEPI, SRW, CCMA, and possibly Barwon Water records.

Information on accessions from irrigation would also be required, which could be obtained from SRW and satellite imagery. Predicting future land use change could be obtained from CCMA, but is likely to be a complex process requiring detailed analysis. Establishing the relationship between land use, vegetation, and drainage changes is certainly going to be a complex requiring extensive modelling and field studies.

The effort to obtain data to characterise changes from land use will be considerably larger and more difficult than groundwater extraction and drought. An alternative approach is to identify the impacts of land use change from the residual or unaccounted impacts that are attributed to extraction and drought. This approach assumes that little or no land use change is likely to occur between now and the end of the renewed licence.

Table 2: Data required to characterising groundwater change

Change	Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Groundwater Pumping	Location of pumping	Yes	None	Negligible
	Historical pumping rates	Yes	None	Negligible
	Future pumping rates	No	Barwon Water to identify future pumping rates and duration of pumping	Low
Drought	Historical rainfall	Yes	Rain gauge most representative of area to be identified	Low
	Future rainfall	Yes	Barwon Water to identify future climate scenarios	Low
	Relationship between rainfall and groundwater recharge	Yes	Check and refine existing relationship between rainfall and recharge to unconfined aquifer and aquitard	Moderate
Land Use Change	Change in vegetation cover	No	Prepare historical vegetation cover maps Prepare future vegetation use maps	High
	Change in land use	No	Prepare historical land use maps Prepare future land use maps	High
	Change in surface drainage	No	Identify changes in land surface drainage and how this affects stream flow and water quality	High
	Relationship between change in land use and groundwater recharge	No	Develop relationship between land use, vegetation cover and drainage to groundwater recharge	High

6.2. Groundwater Processes

6.2.1. Hydrogeological Data

Existing hydrogeological data in the Barwon Downs region is sufficiently detailed to characterise the groundwater processes that lead to impacts on the availability of groundwater for Barwon Water and other groundwater users.

The processes that lead to impacts on aquatic and terrestrial ecology are understood at a conceptual level, but there is insufficient hydrogeological data to characterise the processes to a suitable standard to assess the potential impacts.

The current conceptual model of groundwater flow assumes negligible groundwater flow occurs between the aquifer and the overlying aquitard. This assumes that changes to groundwater flow would have a negligible effect on stream flow where the aquifer is confined (aquitard area). Although there is a high probability that current stream flow is only slightly affected by changes to groundwater, groundwater flow is very slow in aquitards. There is a potential risk that stream flow may be affected in coming years. Measuring water levels in the aquitard is necessary to assess the risk of changes to groundwater reducing flow in streams where the aquifer is confined.

The hydrogeological data needed to characterise groundwater processes to the required standard are described in Table 3. Because the groundwater processes that respond to these changes are essentially the same the monitoring program will need to be able to identify the changes responsible for a specific impact.

Table 3: Hydrogeological data required to characterise groundwater processes

Groundwater process	Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Decline in groundwater levels	Aquifer hydraulic properties	Yes	None	Low
	Aquitard hydraulic properties	Very limited	New bores to test hydraulic conductivity and specific yield of aquitard	High
	Groundwater levels in aquifer	Yes	None	Low
	Groundwater levels in aquitard	No	New bores to measure groundwater levels in aquitard	High
	Evapotranspiration from aquifer and aquitard	Limited	Current vegetation or aerial photo maps for project area Sensitivity testing using existing groundwater model	Low
			Measurement of ET using satellite data (SEBEL)	High
	Presence of perched water table	No	New bores to identify perched water table	High
	Location of confining layers within aquifer recharge area	No	Analysis of drawdown to identify confining areas within aquifer Review of existing bore logs to identify confining layers	Mod to Low

Groundwater process	Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Decline in stream flow	All data for decline on groundwater levels	-	-	--
	Leakage characteristics of streambed	Very limited	New bores and pumping tests near streams to identify streambed leakage	High
	Groundwater levels near streams	Very limited	New bores to identify groundwater flow direction in vicinity of streams	High (Low if combined with above item)
Subsidence	All data for decline on groundwater levels	-	-	-
	Consolidation curve for aquifer and aquitard	Very limited	Undisturbed sampling and tri-axial testing of aquifer and aquitard materials	High (Mod to Low if combined with new bores in aquifer and aquitard)

6.2.2. Hydrological (surface water) Data

Existing stream flow data on Boundary Creek can be used to calculate base flow which, in conjunction with hydrogeological data (Table 3), can be used to evaluate declines in stream flow. The existing Yeodene gauge located on Boundary Creek is affected by the dams located on the creek channel and supplementary flows provided by Barwon Water under existing licence conditions. Correcting the Yeodene gauge data will enable more accurate base flow assessments to be made for Boundary Creek.

The Boundary Creek gauge is representative of streams that are in direct contact with the aquifer but there are no gauges measuring flow where the aquifer is confined (aquitard area). Occasional spot readings are taken in the confined area on Barwon River East Branch but these do not enable baseflow to be calculated. Although current stream flow is unlikely to be significantly affected by groundwater change, the very slow movement of groundwater in aquitards means there is a risk that stream flow may be affected in coming years. Gauges in the confined area provide reliable data on any changes that may occur, and provide base flow data can be used to predict the likelihood of future stream flow decline.

- **Table 4: Hydrological data required to characterise groundwater processes**

Groundwater process	Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Decline in stream flow	Stream base flow in unconfined area	Limited	Adjustment of existing Yeodene gauge data for farm dams located on Boundary Creek Adjustment of Yeodene gauge for supplementary into Boundary Creek Base flow assessment using adjusted Yeodene gauge data	Mod
	Stream base flow in confined (aquitard) area	No	Installation of stream flow gauge(s) Base flow assessment using gauge data	High

6.2.3. Potential Acid Sulphate Soils (PASS)

The decline of groundwater levels may lead to potential acid sulphate soils (PASS) drying out if the groundwater at these sites is connected to the aquifer affected by groundwater changes. If the moisture content of PASS decreases it can become oxygenated by the atmosphere. This can lead to the acidification of groundwater and runoff which may reduce the pH of streams interacting with the groundwater system leading to impacts on aquatic ecology. Increased acidity of groundwater or runoff creates the risk that metals may be mobilised from the soil into groundwater and surface water, which may also impact on aquatic ecology.

Most of the data used to predict the likelihood of PASS drying are obtained from the hydrogeological data use to define groundwater processes (Table 3). This needs to be combined with locating where PASS is present. Chemistry will also need to be identified to understand the potential for PASS to impact on water quality (Table 5).

- **Table 5: PASS data required to characterise groundwater processes**

Groundwater process	Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Drying of PASS	All data for decline on groundwater levels	-	-	-
	Location of PASS	Very limited	Map location and extent of PASS	High
Discharge of low pH and	All data for decline on groundwater levels	-	-	-

Groundwater process	Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
metals to streams and groundwater	All data for drying of PASS	-	-	-
	Chemistry of PASS	No	Sampling and lab testing of PASS	Mod to Low
	Reaction pathways and rates for oxidation of PASS	Very limited	Geochemical modelling to predict contaminant load from dying PASS	Mod

6.3. Impacts

6.3.1. Reduced Surface Water Availability

Minimum flow criteria for unregulated streams (e.g. Barwon Downs area) are usually defined for ecological management purposes, rather than providing security of supply for diverters. SRW may have diversion limits for streams in the project area which could potentially be used to define minimum flow requirements. However, it is likely that minimum flow criteria would be based on impacts on aquatic ecology than availability of surface water for diversion.

If loss of stream flow is expected to impact on diverters it is best to anticipate that SRW will wish to protect their customer base by developing minimum flow criteria.

Understanding the relationship between groundwater extraction and stream flow will enable the impact of pumping on surface water diverters, such as farm dams to be evaluated.

- **Table 6: Data requirement for assessing impact on surface water availability**

Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Minimum flow for existing diverters	No	Existing caps on total diversions in Barwon Catchment SRW advice on minimum flow limits for existing diverters	Mod
Direct measurement of flow gain/loss in Boundary Creek and other streams/rivers	No	Measured change in flow	Low (if gauges identified in Table 4 are installed)

6.3.2. Reduced Surface Water Quality

Regulators do not set minimum water quality criteria for water supply to diverters. It is unlikely that minimum water quality criteria would be developed for surface water diversions. Water quality criteria are more likely to exist for ecological impacts.

6.3.3. Groundwater Dependent Ecosystems

Groundwater-dependent ecosystems (GDEs) are defined as ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain the communities of plants and animals, ecological processes they support, and ecosystem services they provide (SKM, 2011).

The identification of GDEs and their water requirements have recently been standardised as part of the Australian GDE toolbox (SKM, 2011). It is proposed that data collection and methods used to assess the impact on GDEs will be consistent with the GDE toolbox, and the assessments will completed in accordance with the GDE atlas.

6.3.3.1. Increased Pressure on Aquatic Ecosystems

Decreased groundwater discharge (baseflow) to streams may increase pressure on aquatic ecosystems. Currently there are no established flow criteria (i.e. flow rates) based on site specific data to maintain aquatic ecosystems in the Barwon Downs area. Any existing criteria are likely to be very general in nature and not sufficiently detailed enough to enable impacts to be assessed to a required standard.

The FLOWS method is used to define flow criteria to maintain aquatic values in streams. The data required to undertake the FLOWS method is described in Table 7.

The number of streams that will be assessed will depend on the finalised scope of the monitoring program (refer to section 7). This will be determined upon completion of the desktop assessment and site inspections (stage 1) but as a minimum it is recommended that the program will need to include Boundary Creek. Impact on aquatic ecosystems in Boundary Creek has been highlighted several times as an area of concern by the community.

Table 7: Data requirement for assessing impact on aquatic ecology

Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Decline in stream flow	No	Same as data requirements in Table 4	N/A (not additional to Table 4)

Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Characteristics of stream reaches	No	Site surveys to characterise streams into reaches with similar land use, physical habitat and flow regulation	Mod
		Field survey of fish in late spring to confirm values and determine current condition Field survey of macro-invertebrates in spring and autumn to confirm values and determine current condition 12 month water quality monitoring Channel survey at selected sites in each reach	High

6.3.3.2. Increased Pressure on Terrestrial Ecosystems

The extent to which terrestrial ecology in the Barwon Downs area is dependent on groundwater and its sensitivity to the decline in groundwater levels is unknown. Monitoring undertaken as part of the current licence conditions indicate that pressure on vegetation has occurred due to reduced soil moisture. It was not possible to determine whether the reduced moisture was due to reduced groundwater levels in response to drought and/or groundwater extraction, or simply drier surficial soils in response to drought (SKM, 2008).

The current groundwater licence includes drawdown limits but these are triggers to undertake investigations to the causes of the water level decline, and are not criteria that are based on impacts to terrestrial ecology.

Data requirements are identified in Table 8.

- **Table 8 Data requirement for assessing impact on terrestrial ecology**

Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Decline in groundwater levels	Partial	Same as data requirements in Table 3	N/A (not additional to Table 3)

Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Location of suitable monitoring sites	No	Field survey to identify potential monitoring sites, wetlands, and reference sites Validation against groundwater level from new and existing bores to confirm sites are GDEs.	High
Extent of wetlands			
Location of suitable reference sites			
Monitoring of pressure to vegetation	Very limited	Monitoring of sites that are identified as GDEs	High

6.3.4. Reduced Groundwater Availability

There are very few, if any existing groundwater users in the region. Although it is unlikely to be an issue, it is recommended that a database search be conducted.

6.3.5. Reduced Groundwater Quality

Declining groundwater levels can cause groundwater from surrounding aquitards to leak into the aquifer. This may result in a change to groundwater quality. However, saline groundwater is unlikely to occur in the Barwon Downs area and has not been recorded in any of the observation bores in the aquifer. There are very few observation bores in the aquitard that overlies the aquifer but rainfall is significantly larger than evaporation in the region which strongly suggests that the aquitard is unlikely to contain saline groundwater. Monitoring of groundwater salinity from the pumping bores at Barwon Downs have shown a slight decline in salinity since the start of operation since 1986 indicating that the risk of reduced groundwater quality is low.

Changes in groundwater salinity due to saline intrusion from the ocean cannot occur at this location due to the large distance between the bore field and the coast.

If PASS is widespread in the Barwon Downs area and it becomes affected by declining groundwater levels there is a risk that groundwater quality may decline. However, there may be significant buffering and retardation of metals in the aquifer to minimise the risk of widespread decline in groundwater levels if PASS is present and affected by reduced water levels.

- **Table 9 Data requirement for assessing impact on groundwater quality**

Data required	Data Currently Available?	Additional data required	Effort to obtain additional data
Geochemical modelling to predict contaminant load from dying PASS	No	No. Obtained from discharge of low pH and metals to streams and groundwater (refer to Table 5)	N/A (not additional to Table 5)
Water quality in aquitard	No	Collection and analysis of groundwater samples from new bores in aquitard (refer to Table 3)	Low

6.3.6. Increased Fire Risk

Declining groundwater levels may cause peat swamps to become dry. This dryness increases the risk of peat fires (main ignition source is lightning strike). This, in turn, increases the risk of forest fires which can have a disastrous impact on the surrounding national parks. If the fires spread far enough, Colac's water supply will be under threat. The key data to assess increased fire risk is the decline in groundwater levels, which will be calculated from other impacts.

7. Monitoring and Evaluation Program

7.1. Scope

The scope of the program is dependent on:

- data that is needed to determine the impacts that are relevant to the renewal of the groundwater licence, and
- the collection of sufficient data to characterise groundwater changes and processes that cause impacts.

In general, as impacts, processes, and changes are included or are characterised with more data the risk of the monitoring program not achieving its objectives decreases.

To develop the new groundwater monitoring program, the level of risk the current program presents to achieving licence renewal was assessed. The level of risk (Figure 2) was determined from the:

- probability (likelihood) of monitoring data being inadequate (i.e. not technically rigorous and comprehensive) or having significant gaps (including perceived gaps/weaknesses by the community even if these gaps are not significant from a technical perspective, refer to Table 10), and
- potential for the licence application being rejected or significantly delayed if monitoring is inadequate (i.e. consequences if data is deemed inadequate, refer to Table 11).

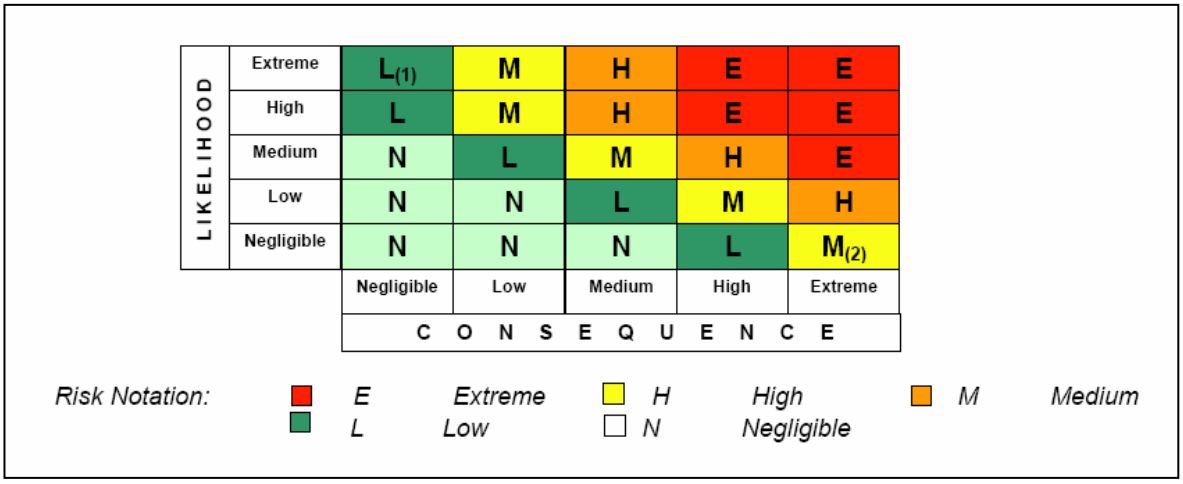
Comparing the data currently being collected to the data required to characterise groundwater variability, groundwater processes, and assess impacts (as described in Section 6) shows that there is a high risk that the licence renewal will either be rejected or significantly delayed if the monitoring program is not revised (the risk assessment is presented in Appendix B). The gap between the datasets described in Section 6 and the current program are identified and the risk the gap presents to the licence renewal is identified in Appendix B.

Given that the Barwon Downs bore field is critical to maintaining a low cost and affordable water supply for the Barwon region, it has been assumed that the preferred monitoring program (the "Base Case", Figure 3) would need to present a low risk to successful licence renewal. Where data is considered to be less critical to achieving licence approval, or where the risk rating is relatively insensitive to the type or amount of data collected, the required level of risk is relaxed to the lowest that can be reasonably achieved without significantly affecting the low risk objective.

The Base Case also excludes the effect of land use change (Figure 3). This can be determined by taking into account the effects of groundwater pumping and drought (i.e. the effect of land use change is the residual impact after groundwater extraction and drought are taken into account). Directly assessing the impacts of land use change is also likely to have a very high cost, so assessing it indirectly is considered a more cost effective and therefore, practical approach.

Including the direct assessment of land use change represents a "Full Scope" monitoring program. Programs with a scope that is less than the "Base Case" would involve less data collection with a higher risk of not achieving licence renewal (Figure 3).

- **Figure 2: Risk Matrix**



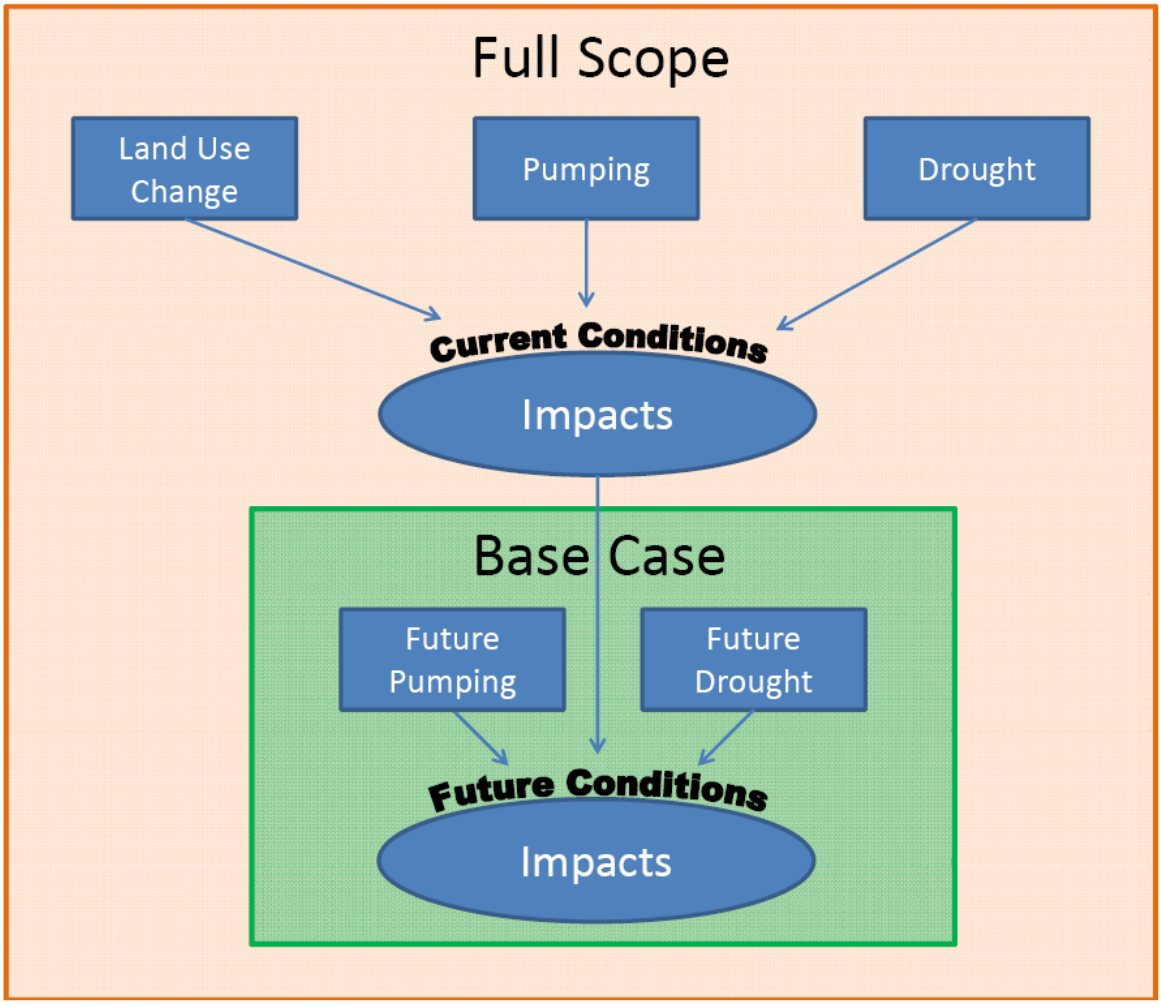
- **Table 10: Likelihood Table**

Rating	Probably of monitoring data being inadequate or having significant gaps
Extreme	0.9 to 1.0
High	0.33
Medium	0.1
Low	0.033
Negligible	0.01

- **Table 11: Consequences Table**

Rating	Definition of Rating
Extreme	>70% chance of licence application being rejected >50% chance of licence delayed for new studies and/or more monitoring data
High	50% chance of licence application being rejected 50% chance of licence delayed for new studies and/or more monitoring data
Medium	20% chance of licence application being rejected 20% chance of licence delayed for new studies and/or more monitoring data
Low	0% chance of licence application being rejected 10% chance of licence delayed for new studies and/or more monitoring data
Negligible	0% chance of licence application being rejected 5% chance of licence delayed for new studies and/or more monitoring data

- **Figure 3 Changes assessed in the "Full Scope" and "Base Case" programs (note "Full Scope" includes the "Base Case")**



7.2. Base Case

The monitoring program for the Base Case has been divided into five categories representing each discipline, as follows:

- G: Groundwater
- T: Terrestrial ecology
- A: Aquatic ecology
- H: Hydrology (surface water)
- P: Potential acid sulphate soils and fire risk

The full detail of the monitoring program is presented as a table in Appendix B. The structure of the monitoring program table is presented in Table 12 .

Table 12 Structure of Monitoring Program Table

Component	Detail	Column in Appendix B
Monitoring activity identifier	Codes G1, G2, T1, etc are used to identify each activity	A
Description of activity	Brief description	B (details in column I)
Purpose of activity	Groundwater processes addressed	C
	Potential impacts addressed	D
	Issue being addressed	E and F
Risk to renewal of licence	Gap in current program	G
	Risk with current monitoring	H
	Monitoring tasks to address gaps and risk. These are divided into 4 categories 1. Preliminary desk top using existing data 2. Desk top using existing data with small field component 3. Detailed analysis using new and existing data 4. Major field activity to install new monitoring sites, or monitoring activities for new sites	I
	Risk under proposed monitoring	J
Implementation	Start year	K
	Monitoring frequency	L
Inter-dependencies with other activities	-	M
Preliminary cost estimate	-	N

The monitoring program comprises four different categories with increasing level of effort. These are described below and can also be found in Table 13:

1) Preliminary desk top assessment and site inspections using existing data
2) Desk top using existing data with small field component
3) Detailed analysis using new and existing data
4) Major field activity to install new monitoring sites, or monitoring of new sites

The desk top activities are primarily for assessing existing data to determine final scope of new activities in the program and/or preliminary site selection. The detailed analyses and major field activities represent the active monitoring program. The current scope of the major activities is based on current understanding of the hydrogeology. The final scope of the major activities, in most cases, depends on the outcome of the desk top activities.

The major activities include establishing new monitoring sites, field testing and sampling, detailed assessments, and on-going monitoring. These are summarised in Table 13.

A summary of the data to be collected, the specific issue being addressed and activity required to obtain the data for the major field activities and detailed analyses for the five disciplines are provided in Table 14 to Table 17.

Table 13 Summary of Major Field Activities and Assessments

Activity	Heading
New Monitoring Sites	36 new observation bores
	1 new stream gauge
	1 new rain gauge
	10 to 20 new vegetation monitoring sites
Field Testing/Sampling	2 pump tests
	Slug tests in all new bores
	Sampling and testing of groundwater quality from all new bores
	Macro-invertebrate and fish surveys (spring and autumn) for Boundary Creek
	Water quality sampling in one stream (Boundary Creek)
	Cross sectional surveys of stream bed (Boundary Creek)
	Mapping and sampling of PASS
Assessments	Identify groundwater evapotranspiration rates (key input to groundwater modelling)
	Groundwater modelling to predict change in groundwater levels and stream flow in response to pumping (and contribution from other causes such as drought)
	Ecological status of streams

Activity	Heading
	FLOWS study to determine sensitivity of aquatic ecology to reduced flows in streams
	Sensitivity of vegetation to declining groundwater levels
	Potential for PASS to generate acid drainage and mobilise metals
	Assessment of fire risk
	Annual reporting of monitoring data and revision of impact assessments
Monitoring	Monthly reading of groundwater levels in new bores
	Continuous flow gauging in new stream gauges
	Continuous rainfall measurement in new gauge
	Continuous water quality in temporary stream monitoring sites
	Yearly monitoring of new and existing vegetation sites

Table 14 Major Groundwater Field and Assessment Activities

Data Type[1]	Specific Issue	Activity	Scope dependent on preliminary assessment?
Historical and future bore field pumping (G1)	Groundwater pressure response to pumping in the confined section of the aquifer	Currently monitored	No
Aquifer water levels in confined aquifer (G2)			
Aquifer water levels in unconfined area (G3, G4, G5, G6, G11)[1]	To determine if existing bores in unconfined areas are monitoring the water table (and not confined sub-aquifer)	Drill 5 bores	Yes
		Monthly monitoring of water levels in new bores	
	To better define changes in aquifer water levels and flow directions in upper reaches of Boundary Creek are caused by pumping or other causes	Drill 5 bores	Yes
		Monthly monitoring of water levels in new bores	
	To determine water table depth at monitored vegetation sites	Drill 4 bores	Yes
		Monthly monitoring of water levels in new bores	
	Provide baseline water table data that is not influenced by pumping	Drill 2 bores	Yes
		Monthly monitoring of water levels in new bores	
	Identify presence of perched water table in unconfined area	Drill 6 bores	Yes
Aquitard water levels in confined area	To determine water table depth at monitored vegetation sites	Drill 4 bores	Yes
		Monthly monitoring of	

Data Type[1]	Specific Issue	Activity	Scope dependent on preliminary assessment?
(G7, G8, G9)		water levels in new bores	
	Direction of groundwater flow and water table depth in aquitard (particularly for flow to/from streams and wetlands)	Drill bores 8 bores 6 to water table, 2 to middle of aquitard and nested with 2 water table bores	Yes
		Monthly monitoring of water levels in new bores	
	Provide baseline water aquitard table data that is not influenced by pumping	Drill 2 bores	Yes
		Monthly monitoring of water levels in new bores	
Groundwater modelling (G10)	Identify impacts attributed to bore field operation	Revise and re-calibrate model using new data obtained from	No
Evapotranspiration (ET) from the water table (G12)	Improve estimates of steam flow depletion by improving the reliability of this data	Use remote sensing methods (SEBEL) to measure ET	Yes
Leakage characteristics of the aquitard (G13)		Hydraulic conductivity tests in aquitard bores established in G7, G8, and G9	Yes
Rainfall in recharge area (G14)		Establish new gauge	Yes
Leakage characteristics of Boundary Creek (G15)		Conduct pumping tests near creek channel	Yes
Base flow and seepage to/from Boundary Creek (G16)		Install new and./or upgrade existing gauges	Yes
		Continuous monitoring of gauges	

1. G4, G5, etc are the activity codes used in the detailed description of the monitoring program in Appendix B

Table 15 Major Terrestrial Ecology Field and Assessment Activities

Activity	Specific Issue	Task	Scope dependent on preliminary assessment?
Identify condition of terrestrial vegetation in unconfined area (T1)	Are current vegetation monitoring sites representative of local vegetation	Field survey to identify suitable monitoring sites	Yes
	Is vegetation sensitive to changes in water table depth	Validate sites against water table depth information	Yes
		Identify suitable reference sites	Yes
		Yearly monitoring	yes
Identify condition of terrestrial vegetation in confined area (T2)	Are current vegetation monitoring sites representative of local vegetation	Field survey to identify suitable monitoring sites	Yes
	Is vegetation sensitive to changes in water table depth	Validate sites against water table depth information	Yes
		Identify suitable reference sites	
		Yearly monitoring	Yes

Table 16 Major Aquatic Ecology Field and Assessment Activities

Activity	Specific Issue	Task	Scope dependent on preliminary assessment?
Reach and site selection in Boundary Creek (A1)	Is Boundary Creek divided into distinct reaches with different morphology and ecology?	Field inspection of Boundary Creek	Yes

Activity	Specific Issue	Task	Scope dependent on preliminary assessment?
Fish and Macro-invertebrate surveys of Boundary Creek (A2)	Identify ecological values for each reach	Fish surveys	Yes
		Macro-invertebrate surveys	
		Water quality monitoring	
Determine minimum flow requirements for Boundary Creek (A3)	Identify minimum flow required to maintain ecological heath of Boundary Creek	Bathymetric survey of channel surveys of selected sites	Yes
		Develop hydrological model for surveyed sites	
		Hydrological analysis using REALM	
		Environmental flow determination	

- **Table 17 Major Hydrology (surface water) and PASS Field and Assessment Activities**

Activity	Specific Issue	Task	Scope dependent on preliminary assessment?
Stream flow gauging in Boundary Creek (H1)	Obtain stream flow data specific to the reaches used for the aquatic ecological assessments, and groundwater base flow calculations	Evaluate suitability of current Yeodene gauge to represent flow in upstream reaches	Yes
		Identify new gauge sites (if required)	
		Install new gauges	
		Gauge monitoring	
PASS and Peat assessment in unconfined areas (P1)	Identify presence and extent of PASS and fire risk from dried Peat	Field survey and sampling	Yes
		Determine acid generation capacity and fire risk from dried peat	
PASS and Peat assessment in confined areas (P2)		Field survey and sampling	
		Determine acid generation capacity and fire risk from dried peat	

7.3. Schedule

The schedule is divided into four main components:

1. Desk top assessment and site inspections to finalise monitoring program and cost
2. Installation of new monitoring assets and major field activities
3. Data analysis and impact assessments
4. On-going monitoring and annual revision of impact assessments

The desk top assessments are assumed to be undertaken in 2012/13 financial year, with asset construction expected to commence in the 2013/14 financial year.

A Gantt chart showing the full schedule is presented in Appendix C, as well as a schedule showing the preliminary assessment phase only.

7.4. Preliminary Cost Estimate

A preliminary cost estimate to undertake the Base Case has been prepared based on recent experience in undertaking similar activities. The cost estimate is expected to be within 30% of detailed costing. A 30% contingency to allow for expansion of the program after completion of the desk top assessment has been included (this is not an allowance for the uncertainty in current cost estimate). A key assumption is that permissions to obtain access to land for establishing new site or other field activities would be the responsibility of Barwon Water.

The preliminary cost estimate for the Base Case monitoring program is $2.7M excluding GST ($2.9M including GST, Table 18).

Table 18 Preliminary Cost estimate for Base Case

Component	Estimate Cost
Desk top assessment and detailed costs for program	$150,000
Installation of new monitoring sites	$1,100,000
Analysis and impact assessments	$450,000
On-going monitoring	$150,000
Project management	$200,000
Sub Total	$2,050,000
30% Contingency	$615,000
Total excluding GST	$2,665,000
GST	$266,500
Total including GST	$2,931,500

7.5. Full Scope Case

The "Full Scope" monitoring program includes assessing the influence of land use change on groundwater recharge and the resulting impacts (Figure 3).

Given the high cost to identify the land use changes in sufficient detail to explicitly determine how these changes have led to current impacts, coupled with the low probability that any significant land use change will occur in the period leading up to and after the licence renewal there does not appear to be any significant benefit in assessing land use change.

There may be a case for including very recent land use changes that tend to rapidly impact on groundwater systems (e.g. irrigation, damming creeks). If required, the need to include these types of land use change could be included into the desk top phase of the monitoring program.

A very preliminary estimate of costs to include all land use changes into the Base Case is in the order of $1M.

Due to its high cost, complexity, and moderate to high risk of providing inconclusive results it not recommended that a detailed assessment of land use change be included in the monitoring program.

8. Conclusions

The current groundwater monitoring program meets the requirements of the existing groundwater licence and represented best practice at the time when the licence was issued. Due to an increasing understanding of the interactions between groundwater and surface water, and increased awareness of environmental issues, stakeholders and the community may place a higher priority on the following issues during the licence renewal process:

- Loss of habitat in streams if flows decline,
- Drying of potential acid sulphate soils (PASS) causing degradation of surface water quality, and possibly groundwater,
- Decline in vegetation health due to water table decline, and
- Drying of peat swamps leading to an increased fire risk.

All of these impacts are controlled by groundwater processes, which are affected by groundwater extraction, drought and land use change. The monitoring program must, therefore, be able to adequately characterise the changes and processes that lead to potential impacts.

Land use change is not recommended to be included in the program because it is unlikely to have changed significantly since the commencement of pumping in 1986, is unlikely to change significantly in the period leading up to the licence renewal and over the next licence period, and would add significant cost the program for outcomes that may not be definitive

The current understanding of groundwater processes in the Barwon Downs area are understood sufficiently to enable reliable estimates of groundwater availability for pumping, but there is insufficient data to enable reliable calculations of changes to stream flow and groundwater level to the accuracy required for environmental assessments (related to the extraction of large volumes of groundwater). The region where the aquifer is confined (aquitard area) has no groundwater level monitoring and very little is known about its hydraulic properties. This is a gap in the current monitoring program that needs to be addressed.

There is currently an absence of criteria against which the level of impact can be assessed to identify the sensitivity of the aquatic ecology and vegetation to changes in flow and groundwater level. Understanding flow and water level criteria (limits) will mitigate unacceptable impacts.

Although it is clear that the current monitoring program will need to be expanded to collect a wider range of data from more sites, the preliminary scope provided in this report is likely to change after new data begins to come available from new monitoring and/or the re-evaluation of existing data. To minimise the risk of over or under scoping the program it is recommended that the first stage of

the program involves a desktop assessment and site inspections using existing data to refine and finalise both the scope and costs.

9. Recommendations

The following recommendations are made:

1) That the proposed monitoring program collects sufficient data to improve the current understanding of groundwater processes that lead to impacts, and identifying flow and groundwater level criteria to enable environmental impacts to be calculated. This will also assist with identifying when an unacceptable impact occurs (as outline in Appendix B).
2) That the first stage of the program involve a desktop assessment and site inspections using existing data to finalise the scope and costs.
3) That groundwater level monitoring in the confined section of the aquifer (aquitard area) should be included in the monitoring program as there is limited information at present
4) That stream flow and aquatic ecology monitoring in the aquitard area be assessed during the desktop assessment of the monitoring program.
5) That the program does not evaluate the effects of land use change prior to the commencement of pumping in 1986, but consider including very recent changes such as irrigation and dam construction across perennial streams.
6) That the program identifies the impacts of land use change from the residual or unaccounted impacts that are attributed to extraction and drought. This approach assumes that little or no land use change is likely to occur between now and the end of the renewed licence.
7) That Barwon Water communicate regularly and as early as possible with regulators and stakeholders including the community regarding the proposed monitoring plan, its objectives and the overall design and scope.

10. References

SKM (2008): Barwon Downs Flora Study. SKM reference VW04550: r01mwd_bd_hydrogeolgy6.docx.

SKM (2011): A Framework for assessing the Environmental Water Requirements of Groundwater Dependent Ecosystems. Report prepared for the National Water Commission.

Appendix A Ministerial Guidelines for Licensing Groundwater for Urban Water Supply

WATER ACT 1989

Ministerial Guidelines for Licensing Groundwater for Urban Water Supply

July 2008

MINISTERIAL GUIDELINES FOR LICENSING GROUNDWATER FOR URBAN WATER SUPPLY

EXPLANATORY NOTES TO DELEGATES

The Minister for Water has issued guidelines for licensing groundwater for urban water supply purposes. While guidelines have been issued for some time for surface water (see References below), there have been no guidelines issued concerning licences to take and use groundwater. The guidelines are an essential part of making clear the Minister's intentions as to the conduct of delegated licensing functions. The purpose of the guidelines is to guide delegates in the exercise of the powers delegated by the Minister.

1 Context

In relation to licences to take and use groundwater, the *Water Act 1989* provides that the Minister may issue, sell, amend, approve transfers of, revoke or accept the surrender of licences.

Under provisions in the Act the Minister has delegated his powers in relation to licences to take and use groundwater to Grampians Wimmera Mallee Water Corporation, Goulburn-Murray Rural Water Corporation and Gippsland and Southern Rural Water Corporation.

The Act provides that the Minister may issue guidelines and, by a general condition, require each delegate to exercise delegated powers in accordance with those guidelines.

Although guidelines apply to any person or body exercising a power delegated by the Minister, guidelines do not apply to the Minister (the Minister may still exercise powers that have been delegated) or to VCAT. However, the Minister or VCAT may choose to exercise powers in accordance with guidelines.

2 The nature of the guidelines

The guidelines are a series of statements that guide how the discretion that has been delegated should be exercised. Consistent with the definition and intention, the guideline statements contained are not mandatory conditions and are not specific conditions. For this reason the word "may" has been used rather than "must" or "shall". This distinction is important because guidelines enable the delegates to continue to exercise discretion.

3 Application of the guidelines

The guidelines apply to new applications for groundwater licences for urban water supply purposes and to licence transfers for urban water supply. The guidelines do not apply to the renewal of groundwater licences for urban water supply purposes.

4 Information to be contained in an application

Any application for a groundwater licence or a bore construction licence must contain any information that is prescribed by regulations or required by the Minister or delegate.

The guidelines provide that applications for a groundwater licence for urban water supply may require a groundwater assessment report.

The groundwater assessment report essentially describes the potential yield of the groundwater resource and makes an assessment of potential risks or any adverse impacts arising from the proposed extraction.

The scope of the groundwater assessment reports is provided in the guideline. Generally for small extraction volumes (say less than 100ML/yr) the groundwater assessment reports will be simple because a small drawdown is likely to have a small area of potential impact. Larger extraction volume proposals will generally have larger drawdowns and a larger area of impact; those groundwater assessment reports will need to cover a larger area. The groundwater assessment reports primarily rely on existing information sources such as databases and publications.

Where potential adverse risks are identified (e.g. salinisation, interaction of groundwater with streams, water ways, existing groundwater users or groundwater dependent ecosystems) then the groundwater assessment reports should detail the proposed risk mitigation schemes, such as programs of monitoring and review.

5 Pumping tests and observation bores

The guidelines identify the scope of pumping tests for the purpose of determining the hydraulic parameters (transmissivity and storativity) of the target aquifer, and in some cases related aquitards.

The hydraulic parameters are key pieces of information that underpin a groundwater assessment report. Where there is lack of knowledge or uncertainty on the hydraulic parameters and/or there are potential adverse impacts from proposed groundwater extraction then a groundwater pumping test should be performed to provide base data for the groundwater assessment report. Unlike a pumping test to determine bore yield or select an appropriate pump, a pumping test to determine aquifer parameters requires measurement of water levels in nearby observation bores.

The Guidelines provide for arrangements to be set for the disposal of the pumped discharge from a pumping test. The discharge point should exclude any possibility of extracted water returning to the aquifer and minimise any environmental impacts. The Rural Water Corporations should encourage applicants, to make productive use of the water extracted.

6 3 year licences requiring monitoring and review

The guidelines provide that short term licence (say 3 years) be issued with conditions requiring monitoring, reporting and review. These are intended for moderate or high risk licence applications where there is a lack of knowledge or uncertainty about yield of the target aquifer and/or there are potential adverse impacts from the proposed groundwater extraction. For moderate or high risk licence applications the guidelines contain an example licence template and licence conditions for consideration by the delegate. Some of the template licence conditions may be irrelevant to a particular situation in which case they may be deleted. Other template licence conditions may need to be enhanced. Text identified in **bold** type is where the conditions are expected to be modified specifically to the case in hand.

7 Compensation of other authorised water users

The guidelines contain an example template licence condition requiring the licensee to compensate existing authorised groundwater users that are materially or adversely affected by the taking of water under the licence. The intention is that the licensee will measure and determine impacts and make arrangements for compensation, which is consistent with the role

of urban water corporations. It is expected that all applications for groundwater licences will be made by urban water corporations.

8 Licence transfer

The guidelines contain an example template licence condition stating that transfers of the licence are prohibited. For high risk applications it is considered inappropriate to allow transfers of licence until the resource has been proven.

9 References – Ministerial guidelines for surface waters

a) Ministerial Guidelines for Licensing Irrigation and Commercial Use
b) Procedures for Registering or Licensing Existing and Commercial Use and Dams
c) Guidelines for Farm Dam Transitional Support Measures
d) Waterway Determination Guidelines
e) Ministerial Guidelines for Managing Diversion Licences

MINISTERIAL GUIDELINES FOR LICENSING GROUNDWATER FOR URBAN WATER SUPPLY PURPOSES

I, Tim Holding, as Minister administering the *Water Act 1989*, issue the following Guidelines.

TIM HOLDING
Minister for Water

Date

1 CITATION

These Guidelines may be cited as the Ministerial Guidelines for Licensing Groundwater for Urban Water Supply.

2 COMMENCEMENT

These Guidelines come into operation on the day on which they are issued.

3 DEFINITIONS & INTERPRETATION

"Act" means the *Water Act 1989;*

"bore construction licence" means a licence issued under section 67 of the Act in respect to the construction, alteration and operation of a bore;

"groundwater licence" means a licence issued under section 51 of the Act for taking and using water from a bore;

"Guidelines" means the Ministerial Guidelines for Licensing Groundwater for Urban Water Supply;

"licensing corporation" means –

a) Grampians Wimmera Mallee Water Corporation; or

b) Goulburn-Murray Rural Water Corporation; or

c) Gippsland and Southern Rural Water Corporation.

4 SCOPE

These Guidelines apply to an application made under:

a) section 51 (1) of the Act for a licence to take and use groundwater for the purposes of urban water supply; and
b) section 62 of the Act to transfer a groundwater licence for use at a different location for the purposes of urban water supply;

These Guidelines do not apply to an application made under:

a) section 67 of the Act for a licence to construct, alter, remove or decommission a bore identified in an existing groundwater licence; or
b) section 58 of the Act for the renewal of a groundwater licence.

5 BORE CONSTRUCTION LICENCES

The licensing corporation may issue a bore construction licence with conditions requiring the licensee to obtain and supply information about the bore and groundwater including but not limited to:

a) downhole geophysical surveys;
b) a bore location survey to an accuracy of at least ±5 metres;
c) a bore elevation survey to an accuracy of at least ±0.05 metres;
d) photograph of the bore headworks and the immediate surrounds;
e) a sample analysis of the groundwater chemistry for major ions and total dissolved salts;
f) a pumping test on the bore and measurement of the:
    a. flow rate from the pumping bore;
    b. water levels in the pumping and any observation bores; and
    c. field electrical conductivity and temperature of groundwater extracted.

The licensing corporation may issue a bore construction licence with conditions relating to conduct of a pumping test, including but not limited to:

a) requirements for the disposal of the pumped discharge and the laying of pipelines according to the requirements of any approval authority;
b) selection of the discharge point to minimise the impact to the environment and to exclude the possibility of recharging the aquifer;
c) a requirement for the pumping test to be designed by a qualified hydrogeologist or engineer; or
d) the type of pumping test, the pumping rate and minimum duration for example:
    a. constant rate test, pumping for at least 3 days followed by period of recovery for groundwater licence applications seeking to extract less than 100ML per year;
    b. constant rate test, pumping for at least 7 days followed by period of recovery for groundwater licence applications seeking to extract between 100ML and 400ML per year; or
    c. constant rate test, pumping for at least 14 days followed by period of recovery for groundwater licence applications seeking to extract greater than 400ML per year.

The licensing corporation may issue a bore construction licence with conditions, requiring the licensee to undertake measures to protect surface waters and the riverine environment, provide reports and compensate other authorised groundwater users adversely impacted.

6 GROUNDWATER LICENCES

The licensing corporation may require the groundwater licence application to contain a groundwater assessment report. An example of the type of information required for a groundwater assessment report is contained in Appendix A.

In cases where there is lack of knowledge or uncertainty about the yield of the target aquifer and/or there are potential adverse impacts from proposed groundwater extraction the licensing corporation may:

a) issue a groundwater licence for a short term (not greater than three years) to allow productive use of the groundwater taken while further groundwater monitoring is undertaken to test the groundwater resources; and/or

b) issue the groundwater licence with conditions, as shown in the model groundwater licence in Attachment B, requiring the licensee amongst other things to:
    a. undertake groundwater monitoring programs;
    b. undertake measures to protect surface waters and the riverine environment;
    c. provide annual reports;
    d. compensate other authorised groundwater users adversely impacted; or
    e. provide information from which to assess the renewal of the licence.

APPENDIX A - INFORMATION REQUIREMENTS FOR GROUNDWATER ASSESSMENT REPORTS

1 Aim

This document provides a guide for the preparation of groundwater assessment reports.

2 Purpose of the groundwater assessment report

The groundwater assessment report is a collection of basic information about the groundwater at the proposed groundwater extraction site, a risk assessment of impacts on existing groundwater users and the environment; and proposed monitoring and protection programs to assist in identifying and dealing with any risks.

The licensing corporation refers to the groundwater assessment report when considering an application for a groundwater licence.

3 Data collection

Groundwater assessment reports primarily rely on existing information sourced from databases and publications.

The groundwater assessment report is to include the results of the pumping test at the proposed site and the site inspection of any neighbouring groundwater users and interconnected streams.

Extensive field studies such as detailed environmental studies, or surface – groundwater interaction studies, or complex modelling are not required as part of a short-term licence, but may be required if considering an application for a long-term licence.

4 Report structure

The information required in a groundwater assessment report will depend on the proposed extraction volume, the environmental features and the potential to impact other groundwater users. Small extraction volume proposals (say less 100ML/yr) will be simple, larger extraction volume proposals have larger impact area therefore larger study area, for instance:

Licence application	Groundwater assessment report study area
< 100 ML/yr	0.5 km radius from production site
100 – 400 ML/yr	1.5 km radius from production site
> 400 ML/yr	4km radius from production site or a groundwater management area

Where information is not available, it should be noted in the report with reasons.

All data gaps, sources of uncertainty and assumptions should be quantitatively estimated or described. Uncertainties could be associated with aquifer parameters, model fluxes (i.e. recharge rates), or a lack of understanding of groundwater surface water interaction processes.

5 Contents of groundwater assessment reports

5.1 Part 1: Study area

Description of the area of likely impact and size of study area.

5.2 Part 2: Background information

Site location map

a) Map or photocopy of the study area with the following features:
b) north point;
c) Australian map grid zone, northing and easting;
d) indication of topography.

Groundwater management arrangements

a) General information relating to the site including:
    a. whether it is within a groundwater management area;
    b. permissible consumptive volume;
    c. existing licensed allocations; and
    d. any groundwater management plan operating in the area.

5.3 Part 3: Groundwater setting

a) stratigraphy;
b) potentiometric levels;
c) groundwater salinity at site;
d) pumping bore locations;
e) locations of licensed allocations and domestic and stock bores;
f) hydraulic conductivity and storage parameters of target aquifer; and
g) summary of pumping test report.

5.4 Part 4: Proposed groundwater extraction and risk assessment

Description of the location of each of the proposed extraction bores, depth of bores, proposed yields and timing of extraction.

Assessment of changes in water level and/or aquifer storage over both short and long term (1 month, 6 month, 1 year, 3 year timescales) using an analytical model (i.e. steady state).

Description of the potential impacts of predicted water level changes arising from extraction and the significance of these on existing groundwater users, waterways, groundwater dependent ecosystems or changes to water quality.

5.5 Appendix 1 – Bore Data

a) downhole geophysical logs;
b) bore location coordinates;
c) bore elevation;
d) bore construction diagram;
e) photographs of the bore showing headworks and the immediate surrounds; and
f) chemical analysis of water samples.

5.6 Appendix 2 - Pumping Test Report

a) data obtained from the test;
b) determination of hydraulic parameters; transmissivity and storativity of the target aquifer and aquitards;
c) plots of drawdown curves.

5.7 Appendix 3 - Groundwater Monitoring and Protection Programs

Description of the management programs designed to measure the extraction of groundwater, monitor the behaviour of the groundwater, protect the aquifer against salinisation and protect environments dependent on the interaction between groundwater and surface water. Suggested programs are:

a) Water level monitoring program which:
    a. Identifies the location and purposes of all observation bores and other existing bores;
    b. details of the requisite monitoring regimes;
    c. provides a demarcation of the predicted area of influence of the bore on the aquifer; and
    d. predicts water level trajectories and residual drawdowns based on intended extraction rates, aquifer characteristics and recharge mechanisms.
b) Groundwater extraction monitoring program which:
    a. Requires the installation of water meters;
c) Groundwater salinity protection program which:
    a. Details the location of representative groundwater sampling points and the associated monitoring regimes;
d) Surface water and riverine environment protection program which:
    a. Details the location of representative groundwater sampling points, associated monitoring regimes and trigger levels for review.

APPENDIX B - MODEL LICENCE TO TAKE AND USE GROUNDWATER

WATER ACT 1989

SECTION 51

GROUNDWATER LICENCE NO : […….]

(LICENCE TO TAKE AND USE GROUNDWATER FROM A BORE)

[*LICENSING CORPORATION NAME* **]AUTHORISES:**

[LICENSEE NAME & ADDRESS]

to take and use groundwater from the bore or bores specified in the First Schedule for the purpose and subject to the conditions specified in the Second Schedule appended to this licence.

This licence is valid for […….**years]** and expires on [**date]**.

Signed :

Authorising Officer: ……

Date : ……

All communications are to be addressed to:

[LICENSING CORPORATION NAME &

ADDRESS]

FIRST SCHEDULE

1.	Type of use for which water is to be taken.	
2.	Maximum volume of water that may be taken in any year.	
3.	Maximum volume of water that may be taken in any day.	
4.	Description of land on which the water may be used.	
5.	Bores from which water may be taken.	***Bores to be added during the period of the licence, subject to normal bore construction licensing requirements.***
6.	Authorised use from each licensed bore.	

SECOND SCHEDULE

1 GROUNDWATER MONITORING AND PROTECTION PROGRAMS

The licensee must develop and implement management programs to measure the taking of groundwater, monitor the behaviour of the groundwater, protect the aquifer against salinisation and protect environments dependant on the interaction between groundwater and surface water. The required programs are a:

- Water level monitoring program;
- Groundwater extraction monitoring program;
- Groundwater salinity protection program; and
- Surface water and riverine environment protection program.

The requirements for each program are described in more detail in the following clauses.

1.1 Water level monitoring program

1.1.1 Infrastructure and equipment installation and maintenance

The licensee must install observation bores at appropriate locations to monitor the aquifer response to the extraction of groundwater permitted by this licence; and at points where there may be impacts on other groundwater users or interaction between surface water and groundwater.

The licensee must ensure that the headworks of all observation bores referred to in the water level monitoring program are properly maintained, including the following:

- an annual inspection to ascertain the condition and maintenance requirements for headworks;
- repair and/or replacement of damaged or worn headworks components **within …….. days of establishing the need for repair/replacement**; and
- maintain a record of all maintenance work undertaken on the headworks.

1.1.2 Monitoring frequency

The licensee must undertake water level monitoring in accordance with the following:

- the frequency of the initial monitoring program will be **.....** commencing **on the first day of pumping** and continuing **for ..... weeks**;
- the frequency of the ongoing monitoring program will be **.....** commencing **on completion of the initial monitoring program** and continuing **until expiry of this licence**;

1.1.3 Reporting requirements

The licensee must prepare and submit to the licensing corporation, in a format suitable to facilitate the upload of information to the state groundwater database, reports on the water level monitoring program, which document the following:

- plots of bore hydrographs depicting the water levels for each bore listed in the program from when monitoring first commenced;
- contour maps depicting residual drawdown for each incremental reporting period and for the entire period since the commencement of monitoring;
- details of any bore failure determined from the inspections of headworks condition during the reporting period;
- details of any abnormal water level readings during the reporting period;
- details of any issues arising from the monitoring results, including significant variations to predicted water level trends and associated recommendations.

The licensee may prepare recommendations for any changes to the water level monitoring program and to the First Schedule based on monitoring results.

In preparing the report, the licensee must comply with any technical and procedural guidelines provided by the licensing corporation.

1.2 Groundwater extraction monitoring program

1.2.1 Infrastructure and equipment installation and maintenance

The licensee must install water meters to measure the volume of groundwater extracted from each of the bores listed in the First Schedule. The licensee must install a meter that complies with any national metering and installation standards adopted from time to time. The licensee must refer to the licensing corporation for the appropriate meter type.

The licensee must ensure that all meters referred to in the First Schedule are:

- regularly inspected to ascertain the condition and maintenance requirements;
- tested for accuracy on an annual basis;
- recalibrated or replaced if the meter is found to be outside the acceptable range of accuracy **within ..... of testing**;
- replaced within 30 days if found to be damaged.

A record of all maintenance work undertaken on the meters is to be maintained by the licensee.

1.2.2 Monitoring frequency

The licensee must ensure that all meters referred to in the First Schedule are read in accordance with the following:

- the frequency of the initial meter reading program will be **.....** commencing **on the first day of pumping** and continuing **for ..... weeks**;

- the frequency of the ongoing meter reading program will be **.....** commencing **on completion of the initial monitoring program** and continuing **until expiry of this licence**; and

1.2.3 Reporting requirements

The licensee must prepare and submit to the licensing corporation reports on the groundwater extraction monitoring program, which document the following:

- details of any meter accuracy or maintenance problems established during the reporting period;
- plots depicting water use from each bore and for the entire bore field from when monitoring first commenced.

The licensee may make recommendations for any changes to the groundwater extraction monitoring program and to the First Schedule based on monitoring results.

In preparing the report, the licensee must comply with any technical and procedural requirements of the licensing corporation.

1.3 Groundwater salinity protection program

1.3.1 Monitoring frequency

The licensee must undertake salinity monitoring in accordance with the following:

- the frequency of the initial salinity monitoring program will be **.....** commencing **on the first day of pumping** and continuing **for ..... months**;
- the frequency of the ongoing salinity monitoring program will be **.....** commencing **on completion of the initial monitoring program** and continuing **until expiry of this licence**; and

1.3.2 Reporting

The licensee must prepare and submit to the licensing corporation, in a format suitable to facilitate the upload of information to the state groundwater database, reports on the groundwater salinity protection program, which document the following:

- plots of groundwater salinity levels at each sampling point listed in the program from when monitoring first commenced;
- contour maps depicting salinity trends for each incremental reporting period and for the entire period from when monitoring first commenced;
- details of any abnormal salinity level readings during the reporting period; and
- details of any issues arising from the monitoring results, including significant variations to predicted salinity trends and associated recommendations

The licensee may make recommendations for any changes to the groundwater salinity protection program and to the First Schedule based on monitoring results.

In preparing the report, the licensee must comply with any technical and procedural requirements of the licensing corporation.

1.4 Protection of surface water and riverine environment

1.4.1 Environmental Monitoring

The licensee must undertake environmental monitoring in accordance with the following:

- the hydraulic connectivity between the surface water and groundwater in the vicinity of the **river** must be maintained, with a gradient of groundwater flow towards the river, as measured at **……..observation bore(s)**; and
- the maximum allowable drawdown will be at a water level in **observation bore** of **mAHD,** which represents an effective decline of **…….m** from the current static water level.

1.4.2 Reporting

The licensee must prepare and submit to the licensing corporation, in a format suitable to facilitate the upload of information to the state groundwater database, reports on the environment protection program, which document the following:

- all recorded water levels in **observation bore(s)** since commencement of pumping;
- plots depicting the change in hydraulic connectivity during each incremental reporting period and for the period since the commencement of pumping;
- projections of water table decline for the following reporting period;
- proposed management measures and/or interventions to arrest the decline in water level if it is found that the water table could reach the above mentioned trigger level.

The licensee may make recommendations for any changes to the environment protection program and to the First Schedule based on the findings from assessment of conditions over the reporting period.

In preparing the report, the licensee must comply with any technical and procedural requirements of the licensing corporation.

2 PREPARATION AND REVIEW OF PROGRAMS AND REPORTS

2.1 Modification to programs

The licensee, with the approval of the licensing corporation, may modify the programs listed in clause 1 of the Second Schedule.

Should the licensing corporation at any time consider that a program listed in clause 1 of Second Schedule be deficient, it may require the licensee to modify the program accordingly.

2.2 Annual reporting (annual operation report)

The licensee must submit to the licensing corporation reports on the programs listed in clause 1 and described in clauses 1.1.3, 1.2.3, 1.3.2 and 1.4.2 of Second Schedule for the following reporting periods:

- **..... months** after the date of issue of this licence; and
- **.....** (annual operation report) thereafter **until expiry of this licence**.

The licensee must ensure that the reports are submitted to the licensing corporation within sixty days of the end of each reporting period.

3 COMPENSATION OF OTHER AUTHORISED WATER USERS

If the taking of water under this licence materially and adversely affects any existing authorised user of water, the licensee must compensate that person by providing:

- an alternative water supply at the cost of the licensee; or
- financial compensation in a manner agreed between the parties.

The licensee must not materially affect any existing authorised user of water until compensation arrangements are put in place. To this end, the licensee must monitor all potentially impacted domestic and stock bores in the monitoring program outlined in clause 1.1 of the water level monitoring program.

The licensee must advise the licensing corporation of the persons to whom compensation has been made.

4 GOOD PRACTICE

The licensee must implement the requirements of this licence in accordance with contemporary industry standards, protocols and regulatory requirements.

Where this licence requires the licensee to undertake an action on an annual, quarterly, weekly or other periodic basis, the licensee must undertake the action so that as far as reasonably possible a regular and evenly-spaced pattern is achieved.

5 POLLUTION

The licensee must not pollute any groundwater through the spillage of fuel or lubricant or any other matter used in connection with works and appliances.

6 CHARGES

The licensee must pay the following charges under this licence when requested by the licensing corporation:

- the standard fee set by the licensing corporation for a licence issued under section 51 of the Act to take and use groundwater; and
- the standard fee set by the Licensing corporation for a licence issued under section 67 of the Act to operate works to take and use groundwater.

7 FURTHER INFORMATION

If required by the licensing corporation, the licensee must provide to the licensing corporation within 14 days such further information as reasonably required to demonstrate that the licensee is complying with the requirements of this licence.

8 TRANSFER OF LICENCE

Temporary or permanent transfer of this licence or part of this licence to another owner is not permitted.

9 RENEWAL OF LICENCE

To facilitate the renewal of this licence, the licensee should, no later than 6 months prior to the expiry of this licence,

- advise the licensing corporation of intentions to apply for renewal of the licence and the nature of the renewal that is likely to be sought; and
- request the licensing corporation to advise of the form and manner to be used in applying for renewal of the licence and the information to be contained in the application review report. The type of information that the review report may address includes the following:

a) a review of the behaviour of the groundwater system from the commencement of pumping;

b) summaries and interpretation of any scenario testing conducted using a hydrogeological model;

c) an assessment of the impacts on groundwater;

d) any recommended parameters for the future taking of groundwater under this licence that will ensure the protection of the groundwater resource, the environment, or other users dependent on groundwater;

e) any proposed changes to the programs listed in the Second Schedule; and

f) any proposed changes to the conditions listed in the First Schedule.

10 DEFINITIONS

In this licence:

"Act" means the *Water Act 1989*;

"business days" means days that the Licensing corporation's office at location is open for normal business and excludes weekends and public holidays;

"licensing corporation" means the ..... Corporation trading as XXX

"days" means calendar days unless specifically stated otherwise;

"domestic and stock use" has the same meaning as in section 3 of the Act;

"year" means a period of 12 months commencing 1 July.

Appendix B Base Case Monitoring Program and Risk Assessment

Purpose of Monitoring	
Defining Processes	Evaluating impacts
Green: Water table decline	Green: Stress on terrestrial GDE
Grey: Stream flow decline	Grey: reduced stream flow availability and quality
Blue: Drying of PASS	Blue: Stress on aquatic GDE
Orange: water quality decline – streams	Orange: Increased fire risk
Purple: water quality decline –	Purple: reduced groundwater

Additional controls (recommended activity/ies)
White: No change
Grey: Analysis using existing data
Blue: Analysis using existing data with site investigation component
Orange: Analysis using new data
Purple: Installation of new monitoring site or revision of existing program

A	B	C	D	E	F	G	H	I	J	K		L	M
Activity #	Monitoring activity or assessment	Purpose of Monitoring		Specific issue	What is the monitoring activity trying to answer?	Gap in current prog.	Prelim. risk ranking	Additional controls (recommended activity/ies)	Residual Risk Ranking	Timing for implementation		Ongoing activity	Interdependencies
		Defining Processes	Evaluating impacts							Dec-13	13/14	Duration Sampling frequency Review frequency	
G1	Historical and future pumping rates at bore field			Monitor change in aquifer pressures and flow directions due to pumping or other causes	Is BW's pumping/extraction the only cause of changes in aquifer pressures and/or flow directions.	None	L: L C: L R: N	No change	L	-	-	Ongoing Monthly Yearly	-
G2	Aquifer water levels in confined areas					None	L: M C: M R: M	Liaise with DSE to ensure current DSE program is kepttify at the current number of bores and sampling frequency, bores are maintained, and will be replaced if they are decommissioned.	L	✓	-	Ongoing Monthly Yearly	-
G3a	Aquifer water levels in unconfined areas			To determine if existing bores in unconfined areas are monitoring the water table (and not confined sub-aquifer)	Are water levels collected in the unconfined areas representative of the water table or a confined sub-aquifer? This is important because it may man current (and future) impacts of pumping on streamflow are less than currently assumed, and impact on current and future trigger levels.current and future trigger levels, and predicted impacts on stream flow and aquatic ecology of B. Ck.	Partial	L: H C: M R: M	• Check if current bores are in confined part of aquifer (include DSE bores if additional to BW bores) ➢ Review bore and geophysical logs to check potential for aquitards within the aquifer ➢ Use pumping test analysis methods on existing water level and pumping data to estimate degree of confinement ➢ Identify sites for additional bores if existing bores shown not to be representative of the water table	L	✓	-	-	
G3b								Drill additional bores if required at existing sites (assume 5 sites)		✓	✓	-	-
G3c								Monthly monitoring of water levels in new bores	L	-	✓	Ongoing Monthly yearly	
G4a				To better define changes in aquifer water levels and flow directions in upper reaches of B. Ck are caused by pumping or other causes	Are aquifer water levels and groundwater flow direction in the upper reaches of B.Ck caused/being impacted by BW's pumping? Current number of bores in this area is small so the effects of pumping on this area is not well defined.	Partial	L: M C: M	Check to see if there are any unused DSE bores in this area that could be used, and if there is any current DSE monitoring that could be used or augmented.	L	✓	-	-	-
G4b							R: M	Drill additional 5 bores if required		✓	✓	-	-
G4c								Monthly monitoring of water levels in new bores	L	-	✓	Ongoing Monthly Yearly	
G5a				To determine water table depth at monitored vegetation sites	To determine if the existing vegetation sites are groundwater dependent ecosystems. This can be determined by monitoring the water table to see if the water table is shallow enough for existing veg monitoring sites to be groundwater dependent.	Large	L: H	Identify vegetation monitoring sites that require nearby bore for water table depth monitoring	L	✓	-	-	T1a, T2a, T3a, G7a
G5b							C: M R: H	Drill water table monitoring bores (assumed to be 4 bores) • Each bore to be geophysically logged and tested to determine aquitard properties		✓	✓	-	
G5c								Bores to be monitored for water levels on monthly basis	L	-	✓	Ongoing Monthly Yearly	
G6a				Provide baseline water table data that is not influenced by pumping	To demonstrate natural aquifer performance which is not influenced by BW's pumping. This can be done trhough collecting baseline water table data which is outside the cone of influence casued by pumping.	Large	L: H	Review groundwater level hydrographs and existing groundwater model outputs to identify existing bores or sites for baseline monitoring	L	✓	✓	-	
G6b							C: M	Drill baseline monitoring bores (if required). Assume 2 bores		-	✓	-	-
G6c							R: H	Bores to be monitored for water levels on monthly basis		-	✓	Ongoing Monthly	

																					Yearly	
G7a	Aquitard water levels										Water table in aquitard at monitored vegetation sites	To determine if the existing vegetation sites are groundwater dependent ecosystems. This can be determined by initaillly measuring the current water table depth followed by monitoring to determine if the water table is affected by pumping.	Large	L: H	· Identify aquitard vegetation monitoring sites that require nearby bore for water table depth monitoring	L	✓	-	-	T1a, T2a, T3a, G5a
														C: M	➢ Bore sites to be selected in conjunction with item G5a							
G7b														R: H	• Drill water table monitoring bores (assumed to be 4 bores). Each bore to be geophysically logged and tested to determine aquitard properties		-	✓	-	
G7c															Bores to be monitored for water levels on monthly basis	L	-	✓	Ongoing Monthly Yearly	
G8a											Direction of groundwater flow and water table depth in aquitard (particularly for flow to/from streams and wetlands)	To understand how much groundwater is contributing to base flows in streams and wetlands in the area where the aquitard is present. The direction of groundwater flow and depth to water table will assist with understanding where streams are losing and gaining (groundwater surface water connectivity) and water table depth will give an indication of the volume released. this data, along with other water level data from the aquitard, will significantly improve the relaibility of impacts predicted by the groundwater model.	Large	L: H	· Prepare estimate of water table depth in the aquitard area (using existing model) as a guide		✓	-	-	
														C: M	• Identify 8 sites for drilling 10 bores							
														R: H	• Sites to be located at increasing distance from bore field and in a manner that enables direction of flow to/from Barwon River to be identified and the effect of different aquitard thicknesses on changes to water table depth.					
G8b															• Drill bores ➢ 8 bores to be drilled to water table depth (assume average depth of 30 m) ➢ 2 bores to be drilled to middle of aquitard (assume 100 m depth), and nested with 2 water table depth bores ➢ Each bore to be geophysically logged and tested to determine aquitard properties	L	✓	-	-	G7b
G8c															Bores to be monitored for water levels on monthly basis		-	✓	Ongoing Monthly Yearly	G7c
G9a											Provide baseline water aquitard table data that is not influenced by pumping	To demonstrate natural aquitard performance in areas not influenced by BW's pumping. This can be done trhough collecting baseline water table data which is outside the cone of influence.	Large	L: H	Identify sites that are beyond the current boundaries of the aquifer drawdown, and are not expect to be influenced by pumping using existing groundwater model.	L	✓	-	-	
G9b														C: M	Drill baseline monitoring bores (if required). Assume 2 bores		-	✓	-	
G9c														R: H	Bores to be monitored for water levels on monthly basis		-	✓		
G10a	Groundwater modelling										Predict impacts of pumping and separate pumping from drought	Modelling will help differentiate the impacts of groundwater pumping against natural environmental conditions such as drought. This will address the community's concern about groundwater management because it will clarify if groundwater is causing or exacerbating natural drought conditions. The model could also be used to evaluate the impactsof different pumping scenarios, incuding ASR, and identify/modify suitable triggers for ongoing borefield operation.	Large	L: H	• Refine and re-calibrate existing groundwater model using data obtained from all items above.	L	-	✓	5 years	
														C: M	• Use model to differentiate the effects of pumping from reduced rainfall on water table depth and stream flow.				Yearly	
														R: E	• Use model to predict changes to water table depth and stream flow for typical bore field usage (ie during low rainfall periods).				yearly	
															• Use model results as inputs to GDE impact assessments					
G10b												Update model and impact with new data			Revise and recalibrte model and predicted impacts using new data from previous 12 months of monitoring					
G11a	Perched water table levels in unconfined area										Differentiation of regional water table levels from perched water table (are terrestrial GDE supported by perched water table)	If perched aquifers can be identified then, depending on their location, it could be shown that groundwater pumping has a lesser impat on vegetation and streamflow than the current concepotual model indicates. At the moment the current conceptual model assumes vegetation is accessing the same groundwater that is being pumped (ie there is no perched water table). If this is shown not to be the case then the area impacted or total impacts would be less.	Large	L: H	• Identify drilling sites to identify perched water table	M	✓	-	-	T1a, T2a
G11b														C: L	• Drill 6 sites using augers (ie without water) to a depth of 20 m or shallower.		✓	✓	-	-
														R: M	➢ Bores to be to geophysically logged (neutron probe or similar) to identify presence/absence of perched water table					
															➢ If perched water table identified, then construct bore with piezometer to monitor perched water table					
G11c															Bores to be monitored for water levels on monthly basis		-	✓	Ongoing Monthly Yearly	
G12a	Evapotranspiration from the water table										Improve estimates of stream flow depletion and water table decline by improving our estimates of ET, aquitard leakage, and rainfall in recharge areas	These activities (measuring ET, leakage of aquitard and recharge) will ensure that there is more accurate data to calculate the water balance. This will help refine estimates of stream flow depletion and water table decline (which may impact volumetric entitlements associated with licence conditions).	Large	L: H	Use current model to check sensitivity of stream flow impacts to ET	M	✓	-	-	
G12b														C: M	Identify ET using SEBEL		-	✓	-	
G12c														R: H	Upgrade and re-calibrate groundwater model		-	✓	-	
G13a	Leakage characteristics of the aquitard												Large	L: H	• Analyse existing bore field pumping data and observation water levels to obtain initial estimates of stream bed leakage characteristics for Boundary Creek	L	✓	-	-	

															C: M	• Use current model to check sensitivity of stream flow impacts to aquitard characteristics						
G13b															R: H	• Sample and test cores from bores drilled into aquitard		-	✓	-		G7b, G8b, G9b
																• Carry out slug tests in bores drilled into aquitard						
G13c																Upgrade and re-calibrate groundwater model		-	✓	-		
G14a	Measurement of rainfall in groundwater recharge area													Partial	L: L	• Assess the suitability of the Pennyroyal Ck rain gauge as representative of rainfall on the main groundwater recharge area	L	✓	-	-		
															C: M	• Identify most suitable location for rain gauge on recharge area (if required)						
G14b															R: L	Establish automatic rain gauge on recharge area (if required)		✓	-			
G14c																Ongoing monitoring of rain gauge		-	✓	Ongoing Hourly Yearly		
G15a	Leakage characteristics of B. Ck river bed											Improve estimates of stream flow depletion by improving our understanding of streambed leakage and by direct measurement	To understand the rate at which water transfers between the stream bed of B. Ck and the aquifer - this will improve the relaibility of predicted chnages to streamflow due to pumping and/or drought, and and help determine establish whether current environmental releases are worthwhile/benefiting the environment/water dependent ecosystem.	Large	L: H	• Analyse existing bore field pumping data and observation water levels to obtain initial estimates of stream bed leakage characteristics for Boundary Creek	M	✓	-	-		
															C: L	• Use current model to check sensitivity of stream flow impacts to ET						
G15b															R: M	Identify suitable existing bores near Boundary Creek to conduct two short duration (48 to 72 hour) pumping tests in close proximity to the stream bed of Boundary Creek		-	✓	-		
G15c																Upgrade and re-calibrate groundwater model		-	✓	-		
G16a	Direct measurement of flow gain/loss in B. Ck and other streams/rivers													Large	L: H	Evaluate suitability current gauge location, sensitivity, sampling frequency, and parameters for measurement of flow and base-flow trends	L	✓	-	-		
G16b															C: M	Install new and/or upgrade existing gauges		-	✓	-		
G16c															R: H	Operate gauges		-	✓	Ongoing Hourly Yearly		
T1a	Identify condition of terrestrial ecology – unconfined area											Select suitable monitoring sites	Are the veg monitoring sites representative of local veg, and veg that is sensitiveto chnages in the water table depth.	Large		• Review DSE ecological veg class (EVC) modelling	L	✓				T2a, T3a
																• Conduct Aerial Photography Interpretation • Identify potential monitoring sites • Field survey of potential monitoring sites • Validate against hydrogeological data						
T1b																		-	✓			T2b, T3b, G11b
T1c																Implement monitoring		-	✓	5 years Yearly Yearly		T2c, T3c
T2a												Determine extent and type of perched wetlands	Are veg sites that are sensitive to groundwater using perched groundwater rather than the regional water table. Perched groundwater is much less likely to be affected by pumping, so it is important to identify if perched wtlands are present.	Large		• Review DSE ecological veg class (EVC) modelling	L	✓				T1a, T3c
																• Conduct Aerial Photography Interpretation • Identify potential sites to evaluate dependence on perched WT						
T2b																Field survey of potential monitoring sites		-	✓			T1b, T3b, G11b
T2c																Implement monitoring		-	✓	5 years Yearly Yearly		T1c, T3c
T3a												Identify suitable reference sites		Large		• Determine appropriate criteria for Reference Sites	L	✓				T1a, T2a
																• Undertake API and preliminary field surveys to locate areas for Reference Sites						
T3b																Field survey of potential monitoring sites		-	✓	-		T1b, T2b
T3c																Implement monitoring		-	✓	5 years Yearly Yearly		T1c, T2c
T4a	Identify condition of terrestrial ecology – aquitard area											Select suitable monitoring sites	As per T1a, b, c.	Large		• Review DSE ecological veg class (EVC) modelling	L	✓		-		T5a, G7b
																• Conduct Aerial Photography Interpretation • Identify potential monitoring sites • Field survey of potential monitoring sites • Validate against hydrogeological data						
T4b																		-	✓	-		T5b
T4c																Implement monitoring		-	✓	5 years Yearly Yearly		T5c
T5a												Identify suitable reference sites	As per T3a, b, c.	Large		• Determine appropriate criteria for Reference Sites	L	✓		-		T4a, G7b
																• Undertake API and preliminary field surveys to locate areas for Reference Sites						
T5b																Field survey of potential monitoring sites		-	✓	-		T4b
T5c																Implement monitoring		-	✓	5 years Yearly		T4c

																				Yearly		
A1a	Reach and site selection										We don't know how different reaches within Boundary Creek and other relevant streams are likely to be affected by groundwater pumping, nor do we know their current condition and the other stressors that may affect condition in those reaches.	This is the first step in assessing the aquatic ecology of B. Ck. Results will be used to design how the aquatic ecology will be identified, and where monitoring should be undertaken in A2a, b, and c.	Large	L: E C: H	Desktop review of other studies to determine likely groundwater contributions to different reaches in Boundary Creek and possibly other rivers such as Dividing Creek and West Barwon River and desktop review of hydrological data to determine flow regime in different reaches.	L: M C: M	✓	-	-	Need information on perched versus groundwater fed stream reaches
A1b														R: E	Field visit to divide Boundary Creek and potentially Dividing Creek and West Barwon River into reaches based on land use, physical habitat and flow regulation. Field visit may characterise reaches as potential impact and reference reaches and will select representative assessment and monitoring sites in each reach	R: M				
A2a	Desktop assessment to determine likely values in the study reaches										Identify ecological values in each reach and determine current condition and to compare values and condition between reaches that have different stressors	Identify the current ecological condtion of B. Ck	Partial	L: E	Desktop assessment to determine likely values in the study reaches	L: M	✓	-	-	
A2b	Field survey of fish, macroinvertebrates and water quality in each reach and to confirm values and determine current condition												Large	C: H	Field survey of fish in late spring to confirm values and determine current condition	C: M	✓	-	-	
A2c														R: E	Field survey of macroinvertebrates in spring and autumn to confirm values and determine current condition	R: M	✓	-	-	
A2d															12 month water quality monitoring		✓	-	-	
A3a	Use the FLOWS method to determine minimum flow requirements for aquatic values that we want to maintain or rehabilitate in each target reach										We don't know the specific flows that are required to maintain or rehabilitate aquatic ecology values in Boundary Creek or other rivers	To understand flow requirements to maintain and/or rehabilitate aquatic ecological values in B.Ck (and potentially other creeks and rivers)	Large	L: E	Channel survey at selected sites in each reach	L: M	-	✓	-	
A3b														C: H	Develop hydraulic model for surveyed sites	C: M	-	✓	-	
A3c														R: E	Hydrological analysis for each reach using existing REALM, this may require establishing new flow gauges in selected reaches to collect more reliable flow data	R: M	-	✓	-	
A3d															Environmental flow determination based on flow requirements of target biological values		-	✓	-	Help to know likely changes to stream flow due to groundwater pumping
H1a	Flow gauging in B. Ck.										Assess if current gauge location suitable for measuring total flow and base flow in B. Ck?		Partial	L: H	Evaluate suitability current gauge location, sensitivity, sampling frequency, and parameters for measurement of flow and base-flow trends	L	✓	-	-	G16a
H1b											Identify flow gauge locations on B. Ck for aquatic ecology assessment			C: M	Field visit to divide Boundary into reaches based on land use, physical habitat and flow regulation. Field visit may characterise reaches as potential impact and reference reaches and will select representative assessment and monitoring sites in each reach		✓	-	-	A1a, A1b
H1c											Install new gauge and monitor			R: H	Install new gauge on B. Ck		✓	-	-	G16b
H1d															Monitoring		✓	-	5 years Hourly Yearly	G16c
P1a	PASS and peat assessment in unconfined area										Identify type and extent of peat and PASS in B. Ck catchment		Partial	L: M	Review existing information and identify most likely topographic and hydrogeological settings where peat and PASS may be present	L	✓	-	-	
P1b														C: M	Field survey to collect soil cores for analysis of composition and aid generating potential		✓	-	-	
P1c														R: M	Describe and map extent of peat and PASS		✓	-	-	
P1d											Assess risk of water quality changes to B. Ck		Large	L: H C: M	Model expected changes to B. Ck water quality in response to predicted water table changes and stream flow reduction		✓	-	-	
P1e											Assess fire risk in B. Ck catchment			R: H	Model fire risk in response to predicted water table changes		-	✓		
P2a	PASS and peat assessment in aquitard area										Identify type and extent of peat and PASS in streams in aquitard area		Partial	L: M	Review existing information and identify most likely topographic and hydrogeological settings where peat and PASS may be present	L	-	✓	-	
P2b														C: M	Field survey to collect soil cores for analysis of composition and aid generating potential		-	✓	-	
P2c														R: M	Describe and map extent of peat and PASS		-	✓	-	
P2d											Assess risk of water quality changes to streams in aquitard area		Large	L: H C: M	Model expected changes to water quality in aquitard area streams in response to predicted water table changes and stream flow reduction		-	✓	-	
P2e											Assess fire risk in B. Ck catchment			R: H	Model fire risk in response to predicted water table changes		-	✓	-	

Appendix C Base Case Schedule

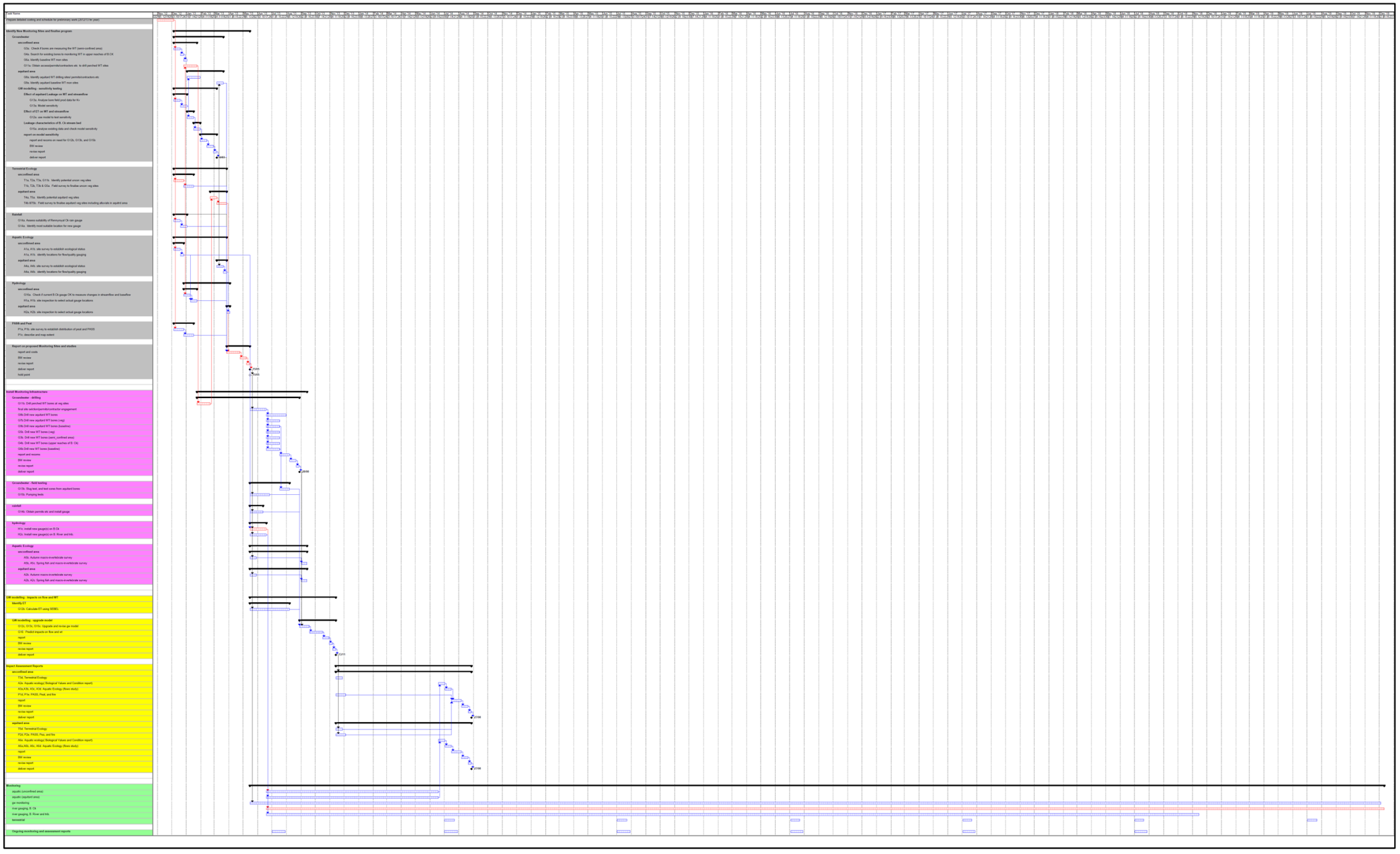
Full Program

grey is preliminary desk top

pink is establishing new monitoring sites

yellow is impact assessments

green is ongoing monitoring)


Task Name
Prepare detailed costing and schedule for preliminary work (2012/13 for year)
Identify New Monitoring Sites and finalise program
Groundwater
unconfined area
G3a. Check if bores are measuring the WT (semi-confined area)
G4a. Search for existing bores to monitoring WT in upper reaches of B.CK
G4a. Identify baseline WT mon sites
G11a. Obtain access/permits/contractors etc to drill perched WT sites
aquitard area
G6a. Identify aquitard WT drilling sites/ permits/contractors etc
G9a. Identify aquitard baseline WT mon sites
GW modelling - sensitivity testing
Effect of aquitard Leakage on WT and streamflow
G12a. Analyse bore field pmd data for Kv
G13a. Model sensitivity
Effect of ET on WT and streamflow
G12a. use model to test sensitivity
Leakage characteristics of B. Ck stream bed
G15a. analyse existing data and check model sensitivity
report on model sensitivity
report and recoms on need for G12b, G13b, and G15b
BM review
revise report
deliver report
Terrestrial Ecology
unconfined area
T1a, T2a, T3a, G11b. Identify potential uncon veg sites
T1b, T2b, T3b & G5a. Field survey to finalise uncon veg sites
aquitard area
T4a, T5a. Identify potential aquitard veg sites
T4b &T5b. Field survey to finalise aquitard veg sites including alluvials in aquitrd area
Rainfall
G14a. Assess suitability of Rennymuir Ck rain gauge
G14a. Identify most suitable location for new gauge
Aquatic Ecology
unconfined area
A1a, A1b. site survey to establish ecological status
A1a, A1b. identify locations for flow/quality gauging
aquitard area
A4a, A5. site survey to establish ecological status
A4a, A4b. identify locations for flow/quality gauging
Hydrology
unconfined area
G16a. Check if current B.Ck gauge OK to measure changes in streamflow and baseflow
R1a, R3a. site inspection to select actual gauge locations
aquitard area
R2a, R2b. site inspection to select actual gauge locations
PASS and Pool
P1a, P1c. site survey to establish distribution of pool and PASS
P1c. describe and map extent
Report on proposed Monitoring Sites and studies
report and costs
BM review
revise report
deliver report
hold point
Install Monitoring Infrastructure
Groundwater - drilling
G11b. Drill perched WT bores at veg sites
final site selection/permits/contractor engagement
G9b.Drill new aquitard WT bores
G9c.Drill new aquitard WT bores (veg)
G9c.Drill new aquitard WT bores (baseline)
G3b. Drill new WT bores (veg)
G3c. Drill new WT bores (semi_confined area)
G4b. Drill new WT bores (upper reaches of B. Ck)
G9b.Drill new WT bores (baseline)
report and recoms
BM review
revise report
deliver report
Groundwater - field testing
G13b. Slug test, and test cores from aquitard bores
G15b. Pumping tests
rainfall
G14b. Obtain permits etc and install gauge
hydrology
H1c. install new gauge(s) on B.Ck
H3c. install new gauge(s) on B. River and trib.
Aquatic Ecology
unconfined area
A3b. Autumn macro-invertebrate survey
A5b, A5c. Spring fish and macro-invertebrate survey
aquitard area
A3c. Autumn macro-invertebrate survey
A2b, A2c. Spring fish and macro-invertebrate survey
GW modelling - impacts on flow and WT
Identify ET
G12b. Calculate ET using SEBS
GW modelling - upgrade model
G12c, G13c, G15c. Upgrade and revise gw model
G12. Predict impacts on flow and wt
report
BM review
revise report
deliver report
Impact Assessment Reports
unconfined area
T3d. Terrestrial Ecology
A2e. Aquatic ecology(Biological Values and Condition report)
A3a,A3b, A3c, A3d Aquatic Ecology (flows study)
P1d, P1e. PASS, Pool, and fire
report
BM review
revise report
deliver report
aquitard area
T5d. Terrestrial Ecology
P2d, P2e. PASS, Pool, and fire
A5e. Aquatic ecology(Biological Values and Condition report)
A5a,A5b, A5c, A5d Aquatic Ecology (flows study)
report
BM review
revise report
deliver report
Monitoring
aquatic (unconfined area)
aquatic (aquitard area)
gw monitoring
river gauging, B. Ck
river gauging, B. River and trib.
terrestrial
Ongoing monitoring and assessment reports

Preliminary Assessments Only