

5.2 Groundwater

5.2.1 Scope of Proposed Monitoring

There is a network of existing groundwater monitoring bores located across the site, illustrated in Figure 5-3. A stratified program of monitoring is proposed, depending upon whether works are occurring in particular catchments, as follows:

- A surveillance baseline monitoring event will be carried out within six months of commencing work for both groundwater levels and chemistry.
- All bores within the site will be sampled on a biannual basis, up to and for 12 months after active construction works are completed in respective catchments.
- Those bores within catchments where there are construction activities occurring, but which are not in close proximity to areas of active construction works, will be sampled on a quarterly basis (by 'active' construction we refer to those works associated with land forming and bulk excavation and filling works, not house construction works which will follow this phase).
- Those bores within catchments where there are construction activities occurring and which are in close proximity (i.e. within 500m) to areas of active construction works will be sampled on a monthly basis.

'Development Works' refers to site establishment activities such as ground preparatory works, drainage works, bulk earthworks, vegetation clearing and grubbing, but does not include construction of residential housing or commercial premises.

5.2.2 Surveillance Baseline

As outlined above, in order to supplement the existing groundwater data set, it is proposed to collect at least one sampling round of data for a complete set of parameters prior to construction. This will involve sampling of the following:

Field Parameters:

- Water level;
- pH;
- Electrical conductivity;
- Temperature; and
- Dissolved oxygen.

Analytical Parameters:

- Major Anions (Alkalinity);
- Major Cations;
- Total nitrogen, Organic N, Ammonia N and NO_x;
- Total phosphorus and filterable reactive phosphorus;
- Soluble sulfate (Cl⁻:SO₄²⁻) ratio;

5.1.9 Summary of Surface Water Quality and Hydrology Monitoring

Table 5-1 Surface Water Quality Monitoring Summary

Monitoring Category	Nature of works	Commencement	Cessation
Freshwater Ambient	- Monthly ambient water quality surveys at eight locations within the site, three each respectively on Bells Creek North and Bells Creek South and two on Lamerough Creek - The following water quality parameters to be measured via a combination of in situ measurements using a pre-calibrated water quality instrument and water sampling and subsequent laboratory analyses: - pH; - Conductivity; - Temperature; - Turbidity; - Dissolved oxygen - Total Suspended Solids; - Total nitrogen, Organic N, Ammonia N and NO_x; - Total phosphorus and filterable reactive phosphorus; - Chlorophyll 'a'; - Iron; and - Aluminium.	6 months ⁴ before development starts in upstream catchments	A minimum of 12 months after all development work has been completed within the respective catchment
Event Based	- Event based water quality samplers will be installed on Bells Creek North and South at the upper and lower boundaries of the Caloundra South site. - Additional event based water quality samplers will be deployed midway along Bells Creek North and South before substantial urban land development works are to commence in the areas upstream of these locations. - These samplers will be triggered by flows in either of the creeks, and will collect composited, flow proportional samples from significant run-off events. These samples will be analysed for the following parameters: - Flow - Total Suspended Solids; - Total Nitrogen; and - Total Phosphorus	6 months ³ before development starts in upstream catchments	12 months after all development work has been completed within the respective catchment
Estuarine EHMP	Two Ecosystem Health Monitoring Program (EHMP) sites within Bells Creek downstream of the development	Immediately	3 years after all development work has been completed on the site
Real Time Turbidity	- Establish real time turbidity monitoring stations at the following locations (five stations in total): - Bells Creek North and South at the lower boundary of the Caloundra South site - Bells Creek North and South at the upper boundary of the Caloundra South site; and - The downstream extent of the development footprint within the Lamerough Creek Catchment	6 months ³ before development starts in upstream catchments	12 months after all development work has been completed within the respective catchment
Load Based	- Two sites will be established within the ultimate development footprint and data collected for a two (2) year period to quantify the quality of run-off from the site, commencing within one year of construction starting elsewhere on the site. - At each site, an event-based stormwater sampler will be installed and stormwater flow and quality data collected from at least 20 representative storms over a two year period. Samples collected will be composited and event mean concentrations for each storm event derived.	As soon as practical	10 representative storms from each of two years are required to be monitored
Treatment Device	- Monitoring will occur for one representative established bioretention system and one representative established wetland system. - Event-based stormwater samplers will be installed upstream and downstream of these devices and stormwater flow and quality data collected from 10 representative storms. - Samples collected will be composited and the event mean concentration for each upstream and downstream sampling site derived such that load reductions can be calculated.	Upon the effective completion of some of the earlier parts of the Northern Residential and Northern Employment precincts	After data have been collected from 10 representative storms
Construction Stage	- Regular (daily and after major rain events) site inspections of all erosion and sediment control measures. - Regular (daily and after major rain events) inspections of areas surrounding construction site to detect and manage any occurrence of sediment deposition off-site. - Rainfall will be recorded at 9am each working day from an installed rain gauge. - All construction activities will be monitored daily for compliance with erosion and sediment control measures. - Turbidity, pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO) will be measured daily within sediment basins within each precinct.	With the commencement of construction works in any precinct	At the completion and stabilisation of 'active' works in any locality.

⁴ As described earlier, weather patterns during this period need to be taken into consideration when the collected data are interpreted

- Nutrients (e.g. Nitrate and nitrite);
- Dissolved metals; and
- PAHs including BTEXN, TPH, TRH.

Information gathered as part of this surveillance monitoring program will update the baseline data sets that have been collected on the site over many years.

5.2.3 Additional Groundwater Monitoring Bores

Additional shallow groundwater bores will need to be installed and included in the overall groundwater monitoring program. These additional monitoring sites (refer Figure 5-3) have been selected on the basis of their proximity to:

- Frog conservation zones and associated Wallum sedgefrog habitat that is to be retained or enhanced on site.
- Upland (control) sites for groundwater levels outside of retained frog habitat areas.
- The downstream reaches of Bells Creek North, Bells Creek South and Lamerough Creek (related to confirming no transport of acidity, dissolved metals or other contaminants off site via groundwater processes).

As shown in Figure 5-3, some of these sites have been co-located with existing bores.

Monitoring will be conducted for the following parameters at all existing and additional bores:

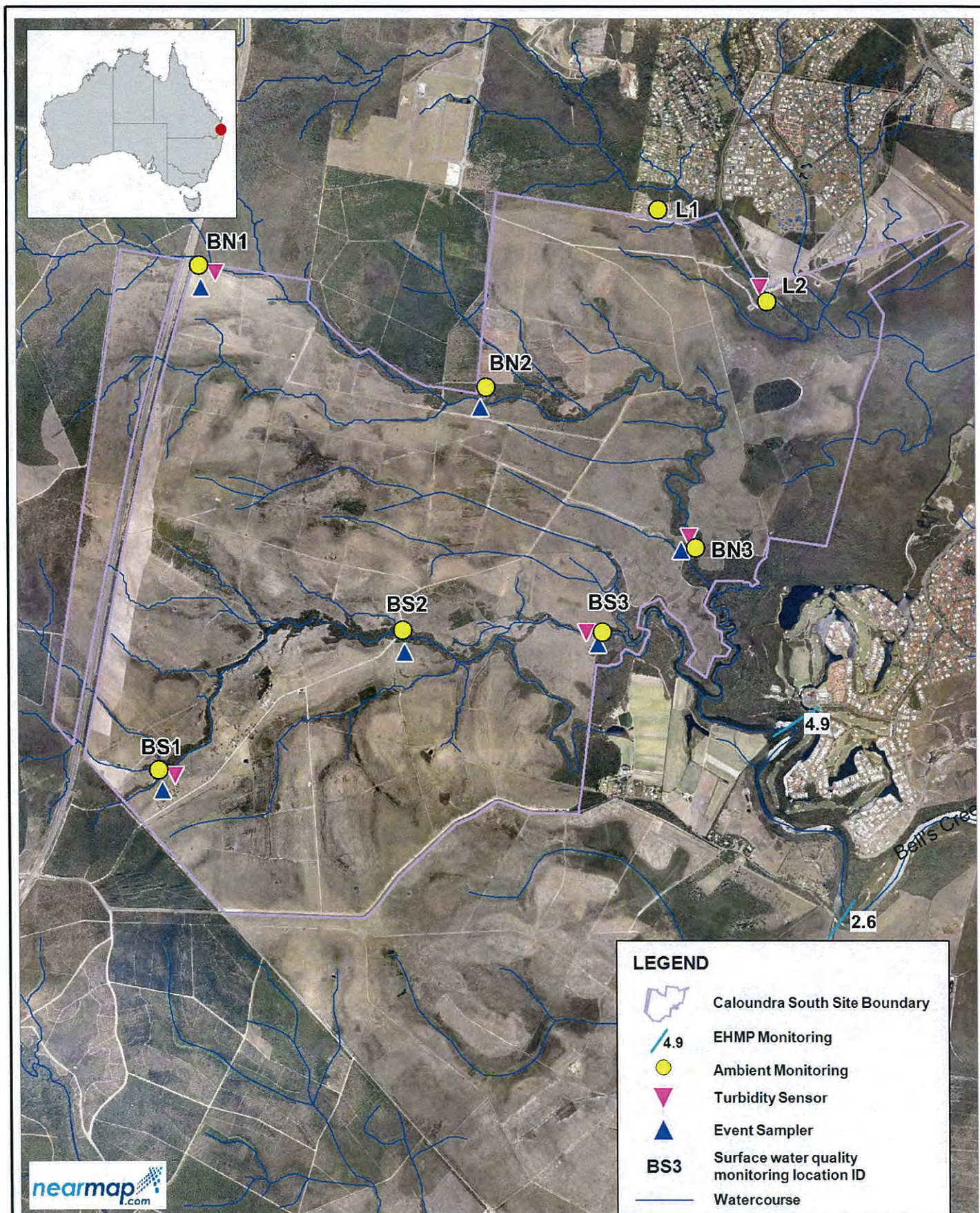
- Water level;
- pH;
- Electrical Conductivity;
- Total nitrogen, Organic N, Ammonia N and NO_x;
- Total phosphorus and filterable reactive phosphorus;
- Dissolved Iron; and
- Dissolved Aluminium.

Water quality testing for heavy metals (cadmium, chromium, copper, nickel, lead, and zinc) will be conducted in association with the aforementioned biannual surveys.

5.2.4 Summary of Groundwater Quality and Hydrology Monitoring

Table 5-2 Groundwater Quality Monitoring Summary

Monitoring Category	Nature of Works	Commencement	Cessation
Surveillance Baseline	- Periodic samples and analysis at groundwater locations on site shown in Figure 5-3 - Field Parameters: - Water level; - pH; - Electrical conductivity; - Temperature; and - Dissolved oxygen. - Analytical Parameters: - Major Anions (Alkalinity); - Major Cations; - Total nitrogen, Organic N, Ammonia N and NO_x; - Total phosphorus and filterable reactive phosphorus; - Soluble sulfate (Cl-SO₄²⁻) ratio; - Dissolved metals; and - PAHs including BTEXN, TPH, TRH.	- A surveillance baseline monitoring event will be carried out within six months of commencing work for both groundwater levels and chemistry; - All bores within the site will be sampled on a biannual basis, - Those bores within catchments where there are construction activities occurring, but which are not in close proximity to areas of active construction works, will be sampled on an annual basis (by 'active' construction we refer to those works associated with land forming and bulk excavation and filling works, not house construction works which will follow this phase); and - Those bores within catchments where there are construction activities occurring and which are in close proximity (i.e. within 500m) to areas of active construction works will be sampled on a monthly basis.	12 months after active construction works are completed in respective catchments
Additional Boreholes	- Additional shallow groundwater bores will need to be installed and included in the overall groundwater monitoring program. These additional monitoring sites (refer Figure 5-3) have been selected on the basis of their proximity to: - Frog conservation zones and associated Wallum sedgefrog habitat that is to be retained or enhanced on site; - Upland (control) sites for groundwater levels outside of retained frog habitat areas; and - The downstream reaches of Bells Creek North, Bells Creek South and Lamerough Creek (related to confirming no transport of acidity, dissolved metals or other contaminants off site via groundwater processes). - Monitoring will be conducted for the following parameters at all existing and additional bores: - Water level; - pH; - Electrical Conductivity; - Total nitrogen, Organic N, Ammonia N and NO_x; - Total phosphorus and filterable reactive phosphorus;; - Dissolved Iron; and - Dissolved Aluminium.	As per surveillance baseline	12 months after active construction works are completed in respective catchments



Title:

Recommended Surface Water Quality Monitoring Locations

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Approx. Scale

Figure:

5-1

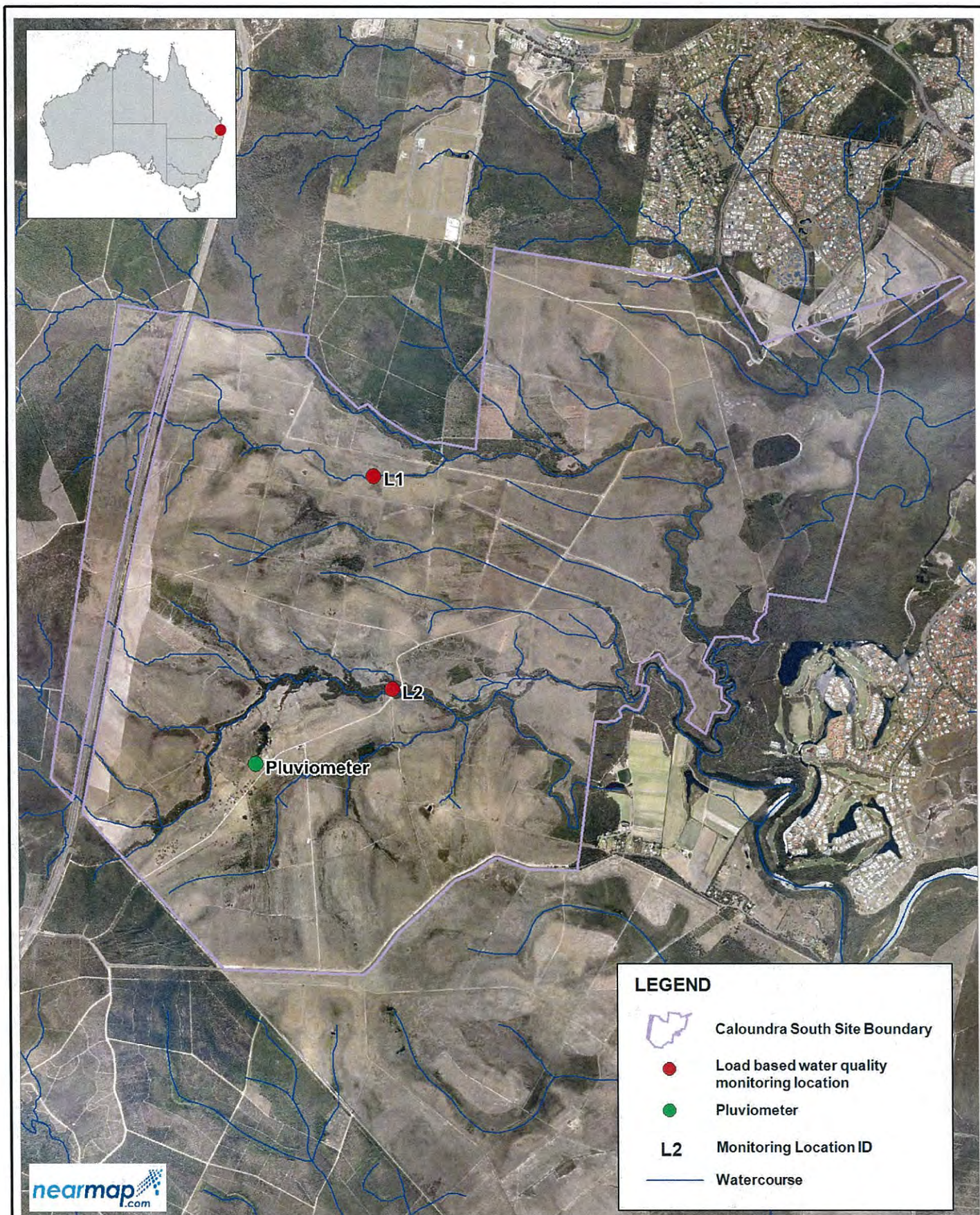
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Title:

Proposed Load Based Monitoring Locations

Figure:

5-2

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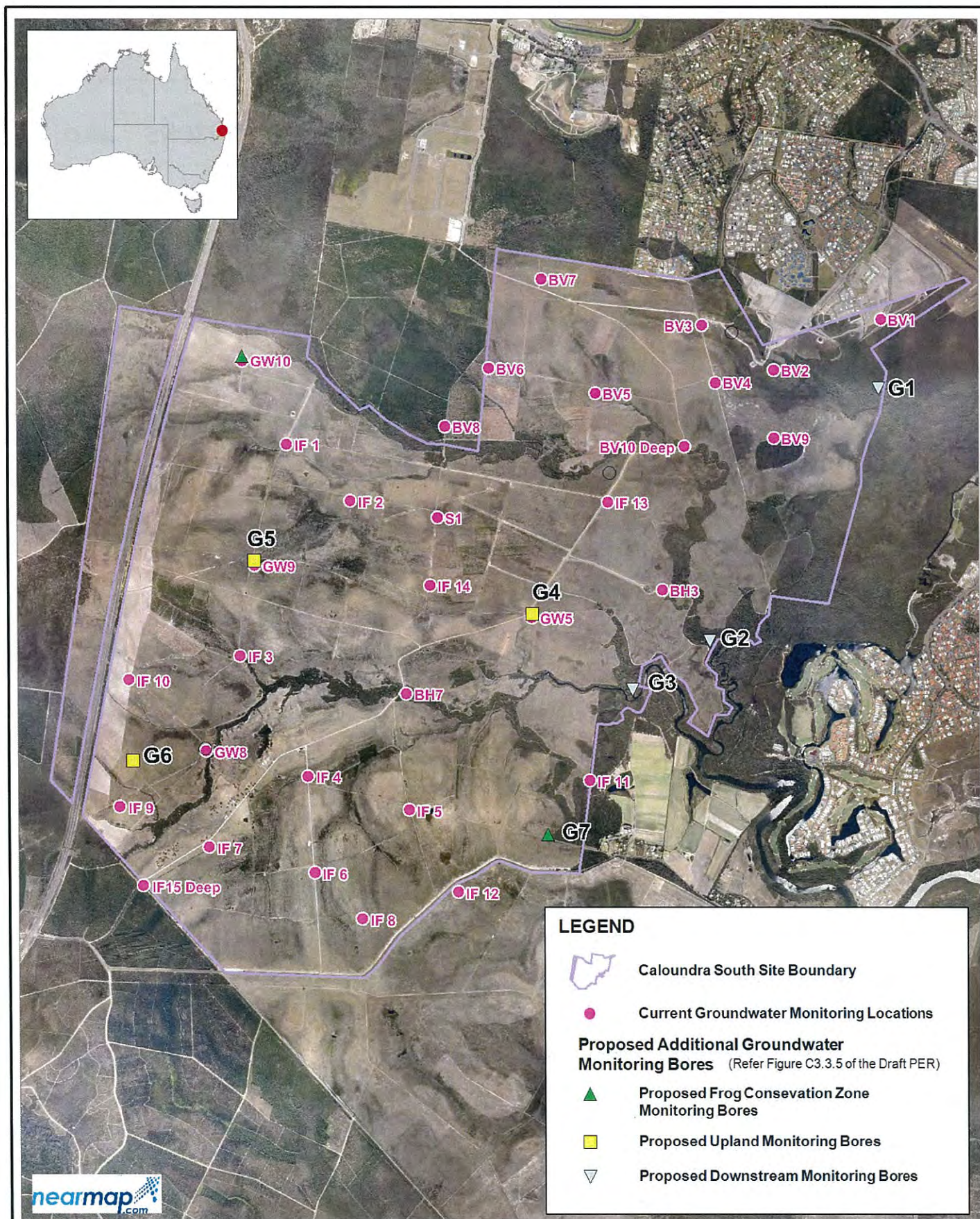
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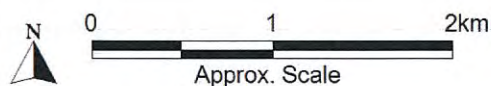


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Groundwater Monitoring Locations

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6 RISK ASSESSMENT OF MODELLING, ASSUMPTIONS AND PREDICTIONS USED

6.1 Background

All modelling undertaken utilising predictive modelling tools is highly dependent on the quality of the input data, the calibration and validation processes performed and the assumptions made in conducting the modelling. The aim when developing models is to develop purposeful, credible models from data and prior knowledge, in consort with end-users.

With respect to Caloundra South, several tranches of modelling were undertaken to investigate the development impacts and potential mitigation measures. These included:

- Catchment modelling of the site and subcatchments upstream, within and downstream of the development;
- Receiving water quality modelling to examine impacts on Bells Creek and Pumicestone Passage;
- Precinct scale stormwater quality modelling; and
- Precinct and development scale water balance modelling.

It is not appropriate in this section to outline all the details and assumptions of each modelling package, however a basic risk assessment has been performed for these modelling tasks as set out below. Complete details of the models used, their parameterisation and assumptions are contained within the relevant reports prepared for the PER and PER supplement, with the following summaries being provided herein:

- Catchment modelling;
- Receiving water quality modelling;
- Stormwater quality modelling; and
- Water balance modelling.

6.2 Risk Assessment

This risk assessment was undertaken in general accordance with the risk management standard AS/NZS ISO 31000:2009, which includes the following steps:

- Identify the risks;
- Analyse the risks;
- Evaluate the risks; and
- Mitigate or treat the risks.

Whilst the risks associated with predictive modelling do not necessarily fit well into a 'typical' risk assessment process, where possible the elements defined above have been used to conduct this assessment.

6.2.1 Identify the Risks

As with any modelling effort, the risks in utilising predictions based on the modelling are dictated by several factors. These risk factors include:

- The purposes for modelling are clearly stated and understood;
- The suitability of the models chosen to represent the processes and characteristics of the problem being modelled;
- Uncertainties within the forcing data used are understood and quantified where possible;
- Use of forcing data considers the specifics of the location being modelled (both temporally and spatially);
- Model parameters chosen are locally relevant and suitable for the chosen models;
- Model operators have sufficient skill to use the predictive tools chosen and understand the implications of model outputs and uncertainties;
- Quantified calibration and verification is undertaken where necessary and applicable; and
- Model outputs are compared to other techniques.

Each of the above represents a risk to the reliability and robustness of the model predictions and any decisions that may have been supported by modelling outputs.

6.2.2 Analyse the Risks

Each of the identified risk factors are analysed below.

- The purposes for modelling are clearly stated and understood* – In the case of the Caloundra South, the primary purpose of each model was to quantify the likely impacts from development of the site on specific environmental objectives, and to provide forcing data for “downstream” models such as catchment and receiving water models. Secondary objectives were identified such as minimising the extent of impact, optimising treatment measure performance and sizing and minimising overall demands on water resources. In each case, these purposes were clearly identified at the commencement of each modelling task.
- The suitability of the models chosen to represent the processes and characteristics of the problem being modelled* – Each of the model frameworks chosen were those that represented the latest model developments (such as MUSIC, Source, Urban Developer etc all developed through Australian based research), or those which had previously been applied to the region.
- Uncertainties within the forcing data used are understood and quantified where possible* – A large range of forcing data was used for each of the modelling frameworks applied to Caloundra South. In all cases, the best available locally specific data was chosen, however the uncertainty in some of that forcing data was not always explicit (e.g. rainfall data). As with any monitoring data, there is likely to be some degree of uncertainty in the results, for example water quality monitoring data from laboratory analysis has explicit uncertainties calculated and these vary with the magnitude of the result, such that numbers closer to detection limits of the analyses have higher uncertainties than those with higher analysis results.

- d) *Use of forcing data considers the specifics of the location being modelled (both temporally and spatially)* – Any forcing data used for Caloundra South modelling was that which was the most locally specific for the site. In some cases there may be variability across the site for some spatial characteristics (e.g. rainfall), in which case more forcing data was obtained to mitigate such issues.
- e) *Model parameters chosen are locally relevant and suitable for the chosen models* – Model parameters used in the Caloundra South modelling were selected based on industry guidance (e.g. SEQ MUSIC Modelling Guidelines), or from applications of the same models in similar regions.
- f) *Model operators have sufficient skill to use the predictive tools chosen and understand the implications of model outputs and uncertainties* – If modellers do not have sufficient experience in the use of models, it is highly likely that significant errors could be made without recognition that this has occurred. In the case of Caloundra South, all modelling tasks were undertaken and/or supervised by highly experienced professional modellers with specific experience in applying the model frameworks to similar sites and in the same region.
- g) *Quantified calibration and verification is undertaken where necessary and applicable.* – Calibration and verification of model outputs are essential where definitive representation of existing conditions are required. Where this was completed for the Caloundra South site's existing conditions, the catchment and receiving water quality models utilised significant local observed data to undertake calibration and verification for each framework and these works were outlined in various modelling reports.
- h) *Model outputs are compared to other techniques* - Where possible, model outputs should be compared to other modelling outputs or appropriate quantification techniques. In the case of the work undertaken for Caloundra South, outputs from smaller scale models were compared to the larger regional models. For example, outputs from MUSIC stormwater models were compared to the catchment models and other techniques for estimating flows and pollutant export.

6.2.3 Evaluate the Risks

The identified risks were evaluated utilising risk tables included in Appendix A. The method for evaluating risks involved assessing the 'likelihood' of an environmental impact occurring with the 'consequence' of an environmental impact occurring. This likelihood and consequence ratings are based on the analysis of risks as discussed above.

6.2.4 Mitigating the Risks

Of all the risks described above, the only one that was identified as a moderate risk was if the uncertainties within the forcing data used were understood and quantified where possible. In terms of Caloundra South, a large range of forcing data was used for the modelling frameworks applied. In each case, the forcing data used was that which was considered "best practice" or industry standard. As such, the outputs of the models are likely to be consistent with any other models developed for similar sites across Australia and represent best modelling practice. This was recognised as such in the reviews of the modelling works undertaken.

Table 6-1 Risk Evaluation

Risk Factor	Description of Impact	Likelihood of Impact	Consequence of Impact	Risk Rating
The purposes for modelling are clearly stated and understood;	If the purpose of a model is not understood, then incorrect modelling predictions may be derived or may not be appropriate to the site	Very unlikely (1)	Minor (2)	Low (3)
The suitability of the models chosen to represent the processes and characteristics of the problem being modelled;	Models which do not portray the processes or characteristics are not likely to account for the dynamics of changes across the site or on receiving environments	Very unlikely (1)	Minor (2)	Low (3)
Uncertainties within the forcing data used are understood and quantified where possible;	If the uncertainties are too large, the model outputs may not be able to discretise any potential changes in impacts as a result of the modelled scenarios	Moderate (3)	Minor (2)	Moderate (5)
Use of forcing data considers the specifics of the location being modelled (both temporally and spatially);	Where forcing data is not locally specific, it may result in model outputs that do not account for spatial or temporal variability of the local environment	Unlikely (2)	Minor (2)	Low (4)
Model parameters are chosen are locally relevant and suitable for the chosen models;	If inappropriate parameters are chose the model outputs are not likely to represent the site and give misleading outputs	Unlikely (2)	Minor (2)	Low (4)
Model operators have sufficient skill to use the predictive tools chosen and understand the implications of model outputs and uncertainties;	Inexperienced modellers will not have a full understanding of the implications of data, parameters and assumptions used and can result in outputs that do not adequately account for impacts or site conditions	Very unlikely (1)	Moderate (3)	Low (4)
Quantified calibration and verification is undertaken where necessary and applicable; and	Uncalibrated and unverified models are usually worse than no model at all	Unlikely (2)	Minor (2)	Low (4)
Model outputs are compared to other techniques	Without some cross verification of techniques, the decision maker has no concept of the robustness and reliability of the model prediction	Unlikely (2)	Minor (2)	Low (4)

7 PERFORMANCE INDICATORS AND GOALS

7.1 Water Quality – Construction Stage

Impacts to downstream water quality are avoided or otherwise minimised in accordance with the achievement of the following water quality performance criteria for site sedimentation basins:

- pH 6.5 to 8.5.
- Discharge turbidity offsite (as measured by the downstream automated turbidity monitor) to be less than 10% above background with background being the quality of water entering the site *via* the culverts where Bells Creek North and South pass under the Bruce Highway for any events up to and including the design rainfall event as specified below.
- Nutrients (nitrogen and phosphorus) to be managed through normal erosion and sediment control practices.
- The following monitoring regime will be integrated into each Precinct-based CEMP:
 - Regular (daily and after major rain events) site inspections of all erosion and sediment control measures;
 - Regular (daily and after major rain events) inspections of areas surrounding construction site to detect and manage any occurrence of sediment deposition off-site;
 - Rainfall will be recorded at 9am each working day from an installed rain gauge;
 - All construction activities will be monitored daily for compliance with erosion and sediment control measures; and
 - Within sediment basins, turbidity, pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO) will be measured daily.

Corrective actions will be required each time there is either a significant (i.e. greater than 25%) exceedance of the above stated performance standards for discharges from site sediment basis or if there are similar triggers of the automatic turbidity monitoring infrastructure. If lesser exceedances are observed (e.g. between 15 and 25%) then initial surveillance assessments will be triggered that may identify areas that could be better managed, thereby reducing off site export of sediments.

7.2 Water Quality – Operational Stage

7.2.1 Receiving Water Quality

7.2.1.1 Pumicestone Passage

The existing water quality behaviour of Pumicestone Passage is to be quantified using historical EHMP data. These data should relate the behaviour of two control sites (EHMP sites 1309 and 1310) to one impact site (EHMP site 1311). The locations of these sites are shown in Figure 7-1.

Figure 7-1 The relationship between the control and impact sites should use three month running averages of EHMP water quality data as a key performance metric.

For key water quality parameters, appropriate in situ relationships between water quality levels at the control and impact sites will be developed using EHMP data. Figure 7-2 to Figure 7-10 illustrate such relationships that have been derived using existing data for a range of water quality parameters. These data show the following:

- A 'line of best fit' describing the relationship between the water quality at the control and impact sites – which, as shown in most cases indicates a very good level of fit between the two datasets.
- 'Investigation' and a 'corrective action' lines, defined respectively as being located 1.5 and 3 standard deviations outside the 'line of best fit'. These lines effectively encompass the majority of **natural** variability in water quality levels in Pumicestone Passage.
- Any data recorded at the impact site during the construction and/or operational stages of the project that is located between the two 'investigation' lines will not require any action as these data are indicating water quality levels in Pumicestone Passage that is effectively comparable to pre-development conditions.
- Should data recorded at the impact site during the construction and/or operational stages of the project fall between the 'investigation' and 'corrective action' lines (see for example Figure 7-2), then site-specific investigations as outlined in separate Environmental Management Plan (EMP) documentation for this project will be triggered to define whether development works are affecting receiving water quality and, if necessary, corrective action may be commenced.
- Should data recorded at the impact site during the construction and/or operational stages of the project fall outside the 'corrective action' lines, then more detailed assessments and site-specific actions will be triggered.

Regular (2 yearly) reviews of the relationships illustrated in Figure 7-2 to Figure 7-10 should be conducted to capture any potential overall long-term changes in water quality within Pumicestone Passage which may result from works being conducted elsewhere in the catchment.

7.2.2 Receiving Water Quality in Bells Creek

A similar approach should be taken to triggers for water quality management in Bells Creek, with in this case the relationship between the two Stockland funded EHMP sites in Bells Creek (impact sites) and the behaviour of two control sites in Pumicestone Passage (again EHMP sites 1309 and 1310) being used. This will require the collection of 6 months more background data in Bells Creek as the available data set in Bells Creek (see Figure 7-10) is still somewhat scarce for these assessments to have any real statistical strength.

Regular (2 yearly) reviews of these relationships should also be conducted to capture any potential overall long-term changes in water quality within Pumicestone Passage which may result from works elsewhere in the catchment.

7.2.3 Site Pollutant Export Loads

A load based monitoring program will be conducted on the site to further define both existing pollutant loads washing from the site and to assist in determining how these loads may change with development of the site. Given that there is likely to be significant variability between and within event monitoring sites as noted in previous stormwater monitoring studies (BCC 2005), monitoring data will be compared with the predicted loads from previous modelling of the site and where

differences greater than 2 standard deviations of the mean annual loads are identified, further site investigations and comparison with other monitoring activities will be undertaken to determine whether these are due to variability or indicative of changes in load runoff from the site. This load base monitoring will also be informed by the load based monitoring of treatment devices.

7.3 Groundwater

During major construction/earthworks periods, an analysis of groundwater level variability suggests that trigger values will need to be established for each bore in the monitoring network. Recommended trigger values for monitoring groundwater levels during major construction periods are shown in Table 7-1.

Based on the data, for high groundwater levels, the initial recommendation is to use the 80th percentile as the depth to water value that triggers additional groundwater monitoring and the 90th percentile as the depth to water that triggers a review of site earthworks and construction procedures. In particular, proper land elevation, vegetation and drainage designs will need to be reviewed at these trigger levels.

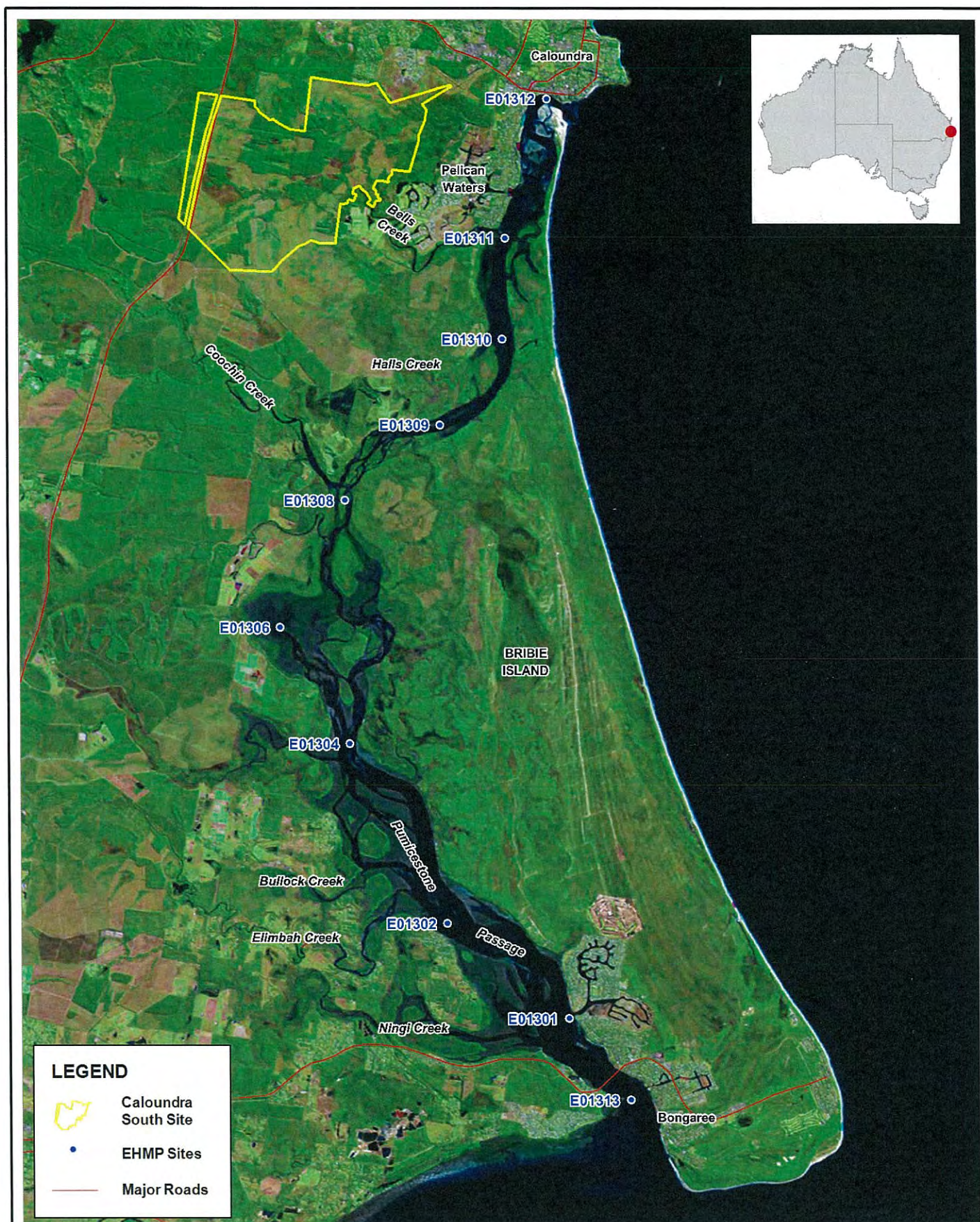
For low groundwater levels, the initial recommendation is to use the 20th percentile as the depth to water value that triggers additional groundwater monitoring and the 10th percentile as the depth to water that triggers management response.

For groundwater quality, a change of more than 10% from the average of previous baseline data should trigger an initial investigation as to potential cause and effect (and action if deemed necessary) and a 20% change should trigger corrective action.

Table 7-1 Recommended Groundwater Level Trigger Values

Statistic	GW10	GW10 shallow	GW8	GW8 shallow	GW9 deep	GW9 vs	S1 deep	S1 vs	S2 shallow
	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL
Average	10.81	10.94	6.61	4.04	11.69	11.64	6.79	6.95	6.56
Minimum	10.56	10.87	5.61	3.74	10.15	11.62	5.39	6.95	6.18
Maximum	11.15	11.01	7.50	4.33	12.15	11.66	7.78	6.95	6.95
Percentile 90%	11.1						7.2		
Percentile 80%	11.0						7.1		
Percentile 20%	10.6						6.48		
Percentile 10%	10.5	10.88	6.01	3.81	10.57	11.62	6.26	6.95	6.26

Statistic	BHH6	Bh3 vs	Bh3 deep	Bh3 shallow	BHH6 shallow	BV3 vs	GW5	GW5 shallow	GWH5	GWH5 shallow
	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL	mbGL
Average	0.74	2.04	1.28	1.31	1.88	5.82	3.99	4.23	19.59	21.96
Minimum	0.23	1/78	0.47	0.36	1.78	5.60	2.76	4.07	16.15	21.96
Maximum	1.24	2.30	2.34	2.23	1.96	6.04	4.69	4.38	22.78	21.96
Percentile 90%	1.12						4.6		21.8	
Percentile 80%	1.0						4.5		21.3	
Percentile 20%	0.4						3.8		17.6	
Percentile 10%	0.33	1.83	0.68	0.64	1.80	5.64	3.37	4.10	16.94	21.96



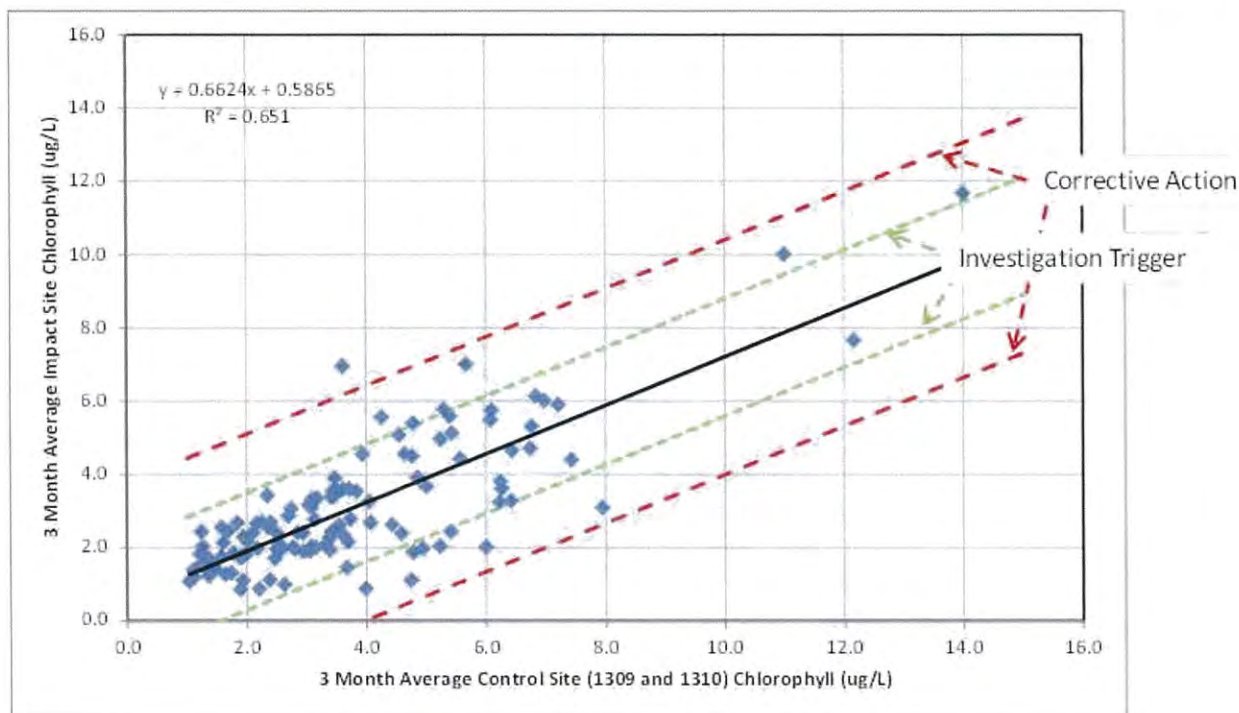


Figure 7-2 EHMP Data Assessment – Pumicestone Passage – Chlorophyll a

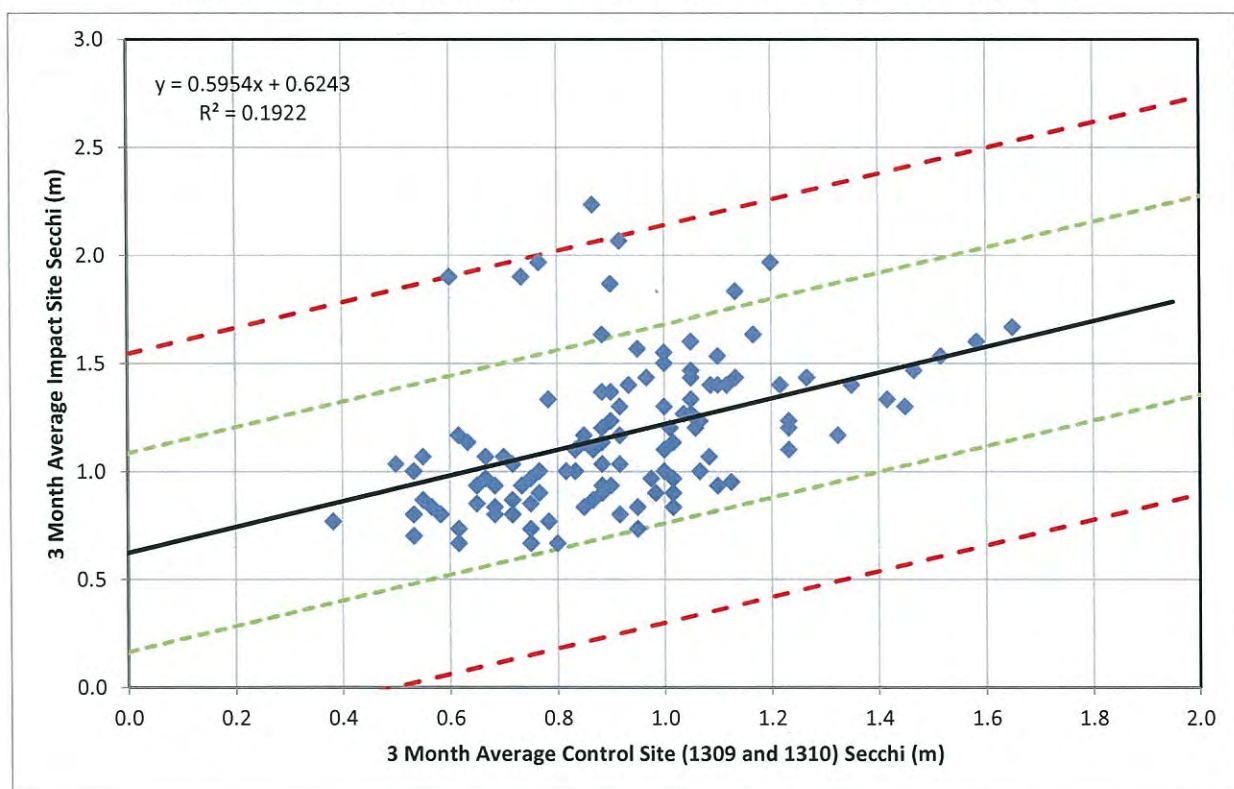


Figure 7-3 EHMP Data Assessment – Pumicestone Passage – Secchi

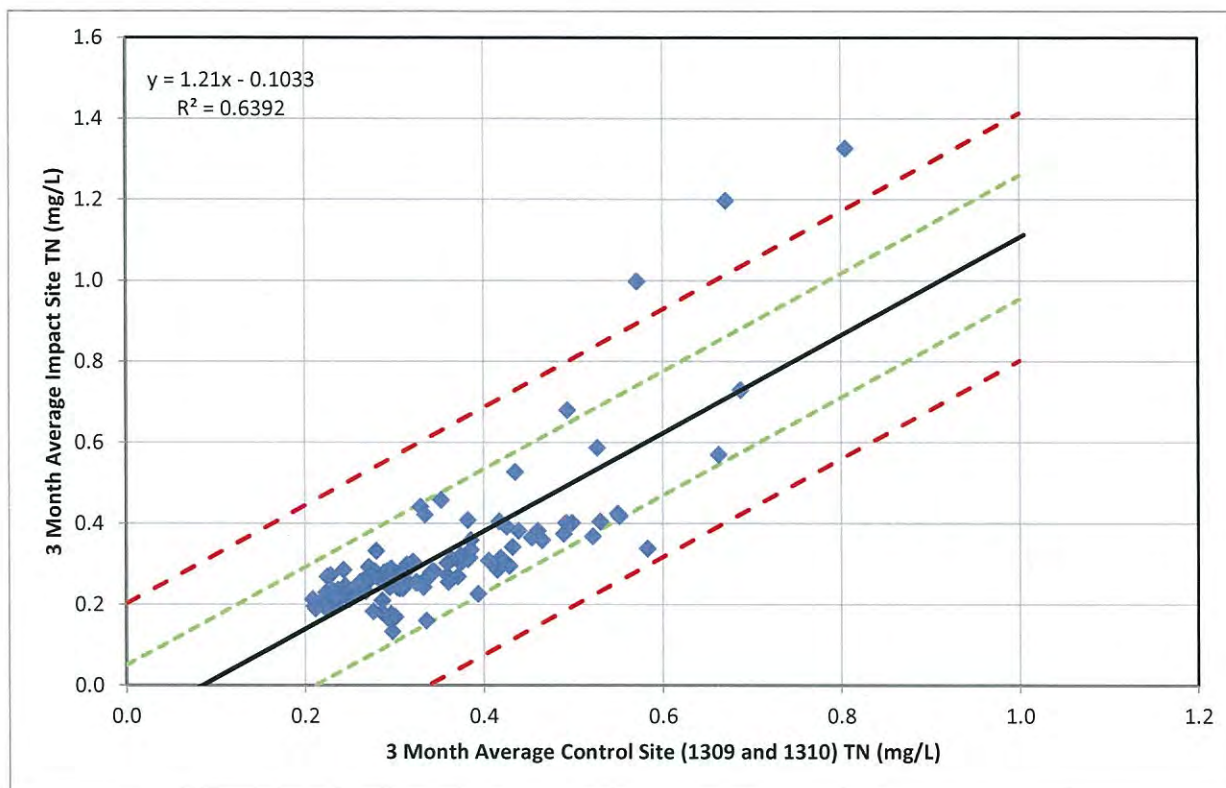


Figure 7-4 EHMP Data Assessment – Pumicestone Passage – Total N

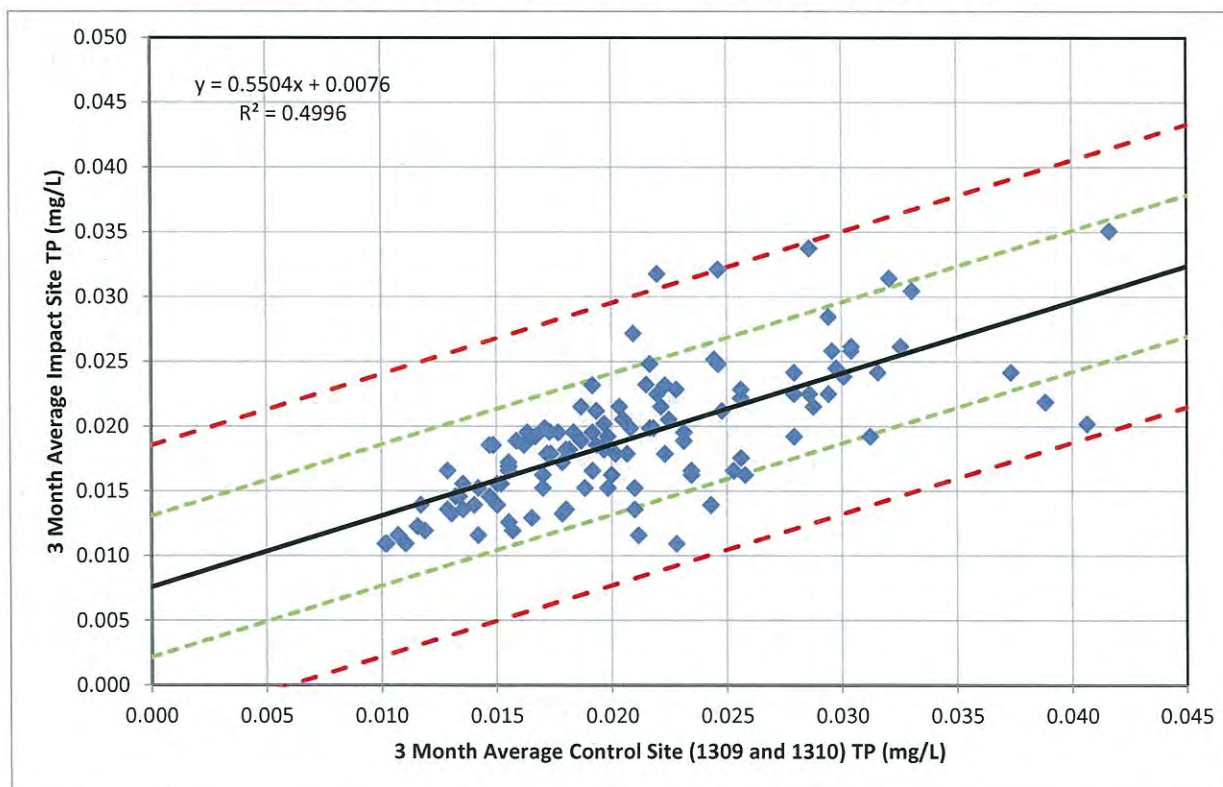


Figure 7-5 EHMP Data Assessment – Pumicestone Passage – Total P

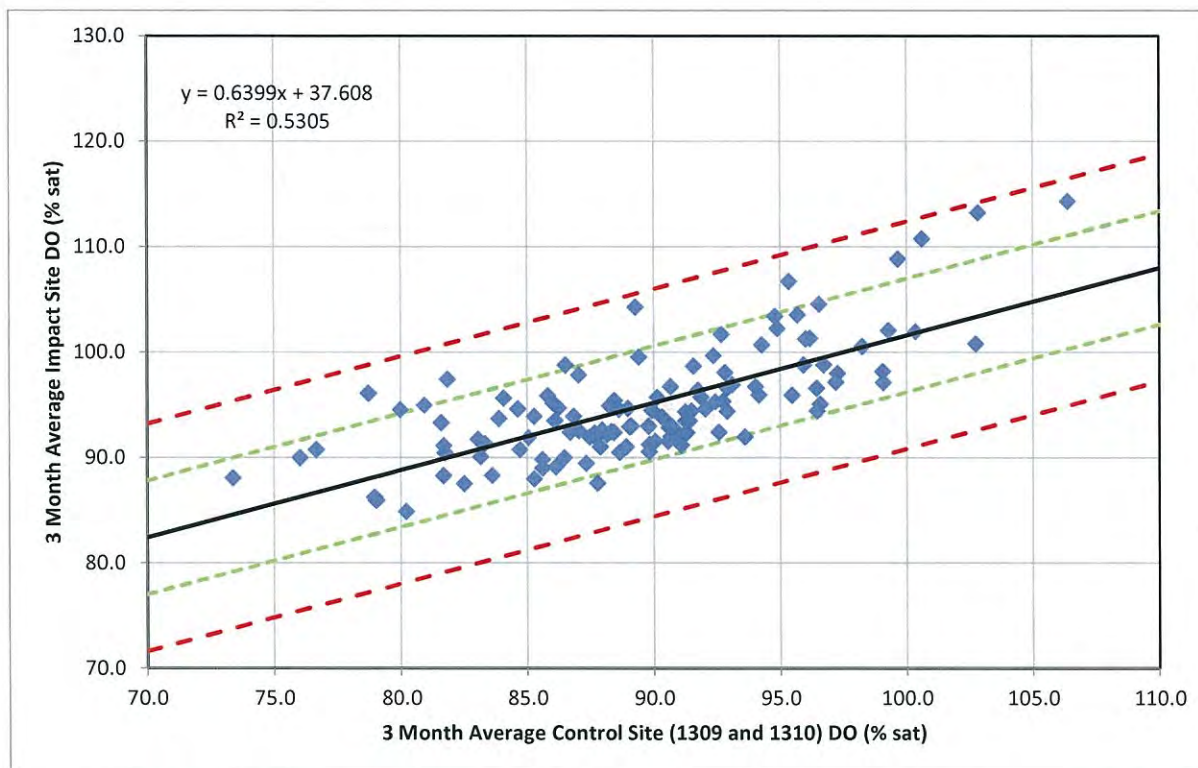


Figure 7-6 EHMP Data Assessment – Pumicestone Passage – DO

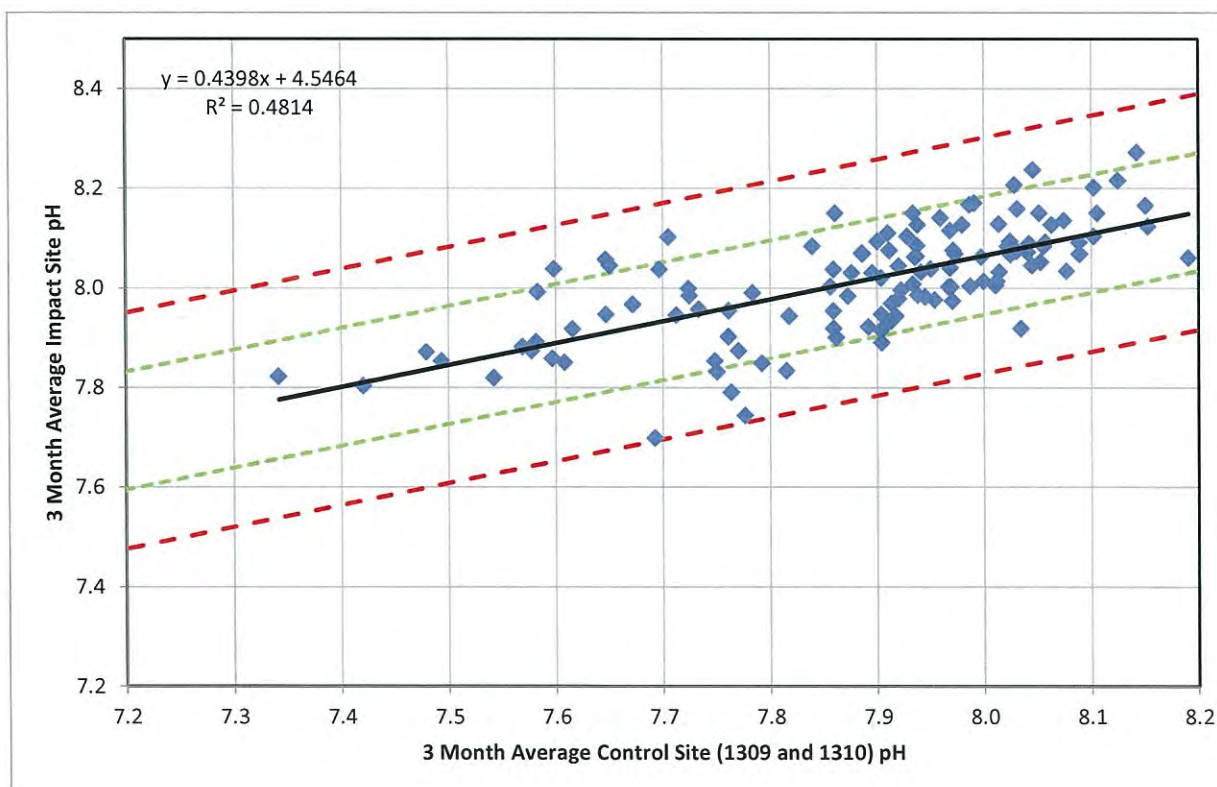


Figure 7-7 EHMP Data Assessment – Pumicestone Passage – pH

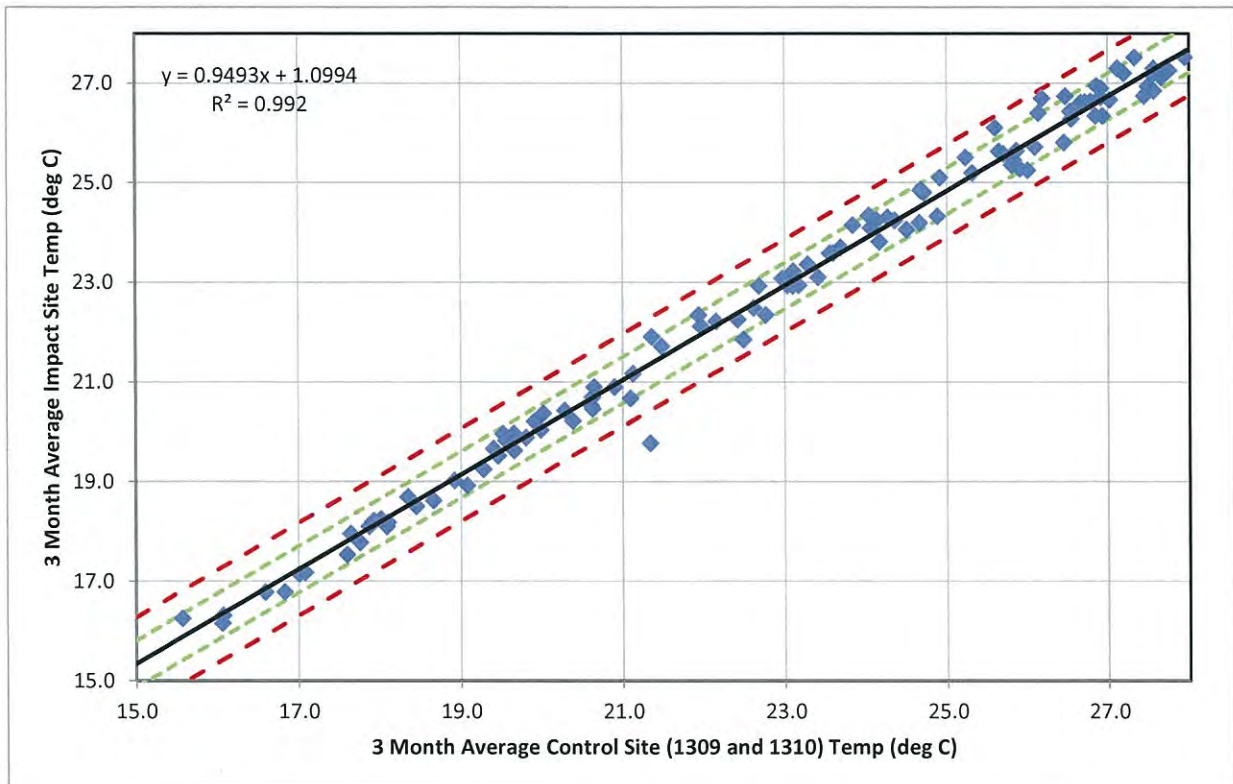


Figure 7-8 EHMP Data Assessment – Pumicestone Passage – Temperature

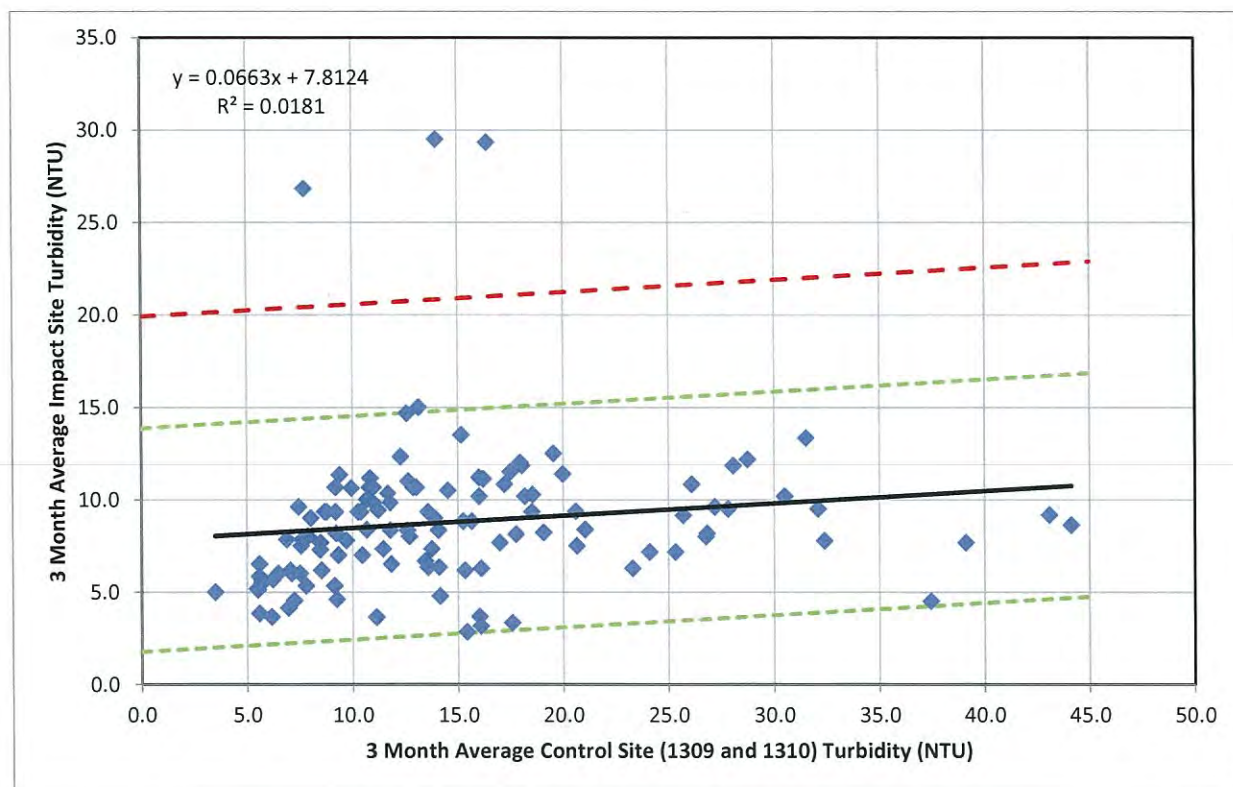


Figure 7-9 EHMP Data Assessment – Pumicestone Passage – Turbidity

8 CORRECTIVE ACTIONS

8.1 Water Quality - Construction Stage

Specific corrective actions will be developed as part of the Precinct-based CEMPs. Generally, where performance criteria are not being met, the following measures will be implemented:

Contractor to amend erosion and sediment control measures as required in consultation with the Superintendent to address deficiencies through regular monitoring and inspections and in consultation with relevant regulatory agencies.

Erosion and sediment control devices will be cleaned, repaired or replaced whenever inspections show signs of noncompliance or ineffective capability/capacity.

Works will cease and/or other corrective actions taken (e.g. not allowing release of water from sedimentation basins) where erosion and sediment control devices are found not to be in accordance with the management and mitigation actions outlined in this plan or otherwise the performance requirements outlined above.

Areas of exposed soils and extensive scour or erosion will be rehabilitated as soon as practicable after detection.

8.2 Water Quality - Operational Stage

8.2.1 Pumicestone Passage and Bells Creek

Generally, the water quality of the operational stage of the development will be highly dependent upon the performance of specific treatment measures within the development. Given that these are to be independently evaluated through a specific monitoring program, corrective actions will therefore need to be focussed on the treatment measures, but also consider overall implementation of the various management measures across the development.

Corrective actions related to operational phase water quality include the following:

- Review of existing data sets to examine trends and spatial context of any failures of WQOs;
- Identification of the source of the outliers (chronic or acute failure);
- Where sources are identified, investigate implementation of water quality management measures in these locations to ensure that they are established appropriately and functioning as designed. Specific rectification measures will be identified as part of the design process for each treatment measure;
- Investigation into potential spills/contamination event; and
- Examination of the load based monitoring and automated turbidity monitoring to determine if any trends are consistent with the changes in ambient water quality occurring in the operational phase.

8.2.2 Site Pollutant Export Loads

No corrective actions nominated

8.2.3 Groundwater

Corrective actions following a detection of an exceedance of a groundwater trigger levels as established above may include the following:

- The review of site construction management practices;
- Localised filling or excavation works to adjust land elevations;
- Changes to proposed re-vegetation and ecological enhancement strategies;
- Review of site surface water management devices (WSUD) and stormwater harvesting practices;
- Detection and remediation of spills or other contaminant releases (if groundwater quality is detected as being affected); or
- Review and amendment of acid sulphate soil management practices in the context of unusually low groundwater pH or the presence of dissolved metals at downstream monitoring locations.

9 ADAPTIVE MANAGEMENT MECHANISMS

Adaptive management of the implementation of treatment measures across the Caloundra South site is planned through the adoption of the various monitoring programs, especially those focussed on treatment measure performance. Initial stages of the development will occur in the Lamerough Creek catchment and it is intended that the implementation of the construction and operational treatment systems will be “trialled” in these catchments and modified through design and implementation such that when the development staging moves into the Bells Creek catchments, the performance and implementation of the treatment measures will have been optimised.

Furthermore, the ongoing review of monitoring outputs will provide sufficient data with which to undertake regular reviews of progress of the management actions and make appropriate changes where necessary. At this stage in the development process, these are not yet explicit; however an adaptive management framework underlies the monitoring program development and corrective actions identified.

In regard to adaptive management on the site, we note as follows:

- Stockland and their nominated contractors undertaking development works on the site will be the parties ultimately responsible and accountable for ensuring that actions associated with adaptive management take place.
- Stockland will appoint a suitable external consultant to implement, coordinate and oversight all environmental monitoring works. This consultant will be **independent** of the development contractor and will ensure appropriate accountability of monitoring as a trigger for corrective actions.
- Regular reports will be provided to relevant regulatory authorities and to the wider community as required by all Development Approvals in regard to
 - The overall nature and results of monitoring works;
 - Any trends in the results obtained by these works;
 - What, if any, corrective action triggers have been initiated as a result of the monitoring, and finally; and
 - How effective these measures have been.
- Should actions be required, Stockland and their nominated development contractors will be responsible for the implementation and refinement of same to ensure that appropriate environmental protection goals associated with the project are achieved.

APPENDIX A: RISK ASSESSMENT TABLES

Score		TABLE OF CONSEQUENCE
		Environment
5	Very High/ Catastrophic	Catastrophe, irreversible damage to sensitive environment. Likely prosecution.
4	High/ Major	Disaster, high levels of media attention, prolonged but reversible damage to environment.
3	Moderate	Substantial environmental nuisance but full recovery expected.
2	Low/ Minor	Minor detrimental effect to environment.
1	Very Low/ Insignificant	Low environmental impact

TABLE OF LIKELIHOOD		
Score		Likelihood
5	Almost certain	The event is expected to occur in most circumstances. Likely to occur frequently.
4	Likely/ probable	The event will probably occur in most circumstances.
3	Moderate/ occasional	The event should occur at some time. Likely to occur sometime.
2	Remote/ unlikely	The event could occur at some time. Unlikely but possible.
1	Rare/ very unlikely	The event may occur only in exceptional circumstances. Assumed it may not be experienced.

Risk= Consequence +Likelihood						
		Risk Rating				
Consequence	5	6	7	8	9	10
	4	5	6	7	8	9
	3	4	5	6	7	8
	2	3	4	5	6	7
	1	2	3	4	5	6
		1	2	3	4	5
		Likelihood				

Risk Rating	Definitions
8-10	Intolerable
7	High
6	Significant Risk
5	Moderate Risk
2-4	Low Risk

APPENDIX B: CATCHMENT MODELLING DETAILS

Model Background

Source Catchments was used to define the catchment derived flows of water and associated loads of diffuse pollutants entering Pumicestone Passage. This modelling framework is developed and promoted by the eWater CRC, a federally funded Cooperative Research Centre combining Australia's pre-eminent research organisations, State Government water regulators and industry practitioners. The model's 'pedigree' stretches back some 10 years, being based on the original Environmental Management Support System (or EMSS) developed in the early part of this decade for the SEQ Healthy Waterways Partnership (HWP) to define diffuse loads to Moreton Bay and other South East Queensland (SEQ) waterways.

Model Data Sets and Model Configuration

The **Source Catchments** model developed for and applied by this project has been built upon many years of previous investigation in the Pumicestone Passage catchment and further afield in SEQ by BMT WBM staff and other local researchers. Of key significance in this regard are many of the data sets used to build the model itself. These data sets are introduced and described below.

Topography

Topography (land form, elevation, etc) is a key driver of how water washes from the Pumicestone Passage catchment. BMT WBM has been working for many years on developing the best possible Digital Elevation Model (DEM) of the SEQ region in our role as a key service provider to the HWP. This DEM has seen us obtain, review and combine many disparate data sources for the region.

Land Use

Land use is also an important data requirement of a **Source Catchments** model as it is a driver of diffuse loads predictions. In the case of the model developed for this project, we were able to access the most recent (2006) regional land use mapping data for the Pumicestone Passage catchment from DERM. The DERM data were then classified by functional units for the purpose of catchment modelling for efficiency as similar land use designations will have similar hydrologic and pollutant export characteristics. A summary of the total areas per functional unit is provided in the table below.

2006 Functional Unit Areas

Functional Unit	Area (ha)	% of Total Catchment
Broadacre Agriculture	903	1.32%
Dense Urban	431	0.63%
Grazing	5,225	7.66%
Green Space	48,259	70.72%
Intensive Agriculture	5,955	8.73%
Rural Residential	1,872	2.74%
Urban	2,658	3.89%
Water	2,941	4.31%
Total	68,244	

Rainfall

Rainfall data are also fundamental to the development and running of a **Source Catchments** model. In the case of this study, we have had access to (and adopted for use) daily synoptic rainfall data sets across the entire catchment of Pumicestone Passage as provided via the DERM SILO database. These data encompassed the period from 1980 to 2009.

Evapotranspiration

Evapotranspiration data are also crucial to accurately simulating the water balance/hydrology of a catchment. In the case of our modelling of the Pumicestone Passage catchment, we were able to apply long term potential evapotranspiration (PET) data sets produced by the Bureau of Meteorology.

Soils

Soil data for the Pumicestone Passage catchment are available and could have been expected to be required for this model study. However, in the case of the development of the Pumicestone Passage **Source Catchments** model, such data were not directly required as the influences of soils on rainfall-runoff processes were implicitly included via the model hydrologic calibration. Similarly, the influence of soils on the pollutant concentration of stormwater runoff was also implicitly included via the model pollutant washoff/generation model formulation and calibration.

Model Configuration

The various data sets described above were collated, reviewed and quality assured before being used for an initial 'build' of a prototype **Source Catchments** model. This model was tested for suitability and several modifications made to enhance its functionality.

Model Calibration and Validation

The Pumicestone Passage **Source Catchments** model was constructed using relevant model coefficients which were calibrated/validated by other substantial studies conducted in the SEQ region over recent years, and in particular over the last 12 months by BMT WBM. These studies focussed primarily on calibration of the hydrologic (i.e. rainfall-runoff) and water quality (i.e. pollutant export) elements of the model. A summary of the works conducted in this regard and examples of relevant investigation results within (and adjacent to) the catchment of Pumicestone Passage is provided below.

Hydrologic Calibration

In association with regional modelling work being conducted by BMT WBM, a major hydrologic recalibration exercise of the rainfall-runoff elements of **Source Catchments** has recently been undertaken. This exercise involved comprehensive model parameter optimisation assessments using highly sophisticated multiple scenario simulation software. Essentially, this resulted in many thousands of model scenarios (automatically generated using various model parameter sets generated using random seeding techniques) for models forced using the rainfall and evaporation data identified above until the optimal calibration result was obtained with reference to gauged daily stream flow records. These records, collected by DERM, extended over many years, thereby

encompassing wet, dry and average rainfall conditions. We provide the following summary of salient assessment results.

For the comprehensive SEQ model and this study, the hydrologic run-off model used to simulate catchment flows was SimHyd which is a conceptual rainfall-runoff model within **Source Catchments** that simulates daily runoff, including baseflow, using daily precipitation and PET data.

Some manual adjustment was performed to the SimHyd coefficients for the catchments encompassing the Caloundra South project area in order to simulate correct runoff volumes associated with those catchments. Typical rainfall-runoff coefficients (ratio of total runoff to total rainfall) from the Caloundra South event based water quality monitoring program conducted by BMT WBM on behalf of Stockland were approximately 0.4, which are relatively high and are possibly due to elevated groundwater levels. As such, the hydrologic parameters of the Caloundra South catchments were modified to reflect the site conditions. Because most of the area within the Caloundra South site is classified as green space, the modifications to hydrologic parameters were made to green space for the Caloundra South sites. These SimHyd parameters are presented in the table below.

Caloundra South SimHyd Parameters

SimHyd Parameter	Value
Baseflow Coefficient	0.1
Impervious Threshold	1.0
Infiltration Coefficient	65
Infiltration Shape	1.50
Interflow Coefficient	0.75
Pervious Fraction	0.992
Rainfall Interception Storage Capacity	0.6
Recharge Coefficient	5.0
Soil Moisture Storage Capacity	120

Pollutant Export Calibration

Again in association with regional modelling investigations being conducted by BMT WBM, in this case on behalf of the eWater CRC, a major review has been completed of event based pollutant load monitoring data collected in recent years in SEQ. This event monitoring data collection program has been specifically targeted at obtaining highly relevant water quality data during significant runoff events from a range of land uses and catchments across the region, and has extended now over a two-year period. In total, some 73 storm events have been sampled, providing one of the most comprehensive, synoptic multi-land use data collection studies in Australia. Key participants in this data collection study, which was championed and coordinated by the HWP and DERM personnel, included DERM, SEQ Water, Local Governments and community based organisations in the region.

The ultimate product of this investigation, which (like the hydrologic calibration) is a regionally specific and relevant set of pollutant export coefficients for SEQ. The following summary is provided of the results of this investigation as they related to the catchment of Pumicestone Passage. The pollutant load values in **Source Catchments** are modelled as event mean concentrations (EMC) and dry weather concentrations (DWC) which characterise concentrations for storm events and inter-event, or ambient, conditions respectively.

The values used for EMCs in this study constitute the optimised values estimated from the eWater CRC study. Those values are provided in the table below. Urban values were applied to urban, dense urban and rural residential functional units because the eWater CRC study did not include analysis of dense urban and rural residential functional units, and this was deemed an appropriate surrogate for these functional units.

Also included in the table below are dry weather concentrations (DWC) which are consistent with values adopted previously for the area. In some instances, due to collating data sources together, some DWCs were greater than EMCs. In those instances, EMC values were assigned to the DWC. Pollutant export loads for chlorophyll a and salinity were set to 0.

General EMC/DWC values

Functional Unit	EMC (mg/L)			DWC (mg/L)		
	TSS	TN	TP	TSS	TN	TP
Broadacre Agriculture	281	2.300	0.318	5	0.50	0.015
Grazing	265	2.612	0.259	5	0.83	0.050
Green Space	22	0.725	0.018	3	0.50	0.015
Intensive Agriculture	1032	2.555	0.480	10	0.50	0.015
Urban*	817	0.826	0.953	7	0.83	0.050

* Applied to Urban, Dense Urban, and Rural Residential

Also of direct relevance to these investigations are the findings of a two (2) year baseline data collection monitoring program conducted on the Caloundra South site by BMT WBM on behalf of Stockland. The results of this program have also been used to inform the modelling work conducted using **Source Catchments**. The monitoring program provided both EMC and DWC values used in the catchment modelling for the catchments that correspond to the Caloundra South site. Those EMC/DWC values are specified in the table below. Because the majority of the Caloundra South site within the catchment model is classified as green space, the EMC/DWC values will only be applied to the green space. The remainder of the DWC values were taken from and are reported in the table below.

Caloundra South Monitoring Program EMC/DWCs for Green Space

Subcatchment	EMC (mg/L)			DWC (mg/L)		
	TSS	TN	TP	TSS	TN	TP
SC #3 (Site 1)	29.3	1.25	0.08	15.0	1.10	0.07
SC #5 (Site 2)	11.4	0.80	0.03	8.0	0.80	0.03
SC #6 (Site 3)	9.5	1.04	0.04	8.0	0.92	0.03
SC #4 (sites 2 and 3)	11.0	0.85	0.03	8.0	0.85	0.03

Model Application

The **Source Catchments** model as described above has been used to quantify the large scale/whole of catchment flows and loads of pollutants entering Pumicestone Passage. These loads will be crucial in driving and influencing water quality levels in Pumicestone Passage. The model was executed as existing conditions then modified to reflect the effects of the Caloundra South development under a range of scenarios, including a cumulative impact assessment using future land use data.