BMT WBM

the long view group

Halls Creek Environment Report Summary - 2015

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Confidential

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Synopsis: **A review of relevant environmental factors, potential impacts, performance objectives and opportunities to add benefit associated with the prospective future development of the Halls Creek Identified Growth Area (IGA) site.**

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Acknowledgements

This report has been prepared for Stockland Pty Ltd to review the relevant environmental factors, potential impacts, performance objectives and opportunities to add benefit associated with the prospective future development of the Halls Creek Identified Growth Area (IGA) site

The report has been prepared by a consortium of professional engineering and scientific consulting firms as shown in the Table below:

Consultant	Area of Responsibility
BMT WBM	Project-Co-ordination; Water Quality, Aquatic Ecology, and Flooding
The Long View Group	Project Co-ordination; Land Use, Cultural Heritage
Golder Associates (now trading as Core Consultants)	Geology, Soils and Topography
Ecosmart Ecology	Terrestrial Fauna
Arup	Terrestrial Flora
RPS	Groundwater

Contents

Contents

List of Figures

Contents

List of Tables

Executive Summary

Halls Creek

Halls Creek is a 1,280ha site located at the southern edge of the Sunshine Coast.

The site has been degraded through previous forestry practices. Around 87% of the land is cleared and now used for cattle grazing.

The site is currently not within the urban footprint and has no development rights.

Identified Growth Area

Since 2009, the Stockland owned Halls Creek site has been nominated as an Identified Growth Area within the South East Queensland Regional Plan (SEQRP). Identified Growth Areas are nominated in advance of need. This lead-time is necessary to allow time for investigation and planning, which typically can take 10-15 years.

Before the Halls Creek Identified Growth Area can be considered for future development, thorough investigations will need to take place to assess whether the site is suitable. The SEQRP currently has extensive planning assessment criteria to be addressed before future development can be considered.

Key outcomes:

Improved understanding of Halls Creek site and the site's capacity to support development and protect environment

Site highly disturbed and modified from previous forestry use.

The site is located outside the boundaries of the Moreton Bay Ramsar site and other waterways of conservation significance

Onsite and offsite environmental values can be protected and enhanced with appropriate mitigation

Water quality objectives can be achieved with appropriate mitigation

Groundwater quality and quantity can be managed to protect important plant and animal species

High flood immunity for areas proposed for development

Development can deliver restoration of regional biodiversity corridor

Minimum 780ha – land that appears suitable for development, subject to further investigations and application of mitigation measures

Up to 500 ha – land best suited for rehabilitation

Environmental assessment of Identified Growth Areas

The SEQRP requires that investigation of any Identified Growth Area needs to consider whether environmentally sensitive areas within and adjacent to the site can be protected and enhanced under a development scenario and whether high environmental outcomes can be achieved.

Report Methodology

The site has been studied over many years. This environment report updates existing knowledge and is based on existing data and new information collected through field surveys and further research. The report compares the site's environmental conditions with relevant environmental performance objectives, under a development scenario. Modelling has been undertaken to understand the effects of future development on water quality and hydrology. The full data set and findings is available in a technical report, with this detailed summary prepared to suit a broad, non-specialist audience.

Executive Summary

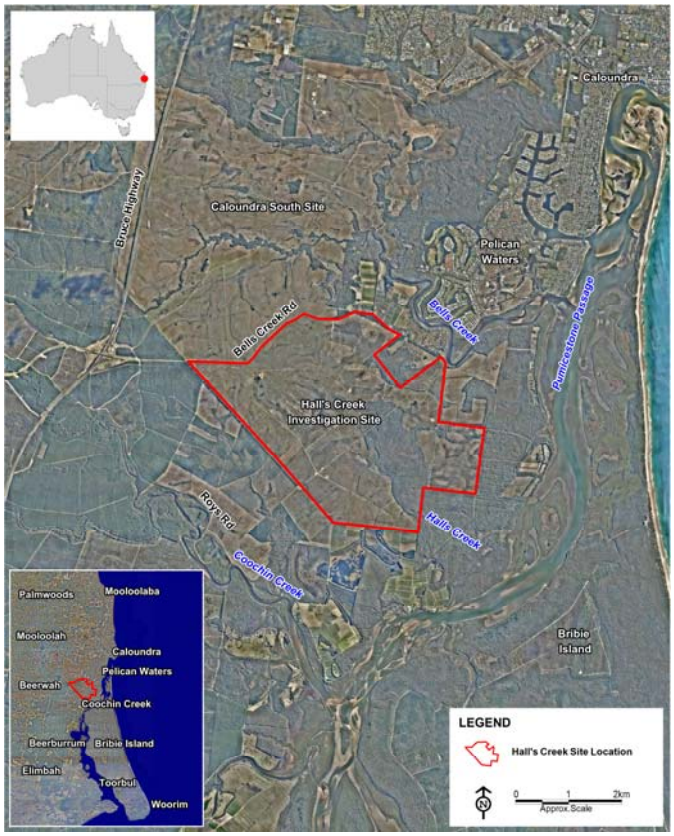


Figure 1 Site locality plan

Role of This Report

While the Halls Creek site may not be needed for development before 2031, the intention of this report is to further understand the environmental values of the site and in adjacent areas to assess whether the site may be suitable for urban development. The report identifies constraints and opportunities to protect and enhance the site and offsite environmental values. The report identifies where development appears most practical and areas that may need to be avoided or further investigated.

Key Features of the Site

The 1,280ha land holding has no coastal frontage and is located a minimum of 1.6 kilometres from the Pumicestone Passage. Most of the land was cleared with the establishment of pine plantations from the 1960s. Over time the pine plantations have been progressively removed and the site is now predominantly grassland. Remnant vegetation is largely confined to a paperbark wetland located in an eastern lowland section of the site.

The Halls Creek site is largely a self-contained sub-catchment, comprising approximately 1% of the entire Pumicestone Passage catchment. The majority of the site drains through a number of minor gullies to a 140ha modified freshwater wetland. The wetland has been degraded by the historical forestry and agricultural uses of the site, but continues to support remnant (Melaleuca) vegetation communities. A portion of the catchment along the southern boundary of the site drains to Coochin Creek.

Figure 2 Current land use and conditions at the Halls Creek site

Topography across the site ranges from 2.5m Australian Height Datum (AHD), rising to around 20m AHD in the west and north-west of the site

The Moreton Bay Ramsar site does not extend into the Halls Creek site; however the estuarine sections of Halls Creek (downstream of the site) and Pumicestone Passage have Ramsar wetland status. The lower estuary sections of the Coochin Creek and Halls Creek (both downstream of the site) are also listed as High Ecological Value (HEV) and protected under the Queensland Environmental Protection (Water) Policy. The freshwater Coochin Creek HEV area extends upstream into the catchment and includes several minor waterways on the Halls Creek site along its southwest boundary.

Opportunity to Enhance Environmental Values

There are significant opportunities to rehabilitate the site to restore and protect local environment values. A proposed dedication of up to 500ha rehabilitation area covering 40% of the site is proposed.

This would create a significant buffer to the Pumicestone Passage and link to conservation areas to the north and south to contribute to a large habitat corridor.

The majority of site drains into the modified Melaleuca wetland on site, which would also benefit from rehabilitation.

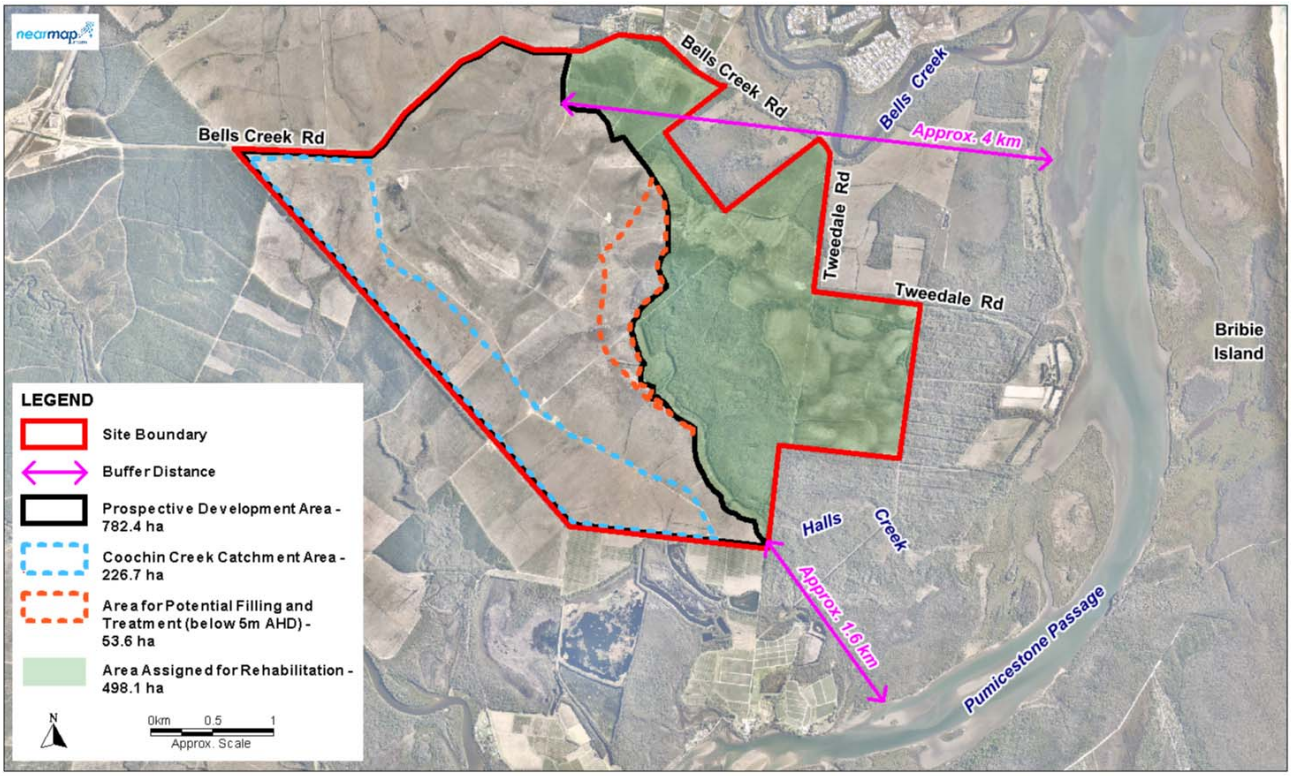


Figure 3 Rehabilitation of the eastern section of the site (shaded green) will increase the buffer to Pumicestone Passage to between 1.6km (min) and 4km (max)

Key Findings

Development Potential - Overview

Development of a minimum of 780ha of the site appears appropriate and practical; provided specific areas are avoided and well planned onsite mitigations are adopted.

The development constraints map identifies areas that either should be avoided or studied in more detail prior to consideration for future development.

The rehabilitation of the up to 500ha of vegetation corridor and the degraded on-site wetland area is fundamental to the achievement of positive environmental outcomes.

Table 1 Overview of site development potential

Location	Approx. Area	Description
Rehabilitation area	500 ha	Rehabilitation confirmed as best land use Considerable environment benefit
Potential Development Area – low/ least constraint	500 ha	Development potential Further investigation to confirm urban development potential High development standards and mitigations would be needed
Potential Development Area - Acid Sulphate Soils Management Area	54 ha	Potential development area with investigations identifying low potential for ASS – further investigations required Specific development controls required and implementation of traditional management approaches.
Potential Development Area - Coochin Catchment Area	226ha	Potential development area – site part of Coochin Creek Catchment Higher development standards and mitigations will be required.

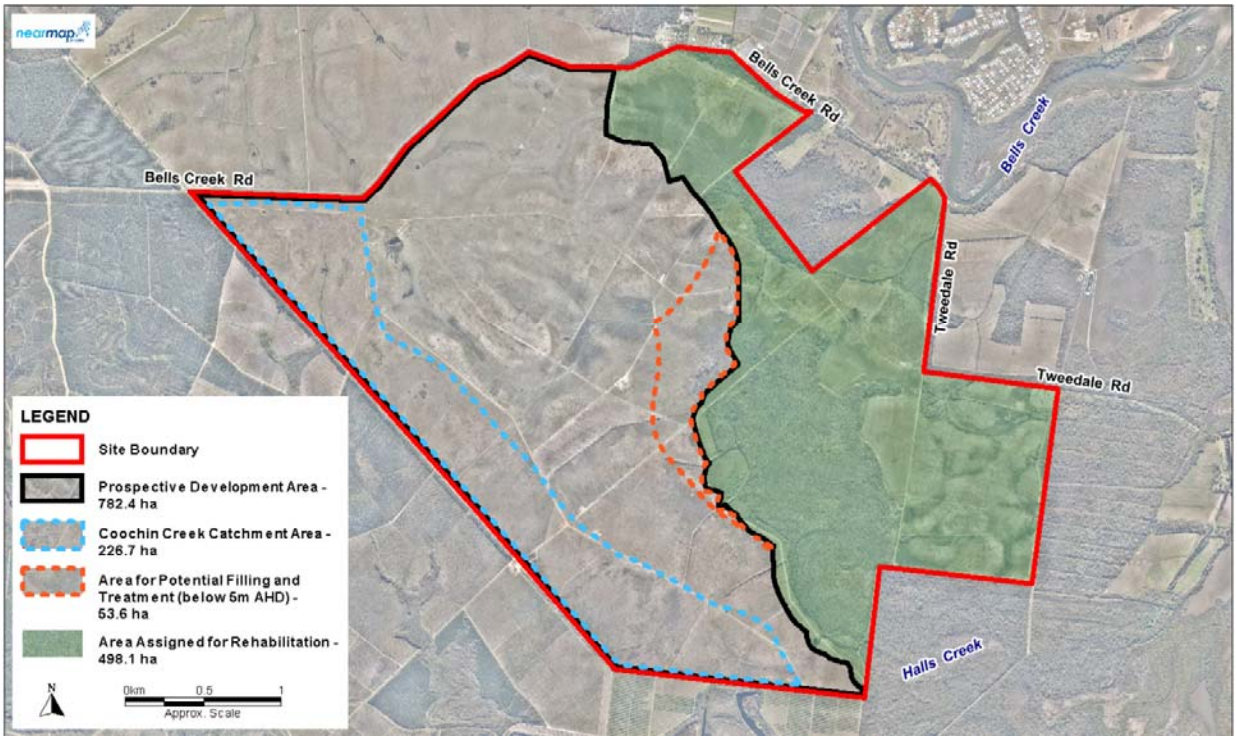


Figure 4 Site development, rehabilitation and investigation areas

Effective water quality and stormwater management

Modelling demonstrates the site can achieve the relevant water quality objective of no 'net worsening' in water quality within Pumicestone Passage and the Coochin Creek catchment.

Modelling also demonstrates that no substantial and measurable change in the water quality and hydrological regime of wetlands within the Ramsar site can be achieved, with appropriate mitigations.

The application of best practice water management treatment processes, including: rainwater harvesting tanks, rain gardens, vegetated channels, bio-retention basins, vegetated buffer areas and environmental protection and rehabilitation, will achieve positive water quality outcomes.

The volume and frequency of stormwater flows from the site would increase under a developed scenario. Water sensitive urban design elements, such as retention basins would need to be adopted to minimise changes to downstream hydrology. In this context, the large freshwater wetland on the site will act as a mixing zone and a water storage and buffer to reduce potential downstream impacts.

Rehabilitation of a 100m buffer to the wetland is recommended (as part of the overall area of the site assigned for rehabilitation) to further enhance water quality and manage stormwater volumes.

Protecting groundwater

Effective monitoring and management of groundwater levels and quality will be required to maintain conserved and rehabilitated groundwater dependent and other ecosystems, including naturally acidic wallum frog habitat and Halls Creek wetland.

Proposed on-site mitigations can reduce the potential for adverse changes to the existing groundwater quality both on and off the site. A key mitigation will be to maintain groundwater levels in drainage areas sustaining the water supply to the wetland.

High flood immunity

The majority of the site has high flood immunity, requiring limited fill.

Areas of the site with lower elevations are not being considered for future development. Instead they are allocated for conservation and rehabilitation. With mitigation, flooding impacts can be contained on site.

Avoiding impacts upon the Coochin Creek catchment

The Coochin Creek catchment has high environmental values downstream of the site. A higher standard of urban development would be necessary to limit any adverse changes. Further assessment of this area would be needed to understand appropriate land uses to ensure protection of these important downstream environmental values.

Terrestrial fauna

Acid frog species are the most significant threatened fauna present onsite.

Appropriate land use allocation and onsite management is proposed to sustain wallum frog habitat. Future development presents the opportunity to improve fauna values by rehabilitation of land in the east, thereby increasing the extent of natural habitats for a variety of fauna species (including wallum frogs).

Maintaining supportive groundwater conditions will be required to maintain and successfully rehabilitate habitat. Studies indicate that traditional movement opportunities can be improved in existing and new vegetation/habitat corridors and areas.

Aquatic ecology

Despite its long disturbance history, the site supports a network of artificial channels, wetland and water storages that represent potential habitats for a range of aquatic vegetation and fauna species.

While the aquatic habitats on the site are suitable for the endangered Oxleyan Pygmy Perch and Honey Blue Eye, neither of these freshwater fish were detected in water bodies on site or in the Halls Creek wetland.

The estuarine areas downstream/offsite of the site represent the highest aquatic ecology values.

Water quality and quantity modelling indicates that habitats for threatened aquatic species on the site can be protected and maintained. Through careful management of on-site water quality and hydrology, estuarine habitats within the Moreton Bay Ramsar site downstream can also be protected.

Terrestrial flora

Around 87% of the site is cleared and now used for cattle grazing. Exotic grassland and small pockets of pine cover the majority of the site.

It is recommended that clearing and development is excluded from the remnant Halls Creek wetland and some of the heathland vegetation communities on the site to the east. The site also supports small communities (in a 2ha area) of Mount Emu She-oak and Christmas Bells.

The increase in freshwater flows into the wetland under a developed scenario would not be considered to result in changes to the structure, health and condition of the wetland.

It is proposed to increase the proposed conservation/ rehabilitated area on site.

Acid sulphate soils

The site has natural and actual soil acidity. Natural soil acidity has ecological benefit, particularly for wallum frog species that prefer acidic conditions. To avoid actual and potential Acid Sulphate Soil (ASS) impacts, development and disturbance of land below 5m AHD will generally be restricted and subject to more detailed investigations. The vast majority of these areas are already allocated for conservation and habitat rehabilitation purposes and would therefore not be disturbed by future development.

Cultural heritage

The Halls Creek site has been highly disturbed and does not contain any recorded and/or protected non-indigenous cultural heritage sites.

The site is located in the traditional country of the Kabi Kabi people. A Cultural Heritage Management Plan has been agreed for the site. Archaeological remnants and debris have been found in five sites within the site. The material had been highly disturbed by previous site clearing. The materials found were indicative of transient, intermittent use of the land and no evidence was found of longer term or ceremonial occupation.

Ongoing studies and investigation

Further studies and more detailed analysis will be needed to build upon the work completed to date. If the site is needed for future development, Stockland would be required to undertake additional environmental studies.

1 Halls Creek Environment Report

1.1 Purpose of this Report

The Halls Creek site, a 1,280 hectare (ha) parcel of land owned by Stockland and located to the south of the Caloundra South master planned community has been nominated as an Identified Growth Area (IGA) in the State Government's South East Queensland Regional Plan (SEQRP) since 2009.

Stockland has sought preliminary environmental information about the site to inform a broader response to the State Government (and other interested stakeholders) about the longer-term development potential for the Halls Creek IGA site.

The SEQRP outlines a process for determining the suitability of IGAs to accommodate longer-term population growth. In relation to environmental matters, the SEQRP requires that the IGA investigation needs to consider the site's ability to protect environmental values and achieve high environmental performance.

If the site is able to meet extensive IGA requirements and planning and environmental approvals are successful, the development would not commence until post-2031.

Given this long lead-time, this environmental review is necessarily preliminary in nature and is intended to:

- Provide an overview of the environmental values of the site
- Identify where development looks most practical
- What areas may need to be avoided
- Site-wide rehabilitation and conservation opportunities
- Performance objectives to be achieved
- Provide direction about further areas of necessary investigation.

More specifically, the report's objectives are to:

- Describe the baseline environmental conditions of the site and relevant offsite conditions
- Present the findings of preliminary environmental investigations both on the site and downstream of the site (offsite)
- Define, where possible, the key environmental constraints to the developable area of the site and where development appears practical
- Understand key interactions between environmental matters on the site and with downstream (offsite) environments
- Develop a greater understanding of the likely impacts of potential development recognising that the current study is being undertaken at a very early stage and that greater scientific certainty will be sought if any proposal to develop the site progresses
- Define environmental performance objectives to set benchmarks early in the process, noting the learnings obtained through the investigations and planning approval process of the Caloundra South master planned community

- Demonstrate if and how a net environmental benefit could be achieved from developing the site
- Identify key knowledge gaps around environmental impacts and recommend additional monitoring, surveys and assessments that will improve scientific certainty about these impacts over time
- Outline at a high level the likely environmental approvals, noting these will be subject to change in the period to 2031.

1.2 Key Site Features

The 1,280ha land holding has no coastal frontage and is located a minimum of 1.6km from the Pumicestone Passage. Due to past land uses and clearing, the site's hydrology has been significantly altered, fire regimes have changed and remnant vegetation only exists on around 13% of the site.

As shown in Figure 1-1, the site comprises the majority of the catchment of Halls Creek, which traverses the site before flowing through a section of the Bribie Island National Park (located adjacent to the site) and then discharging into the Pumicestone Passage to the south-east.

On site remnant vegetation is largely confined to a modified 140ha paperbark wetland, called the Halls Creek Wetland which has been degraded by historical land uses. An area of the site (226ha) on the south-western edge is contained within Coochin Creek catchment which also drains into Pumicestone Passage.

Topography across the site ranges from 2.5m Australian Height Datum (AHD), rising to around 20m AHD in the west and north-west of the site.

The upper portion of the Halls Creek catchment is characterised by modest slopes, formed of predominantly lateritic materials, comprising poorly sorted clayey sand and gravel overlying sandy clay layers.

The lower portion of the catchment off-site flattens to brackish intertidal (mangrove) wetlands in the lower reaches.

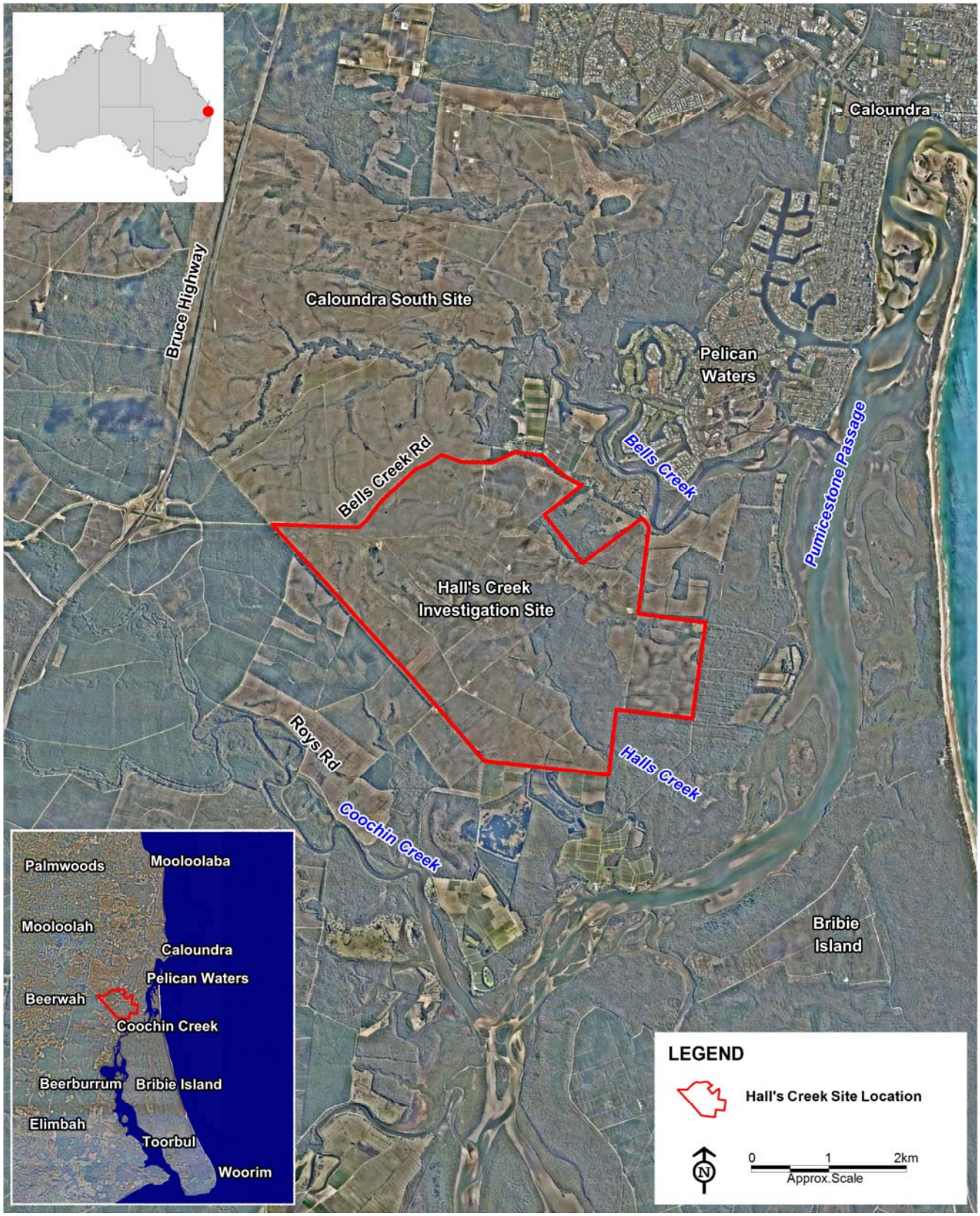


Figure 1-1 Site locality plan

1.3 Preliminary Development Layout

In order to understand potential impacts and opportunities, a preliminary development layout has been prepared for the Halls Creek site, which includes early commitments to rehabilitation and conservation.

While potential development would be subject to considerable future assessment, a notional development footprint was needed to assess and model potential constraints and benefits.

Based on a preliminary assessment of development potential for the Halls Creek IGA, the following outcomes are possible (dependent on detailed design, environmental impact considerations and approvals):

- Residential Development: 10,000 – 12,000 Dwellings
- Retail Development: 1 District Centre, 5 Neighbourhood/Local Centres
- Schools: 4 Schools
- Employment: 100ha of employment land
- Conservation Area: up to 500ha (140ha in Halls Creek wetland and 360ha in surrounding rehabilitation area)

1.4 Approvals

Although the site would not be required until post 2031, under the current SEQRP, any development proposal at Halls Creek would be subject to a wide array of statutory approvals. Site approvals are likely at the:

- Federal level (through a referral and controlled action decision under the *Environment Protection and Biodiversity Conservation Act 1999*);
- State level through the *Sustainable Planning Act 2009* (and its successor the Planning and Development Act which at the time of writing this report is a Bill in Parliament); and
- Local Government level under the relevant local government planning scheme.

Open communication and community consultation would be expected features of these planning processes. It is anticipated that any detailed planning would not be needed for a minimum of ten to fifteen years.

This report is being produced at a very early stage in the planning process. If the site progresses through the planning and environmental approval processes, Stockland would be required to undertake additional environmental studies in the future.

2 Geology, Soils and Topography

The site has natural and actual soil acidity. Natural soil acidity has ecological benefit, particularly for wallum frog species that prefer acidic conditions. To avoid actual and potential Acid Sulphate Soil (ASS) impacts, development and disturbance of land below 5m AHD will generally be restricted and subject to more detailed investigations. The vast majority of these areas are already allocated for conservation and habitat rehabilitation purposes and would therefore not be disturbed by future development.

A review of previous studies and preliminary site based investigations were undertaken to provide an understanding of the topography and baseline soil conditions, specifically to determine the presence or absence of Acid Sulphate Soils (ASS).

During the last 6,500 to 10,000 years (the Holocene period) Pyritic soils or ASS, were deposited in coastal zones throughout the world. If disturbed, the iron pyrite in these sediments oxidises producing sulphuric acid that subsequently lowers the pH in surface runoff and groundwater. In some circumstances this can lead to the release of aluminium and iron from the sediments into the runoff and groundwater of the surrounding environment. Given the sensitivity of downstream receiving environments, characterisation of ASS on site at this early stage is considered a priority.

2.1 Baseline Conditions

Topography across the site ranges from less than 2.5 m Australian Height Datum (AHD) within the low-lying eastern portion of the site, rising to above 20 m AHD in the west and north-west of the site. Approximately one third of the site is located at elevations below 5m AHD.

ASS are only found in soils of alluvial origin and generally occurs below about 5 m AHD, but may be found as high as 20 m AHD if Holocene deposits are present. Fill material of alluvial origins may contain disturbed ASS. Sulfidic materials may also occur in parent rock material and their residual weathering products however; the acidity is bound into the rock matrix and does not readily generate acid runoff.

The proposed Halls Creek site is situated mainly on recent alluvial deposits of Quaternary age (Pleistocene age) overlying residual geology, predominantly sandstone. The eastern part of the site includes areas of ‘undifferentiated flood plain’ comprising clay, silt, sand and gravel alluvium flood plain deposits, including some Holocene age deposits that may include ASS. Typically ASS occurs only in Holocene deposits, although some low level ASS may occur in older Pleistocene deposits.

In Queensland, ASS assessments are generally conducted in accordance with the requirements of the new single State Planning Policy 2013 Guideline "State Interest – Emissions and Hazardous Activities, Guidance on Acid Sulphate Soils and sampling and analysis is planned using the Queensland Department of Natural Resources and Mines (NRM) "Guidelines for Sampling and Analysis of Lowland Acid Sulphate Soils in Queensland - 1998", developed by the Queensland Acid Sulphate Soils Investigation Team (QASSIT).

Due to the preliminary nature of this review and the very early planning phase, a broad, high-level overview assessment was considered appropriate to meet the assessment objectives and confirm the presence or absence of ASS within the site. The approach to the preliminary site investigation was to target a number of ‘typical’ elevation areas within the site. The areas included:

- One area where development and excavation works are likely to occur and no ASS are anticipated

- Another area where ASS are expected (i.e. Holocene deposits), but which is designated for rehabilitation and is not anticipated to be disturbed by the development.

2.2 Key Findings

As described above, investigations have defined three key areas on site:

Area 1: Potential Environmental Conservation Area below 5 m AHD

As expected, some of the low-lying areas below 5m AHD within the eastern portion show a high probability of ASS. ASS identified in these locations typically occur at depths greater than 1 m below ground level. Disturbance of these actual and potential Acid Sulphate Soils and these areas are not recommended. As these areas have been earmarked as rehabilitation and conservation zones on site, they are expected to experience little or no disturbance during future development. Accordingly, treatment and management measures are not required.

Area 2: Potential Development Area below 5 m AHD

The middle portion of the site, transecting from north to south generally comprises areas that have been characterised as having **low probability of ASS**, with the land being between the 5 m AHD contour and the outer limit of Holocene deposition. Soils with actionable levels of net acidity appear to be distributed uniformly laterally and vertically across the proposed development area below 5 m AHD.

These net acidity values represent almost entirely actual acidity, with very little potential for further acid generation indicated. In the vast majority of these soils, existing acidity does not appear to be attributed to oxidised sulphur and may be due, at least in part, to weak organic acids derived from decaying organic matter in the surface soils or associated with naturally acidic properties of the siliceous parent rock.

Area 2 should be subject to further detailed site investigation to better understand the nature of the soils present. Current investigations identify a low possibility of ASS and this part of the site could be developed with traditional management approaches.

Area 3: Potential Development Area greater than 5 m AHD

The western portion of the site lies above the established boundary of the limit of Holocene alluvial deposition and generally ranges in elevation from above 5 m AHD to above 15 m AHD. This area overlies the majority of the areas proposed for development within the site.

Soils with actionable levels of net acidity appear to be distributed uniformly laterally and vertically across the potential mixed-use development areas above 5 m AHD. It should be noted that 100% of the net acidity values were due to actual acidity, with little to no potential for further acid generation indicated.

Similar to Area 2 soils, the acidity in Area 3 may be due to organic acids or siliceous parent rock rather than oxidised sulphur. Area 3 (particularly above 5m AHD) is generally suitable for development.

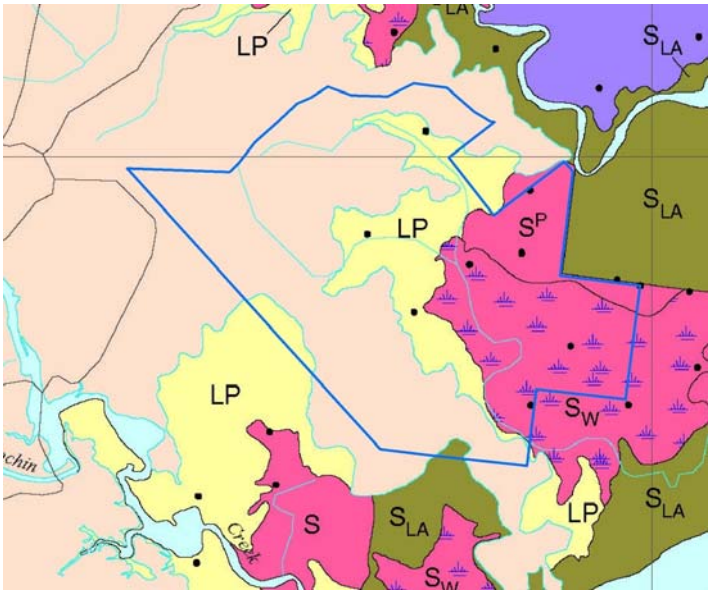


Figure 2-1 Extract map of acid sulphate soils

Notes:
LP: Land between the 5m AHD contour and the outer limit of Holocene, estuarine ASS (i.e. land <5 m AHD) as mapped at this scale, with low probability of ASS occurrence, Limited field investigation.
SW: Land mapped at 1:100 000 scale where ASS occurs within 5 m of the surface, subscript w indicates areas associated with Melaleuca sp. Wetlands and occasionally Casuarina glauca communities. Oxidisable sulphur % in surface layers may be highly variable and often exceeds the 'Action Criteria",
SP: Indicates sediments of Pleistocene age1, so that SP5+ indicates sulfidic sediments of (Pleistocene age) deeper than 5m.

2.3 Mitigation

The following mitigation measures are recommended for management of ASS:

- Development in Area 1 below 5m AHD should be avoided, as per the preliminary development layout.
- Area 2 should be subject to further detailed site investigation to better understand the nature of the soils present. Current investigations identify a low possibility of ASS and this part of the site could be developed with traditional management approaches.
- Area 3 proposed development areas (particularly above 5m AHD) are generally suitable for development.
- A site specific ASS Environmental Management Plan (EMP) would need to be prepared for all future development areas. This would need to include a recommendation not to adopt traditional lime neutralisation treatment, as a slight to moderate soil acidity regime is considered desirable, given the likely presence of the acid frog habitats.
- Establishing baseline groundwater and surface water chemistry for the down gradient receiving environment is required. Monitoring water quality at these locations regularly during construction activities would also be required.

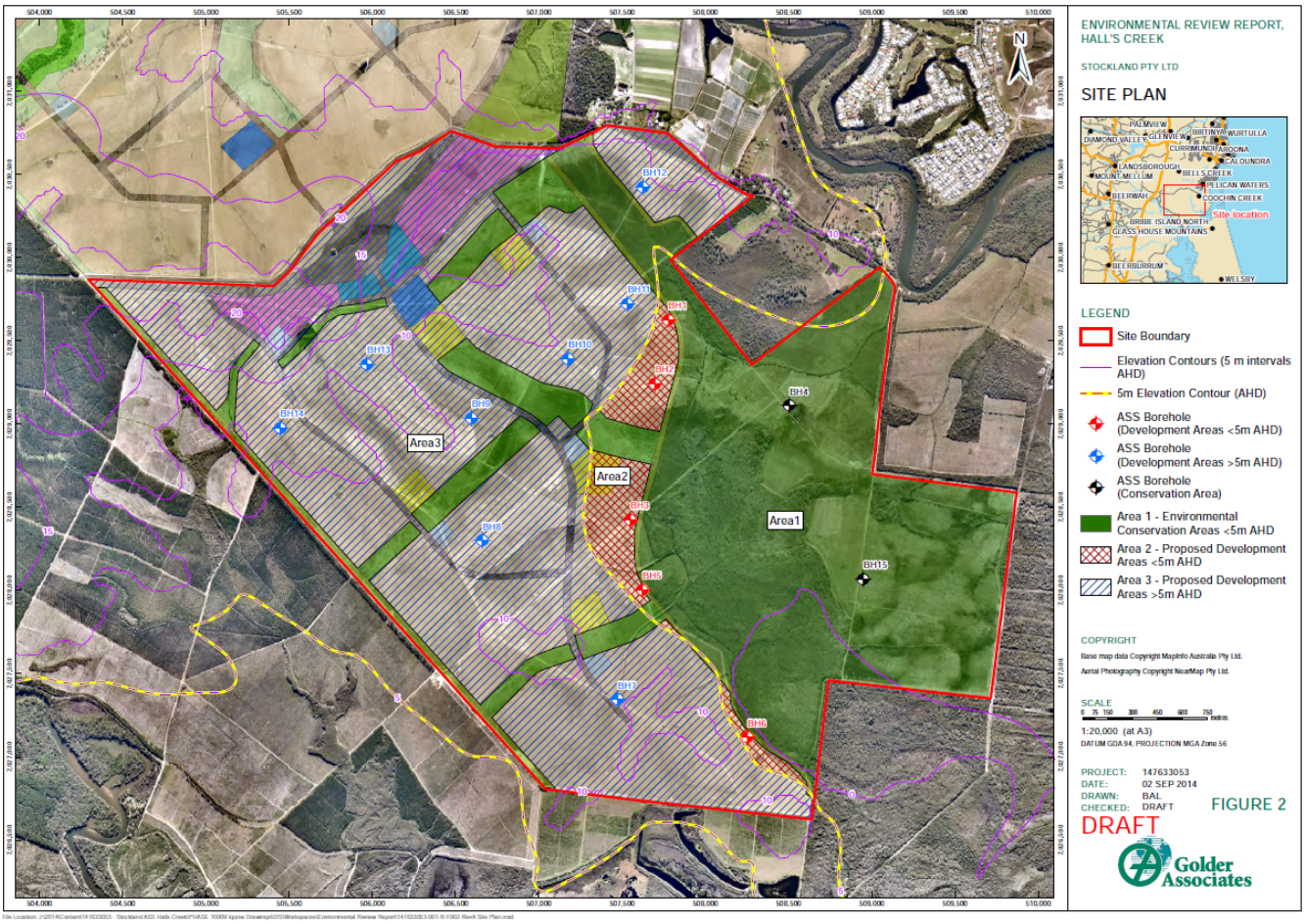


Figure 2-2 Borehole investigation areas and monitoring sites

Performance Objectives for Acid Sulphate Soils

- Potential impacts from actual and potential ASS are managed to protect the environmental values of surface and groundwater resources (and associated ecological habitats) both on and off the site; and
- Management of ASS on the site does not preclude the achievement of other environmental performance objectives such as the conservation of naturally acidic wallum frog habitat.

3 Groundwater

Effective monitoring and management of groundwater levels and quality will be required to maintain conserved and rehabilitated groundwater dependent and other ecosystems, including naturally acidic wallum frog habitat and Halls Creek wetland.

Proposed on-site mitigations can reduce the potential for significant adverse changes to the existing groundwater quality both on and off the site. A key mitigation will be to maintain groundwater levels in drainage areas sustaining the water supply to the wetland.

Previous investigations and the numerical groundwater model created for the adjacent Caloundra South project (Stockland 2012) were used to provide an initial assessment of groundwater implications from development at Halls Creek.

3.1 Baseline Conditions

There are two aquifer systems of note identified within the Halls Creek catchment:

- A shallow alluvial (perched) aquifer system associated with the unconsolidated Quaternary and Holocene sediments (called the alluvial aquifer)
- A fractured rock aquifer system within the Jurassic sandstone (called the regional aquifer).

Shallow groundwater flow drains towards the catchment centre and then in a general south-easterly direction. This reflects the topography of the site.

The regional groundwater flow in the deeper sandstone aquifer is influenced locally by areas of recharge and or discharge but is generally flows in an easterly direction. Recharge is via direct rainfall infiltration and through the infiltration of overland runoff.

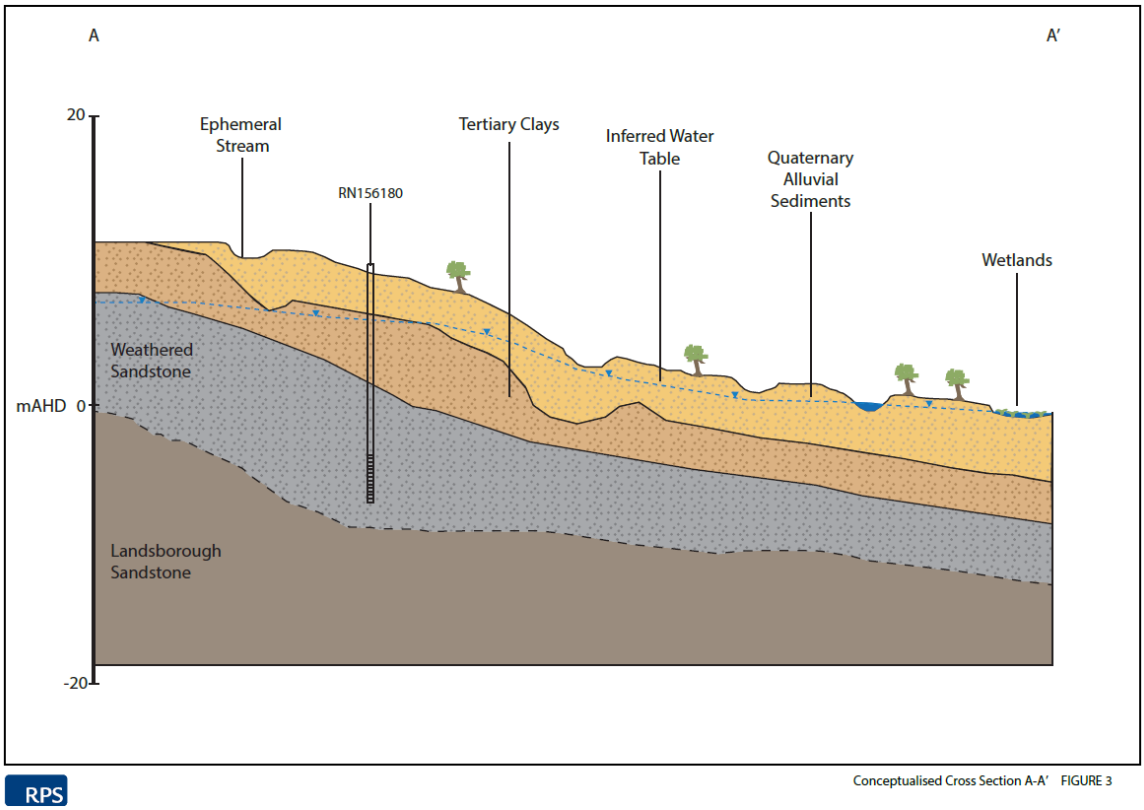


Figure 3-1 Underlying geology and groundwater characteristics of the site

The previous land use practices (pine forest plantations and clearing for grazing) have altered groundwater levels and quality. Following land clearing, it is likely that the water table has recovered to levels above the natural equilibrium (i.e. prior to clearing of the original native vegetation). A higher water table is the result of less discharge from evapotranspiration and increased recharge resulting from clearing and disrupted drainage.

The Landsborough Sandstone is recharged along the bedrock exposures in upland areas west of the Bruce Highway. The system discharges to the major stream systems such as Bells Creek and directly to marine waters along Pumicestone Passage and at Pelican Waters.

Groundwater levels on the site are shown to range between 0 and 8m below surface. The elevated water levels in the alluvial sediments (0 to 4m below surface) indicate that there is a limited hydraulic connectivity with the underlying bedrock. The clay (lateritic) layers below have a reduced permeability and potentially form a semi-confining layer between the alluvial and underlying sandstone. Previous geophysical surveys noted that perched aquifer systems occur predominantly in areas where weathered sandstone outcrops (Ezzy 2004).

The groundwater table is closest to the surface in the low-lying sections of the site. The presence of a shallow unconfined groundwater table has been documented in previous studies with a natural groundwater elevation typically 0 to 2m below the surface (Ezzy 2004).

The groundwater quality at the site is influenced by historical land use. It is relatively fresh with measured salinity levels generally below 1,000µS/cm (seawater is typically around 54,000 µS/cm). The groundwater within the underlying fractured sandstone aquifer demonstrates a slightly elevated salinity level. It is of low pH ranging from 3 to 4 pH (RPS 2012) resulting from previous land disturbance and the associated oxidation of naturally pyritic soils. Available pH levels from the registered groundwater bores, show pH levels to be around 5.4 to 6.2 pH.

Groundwater dependant ecosystems (GDEs) and sensitive receptors include:

- On site – heath ecosystems supporting wallum frogs and the Halls Creek Wetland which is fed by the near surface water table
- Off site – downstream aquatic ecosystems in the adjacent National Park, the adjacent State Forest areas of Coochin Creek Catchment, as well the Halls Creek estuary and the Ramsar listed Pumicestone Passage
- Existing (licensed) groundwater users, which include neighbouring rural landholders and Pelican Waters to the north-east of the site.

3.2 Key Findings

Modelling demonstrates that groundwater in the Halls Creek catchment has been impacted by historical land use, particularly clearing activities. Potential development would result in a localised and short-term water level decline associated with a decrease to groundwater recharge during the development stages.

This decline would have no impact at a regional scale (e.g. outside of the site and immediate surrounds) with groundwater drawdown confined to within the site boundaries.

The Halls Creek wetland on site has been identified for conservation and rehabilitation and needs to be sustained. Avoiding significant adverse changes to groundwater levels through the

maintenance of levels within the range of natural variability along the drainage corridor leading into the site wetland is proposed to assist in sustaining the subsurface drainage supply to the wetland.

The potential impacts to the alluvial aquifer are less well understood and routine groundwater monitoring would be required to better understand this resource and the surface water interaction.

While the lower lying parts of the site (less than 5m AHD) are largely proposed for conservation and rehabilitation, modelling has identified that development of these areas could result in lowered ground water levels.

It is recommended that further investigation on identified groundwater dependent ecosystems such as the wetland is completed as part of detailed investigations in the future. This would include routine monitoring of groundwater levels and quality in the alluvial aquifer. Following this monitoring an updated groundwater model would allow for the evaluation of potential impacts to the alluvial and bedrock aquifers and its sensitive receptors.

3.3 Opportunities to Add Benefit

Given that the site has been impacted by vegetation clearing there is potential for future development to implement measures to return the site to a groundwater regime that is closer to its original conditions (e.g. pre-clearing).

The quality of the existing groundwater resource in the area can be maintained and potentially improved through careful planning and management. Supporting measures would include:

- Monitoring of the groundwater network to further understand the hydrogeological processes.
- Maintenance of the existing ephemeral channels to allow surface water flow to continue to contribute to aquifer recharge on site and/or through the provision of alternative drainage channels.
- Maintenance of vegetation along on-site drainage corridors, which would contribute to catchment drainage and increase the water quality of groundwater recharge.
- Installation of soak pits to enhance groundwater recharge. This measure can overcome reduction to groundwater recharge due to rainfall interception by rooftops and hard impervious ground surfaces.
- Incorporation of groundwater monitoring and corrective actions as part of a construction environmental management plan. This can mitigate potential changes during bulk earthworks and reduce potential transport of turbid or acidic groundwater during active construction periods.

Performance Objectives for Groundwater

- No significant adverse changes to the natural variability of groundwater levels off the site
- No significant adverse changes to groundwater quality off the site
- Maintenance and management of groundwater levels and quality on the site does not preclude the achievement of other environmental performance objectives such as the conservation of retained wallum frog habitat
- Improved understanding and management of local groundwater resource

4 Water Quality

Modelling demonstrates the site can achieve the relevant water quality objective of no 'net worsening' in water quality within Pumicestone Passage and the Coochin Creek catchment.

Modelling also demonstrates that no substantial and measurable change in the water quality and hydrological regime of wetlands within the Ramsar site can be achieved, with appropriate mitigations.

The application of best practice water management treatment processes, including: rainwater harvesting tanks, rain gardens, vegetated channels, bio-retention basins, vegetated buffer areas and environmental protection and rehabilitation, can achieve positive water quality outcomes.

The volume and frequency of stormwater flows from the site would increase under a developed scenario. Water sensitive urban design elements, such as retention basins would need to be adopted to minimise changes to downstream hydrology. In this context, the large freshwater wetland on the site will act as a mixing zone and a water storage and buffer to reduce potential downstream impacts.

Rehabilitation of a 100m buffer to the wetland is recommended (as part of the overall area of the site assigned for rehabilitation) to further enhance water quality and manage stormwater volumes.

The sensitive nature of environments within and particularly downstream of this site have been extensively studied and are well known and understood. An appropriate internal site management regime will need to be implemented to protect these environments, as was the case for the nearby Caloundra South landholding. A site management regime will need to give due consideration to the following key processes:

- *Hydrology*: The volume and frequency of stormwater flows from the site, post-development, will require management such that there are minimal changes to site hydrology to assist the ecosystem resilience of internal and downstream waterways.
- *Pollutant loads*: Appropriate treatment of internal site stormwater runoff via water sensitive urban design (WSUD) measures will need to prevent any significant increase in the amount of stormwater pollutants (e.g. sediments, nutrients) discharging to waterways downstream to protect their ecological properties.

4.1 Methodology

This preliminary investigation has sought to assess the potential impacts of the generation, transportation and management/treatment of flows and pollutant loads from the areas that may be developed in the future. The following scenarios have been tested:

- The existing undeveloped site
- The proposed developed site with proposed stormwater management strategies.

Best practice industry recognised water quality modelling software called MUSIC has been used for this assessment.

Potential changes in downstream water quality have also been assessed using sophisticated whole of catchment hydrologic and pollutant export models and two dimensional, in stream, water quality models of Pumicestone Passage.

The potential treatment/buffering effect that would be provided by the Halls Creek Wetland to Halls Creek and Pumicestone Passage has been excluded from the analysis in order to provide significant conservatism to the study findings. This conservatism means that modelled impacts are likely to be overstated.

4.2 Baseline Conditions

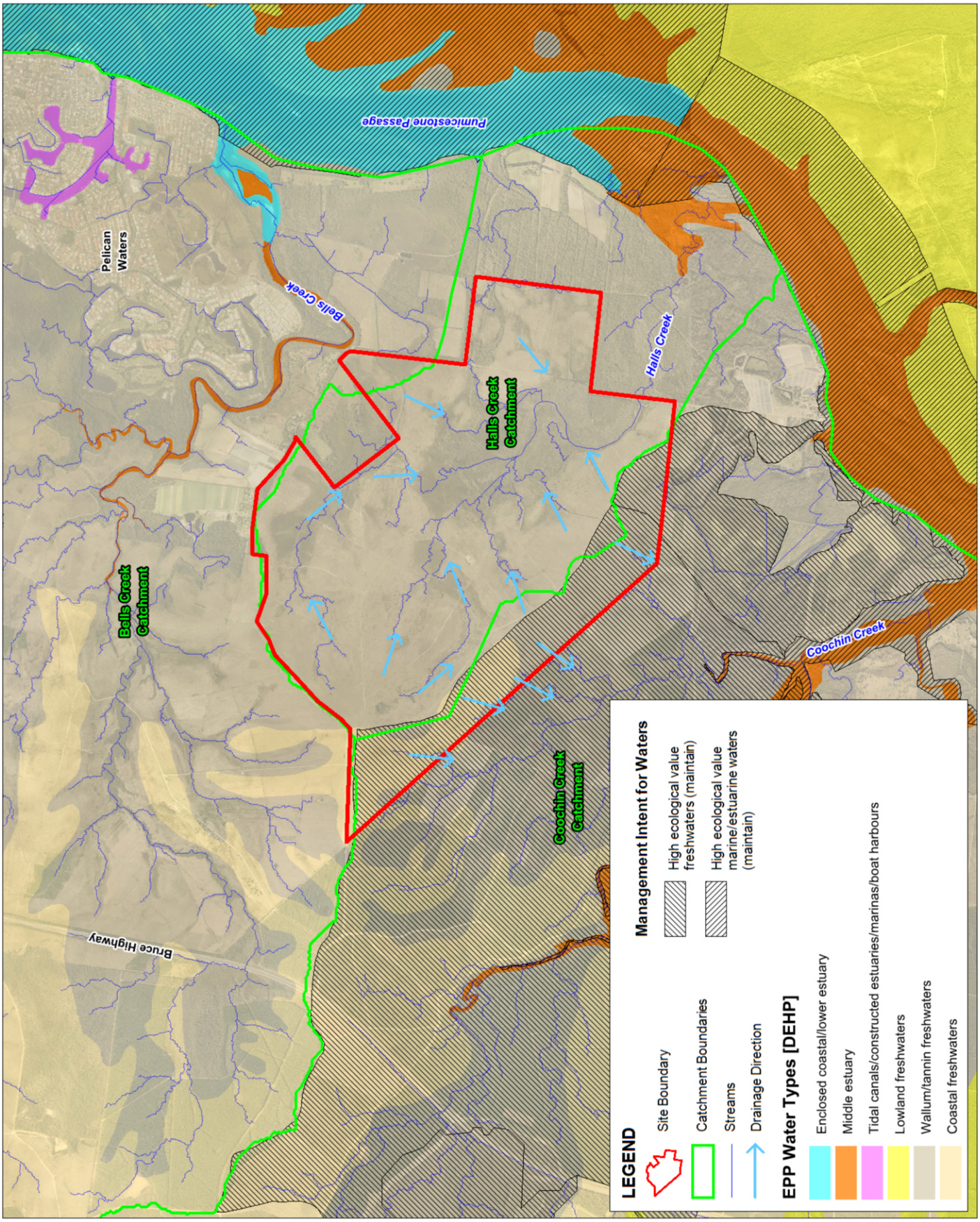
The site has no direct frontage to Pumicestone Passage.

As shown in Figure 4-1, the Halls Creek catchment is self-contained on the site and comprises around 1% of the entire catchment of Pumicestone Passage. The majority of the site drains through a number of minor gullies to the large (140 ha), modified internal freshwater wetland (Halls Creek wetland) which subsequently overflows through a transitional/brackish creek system into to the estuarine sections of Halls Creek.

A smaller portion of the site (226ha) along the southern boundary is part of the Coochin Creek catchment and drains to Coochin Creek, which also eventually discharges to Pumicestone Passage.

The Moreton Bay Ramsar site does not extend into the Halls Creek site; however the estuarine sections of Halls Creek (downstream of the site) and Pumicestone Passage have Ramsar wetland status. The lower estuary sections of the Coochin Creek and Halls Creek (both downstream of the site) are also listed as High Ecological Value (HEV) and protected under the Queensland Environmental Protection (Water) Policy. The freshwater Coochin Creek HEV area extends upstream into the catchment and includes several minor waterways on the Halls Creek site along its southwest boundary.

Unmanaged hydrologic and water quality changes associated under a developed scenario have potential to affect the ecological characteristics of the wetlands south of the site, and the estuarine reaches of Halls Creek and adjacent portions of Pumicestone Passage. However this would not be permissible given the high conservation values of the downstream waterways, and Stockland is seeking advice on best practice surface water quality and quantity management for application across the site.



Title:

Catchments and Water Types for Site and Surrounds

Figure: **4-1**

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4.2.1 Nearby Land Values

Land use values adjacent to the site include:

- Wetlands of High Ecological Significance [HES] and General Environment Significance [GES]) located south of the site
- Adjacent protected areas including the mainland extension of the Bribie Island National Park (bounded by the Halls Creek site to the southeast)
- State Forest to the south of the site
- Fish Habitat Area and State Marine Park designations within Pumicestone Passage and adjacent tidal tributaries further south of the site.

4.2.2 Stormwater

The stormwater quality management strategy for the site will need to be guided by and achieve the following overarching objectives, particularly for downstream receptors, which have higher conservation status:

- Meeting water quality objectives that result in 'no net worsening' in water quality within Pumicestone Passage and the Coochin Creek (resulting from any future proposed development);
- No substantial and measurable change in the water quality and hydrological regime of the wetlands with Ramsar status (i.e. Pumicestone Passage and the estuarine sections of Halls Creek south of the site and Coochin Creek).

4.2.3 Function of the Wetland

Even in its current modified condition, the existing wetland on site provides a significant 'buffer' to any changes in the hydrology and water quality behaviour of the upstream catchment. This function can continue and potentially be enhanced as part of future development.

Drainage from the wetland is further controlled and restricted by an elevated rock base road/track (with drainage structures) located along the eastern site boundary.

The majority of all runoff from this self-contained catchment will collect and pass through the on-site wetland before entering the estuarine reaches of Halls Creek. This is a unique situation, with a further benefit that the entire potential development area and its catchment is under the ownership and management of one landowner. This combination presents an opportunity to ensure high levels of site improvement and downstream environmental protection.

4.2.4 Existing Water Quality

Site water quality is typically acidic, freshwater with only limited saline influences in the area closest to the coast. Only one monitored site had high turbidity, due to a dedicated stock crossing within one of the adjacent overland flow channels.

The low pH, in combination with the low conductivity of site waters means that the receiving environment is not resilient to acidic runoff or potential pH changes, if they were to occur.

Pumicestone Passage water quality data from the Ecosystem Health Monitoring Program (EHMP) provides comprehensive ambient physio-chemical water quality parameters from late 2001 to early 2014.

Reflective of the modified nature of the site and surrounding catchment, the data shows that existing water quality generally does not satisfy water quality objectives for turbidity, total nitrogen, total phosphorus and chlorophyll-a.

4.3 Modelling Approach – In Brief

A range of base case (undeveloped) and developed scenarios both on and off the Halls Creek site were modelled as part of the current study. To establish a 'worst case' base for comparison, these scenarios were modelled **without** Water Sensitive Urban Design (WSUD) or other water quality mitigation measures. The four scenarios included:

(1) Existing/base case (no new development works)

(2) Base case together with development of the site

(3) Base case together with development of the Beerwah East IGA site

(4) Base case together with development of the Caloundra South, Halls Creek IGA and Beerwah East IGA sites.

Modelling was conducted for a two year period with a 3 month 'warm up' demonstrating a dry and wet year scenario.

Water quality statistics were generated for the following parameters: salinity, Total Suspended Solids -TSS, Dissolved Oxygen - DO, Total Nitrogen - TN, Total Phosphorous -TP and chlorophyll-a. Simulated results were extracted from a range of sites located within the model domain and placed along Pumicestone Passage.

The following results were observed across the four scenarios:

- As could be expected, there are far greater predicted water quality changes in Pumicestone Passage as a result of modelled land use change in the 'wet' rather than the 'dry' year;
- Salinity changes in Pumicestone Passage as a result of the various development cases are predicted to be small but with detectable changes to salinity under prolonged wet weather conditions;
- Proportionally, the impacts of the Beerwah East land use change case upon salinity in the Passage are highest, due to the discharge of much of the runoff from this area into Coochin Creek, which subsequently discharges into some of the most poorly flushed sections of the Passage (compared to increased flushing rates at Halls Creek and Bells Creek to the north);
- TSS levels are predicted to change appreciably, and again especially so in the case of Beerwah East. This result indicates that rigorous WSUD applications will be required for all sites;
- DO levels seem to be largely unchanged;
- TN levels will increase with development, and Beerwah East has most potential for change. Again, WSUD measures will be needed to mitigate this impact;
- TP levels will increase with development, and Beerwah East has the most potential for change. Again, WSUD measures will be needed to mitigate this impact; and

- Chlorophyll *a* levels seem largely unchanged.

When comparing the water quality results across the development scenarios, Beerwah East has been shown to generate the greatest potential for impacts. The effect on key parameters of water quality (e.g. sediments, nutrients and salinity) from modelled land use changes at the Beerwah East site are far greater than those of Halls Creek and Caloundra South (as interpreted from the 'developed all' case) as much of the Beerwah East area drains into Coochin Creek, which subsequently enters Pumicestone Passage in its most poorly flushed section.

4.4 Key Findings and Mitigation

As shown by the unmitigated modelling results, if development were to occur on the Halls Creek site with no management intervention, there would be significant potential for adverse water quality impacts on the protected downstream reaches of Halls Creek and on the Pumicestone Passage.

To manage these potential impacts, the following water quality mitigations are proposed:

- Section of the Halls Creek site within Halls Creek Catchment: New land uses can be considered provided extensive stormwater quality management are implemented. Mitigation measures will need to achieve stormwater pollutant load removal rates higher than typical requirements in DSDIP's (2013) "State Planning Policy" The protection and extension of the wetland will provide a significant additional 'buffer' to any pollutant export changes caused by the potential development of upstream areas upon downstream environment values.

  Section of Halls Creek site that is within Coochin Creek Catchment: New land uses should only be allowed if management interventions will result in no adverse change within the Coochin Creek catchment (given the environmental sensitivity of this waterway and that Coochin Creek discharges to some of the most poorly flushed sections of Pumicestone Passage).

An extensive and integrated whole of catchment stormwater management strategy consisting of education, rainwater harvesting tanks, rain gardens, vegetated channels, bio-retention basins, vegetated buffer areas and environmental protection and rehabilitation is proposed for the site. Any commercial development will also need to demonstrate compliance with standard 'best practice' targets for stormwater management.

The flow and loads from the developed areas of the site entering the wetland **with and without mitigation** are listed below.

Table 4-1 Predicted annual flows and pollutant loads from the site (developed areas only) to remnant *Halls Creek Wetland* (1997-2006)

Parameter	Existing Site	Developed Site with No Treatment	Developed Site with Treatment	% Increase from Existing Site	% Removal
Flow (ML/yr)	2 700	5440	3 770	40%	31%
Total Suspended Solids (kg/yr)	27 600	907 000	13 600	-51%	99%
Total Phosphorus (kg/yr)	105	1 860	102	-3%	95%
Total Nitrogen (kg/yr)	2 690	11 700	2 520	-6%	78%
Gross Pollutants (kg/yr)	0	121 000	0	0%	100%

The results show that the proposed stormwater management mitigation strategy for the site will:

- Achieve a reduction in pollutant loads that is significantly higher than typical 'best practice' targets (relative to the developed site without treatment). For example, typical 'best practice' pollutant load removal rates for areas proposed for development include an: 80%, 60%, 45% and 90% removal of total suspended solids, total phosphorus, total nitrogen and gross pollutants respectively. The proposed strategy for the site will achieve higher removal rates for these pollutants entering Halls Creek of: 99%, 95%, 78% and 100%.
- Decrease the pollutant loads of total suspended solids, total phosphorus, and total nitrogen discharged from potential development areas (relative to the existing site).

Noting the conservatism in the modelling that excludes any treatment benefits associated with the on-site wetland, these results provide further assurance, that with mitigation, the balance of the site has sound development prospects.

Rehabilitation of the nominated areas will also significantly improve the health of downstream waterway areas through improved catchment hydrology and reduced pollutant loads. In particular, the on-site Halls Creek wetland will provide a major attenuation role to catchment runoff for low to moderate flows. Further attenuation will result as residual flows pass through the downstream sections of the wetland and eventually enter Halls Creek proper.

A 100m buffer to the wetland (as part of the overall 500ha area proposed for rehabilitation) is recommended to further enhance water quality and manage stormwater volumes.

Enhancement of this storage function of the on-site wetland (to offset the additional volume of run off from upstream site development) is also an area that could be further explored. A range of strategies can be examined including:

- Earthworks to increase the wetland's area and/or volume
- Altering the flow regime to maintain higher water levels throughout the year; and/or
- Creating additional terminal wetlands within buffer areas that improve or enhance recharge of groundwater.

Each of these mitigation strategies will need to be carefully considered in terms of potential impacts on the achievement of other performance objectives. These include terrestrial and aquatic ecology and groundwater management. ASS management is also important as the bulk of the wetland area is below 5m AHD.

Performance Objectives for Water Quality

- 'No net worsening' in water quality within Pumicestone Passage and the Coochin Creek catchment (due to potential development of the Halls Creek Site)
- No substantial and measurable change in the water quality and hydrological regime of the wetlands with Ramsar status (i.e. Pumicestone Passage and the estuarine sections of Halls Creek and Coochin Creek HEV areas).

5 Flooding

The majority of the site has high flood immunity, requiring limited fill.

Areas of the site with lower elevations are not being considered for future development. Instead they are allocated for conservation and rehabilitation. With mitigation, flooding impacts can be contained on Site.

Any future development will need to demonstrate acceptable levels of flood immunity in accordance with relevant State Government standards for proposed residential and other land uses. Future development will also need to ensure no worsening of any flooding impacts for sensitive offsite locations.

Two previous flood-modelling assessments were undertaken for the site, as outlined in '*Caloundra South Flood Study'* (2013) and the '*Caloundra Downs Development: Flood Risk Management Strategy*' (2009).

A comparable version of the site design and layout was modelled as part of these prior flood studies, which is not substantially different to the preliminary site layout, presented earlier in this report.

5.1 Key Findings

The 2013 Flood Study found that all flooding impacts could be contained within the site. In addition:

- Both previous flood reports concluded that the most significant storm duration varied across the site. Shorter duration events more significant in the upper reaches of the catchment (generally the western portion of the site) and longer durations storm-tide related events are more significant in low-lying areas (the eastern section of the site).
- Both investigations found that the overriding flooding mechanism (should it eventuate) in the lower section of the site was storm tide inundation while fluvial flooding, originating from the Halls Creek catchment, dominated in other areas.
- As the site is generally contained within the Halls Creek catchment, potential development of the site would not have any significant adverse flooding impacts external to the site. As only a relatively small proportion of the site will require filling, any changes to the flooding regime are likely to be small and contained within the site boundary. Furthermore, due to the dominance of storm tide inundation in the lower areas of the site (as a potential impact), any increase in water surface levels as a result of potential development will likely be less than the storm tide inundation level. A possible exception in this regard is the potential for flooding impacts within three rural lots (RP129373/1, RP129373/2 and C31615/29) situated immediately north of the lower area conservation zone. Minor flooding impacts are possible in these areas and they will need to be carefully considered in the context of possible flood mitigation actions.

5.2 Mitigation

Based on the assessments to date, flooding would appear to be easily managed. Standard flood impact mitigation measures can be incorporated within potential development areas to prevent flooding impacts.

Flooding

As shown in Figure 5-1, any proposed development configuration will require fill in limited areas to raise lot levels above the 100 year ARI event, including an allowance for climate change. Assuming the inclusion of adequate mitigation works, the impacts of this can be fully contained within the site.

Based on current knowledge, from a flood immunity perspective the site appears suitable for development, provided that on site flood mitigation measures are adopted.

Performance Objectives for Flooding

- The overarching objective for flooding will be no increase in flood levels on properties outside the site (e,g. either upstream or downstream) whilst simultaneously providing appropriate level of flood risk within the site.
- The achievement of this performance objective for flooding should not preclude achievement of other relevant performance indicators outlined in this report, noting the strong interactions between flood management and water quality and surface hydrology, groundwater and ecological habitats that could be affected by changes to the flood regime on and off the site.

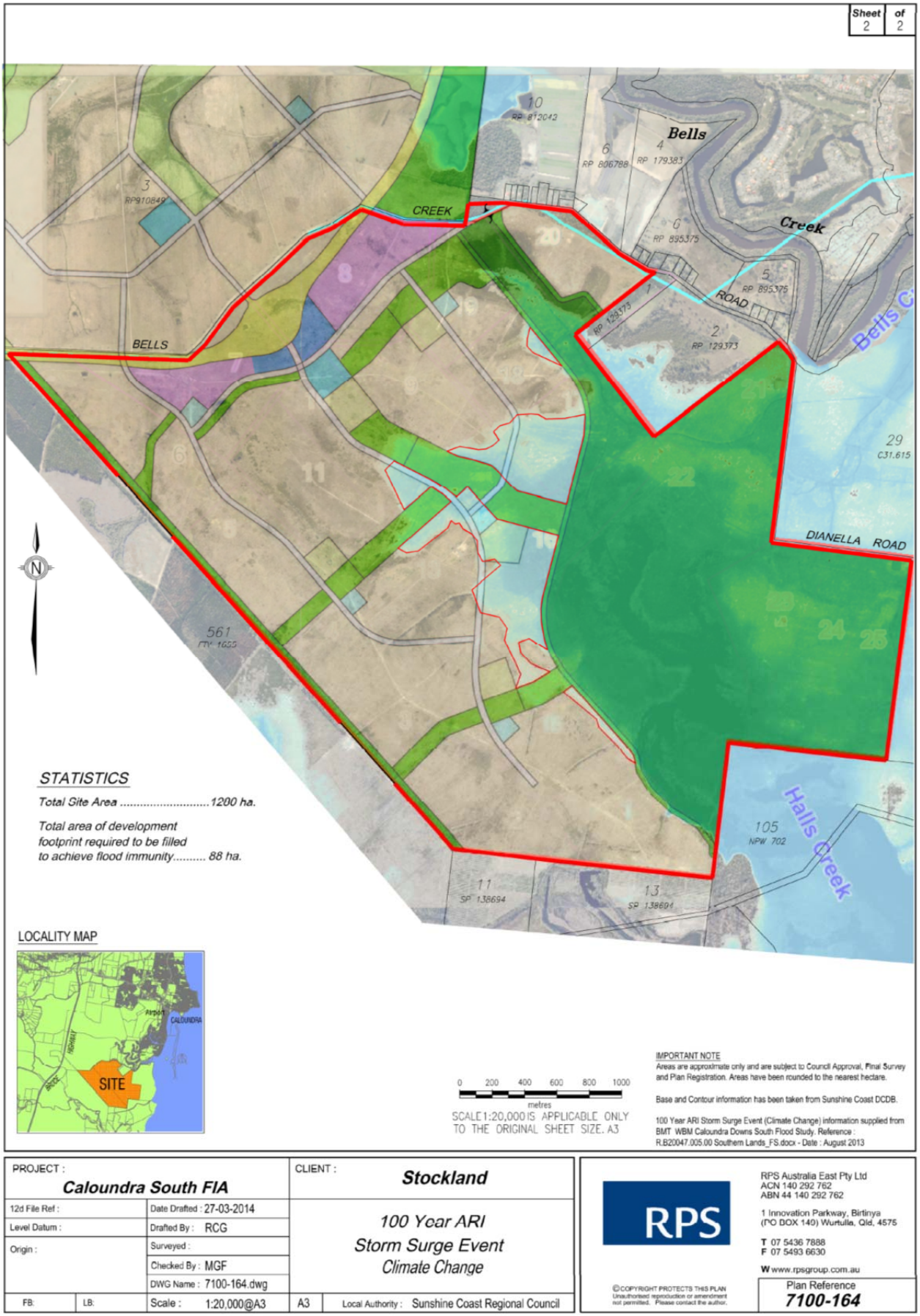

Figure 5-1 100 Year ARI storm surge event with climate change

6 Terrestrial Fauna

Acid frog species are the most significant threatened fauna present onsite.

Appropriate land use allocation and onsite management is proposed to sustain wallum frog habitat. Future development presents the opportunity to improve fauna values by rehabilitation of land in the east, thereby increasing the extent of natural habitats for a variety of fauna species (including wallum frogs).

Maintaining supportive groundwater conditions will be required to maintain and successfully rehabilitate habitat. Studies indicate that traditional movement opportunities can be improved in existing and new vegetation/habitat corridors and areas.

The site has been subject to a number of fauna surveys and evaluations since 1999. A field inspection was also undertaken in July 2014, which sought to resolve historical mapping differences in the extent of potential wallum frog habitats. These surveys have highlighted the following priority values:

- Wallum Froglet, listed as Vulnerable under the *Nature Conservation Act 1994* (NC Act)
- Wallum Rocketfrog, listed as Vulnerable under the NC Act
- Wallum Sedgefrog, listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and NC Act
- Downstream populations of Water Mouse (in Pumicestone Passage), listed as Vulnerable under the EPBC Act and NC Act
- Five migratory species listed under the EPBC Act, though none should be considered to be an 'important population'
- A north/south corridor linking values within the Bribie Island National Park to wetland vegetation immediately west of Pelican Waters, including potential passage for wallum frog species.

While future development has the potential to reduce the extent of wallum frog habitat (in particular), any potential loss of habitat would be offset within low-lying protected areas in the east of the site. Development presents the opportunity to improve fauna values by rehabilitation of land in the east, thereby increasing the extent of natural habitats for a variety of fauna species (including wallum frogs).

Existing fauna movement opportunities can be improved to allow near continuous passage through native vegetation from the Bribie Island National Park in the south to habitats west of Pelican Waters.

6.1 Baseline Conditions

6.1.1 Fauna Habitats and Vertebrate Communities

Mapping of pre-clearing vegetation by the Queensland Herbarium shows the site once supported extensive areas of wet heath and Melaleuca wetland (i.e., REs 12.3.4 and 12.3.13). Most of this was cleared and drained with the establishment of exotic pines in the 1950s and 1960s.

Pines have been progressively removed since the mid to late 1990s, and the site is now predominantly exotic grassland used for grazing purposes.

Based on recent surveys, four broad vegetation groups (i.e., vertebrate habitats) include:

(1) Exotic grassland/ex-pine plantation (including small pockets of remaining pine), covering the majority of the site

(2) Non-remnant low-lying sedge dominated communities (analogous to RE 12.3.13/12.3.14)

(3) Remnant *Melaleuca quinquenervia* open forest/wetland (RE 12.3.4)

(4) Remnant wet heathland (RE 12.3.13), which is associated with a drainage line located in the north.

Slashing and chopper rolling, a method of controlling and removing pine and woody regrowth continues, to shape all non-remnant habitats.

Detailed baseline studies by Hyder (1999) identified 154 vertebrate species across Caloundra South and Halls Creek including 16 frogs, 11 reptiles, 110 birds and 17 mammals.

6.1.2 Wallum Frogs

Three species of wallum frog, protected under legislation, are known to occur:

- Wallum Froglet (*Crinia tinnula*), Vulnerable under the NC Act
- Wallum Rocketfrog (*Litoria freycineti*), Vulnerable under the NC Act
- Wallum Sedgefrog (*Litoria olongburensis*), Vulnerable under both the EPBC Act and NC Act.

Large areas of the site during the Hyder survey (1999) were covered by exotic pine, a vegetation type which is unsuitable for Wallum Rocketfrogs and Wallum Sedgefrogs. With the clearing of this vegetation, transpiration will have reduced, allowing surface water to pool more frequently and persist for longer.

With the return of favourable habitat conditions, Wallum Rocketfrogs and Wallum Sedgefrogs are likely to have recolonised from pockets of native vegetation, and/or from nearby populations (such as those on Caloundra South). During favourable rainfall conditions (e.g., such as those experienced in 2012), current populations of these two species are likely to be at their highest since pre-clearing disturbance occurred.

Figure 6-1 Remnant wet heath/sedgeland in the north: known habitat for the Wallum Sedgefrog. July 2014

6.1.2.1 Wallum Froglet and Wallum Rocketfrog

The Wallum Froglet is well known at Halls Creek, described in Hyder (1999) as “common across the whole site, even throughout cleared areas and pine plantations”. This has been confirmed by recent work (EcoSmart Ecology unpublished data; ARUP 2013; AWC and EcoSmart Ecology 2014; this study).

While the species requires specific water conditions (tannin stained acid waters), it can tolerate vegetation disturbance and will occur in most wet remnant and non-remnant vegetation. The species is widespread and should be considered likely wherever surface water pools at Halls Creek.

In contrast to the Wallum Froglet, the Wallum Rocketfrog is not well known at Halls Creek, first recorded in 2012 (EcoSmart Ecology unpub data). However the species is known to occur in disturbed habitats, particularly areas of regrowth wet heath. It is known to occur in similar habitats and locations to the north on Caloundra South (EcoSmart Ecology 2013).

While the Wallum Froglet can occur in even the smallest of water bodies, the Wallum Rocketfrog tends to associate with pools of water, or in areas were many small pools aggregate.

6.1.2.2 Wallum Sedgefrog

Wallum Sedgefrog records are typically aggregated in remnant habitats of RE 12.3.13, such as the area associated with the drainage located in the north, or in areas of RE 12.3.13/12.3.14 regrowth. Suitable regrowth areas typically include low-lying locations cleared of pine where wet furrows support the growth of sedges and surface water may persist for several weeks following heavy summer/autumn rain.

There is a notable absence of Wallum Sedgefrogs in the area of regrowth sedgeland (native dominated) immediately adjacent the Halls Creek wetland. Recent monitoring suggests that water quality parameters in this wetland may not be suitable, due to high levels of ions, including free aluminum. At this stage it is not considered suitable habitat.

As shown in Figure 6-2, known and possible Wallum Sedgefrog habitats based on existing information and field inspections are placed in four (4) categories depending on factors such as the presence of surface water and particular vegetation types (such as native sedges). Nearby Wallum Sedgefrog populations have been located in areas dominated by exotic grasses and few native sedges (i.e., Caloundra South, see EcoSmart Ecology 2013). As such, mapping requires verification during a representative summer wet season.

Except for remnant wet heath/sedgeland in the north, areas of known and potential habitat are currently subject to periodic slashing and/or chopper-rolling which may affect the amenity of habitat for Wallum Sedgefrogs in the short term. In the longer term, however, slashing/chopper-rolling may be important for suppressing woody regrowth which, if left unchecked, could reduce the extent of suitable habitat for Wallum Sedgefrogs.

6.1.2.3 Water Mouse (Xeromys myoides)

Targeted surveys for Water Mouse were undertaken by Hyder (1999), and failed to locate this species onsite. It was determined that no suitable habitat was present. However, suitable habitat and Water Mouse evidence is known to occur downstream, associated with mangrove and intertidal areas (particularly reeds and Marine Couch) along the Pumicestone Passage.

For the purpose of this assessment, it has been assumed that Water Mouse populations are present downstream, and that future developments must ensure that no indirect impacts occur downstream.

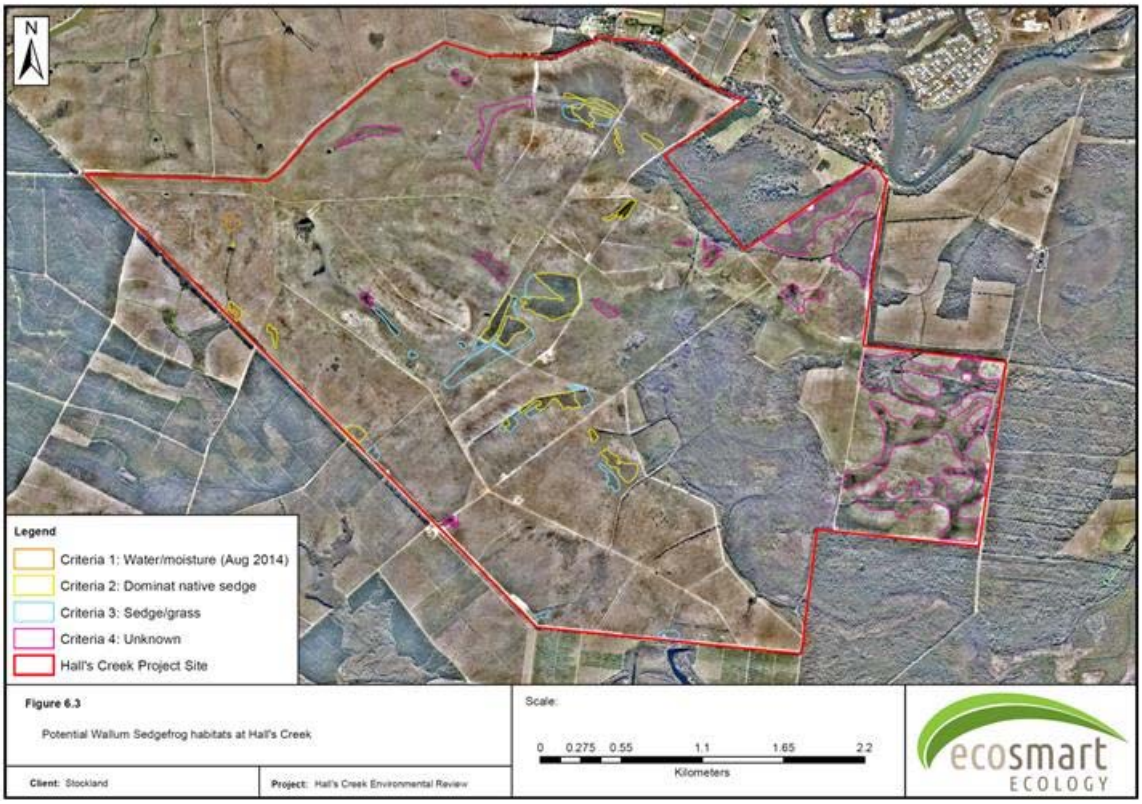

Figure 6-2 Potential Wallum Sedgefrog habitats on the site

6.1.2.4 Migratory Species

Five migratory bird species have been recorded onsite: Eastern Great Egret (*Ardea modesta*)[1]: Cattle Egret (*Ardea ibis*); White-breasted Sea-eagle (*Haliaeetus leaucogaster*); Rainbow Bee-eater (*Merops ornatus*); and Rufous Fantail (*Rhipidura rufifrons*).

In addition to these species, White-throated Needletail (*Hirundapus caudacutus*) is also likely to occur as an aerial forager. Latham's Snipe (*Gallinago hardwickii*) may also occur, though would be largely restricted to wet vegetation or heath.

Whilst all known or possible migratory species are abundant and widespread in the local area and region, no migratory bird populations at Halls Creek constitute a 'significant population', as defined under the EPBC Act.

6.2 Wildlife Corridor Values

A wildlife corridor of regional value flows through, and to the immediate east, of the Halls Creek site. This north-south corridor includes vegetation to the immediate east of Halls Creek (i.e., along the Pumicestone Passage), before continuing inland along Bells Creek and then north through wetlands west of Pelican Waters.

The corridor is weakly connected at several locations, and for many species the corridor may act as a series of 'stepping stones'.

[1] Listed as *Ardea alba* sensu lato under the EPBC Act 1999.

The corridor may not be suitable for less mobile species. Remnant *Melaleuca* vegetation (RE 12.3.4) and remnant wet heath (RE 12.3.13) in the north contribute to this pathway.

6.3 Key Findings and Mitigation

Potential development impacts to priority fauna values, and possible mitigation measures, include:

- An area of 33 ha of acid frog habitat would potentially be lost through development. Much of this habitat has been created due to the current site management practices. A change in these practices and seasonal change would see this vary or reduce. If site management was to reduce it is likely that suitable habitat conditions would be altered, particularly with pine re-growth.
- The potential loss of wallum frog (including Wallum Sedgefrog) breeding habitat would require the procurement or creation of suitable offsets. Considerable knowledge about acid frog habitat re-creation has been gained through Caloundra South planning and would be applied to any mitigation and offset at the Halls Creek site. Areas identified as 'conservation' coincide with low-lying water logged wetlands, sedgelands or grasslands. These areas connect with, and are immediately adjacent to, the 'wetland' zone. On face value rehabilitation of this area presents the opportunity for wallum frog habitat protection, augmentation or creation. However Wallum Sedgefrogs (and other wallum frogs) are absent from the immediately adjacent wetland zone, despite habitat in the wetland appearing superficially suitable. Preliminary evidence suggests that water quality may be a significant factor, and if confirmed, may also affect habitats within the rehabilitation area. Further work is required to understand the absence of Wallum Sedgefrog from these habitats in order for habitat protection/creation in the rehabilitation zone to be considered a viable mitigation option.
- Wallum frog habitats can be indirectly affected by adverse run-off from urban development. Suitable wallum habitats are typified by low nutrient, low ion, low pH (between 4 and 6), tannin stained waters. Potential development will need to consider drainage within and adjacent to these habitats on site as well as localised changes to water quality in adjacent wallum habitats. A range of detailed mitigation measures proposed for Caloundra South would also be appropriate for the site.
- In addition to affecting water quality, urban development can indirectly impact wallum frog values by altering hydrological regimes. Wallum Sedgefrogs typically inhabit wetlands, which dry during the winter, and flood for extended periods (typically 6+ weeks) during the summer wet season. Often this cycle is closely linked to sub-surface groundwater, particularly perched aquifers within 1-2m of the soil surface. Urban developments, which reduce infiltration, can reduce the frequency or duration of pooling surface water. Conversely increased permanence of water can also adversely affect populations (Meyer *et al* 2006). Development will require evaluation and mitigation of these impacts.
- Vegetation to the north of the site associated with the drainage line should be maintained. This will reinforce the movement opportunity for a variety of fauna species between the site and Caloundra South. The low-lying nature of this corridor, with its associated sedge communities and wet heath is distinctive. Few other alternatives for corridor realignment are available.
- Water Mouse habitats are a considerable distance downstream from possible development areas. Indirect impacts through adverse water quality to Water Mouse habitats (including the

loss of prey) are not expected, but appropriate documentation and consideration of these values will need to accompany any development application.

6.4 Opportunities to Add Benefit

There are two significant opportunities, which if implemented, would add significant worth to local fauna values, and would lead to a near continuous stretch of vegetation from the Pumicestone Passage (Bribie Island National Park) north to west of Pelican Waters (separated only by Bell's Creek Road).

The specific opportunities are:

(1) Rehabilitation of cleared land in the east to improve wallum frog values and provide significant additional habitat (forest/woodland) for a variety of local species expanding the important environmental values adjacent the site

(2) Retention of connectivity and movement opportunity to Caloundra South along the northern drainage line. The protection of existing remnant habitats associated with the wetland and wet heath in the north (RE 12.3.13) will maintain existing movement opportunities for a variety of fauna species.

The value of this corridor could be significantly improved by rehabilitation of currently cleared areas to connect habitats associated with the wetland (RE12.3.4) to wet heath vegetation (RE12.3.13) in the north.

In addition, the area to the west of the wet heath (RE 12.3.13), can connect the site to significant habitats on Caloundra South. This work could significantly improve connectivity between wallum frog habitats on these two properties.

Performance Objectives for Terrestrial Fauna

- No net loss of Wallum Sedgefrog breeding habitats on the site
- Retention and/or improvement of traditional movement opportunities and existing corridor vegetation/habitat
- Habitat improvement and augmentation in proposed non-development areas
- Maintenance or improvement of natural water quality within the site (low pH, low ion, tannin-stained)

7 Terrestrial Flora

Around 87% of the site is cleared and now used for cattle grazing.

Exotic grassland and small pockets of pine cover the majority of the site.

The remnant Halls Creek wetland and some of the heathland vegetation communities on the site contain important flora. The site also supports small communities (in a 2ha area) of Mount Emu She-oak and Christmas Bells. It is recommended that clearing and development is excluded from these areas.

The increase in freshwater flows into the wetland under a developed scenario would not be considered to result in changes to the structure, health and condition of the wetland.

It is proposed to increase the proposed conservation/ rehabilitated area on site.

The vast majority of the site is cleared. The vegetation communities currently present within the site have been subject to various levels of historical and ongoing disturbance. This has primarily occurred through clearing of remnant vegetation to establish pine plantations and the current management of the site as a cattle grazing property.

The vegetation communities present on the site are likely to be a result of the site drainage and topography, as well as the current site management practice of chopper rolling to manage pine re-growth.

Within the site, there are still some elements of the terrestrial flora and vegetation communities that have significance at a State and National level. These have been identified using a combination of desktop (including database searches) and field surveys carried out in July and November 2013 and August 2014 both onsite and downstream from the site.

7.1 Baseline Conditions

During the field surveys in 2013 and 2014 the boundaries and vegetation composition of mapped remnant REs were assessed for remnant status and floristic composition.

The vast majority of the site is cleared. There are two patches of intact, remnant vegetation on the site. In the south-eastern corner of the site there is a 140ha patch of remnant Broad-leaved Melaleuca (Paperbark) open forest/woodland and wetland (RE 12.3.5), associated with the Halls Creek drainage depression. It is the only patch of regulated vegetation under the Queensland *Vegetation Management Act, 1999* (VM Act) on site.

Figure 7-1 Paperbark wetland

In the north-west corner of the site there is a smaller 32ha patch of closed heathland (RE 12.3.13). This is not mapped as regulated vegetation under the VM Act, but the structure and condition of this community can be considered as remnant. This is located in a drainage depression associated with the upstream reaches of Halls Creek.

These areas of remnant vegetation are also known to support the two species of significant flora recorded on the site – Mount Emu She-oak and Christmas Bells. Other suitable, good quality habitat for significant flora species is restricted to the two patches of remnant vegetation within the site.

There is also currently an approved Property Map of Assessable Vegetation (PMAV) within the Stockland landholdings of the site (PMAV reference 2008/009340).

During the site analysis eight vegetation communities or types were identified within the study area, as shown in the table below.

Table 7-1 Site-based vegetation communities, total area and percentage of the site

Vegetation community	Area (ha)	% of Halls Creek study area[2]
Pasture	848.7	62.1%
Reedy drainage line	2.7	0.2%
Melaleuca regrowth +/- pine	50.1	3.7%
RE12.3.13, 12.3.14 regrowth - pasture dominant	139.1	10.2%
RE12.3.13, 12.3.14 regrowth - native dominant	62.9	4.6%
RE 12.3.5 – remnant	197.2	14.4%
RE12.3.13 – remnant	31.8	2.3%
RE 12.9-10.4 – remnant	33.9	2.5%
TOTAL	**1,366.3**	**100%**

[2] As shown in Figure 7-2, the study area for the terrestrial flora assessment includes areas outside the boundaries of the Halls Creek site situated to the southeast.

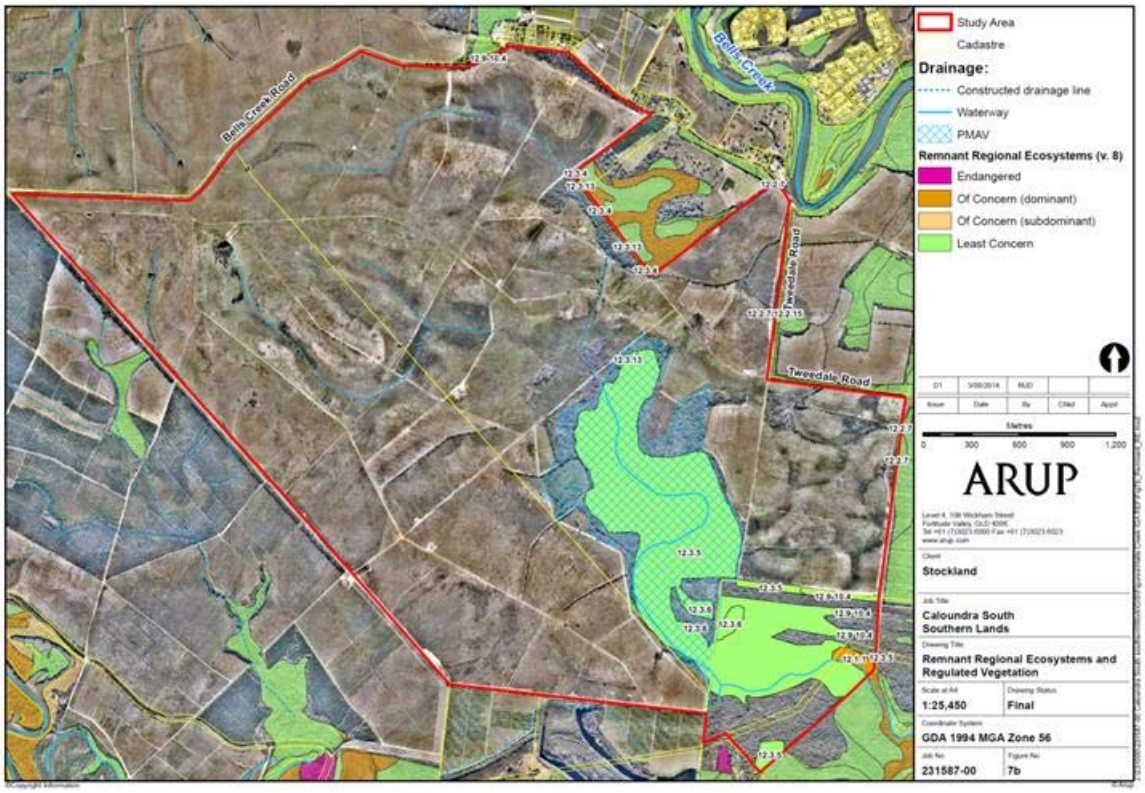

Figure 7-2 Remnant regional ecosystems and regulated vegetation

7.2 Significant Flora Species

The site has the potential for a range of significant flora species (those defined as near-threatened, vulnerable or endangered under the NC Act and listed threatened under the EPBC Act).

The site is known to only support two very small populations of two significant flora species comprising an area of less than 2ha of the entire site which would need to be protected or relocated:

- The EPBC Act listed endangered Mount Emu She-oak *Allocasuarina Emuina.* Two locations (not previously identified in the Recovery Plan for the species) have been identified and can be considered an “important population”:
  - one location with fifty (50) plants within approximately 200m^2 located on the western boundary of the site. There is evidence that this population is in decline, meaning that its long term viability is under question
  - another site identified through fieldwork in July 2014 within RE 12.3.13 on the upstream section of the Halls Creek drainage line. This is a very healthy population with evidence of recruitment. Initial surveys indicate this population covers an area of approximately 1.55ha and sampling indicates that density of plants is approximately 400 plants/ha. At this stage, it is approximated that the population is around 620 plants.
- The NC Act listed Christmas Bells *Blandfordia Grandiflora*, was identified in the 2013 field survey within the remnant closed, wet heathland with a dense sedge understory (RE 12.3.13) in the north-western corner of the site. Thirteen plants were recorded in a sample area of approximately 5,000m^2. Based on this sample, the estimated population size in the 2ha closed/wet heath area is a maximum of 52 plants. An isolated group of Christmas Bell plants

was also observed along a drainage line near the centre of the site in late 2014. Further surveys will need to be undertaken in this area but it is likely that the habitat conditions at this location are less favourable than the remnant wet heathland areas in the north-western corner of the site.

Figure 7-3 Example of reedy regrowth along drainage line

7.3 Key Findings

It is recommended that clearing and development is excluded from the remnant Melaleuca wetland and heathland vegetation communities on the site.

The areas of remnant Melaleuca Paperbark wetland and heathland on the site are considered to be dependent on surface water and groundwater interactions in the site. Changes to levels and periods of inundation can lead to gradual community level changes in the vegetation communities.

Broad-leaved Paperbark trees can tolerate a wide range of flooding, soil moisture, salt and nutrient deficient soils (Watt et al 2009), although adequate soil moisture is required for long-term retention and management of these patches of vegetation (Joyce 2006).

The modelled increase in freshwater flows in a developed scenario is not considered likely to result in changes to the structure, health and condition of the vegetation community within the Halls Creek wetland.

Changes to groundwater levels, including periods and extent of inundation can result in changes to heathland vegetation communities, with wetter conditions causing a trend towards open sedgeland communities and drier conditions favouring larger, woody plants.

Maintenance of fire regimes, including frequency, severity and seasonality elements, is an important element of the ecology of the remnant vegetation communities within the site. A fire management plan will need to be implemented across the site, which takes into account the 3-5 year return fire interval for Christmas Bells and a longer 8-12 year fire return interval for Mount Emu She-oak in the areas of remnant heath.

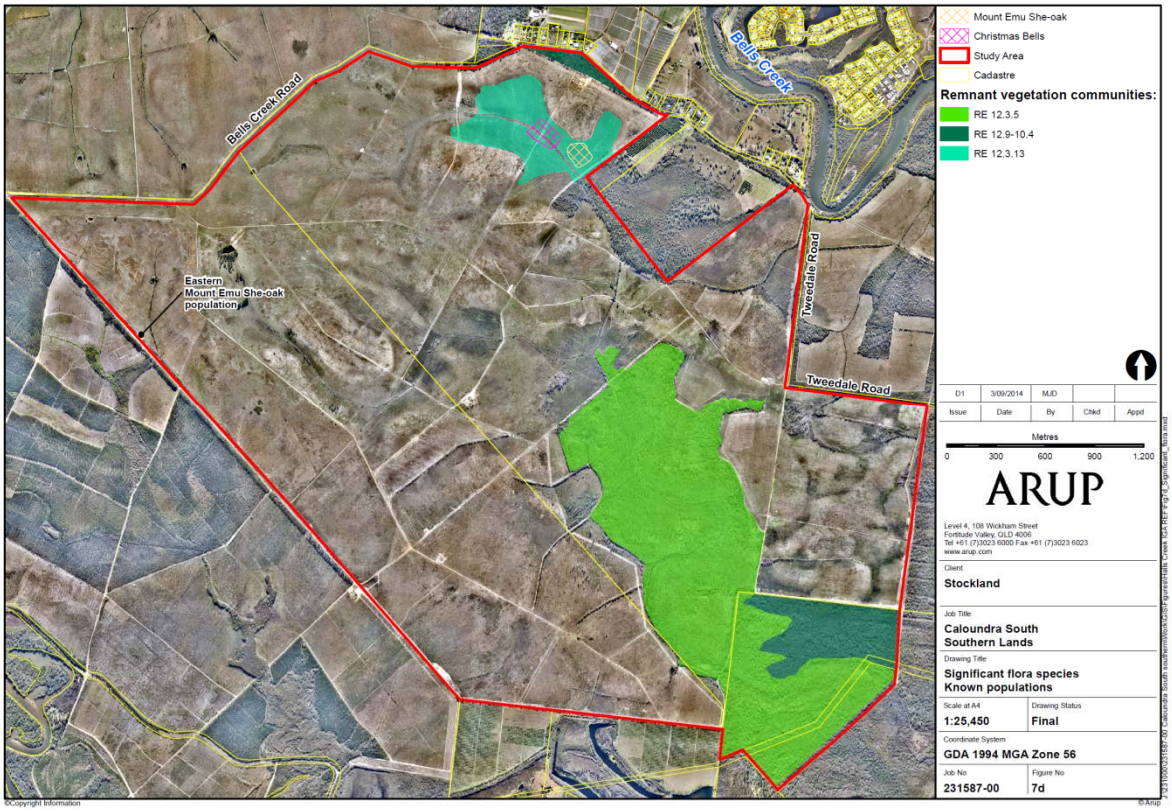

Figure 7-4 Known populations of significant flora species

Previous site investigations identified six (6) flora species that are declared weeds under the Land Protection (Pest and Stock Route Management) Act 2002 (LP Act); namely:

- Lantana *Lantana camara*
- Chinese Elm *Celtis sinensis*
- Broad-leaved Pepper Tree *Schinus terebinthifolius*
- Camphor Laurel *Cinnamomum camphora*
- Singapore Daisy *Sphagneticola trilobata*

These are listed as Class 3 declared plants under the LP Act. This means that these species will need to be controlled and a construction-based and longer-term weed management will be required.

7.4 Opportunities to Add Benefit

There is an opportunity to provide a revegetated corridor between the two remnant RE patches on the site to create a single, connected area of native vegetation.

Outside of the two patches of fragmented remnant vegetation on the site, exotic pasture grasses dominate, with some native regrowth. Additional flora surveys are recommended across the balance of the site, noting there may be isolated patches of suitable habitat for significant flora species (such as Christmas Bells) outside of these remnant areas that could be targeted for transplantation into the future conservation area.

Opportunities can also be considered to implement revegetation works between the Bribie Island National Park and the patch of remnant Broad-leaved Paperbark forest, all contributing to a larger connected corridor to the Environmental Protection Zone of Caloundra South to the north.

Performance Objectives for Terrestrial Flora

- Retain and protect remnant Regional Ecosystems and vegetation communities
- Retain, protect and enhance known populations and habitat for threatened flora species
- Reduce fragmentation and enhance ecological connectivity along the regional biodiversity corridor that extends from the north between the Environmental Protection Area at Caloundra South and south towards the Bribie Island National Park

8 Aquatic Ecology

The site has a long disturbance history, however the artificial channels, Halls Creek wetland and onsite storages represent potential habitats for aquatic species.

Any future land use change would need to maintain or improve natural water quality to support habitat for aquatic ecology.

While the aquatic habitats on the site are suitable for the endangered Oxleyan Pygmy Perch and Honey Blue Eye, neither of these freshwater fish were detected in water bodies or in the wetland.

The offsite estuarine areas downstream of the site represent the highest aquatic ecology values.

Water quality and quantity modelling indicates that habitats for threatened aquatic species on the site can be protected and maintained.

Through careful management of on-site water quality and hydrology, estuarine habitats within the Moreton Bay Ramsar site can also be protected.

Despite its long disturbance history, the site supports a network of artificial channels, wetland and water storages that represent potential habitats for a range of aquatic vegetation and fauna species.

Figure 8-1 Example of drainage channel – water is relatively clear, tannin-stained

The site is also located adjacent to (and drains into) Pumicestone Passage, an estuarine channel that forms part of the Moreton Bay Ramsar wetland site, which supports a range of species and habitats of high biodiversity value.

The surrounding land areas and waterways support species, communities and habitats of high aquatic biodiversity and fisheries significance.

Nature conservation areas (Ramsar, Marine Park, Fish Habitat Area) are situated downstream of the site with key migratory species present in estuarine and marine areas (turtles, dugong, and waterbirds). The site supports optimal habitat conditions for two nationally threatened ‘wallum’ fish

species found in the bioregion (*Nannoperca oxleyana* and *Pseudomugil mellis*). However, neither species were recorded in the most recent surveys.

The hydrological conditions of the Halls Creek site have a key influence and control on the ecological features and processes of the site and in downstream areas. A drainage line traverses areas of wallum and paperbark wetland, which provides important habitat for flora and fauna species. These habitats, and the species that occur in them, rely on surface and ground water for their healthy functioning.

The present study has used searches of relevant databases, a review of previous studies, and where there was inadequate existing information, supplementary field investigations.

The littoral wetland vegetation communities (mangroves, saltmarsh and fringing wetland communities) in the Halls Creek estuary (outside of the Site) were mapped on the basis of existing information and ground truthing. Discrepancies in existing vegetation mapping were remapped by digitising the vegetation from aerial photographs of the study area to reflect actual conditions. An intertidal and seagrass meadow survey was undertaken on 15th July 2014. An aquatic ecology survey was conducted from the 9th to 11th July 2014 where eighteen sites were surveyed.

An assessment of structural habitat characteristics and aquatic vegetation was conducted at each site using a modified version of the AusRivAS sampling protocol (DNRM 2001). At each monitoring site *in-situ* measurements of the physico-chemical water quality parameters were measured.

8.1 Baseline Conditions

8.1.1 Habitats

Aquatic habitat types present in the study area at the time of surveys include:

- **Natural flow paths and artificial drains** - generally dry at the time of sampling with occasional pools. Riparian tree cover was variable reflecting the history of clearing on the site. The extensive sedge cover at most sites provided high degree of structural micro-habitat complexity for aquatic fauna. Water quality conditions were typical of 'wallum' creeks in south-east Queensland. Waters were acidic, with three sites meeting Water Quality Objectives although pH was higher than in the Halls Creek wetland and within the typical range to support wallum habitats. DO was below the WQO and electrical conductivity was low.
- **Lacustrine wetland (lake)** – represented by a permanent artificial lake/dam in the northern sector of the site with relatively good water quality. Highly disturbed by cattle with a mix of *Pinus radiata* and Melaleuca, and apart from sparse patches of *Cyperus* spp., the sedge/emergent macrophyte cover was low. The artificial lake supports a range of aquatic fauna habitat values (refugia, complex habitats etc.) that are important at a site-scale.
- Flooded Melaleuca palustrine wetland (Halls Creek wetland) – represented by the *Melaleuca* forest in the southern sector of the site. The trunk and roots of *Melaleuca*, together with woody debris (fallen trees, branches etc.), provide an abundance of micro-habitat types. Aquatic macrophytes were sparse at the time of survey. The wetland provided optimal habitat conditions for small-bodied fish including the two threatened wallum species.

Waters were highly acidic (pH 3.2 to 3.9) at the time of sampling, which was well below the water quality objective[3] range (pH 5.0 to 7.0). Dissolved oxygen concentrations (20 to 84% saturation) were below the WQO at all sites (85-110% saturation). Waters were clear, and had low colour and low turbidity (1.7 to 9.0 NTU) at the time of sampling, however during rainfall the wetland can become highly turbid (BMT WBM, pers. obs. May 2014). Electrical conductivity values increased with distance downstream, ranging from 240 µS/cm at upstream sites to 1079 µS/cm at the most downstream site.

The low pH and to a lesser extent dissolved oxygen concentrations measured here would likely be outside the tolerance range of most aquatic vegetation and fauna species. While 'wallum' dependent species are adapted to moderately low pH levels, the values recorded here could cause direct physiological stress to most species. It is also expected that low pH would lead to the precipitation of many metals and metalloids, resulting in toxic effects to aquatic biota. Therefore, despite the presence of optimal structural habitat conditions, water quality conditions within the wetland severely limit its capacity to support most aquatic flora and fauna species.

- **Palustrine marshes** – represented by small soaks located throughout the subject site. At the time of sampling, all marshes inspected did not support sufficient standing water to undertake sampling (i.e. water depth less than 0.2 m). All marshes inspected had a high cover of sedges and ferns, which during wetter periods would provide complex structural habitats for aquatic macro-invertebrates.

8.1.2 Freshwater Fauna - Fish

A total of 331 individuals from six native species and one introduced species were recorded. The most abundant species were firetail gudgeon (39% of individuals), empire gudgeon (36% of individuals) and eastern gambusia (18% of individuals).

Species richness was highly variable among sites, ranging from zero at the downstream palustrine Melaleuca sites, one species at site 44 (Coochin Creek) and sites 28 and 16 (lower Halls Creek), and three to six species were recorded at the other sites.

The artificial dam (site 49) had the highest species richness and abundance of fish overall. The presence of permanent, relatively good quality water in the dam is likely to be a key factor contributing to its values as a fish habitat.

No fish were recorded at the four flooded Melaleuca wetland sites. Only low fish abundance was recorded at the sites directly adjoining the wetland, largely due to the low pH and likely high metal concentrations at or outside the tolerance limits of most fish species.

Only one introduced species was recorded; the noxious pest eastern gambusia (*Gambusia holbrooki*) which was abundant in places, particularly at the Coochin Creek site (51% of fish) and at the dam site (21% of fish).

In terms of native fish, the most abundant species overall were gudgeons, namely firetail gudgeon *Hypseleotris galii* (39% of individuals), empire gudgeon *Hypseleotris compressa* (36% of individuals), and striped gudgeon *Gobiomorphus australis* (4% of individuals). Two eel species (*Anguilla reinhardtii* and *A. australis*) and Australian bass (*Macquaria novemaculeata*) were recorded in low numbers.

[3] For wallum/tannin stained streams. Note that this WQO has been applied as there are no available WQOs for wetlands at the time of reporting

Given the limited waterway area within the site, it is unlikely to be an especially important fisheries habitat. Instead, the site is considered to have fisheries habitat values that are broadly representative of small coastal floodplain creeks in the wider Pumicestone Passage basin.

The site supports optimal habitat conditions for two threatened 'wallum' fish species found in the bioregion (*Nannoperca oxleyana* and *Pseudomugil mellis*). Neither species were recorded in the present study. However, both species are cryptic, and non-detection during a one-off survey does not necessarily mean that they are not present within a waterway.

8.1.3 Invertebrates of Conservation Significance

There are no threatened invertebrate species (listed under EPBC or *Nature Conservation Act 1992* (NC Act)) with an aquatic life-stage known to occur in the bioregion.

Terrestrial wetland invertebrate species including dragonflies and crayfish were not targeted in this assessment. However, during fish surveys the swamp crayfish *Tenuibranchiurus glypticus* was recorded in the sedge-lined habitats within Coochin Creek (site 44). This species, which is listed as Endangered under the IUCN Red List, is thought to be restricted to SE Queensland and inhabits coastal wallum swamps among sedges (Coughran *et al.* 2010). Suitable habitat for this species is present on and off the site. Further targeted surveys would be required to determine its status on the site.

8.1.4 Estuarine Habitats

In the context of estuarine and coastal wetland vegetation communities downstream of the site, the following RE types have been identified within the study area and surrounding areas: saltmarsh/saltpan (RE 12.1.2) and mangroves (RE 12.1.3), Casuarina and Melaleuca dominated riparian vegetation and estuarine wetlands (RE 12.1.1, 12.2.7, 12.3.5, 12.3.6) and other dune and coastal vegetation (RE 12.9-10.4).

These vegetation communities form distinct zonation patterns, which are driven mostly by the tolerances of different species to inundation and salinity, as well as soil conditions and biological processes, such as recruitment, competition, and dispersal. The typical zonation pattern in estuarine creeks is (from landward to seaward):

- Terrestrial vegetation (typically Eucalypt forest, scrublands and cleared lands)
- Casuarina and Melaleuca forest and wetlands
- Saltmarsh and saltpan
- Mangrove forests.

Mangrove shrub-land to low closed forest was present along the length of the estuarine sections of Halls Creek downstream to Halls Bay Pumicestone Passage. Most mangrove forest within the (offsite) study area was considered to be in good ecological condition.

Saltmarsh is an intertidal wetland type that relies on the periodic inundation of salt water and is generally found as a zone landward of mangrove stands. Most of this saltmarsh within the study area (offsite) occurred as large, isolated patches situated east and south of Halls Bay. Halls Bay is a small embayment off the main channel of Pumicestone Passage. Halls Bay is the receiving environment of waters draining from the Site. Seagrass meadows mapped in Halls Bay were comprised of sparse (less than 20% cover) assemblages of *Halophila ovalis* and *Zostera muelleri*.

A thin layer of silt covered the seagrass at several of the sites. The limited and changed seagrass coverage from that mapped in 2002 was likely a response to low light availability.

8.2 Key Findings

As outlined above, the site supports optimal habitat conditions for two threatened freshwater 'wallum' fish species found in the bioregion (Oxleyan Pygmy Perch and Honey Blue Eye), but neither species were recorded in the present study. However, both species are cryptic, and non-detection during a one-off survey does not necessarily mean that they are not present within a waterway.

Assuming these species are not present, the estuarine areas downstream/offsite of the site represent the highest aquatic ecology value and development constraint. This area represents a state conservation reserve (Moreton Bay Marine Park), contains the internationally significant wetland protected under the EPBC Act 1999 (Moreton Bay Ramsar site), and supports a range of aquatic ecosystem values including the provision of fisheries habitat.

On this basis it is recommended that proposed development should not result in detectable and ecologically significant changes to hydrology, water quality and biotic components within the (offsite) Halls Creek estuary. This and other aquatic ecology constraints are described in the table below:

Table 8-1 Summary of aquatic ecology constraints

Ecological feature	Constraint level	Location
Farm Dam	Low	While supporting largest number of fish species, small size and lack of connectivity limits its aquatic biodiversity values Threatened aquatic species unlikely to be supported Limited opportunity to improve aquatic habitat values at a site-wide scale
Flooded Melaleuca on the subject site	Low / High	Critical to maintaining connectivity between the subject site and downstream wetland habitats Limited aquatic habitat values due to poor water quality Presently low constraint, with possible adverse effects to downstream environments at present Potentially good aquatic habitat if water quality conditions (low pH) could be improved
Sedge lands on the subject site	Low – Medium	Sedge lands (on-site) provide potential habitat for an IUCN listed threatened crayfish species (a mainly terrestrial wetland associated species)
Creeks within the subject site	Low – Medium	Threatened freshwater fish not currently supported on-site, but additional survey required to confirm Potential habitat for threatened crayfish (additional survey required to confirm) Connectivity for aquatic fauna movements
Downstream Ramsar wetland / threatened marine fauna / seagrass	High	Ramsar site located off-site but in receiving waters Potential indirect impacts (hydrology, water quality) to ecological values – requires mitigation

8.2.1 Avoiding Changes to Hydrology and Water Quality

Potential development, most notably increases in the area of impervious surfaces and possibly alterations to drainage, will result in change to on-site hydrology. Water management systems will need to be designed to minimise impacts to on-site aquatic habitats from these changed hydrological conditions.

In downstream areas off the site, the state of the shoals in Halls Bay (e.g. the estuarine inlet of Halls Creek) is controlled predominantly by tidal processes, with major flood events likely to cause scouring of the channel and redistribution of shoals. Development proposals will need to be designed to not affect the magnitude or timing of moderate to high flow events.

Changes to catchment hydrology also have the potential to modify biological character of habitats and species in downstream estuarine environments. Estuarine fauna communities are directly influenced by fluvial flow regimes. Fisheries catch is often elevated during or following years of high flow, however the causality of such relationships and precise flow requirements of estuarine systems are not known.

Future development proposals will need to ensure there is limited impact on the magnitude or timing of moderate to high flow events, or significantly reduce the frequency of low flow events.

Tidal processes will continue to control water levels within the offsite estuarine creek, which is of particular importance to maintaining the distribution and structure of estuarine vegetation. It is not known to what extent surface water and groundwater hydrology controls vegetation communities within the Ramsar site, and the likely impacts to these communities.

Common to most development scenarios, the potential for water quality impacts could result from three key processes:

- Increase in pollutant loads (e.g. nutrient, metals etc.) from catchment activities
- Altered hydrology, which can effect salinity and concentrations of other dissolved substances within downstream receiving waters (see above)
- Accidental releases of toxicants resulting from spills.

An environmental management objective during all construction will be to ensure that water leaving the work sites will be of similar quality to that of receiving waters and that contaminants do not leave the site. A construction phase Environmental Management Plan (EMP) will be required.

While unlikely, a change to groundwater hydrology that results in further lowering of pH and increased metal concentrations in downstream estuarine ecosystems is considered to represent a significant risk requiring on-site monitoring.

Given these sensitivities, it is important that releases of waters from the subject site do not result in substantial changes to water quality in downstream receiving environments, in accordance with proposed mitigation measures for groundwater and surface water quality.

Measures to maintain, rehabilitate and enhance aquatic communities in the project area are also assisted by proposed measures for terrestrial ecology. These include preparation of a Weed Management Plan as well as a Pest and Animal Control Plan covering construction and operational activities.

8.3 Opportunities to Add Benefit

Given the generally disturbed nature of the subject site, there are significant opportunities for site restoration to improve aquatic ecosystem values. In particular:

- Rehabilitation of riparian vegetation and aquatic habitats on Halls Creek between the heathlands in the north-eastern corner of the site, and the flooded Melaleuca forest.
- Water management strategies leading to enhancement of water quality conditions within the flooded Melaleuca forest in the south-eastern sector of the subject site.
- Rehabilitation of degraded wetland (and terrestrial) environments outside the subject site to enhance general biodiversity values and resilience of the Ramsar wetland.

Performance Objectives for Aquatic Ecology

- Protect and maintain habitats for threatened aquatic species on the site
- No loss of estuarine habitats within the Moreton Bay Ramsar site
- No measurable, substantial and ecologically significant changes to the hydrology or water quality downstream of the site within the Moreton Bay Ramsar site.

9 Cultural Heritage

The Halls Creek Site has been highly disturbed and does not contain any recorded and/or protected non-indigenous cultural heritage sites.

The site is located in the traditional country of the Kabi Kabi people. A Cultural Heritage Management Plan has been agreed for the site. Archaeological remnants and debris have been found in five sites within the site. The material had been highly disturbed by previous site clearing. The materials found were indicative of transient, intermittent use of the land and no evidence was found of longer term or ceremonial occupation.

The site is located in the traditional country of the Kabi Kabi people. Archaeological research provides evidence that aboriginal occupation of the broader region goes back at least 22,000 years. The use of the coastal areas, particularly Bribie Island and Pumicestone Passage, and the Maroochy and Mooloolah Rivers is well documented in both indigenous oral history and the archaeological record.

The Glasshouse Mountains were of immense significance to the Kabi Kabi people. The land between the coast and mountains was regularly traversed, typically along resource-rich corridors such as rivers, creeks, floodplains and wallum. Such corridors exist on the Halls Creek Site connecting between the coast and mountains, however there are no recorded sites or items on the Cultural Heritage Register.

The Kabi Kabi are the recognised Aboriginal Party for the area, pursuant to the *Aboriginal Cultural Heritage Act 2003* (ACHA 2003), and hence are the appropriate group to consult in relation to indigenous cultural heritage.

A Cultural Heritage Survey has been undertaken and a Cultural Heritage Management Plan (CHMP) developed in consultation with representatives of the Kabi Kabi people. The survey involved surface inspection of a number of transects identified by preliminary research. Archaeological remnants and debris were found in five sites within the Halls Creek Site.

Figure 9-1 Sites with archaeological remnants and debris on the site

The material appeared to be highly disturbed by previous site clearing and was removed from the site for preservation purposes. The materials found were indicative of transient, intermittent use of the land and no evidence was found of longer term or ceremonial occupation. Accordingly, the sites within the Halls Creek Site have been assessed to have low overall indigenous cultural heritage significance.

Since the survey, the sites identified for future monitoring have been excavated and monitored in accordance with the requirements of the CHMP. It is proposed that representatives of the Kabi Kabi would also be present during the construction phase to monitor works that may impact on unidentified cultural heritage and contractors would be required to fulfil their obligations under the relevant legislation and CHMP.

European occupation of Halls Creek Site has been limited to forestry and agricultural activities with little or no physical settlement occurring on the land. The Halls Creek Site has been highly disturbed and does not contain any recorded and/or protected non-indigenous cultural heritage sites. Given the relatively short occupancy of the site by non-indigenous Australians, it is not likely that any sites of significance will be located during the construction process. Despite this, construction staff will receive training on procedures should any sites be located.

Performance Objectives for Cultural Heritage

- Protect and manage all known or potential sites of cultural heritage significance.

10 Summary

The key outcome of the preliminary environmental investigations undertaken by this study has been to:

- Provide an overview of the environmental values of the site;
- Identify where development looks most practical;
- What areas may need to be avoided;
- Rehabilitation and conservation opportunities;
- Performance objectives to be achieved; and
- Provide direction about further areas of necessary investigation.

Based on the findings of these investigations, the site's development potential, areas for future conservation and rehabilitation and constraints are outlined below and shown graphically in Figure 10-1.

10.1 Development Potential

A minimum of 780 ha of the site is identified as suitable for development or otherwise requiring further investigation. These include: the Coochin Creek catchment area (identified as a freshwater HEV area) and land areas below 5m AHD outside of the proposed rehabilitation area that have a greater potential for ASS. These investigation areas are further discussed in section 10.3 below.

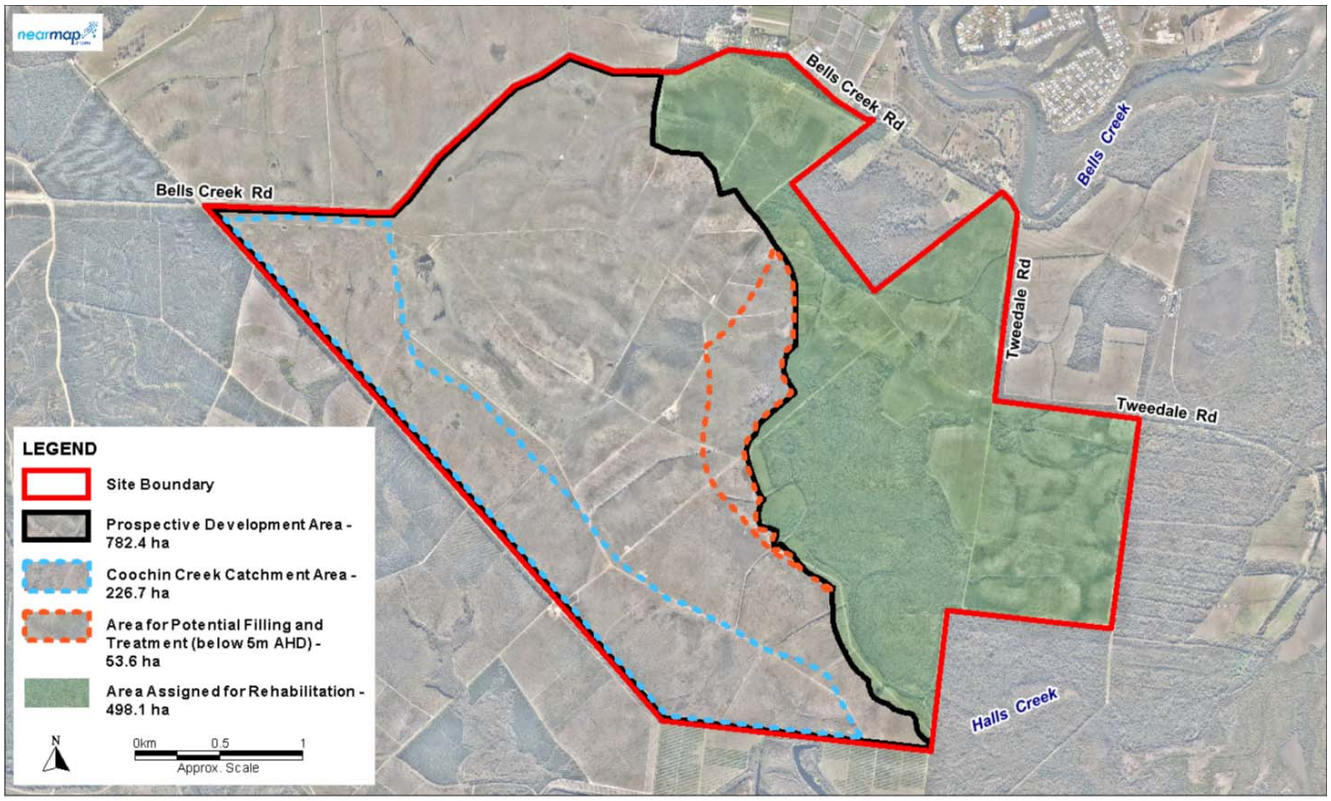

Figure 10-1 Site development, rehabilitation and investigation areas

10.2 Areas Proposed for Conservation and Rehabilitation

Up to 500ha of land is considered least suitable for development and should be rehabilitated and conserved.

This extensive rehabilitation would create a significant buffer (between 1.6km – 4 km) to the Pumicestone Passage and link to other conservation areas to the north and south to restore a large habitat corridor.

The protection and rehabilitation of these areas will significantly improve the health of downstream waterway areas, through improved catchment hydrology and reduced pollutant loads.

10.3 Constraints

A summary of constraints is provided below, to guide future land use planning and areas of future investigation. These are shown graphically in Figure 10-2.

Soil and groundwater constraints to potential development at Halls Creek include:

- Actual and potential ASS located below 5m AHD present a constraint to development. However, rehabilitation of the majority of this area is planned, with minimal surface disturbance likely.
- Soils within Area 2 (areas in the central part of the site below 5m AHD identified for potential development) are identified as requiring further ASS investigation noting initial sampling has indicated these areas may be suitable for development.
- Areas above 5 m AHD would not be constrained with the implementation of appropriate mitigation measures to respond to the natural acidity that is present in these areas.
- The main groundwater constraints relate to interaction with ASS, wallum frog habitats and the wetland, with relevant considerations including:
    - Land use considerations and mitigations will need to be implemented to avoid reduction or other significant change to the local alluvial aquifer and to maintain wallum frog breeding reliant on this groundwater
    - Sustaining groundwater supply to Halls Creek wetland and maintaining it as an undeveloped buffer, will also benefit groundwater resources on the site
    - Land use considerations and mitigations will need to be implemented to avoid changes in groundwater levels that may otherwise impact environmental values which need to be conserved and or rehabilitated. This refers to broad scale filling and excavation in potentially developable areas on site that could otherwise potentially cause groundwater to pass through naturally acidic soils or expose potential acid sulphate soils (PASS) resulting in the mobilisation of acidic groundwater to other parts of the site and potentially off site.

Surface water constraints include:

- Carefully managing higher intensity development in the Coochin Creek catchment within the site to protect downstream water quality and hydrology in the adjacent High Ecological Value (HEV) area to the south
- An advanced stormwater management approach will need to be implemented throughout the remainder of the site draining to Halls Creek. This will require adequate land allocations across

the site for rain gardens, treatment wetlands and other infrastructure to protect downstream water quality

- A nominal 100 m buffer area is recommended adjacent to the Halls Creek wetland to assist in enhancing the function of the wetland for water quality and stormwater management requirements – noting this area would suit vegetation rehabilitation, stormwater wetlands and low intensity recreational infrastructure.

There are no significant **flood constraints** identified for the site with the adoption of appropriate mitigation measures in the design and layout.

With respect to **terrestrial and aquatic ecology**, the following constraints and opportunities have been identified onsite:

- Approximately 33ha of acid frog habitat would be lost to the potential development. Considerable knowledge about acid frog habitat re-creation has been gained through Caloundra South planning and would be applied to any mitigation and offset at the Halls Creek site.
- The remnant Broad-leaved Paperbark open forest/wetland (RE 12.3.5) located in the south-east corner of the site should be retained and rehabilitated.
- The remnant heathland (RE 12.3.13) located in the north eastern part of the site should be retained.
- The two populations of Mount Emu She-oak and supporting habitat which may require translocation and/ or offset.
- The known small populations of Christmas Bells and supporting habitat which may require translocation and/ or offset.
- While the aquatic habitats on the site are suitable for the endangered Oxleyan Pygmy Perch and Honey Blue Eye, neither of these freshwater fish were detected in water bodies on site or in the Halls Creek wetland.
- The amount of and nature of any offsets (direct, financial or indirect) will depend on the policy and legislative obligations at the time of planning.

Downstream (offsite) ecological values in the adjacent National Park, Halls Creek estuary and Pumicestone Passage (fish, invertebrates, migratory birds, water mouse) would not be directly impacted by potential future development of the site. However, these values are dependent on water quality and hydrological performance objectives of the site, as well as long-term management of weeds and pest animal species in rehabilitated areas.

There were no identified constraints with respect to **cultural heritage**.

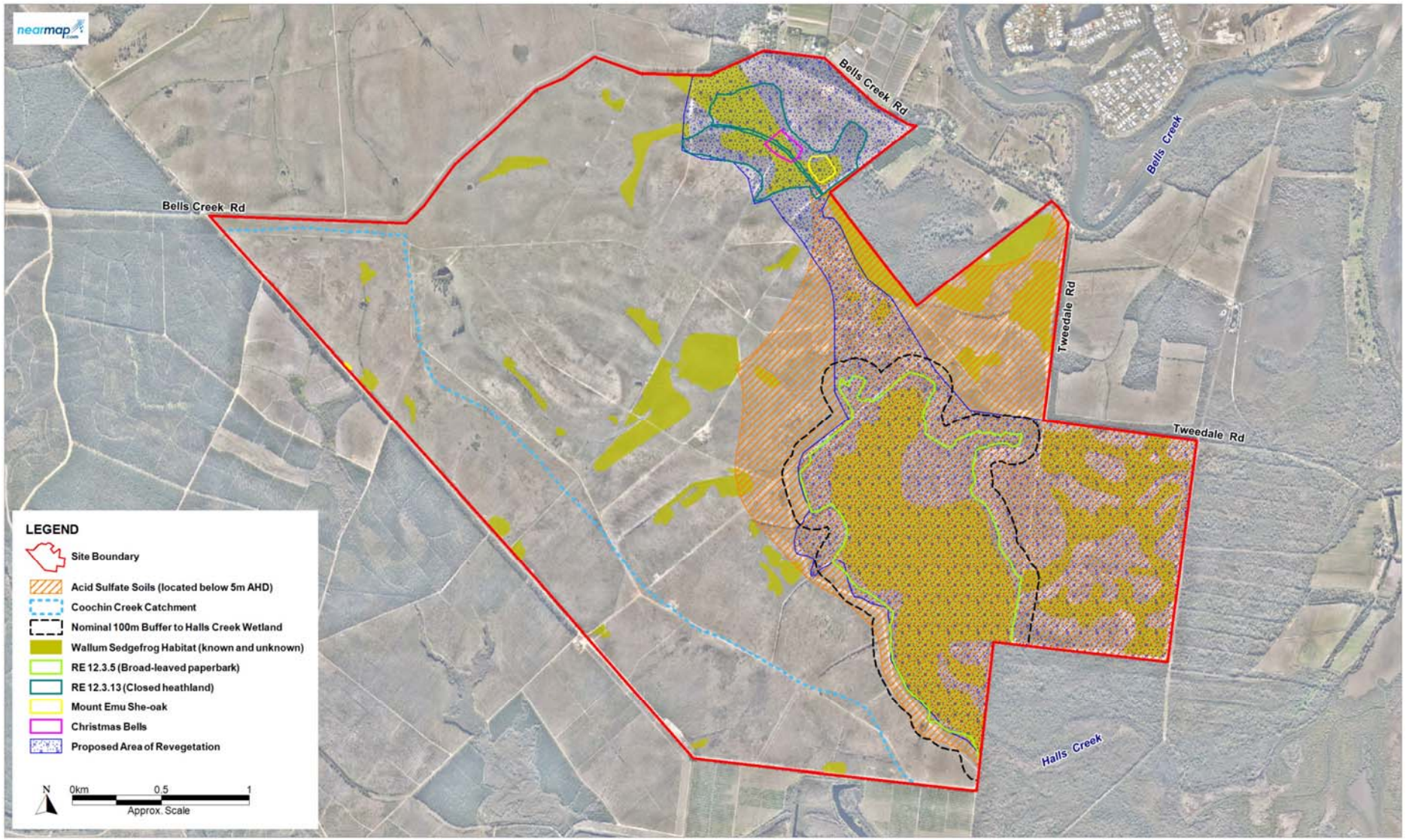

Figure 10-2 Environmental constraints to development

11 References

Arup (2013). Caloundra Downs South, Ecological Assessment Report. Prepared for Stockland Pty Ltd, December 2013.

Australian Wetland Consultancy and EcoSmart Ecology (2014). Assessment of Litoria olongburensis habitat within the northern precinct areas of the Caloundra South Urban Development Area. Prepared for Stockland Pty Ltd, March 2014.

EcoSmart Ecology (2013) Chapter C9: Wallum Sedgefrog. In Caloundra South Public Environmental Report. Prepared for Stockland Pty Ltd, 2012.

Ezzy, T.R., O'Rourke, A.J. & Cox, M.E. (2004) Hydrogeological Assessment of the Caloundra South II Site and Bells Creek Catchment, report for Lensworth Group Limited, School of Natural Resource Sciences, Queensland University of Technology, April, 2004.

Hyder (1999). Caloundra Downs Informal Land Use Investigation. Consolidated Data Report. Supporting Technical Studies. Prepared for Lensworth Pty Ltd, December 1999.

Joyce, K (2006). Wetland Management Profile – Coastal Melaleuca Swamp Wetlands, Ecosystem Conservation Branch, Queensland Environmental Protection Agency.

Meyer, E., Hero, J-M., Shoo, L., and Lewis, B. (2006). National Recovery Plan for the Wallum Sedgefrog and other Wallum-dependant Frog Species. Report to Department of Environment and Water Resources, Canberra. Queensland Parks and Wildlife Service, Brisbane.

RPS (2012) Caloundra South Groundwater Impact Assessment. Report number B18B-B2\001a. 7 June 2012.

Watson, P. (2001). The role and use of fire for biodiversity conservation in south-east Queensland: Fire management guidelines derived from ecological research. South-East Queensland Fire and Biodiversity Consortium, Brisbane.

Watt M.S., Kriticos D.J. & Manning L.K. (2009). The current and future potential distribution of Melaleuca quinquenervia. Weed Research 49: 381–390.

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