CONSERVING ECOSYSTEMS AND MANAGING BIODIVERSITY IN INDUSTRIAL LAND AND SEASCAPES – YABULU NICKEL REFINERY EXPERIENCE

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INTRODUCTION

QNI Pty Ltd (QNI) (a subsidiary of BHP Billiton) manages the 2464 ha Yabulu Refinery land holding, located adjacent to Halifax Bay, approximately 30 km north-west of Townsville in north Queensland. Yabulu Refinery was commissioned in 1974 to extract nickel (Ni) from the local Greenvale lateritic ore body located 225km west of Townsville. The Greenvale deposit was depleted of ore in the early 1990's and alternate feedstocks were obtained from both domestic and offshore sources. Currently, ore is imported from New Caledonia, Indonesia and the Philippines. Approximately 3.5 million wet tonnes of lateritic ore is imported and treated annually, to produce approximately 32 000 t of Ni and 2000 t of Cobalt. The landscape surrounding the Refinery site includes terrestrial, freshwater, estuarine and beach ecosystems with a seaward boundary bordering the Great Barrier Reef Marine Park. Operation of a mineral processing facility in this location requires that sustainable management practices be adopted in the vicinity of the coastal ecosystems and adjacent world heritage area to ensure that the constituent biodiversity is maintained.

ENVIRONMENTAL MANAGEMENT AND PLANNING

Background

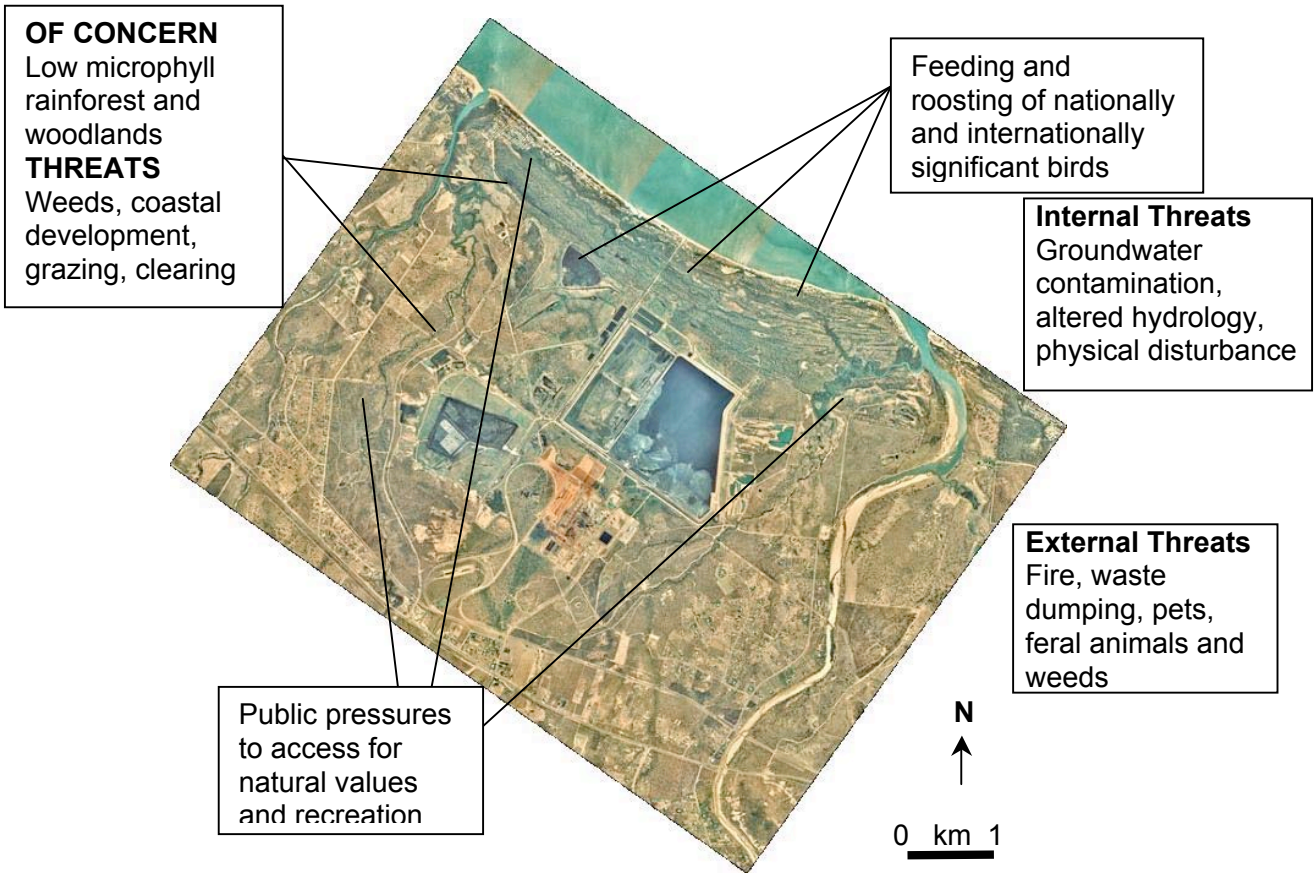
Environmental monitoring of the Yabulu Refinery site and Southern Halifax Bay has been undertaken since 1974, when a program to assess water quality at the site and in the Bay was first established. Recognising the potential for the Refinery operations to influence the surrounding ecosystems and biodiversity (Figure 1), the program was expanded, in October 1996, to include ecological assessment, monitoring and management activities. This provision was considered as a corporate, best practice initiative.

Planning and Management

This monitoring program expansion was a precursor to the commencement of the current Environmental Assessment and Management (EA&M) program that was launched by QNI in June 1997. The lands controlled by QNI at Yabulu are classified into three land management zones based on their environmental values and proposed land use. In addition, QNI recognises certain obligations in relation to the management influence of its activities on the coastal waters of Halifax Bay, which lies immediately east of the Buffer Zone. As such, four environmental management zones are recognised at the Yabulu site (Figure 2)

- **Industrial Zone;**
- **Infrastructure Zone;**
- **Buffer Zone;**
- **Marine Zone.**

Figure 1: Biodiversity issues surrounding Yabulu Refinery.



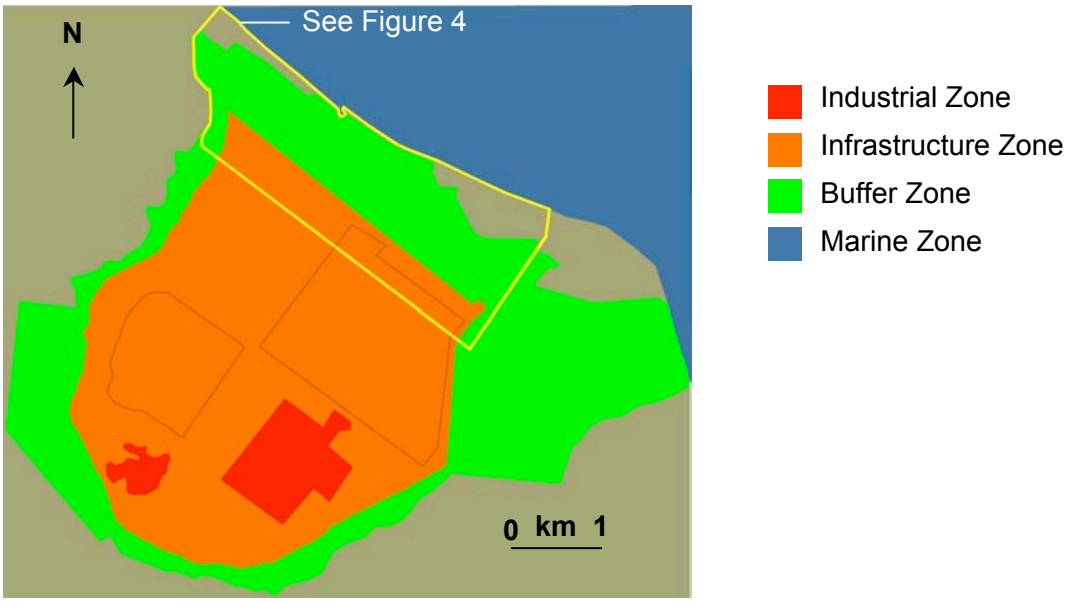
The **Industrial Zone** comprises an area of approximately 50 ha and encompasses the heavy industry footprint, including the refinery and ore stockpile areas. It has no inherent natural values and is managed to control the air, noise and water discharges set by site standards and regulatory limits.

The **Infrastructure Zone** comprises 440 ha and includes all lands enclosed by the Buffer Zone which are currently being used to support industrial refinery processes, or lands that are proposed future development areas. It includes tall grasslands, woodlands, shrublands and wetlands (retention ponds, levees and drains) associated with stormwater management. It does have some biological values but there are no intact native ecosystems within the zone. The biological values come from the utilisation of this constructed landscape by native terrestrial and aquatic fauna.

The **Buffer Zone** comprises 1970 ha of a diverse range of habitats, which surround the infrastructure zone and abut rural residential, grazing land and the Great Barrier Reef Marine Park. It includes sand dunes, beach ridges and swales, mangroves and salt flats, eucalypt and melaleuca woodlands, open forest with low microphyll vine forest understorey, riparian open woodland and grazing lands. This zone is an industrial buffer zone but is managed to maintain the structure, composition and natural processes of the ecosystems within the buffer zone.

The **Marine Zone** comprises an area of southern Halifax Bay represented by a littoral zone (beaches and sand banks), a sub-littoral zone (fine grained sediments on the floor of the Bay and associated banks) and a shallow pelagic zone that is generally turbid due to wave action. The Marine Zone was incorporated into the EA&M Program to ascertain the ecosystem health of Southern Halifax Bay prior to and following the planned cessation of routine ocean discharge of tailings liquor and has now been incorporated into the Great Barrier Reef Marine Park.

Figure 2: Yabulu Environmental Management Zones



Upon establishment, the EA&M program had the following six general objectives

- Establish a model for the various ecosystems within the buffer zone;
- Monitor environmental conditions within the buffer zone and adjacent marine ecosystems;
- Establish key ecosystem 'health' indicators;
- Assess the health of the various ecosystems;
- Recommend remedial actions where required; and
- Develop a scientifically defensible environmental monitoring data set.

The initial four year period of the EA&M program (1998-2001) established a baseline understanding of the ecosystems at the site. A review conducted after the 2001 monitoring period concluded that this initial program had yielded valuable information and provided the basis of a useful environmental site management tool. Based on initial findings and the more holistic view of the Refinery ecosystems, the EA&M program was linked into a Strategic Environmental Management Plan (SEMP) in June 2000 (Figure 3). The SEMP is a 30-year environmental management strategy, which specifies and schedules required remedial, management and on-going monitoring activities combined with four-yearly audits. This adaptive management framework links monitoring data to management objectives and provides long-term feedback on management actions and site biodiversity/ecosystem health.

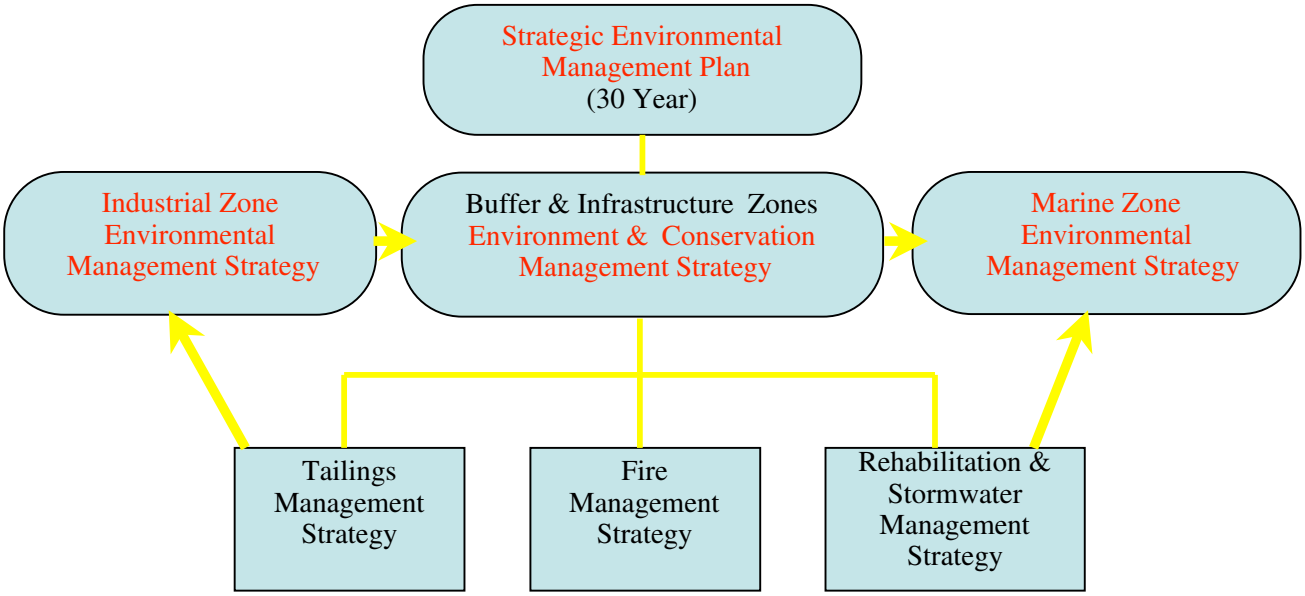
The SEMP has been designed to enable it to be linked with other site planning and management strategies such as:

- Water Supply Strategy;
- Energy Supply and Conservation Strategy;
- Air Protection Strategy;
- Production Strategy,

to provide an integrated system of long term environment, conservation, production and infrastructure planning and management for the Yabulu Refinery site. The broad management aims for a sustainable operation of the refinery are:

- there is no aquatic discharge from the plant site,
- no significant aquatic or terrestrial influence of site operation beyond the boundaries of the site,
- maintenance of ecosystem health in the buffer zone, so that
- the landuse aspirations of future generations are conserved.

Figure 3: Key components of Strategic Environmental Management Plan



The current four year phase of the EA&M Program (2002-2005) is aimed at providing information on community composition and structure with annual monitoring of locally developed functional indices and informing / monitoring the effectiveness of environmental management systems at the Yabulu Refinery. The outcomes will aid in providing a basis for the development of improved compliance criteria for future regulation of the site using ecosystem health indicators.

As indicated in Figure 3 there are various components to the SEMP, based on Management Zones, the annual EA&M program addresses the objectives for each Zone as detailed below.

The objectives of the Buffer & Infrastructure Zones ecological assessment are as follows:

- Confirmation of the environmental conditions within the Buffer and Infrastructure Zones of the Yabulu Refinery site and adjacent Southern Halifax Bay;
- Investigation and characterisation of any potential environmental effects within the Buffer and Infrastructure Zones associated with Yabulu Refinery operations, particularly those related to hydrological modifications and tailings disposal;
- Assessment and quantification, where possible, of any unacceptable environmental impacts accruing from these effects;
- Identification and assessment of the efficacy of remedial / on-going management actions aimed at improving environmental conditions at the Yabulu Refinery site;
- Assessment of the spill risk from tailings ponds in accordance with regulatory and internal management requirements; and
- Development of a scientifically defensible environmental monitoring data set on which to base the assessment of impacts, provide a baseline against which the efficacy of any future remedial / on-going management actions may be assessed and that will meet the requirements of, and contribute to the further development of, the Queensland Water Quality Objectives.

The objectives of the Southern Halifax Bay ecological assessment are as follows:

- Undertake monitoring within Southern Halifax Bay to establish the environmental conditions;
- Investigate and characterise any potential ecosystem changes within the subject area, particularly those associated with the cessation of ocean discharge activities;
- Assess and quantify any environmental impacts accruing from these changes; and
- Continue to develop a scientifically defensible environmental monitoring data set which will meet the requirements of and contribute to the further development of the Queensland Water Quality Objectives.

RESEARCH AND INSTITUTIONAL PARTNERSHIPS

QNI management has pursued a multi-disciplinary approach to the understanding, management and monitoring of the sites natural systems. This has involved engineers, hydrologists, algal biologists, terrestrial, freshwater & marine ecologists, botanists, zoologists, aquatic chemists, project managers and regulators from BHP Billiton, QNI-Yabulu, three universities, consultancy firms and government agencies.

The EA&M program investigations, which have been undertaken by a range of environmental consultants, and academic experts from leading universities, are tabulated below.

Date	Type of Ecological Study	Undertaken By
October 1996	Preliminary ecological assessment: Land north / north-east of 1TP and 4TP	Woodward-Clyde
November 1997	Preliminary ecological assessment: Coastal Sand Buffer Zone	Resource Strategies
October 1997	Ecological assessment: Flora and Fauna of Yabulu Coastal Sand Buffer Zone	Central Qld University
April 1998	Follow-up ecological study: Flora and Fauna of Yabulu Coastal Sand Buffer Zone	Central Qld University
April 1998	Ecological study: Abundance of benthic invertebrates within mangrove ecosystem	Central Qld University
October 1998	Annual ecological monitoring: Coastal Sand Buffer Zone	Central Qld University
September 1999	Southern Halifax Bay Ecological Assessment	Central Qld University, University of Queensland and James Cook University
October 1999	Annual ecological monitoring: Coastal Sand Buffer Zone	Central Qld University
October 1999	Ecological assessment: Buffer and Infrastructure Zones	Central Qld University
October 2000	Southern Halifax Bay Ecological Assessment	Central Qld University, University of Queensland and James Cook University

October 2000	Ecological assessment: Buffer and Infrastructure Zones	Central Qld University
February 2001	Flora and Fauna of the Yabulu Coastal Sands: Report 5 Spring 2000 Monitoring	Central Qld University
February 2001	Southern Halifax Bay Ecosystem Health Monitoring Project Using Biological Assays and Physical Parameters – Tech. Rep. #2	University of Queensland
February 2001	Halifax Bay Water and Sediment Quality Study	James Cook University
August 2002	Flora and Fauna of the Yabulu Coastal Sands: Report 6 Spring 2001 Monitoring	Central Qld University
August 2002	Halifax Bay Marine Monitoring Program	Central Qld University
February 2002	Southern Halifax Bay Ecosystem Health Monitoring Project Using Biological Assays and Physical Parameters – Tech. Rep. #3	University of Queensland
October 2002	Halifax Bay Marine Monitoring Program, QNI Yabulu	Central Qld University
June 2003	Flora and Fauna of the Yabulu Coastal Sands: Report 7 Spring 2002 Monitoring, A report to Yabulu Refinery, QNI Resources Pty Ltd	Central Qld University
May 2003	Southern Halifax Bay Ecosystem Health Monitoring Project Using Biological Assays and Physical Parameters – Tech. Rep. #4	University of Queensland
May 2003	Halifax Bay Water and Sediment Quality Study, November 2002	James Cook University
October 2003	Halifax Bay Marine Monitoring Program, October 2003	Central Qld University
June 2004	Halifax Bay Water and Sediment Quality Study- Pre-wet and Post-wet Season, April 2004	James Cook University
June 2004	Flora and Fauna of the Yabulu Coastal Sands: Report 8 Spring 2003 Monitoring, A report to Yabulu Refinery, QNI Resources Pty Ltd	Central Qld University

The EA&M biodiversity management program contained a number of strategic elements which have evolved since commencement, these included

- biological audit and ecosystem classification and mapping,
- identification and prioritisation of threats,
- development of reaction and remediation programs
- site landuse classification and associated management objectives,
- environmental monitoring and land management program,
- communication program, and
- development of a 30 year environmental management strategy.

The following four tables summarise the works that have been completed as part of the 2003/2004 EA&M Program, which is typical of the methods used in previous EA&M programs.

Terrestrial Monitoring Methods	
Terrestrial Vegetation Sampling	• Basal area of live and dead vegetation • Projective cover of over-storey • Projective cover of combined under-storey and ground storey • Total species richness • Photo record of each community • Analysis of community structure • Nitrogen isotope enrichment analysis
Invertebrate Terrestrial Fauna Sampling	• Pitfall traps containing 70% ethanol

Freshwater Habitat Monitoring	
Freshwater Habitat Assessment	• General site descriptions including site dimensions, dominant physical characteristics, water levels and disturbances • physical and chemical water quality including water clarity (Secchi depth), pH, EC, salinity, dissolved oxygen, temperature, nutrients (NH_3, NO_3^-, NO_2^-)
Freshwater Fauna Assessment	• surveys of waterbirds • surveys of aquatic macrophyte • surveys of macroinvertebrates using pond nets • surveys of fish communities using small baited traps and a seine net plus incidental records from observations and dip net samples

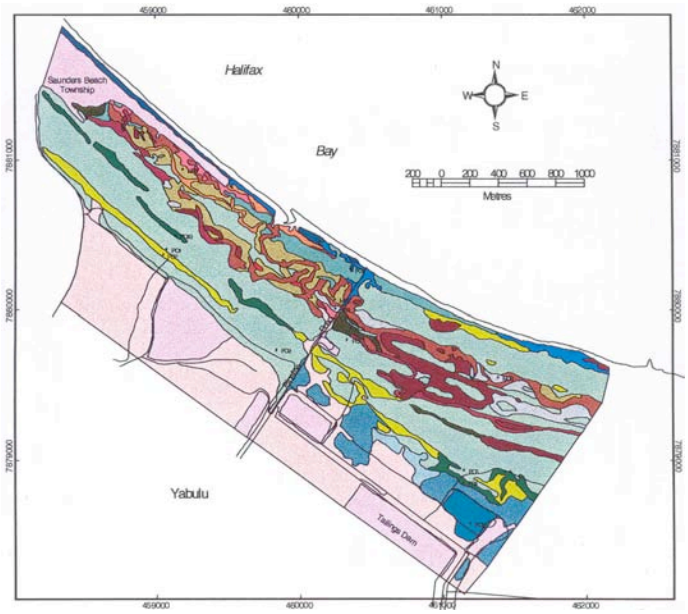
Mangroves and Estuarine Habitat Monitoring	
Mangrove Vegetation	• Quantify leaf litter recorded as percentage cover • Nitrogen isotope enrichment analysis
Estuarine Water Quality	• physical and chemical water quality including pH, EC, salinity, dissolved oxygen, temperature, nutrients (NH_3, NO_3^-, NO_2^-)
Mangrove Crab-hole Counts	• Crab hole densities recorded
Mangrove Crab Scavenging Activity	• Sample leaves tied to fishing lines and observed for herbivore activity
Tidal Flux	• wooden stakes with dyed cloth tapes attached placed at the low water mark
Zooplankton Indicator Groups	• Zooplankton nets (250 μm mesh) suspended in the creek for 5-10 minutes
Presence of Nekton - Fish Guilds and Penaeid Prawns	• 2 and 4 inch gill nets set during the late flood tide period • Seine netting (8 mm mesh) in shallow waters during the day at low tide for smaller fish and prawns • Cast netting at low tide • Observations • Dip nets (1 mm mesh)

Marine Monitoring

Beach Sampling	• Biota samples taken from the mid intertidal and shallow sub-tidal/deep intertidal, sieved through a 1mm mesh and preserved
Sediment Sampling	• Analysis of particle size distribution • Analysis of metals concentrations (weak acid extractable metals from the whole sediment and total metals from the -63µm sediment fraction)
Creek Mouth Discharge Sampling	• temperature, salinity, pH and dissolved oxygen • trace metals concentrations • nutrients (TN,TP, NH_3, NO_3^-, NO_2^-, FRP)
Marine Water Quality	• temperature, salinity, pH and dissolved oxygen • chlorophyll *a* concentration • trace metals concentrations • nutrients (TNTP, NH_3, NO_3^-, NO_2^-, FRP)
Mapping using Sentinel Algae	• Red algae *Catanella nipae* deployed within Halifax Bay anchored for 3 days, recovered and samples tested for tissue _ ^{15}N contents
Macroalgae %N _ ^{15}N Values	• Nitrogen isotope enrichment analysis
Heavy Metals in Bivalves	• intertidal region samples collected and a complete spectrum of metal concentrations in tissue analysed using ICP-MS methodology

A key component of this assessment has been to understand the threatening processes and drivers of ecosystem health and biodiversity. In order to understand these processes and drivers baseline condition monitoring has been undertaken. An example output from the Buffer & Infrastructure Zones ecological assessment is given in Figure 4, whereby various vegetation communities have been mapped (pink = cleared/disturbed areas; red = mangrove/saltmarsh; blue = sand dune and alluvial flats/terraces; and green/yellow = beach ridge vegetation).

Figure 4: Vegetation Communities in the Yabulu Refinery Buffer Zone



The Buffer Zone contains many significant flora communities and faunal assemblages. Monitoring of the Buffer Zone has demonstrated that there are high biodiversity values both in the terrestrial and aquatic environments. A summary of this is found below.

Terrestrial: 16 mammals, 35 reptiles, 159 birds, 367 plants in 44 associations
Freshwater: 30 invertebrate families, 9 fish, 28 water birds, 19 plants
Saltwater: 197 invertebrate and small vertebrate species

Examples of ecosystems of conservation significance protected in Buffer Zone include

- Low microphyll rainforest on coastal dunes
- *Eucalyptus tereticornis* tall woodland/forest on alluvial plains
- *Melaleuca viridiflora* on alluvial plains
- Stream fringing woodlands

Birds of conservation significance protected in Buffer Zone

- Beach Stone-curlew *Esacus neglectus* (vulnerable)
- Black-necked Stork *Ephippiorhynchus asiaticus* (rare)
- Eastern Curlew *Numenius madagascariensis* (rare)
- Grey Goshawk *Accipiter novaehollandiae* (rare)
- Little Tern *Sterna albifrons* (endangered)

as well as 17 species listed under international treaties with Japan and China.

Recognising the Buffer Zone for its habitat value, an agreement with NQ Wildlife Carers was established in 2003 to use QNI land as a release site for rehabilitated wildlife. Over the past 12 months 22 animals have been released on site, which include possums, wallabies and a whistling kite.

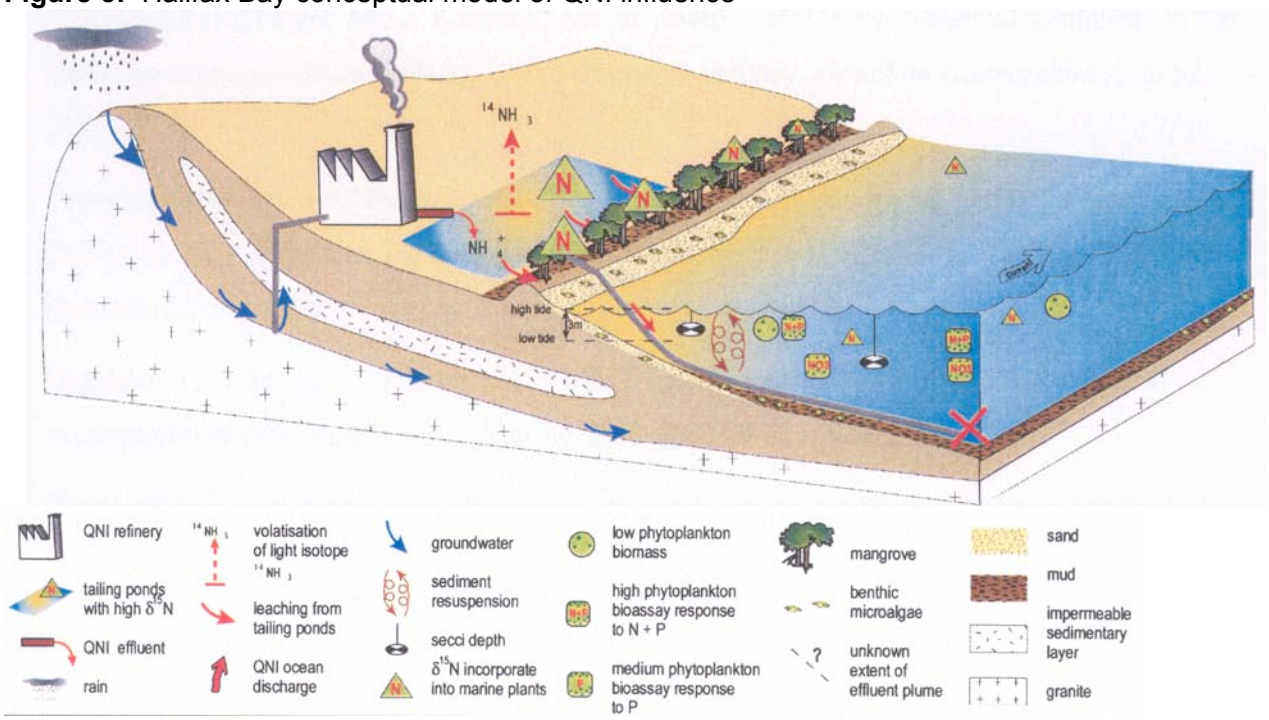
Monitoring Success – Marine Zone - Case Study

Following the addition of site infrastructure and improved site drainage in the 1990's there was increased flow of water to the site tailings ponds. Excess water in the tailings ponds was traditionally released to Halifax Bay via a submerged pipeline, in accordance with licence conditions set by the Environmental Protection Agency (EPA). Conditions in Halifax Bay had been independently monitored since 1974 and results indicated that there was no significant impact from the disposed water on the marine environment. However, QNI recognised that it was not a viable long-term solution for site water management and set a goal, with the EPA, to cease all routine discharge of water to Halifax Bay. QNI invested $25 million in a water recycling facility which is capable of producing 12 ML day^{-1} of recycled water.

In addition to the construction of a water recycling facility, a comprehensive ecological assessment was established in Halifax Bay to further assess if any impacts may be determined prior to cessation of routine ocean discharge. The study involved setting up sentinel and reference sites in Halifax Bay to investigate the intertidal, sub-tidal benthic and water column zones. Various techniques were used, including benthic macroalgae biomass, phytoplankton biomass and response, water clarity and nitrogen isotope signatures. The study was conducted prior to the discharge ceasing and elements of the work are continuing (water and sediment quality).

The findings of the study were that southern Halifax Bay was in a healthy state and supported previous investigations: that discharged excess water from the refinery has had no significant impact on ecosystem values within the marine environment. A conceptual model of the various elements is shown in Figure 5. Further studies (including trace metal concentrations in bivalves and submarine groundwater discharge) have been undertaken to continue evaluation of any residual influence or ongoing effect from seepage of tailings ponds on the marine environment. Results demonstrate that there is no direct correlation between trace metal concentrations in bivalves and distance from the Refinery and that there is no shallow fresh groundwater discharged into the ocean.

Figure 5: Halifax Bay conceptual model of QNI influence



WHERE TO FROM HERE – ECOSYSTEM HEALTH INDICATORS

One of the objectives of the 2003/04 EA&M program is to continue the development of ecological health based compliance criteria for the on-going management of the Yabulu Refinery. Since 1997, QNI Yabulu Refinery and the EPA have been working together to develop the EA&M Program as a best practice initiative. The results of the program over the last four years suggest that monitoring ecosystem health indicators may provide both QNI and the EPA with a more accurate appreciation of the Yabulu Refinery's environmental impacts on environmental health rather than more traditional environmental quality parameters (i.e. ground and surface water quality).

Within the Buffer and Infrastructure Zones it is proposed that the terrestrial vegetation and mangroves; freshwater bodies; and estuary and mangrove mud communities be monitored using ecosystem-based compliance criteria. It is proposed that four different areas / types of communities be considered for the purposes of using ecosystem health indicators. The four areas are listed below:

- Terrestrial vegetation and mangrove communities;
- Freshwater bodies;
- Estuary and mangrove mud; and
- Halifax Bay and the intertidal and sub tidal water columns.

For each area or community type a series of issues needs to be identified and addressed, these include identifying

- Ecological values of target area
- Proposed indicators and what they provide to the assessment
- Methods used and concurrent monitoring requirements
- Environmental stressors

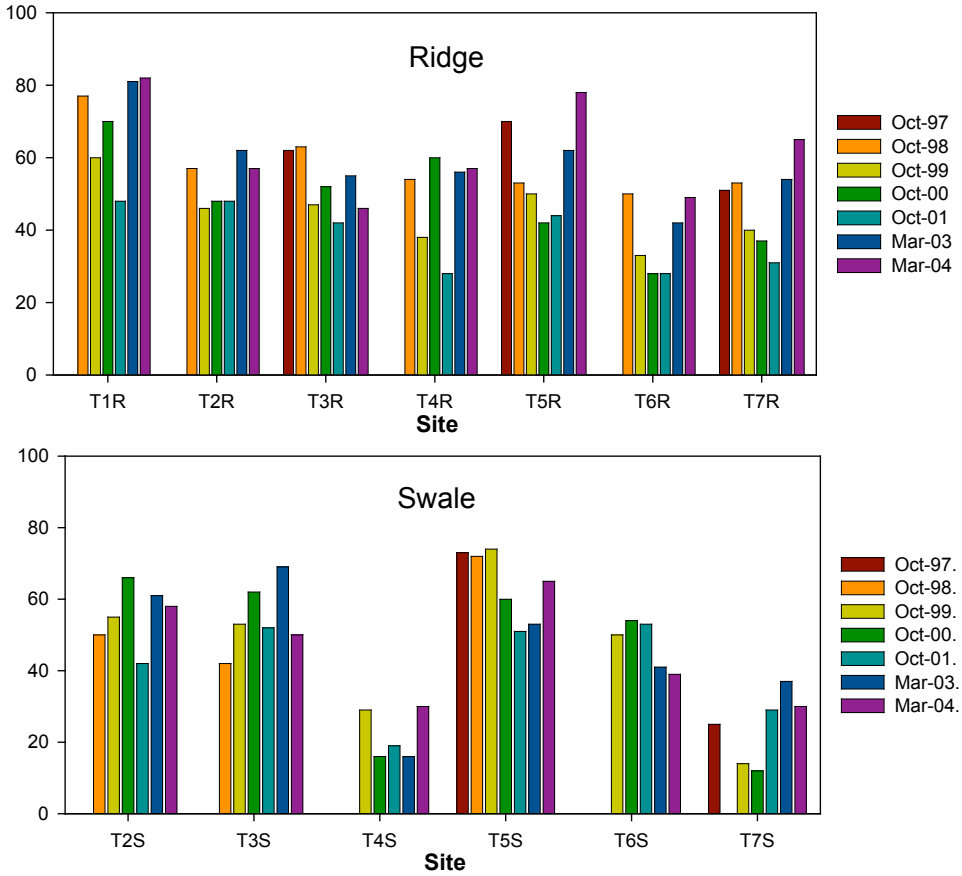
- Reference environment and assessment of non-industrial impact

QNI is working with university scientists, project managers and the EPA to build on current understanding and move to implement ecosystem health-based compliance criteria. QNI will not only be introducing more reflective compliance criteria, but will be involved in developing innovation in environmental regulation in Queensland, providing a case-study for other industry-regulator partnerships in the future. Some examples of potential Ecosystem Health Indicators their application and some considerations are discussed below and presented in Figures 6, 7 and 8.

Terrestrial vegetation on the swale and ridge sites throughout the study area is surveyed annually using indices of vegetation structure. These indices are designed to detect any changes in community structure that may be attributed to refinery activities. Foliage Projective Cover (FPC) of the overstorey (>1.5 m) is based on 100 points at 1 m intervals following a defined pathway within the plot.

Results from the recent EA&M survey show most ridge sites increased slightly in FPC from 2003 levels but were within the range of variation experienced in past years, while FPC decreased at most swale sites from 2003 although it too was within the range of variation experienced in previous years. Further, it can be seen that there are effects relating to season and possible drought effects by the ridge samples in 2000-01 and change in post wet season collection has redressed this anomaly. These results demonstrate the need to understand where samples are collected from within the ecosystem as results may be influenced by other contributing factors (e.g. time of the year, etc.).

Figure 6: Foliage Projective Cover in Buffer Zone Ridge and Swale communities



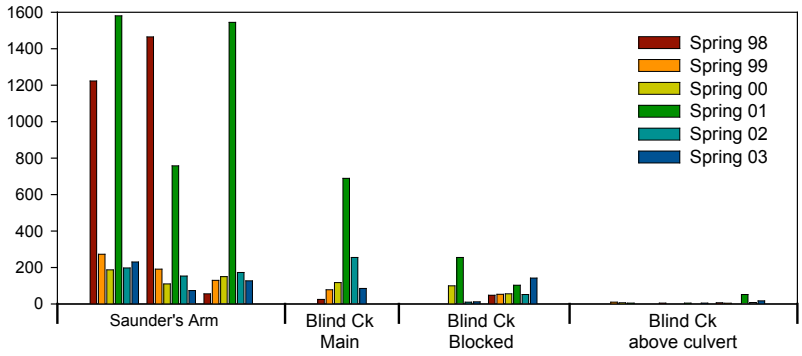
Tidal flows in Blind Creek have been affected by a partial sand blockage caused by historical stormwater management practices; this creates a change from natural conditions that presents a

state from which change can be monitored following restoration works. Monitoring crab hole density and channel litter cover within these blocked channel reaches and comparing them with unblocked channels provides a useful measure of the effects of these channel blockages on the ecosystem.

Crab hole densities were recorded at each mangrove plot. Numbers of crab holes were recorded from 1 m^2 quadrats placed at the top and middle of each 5 by 5 m grid-quadrat (a minimum of 8 samples per site). This positioning was chosen to avoid trampling effects caused by laying out the tapes. Three classes of crab hole size were recorded: small (< 1 cm), medium (1 to 2.5 cm) and large (> 2.5 cm). Crab hole densities of some sites were extremely high and at these sites small crab hole counts were estimated from a smaller (either 0.1 or 0.05 m^2) randomly selected area within the 1 m^2 quadrat.

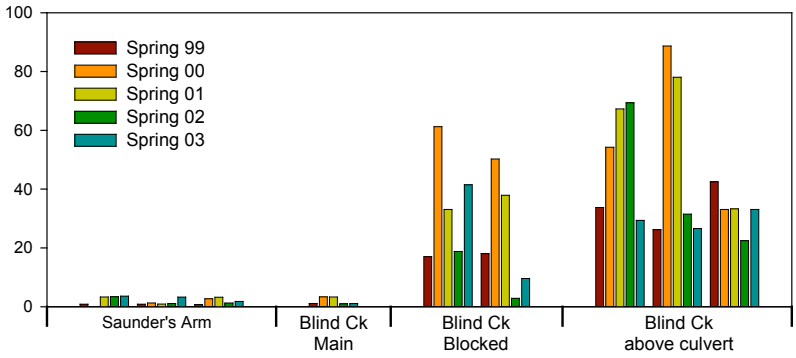
Results from 2003-04 monitoring of crab hole counts for both reference (within the Saunders arm of Blind Creek) and sentinel sites (within the main arm of Blind Creek) were mostly low compared with previous years but all were within the range exhibited in previous years (Figure 7). This general reduction in crab hold abundance at all sites in Spring 2002 and 2003 may be attributable to the extended dry conditions. Crab hole counts within artificially impounded sites appear low compared with unaffected sites.

Figure 7: Crab hole abundance in Blind Creek estuary



The influence of creek blockages on functioning of the mangroves can best be assessed by examining the upper tidal sites at each location as these are affected less by local disturbances in drainage and have known sesarmid crab leaf scavenging fauna present. Litter cover was determined as percentage cover (visual estimate) within the 1 m^2 quadrats. Low litter levels were noted in the Saunders and Main arm of Blind Creek, whereas the sites with impeded drainage all had high levels of litter cover.

Figure 8: Litter Cover in Blind Creek estuary



During the EA&M 2003-04 program leaf scavenging was examined in three reaches of Blind Creek - Saunders arm, Blind Creek downstream of the sand blockage and above the culvert – representing two relatively non-affected reaches and one heavily impacted reach. As in previous years, no leaves were scavenged at the above culvert sites and this compares with 22% of leaves within the Saunders arm and 58% of leaves within the non-affected reach of Blind Creek.

CONCLUSION

The principles and commitments of QNI are espoused in the Health, Safety, Environment, Community and Quality Policy and include QNI's desire to promote sustainable business that is minimising its influence on surrounding ecosystems. Success in achieving sustainable practices and in the reconstitution of ecosystems on industrial lands requires the development of successful management and monitoring practices, consistent and agreed regulatory or institutional arrangements and community or stakeholder confidence.

QNI has a duty of care in managing the land on which it operates and is proving successful in managing the significant ecosystems and their constituent biodiversity from coastal development and other threatening processes. It needs to be recognised that industrial landscapes can be important centres of biodiversity conservation allowing future generations to utilise a healthy and productive environment. Improvements made to manage the land and sea scapes surrounding the Refinery are a result of the partnership approach developed by improved understanding of the ecosystem processes and drivers (science) and the strategic vision and commitment of the Company (management).