8 Terrestrial Impacts and Management

8 TERRESTRIAL IMPACTS AND MANAGEMENT

8.1 Introduction

This chapter of INPEX's draft environmental impact statement (Draft EIS) describes the potential impacts to the terrestrial environment and regional airshed associated with the onshore development area of the Ichthys Gas Field Development Project (the Project). This area includes land above the low-water mark on Blaydin Point and Middle Arm Peninsula in Darwin Harbour.

Components of the Project that will be constructed in this area include the onshore processing plant; support facilities such as the administration and laydown areas; access roads; and the onshore portion of the gas export pipeline from the Ichthys Field which extends 6 km across Middle Arm Peninsula from the pipeline shore crossing to the processing plant.

Details of the onshore infrastructure and activities over the Project's life may be summarised as follows:

- site preparation prior to the commencement of construction activities, such as clearing of vegetation and the development of earthworks
- construction and precommissioning of the onshore facilities
- commissioning of the onshore processing plant
- operation of the onshore processing plant and associated facilities
- decommissioning of the onshore facilities
- site closure and rehabilitation.

The environmental impact assessment provided in this chapter includes discussion of the significance of potential impacts in a regional context and presents management controls that would be implemented by INPEX to mitigate these impacts.

In order to determine the "residual risk" remaining after management controls are applied to mitigate the risks arising from the Project, a risk assessment of the various potential impacts was undertaken according to the methods presented in Chapter 6 *Risk assessment methodology*. Summary tables of the onshore activities, potential environmental impacts, management controls and mitigating factors, and resulting residual risk (consequence, likelihood and risk rating) are provided throughout the chapter.

The risk assessment was undertaken with consideration of sensitive environmental receptors, which include the plants and animals in the immediate vicinity of Blaydin Point and Middle Arm Peninsula. Because of the proximity of the onshore development area to the cities of Darwin and Palmerston, the local community is also a key sensitive receptor. Other impacts to the community associated with factors such as airborne noise and visual amenity are described in Chapter 10 *Socio-economic impacts and management*.

Management controls will be implemented to ensure that all significant potential environmental effects associated with the Project are minimised or avoided. A number of monitoring mechanisms are also proposed that will allow INPEX to gauge the effectiveness of management controls. A comprehensive and auditable environmental management system based on the principles of the International Organization for Standardization's ISO 14000 environmental management series of standards will be implemented to provide a systematic and structured approach to environmental management. The system proposed is described in Chapter 11 *Environmental management program*.

8.2 Physical disturbance

8.2.1 Soil erosion

Onshore construction activities will require large-scale cut-and-fill earthworks to provide level ground surfaces for the plant's processing infrastructure. The main environmental impacts of these earthworks include potential soil erosion of the newly created landforms and generation of dust during construction before bare surfaces are sealed. Erosion risks are described in this section, while dust risks are discussed in Section 8.4.2 *Dust*.

The soils in the onshore development area are considered to be susceptible to erosion because of the region's intense monsoonal rainfall and the structureless and sodic nature of the soils. Even very gentle slopes are prone to erosion if disturbed, and factors such as increased traffic will potentially exacerbate the rate of soil erosion (URS 2009a, provided as Appendix 17 to this Draft EIS).During field geographical studies (see Appendix 17) a 10-cm surface layer of sand was observed in mangrove soils, suggesting surface wash from the upland soils and indicating a natural sedimentation process into the mangroves. The mangroves fringing the shoreline around Blaydin Point act as a sediment trap for erosion from the land. However, the potential rate of erosion from large-scale earthworks at the onshore development area is likely to be higher than natural sedimentation rates.

Burial of mangrove pneumatophores (and other specialised aerial root structures) as a result of excessive soil deposition can lead to reduced vigour or tree death as described in Chapter 7 *Marine impacts and* *management*. The response of different mangrove species to root burial varies, and is likely to be a function of root architecture, tidal range, sediment composition and grain size. In Australian examples, deaths of *Avicennia marina* were caused by sedimentation depths of 12–50 cm, and deaths of *Rhizophora* spp. were linked to sediment depths of 50–70 cm (Ellison 1998).

Unless managed properly, soil erosion from clearing at the onshore development area could create a sedimentation risk to mangroves at the pipeline shore crossing, the onshore pipeline route, and around the boundaries of the processing plant on Blaydin Point. Other vegetation communities such as the eucalyptus woodland and monsoon vine forest along the access roads, the onshore pipeline route and at the boundaries of the processing plant could also be affected by soil erosion. These communities, however, would be less vulnerable to soil erosion impacts with damage likely to occur over a much longer time frame as a result of root exposure.

In areas where the mangrove zone is to be completely cleared from the shoreline (e.g. at the pipeline shore crossing, product loading jetty and module offloading facility) soil erosion from the onshore development area could reach the nearshore marine environment and cause sedimentation and turbidity impacts—these risks are described in Chapter 7.

Management of soil erosion

A Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan and a Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan have been compiled for the Project to manage soil erosion risks; they are included in Chapter 11 as annexes 10 and 15 respectively. These will guide the development of more detailed plans during the construction and operations phases and contain relevant objectives and targets, management controls, and monitoring and reporting procedures. Key management controls included in these plans are as follows:

- Large-scale vegetation-clearing and earthworks will preferentially be undertaken in dry-season conditions. Should clearing and earthworks be required to be undertaken during the wet season, adequate control measures will be implemented to avoid erosion and sedimentation impacts.
- Erosion protection infrastructure (e.g. silt fencing, spoon drains, contouring, and sediment ponds) will be installed to ensure that sediment is contained within the site boundaries as far as is practicable.
- If soil erosion becomes evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope-stabilisation products.

Table 8-1: Summary of impact assessment and residual risk for soil erosion

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Soil erosion	Large-scale earthworks for construction of onshore processing facility. Clearing of vegetation during site preparation.	Sedimentation of mangrove areas around the onshore development area, leading to smothering of pneumatophores and reduced plant growth or death.	Large-scale vegetation-clearing will be undertaken preferentially in dry season conditions to avoid the erosion risks associated with monsoon rains in the wet season. Erosion-protection infrastructure (e.g. silt fencing, spoon drains, contouring, and sediment ponds) will be installed to ensure that sediment is contained within the site boundaries as far as possible. If soil erosion becomes evident, exposed surfaces at the affected area will be stabilised with mulched vegetation, dust suppressants or slope-stabilisation products. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	F (B2)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

- Surface-water drains and discharge points throughout the onshore development area will be designed to minimise erosion.

Residual risk

A summary of the potential impacts, management controls and residual risk for soil erosion is presented in Table 8-1. After implementation of these controls, impacts from soil erosion are considered to present a "low" risk and it is likely that any effects on the environment will be localised and small in scale.

8.2.2 Soil chemistry

Metals

High levels of metals in soil can be associated either with natural mineralisation or with contamination. Background heavy metal concentrations in soils at 73 sampling points across the onshore development area were assessed using a strong acid digest of the fine soil fraction (<2 mm in diameter). This measure represents mineralised metals in the more active soil fraction, for which generic guidelines are available. Following the standard methodology for soil risk assessment laid down in a "national environment protection measure" (NEPM) by the National Environment Protection Council (NEPC 1999), the recorded soil metals concentrations were below generic investigation levels for human health and environmental risk assessment. (The full results of the laboratory analysis are provided in Appendix 17.)

Heavy metals such as aluminium and iron are mobilised into solution in soils affected by acid sulfate weathering. In this instance, under the action of sulfuric acid produced when the sediments are oxidised, high dissolved metal concentrations arise from the dissolution of finely divided iron sulfides, aluminosilicate clays and metal organic complexes in mangrove sediments. The reactivity of mangrove sediments relates to high surface areas per unit volume compared with the upland soils and to higher concentrations of organic matter that will oxidise under strong acid conditions to release metals into solution. Acid sulfate soils are described in more detail below.

Metal toxicity in plants and marine biota may be caused on a localised scale during excavation of acid sulfate soils in the intertidal areas.

In higher parts of the onshore development area, disturbing soil materials will not cause heavy-metal health effects in humans or other environmental receptors.

Acid sulfate soils

Most acid sulfate soils (ASSs) were formed by natural processes over the last 10 000 years. They were originally deposited in marine, estuarine or river settings and occur predominantly in low-lying areas near the coast. Coastal estuarine and mangrove swamp environments develop ASSs because of the waterlogged and anaerobic soil environments where iron sulfide minerals (principally iron disulfide (FeS_2) or iron monosulfide (FeS)) are formed through a process of microbial sulfate reduction. While undisturbed ASSs are harmless, excavation exposes these soils to air and the iron sulfides oxidise to produce sulfuric acid. Water draining from oxidised ASSs can be strongly acidic (pH <3.5). The acid acts on soils and sediment to produce high solution concentrations of toxic metals, especially aluminium and iron, which may have deleterious effects on human health and the environment and may also result in damage to infrastructure (see Appendix 17).

The oxidation of metal sulfides is a natural weathering process that generally occurs slowly and does not pose an environmental concern. However, excavation and drainage can exponentially increase the rate of acid generation. Unmanaged disturbance of areas of ASS and consequent acid drainage from these areas can cause adverse impacts to the terrestrial and intertidal environment, including the following:

- a reduction in soil fertility caused by acidification and metal toxicity, reducing plant growth and limiting germination of new seedlings
- the creation of acid surface scalds at points where affected groundwater discharges to the soil surface
- a loss of visual amenity because of rust-coloured stains, scums and slimes from iron precipitates at the soil surface accompanied by reduced vegetation growth
- the risk of long-term infrastructure damage through acidic water corroding metallic and concrete structures such as foundations, subsurface pipes, retaining walls and roads
- a reduction in water quality in the marine environment and toxic effects on marine biota (these impacts are discussed in Chapter 7).

Soils of the Euro family in the coastal zones around Blaydin Point and Middle Arm Peninsula are particularly prone to acid generation. The Maand, Mullalgah and Rinamatta soil families also present a potential ASS risk, although to a lesser degree (see Appendix 17). Potential ASSs occur in the areas proposed for the pipeline shore crossing, onshore

Table 8-2: Volumes of potential acid sulfate soil to be excavated during site preparation at the onshore development area

Area	Length (m)	Width (m)	Depth (m)	Total volume (m^3)	Estimated weight (t)
Ground flare*	625	300	5	937 500	1 406 250
Pipeline shore crossing (coffer dam)	900	6	5	27 000	40 500
Pipeline mangrove crossing	1 200	3	2	7 200	10 800
Module offloading facility	(irregular shape)			90 000	135 000
Total				**1 061 700**	**1 592 550**

* The construction method for the ground flare has not yet been finalised and this level of excavation may be reduced in the final design.

pipeline route, the ground flare and module offloading facility (see the soil map in Section 3.4.4 *Soils* in Chapter 3 *Existing natural, social and economic environment*). The potential volumes of material to be excavated during site preparation and construction of this infrastructure are presented in Table 8-2. Most of this material is likely to pose a high risk of acid sulfate leaching, and detailed soil testing before construction commences will be used to quantify the extent and strength of ASS in these areas. In addition to the excavated material, the remaining exposed surfaces would be at risk of acid leaching, and neutralising treatment would be required before infrastructure is constructed on top of these surfaces.

The most common ASS treatments involve adding a neutralising (liming) agent sufficient to neutralise the acid from the soil as it is produced over time from the gradual oxidation of the soil sulfides. Field surveys by URS (see Appendix 17) indicated that the acid neutralising capacity of the soils in the onshore development area is low and that the amount of lime in the form of calcium carbonate ($CaCO_3$) that would be required to neutralise acid formed upon excavation of these soils would range from 2.2 to 140 kg of $CaCO_3$ per tonne of soil, with an average of 30 kg per tonne of soil (see Appendix 17). Liming activities require monitoring to identify whether the rate of neutralisation is occurring at a rate equivalent to the oxidation of iron sulfides. If not, some acid leaching may still occur and drainage from liming areas may require treatment prior to discharge. Soils treated using this method, once neutralised, could be utilised as fill material or removed off site for disposal.

The offshore spoil disposal ground used by the Project for dredge spoil (see Chapter 4 *Project description*) may also be used for the disposal of excavated ASS material from the onshore development area. Potential impacts to the marine environment as a result of these disposal activities are discussed in Chapter 7.

Nutrients and organic carbon

The surface or A horizon of the Blaydin soil family that occurs within the monsoon vine forest areas at Blaydin Point and near the pipeline shore crossing contains relatively high levels of organic carbon and nutrients, has a low erosion risk, and is therefore considered highly fertile. This soil type is highly suitable for use as topsoil in revegetation work, and is a valuable resource for rehabilitation activities (see Appendix 17).

There will be areas around the onshore processing plant site that will be cleared during construction for machinery laydown and other activities but which will not be required during operations. Revegetation of these areas will minimise the risk of erosion from bare soils. Rapid reuse of the topsoil (0–300 mm depth) removed during land-clearing, particularly that sourced from areas of monsoon vine forest, is likely to improve revegetation success in these areas.

Management of soil chemistry impacts

A Provisional Acid Sulfate Soils Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 1. This will guide the development of more detailed plans during the construction and operations phases. It contains relevant objectives and targets together with a detailed description of the management controls to be implemented to mitigate acid sulfate leaching; it also includes options for treatment and disposal methods as well as outlining monitoring and reporting procedures.

As the Project is still in a preliminary stage of engineering design, the management controls outlined in the provisional management plan primarily deal with the options available for management of ASS material. The plan will be updated with more specific controls as further geotechnical studies are carried out and as infrastructure design progresses. Additional detailed chemical testing for ASSs will be conducted on site during the front-end engineering design (FEED) phase of the Project, and still more ASS testing will take place when infrastructure designs are mature, prior to construction. Inclusions in the provisional management plan are outlined below.

Various design options are investigated to minimise the quantity of ASS excavation from the site so that minimum management of ASSs is required. Engineering design and management options for avoiding or neutralising ASSs include the following:

- installing columns or piles and a deck structure in the ASS areas in order to minimise the generation of ASSs, with Project facilities constructed on top of the deck
- monitoring of the progress of work when installing columns or piles or a deck structure in the ASS areas to avoid or minimise generation of mud waves
- mixing the soil with cement slurry to harden it, neutralise it and make it more stable.

Management options available to treat and dispose of disturbed ASSs during construction are as follows:

- placing fill material on top of ASSs to form a surface suitable for construction
- neutralising excavated ASSs by mixing them with lime, then reusing the material as backfill or disposing of it at designated onshore sites
- excavation and disposal of ASSs underwater at a designated offshore disposal site, avoiding oxidation of the soils.

A marine sediments and bio-indicators monitoring program will be developed to assess any increase in bioavailable heavy metals as a result of excavation of acid sulfate soils during the construction phase.

Residual risk

A summary of the potential impacts, management controls and residual risk for soil chemistry is presented in Table 8-3. After implementation of these controls, impacts from ASSs are considered to present a "medium" risk and any effects on the surrounding environment are likely to be only localised and minor.

8.2.3 Alteration of surface-water and groundwater flow

In order to determine the likely impacts of the Project on surface and groundwater flows at Blaydin Point, a hydrological model for the area was developed by URS in the period April–October 2008. The conclusions arrived at as a result of this model are summarised below, with the complete technical report (URS 2009b) provided in Appendix 18 to this Draft EIS.

Development of the onshore processing plant will require vegetation-clearing throughout the site and the development of sealed surfaces beneath some facilities (such as the slug catcher, the liquefied natural gas (LNG) trains and the hydrocarbon storage tanks), interspersed with cleared but unsealed areas. The groundwater beneath Blaydin Point is believed to be recharged mainly by the infiltration of rainfall (see Appendix 18) and maintaining sufficient unsealed areas throughout the onshore development area will allow natural infiltration to continue.

Without sufficient recharge of the groundwater aquifer by rainfall, the water table at Blaydin Point could decline and stabilise near mean sea level. This could result in landward migration of the interface between fresh water and sea water and might affect groundwater-dependent ecosystems as well as below-ground services and building foundations (see Appendix 18).

Table 8-3: Summary of impact assessment and residual risk for soil chemistry

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Acid sulfate soils	Earthworks in the onshore development area for the pipeline shore crossing, onshore pipeline, ground flare and module offloading facility.	Acidification of soils, surface water and groundwater, reducing soil productivity and plant growth.	Facilities to be designed to minimise excavation of potential ASS. If excavation is unavoidable, management options include neutralising and re-covering with clean fill, or disposing of off site. As an alternative, excavated ASS material may be disposed of at the offshore spoil disposal ground. Provisional Acid Sulfate Soils Management Plan.	E (E4)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

The vegetation community remaining during the operations phase of the Project that is most sensitive to changes in the groundwater and surface-water regime is the hinterland fringe mangrove community (see Appendix 18). This occurs as a narrow fringe, approximately 20–30 m wide, at the interface between the terrestrial vegetation communities (such as eucalypt woodland) and the tidal flats. (The vegetation communities of the onshore development area are described in Chapter 3.) The hinterland fringe mangrove community is characterised by dependence on freshwater input and low soil salinities. Its elevation on the tidal gradient means that this community receives infrequent tidal (seawater) inundation.

Currently, the hinterland fringe mangrove zone at Blaydin Point receives freshwater runoff and fresh groundwater seepage that is marked in the wet season and less pronounced, but perennial, in the dry season. The onshore processing plant will modify water flows to the hinterland fringe mangrove zone in a number of ways:

- Surface-water flows will increase in total volume.
- Surface-water flows may be concentrated to a small number of discrete areas (near artificial surface-water drains), while other areas may be isolated from water supply and will actually receive less surface-water runoff.
- Surface-water flows will be delivered earlier in the wet season as the natural time delay resulting from soil saturation in the upper catchment will be removed.
- Water-table levels may decrease if a large proportion of the ground's surface is sealed in order to construct the onshore processing plant. If this decrease is enough to allow seawater movement into the groundwater, groundwater seepage may become more saline.

The overall effect on the hinterland mangrove community may be that there will be more luxuriant growth in some areas and dieback in others. Anecdotal evidence suggests that freshwater flows to hinterland mangrove communities have been affected in other areas of Darwin Harbour, including ConocoPhillips' Darwin LNG plant, the East Arm Wharf development area and the Bayview residential area, without significant deterioration in mangrove health.

At Blaydin Point, by distributing surface-water runoff from the onshore development area at numerous points around the perimeter rather than through a single discharge point, the surface-water flow would be partially maintained and the effects of reduced fresh groundwater seepage would be minimal.

The extensive mangrove zones up to 1 km wide that occur seaward of the hinterland fringe are reliant on tidal inundation and are adapted to conditions of higher salinity. These communities are unlikely to be affected by modifications to fresh surface-water drainage and subsurface seepage from the Blaydin Point hinterland.

Surface-water flows in the onshore development area may also be altered by the construction of infrastructure such as roads and pipelines. In particular, a causeway will need to be constructed across the tidal flat between Blaydin Point and Middle Arm Peninsula and allowances will have to be made to maintain water flow to the upper intertidal area above the causeway. Alterations to tidal surface-water flows may affect the long-term survival of localised pockets of vegetation or could result in areas of pooling water that increase the extent of biting-insect habitat.

Management of surface water and groundwater

As noted above, a Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan has been compiled for the Project. This will guide the development of more detailed plans during the construction and operations phases. The provisional management plan contains relevant objectives and targets and provides a detailed description of all management controls and monitoring and reporting procedures to be implemented to manage drainage and groundwater. Key elements of the plan are as follows:

- Some areas of Blaydin Point will remain uncleared or unsealed to allow for some groundwater recharge by rainfall.
- Numerous surface-water drains will be constructed around the perimeter of the onshore development area, which will distribute fresh water to mangrove areas.
- A mangrove health monitoring program will be developed to assess the potential effects of changes to water supply during the operations phase.
- A groundwater quality monitoring program will be developed to check if there are any impacts on groundwater quality.
- Culverts will be installed beneath the causeway between Blaydin Point and Middle Arm Peninsula to maintain surface-water flows across the natural drainage line.

Management of contamination risks to surface-water and groundwater flows are discussed in Section 8.6 *Spills and leaks*.

Table 8-4: Summary of impact assessment and residual risk for surface water and groundwater

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Surface-water management	Sealing of parts of the ground surface throughout the onshore development area for the processing plant and associated infrastructure.	Increase in total volume of surface-water runoff. Alteration of surface-water drainage direction and volumes. Isolation of groundwater system from freshwater recharge, lowering of water table and potential for seawater intrusion. Reduced health or mortality of hinterland mangrove community because of reduced access to fresh groundwater.	Some areas of Blaydin Point will remain uncleared or unsealed to allow for groundwater recharge by rainfall. Install multiple surface-water drains to distribute fresh water into mangroves. Install culverts to maintain natural tidal flows underneath the causeway from Blaydin Point to Middle Arm Peninsula. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	D (B2)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Residual risk

A summary of the potential impacts, management controls and residual risk for surface water and groundwater is presented in Table 8-4. After implementation of these controls, the impacts on surface water and groundwater are considered to present a “medium” risk and it is likely that any effects on the environment will be localised and minor in scale.

8.3 Ecological disturbance

8.3.1 Vegetation-clearing

Construction and engineering constraints prevent any significant reductions in the size of the onshore development area because of the requirements for large areas of laydown and to allow for a permanent design that maintains safe distances between hazardous and non-hazardous areas. As a result, the Project will require approximately 352 ha of vegetation-clearing within the onshore development area. There are also 54 ha of cleared land (including borrow pits and roads) within the disturbance footprint.

The onshore development area clearing footprint will be concentrated in the upper land area, above the intertidal zone. Vegetation in this area is dominated by *Eucalyptus* woodland and there are also two patches of closed monsoon vine forest. Some smaller areas in the intertidal zone will also require clearing and are currently dominated by mangrove communities. The vegetation communities throughout the onshore development area are described in Chapter 3 and the areas of each that are proposed to be cleared are presented in Table 8-5.

The ecological significance of this vegetation-clearing from a regional perspective is discussed by GHD (2009) (provided as Appendix 16 to this Draft EIS) and is summarised below.

Table 8-5: Disturbance areas in the vegetation communities at the onshore development area

Vegetation community	Area proposed to be cleared (ha)
***Casuarina* and beach forest**	**1**
***Eucalyptus* woodland**	**161**
Monsoon vine forest	**66**
Mangrove communities:	
Avicennia–Ceriops open forest	5
Ceriops closed forest	25
Mixed hinterland closed forest	16
Mixed species low closed forest	8
Salt flats	20
Shoreline forest	2
Sonneratia woodland	4
Tidal creek forests	3
Transition zone	0
Subtotal – Mangrove communities	**83**
Melaleuca communities:	
Melaleuca forest	8
Mixed species low woodland	33
Subtotal – Melaleuca communities	**41**
Total*	**352**

* Note that this does not include 54 ha cleared before 2007.

Vegetation communities

Eucalyptus woodland

Eucalyptus woodland is the most widespread vegetation community throughout the Darwin Coastal Bioregion and it is also well represented in conservation reserves (GHD 2009). Although this vegetation type will be cleared more extensively than any other within the onshore development area, the extent of clearing will not significantly reduce the abundance or distribution of *Eucalyptus* woodland at a regional level.

Monsoon vine forest

Monsoon vine forest vegetation in the Darwin Coastal Bioregion is considered to have a higher conservation value than most other vegetation types found in the onshore Project area. Among other attributes, it contains fruiting and flowering plant species that provide a rich food source for some specialised animals, such as frugivorous birds.

The area of monsoon vine forest on Blaydin Point (approximately 65 ha) represents about 4% of the total extent of the vegetation type found around Darwin Harbour (Figure 8-1) and an estimated 1% of mapped monsoon vine forest in the Darwin Coastal Bioregion.

Monsoon vine forest provides habitat for frugivorous birds such as rose-crowned fruit-doves (*Ptilinopus regina*). These birds disperse the seeds of the plants and their presence may be an important factor in maintaining the existence of this vegetation community. Extensive plantings of tropical fruit-bearing trees (e.g. the palm *Carpentaria acuminata*) in suburbs of Darwin and Palmerston and the surrounding rural areas are capable of supporting some of the frugivorous bird species that inhabit monsoon vine forest (GHD 2009).

Threatening processes to the monsoon vine forest in the Darwin Coastal Bioregion include degradation by feral animals (principally pigs), infestation by invasive weeds, and the impacts of more frequent hot, late, dry-season fires (DEWHA 2008).

Mangroves

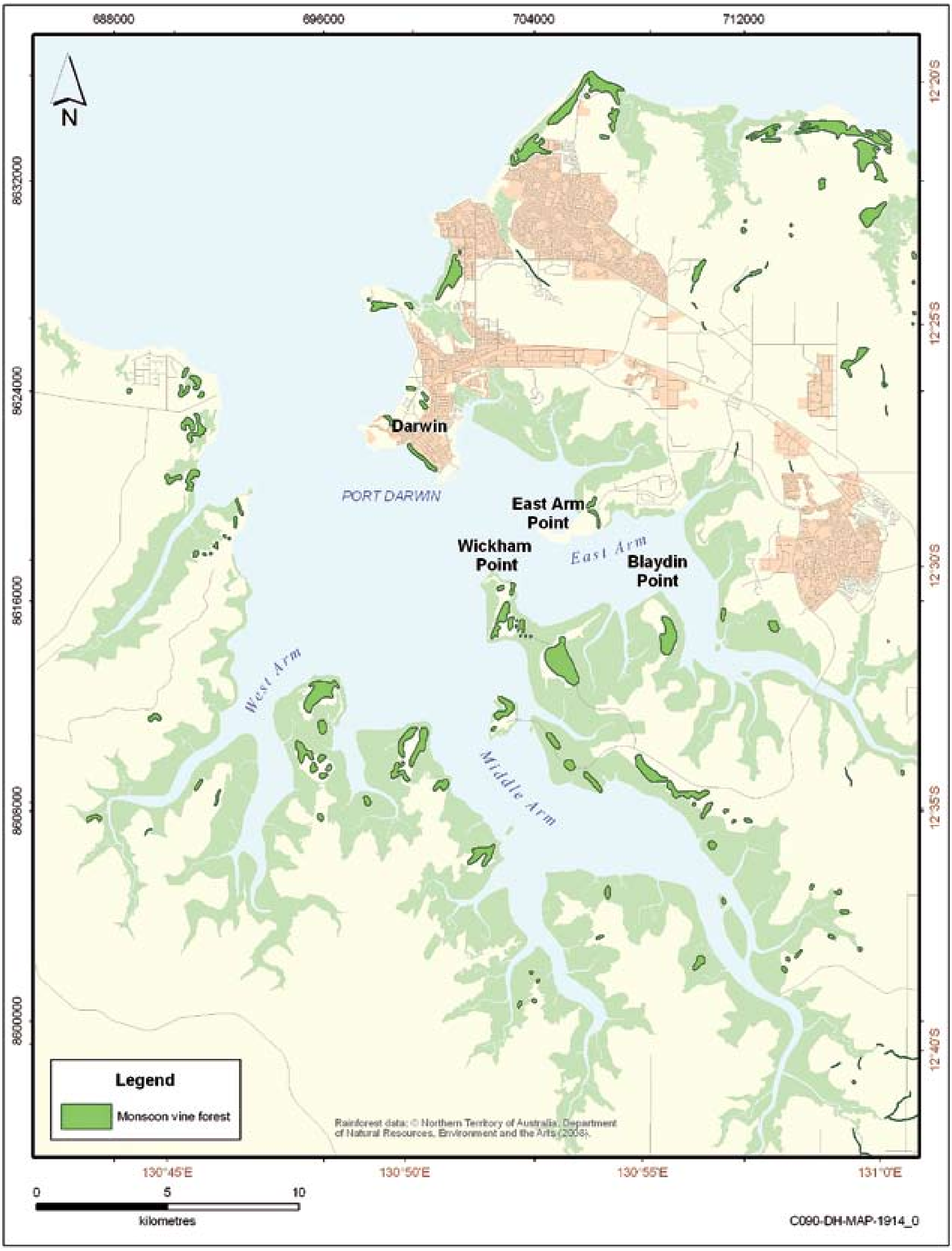
The majority of mangrove areas around Blaydin Point and throughout Darwin Harbour are zoned for "conservation" under the Northern Territory Planning Scheme (DPI 2008) in recognition of the high level of biodiversity contained in these vegetation communities. The mangrove tracts around the Harbour shoreline are extensive, occupying over 27 000 ha. The proposed disturbance of mangrove vegetation communities at the Project's onshore development area (77 ha in total) represents less than 0.3% of that vegetation type found in the Darwin Harbour region, and is an insignificant portion of the vegetation type in the overall context of the Darwin Coastal Bioregion. Clearing is not expected to significantly impact the vegetation type at a regional scale.

Melaleuca

Melaleuca forest is a common lowland vegetation type found throughout the Darwin Coastal Bioregion; it represents 9% of the total area of the bioregion. Clearing at the onshore development area will not significantly reduce the abundance or distribution of this vegetation community.

Significant plant species

As described in Chapter 3, field surveys in 2007 and 2008 indicated that no plant species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) occur in the onshore development area.



Source: Unpublished data (2008) from the Rainforest Database of the Northern Territory's Department of Natural Resources, Environment and the Arts (NRETA)[1].

Figure 8-1: Existing monsoon vine forest patches around Darwin Harbour

1 Now the Department of Natural Resources, Environment, the Arts and Sport (NRETAS).

However, the cycad *Cycas armstrongii*, which is listed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT), does occur in the onshore development area in the eucalypt woodland vegetation community. Impacts to the total population of this species as a result of land-clearing for the Project are not expected to be significant. The cycad is locally abundant across the western Top End region, the Cobourg Peninsula and the Tiwi Islands (Melville Island and Bathurst Island). It is listed as vulnerable because of its poor representation in conservation reserves and because of large-scale land-clearing threats from agriculture, horticulture and forestry (GHD 2009). Where land-clearing has been approved under the formal procedures of the Northern Territory Government (e.g. through the EIS process), no additional permit is required to take cycads for non-commercial purposes on areas designated to be cleared (Liddle 2009).

Management of vegetation-clearing

A Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 15. This will guide the development of more detailed plans during the construction and operations phases. It contains details of applicable management controls, procedures, and monitoring and audit programs. Key components of this plan are as follows:

- The area of vegetation cleared will be the minimum required to safely and efficiently construct and operate the onshore facilities.
- All disturbance, including personnel and vehicle movements, will be contained within the designated onshore development area to avoid impacts to surrounding vegetation. Some additional clearances may be required around the perimeter of the site to allow for appropriate firebreaks.
- Areas to be cleared will be clearly identified prior to work commencing. Clearing boundaries will be marked in the field and on site plans, and a register of clearing activities will be maintained.
- Temporarily disturbed areas within the onshore development area (e.g. near the pipeline shore crossing, along the onshore pipeline route, and small areas around the processing plant) will be revegetated and rehabilitated following the completion of construction activities.
- A vegetation rehabilitation monitoring program will be developed to determine the success of revegetation activities.
- Some topsoil will be stockpiled from cleared areas for future use in rehabilitation.
- Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used both for vegetation rehabilitation and for soil stabilisation. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned.

A Provisional Decommissioning Management Plan has also been compiled and is included in Chapter 11 as Annexe 5. It outlines the processes to be undertaken to determine final landforms and potential rehabilitation activities at the end of the Project's life. This plan will guide the development of more detailed plans at later stages of the Project.

Residual risk

A summary of the potential impacts, management controls and residual risk for vegetation-clearing is presented in Table 8-6. After the implementation of controls and with consideration of mitigating factors, the impacts from vegetation-clearing are considered to present a "low" to "medium" risk and are likely to affect plant and animal populations on only a localised and minor scale. Clearing monsoon vine forest is assigned a "medium" residual risk rating as it is not possible to avoid through engineering design and represents a proportionally higher impact at a regional scale. The fact that mangroves act as primary producers providing habitat and resources to marine biota increases the ecological significance of clearing activities. Nevertheless, removal of these vegetation types in the onshore development area is not considered to threaten significant plant or animal species as similar areas of habitat do exist nearby.

Table 8-6: Summary of impact assessment and residual risk for vegetation-clearing

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Vegetation	Clearing of vegetation during site preparation.	Loss of mangrove habitat. Localised reduction in biodiversity.	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to design, construction and safety requirements. Contain all disturbance (including vehicle movement) within the development footprint. Mangrove communities are common throughout Darwin Harbour and the Darwin Coastal Bioregion. Temporarily disturbed areas within the onshore development area (e.g. near the pipeline shore crossing, along the onshore pipeline route, and small areas around the processing plant) will be revegetated and rehabilitated following the completion of construction activities. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	E (B2)	6	Medium
Vegetation	Clearing of vegetation during site preparation.	Loss of *Eucalyptus* woodland and *Melaleuca* forest habitat. Localised reduction in biodiversity.	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to design, construction and safety requirements. Contain all disturbance (including vehicle movement) within the development footprint. Store topsoil from cleared areas in stockpiles for future use in rehabilitation. Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used for both rehabilitation and soil stabilisation to prevent erosion. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned. *Eucalyptus* woodland and *Melaleuca* forest communities are common throughout the Darwin Coastal Bioregion. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	F (B3)	6	Low
Vegetation	Clearing of vegetation during site preparation.	Removal of cycads, which are classed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT). Localised reduction in biodiversity.	*Cycas armstrongii* is common throughout the Darwin Coastal Bioregion. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	F (B1)	6	Low

Table 8-6: Summary of impact assessment and residual risk for vegetation-clearing (continued)

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Vegetation	Clearing of vegetation during site preparation.	Loss of monsoon vine forest habitat. Localised reduction in biodiversity.	The vegetation-clearing footprint for the onshore development area will be minimised during the design of the onshore facilities, subject to design, construction and safety requirements. Contain all disturbance (including vehicle movement) within the development footprint. Store topsoil from cleared areas in stockpiles for future use in rehabilitation. Cleared vegetation will be mulched and stockpiled on site boundaries or off site. Where possible, the mulch will be used for both rehabilitation and soil stabilisation to prevent erosion. Cleared vegetation that cannot be reused will be disposed of off site. No stockpiled vegetation will be burned. Other monsoon vine forest habitats exist within the region. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	E (B3)	6	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.3.2 Alteration of habitat

Removal of vegetation in the onshore development area will result in some habitat loss and also potential habitat fragmentation for animal species in the area. "Edge effects" of the onshore development area on the remaining vegetation communities around Blaydin Point and Middle Arm Peninsula are also likely to have an impact on the integrity of fauna habitats throughout the life of the Project. Such edge effects could include the spread of weeds into natural vegetation from roadsides, the alteration of microclimatic conditions (such as greater sunlight intensity or exposure to wind) and a reduction in plant health (such as through smothering by dust).

As described in Section 8.3.1 *Vegetation-clearing*, removal of the monsoon vine forest from Blaydin Point is likely to be the most significant alteration of habitat at the onshore development area as this plant community provides food resources to specialised frugivorous birds. However, monsoon vine forest occurs in other areas around Darwin Harbour (see Figure 8-1) and throughout the Darwin Coastal Bioregion, and removal of this habitat does not represent a critical loss at a regional scale (GHD 2009).

The *Eucalyptus* woodland habitat contained the highest species richness for animals during surveys of the onshore development area (GHD 2009; see Appendix 16). However, this woodland occurs in large areas elsewhere on Middle Arm Peninsula and throughout the Darwin region and clearing at Blaydin Point will not represent a major reduction in availability of this habitat type.

The construction phase of the Project presents the greatest risks of injury and death to local animal life, as a result of the clearing of vegetation by heavy machinery in the onshore development area. Increased vehicle movements throughout Middle Arm Peninsula may have an impact on animals from accidental collisions. The excavation of trenches during the construction phase (e.g. at the pipeline shore crossing) will also pose an entrapment risk to some species.

Other potential edge effects that may impact on local wildlife include the invasion of new weeds and pest animals into the habitats surrounding the onshore development area. These risks and the proposed management controls are discussed in Section 8.3.4 *Introduced species*.

Domestic waste will need to be managed to avoid attracting scavengers such as rodents, seagulls, raptors and reptiles to the onshore development area. Ingestion of food scraps and other putrescible waste could have a negative effect on the health of these animals while the attraction of animals to buildings or waste facilities could increase the risk of collisions with the traffic and machinery used in these areas.

Significant animal species

The removal of habitat at the onshore development area may affect individuals of listed threatened species, and some animals may be injured or killed as a result of construction activities. However, this will not affect the survival of the species overall. The onshore development area contains suitable habitat for some threatened species, such as the northern quoll and the floodplain monitor, but these animals are found throughout the Darwin Harbour region. Most animals present at the start of land-clearing activities should be able to move to adjoining habitat on Middle Arm Peninsula or elsewhere in the vicinity.

Management of alteration of habitat

Objectives, targets, management controls and monitoring to protect animals and habitat have been incorporated into the Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (attached as Annexe 15 to Chapter 11).

The management controls to avoid disturbance to vegetation (see Section 8.3.1) also apply to the protection of habitat, in addition to the following prescriptions:

- Major clearing activities will be undertaken in a manner that maximises the opportunities for animal life to move into remaining vegetation in the vicinity.
- "High-risk" entrapment areas (e.g. deep trenches or pits) will be constructed with sloping egress ramps to prevent animals from being trapped. Targeted inspections will be undertaken of these areas and any trapped animals will be removed and released.

The Provisional Waste Management Plan developed for the Project (attached as Annexe 16 to Chapter 11) contains procedures for containing and storing domestic waste at the onshore development area to prevent access by animals. Waste will be transported off site for disposal at a licensed landfill facility.

Residual risk

A summary of the potential impacts, management controls and residual risk for alteration of habitat is presented in Table 8-7. After the implementation of controls and with consideration of mitigating factors, the impacts for alteration of habitat are considered to present a "medium" or "low" risk and are likely to affect animal populations on only a localised and minor scale.

Table 8-7: Summary of impact assessment and residual risk for alteration of habitat

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Habitat	Clearing of vegetation for site preparation.	Loss of habitat for terrestrial fauna.	Major clearing activities undertaken to allow animals to move into the remaining vegetation in the vicinity. Habitat to be cleared is well represented elsewhere on Middle Arm Peninsula, and in the region. No significant animal species recorded in recent surveys of the onshore development area. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	E (B3)	6	Medium
Animals	Temporary creation of trenches and excavations during construction.	Entrapment of animals, with possibility of injuries or deaths.	"High-risk" entrapment areas (e.g. deep trenches or pits) will have sloping egress ramps. Targeted inspections will be undertaken and any trapped animals will be removed and released. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.3.3 Biting insects

There are two main aspects associated with biting insects at the onshore development area:

- New habitat and breeding sites may be created for biting insects.
- Biting insects may affect the health of workers or members of the public.

These impacts were considered in an assessment of the biting insects of the onshore development area carried out by the Northern Territory's Centre for Disease Control (Medical Entomology Section 2009); the findings of the assessment are summarised below. (The full report is provided in Appendix 21 to this Draft EIS.)

Creation of habitat for biting insects

Biting-insect habitat is associated with pooling surface water that allows for breeding (depths as shallow as 20 mm are sufficient) and exposed soil or vegetation substrates. If not carefully managed, disturbance to intertidal areas at the onshore development area is highly likely to create new breeding sites for mosquitoes such as *Aedes vigilax*, *Culex sitiens* and *Anopheles hilli* and members of the *Anopheles farauti* complex. This may include direct disturbance by vehicles and machinery, blockage of tidal flows by roads and other embankments, erosion from stormwater flows or the creation of mud waves by filling activities (Medical Entomology Section 2009).

Construction of the product loading jetty, the module offloading facility, the ground flare and the pipeline shore crossing will result in some disturbance to the intertidal mangrove zone. Land reclamation may also be required for the development of these areas (e.g. the ground flare, depending on final design), where the low-lying tidal flats would be built up by several metres of fill material. This would create an "island" within the mangrove zone around which tidal movements would be altered and ponding could occur.

During construction, sedimentation ponds will be established around the onshore development area to capture silty or potentially contaminated surface-water runoff from the plant site. Stormwater drains that discharge into tidal areas have the potential to create mosquito breeding sites by allowing tidewater and rainwater to collect in ponds. Borrow pits on Middle Arm Peninsula will be extended, or new pits created, to supply fill for construction activities. These pits will fill with water during wet-season rains and will likely support grassy vegetation on the exposed soils.

Artificial receptacles such as used tyres, drums, disused machinery and any rubbish items that can collect rainwater are potential mosquito breeding sites. Equipment and machinery imported from overseas or North Queensland has the potential to harbour the drought-resistant eggs of the dengue-carrying mosquito *Aedes aegypti.* This may include building material, plastic packaging, machinery and tyres or any other item capable of capturing even small amounts of water at any stage.

Prime breeding sites for mangrove biting midges (*Culicoides ornatus*) occur in the upper tidal tributaries of mangrove creeks, associated with pneumatophores of the mangrove species *Avicennia marina* (Medical Entomology Section 2009). These environments exist to the west and south-east of Blaydin Point, and also near the pipeline shore crossing. Project activities are not likely to increase the availability of biting-midge habitat and in fact there may be a minor reduction in the extent of this habitat because of mangrove clearing for the pipeline shore crossing and ground flare.

Health risks

The mangrove areas surrounding Blaydin Point are expected to be substantial seasonal sources of the mangrove biting midge, the most significant pest biting midge in coastal areas of northern Australia. While biting midges are not a disease transmission risk, their painful bites can be a major nuisance and can cause intense itching. Through scratching the bites, susceptible or allergic individuals will develop skin lesions, secondary infections and scarring. Biting-midge infestations can be expected at the onshore development area from May to November, particularly around full and new moons, with peak biting times in the hour before and the hour after both sunset and sunrise (Medical Entomology Section 2009).

There is potential for mosquito-borne disease transmission to workers at the onshore development area or to members of the public in the vicinity. Mosquitoes such as *Aedes vigilax* pose a low to moderate risk of Ross River virus and Barmah Forest virus transmission during the months from September to January, with December and January the highest-risk months because of increased mosquito longevity. This species is likely to breed in poorly draining upper tidal areas surrounding Blaydin Point (Medical Entomology Section 2009).

Culex annulirostris, *Culex sitiens* and *Verrallina funerea* will pose a minor risk of Ross River virus transmission, while *C. annulirostris* will also pose a minor risk of Barmah Forest virus, Murray Valley encephalitis virus and Kunjin virus transmission.

Management of biting insects

Management controls to avoid the creation of biting-insect habitats at the onshore development area are incorporated into the Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (attached as Annexe 10 to Chapter 11). This plan will guide the development of more detailed plans during the Project's construction and operations phases and includes the following strategies:

- Natural drainage will be maintained around roads by installing drains and culverts, particularly in intertidal areas (such as the causeway between Blaydin Point and Middle Arm Peninsula).
- Surface-water drainage channels throughout the onshore development area will be designed to minimise the creation of habitat for biting insects. Drains will be kept free of vegetation.
- Temporary sedimentation ponds used during construction will be designed to minimise the potential for providing biting-insect breeding habitat.
- Regular inspections will be carried out for mosquito larvae in high-risk areas and controls will be implemented as required.

Waste will be regularly removed from site for disposal at an off-site landfill, in accordance with the prescriptions of the Provisional Waste Management Plan (attached as Annexe 16 to Chapter 11).

The pest risks posed by imported equipment and machinery at the onshore development area will be managed according to the Provisional Quarantine Management Plan (attached as Annexe 13 to Chapter 11). All items of machinery will be thoroughly cleaned prior to their arrival at the onshore development area.

Protection of workers from biting insects will be achieved by implementing health and safety measures such as wearing protective clothing and using insect repellent.

Insecticide spraying for mosquito larvae may be undertaken at the onshore development area. Insecticides will be selected for their environmental acceptability.

Residual risk

As biting midges and mosquitoes exist in relatively high abundance naturally in and around the onshore development area, the normal process of risk assessment (whereby the specific impacts of the Project are identified) is not considered applicable in this case. The management controls described above will be implemented to mitigate the risks of providing new biting-insect breeding areas, but during operations it would be virtually impossible to quantify the contribution of the Project to biting-insect populations in the area.

8.3.4 Introduced species

The increased vehicle traffic and ground disturbance at Blaydin Point and throughout Middle Arm Peninsula as a result of Project activities leads to the risk of introduction of new invasive plant and animal species, or to the spread of weeds and pests that already occur in localised areas. Introduced species of concern to the area are described below, along with the proposed management controls.

Weeds

A weed is defined as any non-native plant species whose presence is due to intentional or accidental introduction and which is deemed to have the potential to become an invasive species. Weeds threaten the survival of native plants and animals if they out-compete native species for nutrients, habitat and sunlight. Once established, weed species often produce a large quantity of seed that may remain dormant but viable for long periods of time. In addition, some weed species may be capable of propagating in more than one way, which means they can reproduce rapidly and grow to occupy large areas.

As described in Chapter 3, 12 weed species were recorded in surveys of the onshore development area. Areas where weed infestations already exist are mainly associated with previous disturbance, for example around old borrow pits and access tracks through the bushland. While these weeds are already established in some areas of Blaydin Point and Middle Arm Peninsula, the construction of new roads and cleared areas and the frequent vehicle movements associated with the Project may allow them to spread further into areas of natural vegetation that are currently weed-free. Topsoil from these areas would also contain a persistent weed seed bank, reducing the value of the topsoil for rehabilitation activities.

Four of the weeds at the onshore development area are listed as Schedule Class B/C weeds under the *Weeds Management Act 2001* (NT). These are mission grass (*Pennisetum polystachion*), hyptis (*Hyptis suaveolens*), gamba grass (*Andropogon gayanus*) and lantana (*Lantana camara*). This classification obliges landholders to make “reasonable attempts” to contain the growth and prevent the spread of these species.

During the operations phase of the Project, traffic on the access road from Wickham Point Road to the onshore development area is likely to be the main vector for weed invasion. Roads are common sites of weed introduction and spread, as the surrounding soils are disturbed and weed seeds or plant material can be transported on vehicles and machinery.

It is also noted that Wickham Point Road and many parts of Middle Arm Peninsula are accessible to the general public. Private vehicles travelling through the area also pose a risk of spreading weed material along roadsides and tracks, but management of this risk is outside INPEX's control during the construction and operations phases of the Project.

Pest animals

While some introduced animal species can exist in new habitats without detriment to the existing environment, others can become established as invasive pests and have a deleterious effect on native species through competition for food and habitat and by predation. Some pest animals predate heavily on native species while others can cause changes in habitat through selective grazing of favoured plant species or degradation of land by uprooting plants and burrowing.

Pest animal species that already occur at the onshore development area include the cane toad (*Bufo marinus*), the black rat (*Rattus rattus*) and the feral pig (*Sus scrofa*). Cane toads in particular are widespread throughout the Darwin region and impact heavily on native reptile and mammal populations. No satisfactory broad-scale control methods are currently available for the toad (GHD 2009).

New pest animal species could be introduced to Blaydin Point and Middle Arm Peninsula as a result of increased vehicle and equipment movements associated with the Project, particularly where cargo arrives from overseas vessels at the module offloading facility at Blaydin Point.

Management of introduced species

Weed and pest management objectives, targets, management controls and monitoring procedures are incorporated into the Provisional Quarantine Management Plan and the Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan (annexes 13 and 15 to Chapter 11). These plans will guide the development of more detailed plans during the construction and operations phases. The key management controls proposed are as follows:

- Machinery used for earth-moving and vegetation-clearing will be cleaned and inspected prior to the commencement of work at the onshore development area to identify any attached material that needs to be removed for quarantine reasons.
- A temporary washdown area for earth-moving and vegetation-clearing vehicles will be constructed for the construction phase.
- Infestations of listed weed species (namely mission grass, hyptis, gamba grass and lantana) in the onshore development area and along the access road from Wickham Point Road will be controlled by spraying or removal by hand, in accordance with the requirements of the *Weeds Management Act*.
- Topsoil containing high densities of weed seeds will not be used in rehabilitation.
- A weed monitoring program will be developed and will be implemented throughout the Project.
- Temporary, dedicated quarantine-approved premises (QAP) will be established on Blaydin Point during the construction phase. Vessels, equipment and modules entering from another country will be inspected here for quarantine material. The design of the QAP and the inspection procedures to be implemented will be carried out in accordance with Australian Quarantine and Inspection Service (AQIS) standards.
- Putrescible waste will be stored in covered containers on site to limit access by scavenger animals, and will be transported off site for disposal.

Residual risk

A summary of the potential impacts, management controls and residual risk for introduced species is presented in Table 8-8. After the implementation of controls, the risks of impacts from introduced species are considered to be as low as reasonably practicable and are assigned a rating of "medium" residual risk.

Table 8-8: Summary of impact assessment and residual risk for introduced species

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C[†]	L[‡]	RR[§]
Weeds	Machinery for earthmoving and clearing of vegetation entering the onshore development area from elsewhere in the Northern Territory or Australia.	Accidental introduction of new weed species to Blaydin Point and Middle Arm Peninsula, displacing native species and altering ecosystem function.	Control infestations of listed weeds in the onshore development area and access road. Hygiene procedures will be applied to earthmoving and vegetation-clearing equipment. Weed monitoring. Provisional Vegetation Clearing, Earthworks and Rehabilitation Management Plan.	D (B3)	3	Medium
Pest animals	Vehicles and equipment entering the onshore development area from elsewhere in the Northern Territory and Australia (overland).	Accidental introduction of new pest animal species to Blaydin Point and Middle Arm Peninsula, displacing native species and altering ecosystem function.	Inspect earthmoving and clearing vehicles etc. prior to their arrival at the onshore development area. Covering and storage of putrescible waste, with off-site disposal. Provisional Quarantine Management Plan.	D (B3)	2	Medium
Pest animals	Vessels and equipment entering from another country (overseas).	Accidental introduction of new pest animal species to Blaydin Point and Middle Arm Peninsula, displacing native species and altering ecosystem function.	Establish quarantine-approved premises during construction, according to AQIS requirements. Inspect incoming vessels, modules and equipment for quarantinable material. Provisional Quarantine Management Plan.	D (B3)	2	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.3.5 Changes to fire regime

Fires initiated at the onshore development area could spread into vegetated areas around Blaydin Point and Middle Arm Peninsula. This poses a risk of damage to local vegetated areas as well as to infrastructure in the area and is a safety risk to INPEX's workforce and the general public.

The risk of fire ignition in the onshore development area mainly applies to the beginning of the construction phase when vegetation-clearing is taking place. After the site has been cleared, there will be little combustible material remaining and a much lower risk of fire, despite the presence of ignition sources such as welding and cutting equipment. Likewise, fire risks will be low during the operations phase of the Project because of the large areas of cleared and sealed surfaces, and the availability of firefighting equipment.

Pre-development ecological surveys of the onshore development area (GHD 2009) were conducted 12 to 18 months after bushfires at Blaydin Point and recorded reasonable numbers of birds and reptiles; this indicates that the fires had not rendered the area uninhabitable for these animals. However, no pre-fire data were available against which to compare this survey information. Mammal populations may have been more heavily impacted as few small mammals were recorded in the field surveys (GHD 2009).

Management of fire

A Provisional Bushfire Prevention Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 3. This will guide the development of more detailed plans during the construction and operations phases. The plan contains objectives and targets, as well as details of management controls and provisions, monitoring programs and relevant training for personnel.

Key management controls included in the plan are as follows:

- Control of grassy vegetation (described in Section 8.3.4) provides the main opportunity to limit fuel loads in the vegetation around the onshore development area. Methods are likely to include slashing or spraying. Fuel-reduction burning will not be utilised.
- Firebreaks will be established around Project infrastructure that borders woodlands. Advice will be sought from the Northern Territory's Bushfires Council on firebreak requirements for Blaydin Point.
- Mulched vegetation from clearing operations which is stored on site will be stockpiled in designated areas away from potential ignition sources.
- Stockpiled vegetation from clearing activities will not be burned, but will be reused where possible or disposed of off site.
- Firefighting equipment will be available on site at all times, along with accessible supplies of water.
- Firefighting capability will be available and strategically located firefighting stations will be established at the onshore development area.
- A "hot-work" permit system will be established for all hot-work activities, such as welding and grinding.
- Safe designated smoking areas will be established and receptacles for cigarette butts will be provided during all phases of the Project.

Residual risk

A summary of the potential impacts, management controls and residual risk for fire is presented in Table 8-9. After the implementation of controls, the risks of fire are rated "medium" or "low" and it is considered that they are as low as reasonably practicable.

Table 8-9: Summary of impact assessment and residual risk for fire

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Fire	Vegetation clearing during site preparation (early construction phase).	Bushfire in vegetated areas throughout Blaydin Point and Middle Arm Peninsula. Damage to vegetation, habitat and infrastructure, and risks to public safety.	Emergency response equipment and procedures. Mulched vegetation stored on site from clearing operations will be stockpiled in designated areas, away from potential ignition sources. Stockpiled vegetation from clearing activities will not be burned, but will be reused where possible or disposed of off site. Establish firebreaks around Project infrastructure that borders woodlands, taking advice from the Northern Territory's Bushfires Council. Provisional Bushfire Prevention Management Plan.	E (B3)	4	Medium
Fire	Operating heavy machinery, undertaking "hot work" and operating the ground flare in the vicinity of vegetated areas, during construction and operations.	Bushfire in vegetated areas throughout Blaydin Point and Middle Arm Peninsula. Damage to vegetation, habitat, infrastructure and risks to public safety.	Control fuel load in grassed and vegetated areas to minimise risk of intense bushfires through weed control. Emergency response equipment and procedures. Establish firebreaks around Project infrastructure that borders woodlands, according to advice from the Northern Territory's Bushfires Council. Provisional Bushfire Prevention Management Plan.	E (B3)	2	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.4 Air emissions

Air emissions from the construction, commissioning and operation of the onshore development area will contribute to the Darwin regional airshed, and the potential impacts of these emissions are described in this section. The airshed in the offshore development area is remote from land and settlements, and the pollutants contained in these emissions will not impact on sensitive human, animal or plant receptors. These emissions are therefore not included in the air-quality assessment in this section. Greenhouse gases produced by the Project, and the management strategies proposed for these, are described in Chapter 9 *Greenhouse gas management*.

8.4.1 Construction phase

The key emission of potential concern during the construction phase at the onshore development area is dust (discussed in detail below). Other atmospheric emissions during the construction phase will be associated with maritime vessel engines, with additional airline flights and with the vehicles and equipment required to support the construction crew at the onshore development area. However, the volume and duration of the emissions during construction will not be significant in comparison with emission levels during the operations phase. Furthermore, construction emissions will not be concentrated in a single location for any extended period of time. Air-dispersion modelling has therefore not been undertaken for the relatively short-term construction phase (SKM 2009).

8.4.2 Dust

Fugitive dust is the air emission of potential concern during the construction phase at the onshore development area. Generation of dust can result from the following:

- the clearing of vegetation and site preparation
- earthworks (e.g. site levelling and excavation)
- drilling and blasting activities
- cut-and-fill activities
- wind erosion of stockpiled materials
- vehicle movements on unsealed roads
- loading and transport of loose soil, aggregate and/or other dust-generating material
- the operation of a crushing and screening plant
- the operation of a concrete batching plant.

The volume and duration of the dust emissions generated during construction are expected to be variable and intermittent. The emissions are unlikely to be concentrated in a single location for any extended period of time. Overall, however, the construction phase is of relatively long duration and extends over a large area. The soils at Blaydin Point are also prone to dust generation, as described in Section 8.2.1 *Soil erosion*.

Dust emissions have the potential to decrease vegetation growth by smothering leaves and blocking stomata. Loss of vegetation may in turn impact adversely on animals. The impacts of dust on vegetation around Blaydin Point are likely to be limited to dry-season conditions—rainfall during the wet season would remove dust from leaf surfaces.

Particulate matter in dust may also impact upon the health and safety of workers in the onshore development area and will therefore be reduced wherever possible within the site. Details on the adverse health effects related to dust (referred to as “particulates”) are provided in Section 8.4.3 *Operations phase*.

Management of dust

A Provisional Dust Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 7. This plan will guide the development of more detailed plans during the construction and operations phases. Its key objective is the minimisation of the generation of dust through the implementation of the following controls:

- Roads required for the operations phase will be sealed as soon as practicable after clearing in order to minimise dust emissions from vehicle movements.
- Dust suppression techniques will be applied where necessary to protect worker health, vegetation health, and amenity. This may include spraying from water trucks, irrigation, or stabilisation and revegetation of cleared areas that are no longer needed as soon as practicable during construction.
- Multiple handling of soil or rock materials will be minimised.
- Loads in all trucks transporting soil, aggregate or other dust-generating materials to and from the onshore development area will be sprayed with water to suppress dust.
- Monitoring of dust generation and the effectiveness of management controls will be regularly undertaken.

Residual risk

A summary of the potential impacts, management controls and residual risk for dust is presented in Table 8-10. After the implementation of controls and with consideration of mitigating factors, the impacts from dust are considered to present a “low” risk and are likely to affect the surrounding environment on a very localised and short-term scale.

Table 8-10: Summary of impact assessment and residual risk for dust

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Dust	Earthworks and vehicle movements at onshore development area during the construction phase.	Nuisance and health impacts (of PM_{10}) on the nearby community.	Residential and urban areas are located distant from the onshore development area. Prevailing winds during the dry season are mainly easterly, blowing dust away from Palmerston. Provisional Dust Management Plan.	F (E3)	2	Low
Dust	Earthworks and vehicle movements at onshore development area during the construction phase.	Dust deposition on surrounding vegetation, smothering it and reducing growth. Health impacts on the workforce.	Dust-control measures, including wetting down exposed surfaces. Roads required for the operations phase to be sealed during construction. Provisional Dust Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

8.4.3 Operations phase

To assess the likely impacts on regional air quality of operational emissions from the onshore development area, including their effects on human health and environmental values, air-emissions modelling was undertaken by Sinclair Knight Merz Pty Limited (SKM). This air-quality modelling utilised a three-dimensional computer-based modelling program ("The Air Pollution Model" (TAPM), developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO)), which accounts for dispersion processes such as convection, sea breezes and terrain-induced flows, and can be used to predict photochemical processes.

An assessment of the existing ambient air quality in the Darwin airshed was undertaken prior to consideration of the additional emissions from the Ichthys Project. Existing emissions sources in the Darwin region include the Darwin LNG plant, the Channel Island Power Station, shipping and vehicle emissions, and biogenic emissions from vegetation and soil. Accounting for these various sources in the air-quality model therefore provides a cumulative assessment of the Project's impacts on the Darwin airshed. The technical report produced for this study (SKM 2009) is provided in Appendix 19 to this Draft EIS.

Most of the air emissions during the operations phase of the Project at Blaydin Point will originate from the combustion of fuel gas in the process and power generation plant gas turbines. The key emissions from natural-gas processing include:

- oxides of nitrogen (NO_x, measured as NO_2)
- secondary emissions of ozone (O_3) (produced in the atmosphere from the reaction of NO_2 and volatile organic compounds (VOCs) with sunlight)
- non-combusted hydrocarbons or VOCs
- oxides of sulfur (SO_x measured as SO_2)
- hydrogen sulfide (H_2S)
- carbon dioxide (CO_2)
- particulate matter as PM_{10}[2].

The air-quality criteria applicable to assessing the effects of air emissions on human health and the environment are drawn from the National Environment Protection (Ambient Air Quality) Measure (NEPC 2003). This NEPM was created to provide planning benchmarks to ensure that people throughout Australia have protection from the adverse health effects of air pollution. The standards were developed after analysis of the most up-to-date research from around the world and took into account all available information on the state of Australia's major airsheds. Of the list above, the highest-risk NEPM "criteria air pollutants" that warrant examination in this assessment are NO_2, SO_2, O_3 and particulate matter (as PM_{10}) (SKM 2009).

The CO_2 emissions from the onshore development area are not expected to have any localised impacts on air quality or climate. However, it is acknowledged that CO_2 and other greenhouse gas emissions contribute to climate change on a global scale and require management. Details of INPEX's greenhouse gas management strategies are provided in Chapter 9.

2 Particulate matter smaller than 10 micrometres (10 µm) in diameter.

Benzene, toluene, ethylbenzene and xylenes (collectively known as BTEX) are among the VOCs that typically exist in relatively low concentrations in ambient air and represent a fraction of the compounds emitted from the combustion of fossil fuels. Of the VOCs, benzene is typically considered the highest potential risk.

The most potentially significant source of VOC emissions from Blaydin Point would be from regenerating the aMDEA solvent used to remove CO_2 from the natural gas in the acid gas removal units (AGRUs) (one ahead of each LNG train). Many gas plants around the world "cold vent" the CO_2 stream from their AGRU solvent regenerators directly to atmosphere, even although it contains a small amount of VOCs, including BTEX. However, in order to minimise VOC and BTEX emissions from the Blaydin Point site, INPEX will incinerate the aMDEA regeneration streams from both LNG trains to ensure that almost no BTEX will be emitted. The incinerators will be designed to operate successfully up to 364 days per year. In the event of an incinerator shutdown or scheduled maintenance, a bypass line will route the aMDEA vent stream to atmosphere through a tall and hot gas turbine exhaust stack. This will ensure effective dispersion of VOCs and BTEX to below NEPM monitoring investigation levels until such time as the incinerator is brought back on line.

The design basis for emissions modelling for the onshore processing plant included two gas-processing trains, each with a production capacity of 4.2 Mt/a and each equipped with the following:

- electrical power supplied by gas turbine generators equipped with dry low-NO_x burners
- process refrigeration powered by gas turbine generators with dry low-NO_x burners
- an acid gas removal unit (AGRU) incinerator
- a hot-oil furnace
- emergency flares.

Air emissions from the onshore development area are likely to change under different operating conditions, such as during emergencies or plant maintenance. Flaring is likely to be increased during upset conditions. For the purposes of this assessment, three scenarios have been modelled:

- normal operating conditions
- "upset conditions (1)" where flaring emissions are increased for up to 15 minutes (representing the worst credible case) as a result of a blocked mixed refrigerant compressor outlet. During this time, the mixed refrigerant compressor turbine would be non-operational, causing flaring of mixed refrigerant, while all other plant emissions would continue as normal
- "upset conditions (2)" where flaring emissions are increased for up to 10 hours as a result of depressurising of the propane compressor circuit. During this event, all equipment on one gas-processing train would be shut down and propane would be flared while the other train would continue to operate normally.

Oxides of nitrogen (NO_x)

Oxides of nitrogen (NO_x) is the collective term for nitrogen monoxide (NO) and nitrogen dioxide (NO_2). Nitrogen dioxide (NO_2) is an acidic, corrosive gas that can affect human health by increasing susceptibility to asthma and respiratory infections. Vegetation is adversely affected by exposure to NO_2, in the form of retarded growth rates and crop yields if exposed to very high concentrations. NO and NO_2 are also contributors to ground-level ozone production.

During routine operations at the onshore development area, the maximum cumulative concentrations of NO_2 are predicted to occur to the south-east and north-west of both the Darwin LNG plant and the INPEX onshore development area, as shown in Figure 8-2. Maximum 1-hour NO_2 concentrations on the grid are predicted to be 0.04 ppm, which equates to 34% of the NEPM criterion (see Appendix 19). It is noted that Figure 8-2 presents the highest NO_2 concentrations expected over a 1-hour averaging period—this is the "worst-case scenario", and consideration of longer averaging periods (e.g. 24 hours or one year) results in lower average concentrations of air pollutants. Ground-level concentrations of NO_2 expected in Darwin's central business district (CBD) and Palmerston are provided in Table 8-11.

The NO_2 emissions that could occur during upset conditions are equivalent to or lower than those from normal operations. During "upset conditions (1)" the 15 minutes of flaring do not contribute sufficient extra NO_2 to influence the plant emissions on a regional scale, and during "upset conditions (2)" only one LNG train is operational, reducing emissions from the plant overall (SKM 2009). These NO_2 levels are well below those at which impacts could be expected on human or environmental health in the Darwin region.

Table 8-11: Modelled NO_2 emissions in the Darwin CBD and Palmerston during operations

	Averaging period	Ground level NO_2 concentration (ppm)			
		Routine operations	Upset conditions (1)	Upset conditions (2)	NEPM criteria
Darwin CBD	1 hour	0.0350	0.0350	0.0250	0.1200
	Annual	0.0015	n.a.	n.a.	0.0300
Palmerston	1 hour	0.0250	0.0250	0.0200	0.1200
	Annual	0.0020	n.a.	n.a.	0.0300

n.a. = not applicable.
Source: SKM 2009.

Sulfur dioxide

Sulfur dioxide (SO_2) is a colourless gas with an irritating odour that can contribute to or exacerbate respiratory illnesses such as asthma or bronchitis, especially in elderly or young people. It can also have detrimental effects on the environment through its contribution to the formation of acid rain.

Emissions from the onshore development area result in an increase in maximum ground-level concentrations of SO_2 at the onshore development area, East Arm Wharf and the Darwin CBD as shown in Figure 8-3. The maximum ground-level concentration over a 1-hour averaging period is predicted to be 0.023 ppm, which is 11.5% of the NEPM criterion (SKM 2009). It is noted that air pollutant concentrations measured over a 1-hour averaging period represent the worst-case scenario, and consideration of longer averaging periods (e.g. 24 hours, or one year) results in lower average concentrations of air pollutants. Ground-level concentrations of SO_2 expected in the Darwin CBD and Palmerston over different averaging periods are provided in Table 8-12.

As with NO_2, the SO_2 emissions that could occur during upset conditions are equivalent to or lower than those from normal operations. During "upset conditions (1)" the 15 minutes of flaring do not contribute sufficient extra SO_2 to influence the plant emissions on a regional scale, and during "upset conditions (2)" only one LNG train is operational, reducing emissions from the plant overall (SKM 2009). These SO_2 levels are well below those at which impacts could be expected on human or environmental health in the Darwin region.

Dry deposition of oxides of nitrogen and sulfur

Impacts on vegetation can be caused by acid deposition ("acid rain") when SO_2 and NO_x react with water, oxygen and other oxidants in the atmosphere to form acidic compounds. These acid compounds precipitate in rain or in dry form as gases and particles. The SO_2 and NO_2 gases and their particulate matter derivatives (sulfate and nitrate aerosols) may contribute to air-quality impacts by the acidification of lakes and streams, damage to forest ecosystems and acceleration of the decay of building materials (SKM 2009).

Table 8-12: Modelled SO_2 emissions in Darwin CBD and Palmerston during operations

	Averaging period	Ground-level SO_2 concentration (ppm)			
		Routine operations	Upset conditions (1)	Upset conditions (2)	NEPM criteria
Darwin CBD	1 hour	0.0150	0.0150	0.0100	0.2000
	24 hour	0.0020	n.a.	n.a.	0.0800
	Annual	<0.0004	n.a.	n.a.	0.0200
Palmerston	1 hour	0.0100	0.0100	0.0050	0.2000
	24 hour	0.0020	n.a.	n.a.	0.0800
	Annual	<0.0004	n.a.	n.a.	0.0200

n.a. = not applicable.
Source: SKM 2009.

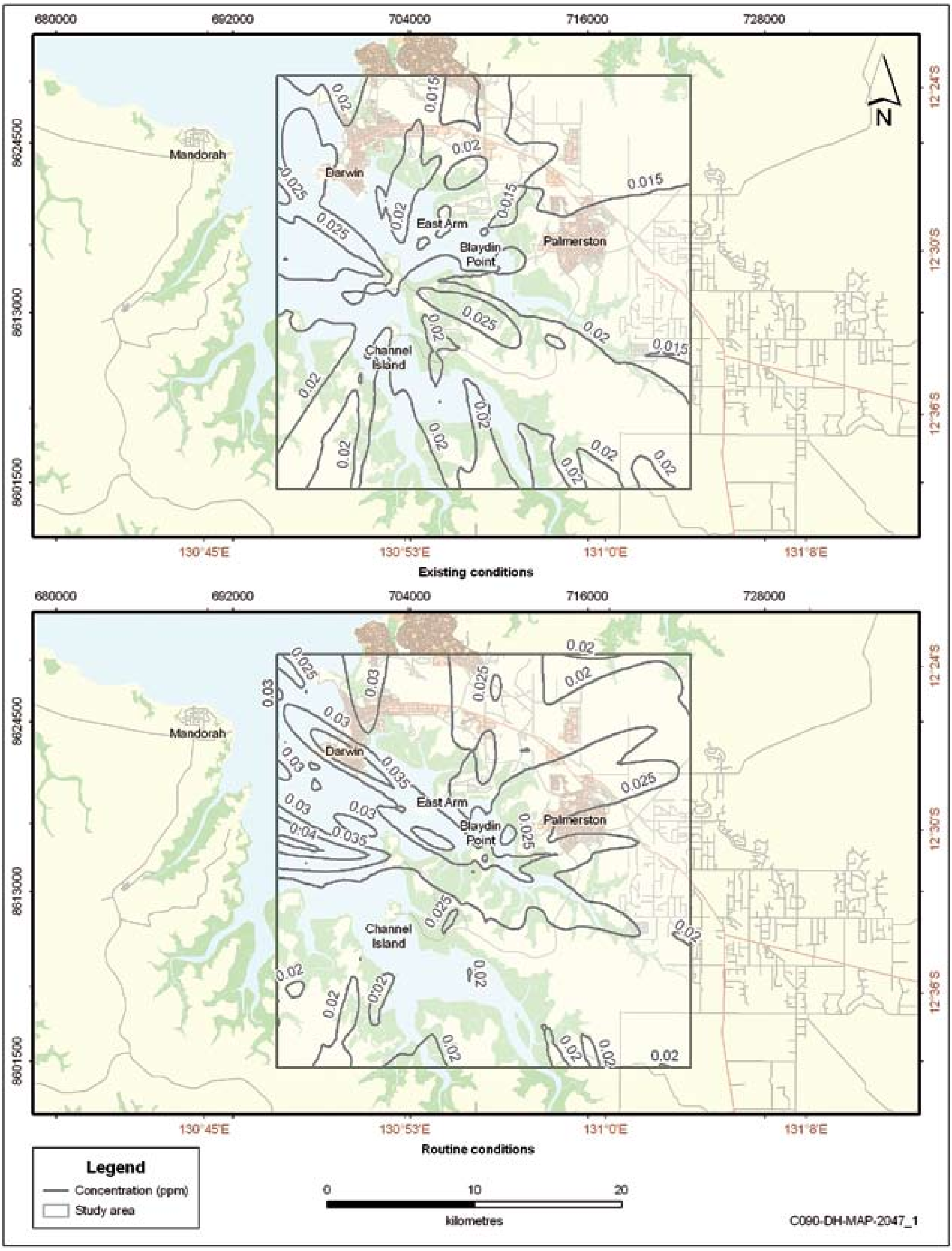


Figure 8-2: Maximum 1-hour ground-level NO_2 concentrations (ppm) during existing conditions and during routine Project operations

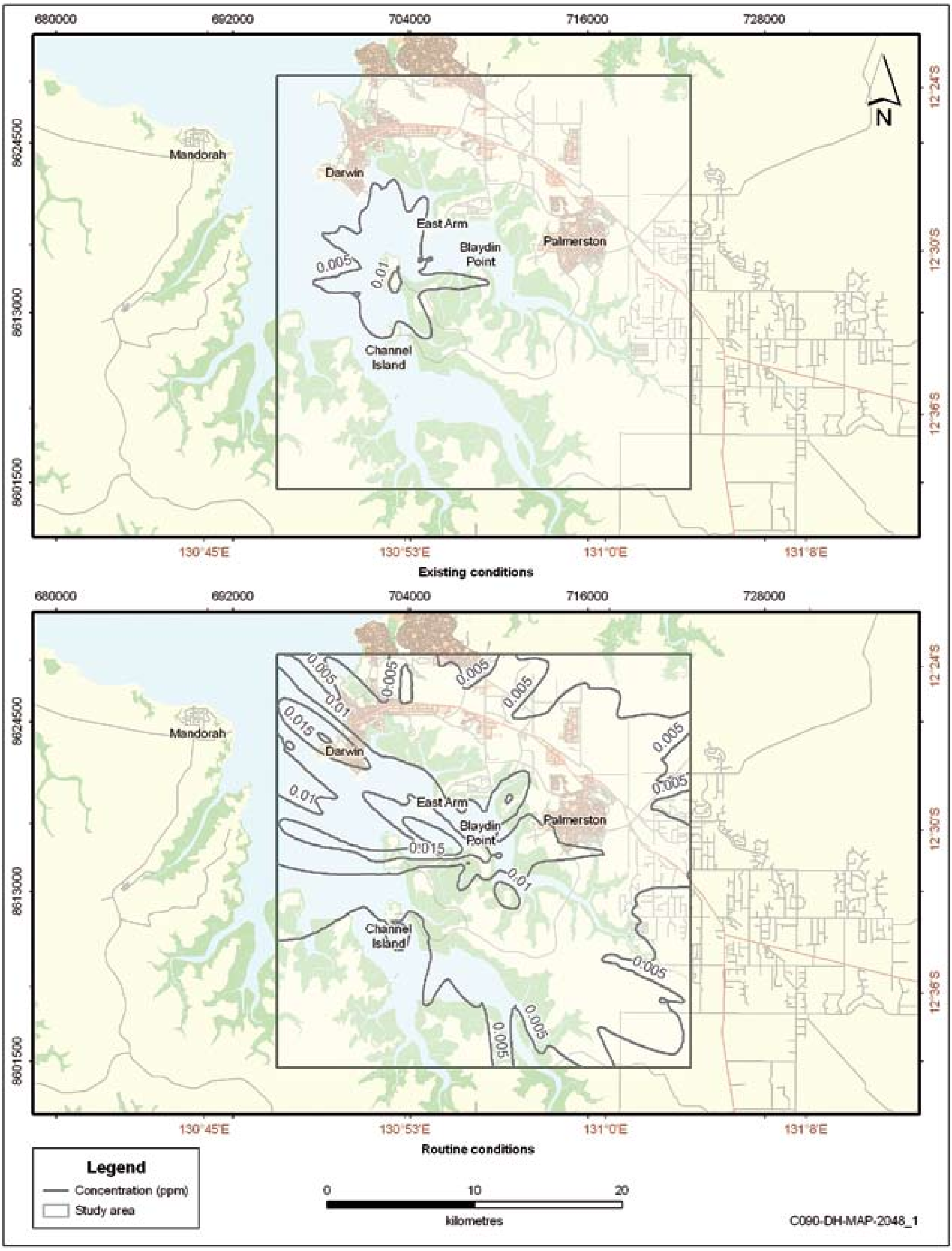


Figure 8-3: Maximum 1-hour ground-level SO_2 concentrations (ppm) during existing conditions and during routine Project operations

Modelling of acid deposition in the Darwin region, incorporating all emissions from existing sources as well as the proposed onshore processing plant, suggests that "typical high" SO_2 and NO_2 deposition levels would be 4 kg/ha·a^{-1} and 6 kg/ha·a^{-1} respectively (SKM 2009).

The World Health Organization (WHO) provides criteria for deposition of nitrogen- and sulfur-based acids below which, to the best present knowledge, significant harmful effects on specified sensitive elements of the environment do not occur. There is very little previous research on the effects of acid deposition in Australian communities or ecosystems. The modelled levels of deposition in the Darwin region as a result of the Project and other sources are well under the standards of 8–16 kg/ha·a^{-1} (SO_2) and 49–66 kg/ha·a^{-1} (NO_2) set by the WHO (2000) as noted by SKM (2009). These levels are unlikely to cause negative effects to vegetation in the region and are highly unlikely to damage buildings and structures.

Ozone

Ozone (O_3) is present in photochemical smog—it forms in the atmosphere by the reaction of NO_2 and VOCs in sunlight and at high temperatures to form a layer of visible, brown or white haze in the sky. Photochemical smog is a regional, and not localised, phenomenon in that ozone is produced relatively slowly through a series of reactions over several hours after exposure to sunlight. Maximum ozone concentrations therefore tend to occur downwind of the main source areas of precursor emissions, and can become recirculated within local and regional circulation patterns (SKM 2009).

The effects on human health of exposure to ozone in the lower atmosphere include irritation of the eyes and exacerbation of respiratory problems. Ozone can also affect plants by retarding growth and damaging leaf surfaces (SKM 2009).

Air emissions modelling shows that emissions from the Project will result in very minimal change to existing levels of ozone in the Darwin airshed (Figure 8-4). The maximum predicted ground level concentration of O_3 during routine operations is 0.06 ppm, which is identical to that predicted to occur in existing conditions (i.e. without the Project). This maximum concentration represents 59% of the NEPM criterion and occurs north of Darwin, over the ocean. The maximum ground-level concentration predicted to occur in Darwin and Palmerston is 0.05 ppm, which represents 48% of the NEPM criterion and is not expected to cause human or environmental health effects. The O_3 concentrations expected during upset conditions are equivalent to or lower than those from routine operations, as is the case for NO_2 and SO_2 as discussed above (SKM 2009). It is noted that air pollutant concentrations measured over a 1-hour averaging period represent the worst-case scenario, and consideration of longer averaging periods (e.g. 24 hours, or one year) results in lower average concentrations of air pollutants.

As described in Chapter 3, current O_3 concentrations in the Darwin airshed are predicted to be low, relative to the NEPM criterion. Both anthropogenic NO_x sources (e.g. motor vehicles) and biogenic VOC sources (e.g. tropical vegetation) contribute to ozone production. Large uncertainties can be associated with estimating biogenic VOC emissions, which sometimes vary across different vegetation types. In order to develop more accurate estimates, a passive VOC sampling program was conducted by SKM in the Darwin region, in both wet- and dry-season conditions in 2009. This research indicated that emissions estimation techniques being drawn from previous scientific literature were correctly estimating biogenic VOC emissions for the Darwin airshed. Overall, natural vegetation contributes much higher levels of ozone precursors to the Darwin airshed than industrial sources (see Appendix 19).

Particulates

Health effects of PM_{10} particulates (i.e. particulates with diameters of 10 µm or less) relate to the exacerbation of pre-existing respiratory problems. The segment of the population that is most susceptible includes the elderly, people with existing respiratory and/or cardiovascular problems, and children. Particulate matter can also enhance some chemical reactions in the atmosphere and reduce visibility. The deposition of larger particles can stain and soil surfaces, create aesthetic or chemical contamination of waterbodies or vegetation, and affect personal comfort, amenity and health (SKM 2009).

In Darwin, smoke from dry-season bushfires can contribute to air PM_{10} concentrations throughout the region. A study conducted in 2000 by the CSIRO found that 24-hour-averaged PM_{10} concentrations were below 10 µg/m^3 in the wet season and averaged approximately 20 µg/m^3 in the dry season. High PM_{10} concentrations recorded during the dry season coincided with days of reduced visibility caused by bushfire smoke (SKM 2009).

The Northern Territory's Department of Natural Resources, Environment, the Arts and Sport (NRETAS) also operates monitoring equipment for PM_{10} at the Charles Darwin University at Casuarina in Darwin's northern suburbs. Monitoring at this site showed no excursions above the NEPM criterion (50 µg/m^3 over

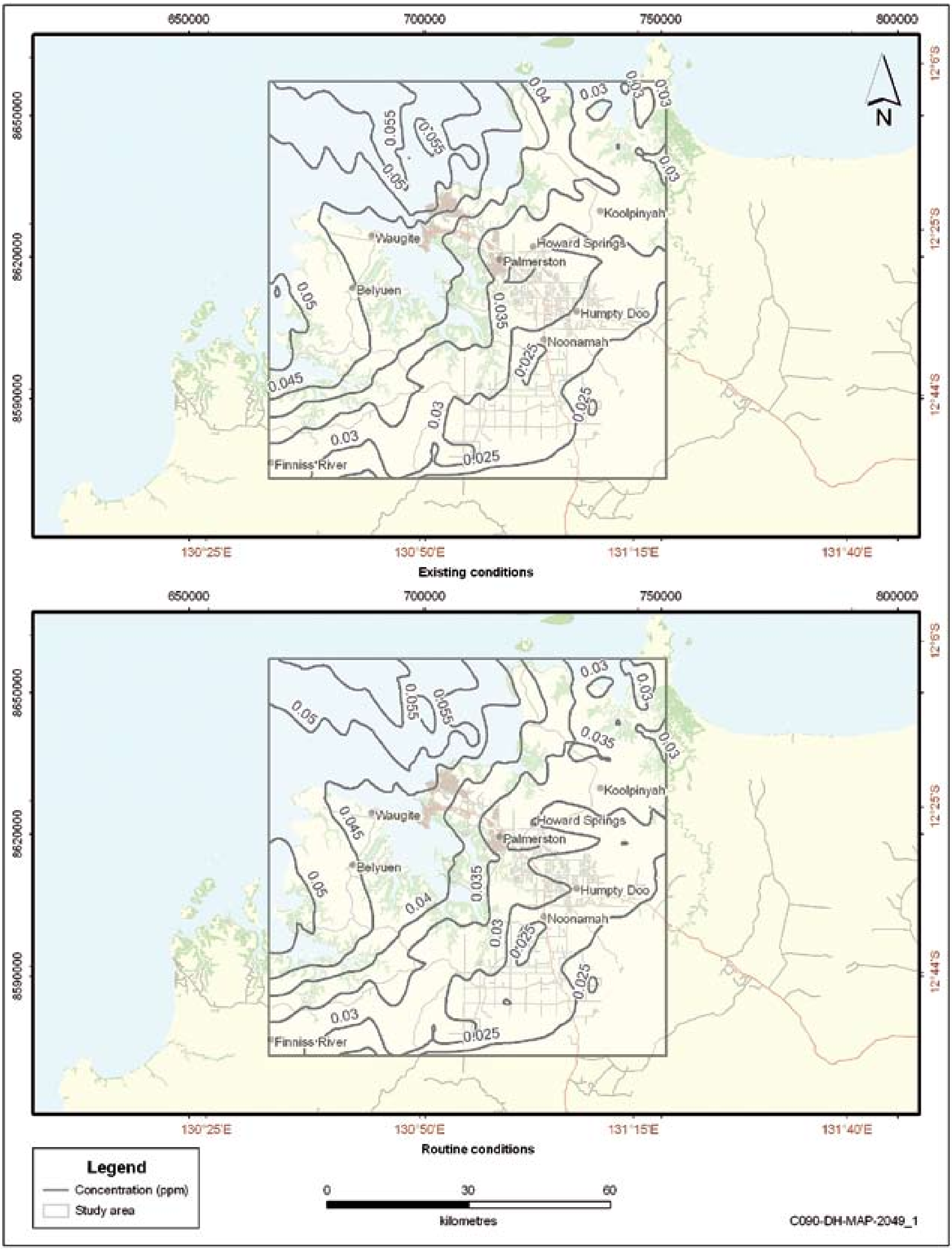


Figure 8-4: Maximum 1-hour ground-level O_3 concentrations (ppm) during existing conditions and during routine Project operations

24 hours) during 2006 and one potential excursion during 2007 (SKM 2009). Combined NRETAS and CSIRO air-quality data sets indicate that there have been four excursions above the NEPM criterion attributable to smoke from bushfires between 2004 and 2008. It is reasonable to assume that occasional PM_{10} excursions will continue to occur in the future.

During the commissioning phase of the Project, extended periods of flaring will be required while the processing equipment, storage tanks and shiploading lines are prepared for LNG production and export activities. This process involves purging with nitrogen and other inert gases and cooling the facilities to –162 °C. Gas produced during this period will be flared off intermittently over a period of several weeks for each of the two LNG trains. This flaring will produce smoke that may be visible from Palmerston and Darwin. As the ambient levels of PM_{10} in the Darwin airshed are normally well below the NEPM criterion limits, exceedances of these limits are not likely to be caused by commissioning smoke at the onshore development area unless commissioning were to coincide with a bushfire event resulting in background PM_{10} levels approaching or exceeding the NEPM limits. INPEX is also investigating ways to design flares with reduced smoke emissions.

Modelling of cumulative emissions for the Project's operations phase (including contributions from other industries, but excluding contributions from bushfire smoke) showed a maximum predicted ground level PM_{10} concentration of 10 µg/m^3 over a 24-hour averaging period, which is 21% of the NEPM criterion. During certain upset conditions, increased rates of flaring may be required and particulates are likely to be produced. Modelling was undertaken for two upset scenarios—"upset conditions (1) (a 15-minute scenario) and "upset conditions (2)" (a 10-hour scenario). "Upset conditions (1)" were predicted to result in higher concentrations of 17 µg/m^3, while "upset conditions (2)" were predicted to cause a reduction in particulate concentrations, down to 6 µg/m^3. These levels are 35% and 12% of the NEPM criterion respectively (SKM 2009). However, should they coincide with a bushfire event which results in background PM_{10} levels approaching or exceeding the NEPM limits, these events could contribute to the occasional excursion above the NEPM PM_{10} criterion for the Darwin airshed.

Odour

Hydrogen sulfide (H_2S) is a sulfurous compound that has the potential to cause odour impacts. To prevent nuisance odour emissions, the WHO air-quality guidelines state that H_2S concentrations should not exceed 7 µg/m^3 for any 30-minute period at any location outside the boundary of an operating plant (WHO 2000).

Hydrogen sulfide will normally be comingled in the AGRU incinerator. In the event that the AGRU incinerator is not functioning, exhaust gases (including H_2S) will be hot-vented through the gas turbine stacks to facilitate gas dispersion, as described in Chapter 5 *Emissions, discharges and wastes*. INPEX has conducted an ALARP ("as low as reasonably practicable") assessment and determined that the likelihood of exceeding the WHO guideline in any one year is six in a million. This is a product of the chance of the incinerator being shut down, combined with the chance of unfavourable meteorological conditions (such as low winds, or temperature inversion layers that prevent emissions from dispersing higher into the atmosphere). As a result, it is considered that nuisance odour emissions attributable to the Project are so unlikely to occur as not to warrant further management controls.

Management of air emissions

A Provisional Air Emissions Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 2. This plan will guide the development of more detailed plans during the construction and operations phases. The plan contains relevant objectives and targets, design initiatives and management controls, as well as details on monitoring and reporting requirements. Some of the key inclusions in the plan are outlined below.

The primary management control for reducing air pollutants is to integrate low-emissions infrastructure into the plant during the initial design phase. Dry low-NO_x gas turbines will be designed to achieve low-NO_x emissions. Other methods of controlling air emissions that have been integrated into the design of the onshore processing plant include the following:

- Residual hydrocarbons and H_2S will be removed from the emission stream by AGRU incinerators.
- In the unlikely event that the AGRU incinerators are shut down, exhaust gases (including H_2S and residual hydrocarbons) will be hot-vented through gas turbine exhaust stacks to facilitate safe dispersion.
- Easily accessible sampling points will be provided on major emission points such as turbines and AGRU exhausts.

In addition, the following emission reduction opportunities will be incorporated into the plant design:

- Boil-off gas from LNG storage tanks and LNG offtake tanker loading operations will be recovered by boil-off gas recompression systems.
- Boil-off gas from the butane and propane storage tanks will be recovered by butane and propane recovery systems. (Boil-off gas from butane and propane tankers will be captured by onboard recovery systems.)
- Ground and tankage flares will be designed to minimise the generation of particulates (smoke).
- The condensate storage tanks will be fitted with floating roofs.
- A commissioning plan will be developed to minimise and manage flaring during the commissioning phase.

The onshore processing plant will be designed to reduce air-pollutant emissions to levels that are as low as reasonably practicable. An air-quality monitoring program will be developed to confirm modelling predictions for ambient air quality in the Darwin airshed.

A number of energy-efficiency and greenhouse gas reduction measures will be applied to the design of the offshore facilities which will also serve to reduce air pollutant emissions in the Ichthys Field. These are described in the Provisional Air Emissions Management Plan and include the following prescriptions:

- Dry gas seals will be used on the main refrigerant compressors.
- Process monitoring systems and alarms will be installed to monitor flaring and process upsets.
- Valves will be installed in the process system to allow for inventory isolation.
- Waste-heat recovery units or heat-recovery steam generators will be installed wherever waste heat can be economically utilised.

Residual risk

A summary of the potential impacts, management controls and residual risk for air emissions is presented in Table 8-13. After the implementation of controls and with consideration of mitigating factors, the risks to air quality are rated as "low". The Project will contribute very minor changes to regional air quality, which is considered well within the required ranges for public and environmental health.

8.5 Waste

8.5.1 Non-hazardous waste

Non-hazardous wastes will be generated at the onshore development area throughout all phases of the Project. Larger volumes of waste will be generated during the construction phase than during operations, because of the higher number of people on site, the generation of offcuts of materials such as timber, cables and steel, and the use of packaging materials like cardboard and plastic. Wastes generated on an ongoing basis are likely to include cardboard and paper, plastic, food scraps, aluminium cans and other domestic waste.

Table 8-13: Summary of impact assessment and residual risk for air emissions

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Air quality	Combustion of fuels (power generation, compression and process heat) during normal operations and upset conditions.	Reduction in local and regional air quality (with respect to NO_x, SO_x, O_3 and PM_{10}). Health impacts on community and local environment.	Design facilities to reduce air emissions to ALARP levels (e.g. low-NO_x technology in gas turbines, incineration of amine plant emissions, low-smoke ground flare). Undertake air-quality monitoring to confirm modelling predictions. Provisional Air Emissions Management Plan.	F (E3)	1	Low
Odour	Venting of AGRU exhaust gases (including H_2S) during AGRU incinerator shutdowns.	Nuisance odour impacts on community.	Redirect AGRU exhaust gases to the gas turbine stacks during AGRU incinerator shutdowns. Rapid dispersion of emissions by most ambient weather conditions. Provisional Air Emissions Management Plan.	F (E3)	1	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

Where these wastes cannot be practicably recycled or reused, they will be disposed of off site at a registered landfill facility. Unless properly managed, the impacts of waste generation and temporary storage on the environment at the onshore development area could include the following:

- unsightly litter
- the attraction of both native animals and pest animals
- harm caused to local animal life
- the generation of offensive odours
- increased fire risk associated with storage of wastes.

Management of non-hazardous waste

A Provisional Waste Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 16. This plan will guide the development of a series of more detailed plans during the construction and operations phases. Key inclusions in this plan are as follows:

- Sufficient space will be provided at the onshore development area to allow for the segregation and storage of wastes.
- During the early part of the construction phase, appropriate temporary containment facilities will be available for storing waste until permanent infrastructure is in place.
- Waste minimisation will be included in the tendering and contracting process.
- Positive efforts will be made to maximise recycling during all phases of the Project.
- Approved and licensed waste contractors will be engaged for waste disposal.
- All solid-waste receptacles (e.g. skips and bins) will have covers and be fit for purpose and in good condition. This will prevent scavenging animals from accessing putrescible wastes.

Residual risk

A summary of the potential impacts, management controls and residual risk for non-hazardous waste is presented in Table 8-14. After the implementation of controls, the impacts from this waste are considered to present a "low" risk and are likely to affect the surrounding environment on only a localised and minor scale.

8.5.2 Hazardous waste

Hazardous wastes are those that pose a threat or risk to public health, safety or the environment. There are a range of hazardous wastes likely to be generated at the onshore development area. These include the following:

- hydrocarbon liquid wastes, including waste oil, grease, lube and engine oils
- molecular sieves and filters
- spent solvents
- mercury filters
- excess or spent chemicals
- contaminated liquids or soils from accidental spills
- spent batteries.

The largest volumes of hazardous waste will be generated during the commissioning phase of the Project and the commencement of operations. Potential impacts to the environment at Blaydin Point

Table 8-14: Summary of impact assessment and residual risk for non-hazardous wastes

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Non-hazardous waste	Generation of waste during construction and operations phases (e.g. domestic waste, packing materials, offcuts).	Littering of environment around Blaydin Point. Attraction of animals. Odours.	Reduce generation of waste through tender conditions and purchasing. Provide adequate space and facilities to segregate and contain waste. Make positive efforts to maximise recycling during all phases of the Project. Cover all bins to exclude animals and prevent windblown waste. Provisional Waste Management Plan.	F (B3)	3	Low

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

from hazardous wastes could be associated with inappropriate handling, storage, transportation and disposal practices. Potential impacts from hazardous waste include the following:

- contamination of soil
- contamination of groundwater or the marine environment
- damage to vegetation
- deaths or injuries caused to native animals.

Management of hazardous waste

The Provisional Waste Management Plan compiled for the Project (see Section 8.5.1 *Non-hazardous waste*) will guide the development of a series of more detailed plans during the construction and operations phases. In addition to the management controls outlined for non-hazardous wastes listed in Section 8.5.1, key inclusions for hazardous wastes are as follows:

- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their disposal.
- All hazardous liquid wastes will be stored over a bund in leakproof sealed containers.

Residual risk

A summary of the potential impacts, management controls and residual risk for hazardous waste is presented in Table 8-15. After the implementation of controls, the impacts from hazardous waste are considered to present a "medium" risk and are likely to affect the surrounding environment on only a localised scale. It is considered that these risks have been reduced to a level that is as low as reasonably practicable.

8.6 Spills and leaks

Hydrocarbons, production chemicals and hazardous wastes will be handled, stored and transported at the onshore development area in all phases of the Project. While measures to prevent the release of these materials into the environment will be in place at all times, there is potential for spills and leaks to occur through accidents and/or failure of equipment.

The potential impact from an accidental spill or leak is dependent on the location of the event and the type and volume of material released. Sealed surfaces and bunding of appropriate areas in the onshore development area, particularly in areas where hydrocarbon spills could occur, are likely to contain minor spills on site without impacts to receptors in the

Table 8-15: Summary of impact assessment and residual risk for hazardous waste

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk		
				C†	L‡	RR§
Hazardous waste	Generation of hazardous waste during construction and commissioning phases.	Localised, low-to-medium-level contamination of soils and surface water from accidental spills.	Minimise waste generation through tender conditions and purchasing. Provide temporary waste-storage facilities during construction, prior to completion of permanent facilities. Make positive efforts to maximise recycling during all phases of the Project. Install appropriate bunding around facilities. Provisional Waste Management Plan.	E (E4)	4	Medium
Hazardous waste	Generation of hazardous waste during operations.	Localised, low-level contamination of soils and surface water from accidental spills.	Minimise waste generation through tender conditions and purchasing. Provide adequate space and facilities to segregate and contain waste. Make positive efforts to maximise recycling during all phases of the Project. Install appropriate bunding around facilities. Provisional Waste Management Plan.	E (E4)	3	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.

† C = consequence.

‡ L = likelihood.

§ RR = risk rating.

surrounding environment. There is a higher risk of loss of containment during the construction phase when ground surfaces may not yet be sealed and temporary bunding may be used to store hazardous substances.

The large volumes of liquid hydrocarbons (condensate) to be stored at the onshore development area during the operations phase presents a risk of loss of containment from the bulk storage tanks and an associated risk of contamination of the groundwater aquifer. Hydrological studies by URS at Blaydin Point (see Appendix 18) suggest that transmissive aquifers below the onshore development area may allow migration of potential contaminants into Darwin Harbour.

Contamination of the groundwater under Blaydin Point could limit any future use of that groundwater resource, both during the operations phase and after decommissioning of the onshore processing plant at the end of the Project. Contamination of soils at the onshore development area could likewise influence options for land use after decommissioning.

Mangroves are known to be particularly susceptible to pollution from hydrocarbon spills and there are well-documented records of mangrove deaths following spills in various parts of the world. Contact with mangrove roots is particularly critical, as coating and trapping of oil among the partially submerged pneumatophores affects normal respiratory and osmoregulatory functions. The impact of hydrocarbon spills on mangroves can be divided into two phases: firstly, the short-term mortality phase caused by coating with fresh condensate and, secondly, the longer-term effects of the weathered hydrocarbons becoming incorporated into sediments, inhibiting the growth of seedlings and larger plants (Volkman et al. 1994).

Management of spills and leaks

A Provisional Onshore Spill Prevention and Response Management Plan has been compiled for the Project and is included in Chapter 11 as Annexe 11. This plan will guide the development of more detailed plans during the construction and operations phases. The plan includes storage and handling procedures to avoid spills and leaks, monitoring and inspections to ensure that containment is maintained, and clean-up and remediation procedures in the event that accidental spills should occur. The following key management controls have been included in this plan:

- Onshore facilities will be designed and constructed in such a way that spills and leaks can be limited or isolated (e.g. through bunding and storage facilities), particularly in areas where there is an elevated risk of spill.
- Material safety data sheets (MSDSs) will be available on site, with information on appropriate spill clean-up and disposal methods.
- Chemicals and hazardous substances used during all phases of the Project will be selected and managed to minimise the potential adverse environmental impact associated with their transport, transfer, storage, use and disposal.
- Spill-response materials and equipment (including personal protective equipment) will be available during all Project phases and will contain equipment to combat both chemical and hydrocarbon spills.
- Personnel who routinely handle hazardous materials or wastes (e.g. refuelling personnel, pump operators, mechanics, and stores personnel) will receive training in handling, transporting and storing hazardous materials or wastes; in reporting and documentation requirements; and in spill clean-up techniques and practices.
- During construction of the onshore facilities, appropriate temporary containment facilities will be utilised for the storage of chemicals, fuel and hazardous waste until permanent infrastructure is in place.
- A groundwater monitoring program will be developed during the operations phase at the onshore development area to allow for regular assessment of groundwater quality and contamination status.
- A marine sediments and bio-indicators monitoring program will be developed to assess any increase in bioavailable heavy metals or petroleum hydrocarbons in intertidal sediments around Blaydin Point which might result from contaminated surface and groundwater flows from the onshore development area.

In addition, the Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan (see Annexe 10 to Chapter 11) includes management controls for surface-water runoff that may be contaminated by hydrocarbon spills during the operations phase. These controls include the following:

- The drainage system will be designed to separate runoff from contaminated areas from runoff from non-contaminated areas. The contaminated wastewater streams will be directed to an oily-water treatment system.
- The oily-water treatment system will be designed to provide a discharge concentration of <10 mg/L petroleum hydrocarbon.

Table 8-16: Summary of impact assessment and residual risk for spills and leaks

Aspect	Activity	Potential impacts	Management controls, mitigating factors	Residual risk*		
				C†	L‡	RR§
Spills and leaks	Storage, handling and transfer of fuels and chemicals during construction.	Localised contamination of soils, surface water or groundwater.	Temporary storage and containment facilities installed while permanent facilities are being constructed. Training provided to personnel who routinely handle hazardous materials (e.g. refuelling personnel, pump operators, mechanics, stores personnel) in handling, transport, storage and clean-up. Provisional Onshore Spill Prevention and Response Management Plan.	E (E4)	4	Medium
Spills and leaks	Loss of containment of production chemicals (e.g. aMDEA#).	Localised contamination of soils and groundwater requiring dedicated clean-up and remediation.	Design of facilities for isolation and containment in high-risk areas. Storage facilities designed in accordance with Australian standards and the requirements of the relevant regulatory authorities. Chemicals selected and managed to minimise the potential environmental impact associated with their transport, transfer, storage, use and disposal. Provisional Onshore Spill Prevention and Response Management Plan.	D (E4)	3	Medium
Spills and leaks	Storage, handling and transfer of fuel and chemicals during operations.	Localised contamination of soils and groundwater requiring dedicated clean-up and remediation. Localised contamination of surface-water runoff. Contamination of groundwater aquifer, with potential flow into Darwin Harbour waters.	Design of facilities for isolation and containment in high-risk areas. Bunding installed in chemical and hydrocarbon storage, handling and transfer areas. Storage facilities designed in accordance with Australian standards, and the requirements of the relevant regulatory authorities. Drainage system will direct potentially contaminated surface runoff to an oily-water treatment system. Onshore Spill Prevention and Response Management Plan. Provisional Liquid Discharges, Surface Water Runoff and Drainage Management Plan.	C (B2)	2	Medium
Spills and leaks	Long-term bulk storage of liquid hydrocarbons (condensate).	Contamination of soils and groundwater that extends off site (e.g. into Darwin Harbour) and is difficult and expensive to remediate. Threats to environmental and human health. Reduction in potential for future use of land and groundwater at Blaydin Point.	Design of facilities for isolation and containment in high risk areas (e.g. condensate tanks). Storage facilities designed in accordance with Australian standards and the requirements of the relevant regulatory authorities. Groundwater monitoring program. Provisional Onshore Spill Prevention and Response Management Plan.	C (E4)	2	Medium

* See Chapter 6 *Risk assessment methodology* for an explanation of the residual risk categories, codes, etc.
† C = consequence.
‡ L = likelihood.
§ RR = risk rating.
# activated methyldiethanolamine.

Residual risk

A summary of the potential impacts, management controls and residual risk for spills and leaks is presented in Table 8-16. After the implementation of controls, the impacts from spills and leaks are considered to present a "medium" risk and are likely to affect the surrounding environment on only a local scale. It is considered that these risks have been reduced to a level that is as low as reasonably practicable.

8.7 Conclusion

8.7.1 Outcome of risk assessment

Activities at the onshore development area that have the potential to impact on the environment include clearing and excavation for site preparation, the construction of the onshore facilities, the generation of emissions during operations (such as air pollutants and noise), and accidental occurrences such as hydrocarbon spills. Baseline surveys and modelling informed an assessment of the potential environmental impacts of these activities.

The risk assessment process, taking into account management controls and mitigating factors, has identified 15 "medium" and 10 "low" residual risk potential terrestrial environmental impacts associated with the onshore development area. These risk ratings are considered acceptably low, mitigating risks to significant or migratory species in the vicinity of the onshore processing plant and minimising pollution and health impacts to the surrounding community.

"Matters of national environmental significance"[3] associated with the onshore development area are threatened and protected animal species, including a number of small mammals, reptiles and terrestrial and migratory birds that could occur in the area. Fauna surveys on site recorded 12 migratory bird species, but no threatened mammals, reptiles or birds. The removal of vegetation for construction of the onshore facilities will reduce the available habitat for these species on a local scale. No threatened ecological communities or Ramsar wetlands[4] occur in, or near, the onshore development area.

The cycad *Cycas armstrongii*, which is listed as "vulnerable" under the *Territory Parks and Wildlife Conservation Act* (NT), occurs in the onshore development area in the eucalypt woodland vegetation community. However, the cycad is locally abundant throughout the Darwin Coastal Bioregion and clearing for the Project does not represent a significant impact to this species on a regional scale.

Important terrestrial habitats that will be affected by vegetation-clearing in the onshore development area include monsoon vine forest and mangroves, which support some specialist species (e.g. bird species that feed on particular fruits or flowers). These vegetation communities occur in other areas around the shores of Darwin Harbour and throughout the Darwin Coastal Bioregion. Mangroves are generally protected from clearing through current planning laws in the Northern Territory, and clearing for the Project represents less than 0.3% of the total area of mangroves in Darwin Harbour. Monsoon vine forest occurs in relatively isolated patches and removing individual patches may have ecological consequences for the remaining patches. At present, there are numerous areas of monsoon vine forest located around the broader Darwin Harbour region and clearing for the Project represents 4% of the total existing area. In addition, existing plantings of tropical fruit-bearing trees in the Darwin suburbs and surrounding rural areas effectively supplement the native monsoon vine forest habitat for some frugivorous animal species.

Terrestrial impacts such as soil erosion and exposure of acid sulfate soils will be minimised by management controls. These impacts will only be associated with construction activities and are likely to be short-term and localised. The onshore development area will be designed to minimise disruptions to natural surface-water flows.

The predictive air-quality model developed for the Project represents a cumulative assessment of impacts to the Darwin airshed. It incorporates the emissions from existing sources (both natural and anthropogenic) and then adds in the predicted emissions from the proposed onshore development area. The model shows that after the addition of the emissions from the INPEX facilities, ground-level air quality in the Darwin region will remain well within NEPM criteria at all times for NO_2, photochemical oxidants (as O_3) and SO_2. Based on measurements conducted by NRETAS, there are likely to be very occasional events, particularly during the dry season, where bushfires will contribute particulate material into the Darwin airshed to the extent that the NEPM criterion for PM_{10} will be approached or exceeded.

3 "Matters of national environmental significance" are defined in the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

4 A Ramsar wetland is a site designated for inclusion on the Ramsar List of Wetlands of International Importance. The Ramsar Convention (the "Convention on Wetlands of International Importance, especially as Waterfowl Habitat") was signed in Ramsar in Iran in 1971 and came into force in 1975. Australia signed the convention in 1971.

Under such conditions and depending on prevailing wind directions, the INPEX facilities may be a minor contributor to a potential excursion of the NEPM particulate matter criterion. However, in the absence of bushfires, the NEPM air-quality criterion for particulates (PM_{10}) will also be met comfortably at all times after the addition of the INPEX facilities.

It is considered that the level of management and risk reduction presented for the onshore development area represents a proactive and conservative approach to maintaining environmental values, while allowing progress for the Project in an economically sustainable fashion. The management controls to be implemented will be further developed in consultation with stakeholders and will continue to be updated throughout the various stages of the Project.

8.7.2 Environmental management plans

As described throughout this chapter, a suite of provisional management plans has been developed to outline the proposed management controls that reduce the potential for terrestrial environmental impacts. These provisional plans will guide the development of more detailed plans as the Project progresses. The 16 plans contain the objectives, targets, detailed actions and monitoring to be carried out to manage a comprehensive spectrum of environmental aspects. They are listed in Table 11-4 of Chapter 11.

INPEX's Health, Safety and Environmental Management Process is described in Chapter 11, and the provisional management plans that have been developed for the Project are attached as annexes to Chapter 11.

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