18. ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: UPSTREAM FACILITIES AND ONSHORE PIPELINES

This chapter identifies and assesses the direct and indirect physical and biological impacts associated with the construction and operation of the upstream facilities and onshore pipelines component of the PNG LNG Project. Measures have been identified to mitigate and manage impacts, and the residual impact assessment assumes that these measures will have been applied.

The chapter begins with definitions and the general approach used for the impact assessment (Section 18.1), and then addresses the resources or receptors that may be subject to impacts: landform and soils (Section 18.2), groundwater (Section 18.3), water resources and hydrology (Section 18.4), water quality (Section 18.5), aquatic ecology (Section 18.6), terrestrial biodiversity (Section 18.7), air quality (Section 18.8) and noise (Section 18.9).

18.1 General Approach

18.1.1 Impact Significance

Environmental impact significance can be expressed in a matrix of the value (or sensitivity) of a receptor and the magnitude of the impact. The method brings structure to complex interactions and takes a range of factors into account, including extent, duration and severity of impact, and whether it is a positive or negative, direct or indirect impact.

Professional judgement and experience, data, models and analogues all contribute to the assessment, which ranges from technical analysis using quantitative criteria (such as quality standards for water or air) to more subjective measures, such as loss of visual amenity. Most impact assessments have to combine both technical and subjective analysis, in order to represent the more value-based issues, on which differences of opinion about significance are inevitable. Examples include the conservation of coral reefs or erosion of cultural values and traditions.

The method, therefore, is not necessarily empirical nor objective. However, the matrix inputs are derived from explicit criteria, and so the basis for each assessment should also be explicit and accessible to scrutiny. In particular, the value judgments inevitably embedded in the results of the matrix should be evident and accessible to re-interpretation.

Only potential impacts that are viewed as being credible outcomes of the project have been considered. As such an analysis of the degree of impact risk has not been included in this assessment *per se*, as any impact included in the impact significance assessment can be implicitly regarded as a credible potential impact.

18.1.2 Types of Impacts

18.1.2.1 Direct and Indirect Impacts

Direct impacts are generally those impacts occurring either within the project footprint (such as clearing) or as a direct consequence of a project activity (such as a waste discharge).

Indirect impacts are those arising from project facilities or activities, but with a degree of separation in time or space (for example the spread of weeds). They are, by their nature, hard to predict except in broad terms.

18.1.2.2 Cumulative and Associated Impacts

A step further removed, are impacts arising from actions of third parties, which the presence of the project may enable or assist. Chapter 24, Cumulative and Associated Impacts, characterises these impacts as scenarios based on speculative assumptions about the influence that the project may have on what other people may or may not do.

18.1.3 Matrix Components

The significance of the potential impacts associated with the construction and operation of the upstream facilities and onshore pipelines of the PNG LNG Project have been derived from the analysis of:

- The amount and type of change, including the timing, scale, size and duration and likelihood of the impact (magnitude).
- The sensitivity of the environment to change, including its capacity to accommodate the kinds of changes the project may bring about (sensitivity of resource/receptor).

18.1.3.1 Impact Magnitude

The magnitude of an impact reflects:

- The intensity or severity of the impact.
- How long the impact will last.
- Over what spatial extent the impact will be felt.

18.1.3.2 Sensitivity of the Affected Receptor

The sensitivity of the environmental receptor will reflect:

- Its formal status, whether by statutory or attributed conservation status, land use zoning or environmental quality standard.
- Its vulnerability to material damage or loss by the impact in question.
- Its iconic or symbolic importance to cultural value systems.

18.1.3.3 Criteria

Each of the main impact subsections (i.e., Sections 18.2, Landform and Soils, to 18.9, Noise) contains a list of the explicit impact magnitude and resource/receptor sensitivity criteria, which are applicable to the impact in question[1]. The impact magnitude and resource/receptor sensitivity are then ranked from very high to minimal and thereby provide the two axes of the impact significance matrix. The impact magnitude also contains a 'positive' ranking to account for impacts that are likely to benefit the population, community or ecosystem.

18.1.4 Impact Significance Matrix

The matrix in Table 18.1 assigns significance to each combination of the impact magnitude and receptor sensitivity rankings. It assumes that the stated mitigation and management measures will have been implemented.

Table 18.1 Matrix of significance

	Sensitivity of Resource/Receptor				
Magnitude of Impact	**Very High**	**High**	**Medium**	**Low**	**Minimal**
Very High	Major	Major	Major	Moderate	Minimal
High	Major	Moderate	Moderate	Minor	Minimal
Medium	Moderate	Moderate	Minor	Minor	Minimal
Low	Moderate	Minor	Minor	Minor	Minimal
Minimal	Minimal	Minimal	Minimal	Minimal	Minimal
Positive	Positive	Positive	Positive	Positive	Positive

Note that only the magnitude of an impact can be reduced, as necessary, by application of engineering or other mitigating solutions: the sensitivity, as assessed, is fixed and is not changed by project activities. The resultant significance therefore reflects the reduction in magnitude that can be achieved by the proposed mitigation.

18.2 Landform and Soils

This section addresses the principal issues (Section 18.2.1), proposed mitigation and management measures (Section 18.2.2), regeneration potential context (Section 18.2.3), and then discusses the residual environmental impacts of project construction and operations activities (Section 18.2.4) relating to landforms and the soils that help determine landform characteristics.

[1] Generalised assessment criteria work well for the LNG Facilities site, offshore and cultural heritage impacts (see Chapter 19, Environmental Impacts and Mitigation Measures: Offshore Pipeline, Chapter 20, Environmental Impacts and Mitigation Measures: LNG Facilities, Chapter 21, Environmental Impacts and Mitigation Measures: Marine Facilities, and Chapter 22, Project-wide Cultural Heritage Impacts and Mitigation Measures) but do not suit the natural diversity of the upstream project area and the different types of impacts being assessed.

Various references to rehabilitation, revegetation and regeneration are made, and are clarified as follows (see also Chapter 31, Glossary):

- Revegetation: the re-establishment and development of a plant cover by either natural or artificial means. Natural revegetation (also called passive revegetation) takes place without intervention and active revegetation takes place with intervention using artificial means, such as ground preparation, fertilisation, seeding or seedling planting.
- Rehabilitation: the measures to stabilise disturbed land, such as recontouring, drainage and topsoil storage and respreading.
- Regeneration: the sustainable natural process by which plants either replace themselves or give way to other species in the process of succession.

The sensitivity of landforms *per se* to disturbance is largely aesthetic and so this chapter makes a qualitative assessment of landform impacts based on susceptibilities of areas concerned and magnitude and duration of the works. The residual impact assessment criteria for soils and landforms are set out in Section 18.2.4, Residual Impact Assessment, in accordance with the method described in Section 18.1, General Approach.

The earthworks, which change landforms, have consequences for other aspects of the environment, notably terrestrial habitat (see Section 18.7, Biodiversity) and downriver water quality and ecosystems (see Sections 18.4, Water Resources and Hydrology, 18.5, Water Quality, and 18.6, Aquatic Ecology).

18.2.1 Issues to be Addressed

18.2.1.1 Construction

Clearing and earthworks expose soils and change landforms and drainage. The direct effects at a given construction site depend on the pre-existing terrain. They will be localised in flat country, but a pipeline ROW or access track formation in cut in steep terrain where spoil is sidecast can extend the area of soil disturbance beyond the active works area by several fold (see Section 3.4.1.2, Right of Way Construction Disturbance Area).

The specific impact issues include:

- Temporary clearance of woody vegetation leaving a relatively intact ground cover.
- Clearance of all vegetation cover, exposing soils.
- Removal of topsoil, exposing bedrock which will then be susceptible to erosion.
- Removal of vegetation and topsoil in steep terrain with sidecasting.
- Compaction of the soil surface.
- Revegetation of completed works areas, including sidecast materials, which consolidates and stabilises soils and landforms and contains surface erosion.

There is also an increased risk of soil contamination from fuels, oils and chemicals that are transported, stored and handled during construction.

The direct impacts of earthworks are conspicuous and especially so in steep terrain for the slope failures, erosion and sedimentation that can follow. However, these specific impacts tend to be transitory in warm, well-watered environments, as time passes and disturbed areas consolidate, revegetate and stabilise. This sequence of disturbance and recovery to some extent mimics natural geomorphological processes, for example:

- Landslides are a feature of the steeper parts of the upstream project area.
- Landslides, in turn, create a source of unconsolidated material in most catchments, with erosion and fluvial sediment transported in overland flow during rainstorms, and sediment delivery to watercourses and sediment deposition as flow rates fall.
- The terrestrial flora and vegetation will typically take advantage of these disturbances to recolonise in a mosaic similar to what occurs naturally.
- Downstream, the aquatic biota are similarly adapted to short but intense exposures to fugitive sediment.

Exceptions to these patterns can arise: if the disturbed areas do not stabilise, but remain as an active zone of instability and a source of erosion and fugitive sediment; if weeds, especially grasses that can carry fire, become established; if the exposed substrate is rocky or infertile; and if the zone of disturbance is so large as to change the post-disturbance vegetation.

As far as direct impacts are concerned, the single most important mitigation measure is the same as the project’s overall engineering objective – that is, limiting bulk earthworks. If this is backed up by remedial stabilisation and revegetation of areas not recovering naturally, then the effects of the direct impacts can be contained.

Less conspicuous but of far greater ecological risk and environmental management priority, however, are the indirect impacts. These relate less to the soil disturbance itself and more to the fact that, if quarantine, weed and pathogen hygiene, fire management and ground stabilisation are inadequate, then the initial disturbance creates vectors for wildfire, weeds and pathogens. In this respect, indirect impacts can be insidious and take effect long after the direct impacts have apparently passed.

The following areas along the project route are most sensitive to these issues and will be the subject of engineering and route planning optimisation during detailed design, as well as preconstruction surveys prior to final route determination, to limit earthworks and associated impacts on landform and soils in the project footprint.

- Hides Ridge area.
- Juha to Hides area.
- Homa deviation.
- Swamps and wetlands of the Kikori River delta.

18.2.1.2 Operations

During operations, construction-disturbed soils and sidecast materials are expected to continue to stabilise progressively as vegetation is re-established naturally or by active intervention.

The main issues relating to soils during operations are anticipated to be limited to the mass movement of construction-generated sidecast material by earthquakes. Impacts to soils during operations could also occur as a result of small leaks or spills of liquid hydrocarbons, fuels, lubricants, and chemicals, as well as releases caused by (highly unlikely) accidents (e.g., liquid hydrocarbons pipeline rupture, fuel tank failure, fuel tanker rollover).

18.2.2 Mitigation and Management Measures

Civil works can generally be accomplished more quickly, safely and at less cost by limiting landform changes, and so it has been a project planning objective to locate pipeline routes as close to existing or previously used roads as practical (see Section 3.3.1, Pipeline Routing Standards). Where works need to break new ground, the normal engineering, planning and design preferences will have the effect of reducing land disturbance to a minimum. For example:

- Routing pipelines and access ways along ridgelines rather than side slopes.
- Avoiding steep slopes, swamps and wetlands.
- Avoiding erosion- or landslide-prone areas.

Specific measures are set out below in Sections 18.2.2.1, Construction, and 18.2.2.2, Operations.

18.2.2.1 Construction

Mitigations to limit landform changes and soil erosion and loss is inherent in many of the pipelines, roadworks and facilities design features, which are summarised below:

Pipeline ROW/Access Way Route Selection and Alignment

- ROWs and access ways will be located within or adjacent to existing disturbed areas where practicable [M65].
- Fine-scale routing of the pipeline ROWs and access ways will be conducted to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable [M141].
- Fine-scale routing will be implemented during FEED and detailed design to mitigate impacts from sidecasting in steep terrain areas and to reduce traversing areas prone to mass failure [M156] by:
  - Examining the separation of the pipeline ROWs and roadways or access tracks to reduce sidecasting where practicable.
  - Using fine particle size organic matting or lattice framework or similar in karst areas to trap organic matter across sidecast where safe and practicable.
  - Implementing sediment control measures downstream of sidecast material where safe and practicable.
- Terrain evaluation and mapping will be undertaken to identify past instabilities [M157].
- Develop a management plant to reduce impacts on pandanus swamp forest. Design ROW and roadways to allow adequate surface and subsurface flows and avoid redirection of stream flows where practicable [M115].

Watercourse Crossings

- Where practicable, the pipeline ROWs and access ways alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses [M140].
- Clearing of riparian vegetation will be limited to the width required to safely accommodate pipeline ROWs and access way and watercourse crossings. Also, the number of watercourse crossings will be reduced, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses [M64].
- River/stream crossings will be limited in areas of high, unstable banks [M158].
- Watercourse crossing construction management plans will be incorporated into the water management plan to address the sensitivities of crossings on an individual watercourse basis [M160]. Plans will consider, where relevant:
  - Watercourse diversions requirements.
  - Disturbance limits.
  - Equipment limitations.
  - Erosion control measures.
  - Fine-scale routing at crossing sites to limit disturbance of particularly large and established riparian vegetation and complex bank habitat structure.
  - Delay of clearing of banks for temporary vehicle crossing until the need for the crossing is imminent, where practicable.

Facility and Pipeline ROW/Access Way Construction Sites

- The number of special vehicle parks will be reduced, and placed in areas of existing disturbance, where practicable [M112].
- Where practicable, land clearing will utilise techniques that preserve the rootstock of removed vegetation in the ground. Cleared vegetation will be spread back on to the rehabilitated ROW and access ways as mulch, where practicable [M74].
- The extent of clearing and earthworks along the pipeline ROWs and access ways will be limited and the time for which surfaces are exposed prior to natural revegetation will be reduced to the extent practicable [M75].
- No machinery will be permitted to leave the pipeline ROWs or access ways to unnecessarily clear additional forest [M87].

Wellpads and Quarries

- Wellpads will be designed and located to reduce the extent of vegetation clearing and earthworks by limiting to the extent practicable, the size of the wellpads [M66].
- The number of quarries developed will be minimised by using previously worked (old) quarries, where practicable [M68].

- Design criteria for pipeline ROW width on Hides Ridge, which includes the access road, is 18 m. During operations the ROW will be allowed to regenerate except for a 10-m-wide access track required for ongoing drilling and maintenance access to the wellpads on the ridge [M77].
- Road base and foundation aggregate material sourced from in-country quarries not developed by the project will be in accordance with the requirements of Land and Community Affairs guidelines and procedures, which provides controls for the amount of gravel extracted from quarries [M69].

For Hides Ridge, additional information on how these mitigation measures has been optimised to reduce landform and soil impacts from sidecast is described in ‘Spineline Route and Crossings’ in Section 2.2.3.3, Gathering Systems and Section 7.10.1.3, ROW Formation Earthworks on Hides Ridge.

Soil Contamination Mitigation

A soil contamination management plan [M130] will be developed as part of the construction environment management plan that will include appropriate procedures for:

- Fuel handling transport and storage procedures.
- Materials handling, storage and disposal.
- Storage and handling of radioactive material.
- Handling of contaminated waste.
- Soil remediation where contamination has occurred.

Diesel storage tanks will be purpose-built, above ground and within double-walled tanks or containment bunds. Oil spill prevention and response measures will be in place in accordance with the project’s spill response plan [M130].

General Erosion and Sediment Control

An erosion and sediment control management plan [M155] will be included as part of the project’s overall water management plan for all construction-related activities to:

- Implement industry good practice erosion and sediment control measures at watercourse crossings, as necessary.
- Reduce stockpiling spoil and soil materials close to waterways (i.e., maintaining a minimum of 10 m from the waterline), where practicable.
- Control of sediment runoff from stockpiles and cleared areas around watercourses.
- Implementation of sediment control measures downstream of sidecast material where safe and practicable.
- Limiting erosion and sediment delivery to streams from new quarries.
- Reducing sidecasting of spoil directly into waterways where practicable.
- Grading pipeline ROWs and access way alignments adjacent to streams away from watercourses.
- Monitoring and maintaining erosion and sediment control measures until adequate soil stabilisation has been achieved.

- Installing diversion drains to intercept uncontaminated surface runoff around facilities and away from construction areas.
- Installing sediment control structures to intercept sediment-laden surface runoff to reduce sediment delivery to watercourses.
- Monitoring for and rectifying areas of problematic erosion at reclaimed watercourse crossings.

Revegetation

- Developing revegetation management procedures that will be detailed in the reclamation plan [M119] and which will include measures to assist revegetation in areas found to be slow to revegetate naturally.
- Identifying areas requiring active regeneration as part of preconstruction surveys [M120] (see Section2.4, Common Construction Activities):
  - On Hides Ridge.
  - In areas between Idauwi and Homa, in particular unstable volcanic terrains.
- Where practicable, soil, mulch and discarded vegetation debris will be spread on reclaimed or rehabilitated disturbed land surfaces to facilitate natural revegetation [M121].
- Where practicable, topsoil will be conserved in designated topsoil stockpile areas at facility construction sites for later reuse [M122].
- Topsoil will be salvaged for rehabilitation of slopes, where practicable [M123].
- Where practicable, trees felled into watercourses will be removed and used for revegetation works [M138].
- Stockpiling spoil and topsoil materials close to waterways will be reduced (i.e., maintaining a minimum of 10 m from the waterline), where practicable [M155].

Following the completion of the pipeline ROWs and access ways construction activities, most areas of disturbed and displaced soils are expected to stabilise through natural revegetation, which generally occurs rapidly in the upstream project area. The re-establishment of vegetation will reduce the rate of soil loss. A discussion on the regeneration potential of the area is provided in Section 18.2.3, Regeneration Potential Context.

18.2.2.2 Operations

There will be no landform impacts associated with the operations of the project. Operations mitigation and management measures in relation to soils will focus on the potential for soil contamination through minor operational spillages of fuels, oils and chemicals.

However, one specific mitigation measure is to conduct post-construction inspections along the upgraded ROW and access way within the catchment of Lake Kutubu [M152], including:

- Checking for problematic erosion areas and implementing remedial works as appropriate.
- Inspecting ditches and culverts and removing accumulated debris, where required.
- Reviewing feedback from water quality monitoring for advance warning of deteriorated water quality due to increased suspended sediment loading.

Potential soil contamination by larger accidental spillages of fuels, oils and chemicals through traffic accidents or a rupture of the Juha–Hides Liquids Pipeline between the Hides Production Facility and the Kutubu Central Gas Conditioning Plant would be managed in accordance with the project's spill response plan [M130], which will be developed prior to commencement of operations.

18.2.3 Regeneration Potential Context

18.2.3.1 Observed Regeneration Potential

This section presents a summary of the successes and failures of natural regeneration of sites disturbed by previous petroleum developments within the upstream project area.

Gillison (1990) and Hartley (1991) examined vegetation regrowth on a range of the Kutubu petroleum development sites, such as wellpads, helipads and access tracks to drill sites. The conclusions of these studies were that regeneration was vigorous. Many pioneer and forest tree species developed rapidly (within three years) on areas of disturbed soils, limestone scree mixed with soils, and sidecast spoil; but revegetation was poor to non-existent on areas of hard limestone pavement or compacted limestone.

The findings of Hartley (1991) are presented in Tables 18.2 and 18.3, which summarise the status of regeneration observed on soil-dominated and limestone-dominated surfaces, respectively. The dependence of regeneration on substrate penetrability is evident.

Example photographs of regeneration are presented in Plates 18.1 to 18.7. Plate 18.1 presents a series of photographs taken between 1991 and 2005 where the existing Kutubu crude oil export pipeline ROW or access way descends the Iwa Range down to the Ai'io River valley. This section required a long bench cut established by spoil sidecasting. By 1996, pioneer and primary forest trees up to 8 m high had naturally established themselves on the sidecast material downslope of the bench, with forest regrowth being well established after 14 years (May 2005). Plates 18.2 to 18.5 show similar regrowth sequences at other locations along the crude oil export pipeline ROW.

In general, natural revegetation on limestone-dominated surfaces, including limestone rubble, has been found to be slow and less successful. Disturbed areas of this type had little or no vegetation on them or were revegetating very slowly in comparison with soil-dominated surfaces. Plate 18.6 and Table 18.3 show poor natural revegetation on hard limestone pavement after about 10 years following excavation. Similarly Plate 18.7 shows poor natural revegetation on limestone rubble along the existing road to the Moran oil field.

Table 18.2 Observed regeneration on soil-dominated disturbed surfaces

Site Type	Regeneration Observed
Disturbed forest floor	*After 4 months:* complete ground cover of grass with some fern and sedge. Vigorous growth of liane *Merremia* present. At least five genera of trees coppicing or growing from seed to a height of 1.5 m. *After 18 months:* at least 14 genera of regrowth forest trees, including climax forest components as seedlings and some coppice present, the tallest to between 6 and 8 m. Vigorous liane growth. Complete ground cover. *After 24 months:* at least 18 genera of forest trees including seedlings represented, with a general height of 5 to 6 m; palms, lianes and wild banana common. Complete ground cover.
Mounded trench fill	*After 4 months:* complete ground cover of grass and fern, mainly *Paspalum conjugatum* and *Dicranopteris*. At least five genera of trees growing from seed, regularly controlled by slashing. *After 24 months:* at least 18 genera of forest trees coppicing and growing from seed. Complete ground cover.
Limestone scree mixed with soil	*After 1 month:* regrowth commencing from coppicing on the very recently cleared but not heavily vegetated side slopes. *After 12 months:* mixed vegetation comprising 5 genera of fern, 3 genera of grasses and at least 10 genera of trees established on slopes where there is old soil surface accessible under sidecast. Seedling height of 1 to 1.5 m. *After 18 months:* regrowth trees are 3 to 5 m tall, and there is complete ground protection. The lower ground surface is shaded, with incomplete cover. *After 21 months:* at least nine genera of regrowth trees around 2 to 3 m tall on the slightly thicker limestone scree. *After 24 months:* at least 12 genera of regrowth forest trees present as seedlings and coppice up to 5 m tall. Clumps of tall *Saccharum* grass, fern and tree ferns present. *After 30 months (2.5 years):* under thin limestone scree, regrowth is 6 to 10 m tall with at least 10 genera of forest regrowth trees, together with wild banana and leafy substrata. *After 42 months (3.5 years):* at least 12 genera of regrowth trees, including seedlings from 1 to 8 m tall. Wild banana, tall *Saccharum* clumps and lianes are prominent. Complete ground cover with a fern understorey. *After 90 months (7.5 years):* complete cover of trees 6 to 10 m tall with an understorey of fern, *Saccharum* and lianes.
Loose soil sidecast	*After 4 months:* complete ground cover of grass *Imperata* with some fern and sedge. Invading lianes present on the margins. *After 18 months:* at least 14 genera of regrowth forest trees, including climax forest components as seedlings and some coppice present, the tallest to between 6 and 8 m. Vigorous liane growth. Complete ground cover. *After 24 months:* at least 18 genera of forest trees, including seedlings represented, with a general height of 5 to 6 m; palms, lianes and wild banana common. Complete ground cover.
Exposed earth cut in forest or grassland	*After 18 months:* at least 14 genera of regrowth forest trees, including climax forest components as seedlings and some coppice present, the tallest to between 6 and 8 m. Vigorous liane growth. Complete ground cover. *After 24 months:* at least 18 genera of forest trees, including seedlings represented, with a general height of 5 to 6 m; palms, lianes and wild banana common. Complete ground cover.

Source: Hartley (1991).

Table 18.3 Observed regeneration on limestone-dominated disturbed surfaces

Site Type	Regeneration Observed
Compacted fine limestone road and hardstand	*After 6 months:* generally no vegetation over most upper surfaces. Mixed weed flora, notably around the edges, with very small sedges in shallow depressions. *After 12 months:* mainly bare surface apart from very few individual stands of *Eleusine* grass and small sedges. Also *Bidens* and *Paspalum*. *After 18 months:* approximately 50% ground cover of sparse, patchy sedge with other individual clumps of thin-stemmed *Saccharum* to 400 mm tall. *After 90 months (7.5 years):* a moss cover with weathered surface between limestone fragments of clay mixed with gravels. *Saccharum* 1 to 3 m tall with an understorey of ferns, lianes and occasional *Spathoglottis*. Very few seedling trees, mostly *Ficus*.
Semi-compacted coarse limestone hardstand	*After 9 months:* 10% ground cover with *Alsomitra* vine, *Asteraceae* weeds and minor grass. *After 12 months:* 20% ground cover of weeds with emerging tree seedlings. *After 18 months:* up to 30% ground cover of ferns, weeds, individual tree seedlings and vine. *After 36 months (3 years):* incomplete cover of fern with up to six species of sapling tree from 100 mm to 1.5 m tall, including *Ficus* and *Spondias*.
Thick limestone sidecast obscuring all former surface	*After 12 months:* very little growth except for surface moss and lichen in wet areas. Scattered *Miscanthus* in clumps at lower locations and very low weed in patches: *Ageratum*, *Eleusine*, *Bidens* and *Echinochloa* or low *Ageratum* and fern with very patchy *Saccharum*. *After 18 months:* sparse fern growth. On stable areas, scattered clumps of *Saccharum* and individual seedling trees of *Ficus*, *Trema* and *Alstonia* from 30 mm to 1 m tall. *After 21 months:* incomplete cover, predominantly fern with patchy, thin-stemmed *Saccharum* and tussocks of *Pennisetum*. Vines migrating from shallow limestone scree over old groundcover include *Merremia*, *Alsomitra*, *Dioscorea* and *Piper*. *After 24 months:* on thick limestone scree, 50% surface cover of fern with *Bidens*, patchy, thin-stemmed *Saccharum*, *Pennisetum* and scattered individual trees. *After 42 months (3.5 years):* about 50% ground cover of fern with few individual tree seedlings from 100 mm to 1.5 m tall.
Exposed limestone face	Limestone faces are slow to regenerate, apart from seams and faults where there is soil or weathered material. At these locations, moss, lichens and ferns are the early colonising plants, and ferns particularly spread across the nearby surface. The face develops a cover of moss and lichen that fluctuates in its intensity and maturity depending upon weather conditions. A relatively short dry period can cause attrition of the delicate vegetation, although the cumulative accretion of organic matter favours subsequent growth. Lianes may grow down from upper levels where there is soil cover at the top of the face, providing cover for less robust colonisers.

Source: Hartley (1991).

Plate 18.1
Regeneration of Kutubu to Kopi access way with cut and fill on ridge descending into Ai'io River

Plate 18.2
Regeneration of the crude oil export pipeline ROW 8 km east of Kutubu

Plate 18.3
Regeneration around Ai'io valve station

Plate 18.4
Regeneration of the crude oil export pipeline ROW approaching Mubi valve station

Plate 18.5
Regeneration on limestone rubble at major ROW excavation in Mubi River karst terrain

Plate 18.6
Example of poor regeneration on limestone pavement

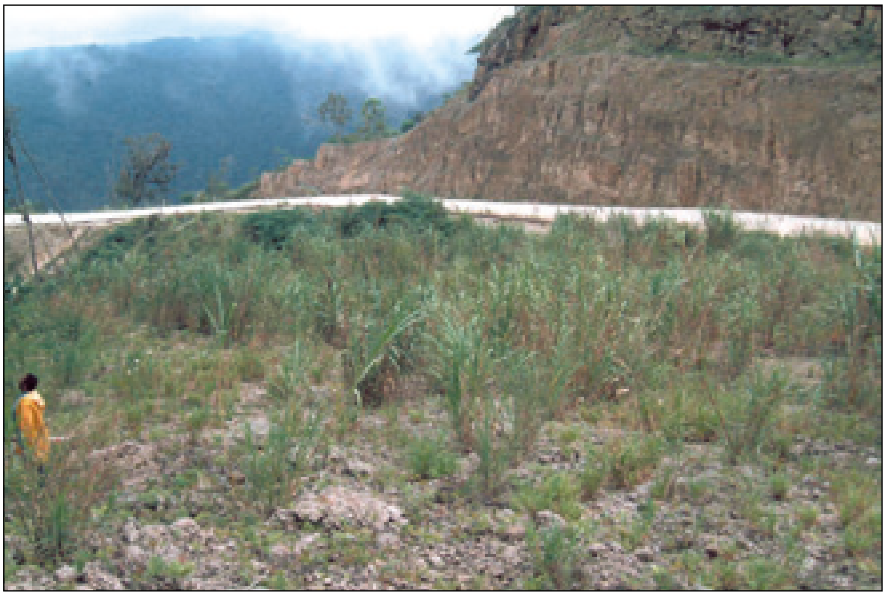


Plate 18.7
Example of poor regeneration on limestone rubble (Moran Road, May 2005)

18.2.3.2 Predicted Regeneration Potential

Appendix 8, Soils and Rehabilitation Impact Assessment, presents a soil impact assessment and rehabilitation study for the proposed pipeline ROW between Juha and Hides. A summary of the key findings relating to regeneration potential are provided in this section.

The Juha–Hides pipeline ROW will traverse a diverse and rugged landscape. Considering the Hides Ridge also, the forest types encompass lowland hill forest (lowland forest on uplands) to the montane *Nothofagus pullei*-dominated forest on Hides Ridge at approximately 2,500 m ASL. Such a large variation is related to the differences in landforms, soils and changes in the climate associated with differing altitudes.

Where temporary clearance occurs, sites are likely to recover by natural regeneration, provided soil is not exposed for a lengthy period of time. The level of rehabilitation needed will vary, depending on the level of impact. Salvaging topsoil and cleared vegetation to spread over exposed areas will be important considerations to promote lasting revegetation. Sidecast areas will present the greatest difficulties for effective rehabilitation.

The potential impacts of construction will depend on a range of factors, including the type, frequency and intensity of disturbance; the properties of the soils impacted (e.g., stability and susceptibility to mass movement); the vegetation type and its ability to naturally regenerate once disturbed; the landscape position; and the rainfall pattern. For example, steep slopes will be prone to gully erosion and mass movement if disturbed, particularly if located in an area of volcanic soils that receives runoff from upper slopes. In contrast, karst plains may be less affected by impacts and are unlikely to be subject to high rates of sheet or gully erosion. Erosion results in the loss of the fertile topsoil and removes the soil seed bank, leaving the unproductive subsoil exposed.

The characteristic types of impacts and the associated regeneration potential are summarised in Table 18.4.

Table 18.4 Types of impacts and associated regeneration potential

Characteristic Type of Impact	Predicted Regeneration Potential
Temporary clearance of woody vegetation, leaving a relatively intact ground cover	Vegetation is expected to rapidly regenerate, particularly in the lowlands. The rate of recovery will be highest in the lowland zone and lowest in the montane zone where growth rates are reduced because of the cooler climate.
Clearance of all vegetation cover, exposing topsoil	Sites will potentially be exposed to erosive rainfall, particularly on sloping sites and in the lowlands where rainfall is highest. Exposed topsoil on sloping sites of volcanic landforms may be rapidly eroded, leaving clay-rich, infertile subsoil. On steeper slopes, erosion gullies may develop (with slips possible), providing an unstable surface for rehabilitation. The subsoil remaining will provide a poor medium for natural regeneration, particularly of native forest species. Typically, grasses will dominate, which may then become permanent grasslands. The area will not revert to forest without active revegetation.

Table 18.4 Types of impacts and associated regeneration potential (cont'd)

Characteristic Type of Impact	Predicted Regeneration Potential
Complete removal of vegetation and topsoil, exposing bedrock	In the lowland zone, these areas have been shown to regenerate effectively on flat or gently sloping karst, provided limestone scree is mixed with topsoil and spread over the bedrock. Regeneration appears to be enhanced where accumulation and decomposition of leaf litter from adjacent forests occur. Where limestone pavement is exposed, the relatively smooth surface may prevent plants establishing; and these areas are likely to remain largely vegetation free for decades without active revegetation.
Complete removal of vegetation and topsoil in steep terrain with extensive sidecasting	For karst terrain in the montane zone, sidecast will not rehabilitate for a long time without active revegetation measures, particularly where little or no topsoil remains. This is also likely to be true for the lowland zone. Where sidecast aggregate comprises larger boulders, sparse regeneration may occur. Although rehabilitation is likely to be unsatisfactory, the slopes may be relatively stable and not prone to slips. Sidecast in volcanic terrain is likely to be subject to erosion, and such areas may flow into adjacent forest, resulting in dieback.
Excessive compaction of the soil surface	A compacted rooting environment will inhibit natural regeneration and growth, slowing the rate of natural revegetation and increasing the time required for a canopy to form.

18.2.4 Residual Impact Assessment

The physical alteration of landform and soils will be long term in nature but the perceptions of impacts will be reduced as disturbed soils and sidecast spoil material stabilise and vegetation re-establishes itself. It is therefore difficult to identify a temporal classification of residual impacts on the terrestrial environment in this case. For soil impact and recovery periods only, the temporal classification of residual impacts is as follows: short term (pre-vegetation re-establishment), medium term (post-vegetation re-establishment) and long term (regeneration). The spatial scale for impacts on landform and soils is limited.

The residual impact assessment process referred to in Section 18.1, General Approach, has been tailored to allow for the assessment of impacts on landform and soils. Impact significance on landform will primarily be based on qualitative judgement, with the support of a defined soils assessment. Residual impact significance on soils has been based on the magnitude of impact and sensitivity of resource/receptor, identified in Tables 18.5 and 18.6 respectively. The matrix of significance used is Table 18.1 (see Section 18.1.4, Impact Significance Matrix).

Table 18.5 Magnitude of impact – soils

Category	Description
Very High	Soil disturbance and displacement may occur up to 200 m from construction sites. Spoil volumes are high and the propensity for slumping and erosion are high. Active regeneration that needs close monitoring is required.
High	Soil disturbance and displacement may occur up to 100 m from construction sites. Spoil volumes are considerable, much of which will erode. Prone to erosion and requires rehabilitation to naturally regenerate.
Medium	Soil disturbance and displacement are localised to within 50 m of construction sites. Spoil volumes and the propensity for surface erosion are low and revegetation can occur by natural processes without intervention.
Low	Soil disturbance and displacement are highly localised to construction sites. Spoil volumes and the propensity for surface erosion are very low.
Minimal	Unlikely to cause detectable change in the environment.

Table 18.6 Sensitivity of resource/receptor – soils

Category	Description
High	Soils have adverse properties if disturbed e.g., unstable and or dispersive. Vegetation is sensitive to disturbance and has a limited capacity to regenerate from a soil seed bank. Recovery may take decades. Sensitive to other disturbances such as fire and weeds.
Medium	Soils may be unstable and relatively easily disturbed. Includes sensitive soils such as very wet, water logged or peaty soils that are easily damaged. Vegetation has some capacity to regenerate if severely disturbed, i.e., from established seedlings or seed rain. Recovery may take decades due to slow growth rates.
Low	Soils are not erosion prone if exposed and have no major adverse properties. Vegetation can recover relatively rapidly by regeneration or by limited active revegetation measures.

18.2.4.1 Construction

Hides Ridge Area

The Hides Ridge is predominantly classified as polygonal karst. This landform supports a high altitude *Nothofagus* forest above 1,800 m and the predominant terra rossa soils are very thin. The steep karst landforms include imposing escarpments, which appear prone to massive landslip. This is a mostly undisturbed environment with very little topsoil, therefore providing a poor rehabilitation medium when exposed, and very slow growth rates. This area is of high sensitivity.

Construction of the spineline and access track will involve highly localised but intensive ground disturbances in this high altitude, steep karst terrain. The aesthetic impact on landform will be major. The magnitude of impact on soils would be considered high to very high.

However, site-specific routing design and construction mitigation and management measures will be implemented. The ROW in this area will be minimised to a width of 18 m to reduce clearance and excavation. In addition, for approximately 10 km of its length along the steeper part of the ridge, the spineline ROW will be constructed on the ridge and the access track will be constructed parallel to the ROW on the side of the ridge to reduce the amount of sidecasting required. As shown in Figure 7.6 in Section 7.10.1.3, ROW Formation Earthworks on Hides Ridge, this optimisation of the route is likely to result in a significant reduction in the amount of spoil that would otherwise have been sidecast, thereby reducing associated landform and soil impacts.

Where spoil is sidecast, the limestone rubble will form a blocky scree slope. Some spoil (mainly limestone scree mixed with soil) may enter sinkholes that are greater than 50 m vertical depth, where most of the material is expected to hang up on the side-slopes with little material reaching the base. Where sidecast occurs, the impacts are difficult to mitigate safely and effectively and construction earthworks will damage a limited number of shallow (less than 50 m deep) sinkholes. However the majority should remain intact. Not all of these potentially affected sinkholes will contain sinkhole swamps. The project's commitment to optimise routing design in steep terrain and to implement rehabilitation measures focussed on minimising sidecast effects will assist in reducing impacts further.

'Shoo-fly roads' will be constructed as required in this area to reduce impacts of construction equipment (see Plate 3.2). ROW clean-up and rehabilitation will be undertaken progressively immediately behind the backfilling crew (see Section 3.4.5, ROW Reinstatement and Rehabilitation). This area will be considered for active revegetation. Invasive weeds need to be monitored as they have the potential to out-compete native species and inhibit natural regeneration. However, as discussed in Section 18.7, Biodiversity, the implementation of a weed, exotic pest and pathogen management plan, including a washdown station at the Hides Gas Conditioning Plant and limiting access to Hides Ridge, will mitigate evasive weed threat.

After the application of these mitigation measures, the magnitude of impacts on soils is expected to be medium with the residual impact significance being moderate in the short term, falling to minimal in the medium term or longer. This would also reflect the significance of impact on landform.

Juha to Hides Area

Construction of the pipeline through the Juha area is subject to diverse landform that supports areas of extreme landform instability and difficult terrain.

In the area supporting the wells and Juha Production Facility, the landform consists of a rough karst plateau in primary, low-altitude, medium-crowned forest. The terrain is steep in this area with a mixture of karst and sedimentary rock, making rehabilitation a challenge. It is expected that the gathering systems and facilities within this area would avoid these limestone features to reduce the significance of impact to minor or minimal (magnitude minimal, sensitivity high). Some active revegetation may be required. However the salvaging of topsoil and cleared vegetation to spread over exposed areas will be important considerations to promote lasting rehabilitation.

From the Juha Production Facility, the ROW for the Juha–Hides Rich Gas Pipeline and the Juha–Hides Liquids Pipeline travels through the Baia River valley, which consists of volcanic landforms highly susceptible to mass erosion and landslip when vegetation is removed. The banks of the Baia River that are crossed by the pipelines are particularly unstable and highly susceptible to erosion if disturbed. This resource is considered to have a high to very high level of sensitivity. The proposed ROW will be located along the more stable northern areas of the Baia River valley, and special construction procedures will be taken into consideration for the crossing of the river to reduce the potential for landslip. Immediately after the laying of facilities in this area, the banks of the watercourse will be reinstated and rehabilitated (see Section 3.4.4.4, Watercourse Crossings). The level of impact significance is expected to be moderate (with the magnitude being medium).

The ROW will then move through the swampy alluvial valley, avoiding Mt Sisa and the Karius Range. The waterlogged nature of much of the soil profile would be very susceptible to construction damage. Special measures will be considered for the laying of pipeline through this area to maintain adequate surface and subsurface flows and connectivity. A number of detours will be required in this region to maintain the construction access grade of 16% as the route crosses this valley. Residual impacts after mitigation on soils in the Juha to Hides area are expected to be minor in the short term (magnitude low) and falling to minimal in the medium to long term.

Homa Deviation

The Homa deviation area consists of highly erodible soils of the Kerewa volcanics, and the management of large volumes of spoil will be a focus during construction.

Steep slopes, unstable volcanic soils and a landslide-prone terrain between the upper reaches of the Bakari and Maruba rivers present construction safety and long-term stability hazards (see Section 6.2.2.2, Options within the Eastern Route). As this is a landslide prone area, the magnitude of impact would be high and the sensitivity of the resource/receptor would be medium.

Deviation around Homa reduces these risks; however, these routing optimisations will require more detailed investigation during FEED and detailed design. Such deviation would reduce the magnitude of impact to low, making the residual impact significance minor, falling to minimal in the long term.

Swamps and Wetlands of the Kikori Delta

Portions of the alignment will traverse swamplands between Kopi and the Omati River Landfall location and the alluvial swamps in the floodplains of the Kikori and Mubi rivers. Residual impacts on soils and landform in these depositional environments are expected to be minor in the short term (magnitude low, sensitivity high), falling quickly to minimal in the medium to long term.

Other Project Construction Works Areas and Quarries

Construction areas for the Hides Gas Conditioning Plant and Juha Production Facility will be located on relatively shallow-gradient terrain. During the grading of the sites, where practicable topsoil will be stripped and either used immediately in site fill and rehabilitation works or stockpiled in spoil areas for subsequent use in rehabilitation works (see Section 2.4.7, Grading and Foundation Excavation). Topsoil will be respread over the final surfaces of areas designated for rehabilitation and landscaping to support regrowth. Surface water drainage systems and sediment retention ponds will be constructed on these sites to reduce the potential for soil erosion and discharge of sediment-laden water to local drainage lines of the Tagari and Tamali rivers (see Section 2.4.4, Erosion Control and Section 2.6.1, Site Preparation at the Hides Gas Conditioning Plant). With these measures in place, residual impact significance is expected to be minor in the short term (magnitude and sensitivity low) to minimal in the long term.

Where possible, existing quarries will be used for project construction. New quarries will be needed, but for most of the length of the construction access way, many of the existing quarries set up for the Kutubu Petroleum Development Project will be able to be extended to supply road-making material and concrete aggregate. The residual impact for this would be minor (magnitude low, sensitivity low) in the short term, falling to minimal in the medium to long term (magnitude minimal, sensitivity low).

18.2.4.2 Operations

No major excavations or bulk earthworks are proposed during operation, and land disturbances during operations are anticipated to be infrequent and limited in extent. Therefore residual impacts to soils will be minimal to minor.

Construction areas will be progressively revegetated either by natural or active revegetation (where required), and so impacts during the operations phase will be limited to potential small operational spillages of fuels, hydrocarbons or chemicals, potentially impacting soils. Procedures to prevent such spillages are intended to ensure that residual soil contamination impacts will be minimal in the short to long term.

Pipelines and facility safety and security systems will be implemented to isolate the occurrence of larger spills of fuels (e.g., fuel tanker accidents) or the accidental release of liquid hydrocarbons. Soil impacts from such incidents will be managed by the implementation of the spill response plan, as part of the environmental management plan.

18.3 Groundwater

This section addresses the principal issues (Section 18.3.1), proposed mitigation and management measures (Section 18.3.2), and discusses residual environmental impacts of project construction and operation activities relating to groundwater resources in the project area (Section 18.3.3). This section summarises the findings of Appendix 6, Groundwater Impact Assessment, which reports the project’s upstream groundwater impacts.

18.3.1 Issues to be Addressed

The main groundwater issues arising during pipeline ROW and access way construction, project facilities construction, and well drilling include:

- Potential contamination associated with drilling, construction, and development of gas production wells. This includes the disposal of treated drilling fluids and the inadvertent loss of very limited quantities of foam drilling fluids during the drilling of fractured upper limestones.
- Potential contamination from fuels, lubrication oils and chemicals due to the transport, storage, and handling of these materials during construction.
- Potential contamination from hydrocarbon product, fuels, lubricating oils and chemicals due to the transport, storage and handling of these materials during operations.

18.3.2 Mitigation and Management Measures

The protection of groundwater from pollution depends on the sound design, the operating principles and methods, and the spill response plan that the project will develop prior to construction.

Measures concerned primarily with protection of surface water quality and management will also protect groundwater resources and these are addressed in Section 18.5, Water Quality.

18.3.2.1 Construction

The following measures will be implemented to avoid the impacts mentioned in Section 18.3.1, Issues to be Addressed, or reduce them as far as practicable.

Water Quality

- Drilling fluids and additives will be sourced from reputable suppliers [M125].
- Well development waters will be captured within mud pits and make-up water pits or similar. Where warranted alternative methods of disposal can be implemented, e.g., via reinjection [M126].
- Wastewater streams associated with drilling, such as water-based, non-toxic whole drilling fluids and completion drilling fluids, will be discharged in accordance with the requirements of the relevant environment (waste discharge) permit [M127].
- Diesel storage systems will be purpose-built, above ground and within double-walled tanks or containment bunds. Hydrocarbon spill prevention and response procedures will be detailed in the spill response plan [M130].

Water Supply

Groundwater extraction will comply with environment (water extraction) permits and will require agreements to be reached with local landowners [M137].

18.3.2.2 Operations

The following measures will be implemented to avoid the impacts mentioned in Section 18.3.1, Issues to be Addressed.

Water Quality

- Diesel fuel and product storage areas will be sealed and bunded. Hydrocarbon spill prevention and response plans will be in place [M130].
- MEG slop storage tanks will be purpose-built, full-containment tanks and bunded [M131].

Water Supply

Operations will comply with environment (water extraction) permits and will require agreements to be reached with local landowners [M137].

18.3.3 Residual Impact Assessment

Tables 18.7 and 18.8 outline the categories and definitions of magnitude of impact, and sensitivity of resource/receptor respectively, which are used in the residual impact assessment on groundwater. The matrix of significance used is Table 18.1, shown in Section 18.1.4, Impact Significance Matrix, and also considers a qualitative assessment of the scale of risk to groundwater resources by project activities (Appendix 6, Groundwater Impact Assessment).

Table 18.7 Magnitude of impact: groundwater

Category	Description
Very High	Impact likely to be severe on the quality of groundwater at a regional scale (greater than 10 km) over a long period of time. Impact has potential to cause substantial exceedence of water quality guidelines. Impact to significantly affect water supply to existing users.
High	Impact likely to be severe on the quality of groundwater at a local scale (between 2 km and 10 km) over a long period. Impact has potential to cause exceedence of water quality guidelines. Impact to significantly affect water supply to existing users.
Medium	Impact likely to be moderate on the quality of groundwater at a local scale (within 2 km and 10 km) and only short term. Impact has potential to cause minor exceedence of water quality guidelines. Impact does not affect water supply to existing users.
Low	Impact likely to be low on the quality of groundwater, at a site scale (within 2 km) and only short term. Impact does not cause exceedence of water quality guidelines. Impact does not affect water supply to existing users.
Minimal	Impact unlikely to be detectable.

Table 18.8 Sensitivity of resource/receptor: groundwater

Category	Description
Very High	Highland karst terrain where soils are shallow and fractured bedrock exposes aquifers. Aquifers where water is used for local domestic use.
High	Creeks and rivers where soils are highly erodible and aquifers rise into the surface waters.
Medium	Large tracts of lowland forest and swamplands where aquifers are less exposed to the surface.
Low	Environment with relatively stable soils where aquifers are less exposed to the surface.
Minimal	Environment with stable soils and aquifers are not exposed to the surface.

18.3.3.1 Construction

The rigs will be fitted with cuttings pits, mudpits, a mud circulating system and well control system, which will serve to contain drilling fluids.

During drilling, small amounts of foam drilling fluids will escape from the wellbore through the fractured upper limestones of Hides Ridge for the short period of time that it will take to drill this vugular geological unit.

As the subsurface hydrogeology of Hides Ridge is largely unknown, it is difficult to predict how drilling fluid constituents, such as foaming agents, corrosion inhibitors, bentonite clay (if used) and polymers, will present themselves in surface or subsurface waters at locations distant from the drilling sites. It is anticipated that there will be ample dilution of the untreated foam drilling fluids, given the high rainfall environment and subsurface groundwater flows that are typical of the area.

It is expected that residual concentrations of drilling fluid constituents would be reduced to the very low levels.

The toxicity characteristics of the foam drilling additives are low (see Supporting Study 12 of Enesar, 2005) and when combined with the anticipated low volumes that will be released, the residual impact significance is expected to be minimal (magnitude minimal, sensitivity very high). The use of foam drilling fluids for surface drilling in limestone terrain in Papua New Guinea is widely practised and no adverse consequences have been reported.

The Angore wells are also expected to contain foam-drilling fluids within the wellbores; however, Juha wells are currently planned to be drilled with fresh water.

18.3.3.2 Operations

In simple terms, if the project were to be built and operated to the adopted standards, then the impacts on groundwater should be minimal.

Residual impacts of minor spillages after mitigation (e.g., implementation of fuel-handling procedures, secondary containment bunds and emergency spill response and clean-up) at the site scale or further afield are predicted to be minimal (magnitude minimal, sensitivity low) in both the short and long term, as the volumes of liquids likely to be involved will be small and cleaned up immediately.

Major accidental spillages and a rupture of either the Juha–Hides Liquids Pipeline, the Hides–Kutubu Condensate Pipeline or any of the MEG pipelines would be addressed by the spill response plan to be developed by the project prior to construction.

Discussion of the potential major pipeline hazards and project hazard design mitigations measures is given in Chapter 27, Environmental Hazard Assessment.

18.4 Water Resources and Hydrology

This section addresses the impact assessment criteria (Section 18.4.1), principal issues (Section 18.4.2), mitigation and management measures (Section 18.4.3), and assesses the residual environmental impacts (Section 18.4.4) of project construction and operations on water resources and hydrology. Section 18.4.4.3 presents a summary of the magnitude levels for the water and hydrology resource impacts.

The residual impact assessment is based on the water resources and hydrology data sources outlined in Section 10.2.7, River Systems and Hydrology, additional data on the hydrology of the Baia and Tagari river systems is described in Appendix 4, Hydrology and Sediment Transport Impact Assessment, and a description of project activities is outlined in Chapter 2, Producing the Gas, Chapter 3, Transporting the Gas, and Chapter 5, Project Logistics.

18.4.1 Definitions and General Approach

Definitions of the spatial and temporal scales of impacts on freshwater aquatic environments give a specific meaning to statements about the degree of an impact.

For aquatic impacts, these definitions are common to the discussion on water resources and hydrology (this section), water quality (Section 18.5, Water Quality) and aquatic ecology (Section 18.6, Aquatic Ecology), and are given below.

The nature and magnitude of impacts are discussed in the respective sections.

18.4.1.1 Spatial and Temporal Assessment Criteria

Residual impacts on the freshwater and estuarine aquatic environments have been evaluated on three spatial (Table 18.9) and temporal scales (Table 18.10).

Table 18.9 Aquatic impact assessment: spatial scales

Spatial Scale	Description
Site scale	Immediate watercourse within 2 km downstream of a project impact location.
Local scale	Extending between 2 km and 10 km downstream from 'site scale' waters and generally includes the main channels of tributary rivers (e.g., Tamalia, Bakari, Maruba, Mandali and Digimu rivers).
Regional scale	Extending more than 10 km downstream from 'local scale' waters and principally includes the main channels of the lower reaches of major rivers of the project area (e.g., Baia, Tagari, Hegigio, Mubi and Kikori rivers).

No classification of spatial scales for standing waters, such as Lake Kutubu, swamps or floodplain off-channel waterbodies are presented, as residual impacts are assessed on an individual standing waterbody basis, which, in effect, is a 'site scale' in itself.

Table 18.10 Aquatic impact assessment: temporal scales

Temporal Scale	Description
Short term	Residual impacts lasting less than 1 year.
Medium term	Residual impacts lasting between 1 year and 5 years.
Long term	Residual impacts lasting more than 5 years.

18.4.1.2 Specific Criteria: Water Resources and Hydrology

Table 18.11 sets out specific criteria for water yield, stream flow durations, bed sediment loading and suspended sediment loading, giving statements about the nature of an impact a precise meaning.

Table 18.11 Specific impact criteria: water resources and hydrology

Water Yield		Bed Sediment Loading	
Minimal	Basically unchanged water yields (less than 10% deviation); indistinguishable from the predisturbance range of surface runoff and/or groundwater flows.	Minimal	Less than 10% of the predisturbance range; basically indistinguishable from the predisturbance range, such that the receiving watercourse can transport all delivered coarse sediments downstream.
Low	Deviations in water yields between 10% and 25% of the predisturbance range.	Low	Between 10% and <25% of the predisturbance range.
Medium	Deviations in water yields between 25% and 50% of the predisturbance range.	Medium	Between 25% and <50% of the predisturbance range.
High	Deviations in water yields >50% of the predisturbance range.	High	Bed sediment loading >50% of the predisturbance range.
Stream Flow Durations		**Suspended Sediment Loading**	
Minimal	Basically unchanged (less than 10% deviation).	Minimal	Deviation <10% of the predisturbance range (basically indistinguishable).
Low	Between 10% and 25% of the predisturbance range.	Low	Between 10% and <25% of the predisturbance range.
Medium	Between 25% and 50% of the predisturbance range.	Medium	Between 25% and <50% of the predisturbance range.
High	>50% of the predisturbance range.	High	>50% of the predisturbance range.

Significance criteria are not presented for suspended sediment loading of standing bodies of water, such as swamps, as suspended sediments will settle out and not remain in suspension.

18.4.1.3 Terrain and Locations

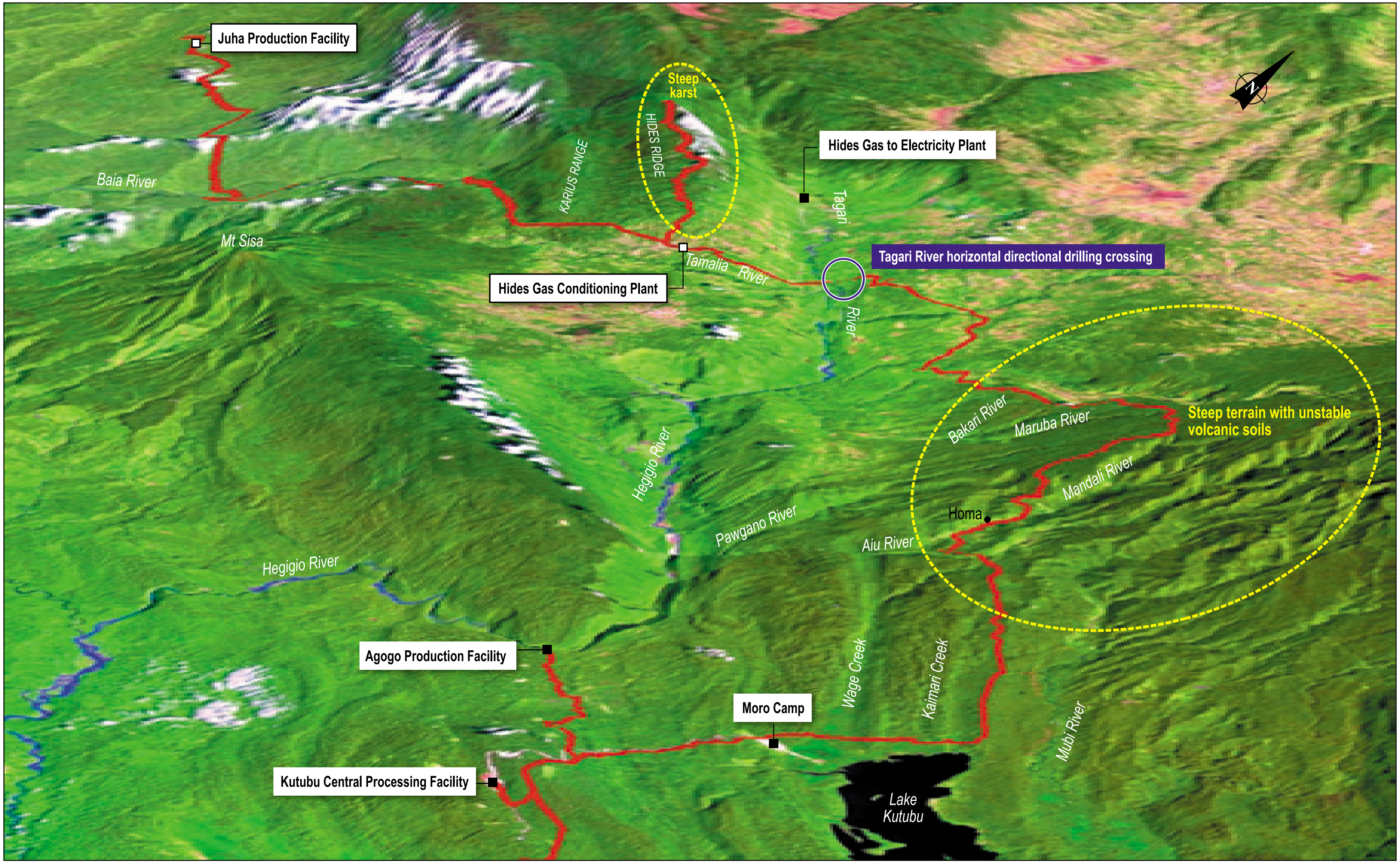
Mitigation measures and impacts are discussed for the terrain types and locations shown in Figures 18.1 and 18.2.

18.4.2 Issues to be Addressed

18.4.2.1 Construction

Construction activities generally have the following effects on water resources and hydrology:

- The exposure of surficial materials to rainfall, erosion and scour delivers coarse and fine sediment via surface runoff to watercourses and water bodies, with corresponding changes in the magnitude, timing, or duration of natural bed and suspended sediment transport and loading.
- The discharge of hydrotest water can increase the stream flow of smaller local watercourses.
- Water abstraction for project requirements, such as camp water, civil works, hydrotesting and process water may affect water availability and stream flow.
- Pipeline construction earthworks at the Omati River Landfall and watercourse crossings may change channel morphology, with flow-on sedimentation or scouring effects.



Note:
Vertical exaggeration x 2.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG	Job No: 1284 File Name: 1284_09_F18.01_HB	Esso Highlands Limited PNG LNG Project	Terrain types (water resources impact assessment): Kutubu-Hides-Juha

Figure No: 18.1

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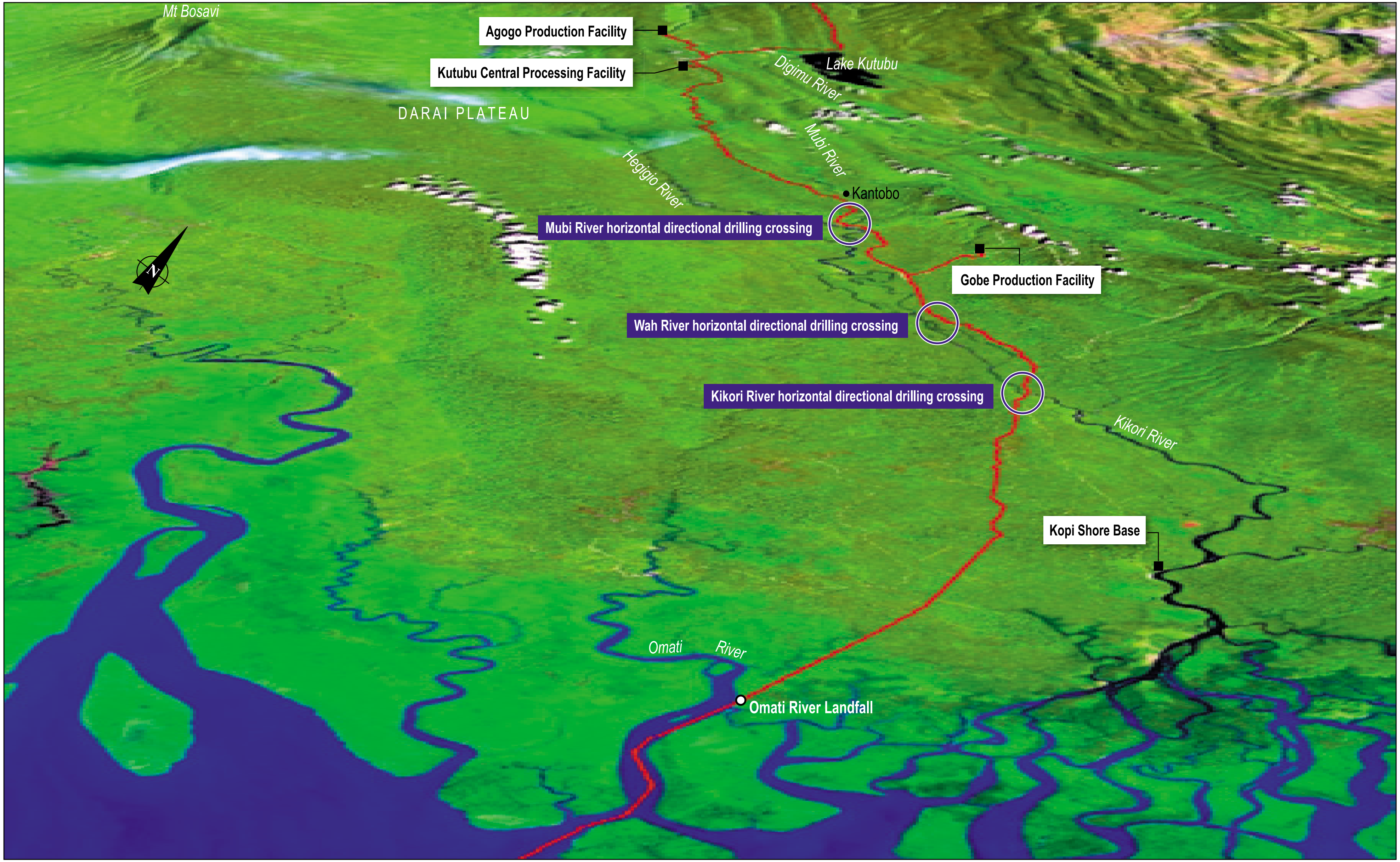


Note:
Vertical exaggeration x 2.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

Job No: 1284	Esso Highlands Limited	Terrain types (water resources impact assessment): Kutubu-Kopi-Omati	Figure No: 18.2
File Name: 1284_09_F18.02_HB	PNG LNG Project		

PGGP-EN-SRENV-000001-001
Rev0

Construction of the Hides Gas Conditioning Plant may increase the amount of sediment reporting to tributaries of the Tagari and Tamalia rivers. These tributaries may become turbid during large rainfall events, which could affect the water quality.

18.4.2.2 Operations

Operational issues are as follows:

- Post-construction soil erosion and mass movements of sidecast material in steep terrain.
- Water abstraction and wastewater discharges.

18.4.3 Mitigation and Management Measures

Mitigation and management measures are as follows.

18.4.3.1 Construction

Management Procedures

The following specific management procedures, which will be developed prior to construction, will be included in the water management plan:

- Erosion and sediment control management [M155].
- Surface water and stormwater management [M159].
- Watercourse crossing management [M160].
- Hydrotest disposal management [M145].

Revegetation management procedures will be included in the reclamation plan [M119].

Water Abstraction

Water taken from watercourses or groundwater will meet environment (water extraction) permit conditions. No additional measures are proposed [M137].

Hydrotest Water

The discharge of water after hydrotesting [M145] will adhere to the following specific measures:

- If small volumes of hydrotest water need to be discharged to land for infiltration, the outflow energies will be dissipated (e.g., via sprinkler or T-bar arrangements) to prevent problematic soil erosion.
- Disposal of hydrotest waters in accordance with good industry practice engineering codes for system gauging, hydrotesting and disposal, and discharges will be required to meet the prescribed quality criteria for ambient water (see Table 18.15) as part of the relevant environmental (waste discharge) permit conditions.
- Pre-discharge sampling and analysis of hydrotest water will be conducted to check that quality complies with the conditions attached to the relevant environment (waste discharge) permit.
- At Hides Ridge [M51], hydrotest water sourced off the ridge will be discharged into the same watershed as its source to prevent cross-contamination with live organisms from another catchment.

Karst Terrain

Where it is practicable to do so, pipelines will be routed at a fine scale, to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel and other karst terrain. This will limit sediment-laden runoff to groundwater through karst geology [M141].

Watercourse Crossings

Environmental mitigation measures for watercourse crossings align closely with engineering objectives and standard practice:

- The duration of construction activities at watercourse crossings will be as short as practicable [M153].
- Erosion and sediment control measures will be implemented as necessary [M155].
- Clearing of banks of watercourses will be delayed for temporary vehicle crossings until the need for the crossing is imminent, where practicable [M160].
- Where practicable, the pipeline ROW and access way alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses [M140].
- At some watercourse crossings, where the watercourse is considered too large and fast-flowing for the use of conventional open-cut trenching methods, horizontal directional drilling may be used to install the pipeline. Horizontal directional drilling is being considered for four locations (Tagari, Mubi, Wah and Kikori rivers) [M142].
- The construction of bridges, abutments and in-river bridge supports (where needed) will take into account the hydraulics of the watercourse in their design to consider stability and flow disruptions [M154].
- The construction and rehabilitation of the ROW in the Omati swamp area will be managed to maintain natural hydrologic flows and connectivity in the surrounding area. Monitoring of vegetation condition in the vicinity of the ROW will be conducted to assess the need for post construction remedial works in this area. The scope of the monitoring program will be developed in the environmental management plan [M162].

Erosion and Sediment Control

Erosion and sediment control measures [M155] to minimise hydrology impacts include:

- Reducing sidecasting material directly into waterways, where practicable.
- Reducing stockpiling spoil and soil materials close to waterways (i.e., maintaining a minimum of 10 m from the waterline), where practicable.
- Controlling sediment runoff from stockpiles and cleared areas around watercourses.
- Grading pipeline ROW and access way alignments adjacent to streams away from watercourses.
- Monitoring and maintaining erosion and sediment control measures until adequate soil stabilisation has been achieved.

- Installing diversion drains to intercept uncontaminated surface runoff around facilities and away from construction areas.
- Monitoring for and rectifying areas of problematic erosion at reclaimed watercourse crossings.

Figure 3.5 shows graded easement drains to prevent erosion into the watercourse and silt fences to prevent sediment runoff into the watercourse.

Kopi Wharf and Shore Base

Design the modified and new wharfs at Kopi to parallel the existing frontage of the Kikori River and to take account of channel hydraulics and other hydrodynamic characteristics of the Lower Kikori River that may affect the long-term stability of the river frontage, which will in turn have the effect of minimising interference with normal riverine processes [M161].

Limiting Sediment Delivery to Watercourses and Lakes

The soil conservation measures outlined in Section 18.2.2, Mitigation and Management Measures, will also limit sediment delivery to watercourses. Additional site-specific measures are required in the four project areas discussed below.

Hides Ridge

There are small pools or swamps at the bottom of some sinkholes along the Hides Ridge (see Plate 10.38). These are the only microhabitats where tree frogs and other water-dependent frogs can breed in high-elevation karst, in which there is otherwise little surface water (see Section 10.3.7, Noteworthy Areas of Terrestrial Biodiversity).

The Hides spineline (see Figure 2.3) will generally follow the ridgeline between sinkholes to avoid side cuts and reduce the quantities of sidecast spoil. As well, the following measures will be adopted:

- The design width of the ROW (including the access road) is 18 m. During operations, the ROW will be allowed to regenerate except for a 10-m-wide access road required for ongoing drilling and maintenance access to the ridge wellpads [M77].
- On Hides Ridge the ROW alignment will be routed to bypass potentially high-value conservation swamps that might provide juvenile nursery habitat or swamps in sinkholes less than 50 m deep where practicable. At sites where this is impractical, sidecast into these high value habitats will be reduced, where practicable [M82].
- One temporary drilling camp is to be established on Hides Ridge, which will be located near Hides Wellpad D and used by successive drilling campaigns [M71].
- The extent of clearing and earthworks along the ROW will be limited and the time period that surfaces are exposed prior to natural revegetation will be reduced to the extent practicable [M75].

The evidence of the existing Hides gas field wellpads is that sidecast materials (i.e., limestone scree mixed with soil) have not reached the bottom of sinkholes greater than 50 m deep (Crome, pers. com., as cited in Enesar, 2005). The limestone scree mixed with soil hangs up on the concave slopes of the deeper sinkholes, with little or no material reaching the bottom where pool or swamp microhabitats may be located. Natural revegetation of the settled scree and soil mix stabilises the scree slope and helps to prevent further downslope migration of the sidecast materials.

South Karius Range and Baia River

South of the Karius Range, the proposed Juha–Hides Rich Gas, Liquids and MEG pipelines ROW and access way cross karst terrain with small pools or swamps at the bottom of some sinkholes. As is the case for the Hides Ridge area, these pools and ponds represent high-value conservation microhabitats. Specific mitigation and management measures for limiting erosion and sediment delivery to these habitats include the following:

- Between Hides Ridge and Juha, the pipelines ROW will be aligned to bypass potentially high-value conservation swamps that might provide juvenile nursery habitats or swamps in sinkholes less than 50 m deep where practicable. At sites where this is impractical, sidecast materials will be reduced to the extent possible [M82].
- The temporary Juha drilling camp will be located within the footprint of the Juha Production Facility [M83].
- Protection for stream heads in the Baia River area and elsewhere in the upstream project area above 1,800 m will be provided by optimisations during detailed design, to reduce erosion and sediment delivery to those watercourses [M85].

Lake Kutubu Catchment

The Ramsar-listed Lake Kutubu has high water clarity and is a centre of fish endemism. The project will implement the following site-specific mitigation and management measures [M152] (in addition to those described in Section 18.2.2, Mitigation and Management Measures), to reduce sediment delivery to the lake's principal inflow streams:

- Regular post-construction site inspections along the pipelines ROW and access ways within the catchment of Lake Kutubu, including:
  - Checking for problematic erosion sites, particularly following storms and protracted periods of heavy rain, and taking appropriate remedial action.
  - Regularly inspecting ditches and culverts to remove accumulated debris.
- Reviewing feedback from water quality monitoring for advance warning of deteriorated water quality due to increased suspended sediment loading.

Upper Bakari, Maruba and Mandali Rivers Area

The pipeline ROW around the southern slopes of Mt Kerewa crosses steep slopes, unstable volcanic soils and a landslide-prone terrain of the headwater subcatchments of the Bakari, Maruba and Mandali rivers. Erosion and sediment control measures are difficult to establish because it is unsafe to work on the very slopes that need to be stabilised. At the same time, environmental and engineering objectives [M64] are closely aligned in this terrain, as follows:

- Limiting the clearing of riparian vegetation to the width required to safely accommodate pipelines ROW and access way at watercourse crossings.

- Minimise the number of watercourse crossings, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses.

18.4.3.2 Operations

No additional mitigation and management measures related to water resources and hydrology are proposed during operations, except for measures to ensure the integrity, security and maintenance of village water supplies, which will be included in the relevant environment (water extraction) and (waste discharge) permits.

The environmental baseline-monitoring program that will be developed prior to construction will provide for the monitoring of post-construction revegetation and overall rehabilitation of erosion-prone areas, especially at river crossings and riparian areas. Problematic sites will be identified and appropriate remedial measures undertaken.

18.4.4 Residual Impact Assessment

This section assesses the residual impacts of project construction and operations on water resources and hydrology, after mitigation and management measures have been implemented.

18.4.4.1 Construction

Water Yield

Residual impacts on water yield are assessed at the site scale or greater to be minimal in the short term or longer, owing to the very small areas of land affected by project infrastructure and pipeline ROWs or access ways, including hard or compacted surfaces.

Stream-flow Regimes

Water for onshore hydrotesting will generally be drawn locally from nearby large rivers, such as the Kikori, Wah, Mubi, Ai'io and Tagari rivers. The overall residual impact significance on stream-flow regimes from changes in surface runoff and water yield is assessed as minimal (magnitude minimal, sensitivity high).

a) Hydrotest Water Abstraction

The total volume of hydrotest water required for the various project pipelines between the Hides Gas Conditioning Plant site and the Omati River Landfall is 153 ML, using the information shown in Table 18.12.

Table 18.12 Hydrotest water volumes

From	To	Pipeline Length (km)	Pipe Diameter (inch)	Discharge Volume (ML)
LNG Project Gas Pipeline				
Hides Gas Conditioning Plant	Kutubu Central Processing Facility	104	32	54
Kutubu Central Processing Facility	Scraper Station (10 km southwest of Kopi)	159	32	83
Kopi Scraper Station	Omati River Landfall	23	34	13
Hides–Kutubu Condensate Pipeline				
Hides Gas Conditioning Plant	Kutubu Central Processing Facility	104	8	3

Note: Other pipelines that will be hydrotested are not included in this table, owing to their short lengths and smaller pipe diameters, with correspondingly much lower discharge volumes.

Typical fill rates for gas pipelines are in the order of 5,000 to 6,000 litres per minute (L/m), which was the case for a 28-inch diameter export gas pipeline in Sakhalin (Lamberson, 2002). Note that fill rates will vary depending upon the pumping equipment used and the head pressure in each pipeline to be tested. For the PNG LNG Project, a conservative fill rate of 10,000 L/m has been assumed for the combined hydrotest water requirements for the LNG Project Gas Pipeline and the Hides–Kutubu Condensate Pipeline. The corresponding water abstraction rate is 0.16 m^3/s. At the pipelines crossing location of the Tagari River, low flow (represented by the 90% exceedence flow) is 49 m^3/s (Appendix 4, Hydrology and Sediment Transport) and a water abstraction rate of 0.16 m^3/s is less than 0.33% of the river's low flow rate. At higher flows, the water abstraction rate is minimal.

IFC Guidelines (IFC, 2007e) recommend:

> Water sourcing for hydrotesting purposes should not adversely affect the water level or flow rate of a natural water body, and the test water withdrawal rate (or volume) should not exceed 10 percent of the stream flow (or volume) of the water source.

It is anticipated that all project hydrotest water abstraction rates can meet these guideline limits based on the calculations of abstraction volumes above.

Overall, the residual impact of hydrotest water abstraction on the flows of major rivers in the upstream project area, which will be the main sources of hydrotest waters, are assessed in the short term or longer as minimal (magnitude minimal, sensitivity high) at the site scale or greater.

b) Hydrotest Water Disposal

Hydrotest water will be tested before discharge at a controlled rate at a location that has yet to be determined; however, it will most likely be in the Omati River. The assessment of the impacts from discharge to the Omati River (the likely discharge location) are given in Section 19.3, Seawater Quality and Hydrology. The disposal locations for other sections of upstream pipe will be determined during FEED and detailed design and will be reported in the Hydrotest Waste Disposal Management Plan.

Should the reuse of hydrotest water from section to section of pipeline (the preferred option) prove infeasible, hydrotesting will adhere to the specific measures outlined above in Section 18.4.3.1, Construction, and water will be tested for compliance to the relevant environment (waste discharge) permit prior to discharge on land or to upstream river.

Bed Sediment Loading

It can be assumed that soil and sediment particles greater than 125 μm diameter will report to watercourses as bed load entrained in the runoff from moderate rainfall or greater.

Bed load greater than the sediment-carrying capacity of a watercourse will result in localised but temporary sedimentation of the watercourse close to the source, with subsequent scouring and downstream sediment transport as flood flows remobilise the deposits further downstream. Construction sediment is finite, and so watercourses will typically return to equilibrium, as they do after natural loads, such as landslides.

Residual impacts on bed sediment loading at the site scale or greater are assessed to be minimal in the short term and longer for pipeline ROW alignments and other site construction in the following terrain types:

- Flat or shallow-gradient karst terrain, swamplands and floodplains.
- Flat or shallow-gradient construction sites at the production facilities, laydown areas, quarries and borrow pits and along pipeline ROWs or access ways.
- Flat terrain at the Kopi Shore Base and wharf.
- Flat terrain at the lower Omati River Landfall.

Increased bed sediment loading and sedimentation impacts are expected in the upper catchments of the Baia River (Juha–Hides pipelines ROW) and northern tributaries of the Hegigio River, such as the Bakari, Maruba and Mandali rivers (Hides–Kutubu pipelines ROW) (see below).

Baia River Area

In general, about 90% of mobilised coarse sediments (greater than 125 μm size fraction) will enter watercourses and the receiving Baia River during heavy rain, when the river is at high flow (the estimated 10% exceedence flow is 365 m^3/s).

Appendix 4, Hydrology and Sediment Transport Impact Assessment, estimated the worst-case scenario for bed sediment loading of the Baia River main channel from construction of the pipelines ROW in the upper catchment. Increased bed sediment loading ranged from a maximum of 5.5% to 2.9% for ROW construction progress rates of 500 m/d and 250 m/d respectively. The percentage increases in bed sediment loading of the Baia River at high flows are much lower (less than 1%) when averaged out over the first year of construction.

Overall, residual impacts of bed sediment loading of the Baia River main channel are assessed in the short term and longer as minimal at the site scale or greater.

Bakari, Maruba and Mandali Rivers Area

The Bakari, Maruba and Mandali rivers are tributaries of the Hegigio River, which in turn becomes the Kikori River. Supporting Study 12 of Enesar (2005) assessed the residual impacts of PNG Gas Project pipeline ROW and road construction across the middle reaches of the Bakari, Maruba and Pawgano rivers (another Hegigio tributary), where there were to be high cut-to-spoil volumes of erodible volcanic soils in steep terrain. The PNG LNG Project has moved the pipelines northwards to higher elevations on less steep terrain and along ridges. This realignment to the headwater catchments of the Maruba River greatly reduces the volume of sidecast material and disturbance generally, and the catchment of the Pawgano River is no longer affected. Table 18.13 shows the approximate segment lengths of the pipelines ROW in the three catchments.

Table 18.13 Pipeline ROW sedimentation into the Bakari, Maruba and Mandali river catchments

Length of Pipelines ROW Segment		Propensity for Sediment Production and Delivery to Watercourses	Comment
Length (km)	**Location**		
3	Bakari River catchment	Low	Low-gradient terrain
1	Maruba River catchment	Low	Low-gradient terrain
3	Maruba–Mandali catchments' watershed	Low	Low-gradient terrain, follows ridge line
14	Mandali River catchment	Medium	Steep terrain

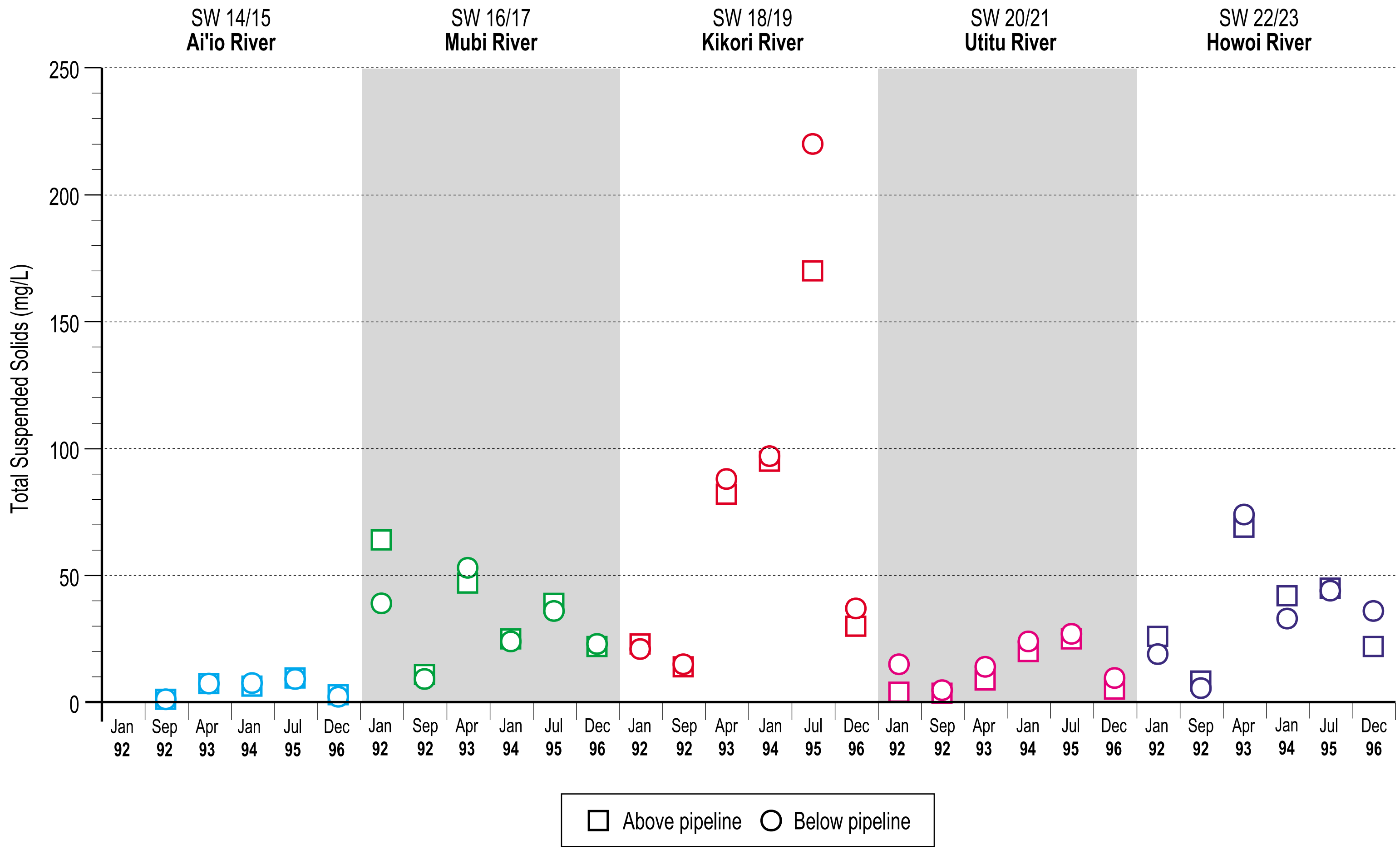
Sidecast spoil will comprise mainly volcanic soils, with a typical composition of gravels (17%), sands (50%), silts (27%) and clays (6%). Significant increases in bed sediment loading of the main channels of Bakari and Maruba rivers are not anticipated.

The 14-km-long segment of the pipelines ROW in the steep terrain of the Mandali River catchment is expected to deliver a substantial bed sediment load to the main channel of this river. However, steep bed gradients and high flow velocities will readily transport this material downstream and eventually into the Hegigio River.

Residual impacts from increased bed loads in the Mandali River are assessed to be minor at the site scale (i.e., at 2 km downstream) in the short term but minimal in the medium term (i.e., more than 1 year) or longer. Residual impacts of increased bed loads on the receiving Hegigio River at the regional scale are assessed to be minimal in the short term and longer.

Increased Suspended Sediment Loading

Heavy rainfall will mobilise fine sediments (less than 125 µm size fraction) into natural drainage systems. Most of the rivers and streams draining upland catchment areas where the pipeline ROW alignments are proposed are steep and fast-flowing, and they are expected to transport all fine suspended sediment loads downstream.



PNG LNG	Job No: 1284 File Name: 1284_09_F18.03_HB	Esso Highlands Limited PNG LNG Project	Kutubu Project water and quality comparison: upstream vs downstream of pipeline river crossings

Figure No: 18.3

PGGP-EN-SRENV-000001-001
Rev0

In general, increased suspended sediment loading in watercourses draining the catchments affected by pipeline ROWs and road construction works rapidly declines into insignificance after construction stops. Figure 18.3 shows monitoring of suspended sediment loads in the Kikori River and tributaries during and after construction for the Kutubu Petroleum Development Project. The results show that there was very little difference between sediment loads at monitoring points above and below the pipeline crossing locations.

Residual impacts on suspended sediment loading at the site scale or greater are assessed to be minimal in the short term and longer for pipeline ROW alignments and other site construction activities at project locations on the following terrain types:

- Flat or shallow-gradient karst terrain, swamplands, and floodplains.
- Flat or shallow-gradient construction sites at the production facilities, laydown areas, quarries and borrow pits and along pipeline ROWs or access ways.
- Flat terrain at the Kopi Shore Base and wharf.
- Flat terrain at the lower Omati River Landfall.

The steeper, unstable terrain of the Baia River (Juha–Hides pipelines ROW) and northern tributaries of the Hegigio River are assessed below.

Baia River Area

In general, about 90% fine sediments (less than 125 µm size fraction) will be mobilised during heavy rain.

Appendix 4, Hydrology and Sediment Transport Impact Assessment, estimated the monthly worst-case suspended sediment loading of the Baia River main channel as increments of 8.9% and 4.8% for ROW construction progress rates of 500 m/d and 250 m/d, respectively (Month 11 and Month 6). The percentage increases are much lower (less than 2%) at high flows when averaged out over the first year of construction.

Overall, residual impacts of suspended sediment loading of the Baia River main channel are assessed in the short term and longer as minimal at the site scale or greater.

Bakari, Maruba and Mandali Rivers Area

Supporting Study 12 of Enesar (2005) assessed suspended sediment loading of the Maruba River by the construction of the PNG Gas Project to be around 0.079 Mt of fine sediments (less than 125 µm size fraction) for a mid-catchment traverse of the originally proposed PNG Gas Project pipeline and Idauwi–Homa access road. The relocation of the PNG LNG Project's pipelines means that additional suspended sediment loading will be much reduced to approximately 10% of Bakari and Maruba river background, which translates into residual impacts assessed in the short term as minimal at the site scale or greater.

In the case of the Mandali River main channel, a suspended sediment increment of between 10% and 20% translates into residual impacts assessed in the short term as low at the site scale and minimal at the local scale or greater. In the medium term and longer, residual impacts are assessed as minimal at all spatial scales.

18.4.4.2 Operations

Aquatic impacts are dominated by fugitive sediment from earthworks, and the end of construction will mean that impacts on water resources, stream flow and bed and suspended loads will rapidly decline to minimal at the site scale in the short term and beyond.

Operational discharges of treated sewage effluent and waste water from existing sources (i.e., existing crude oil and natural gas projects) will continue for the long term, and there will be new discharges from the Juha Production Facility, the Hides Gas Conditioning Plant and upgrades at the existing Kutubu facilities. In the short term and longer, these existing discharges will have a minimal residual impact on the flow regimes of receiving watercourses at the site scale or greater.

18.4.4.3 Residual Impact Summary

In the steep and unstable slopes of the Mandali River, the proposed pipeline ROW will be routed along ridge lines and the shallower gradients at the highest elevations. Residual impacts during construction and at the site scale will be low to minimal in the short to medium term respectively.

Watercourses draining all other terrain types and construction sites are predicted to have minimal impacts in the short term or longer.

Evidence from monitoring of downstream water resources impacts for the Kutubu Project adds weight to the prediction of no material residual impacts on the watercourses of the project area during operations.

18.5 Water Quality

This section presents residual impact assessment criteria (Section 18.5.1), issues to be addressed (Section 18.5.2), mitigation and management measures (Section 18.5.3) and assesses the residual impacts (Section 18.5.4) of construction and operations on surface water quality of the project area after mitigation and management measures have been implemented.

18.5.1 Water Quality Criteria

18.5.1.1 Residual Impact Assessment Criteria

Definitions of the spatial and temporal scales of impacts on freshwater aquatic environments give a specific meaning to statements about the degree of an impact.

For aquatic impacts, these definitions are common to the discussion of water resources and hydrology (Section 18.4), water quality (this section) and aquatic ecology (Section 18.6). The definitions are given in Tables 18.9 and 18.10 in Section 18.4.1.1, Spatial and Temporal Assessment Criteria.

During construction, surface water quality will be most affected by fugitive fine sediments after rainfall, with increases in total suspended sediment (TSS) concentrations in flowing watercourses.

The assessment has defined impact criteria to give meaning to nominal changes in the concentrations of TSS (Table 18.14) The criteria do not apply to non-flowing watercourses, such as swamps, wetlands and sinkholes.

Table 18.14 Study assessment impact criteria: total suspended sediment (TSS)

Minimal	TSS at median flows (i.e., 50% exceedence flow duration) in receiving waters is within 10% of predisturbance background and within the range of natural background variability
Low	TSS at median flows in receiving waters greater than 10% and less than 50% of background
Medium	TSS at median flows in receiving waters is greater than 50% and less than 100% of background
High	TSS at median flows in receiving waters is greater than 100% of background

The criteria are based on median flows, because aquatic organisms are, for most of the time, exposed to the water quality associated with flows around the median. (For example, plus or minus one standard deviation is 68% of the time.)

These criteria have an empirical basis in observed impacts of elevated TSS and enable the assessment of residual impacts on aquatic ecology in Section 18.6.4, Residual Impact Assessment, to be made.

Study assessment impact criteria for other water quality variables have not been defined as aquatic impacts will be dominated by the effect of fugitive sediments, and the discharges of other contaminants from facilities and project activities will be low and controlled by effluent standards and proper operating practice and regulated by PNG's ambient water quality criteria for receiving waters (see below).

18.5.1.2 Receiving Water Quality Criteria

In Papua New Guinea, discharges to receiving waters must not cause a lowering of receiving water quality below the Prescribed Water Quality Criteria of Schedule 1 of the *Environment Act 2000* (Table 18.15).

Criteria to protect aquatic ecosystems apply at the end of the defined mixing zone, which is stipulated by the permit for the particular discharge.

Table 18.15 Prescribed water quality criteria

Parameter	Freshwaters	Brackish Water/Seawater
pH (pH units)	No alteration to natural pH	pH units
Temperature (°C)	No alteration greater than 2	No alteration greater than 2
Turbidity (NTU)	No alteration greater than 25	No alteration greater than 25
Insoluble residues	No insoluble residues or sludge formation to occur	No insoluble residues or sludge formation to occur
Colour	No alteration to natural colour	No alteration to natural colour
Odour (threshold unit)	No alteration to natural odour	No alteration to natural odour
Taste (threshold unit)	No alteration to natural taste	No alteration to natural taste
Dissolved oxygen (mg/L)	Not less than 6.0	Not less than 5.0
Sulfate as SO_4^{2-} (mg/L)	400.0	–
Sulfide as HS^- (mg/L)	0.002	0.002
Ammonia: nitrogen as NH_3-N (mg/L)	pH and temperature dependent*	pH and temperature dependent*
Nitrates (NO_3^- + NO_2^-) (mg/L)	45.0	45.0
Fats (mg/L)	None	None

Table 18.15 Prescribed water quality criteria (cont'd)

Parameter	Freshwaters	Brackish Water/Seawater
Grease (mg/L)	None	None
Oil (mg/L)	None	None
Tars (mg/L)	None	None
Phenols (mg/L)	0.002	0.002
Faecal coliforms[#] (colonies/100 mL)	≤200 per 100 mL	≤200 per 100 mL
Arsenic (mg/L)	0.05	0.05
Barium (mg/L)	1.0	1.0
Boron (mg/L)	1.0	2.0
Cadmium (mg/L)	0.01	0.001
Chromium (VI) (mg/L)	0.05	0.01
Potassium (mg/L)	5.0	450.0
Cobalt (mg/L)	Limit of detection	Limit of detection
Copper (mg/L)	1.0	0.03
Iron, dissolved (mg/L)	1.0	1.0
Lead (mg/L)	0.005	0.004
Manganese, dissolved (mg/L)	0.5	2.0
Mercury (mg/L)	0.0002	0.0002
Nickel (mg/L)	1.0	1.0
Selenium (mg/L)	0.01	0.01
Silver (mg/L)	0.05	0.05
Tin (mg/L)	0.5	0.5
Zinc (mg/L)	5.0	5.0
Chlorine (Total residual) (mg/L)	0.005 at pH 6	0.005
Cyanide, free as HCN (mg/L)	0.005	0.01
Fluoride (mg/L)	1.5	1.5
Pesticides (mg/L)	None	None
Radioactivity (mg pCi/L)	None	None
Toxicants (miscellaneous) (mg/L)	None	None

Notes: Dissolved metals passing a 0.45-micron filter; NTU = nephelometric turbidity units; – = no water quality criterion; pCi/L = picocuries per litre;

[#]The criterion for faecal coliform bacteria is based on not fewer than five samples taken over a 30-day period, in which the median value of the faecal coliform bacterial content of the waters shall not exceed 200 per 100 mL.

*Maximum permitted ammonia nitrogen criteria are dependent on pH and water temperature and are derived from Table 2 in Schedule 1 of the *Environment Act 2000*.

18.5.2 Issues to be Addressed

Project early works, construction and operations have the potential to affect the water quality of watercourses, swamps, sinkholes, wetlands, lakes (i.e., Lake Kutubu), off-river waterbodies and estuaries.

18.5.2.1 Construction

The water quality issues of construction are dominated by fugitive coarse and fine sediments, mainly from construction works areas (see Section 18.4.2.1, Construction). Other issues include:

- The disposal of treated sewage effluent, wastewater and other liquid wastes from the proposed construction camps, resulting in the potential contamination of both surface and groundwater with suspended sediments, nutrients and microbiological contaminants.
- The disposal of treated hydrotest waters from pipeline integrity testing, resulting in the potential introduction of residual small quantities of toxicants (biocides) and oxygen scavengers (ammonium bisulfite or sodium sulfite) into project area watercourses.
- The disposal of treated drilling fluids, resulting in the potential introduction of suspended solids into surface and subsurface watercourses via overland flow following discharges to land.
- Contamination from leaks or spillages of fuels, oils and chemicals due to increased transport, storage and handling of these materials during construction.
- Surface contamination from small-volume drilling fluid discharges, as well as treated wastewater discharges from horizontal directional drilling at major watercourse crossings.

18.5.2.2 Operations

The stabilisation of construction earthworks will curtail fugitive sediment, and so the principal water quality issues during operations relate to:

- The discharge of treated process wastewaters and treated runoff waters from production and processing facilities, and project waste management areas, namely project landfill facilities.
- The disposal of treated sewage effluent.
- Contamination from fuels, oils and chemicals due to increased transport, storage and handling of these materials during operations.
- Seepage from solid waste storage sites.

18.5.3 Mitigation and Management Measures

18.5.3.1 Construction

The following management measures will be prepared and detailed in the project's environmental management plans:

- Erosion and sediment control management [M155].
- Surface water and stormwater management [M159].
- Watercourse crossing management [M160].
- Waste management [M95].
- Wastewater management [M134].
- Revegetation management [M119].

The mitigation and management measures outlined in Section 18.2.2, Mitigation and Management Measures, for reducing potential impacts on soils and in Section 18.4.3, Mitigation and Management Measures, for reducing potential impacts on water resources and hydrology also serve to protect water quality both directly and indirectly.

Additional measures are listed below.

General

- Construction water and wastewater discharges will be treated to comply with conditions for discharge quality specified in the relevant environment (waste discharge) permits [M127].
- Non-equipment areas at plant facilities will be graded and sloped to allow uncontaminated storm water to drain naturally via the stormwater drains prior to routing offsite [M136].
- Where practicable, topsoil will be stripped and stored away from watercourses in designated topsoil stockpile areas at facility construction sites for later reuse [M122].
- A water quality baseline monitoring plan will be developed for the Hides Gas Conditioning Plant and Juha Production Facility implemented as part of the project's water management plan [M164].

Controls on fugitive sediment have been set out in 'Erosion and Sediment Control' in Section 18.4.3.1, Construction.

Watercourse Crossings

Measures in addition to those listed in 'Watercourse Crossings' in Section 18.4.3.1, Construction are:

- Long-term site stability will be achieved at all watercourse crossings and will be confirmed by regular inspections for problematic erosion. Any identified sites of problematic erosion will be assessed and corrective action will be undertaken as required.
- At some watercourse crossings, where the watercourse is considered too large and fast-flowing for the use of conventional open-cut trenching methods, horizontal directional drilling may be used to install pipelines. horizontal directional drilling is being investigated for use on the Tagari, Mubi, Wah and Kikori river crossings [M142].
- Horizontal directional drilling avoids direct impacts on watercourses and water quality but measures are required to limit potential impacts of drilling fluid spillages. Therefore, for watercourse crossings at which horizontal directional drilling will be used, a drilling fluids management system, including drill cuttings settlement and slurry containment pits (see Figure 3.8), will be implemented [M144].
- Horizontal directional drilling sites on either side of a watercourse will be recontoured, graded and rehabilitated after pipe installations are completed to reduce soil erosion and fugitive sediment [M143].

Solid Wastes

The waste management plan (see Chapter 25, Waste Management) will address handling, storage and disposal of waste. Specific measures would include:

- No disposal of waste into watercourses or sinkholes [M92].
- Incinerate organic waste and bury at specified sites [M97].

Biological, pharmaceutical and medical wastes will be treated and disposed of using appropriate technologies that will be detailed in the environmental management plan.

Treated Drilling Fluid Discharges

- Drilling fluids and additives will be sourced from reputable suppliers [M125].
- Wastewater streams associated with drilling, such as water-based, non-toxic whole drilling fluids and completion drilling fluids, will be discharged in accordance with the requirements of the environment (waste discharge) permit [M127].
- Well development waters will be captured within mud pits and make-up water pits or similar. Where warranted alternative methods of disposal can be implemented, e.g., via reinjection [M126].
- Hides Ridge:
  – Dispose of drill cuttings, and other drilling materials away from Hides Ridge [M93].
  – Dispose of wastes from ROW/access way construction activities (not spoil) and camps (including the drilling camp) away from Hides Ridge [M94].

Sewage Treatment Plants

Construction camp sewage treatment plants will be operated in accordance with the manufacturer's specifications and will comply with the conditions for discharge quality (including disinfection) specified in the environment (waste discharge) permit [M133].

Minor Fuel, Oil and Chemical Spillages

The waste management plan will include procedures for the safe handling, transport, storage and disposal of fuels, oils, drilling fluids and chemicals. Measures will include:

- Fuel storage systems will be purpose built, above ground and within double-walled tanks or containment bunds. Oil spill prevention and response plans will be in place. Temporary fuel stores along pipelines ROW and access roads will be correctly bunded during construction [M130].
- Procedures for vehicle/equipment refuelling will be implemented to prevent spillages, including not allowing construction vehicles and equipment to be refuelled near watercourses. Appropriate spill containment equipment will be available at refuelling sites. All drivers will be trained in emergency spill response procedures [M147].
- Vehicles and machinery will be maintained with respect to leaks [M148].
- The washing of equipment, vehicles or machinery near or within watercourses will be prohibited [M150].

Pipeline Integrity

Mainline valves enable sections of a pipeline to be isolated for maintenance or, in the event of a serious leak or rupture, to limit the amount of gas or liquid released. Check valves are simple automatic devices that prevent the contents of a pipeline from flowing backwards.

The LNG Project Gas Pipeline will require three mainline valves spaced at approximately 80 km along the LNG Project Gas Pipeline and provisionally located at Kutubu, Gobe airstrip and at the scraper station 10 km southwest of Kopi. Similarly, four mainline valves at approximately 20- to 25-km intervals will separate the Hides–Kutubu Condensate Pipeline into five segments and limit the volume of a potential spill from each segment to approximately 800 m^3. Other pipelines will have similar mainline and check valves. Measures to contain and manage any pipeline ruptures that may occur within the various gas and liquid hydrocarbon pipelines will be primarily mitigated through engineering design and controls (see Section 3.3.6.2, Mainline Valves and Check Valves, and Section 27.4.1.3, Pipelines).

18.5.3.2 Operations

Table 18.16 derived from IFC (2007e) sets out guidelines for emissions, effluent and waste levels for onshore oil and gas developments.

Table 18.16 Emissions, effluent and waste levels from onshore oil and gas development

Parameter	Guideline Value
Produced water	For discharge to surface waters or to land: • Total hydrocarbon content: 10 mg/L#. • pH: 6 to 9. • BOD: 25 mg/L. • COD: 125 mg/L. • TSS: 35 mg/L. • Phenols: 0.5 mg/L. • Sulfides: 1 mg/L. • Heavy metals (total)*: 5 mg/L. • Chlorides: 600 mg/l (average), 1200 mg/L (maximum).
Completion and well workover fluids	For discharge to surface waters or to land: • Total hydrocarbon content: 10 mg/L#. • pH: 6 to 9.
Stormwater drainage	Stormwater runoff should be treated through an oil/water separation system able to achieve oil and grease concentration of 10 mg/L#.
Cooling water	The effluent should result in a temperature increase of no more than 3°C at edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 m from point of discharge.

Source: IFC (2007e), which also sets out guidelines for treatment and disposal of drill cuttings, produced sand and water, completion and well workover fluids and hydrotest water.

#Project design will work to meet this criterion and will be subject to facilities design optimisation during FEED and detailed design.

*Heavy metals include arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc.

Process Areas

- All operations sites including the Hides and Gobe waste management area will be designed to intercept potentially contaminated water [M149].
- All water and wastewater discharges will be treated to comply with conditions for discharge quality specified in the relevant environment (waste discharge) permits [M134].

- Bunded open drain areas at facility sites will be concreted, kerbed and sloped to intercept runoff potentially containing hydrocarbons to drain catchpits. The catchpits will feed to corrugated interception pits for separation of oil and water. The de-oiled water will be transferred to retention ponds for treatment. Sufficient time will be allowed for sediment and solids to settle within the pond prior to final offsite discharge in accordance with waste discharge permit. Waste oil that is collected from the interception pits and other facility sumps will be recycled by reinjection into the condensate being sent to the Kutubu Central Processing Facility, where practicable [M135].
- A water quality baseline monitoring plan will be developed for the Hides Gas Conditioning Plant and Juha Production Facility implemented as part of the project's water management plan [M164].

Leaks and Spills

- Plant site-specific spill prevention and response plans will detail mitigation and management measures to reduce risks associated with potential sources of leaks and spills. An appropriate number of staff will be trained in the handling of emergency response oil spill scenarios [M130, M151].
- Fuel, lubricating oils and chemicals will be stored in appropriately sized designated areas that have impervious liners and bunds, or are in double-hulled tanks [M146].
- MEG slop storage tanks will be purpose built, full-containment tanks and bunded. Hydrocarbon spill prevention and response measures will be detailed in the project's spill response plan [M130].

18.5.4 Residual Impact Assessment

This section assesses the residual impacts of project construction and operations on water quality after mitigation and management measures have been applied. The assessment applies at the catchment level of the site scale and beyond, and not at the subcatchment level (i.e., small first-order streams directly draining construction areas), where construction impacts will be more pronounced. Residual impacts are assessed on watercourse main channels at the end of the site scale (i.e., 1 km downstream) and the local scale (i.e., between 2 km and 10 km downstream).

18.5.4.1 Construction

Increased Total Suspended Sediment Concentrations and Turbidity

The sediment loadings reported in Section 18.4.4.1, Construction, have been applied to the assessment of their consequences for water quality.

The residual impact significance on a particular watercourse will depend on terrain.

Flat and Shallow-gradient Limestone Terrain

'Increased Suspended Sediment Loading' in Section 18.4.4.1, Construction, notes that '[r]esidual impacts on suspended sediment loading at the site scale or greater are assessed to be minimal in the short term and longer.' This will translate directly to equivalent impacts on water quality.

Swamp Terrain

Sections of the LNG Project Gas Pipeline ROW traverse swamp terrain, mainly between the Kikori River and the Omati River Landfall. This is a depositional environment. Soil displacement will be localised, and there will be little sediment production and delivery to watercourses.

'Increased Total Suspended Sediment Concentration' in Section 18.5.4.1, Construction, notes that '[r]esidual impacts on suspended sediment loading at the site scale or greater are assessed to be minimal in the short term and longer.' This will translate directly to equivalent impacts on water quality.

Steep-gradient Karst Terrain

Sections of the pipeline ROW traverse relatively steep karst terrain (e.g., Hides Ridge and ridgeline to the Juha Production Facility), where bulk earthworks, disturbed and displaced soils, and the sidecasting of spoil will take place. Fine sediments eroded from construction spoil will likely reach surface drainage pathways, many of which travel only a short distance before flowing underground via sinkholes and sinkhole swamps to join the large subterranean flows that characterise this landform type. Since the limestone component of the construction spoil comprises generally competent material, this spoil erosion and fine sediment delivery to watercourses and subterranean waters occurs after the time of deposition.

Special mitigation and management measures will be implemented to avoid or reduce potential impacts on swamp microhabitats at the base of sinkholes that have high value conservation status (See 'Treated Drilling Fluid Discharges' in Section 18.5.3.1, Construction).

Section 18.4.4.1, Construction, assessed that the residual impact of fine sediment loading of watercourses in steep-gradient karst terrain at the site scale or greater to be minimal. Overall, increased TSS concentrations are highly localised and temporary, and the residual impacts on the water quality of surface and subterranean watercourses in steep karst terrain at the site scale or greater are assessed as minimal (not significant) in the short term or longer.

Steep Terrain with Unstable Volcanic Soils

The movement of unconsolidated material generated during the pipelines ROW construction is most likely to occur in steep terrain with unstable volcanic soils.

Assessment of the fine sediment loading from constructing a 35-km-long section of the pipelines ROW across the upper catchments of the Bakari and Maruba rivers and the upper and mid catchment of the Mandali River concluded that, for the Bakari and Maruba rivers, the TSS loading would be minimal at the site scale or greater in the short term or longer, and so impacts on water quality from increased TSS concentrations would be likewise minimal.

Assessment of the Mandali River main channel found that TSS loadings would be minor in the short term at the site scale but minimal at the local scale or greater. In the medium term and longer, residual impacts were assessed as minimal. The implications are discussed below of TSS concentrations on the water quality of the Mandali River.

The detailed assessments of Supporting Study 12 of Enesar (2005) predicted that TSS concentrations in the lower Pawgano River (worst case) downstream of the PNG Gas Project pipeline ROW and access way would increase by 20 mg/L from a background value of 40 mg/L to

60 mg/L (50% increase) at median flows and by 120 mg/L at the 10% exceedence high flow (from 80 mg/l to 200 mg/L, a 150% increase). No increases in TSS concentrations were predicted at the 90% exceedence low flow, when rainfall runoff is minimal and groundwater inflows contribute largely to base or very low flows. The length of the originally proposed pipeline ROW and access way in the Pawgano River catchment was 9 km compared to the proposed 14 km of pipelines ROW in the Mandali River catchment; however, the volume of bulk earthworks and sidecast spoil was higher in the former. The Pawgano River is not affected by the PNG LNG Project pipeline ROW (now rerouted to the north to avoid such difficult terrain). However, the Pawgano River analysis suggests that there will be similar increases in TSS concentrations in the Mandali River main channel downstream of construction areas in the range greater than 10% and less than 30% at median flows.

The criteria outlined in Section 18.4.1.1, Spatial and Temporal Assessment Criteria, translate into residual TSS impacts on the water quality of the Mandali River as minor at the site scale in the short term and minimal at the local scale or greater downstream of dilution from the Adju River and the Hegigio River. In the medium term and longer, residual impacts on water quality are assessed as minimal.

Construction-related increases in TSS concentrations in the Mandali River main channel will diminish as sidecast spoil and sites of erosion stabilise (see Figure 18.3).

Kopi Shore Base

Chapter 5, Project Logistics outlines the modifications and new construction required to upgrade onshore areas at the Kopi Shore Base. The Kikori River at Kopi is turbid with background median TSS concentrations of around 60 mg/L and a high flow relative to locally turbid runoff. The TSS impact of fugitive sediment from construction areas is assessed in the short term and longer as minimal at the site scale or greater.

Increased Metal Concentrations

Dissolved metal concentrations in waters sampled from watercourses across the project area were generally at or around the levels of analytical detection, indicating a lack of metal mobilisation in surface runoff and an absence of mineralised areas or soils at construction sites and along the pipeline and roads ROWs (Appendix 5, Water and Sediment Quality Impact Assessment and Supporting Study 12 of Enesar, 2005). However, there was a general (and normal) positive correlation between increased TSS concentrations and increased particulate metals.

The exceptions to this general picture are bed sediment samples from two small streams draining the site of the proposed Juha Production Facility. Site JUH8 (see Figure 2-1 in Appendix 5, Water and Sediment Quality Impact Assessment) showed a total mercury concentration of 11.3 mg/kg, which exceeded the ANZECC/ARMCANZ (2000) low Interim Sediment Quality Guideline value (ISQG-Low) of 0.15 mg/kg and the high guideline value (ISQG-High) of 1.0 mg/kg.
Section 18.4.4.1, Construction, has assessed the TSS impact of construction on the water quality of the Baia River as minimal at the site scale or greater in the short term or longer. However, water and sediment quality of streams draining the Juha Production Facility site will undergo further baseline characterisation as part of Phase 4 project development activities [M164].

Otherwise, Appendix 5, Water and Sediment Quality Impact Assessment concludes that the metals detected in waters and bed sediments of watercourses and water bodies in the project area represent background geological concentrations, and consider that earthworks related to the construction of the project, while potentially introducing sediment (and thus total metals), will generally not result in the significant elevation of bioavailable metals in watercourses.

Overall, the residual impacts of temporary increases in particulate metal concentrations associated with construction-derived sediments delivered to watercourses are assessed in the short term and longer as minimal at the site scale or greater.

Sewage Treatment Plant Effluents

Construction camp sewage will be treated to meet conditions of the environment (waste discharge) permit for effluent quality and the residual impacts on receiving water quality at the site scale or greater are assessed as minimal in the short term or longer.

Contamination of Watercourses by Fuel, Oil or Chemical Spillages

Residual impacts of minor accidental spillages after mitigation (e.g., implementation of fuel handing procedures and emergency spill response and clean-up plans) at the *s*ite scale or greater are assessed as minimal in the short term and longer, given the small volumes of liquids likely to be involved.

Hydrotest Water Discharges

The location for the discharge of hydrotest water from the onshore pipeline testing is not yet specified, but will most likely be in the Omati River. Hydrotest water will contain residual quantities of an oxygen scavenger (e.g., Champion OS-2), and a biocide (e.g., Bactron B1150). The impacts of discharge are assessed in Section 19.3, Seawater Quality and Hydrology, and discharge will be managed to meet applicable environment (waste discharge) permit conditions. However, if discharge is to land or upstream river, discharge of hydrotest water will adhere to the specific measures outlined above in Section 18.4.3.1, Construction.

Kopi Shore Base

Kopi Shore Base will be the primary logistics centre for pipeline construction activities (see Chapter 5, Project Logistics). Additional turbidity generated by propeller wash from tugs moving barges in and out of the Kopi Shore Base wharf will be small compared to the turbidity of the Kikori River at Kopi, which has background median TSS concentrations of around 60 mg/L and a high flow. The TSS impact of fugitive sediment from tugs involved in barge manoeuvring is assessed in the short term and longer as minimal at the site scale or greater.

18.5.4.2 Operations

Aquatic impacts are dominated by fugitive sediment from earthworks, and the end of construction will mean that impacts on water resources, stream flow and bed and suspended loads will rapidly decline to minimal at the site scale in the short term and beyond.

Operational discharges of treated sewage effluent and waste water from the Juha Production Facility, the Hides Gas Conditioning Plant and upgrades at the existing Kutubu facilities will comply with IFC effluent quality guidelines (IFC, 2007j and IFC, 2007e respectively) and will be monitored for compliance with conditions of the environment (waste discharge) permit. In the short term and longer, these discharges will have a minimal residual impact on the flow regimes of receiving watercourses at the site scale or greater.

18.5.4.3 Residual Impact Summary

Material impacts on water quality relate solely to increased suspended sediment concentrations from earthworks in the steep, landslide-prone terrain and unstable volcanic soils of the Mandali River headwaters.

Watercourses draining all other terrain types and construction sites are predicted to have minimal impacts in the short term or longer.

No material residual impacts are predicted on the watercourses of the project area during the operations.

Community issues or grievances relating to water quality impacts will be investigated, managed and mitigated as described in Chapter 23, Project-wide Socio-economic and Cultural Impacts and Mitigation Measures.

18.6 Aquatic Ecology

This section presents residual impact assessment criteria (Section 18.6.1), issues to be addressed (Section 18.6.2), mitigation and management measures (Section 18.6.3) and assesses the residual impacts (Section 18.6.4) of construction and operations on the onshore aquatic ecology of the upstream project area after mitigation and management measures have been implemented.

The locations of places discussed are shown on Figures 18.1 and 18.2.

18.6.1 Residual Impact Assessment Criteria

18.6.1.1 Aquatic Biological Community Structure

Definitions of the spatial and temporal scales of impacts on freshwater aquatic environments give a specific meaning to statements about the degree of an impact. They are common to the discussion of water resources and hydrology (Section 18.4), water quality (Section 18.5) and aquatic ecology (this section). The definitions are given in Tables 18.9 and 18.10 in Section 18.4.1.1, Spatial and Temporal Assessment Criteria.

During construction, surface water quality will be most affected by fugitive fine sediments after rainfall and criteria for the water quality implications of TSS increases in flowing watercourses have been given in Table 18.14 of Section 18.5.1.1, Residual Impact Assessment Criteria. (The criteria do not apply to non-flowing watercourses, such as swamps, wetlands and sinkholes.)

Criteria for the assessment of the severity of impacts on the aquatic habitats and biological communities have been set out in Table 18.17.

Table 18.17 Specific impact criteria: aquatic biological community structure

Minimal	Habitat alteration or changes in water quality cause no measurable changes in aquatic community structure or function and are indistinguishable from existing natural variability.
Low	Habitat alteration or changes in water quality causes a measurable change in watercourse or other waterbody community structure or function that will persist in the short term (up to 1 year).
Medium	Habitat alteration or changes in water quality cause a measurable change in aquatic community structure or function that will persist in the medium term (more than 1 year and less than 5 years).
High	Habitat alteration or changes in water quality cause a measurable change in aquatic community structure or function that will persist in the long term (more than 5 years).

Section 18.5.1.1, Residual Impact Assessment Criteria, has noted that aquatic impacts will be dominated by the effect of fugitive sediments, and the discharges of other contaminants will be low, generally controlled by effluent standards and proper operating practice, and regulated by PNG receiving water quality criteria for receiving waters. This section is, therefore, focussed on the impacts of TSS loading on aquatic ecosystems and species.

18.6.1.2 Receiving Water Quality Criteria

In Papua New Guinea, discharges to receiving waters must not cause a lowering of receiving water quality below the Prescribed Water Quality Criteria of Schedule 1 of the *Environment Act 2000* (see Table 18.15 in Section 18.5.1.2, Receiving Water Quality Criteria).

These guidelines present water quality criteria for the protection of freshwater and brackish water/seawater ecosystems.

Where the Schedule 1 does not specify a criterion for a particular water quality parameter, the Australian and New Zealand water quality guidelines (ANZECC/ARMCANZ, 2000) have been used, in particular, the trigger values applicable to lowland rivers draining catchments that are slightly disturbed in tropical Australia.

18.6.2 Issues to be Addressed

This section makes an interpretation of the consequences of impacts on water resources and hydrology (Section 18.4.4, Residual Impact Assessment) and water quality (Section 18.5.4, Residual Impact Assessment) for aquatic habitats and aquatic flora and fauna.

18.6.2.1 Construction

Aquatic Habitat Issues

- Loss or degradation of riverine aquatic habitats by in-stream works, such as infilling for land reclamation at the Hides Gas Conditioning Plant and open-cut watercourse crossings.
- Degradation of water quality by suspended sediments.
- Change to the structural diversity of stream habitats by coarse sediment (in-filling of riffle habitat in flowing watercourses or increased sedimentation in pools.

- Changes to overbank flooding and sedimentation of riparian terrestrial habitats, with flow-on effects on shelter, shading and energy inputs of organic matter and food.
- Sedimentation of sinkhole streams, swamps and ponds by coarse and fine sediments from sidecast spoil and soil erosion.
- Risk of surface water contamination from leaks or spillages of fuels, oils and chemicals.

Aquatic Flora and Fauna Issues

- Consequential impacts of sedimentation and changes in water quality on benthic and open-water aquatic flora and fauna, particularly sediment-intolerant organisms in clear-water waterbodies.
- Introductions of noxious aquatic weeds or exotic fish.
- Barriers (e.g., culverts and flow blockages) to fish or prawn migrations and other longitudinal movements.

Water-associated Fauna Issues

- Effects on the aquatic life stages of terrestrial fauna (such as tree frogs) and of susceptible life stages of amphibians.

18.6.2.2 Operation

The stabilisation of construction earthworks will curtail fugitive sediment. Chemical or fuel accidents aside (see Chapter 27, Environmental Hazard Assessment), Sections 18.4, Water Resources and Hydrology, and 18.5, Water Quality, have demonstrated a minimal operational impact on water resources, hydrology and water quality.

18.6.3 Mitigation and Management Measures

18.6.3.1 Construction

The mitigation and management measures outlined in Section 18.2, Landform and Soils, Section 18.3, Groundwater, Section 18.4, Water Resources and Hydrology and Section 18.5, Water Quality, also serve to protect aquatic habitats and resident aquatic flora and fauna. In addition, project workers or contractors will be prohibited from disturbing or harassing wildlife, hunting, fishing, gathering plants or bush foods, or possessing wildlife products while they are working, travelling in project vehicles, or residing in project field accommodation. Appropriate site inductions will encourage compliance.

18.6.3.2 Operations

Section 18.5.3.2, Operations, and Chapter 30, Environmental Management, Monitoring and Reporting set out measures to limit the generation of operational wastes and to treat wastewaters in order to comply with discharge standards and ambient water quality criteria of Table 18.15 in Section 18.5.1.2, Receiving Water Quality Criteria, to monitor compliance and to avoid and deal with leaks and spillages.

18.6.4 Residual Impact Assessment

This section assesses the residual impacts of project construction and operations on aquatic ecology after mitigation and management measures have been applied. The assessment applies at the catchment level of the site scale and beyond, and not at the subcatchment level of the thousands of small first-order streams directly draining construction areas, where construction impacts will be more pronounced. Residual impacts are assessed on watercourse main channels at the end of the site scale (i.e., 1 km downstream) and the local scale (i.e., between 2 km and 10 km downstream).

18.6.4.1 Construction

The residual impact assessments in Section 18.4, Water Resources and Hydrology, and Section 18.5, Water Quality, respectively have found minimal impacts on water resources and hydrology and water quality for all but the effect of fugitive sediment during construction on the Mandali River upstream of its confluence with the Adju River. These findings underpin the aquatic ecological impact assessment of aquatic habitats, flora, macroinvertebrates, fish, crocodiles and freshwater turtles below.

Aquatic Habitats

Surface Riverine Habitats

The construction residual impact assessments in Section 18.4, Water Resources and Hydrology, and Section 18.5, Water Quality, have assessed coarse sediment loading and increased TSS concentrations as minimal at the site scale or greater in the short term and longer for rivers draining construction areas in the following terrain types or areas:

- Flat and shallow-gradient karst terrain.
- Steep-gradient karst terrain.
- Lake Kutubu catchment.
- Floodplain off-channel waterbodies, swamps and low-lying terrain.
- Kikori and Omati deltas and estuaries.

In the Mandali River at site scale in the short term (see Section 18.5.4.1, Construction), increases in bed sediment loading after heavy rain will create localised areas of temporary sediment deposition, with smothering of river bed habitats, in-filling of stony substrata and a consequent loss of void spaces of the benthic habitat. The Mandali River is a naturally clear-water tributary of the turbid Hegigio River and so fugitive construction sediment represents an impact that naturally occurs sporadically (for example, after a landslide). Like landslides, however, fugitive construction sedimentation is temporary and supports an assessment of the residual impacts of construction on the aquatic habitats of the Mandali River main channel at the site scale as minor in the short term, but minimal in the medium term or longer.

The consequences of aquatic habitat loss or deterioration on the aquatic biological communities of the Mandali River main channel are discussed below.

Subterranean Riverine and Sinkhole Swamp Habitats in Steep Karst Terrain

The mitigation measures to protect sinkholes on Hides Ridge (see Section 18.4.1.3, Terrain and Locations) match the criterion for 'minimal' impact set out in Table 18.17 at the *s*ite scale or greater in the short term or longer.

The karst terrain along the Kantobo to Mubi River section of the PNG LNG Gas Pipeline ROW (see Figure 18.2) is of note for the presence of a species of cave-dwelling fish, a blind gudgeon (*Oxyeleotris caeca*). This species occurs in sinkholes and subterranean streams in the eastern catchment of the Mubi River. The proposed LNG Project Gas Pipeline ROW is located in the western catchment of the Mubi River, which is outside the known habitat area of this species but where it may well be present. If so, it will have survived the construction and installation of the existing crude oil export pipeline in this same location. For these reasons, the magnitude of impact on this species corresponds to minimal (see Table 18.17) at the site scale or greater in the short term or longer.

Lacustrine Habitats (Lake Kutubu)

The pipelines ROW within the catchment of Lake Kutubu includes two crossings of Wage Creek (one in its upper catchment and one just upstream of Lake Kutubu) and one crossing of Kaimari Creek just upstream of the lake (see Figure 18.1). Section 18.5.4, Residual Impact Assessment, found fugitive sediment impacts to be minimal in this area of moderate limestone terrain. Moreover, earthworks and stream crossings will be similar in nature, location and extent to the construction of the road from Poroma to Moro in 1993 and will be subject to sediment control measures (see Section 18.5.3, Mitigation and Management Measures). The fugitive bed and suspended sediment material from construction will involve material similar to the natural sediment load of Wage Creek forming its bird's foot delta in Lake Kutubu.

On this basis, residual impacts of construction activities on the aquatic habitats of Lake Kutubu's two major inflow streams are assessed in the short term and longer as minimal at the site scale or greater. No significant residual impacts of construction on the aquatic habitats of Lake Kutubu are anticipated.

Floodplain Off-channel Waterbodies and Swamp Habitats

The residual impact assessment in Section 18.4, Water Resources and Hydrology, indicated that floodplain swamps and wetlands are the least likely to be impacted by construction-derived sediments, because water flows are too low to transport them in these depositional environments. Residual impacts of fugitive sediment on swampland and floodplain aquatic habitats at the site scale or greater are assessed as minimal (not significant) in the short term or longer.

Estuarine Habitats

Section 18.4, Water Resources and Hydrology, assessed sediment loading at the Kopi Shore Base as minimal (see Figure 18.2).

Aquatic Flora

Aquatic flora provides food for herbivorous benthic macroinvertebrates (e.g., grazers and scrapers) and the young life stages of fish and amphibians. Most of the flowing waters in the project area are naturally turbid. They have a very low aquatic primary production compared to the inputs of terrestrial organic matter that form the basis of the food chain (and this is reflected in the predominance of shredders and detritivores among the resident macroinvertebrate, see Appendix 2, Aquatic Fauna Impact Assessment). On the other hand, primary production is high in Lake Kutubu and in the permanent swamps and wetlands of the project area.

Thus, the flowing waters most likely to receive and carry fugitive sediment are also those naturally least susceptible to impact on aquatic flora. Conversely, the susceptible, still-water habitats are found in environments, in which heavy fugitive sediment loads are less likely to occur in the first place.

The exceptions to this pattern are the clear-water, first order tributaries, and in particular, the Mandali River, where sedimentation impacts have been predicted to be minor at the site scale in the short term (i.e., in the first year of construction, see the residual impact assessment in Section 18.5, Water Quality). The Mandali River is a clear-water tributary of the Hegigio River. Like the other clear-water tributaries (e.g., Bakari and Maruba rivers) that drain the same local steep terrain with unstable but undisturbed volcanic soils and intact forest cover, the Mandali River has good water quality with low TSS concentrations and turbidities (see Figure 18.1).

High water clarity is conducive to in-stream primary productivity by benthic flora; on the other hand, aquatic macrophytes are not favoured by variable flow regimes and high water velocities.

Temporary sediment deposits in the main channel will smother benthic flora of algae, diatoms and periphyton attached to the surfaces of boulders, stones and woody debris. However, the recovery of primary productivity once construction work is finished supports a residual impact assessment of minor at the site scale in the short term only, but minimal at the local scale downstream of the confluence of the Mandali and Adju rivers in the medium term and beyond.

Macroinvertebrates and Fish

Like aquatic flora, construction-derived bed load (coarse) sedimentation effects on benthic macroinvertebrates and fish are only likely to be material in the Mandali River. Habitat, smothering, increased TSS concentrations in the water column, infilling of interstitial habitat in streambed riffles and the loss or reduction of food from in-stream primary production (see Aquatic Flora above) can be expected to temporarily lower species diversity and density, with concomitant reductions in mainstream secondary production brought about by biomass reduction and depressed growth rates.

Most construction-derived fine sediments will report to the Mandali River during heavy rain when the river flow is currently high. High flows are intermittent in peaky, first-order catchments like the Mandali River (for example, the 10% exceedence high flow occurs over 36.5 days per year) and so the periods of high suspended solids will be short (see below).

Macroinvertebrates

Supporting Study 12 (Enesar, 2005) notes that the effects of suspended sediments on benthic macroinvertebrates are time-concentration dependent, and the TSS concentrations occurring around average or median flows (represented by the 50% exceedence flow duration) are those to which macroinvertebrates are exposed for the longest cumulative period of the time.
Section 18.5.4, Residual Impact Assessment, estimated increases in TSS concentrations in the Mandali River main channel downstream of construction activities at the site scale to be in the

range greater than 10% and less than 30% above background values at median flows. Supporting Study 12 (Enesar, 2005) finds that many benthic macroinvertebrates species tolerate much higher TSS concentrations than those predicted above for median flows in the Mandali River. Therefore, most benthic macroinvertebrates of the Mandali River would be expected to tolerate intermittent and more prolonged exposure to these predicted short-term increases in TSS concentrations at high and median flows during the first year following construction (i.e., in the short term).

The macroinvertebrate fauna will recover progressively as the benthic habitats clear of settled sediments and water quality improves. Recolonisation will take place by egg-laying insects and recruitment (drift) of macroinvertebrates from unaffected upstream and side tributaries, and is likely to be rapid. Freshwater crayfish (*Cherax cf. albertisii*) are expected to be present in the main channel and will recolonise by upstream and downstream migration and recruitment from the river’s tributaries.

On this basis, the assessed minor, site-scale and short-term construction residual impacts on hydrology and water resources (Section 18.4.4.1, Construction) and water quality (Section 18.5.4.1, Construction) translate directly to the equivalent impact on the benthic macroinvertebrate fauna of the Mandali River main channel of minor in the short term at the site scale, but minimal in the medium term or longer.

Fish

The response of fish populations to the minor, short-term and localised impacts on hydrology and water resources and water quality can vary with the species, life stage, season, and habitat requirements.

Sedimentation of stones-in-current or cobble substrata and a corresponding reduction of void spaces will temporarily reduce the structural diversity of stream-bottom fish habitats. Sediment deposition will temporarily reduce the survival of the eggs, larvae and juvenile stages in the life cycle of river gobies, gudgeons and tandans. However, it is to be expected that Mandali River main channel fish species will also breed and maintain self-sustaining populations in unaffected tributaries.

Supporting Study 12, (Enesar, 2005), provides a review of the generalised effects of increased suspended sediment concentrations on fish. Both clearwater and turbid water fish are known to be tolerant of elevated TSS concentrations at high flows that occur intermittently (Alabaster & Lloyd, 1982; Newcombe & MacDonald, 1991; Shaw & Richardson, 2001; Berry et al., 2003). The increments in TSS concentrations at median to high flows attributable to project construction work (see ‘Macroinvertebrates’ above) are expected to be readily tolerated by fish in the Mandali River. However, the physical effects of sedimentation of riffle habitats are expected to mask the effects of increased TSS concentrations on fish.

Like invertebrates, the fish fauna is expected to recover once the source of sediment supply is removed, with recolonisation by recruitment of fry from unaffected tributaries and from upstream migration.

On this basis, the assessed minor, site-scale and short-term construction residual impacts on hydrology and water resources (Section 18.4.4.1, Construction) and water quality (Section 18.5.4.1, Construction) translate directly to the equivalent impact on the benthic macroinvertebrate fauna of the Mandali River main channel of minor in the short term at the site scale, but minimal in the medium term or longer.

Amphibians

Residual impacts on the aquatic life stages of amphibians in the main channel of the Mandali River are expected to be similar to those predicted for aquatic flora, macroinvertebrates and fish.

The project's effects on the aquatic life stages of terrestrial frogs on Hides Ridge are addressed in Section 18.4.3, Mitigation and Management Measures.

Freshwater Turtles and Crocodiles

There are six species of freshwater turtles in the river systems of the upstream project area. Most of the adults of these species tend to inhabit slow-moving river main channels (both freshwater and estuarine reaches), grassy lagoons, swamps, lakes and water holes in the lower Kikori and Omati rivers and the Kikori–Omati delta.

Both the New Guinea freshwater crocodile and the saltwater crocodile are frequently found in turbid waters of the lower reaches of the Omati and Kikori rivers, and in clear-water swamp areas of their lowland floodplains.

The residual impact assessments in Sections 18.4, Water Resources and Hydrology, and 18.5, Water Quality, predict a minimal sedimentation impact on these habitats, which equates directly to a minimal residual impact on freshwater turtles and crocodiles at the site scale or greater in the short term and longer.

Aquatic Resource Use – Subsistence Fisheries

The residual impacts of construction on subsistence fishing in the Mandali River catchment are assessed as minimal in the short term or longer. Fishing is a minor component of subsistence life and the villagers of Homa and other riparian landowners have access to similar unaffected potential subsistence fishing areas.

Any issues raised by the community in relation to resources will be subject to investigation and management under the project's grievance procedure (see Section 9.8.2, Grievance Mechanism).

18.6.4.2 Operations

Normal Operations

Aquatic impacts are dominated by fugitive sediment from earthworks, and the end of construction will mean that impacts on the aquatic ecology will rapidly decline to minimal at the site scale in the short term and beyond.

Operational discharges of treated sewage effluent and waste water from the Juha Production Facility, the Hides Gas Conditioning Plant and upgrades at the existing Kutubu facilities will comply with the conditions specified in the environment (waste discharge) permit and will be monitored for compliance with PNG receiving water quality criteria (see Table 18.15). In the short term and longer, these discharges will have a minimal residual impact on the flow regimes of receiving watercourses at the site scale or greater.

Accidental Leaks or Spillages

Measures to contain and manage any unscheduled discharges at production or processing facility sites are described in the site spill response plan to be developed prior to construction.

18.6.4.3 Residual Impact Summary

Material aquatic ecological impacts relate solely to increased suspended sediment concentrations from earthworks in the steep, landslide-prone terrain and unstable volcanic soils of the Mandali River headwaters.

Watercourses draining all other terrain types and construction sites are predicted to have minimal impacts in the short term or longer and there are no material residual impacts predicted on the watercourses of the project area during the operations.

Application of the matrix of impact magnitude vs receptor sensitivity (see Table 18.1 in Section 18.1.4, Impact Significance Matrix) for the significance of the residual impacts on aquatic ecology gives an assessment of minimal, on the basis that, while sensitivity ranges from low to very high (for Lake Kutubu), the magnitude of the impact is low (for Mandali River) or minimal.

18.7 Biodiversity

The impact analysis presented in this section is based on the biodiversity studies and overview report presented in Appendix 1, Biodiversity Impact Assessment. The overview report brings together the individual biodiversity studies, and collates the suggested lines of impact analysis and potential mitigation options and expands them into a detailed assessment of the potential physical and biological effects on terrestrial habitats, flora and fauna for the upstream component of the PNG LNG Project.

A formal process of developing mitigations was adopted; suggested mitigations from the many specialist reports produced for the PNG LNG Project were compiled and reviewed at a workshop with ecological specialists, project managers and design engineers. Each potential mitigation option was individually evaluated on its potential effectiveness, safety, practicality and cost, and based on this analysis, mitigation measures were either accepted, rejected or refined. New mitigations were also devised. The resultant mitigations were then progressively refined to produce a final set relevant to terrestrial biodiversity, which were then used to make the impact analysis presented in Appendix 1, Biodiversity Impact Assessment.

18.7.1 Residual Impact Assessment Criteria

The general approach of impact assessment is as outlined in Section 18.1, General Approach. For the biodiversity impact analysis, the magnitude of impacts were defined for three biodiversity parameters; habitat, populations and other ecological effects and are presented in Table 18.18. Table 18.19 presents the sensitivity criteria of the resource/receptor. The significance matrix is presented in Section 18.1.4, Impact Significance Matrix as Table 18.1.

Table 18.18 Magnitude of impact: biodiversity

Category	Description		
	Habitat	Populations	Other Ecological Effects (barrier effects, contamination, exotics etc.)
Very High	Large impact on substrates and habitats that will be permanent and reduce ecosystem survival and health over large areas within the project area or a local region possibly leading to system collapse. Recovery, if possible, likely to take more than 25 years, or never.	Populations will be lost from impact site and losses may cause local extinctions in a Special Area or within entire project area or region.	Impact may be widespread affecting greater than 10% of project area or local region, perhaps up to a national scale.
High	Substrates will be lost and replacement or treatment may be difficult/impossible. If replaced, succession may not lead to original habitat lost and/or degradation of habitat extends more than 1 km beyond impact site. Habitat regeneration, if allowed, will be slow and good tree cover may take up to 25 years after substrate treatment or replacement. Loss of habitat may affect up to 10% of the habitat's range within the project area or within any one Special Area.	Impacts will involve local loss of population for at least 25 years or recolonisation may never occur. Any losses of local population likely to seriously reduce chances of species persisting in a Special Area and/or would significantly reduce likelihood of species persisting in the project area or local region. No national impacts.	Impact is regional affecting up to 10% of project area or local region.
Medium	Substrates will be lost and replacement or treatment may be necessary to initiate successions. Unlikely to be long-term reduction in site capacity to support original habitat. Loss of and/or degradation of habitat extends up to 500 m beyond impact site. Regeneration will be slow and good tree cover may take up to 12 years after substrate treatment.	Impacts will involve local loss of population for up to seven years or recolonisation may never occur. However loss of the local population highly unlikely to affect survival of species within project area or region.	Detectable up to 10 km from impact site.
Low	Substrates may be disturbed or lost but habitat can readily regenerate on remaining substrate. Short-term (one to three years) reduction in site capacity to support original habitat. Impacts restricted to impact site. Habitat regeneration capable of starting within one to three years and successions likely to proceed normally to good tree cover in forest within five years after regeneration.	Impacts likely to involve loss of a portion of the local population that will reduce the chances of long-term survival in remaining habitat around the project site and species may be temporarily lost. Rapid recolonisation will occur within three years after development of successions to the stage of forest canopy closure.	Effects immediate surrounds from impact and detectable up to 2 km from impact site.
Minimal	Deleterious impacts unlikely to be detectable on habitats.	Loss of a few individuals, or home ranges may retract but unlikely to be any long-term lowering of the viability of local populations, i.e., those around the project site. Changes only detectable by population monitoring pre- and post-impact.	Not detectable.
Positive	Change is likely to benefit the species community or ecosystem. This will be detectable by rapid assessment program surveys pre- and post-impact showing occurrence of species at sites that they did not occur at before.		

Table 18.19 Sensitivity of resource/receptor: biodiversity

Category	Description	
	Sites and/or Habitats	**Species**
Very High	An internationally designated site. A Special Area within the project area. A designated national protected area e.g., Wildlife Management Area (WMA). An area with an unusually high concentration of very high and high category species. Site supports 20% or more of a national population of any species.	A population of internationally important species in IUCN category Critically Endangered.
High	A sustainable area of priority habitat identified by WWF. Habitat of particular sensitivity that is hard to restore or regenerate (focal habitat). Site supports up to 20% of national population of any species.	A population of internationally important species in IUCN categories Endangered or Vulnerable.
Medium	A local reserve. A high diversity area with a moderate concentration of very high and high category species. Site supports up to 10% of national population of any species.	A population of a species in IUCN category Near Threatened and/or classified as Protected under PNG legislation.
Low	Sites that enrich the local area. A low to moderate diversity area with a low concentration of very high and high category species.	A population of a species that is either classified by IUCN as Data Deficient and/or as Restricted under PNG legislation.
Minimal	Lower ecological value.	A population of a species that is classified by IUCN as of Least Concern or is unclassified and is not listed under PNG legislation.

18.7.2 Issues to be Addressed

For this section, impacts have been grouped into twelve and nine categories of direct and indirect impacts respectively. Table 18.20 relates these impacts to habitat and flora, and fauna, and to the construction and operations phases of the project.

Table 18.20 Relevance of impacts during construction and operations

Impact Type	Construction		Operations	
	Habitat and Flora	**Fauna**	**Habitat and Flora**	**Fauna**
Direct Impacts				
Habitat loss	X	X		
Edge effects	X	X	A	A
Barrier effects	X	X	A	A
Erosion, movement of spoil and changes to hydrology	X	X	A	A

Table 18.20 Relevance of impacts during construction and operations (cont'd)

Impact Type	Construction		Operations	
	Habitat and Flora	Fauna	Habitat and Flora	Fauna
Direct Death of Fauna				
Fauna falling in the pipe trench		X		
Project traffic and other operations		X		C
Loss of breeding and display grounds		X		A
Other				
Materials handling	X	X		C
Disposal of hydrotest water	X	X		
Dust	X	X	X	C
Noise, lights and other disturbance		X		X
Physical damage and disturbance to caves		X		X
Indirect Impacts				
Fire	X	X	I	I
Improved access to project area	X	X	I	I
Pests, Weeds and Diseases				
Dieback and other forest diseases	X	X	I	I
Invasive species - weeds	X	X	I	I
Invasive species - exotic fauna	X	X	I	I
Hunting and Collecting				
Hunting by project workers and contractors	X	X	X	X
Hunting by non-project personnel	X	X	X	X
Collecting flora by project workers and contractors	X	X	X	X
Collecting flora by non-project personnel	X	X	X	X

X = impact concentrated at this phase; C = impact continuing but at a low level; A = impact ameliorating with time; I = impact possibly increasing with time.

Definitions of direct and indirect impacts are provided in Section 18.1.2, Types of Impacts.

18.7.3 Mitigation and Management Measures

The proposed mitigation and management measures related to biodiversity are presented in Table 18.21[2].

[2] Mitigations have been slightly reworded from those found in Appendix 1, Biodiversity Impact Assessment, to match with the approved upstream mitigations table. This has involved no changes to the intent or scope of the mitigations in Appendix 1, Biodiversity Impact Assessment.

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and other Disturbance	Project Traffic and other Operations	Fire	Dieback and other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - project Personnel	Improved Access to Project Area
The standard ROW width for the project is 30 m and following construction the ROW will be allowed to naturally regenerate except for 15 m, to allow for a gap in the canopy for aerial surveillance of the pipeline. If there is a requirement to exceed the ROW design width, the contractor shall seek approval through a formal procedure from the operator [M76].	X	X	X	X		X	X	X							X											
No machinery will leave the ROW or project access roads/access ways to unnecessarily clear additional forest [M81].	X	X	X	X		X	X	X			X				X											
Clearing of riparian vegetation will be limited to the width required to safely accommodate pipeline ROW/access way and watercourse crossings. Also, the number of watercourse crossings will be reduced, to the extent practicable, to limit riparian soil erosion and sediment delivery to watercourses [M64].	X	X	X	X		X		X																		
Watercourse crossing construction management plans will be incorporated into the water management plan that addresses the sensitivities of crossings on an individual watercourse basis. Plans [M160] are to consider, where relevant: • Watercourse diversions requirements. • Disturbance limits. • Equipment limitations. • Erosion control measures. • Fine-scale routing at crossing sites to limit disturbance of particularly large and established riparian vegetation and complex bank habitat structure. • Delaying the clearing of banks of watercourses for temporary vehicle crossing until the need for the crossing is imminent, where practicable.	X	X	X	X		X		X																		

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts									
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Where practicable, trees felled into watercourses will be removed and used for revegetation works [M138].	X	X	X	X		X																				
Where practical, stabilise cleared banks to provide a suitable habitat for recolonisation [M139].	X	X	X	X		X	X	X																		
Where practicable, the pipeline ROW/access way alignment approaches to watercourses will be kept as close to right angles as possible to limit disturbances to the banks of watercourses [M140].	X	X	X	X		X	X	X																		
Wellpads will be as small as practicable, designed and located to reduce the extent of vegetation clearing and earthworks required for their construction [M66].	X	X	X	X		X									X											
The duration of construction activities at watercourse crossings will be as short as practicable [M153].	X	X	X	X		X									X											
ROWs and access ways will be located within or adjacent to existing disturbed areas where practicable [M65].	X	X	X	X		X	X	X																		
Where practicable, land clearing techniques that preserve the rootstock of removed vegetation in the ground will be used. Cleared vegetation will be spread back on to the ROW as mulch, where practicable [M74].	X	X		X		X	X	X			X															
The design criteria for ROW width on Hides Ridge, which includes the access road, is 18 m. During operations the ROW will be allowed to regenerate except for a 10 m access road required for ongoing drilling and maintenance access to the wellpads on the ridge [M77].	X	X	X	X	X	X	X	X			X				X					X						
If practical and safe, trees over 1 m dbh will be retained at camp locations [M86].	X	X	X	X		X									X											

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Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Where trees are to be felled by hand, directional felling will be used on trees >50 cm dbh so they land in natural slots between standing trees or along the axis of tracks to reduce damage to the remaining forest [M78].	X	X	X	X		X	X	X							X				X							
Machinery scraping stems of standing trees adjacent to or off the ROW will be reduced [M79].	X	X	X	X		X	X	X							X				X							
Revegetation management plans will be developed and detailed in the project's reclamation plan, which will include measures to specifically assist revegetation in areas found to be slow to revegetate naturally [M119].	X	X	X	X		X	X	X			X															
Areas requiring active revegetation will be identified [M120]: • On Hides Ridge. • In areas between Idauwi and Homa, in particular, unstable volcanic terrains.	X	X	X	X		X	X	X			X															
Fine-scale routing of the ROW/access ways will be conducted to reduce traversing particularly erosive soils on steep slopes and to limit the number of pipeline crossings of clear-water streams, sinkholes, off-channel waterbodies and other karst terrain, where practicable [M141].	X	X	X			X					X															
Stream heads in the Baia River area and elsewhere in the upstream project area above 1,800 m, will be protected to reduce entry of erosion material [M85].	X		X	X	X	X					X				X					-						
On Hides Ridge and between Hides Ridge and Juha, the route will be aligned to bypass potentially high-value conservation swamps or swamps in sinkholes <50 m deep, where practicable. At sites where this is impractical, sidecast into these high value habitats will be reduced [M82].	X		X	X		X					X				X											
No quarries beyond cut will be established on the Hides Ridge where practicable [M67].	X	X	X	X		X									X											

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
The number of quarries in operation [M68] will be minimised by: • Using previously worked (old) quarries, where practicable. • Using limestone generated by construction activities for road-base material.	X	X	X	X		X									X											
A pre-clearance survey of pinnacles will be conducted along the ROW/access ways for caves to determine presence of bat colonies and where colonies are located in proximity to the ROW/access ways, procedures to reduce disturbance will be implemented, where practicable. Potential quarry sites will not be located near caves with colonies containing protected bat species [M105].	X		X	X		X			X													X	X			
The number of special vehicle parks will be reduced and placed in areas of existing disturbance where practicable [M112].	X	X	X	X		X									X											
No construction camps will be allowed on Hides Ridges beyond Hides Wellpad A (with the exception of drilling camps) [M70].	X	X	X	X		X									X											
If a temporary drilling camp is necessary on Hides Ridge, there should be only one, located near Hides Wellpad D and used by successive drilling campaigns [M71].	X	X	X	X		X									X											
Where practicable, the use of timber felled during wellpad, pipeline, access way/ROW and facility site clearing, will be promoted for project uses [M72].	X	X	X	X		X					X															
Lights will be directed at facilities etc. to eliminate shine into surrounding forest, where security allows [M104].	X	X	X	X	X											X										
Speed limits will be controlled via posted speed limit signs on project unsealed roads and pipeline ROWs (when required) and vehicles will be kept to marked trafficable areas, which will be maintained in a damp and compacted condition (when required) to enhance safety and minimise dust emissions [M178].			X	X										X		X	X									

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Speed limits on project unsealed roads and pipeline ROWs will be controlled via posted speed limit signs, and vehicles kept to marked trafficable areas to prevent injury to fauna [M59].			X	X	X												X									
No herbicides will be used unless for the eradication of a serious invasive environmental weed [M80].	X	X	X		X	X	X	X							X											
Erosion and sediment control measures will be developed in the water management plan [M155] for all construction-related activities to: • Implement industry good practice erosion and sediment control measures at watercourse crossings, as necessary. • Prohibit stockpiling spoil and topsoil materials close to waterways (i.e., maintaining a minimum of 10 m from the waterline). • Control sediment runoff from stockpiles and cleared areas around watercourses. • Implement sediment control measures downstream of sidecast material where safe and practicable. • Limit erosion and sediment delivery to streams from new quarries. • Prohibit sidecasting material directly into waterways where practicable. • Grade pipeline ROW/access way alignments adjacent to streams away from watercourses. • Monitor and maintain erosion and sediment control measures until adequate soil stabilisation has been achieved. • Install diversion drains to intercept uncontaminated surface runoff around facilities and away from construction areas. • Install sediment control structures to intercept sediment-laden surface runoff to reduce sediment delivery to watercourses. • Monitor for and rectify areas of problematic erosion at reclaimed watercourse crossings.	X	X	X	X	X	X					X				X					X						

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
At Hides Ridge, hydrotest water sourced off the ridge will be discharged into the same watershed as its source to prevent cross-contamination with live organisms from another catchment [M51].	X	X	X	X									X							X	X					
Disposal of any waste into forest, streams or sinkholes will be prohibited [M92].	X	X	X	X	X							X														
Dispose of drilling fluids, drilling cuttings and other drilling materials in an appropriate manner away from Hides Ridge [M93].	X	X	X	X								X														
Wastes from ROW/access way construction activities (not spoil) and camps (including the drilling camp) will be disposed away from Hides Ridge [M94].			X			X						X			X											
Waste management procedures will be established to control and appropriately manage all non-biodegradable materials. [M95].			X	X	X							X														
Sewage will be managed appropriately to limit environmental contamination [M96].	X	X	X	X	X							X														
Organic waste will be incinerated and then buried at specified sites [M97].	X	X	X	X	X							X														
Fuel, lubricating oils and chemicals will be stored in appropriately sized designated areas that have impervious liners and bunds, or are in double hulled tanks. This includes temporary fuel stores along the ROW and access roads [M146].	X	X	X	X	X							X														
Washdown or fuel handling will be prohibited near or in streams [M99].	X	X	X	X	X							X														
Appropriate fuel handling transport and storage procedures will be established in EMPs [M100].	X	X	X	X	X							X														
Appropriate materials handling, storage and disposal procedures will be established in EMPs [M101].	X	X	X	X	X							X														
Appropriate storage and handling of radioactive material techniques will be established in EMPs [M102].	X	X	X	X	X							X														

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Appropriate waste handling procedures will be established in EMPs [M103].	X	X	X	X	X							X														
Industry good practice for construction camps will also apply to management of environmental effects from temporary fly camps and pioneer camps [M73].	X	X	X	X		X													X	X	X	X		X		
The potential Bulmer's fruit-bat colony near Angore will be investigated and, should a colony be found near Angore or elsewhere in the project area, a management plan will be designed and implemented [M106].	X		X	X	X	X			X																	
Cave management protocols for worker and contractor inductions will be established to prohibit unnecessary disturbance of bat colonies by project workers [M107].			X	X		X			X													X				
Restricting access to caves with bats will be considered to prohibit unnecessary disturbance by project workers [M108].			X	X		X			X													X				
Blasting within 100 m of known colonies of cave bats will be limited or controlled (where practicable) [M109].			X	X		X			X																	
Grade 1 bat surveys will be conducted where practicable prior to construction in areas likely to be inhabited by bats, grade 2 bat surveys in areas where blasting is contemplated, and grade 3 bat surveys where required (after checking with the local community for presence of bat caves near the route) to limit disturbance [M110].	X		X	X		X			X																	
Where safe and practicable, the open pipeline trench will be patrolled to rescue and record fauna that fall into the trench [M56].			X	X						X																
Procedures to prohibit PNG LNG Project workers or contractors disturbing bird-of-paradise and bowerbird display grounds or trees identified next to the ROW, will be established. A pre-clearance survey will be conducted to identify such sites [M87].			X	X	X										X							X				

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Disturbance/harassment of wildlife, hunting of fauna, gathering of plants or bush foods, or possession of wildlife products by project workers or contractors while working, travelling in project vehicles, and residing in project field accommodation will be prohibited [M57].			X	X	X				X													X		X	X	
Appropriate inductions to encourage staff to comply with hunting and collecting regulations will be implemented [M58].			X	X	X						X											X		X	X	
Procedures will be established to prohibit PNG LNG Project workers or contractors from establishing any gardens or introducing or transporting any plants, seeds or animals within the project area (including the translocation of fish species) [M53].	X	X	X	X	X	X													X	X	X					
Project-wide quarantine management will to be developed and enforced, as part of the ecology, natural habitat and biodiversity management plan, encompassing personnel and freight movements in and out of, and within, the project areas, and establishing inspection and treatment standards and procedures for all freight types, including pipe and imported rock [M54].	X	X	X	X	X														X	X	X					
Weed and exotic pest control management procedures that identify foreign and invasive weed and exotic pest threats will be implemented in the ecology, natural habitat and biodiversity management plan and appropriate control measures will be taken [M118].	X	X	X	X	X														X	X	X					
Vehicle washdown facilities will be implemented and the import of exotic species, including seed into the project area, will be banned [M117].	X	X	X	X	X														X	X	X					

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Weed, exotic pest and pathogen management procedures will be established to protect the biodiversity of Hides Ridge and Juha areas. This will include establishment of chemical washdown points at or near the Hides Gas Conditioning Plant to prevent weeds and pathogens being transported to and within Hides Ridge and Juha for the life of the project. The plan will be detailed in the ecology, natural habitat and biodiversity management plan [M52].	X	X	X	X	X														X	X	X					
It will be prohibited to transport live animals, plants or seeds to the Juha or Hides Ridge areas [M50].	X	X	X	X	X														X	X	X					
If fire hazard exists, pushed vegetation will be left to rot at forest edge rather than burnt [M60].	X	X	X	X	X													X								
A bush and forest fire management plan for the construction and operations phases of the PNG LNG Project will be developed and implemented aimed at ensuring the likelihood of the project starting any wildfires is very low. The plan will include banning the burning of cleared vegetation and other fires in the montane environment in drought years [M61].	X	X	X	X	X	X									X			X								
All new project road sections constructed for logistics transfer between Kopi and the Hides Gas Conditioning Plant will have controlled access for project use only following completion of construction [M88].	X	X	X		X																	X	X	X	X	X
All ROWs/access ways between the Omati River Landfall and the Kopi bypass deviation will be made impassable at the end of project construction, and those on Hides Ridge will be made impassable at the end of the project [M89].	X	X	X																			X	X	X	X	X
Access to Hides Ridge and Juha on the Juha and Hides Ridge access ways to the west of Hides Wellpad A will be controlled and a permit system for vehicle access over the lifetime of the project will be implemented [M90].	X	X	X		X																	X	X	X	X	X

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Pipeline security procedures will be established, including procedures for heavy logging trucks on road sections where the pipeline is buried [M91].	X	X	X	X	X																					X
The conservation activities of environmental non-government organisations in the project area will be encouraged [M62].	X	X	X		X													X	X	X	X		X		X	X
Conservation education in villages in the project area will be encouraged [M63].	X	X	X	X	X													X	X	X	X		X		X	X
The extent of clearing and earthworks along the ROW will be limited and the time for which surfaces are exposed prior to natural revegetation will be reduced to the extent practicable [M75].	X	X	X	X	X	X	X	X			X			X												
The temporary Juha drilling camp will be located within the footprint of the Juha Production Facility [M83].	X	X	X	X		X									X											
The temporary Angore drilling camp will be located within the footprint of the Hides Gas Conditioning Plant [M84].	X	X	X	X		X									X											
As part of the use of renewable resources plan, develop an approved chain of custody for timber sourced for the project, to assist in limiting the use of illegally harvested timber [M113].	X			X	X	X																		X	X	X
Management procedures to reduce impacts on *Nothofagus* forest and the spread of dieback will be developed in the ecology, natural habitat and biodiversity management plan, designed to allow adequate surface and subsurface flows and avoid redirection of stream flows where practicable [M116].	X	X	X	X		X	X												X							

Table 18.21 Proposed mitigation and management measures in relation to biodiversity impacts (cont'd)

Proposed Mitigation or Management Measures	Biodiversity Element			Project Activity		Direct Impacts												Indirect Impacts								
	Habitat	Flora	Fauna	Construction	Operations	Habitat Loss	Edge Effects	Barrier Effects	Physical Damage and Disturbance to Caves	Fauna Falling in the Pipe Trench	Erosion, Movement of Spoil and Changes to Hydrology	Material Handling	Disposal of Hydrotest Water	Dust	Loss of Breeding and Display Grounds	Noise, Lights and Other Disturbance	Project Traffic and Other Operations	Fire	Dieback and Other Forest Diseases	Invasive Species – Weeds	Invasive Species – Exotic Fauna	Hunting by Project Workers and Contractors	Hunting by Non - Project Personnel	Collecting Flora by Project Workers and Contractors	Collecting Flora by Non - Project Personnel	Improved Access to Project Area
Hydrotest disposal management [M145] will be developed in the water management plan that includes adherence to guidelines and measures as follows: • Disposal of hydrotest waters in accordance with industry good practice engineering codes for system gauging, hydrotesting and disposal. • Measures to hold and treat hydrotest waste water where necessary prior to release so the quality meets the requirements of the relevant water discharge permit. • Pre-discharge sampling and analysis of hydrotest water to check that quality complies with the conditions attached to the relevant water discharge permit. • If the waste water is to be discharged to land for infiltration, the outflow energies will be dissipated (e.g., via sprinkler or T-bar arrangements) to prevent problematic soil erosion.	X		X	X									X													
Procedures for vehicle/equipment refuelling will be implemented to prevent spillages, and appropriate spill containment equipment will be available at refuelling sites and construction sites. All drivers will be appropriately trained in emergency spill response procedures [M147].	X	X	X	X	X							X														

18.7.4 Residual Impact Assessment

The discussion of residual impacts associated with biodiversity is structured as follows. Section 18.7.4.1 analyses the direct residual impacts, Section 18.7.4.2, the indirect residual impacts, Section 18.7.4.3, the residual impacts on noteworthy areas, Section 18.7.4.4, impacts on conservation areas, Section 18.7.4.5, residual impacts on listed species and Section 18.7.4.6, residual impacts on migratory fauna. Section 18.7.4.7 presents an overall conclusion related to terrestrial biodiversity residual impacts.

18.7.4.1 Direct Impacts on Habitats, Flora and Fauna During Construction and Operations

Direct Impacts of Habitat Loss

Habitat will be lost through clearing for the pipeline ROWs, access roads, temporary camps, gas wellpads, new facilities, laydown areas, quarries and wharves. Table 18.22 presents areas lost to the major components of the project. These figures are approximate and may vary by 15% to 20% depending upon the final configuration of the project.

Table 18.22 Estimated habitat losses produced by the upstream component of the project

Project Component	Primary Tropical Forest (ha)	Primary Tropical Forest but with Some Disturbance (ha)	Late Secondary or Heavily Disturbed Primary (ha)	Degraded Areas* (ha)	Total (ha)	% Primary Lost to Component	% Contribution to Total Losses	% Contribution to Primary Losses
ROWs	899	386	238	738	2,261	39.8%	80.4%	85.1%
Heartbreak Hill road route	100	20	1	1	122	81.2%	4.4%	9.5%
Logistics road along crude export oil pipeline ROW	0	0	0	148	148	0.0%	5.3%	0.0%
Wellpads	14	2	4	6	26	53.8%	0.9%	1.3%
Juha Processing Facility	31	0	0	0	31	100.0%	1.1%	3.0%
Hides Gas Conditioning Plant	0	0	0	78	78	0.0%	2.8%	0.0%
Other**	11	17	45	70	143	8.0%	5.1%	1.1%
Totals	**1,055**	**425**	**288**	**1,041**	**2,809**		**100.0%**	**100.0%**

* Includes gardens and secondary complexes, logged forest, existing facility areas, pioneer and early secondary growth.
** Temporary camps, pipeyards, laydown areas, etc.

A total of approximately 2,809 ha will be cleared, half in areas not previously disturbed by oil and gas developments[3] and half in areas previously impacted by the oil project. Of this cleared land, 37% will be in degraded areas such as pioneer and early secondary areas, garden complexes and logged forest and 38% will be in primary tropical or Class A1 forest (i.e., more-or-less undisturbed primary tropical forest (see Appendix 1, Biodiversity Impact Assessment). A further 15% of clearing will be in disturbed primary or Class A2 forest that, although retaining most primary tropical forest characteristics, has been disturbed in the recent past either naturally by

[3]This includes areas where flowlines were hand-built and wells were drilled using helicopter access.

landslides for example or by humans. The remaining losses (10%) will be in late secondary or heavily disturbed primary forests, which have much poorer structure than primary forest but retain high biodiversity values. An estimated 69% of the primary tropical forest (Class A1) losses will be in areas not previously disturbed by oil and gas developments.

The project components contributing most to the loss of primary tropical forest are:

- The pipelines between the Juha Production Facility and Hides Gas Conditioning Plant (27% of the total loss of primary tropical forest).
- The Hides Spineline ROW (9%).
- The LNG Project Gas Pipeline ROW from the Benaria River to Lake Kutubu (23%).
- The Heartbreak Hill logistics road route (9%).
- The LNG Project Gas Pipeline ROW from the Kikori River crossing to the Omati River Landfall (8%).

Between them, these five project elements account for three quarters of predicted total primary tropical forest (Class A1) losses.

An estimated 86% of primary tropical forest losses (919 ha) and 82% of losses in Classes A1 and A2 (1,220 ha) are concentrated in five broad vegetation groups (BVGs): lower montane small-crowned forest, lower montane small-crowned forest with *Nothofagus*, lower montane very small–crowned forest complexes with *Nothofagus*, medium-crowned to small-crowned forest complexes, and low-altitude medium-crowned forest. No BVG within the upstream component of the project area is predicted to lose more than 0.25% of its total area.

It is not possible to express the primary tropical forest losses as a percentage of primary tropical forest within the entire upstream project area or any bioregion or any BVG because there is no current information on the amount of primary tropical forests in those areas. However, it is possible to examine total losses, irrespective of condition, and none exceeds 0.25% of any BVG within the upstream project area (Table 18.23), indicating that no particular vegetation type is put at conservation risk by clearing for the upstream part of the project. The BVGs are mapped in Figure 10.12.

Table 18.23 Estimated habitat losses within BVGs produced by the upstream component of the project

Broad Vegetation Group (BVG)	Area (ha) of BVG in Project Area	Estimated Losses (ha)	%
Montane forest (>3,000 m) with/without grassland	6,410	0	0%
Grasslands	34,631	0	0%
Scrub	1,964	0	0%
Lower montane small-crowned forest	218,897	423	0.19%
Lower montane small-crowned forest with conifers	26,417	0	0%

Table 18.23 Estimated habitat losses within BVGs produced by the upstream component of the project (cont'd)

Broad Vegetation Group (BVG)	Area (ha) of BVG in Project Area	Estimated Losses (ha)	%
Lower montane small-crowned forest with *Nothofagus*	197,725	467	0.24%
Lower montane very-small-crowned forest complexes	33,372	0	0%
Lower montane very-small-crowned forest complexes with *Nothofagus*	98,894	181	0.18%
Medium crowned to small-crowned forest complexes	579,184	688	0.19%
Medium crowned to small-crowned forest complexes with *Nothofagus*	55,585	139	0.25%
Low altitude large-crowned forest	38,277	0	0%
Low altitude medium-crowned forest	491,041	540	0.11%
Low altitude small-crowned forest with *Nothofagus*	4,517	10	0.22%
Large to medium-crowned lowland forest	6,279	0	0%
Small-crowned lowland forest	55,475	72	0.13%
Open lowland forest	38,938	91	0.23%
Open lowland forests and freshwater swamps	6,750	4	0.06%
Swamp forest complexes	77,152	57	0.07%
Swamp woodland and forest complexes	24,036	42	0.17%
Mangroves	124,327	0	0%
Non-forested areas	126,789	100	0.08%
Rivers or lakes	18,434	0	0%
Grand Total	**2,265,096**	**2,811**	**0.12%**

Three bioregions (Seribi Lowlands, Libano-Hegigio and the Darai Plateau, see Figure 10.11) will not be affected by clearing. The small Iagafu-Agogo Limestone Uplands and the Moro Region bioregions, where the oil facilities are located, will lose 0.98% and 0.58% of their vegetation respectively. The Western Lowlands will lose a similar percentage to the Moro region but the latter is a small discrete area around Lake Kutubu, whereas the former is a part of a more extensive region that extends to the west and south. The data suggest no bioregion will be put at conservation risk by clearing for the project (Table 18.24).

Table 18.24 Estimated habitat losses (ha) from the 12 bioregions

	Kikori Lowlands	Seribi Lowlands	Libano-Hegigio	Darai Plateau	Western Lowlands	Western Foothills	Mubi River Karst	Moro Region	Iagafu-Agogo Limestone Uplands	Western Volcanics	Eastern Upland Volcanics/ Karst	Northern Montane Karst	Total
Area of vegetation in bioregion	773,405	97,077	80,234	178,520	50,616	41,381	283,689	23,973	33,617	178,471	415,791	108,322	2,265,096
Primary forest	176	0	0	0	20	208	110	52	125	60	193	111	1,056
Primary forest but with some disturbance	55	0	0	0	0	0	34	68	183	11	51	22	424
Late secondary or heavily disturbed primary forest	53	0	0	0	0	29	61	2	2	7	112	22	288
Other*	414	0	0	0	0	2	232	13	20	151	192	19	1,042
Total of habitat losses	698	0	0	0	21	238	437	135	331	230	548	175	2,811
% of vegetation lost from bioregion	0.09%	0%	0%	0%	0.04%	0.58%	0.15%	0.56%	0.98%	0.13%	0.13%	0.16%	0.12%

* Includes pioneer/early secondary, gardens, secondary complexes, logged forest and existing facility areas. Also includes river surfaces.

Forest disturbance *per se* need not necessarily have a major impact since tropical forest dynamics depend upon disturbance of some sort. New Guinea forests in general tolerate disturbances, such as those caused by natural tree falls and landslides. If clearing mimics these regional phenomena, there need not be any permanent change to forest landscape dynamics and overall habitat persistence. Permanent deforestation comes about when substrates are irrevocably altered or when disturbance regimes produce continuous and expanding loss of habitat. Mitigations have therefore focused on restricting clearing beyond that strictly required for project construction by avoiding unnecessary expansion of the ROW, unnecessary vehicle movements into the forest, sidecasting spoil and felling trees into the forest at the edge of clearings. Some 43 mitigations are specifically designed to prevent expansion of clearing (see Table 18.21).

Stream banks and riverine vegetation generally support a specific biota. Eight of the mitigations for clearing are designed to control clearing at river crossings and focussed as much on the small creeks higher up the catchment as on the major rivers because, in terms of biodiversity, stream heads, particularly at high altitude, are of high biodiversity value.

When assessing impacts the following are relevant:

- An estimated 90% of the clearing is in a long thin line and not concentrated in any particular zone of the project area.
- Of the remaining areas to be cleared, the Juha Processing Facility will produce the largest single loss of primary forest (31 ha). No other patch of clearing is over 15 ha.
- These losses are not designed to be permanent. While the project logistics roads will remain open, the ROW will be allowed to revegetate for all but 15 m over the pipe (10 m on Hides), and the shoo-fly roads, temporary construction camps and laydown areas will be restored or allowed to regenerate (see Plates 18.1 to 18.5). This means that 76% and 80% respectively of the areas of primary forest (Class A1) and disturbed primary forest (Class A2) cleared will start to regenerate within one or two years after disturbance. Within 30 years (at project end), evidence from regeneration on the existing crude oil pipeline ROW (see Section 18.2.3, Regeneration Potential Context) indicates that this will have regenerated to late secondary forest with high biodiversity values. The remaining cleared areas that will be decommissioned at project end will then start regenerating.
- No open wetlands will be lost, although closed canopy swamp woodland and forest complexes will be cleared in the Kopi to Omati segment of the ROW.
- Previous experience with the civil works for the oil project has shown that most (97%) of the area that has been allowed to regenerate along the crude oil export pipeline is regenerating well (see Section 18.2.3, Regeneration Potential Context, and Appendix 8, Soils and Rehabilitation Impact Assessment). Soil-dominated surfaces, the dominant substrate through gentle terrain, and limestone cuttings rehabilitate adequately; but limestone pavement, rubble and sidecast rehabilitate poorly (see Plates 18.6 and 18.7) and mitigations have been designed to assist regeneration in these difficult terrains.

Residual Impact of Habitat Loss

The magnitude of the impact of habitat loss on habitat, flora and fauna is estimated to be minimal following implementation of the mitigation and management measures. Considering the sensitivity of the upstream project area as very high, the residual impact significance of loss of habitat after mitigation is predicted to be minimal.

Direct Impacts of Edge and Barrier Effects

Edge and barrier effects occur in forest that abuts cleared areas such as the pipeline ROWs and can result in degradation of biodiversity and ecological values within the forest beyond the area of clearing.

Edge effects occur where two dissimilar habitats, in this case forest and cleared ROW, abut each other: each influences the other along the boundary, and physiological and ecological effects can propagate from the edge several hundred metres into the forest. This can produce continued degradation of forest adjacent to the edge and possible retreat of the forest edge.

Edge effects in primary tropical forest include the sun and wind drying out the edge, the increase of wind throw of trees close to the edge, and changes to the forest microclimate away from the edge. The ground layer desiccates, and the forest edge becomes more susceptible to fire. This phenomenon is exacerbated where there is a wide cleared area next to the forest and on steep slopes exposed to the wind above cuttings.

Weeds, exotics and flora and fauna adapted to drier habitats and secondary forest can penetrate the forest along these edges and primary forest specialist fauna tend to retreat from the forest edge as it dries out and becomes lighter.

Experience with the oil project indicates that, below about 1,800 m altitude, the forest edge rapidly seals over and edge effects are temporary, particularly in volcanic areas (such as between the Maruba and Mandali Rivers) and alluvial areas (for example, between the Kikori River crossing and Omati). In areas difficult or slow to regenerate, particularly the high-altitude karst where cold conditions reduces growth rates, edge effects are more persistent.

Severe edge effects that promote retreat of the forest edge are more likely where the edge has been severely damaged by construction activities, where edges are very exposed (such as on top of high, wide cuttings), or where linear clearings surround small blocks of forest (such as between hairpin bends).

Most of the mitigations for forest clearing (see Table 18.21) can reduce edge effects because they focus on reducing damage to the standing forest adjacent to the ROW. However the most effective mitigations are those that allow the ROW to regenerate except for a narrow area over the pipelines.

Barrier effects are related to edge effects and occur where a strip of non-forest habitat acts as a barrier to movement of forest fauna, pollen and seeds. The important issue is whether the barrier effect is 100% and splits the population into subpopulations, each with a reduced chance of survival. Rivers provide barriers to many forest animals, and long linear clearings in forest provide another, particularly to specialist primary forest species.

Barrier effects have been demonstrated for a wide range of animals; those with a particular aversion to crossing linear gaps such as roads include specialist terrestrial and arboreal marsupials, primary forest birds and several reptiles and amphibians.

An untrafficked ROW does not present the same barrier effect as a road, in that a road's barrier effect is exacerbated by the dangers of vehicular movements. Nonetheless, all linear cleared corridors present some kind of barrier to many species.

Barrier effects can be mitigated by maintaining as narrow a cleared ROW as possible, allowing the ROW and access roads to regenerate as far as possible, and, ideally allowing the canopy to close wherever possible. Most of the mitigations for clearing and edge effects (see Table 18.21) are useful in reducing barrier effects; but, for the life of the project, canopy closure will not be allowed on the ROWs. However, the ROWs will be allowed to regenerate and the residual gap will be 15 m (10 m on Hides Ridge), a distance that is predicted to not present a significant barrier to movement of spores, pollen, dispersers of seeds, or to any other fauna, especially as the gap will not be over bare ground but instead kept free of tree canopy. Leaf litter will accumulate in this gap, and shrub and small tree growth will occur. Although some species may still be reticent about crossing such gaps, it is likely to be only a few and it is unlikely that inhibition will reach 100%.

Where the logistics track and a ROW are side by side and in very steep terrain where big cuts are required, a wider clearing will result, and edge effects and barrier effects will be more severe. If the ROW and logistics road are offset, there will be two narrower clearings. Edge effects will erode the ecological and biodiversity qualities of the intervening strip, but it is likely to reduce edge effects on the forest on either side of the clearings and reduce barrier effects by providing a stepping-stone to cross the ROW-road combination.

Residual Impacts of Edge and Barrier Effects

Considering that in most areas the pipeline construction disturbance area width will be 35 m or less, that 20 m of this will be allowed to regenerate, and that where they are in close proximity, roads and ROWs will be offset, the magnitude of the impact of edge effects after mitigation is estimated to be minimal for flora and fauna in most areas, and low in high-altitude karst areas for fauna. Considering the sensitivity of the upstream project area as very high, the residual impact significance after mitigation of edge effects is predicted to be minimal in most areas for fauna and flora and moderate in high-altitude karst areas for fauna.

The narrow ROW after regeneration is predicted to present no significant barrier to movement of spores or pollen and most fauna. Therefore the magnitude of the impact of barrier effects on flora and most fauna over large sections of the ROWs is estimated to be minimal following mitigation. Considering the upstream project area as a very high sensitivity receptor, the overall significance of the residual impact after mitigation of barrier effects on flora and most fauna is predicted to be minimal.

However, there are some fauna species where the barrier effects may be more severe. These include some arboreal mammals inhabiting higher elevations (which rarely if ever come to the ground and need canopy connections), microhylid frogs at upper elevations (which may have difficulty crossing dry roads), and in high, very rugged areas, wide cuts will intensify any barrier effect due to the steep, bare batters. The barrier effect for these fauna and in these areas may be harder to mitigate, particularly at large cuttings, but it is unlikely that the effect is capable of splitting a local population into two subpopulations. The high cuttings inevitably give way to less severe terrain and there will always be places where the ROW will be narrow enough to allow movements across it.

In these special circumstances, the magnitude of the impact of barrier effects on fauna is estimated to be medium.

Considering the fauna and flora of the upstream project area as a very high receptor, the overall significance of the residual impact after mitigation of barrier effects is predicted to be minimal for most areas and species and moderate for arboreal species in high karst areas and for many species at high, wide cuttings. None of these impacts are likely to eliminate any species or population from the upstream project area or any bioregion.

Direct Impacts from Erosion, Movement of Spoil and Changes to Hydrology

The effects of habitat loss and edge and barrier effects can be exacerbated by erosion, sidecasting and dumping of spoil. Cuts for roads and ROWs in very steep areas will result in sidecast material eliminating more forest, thus increasing the real width of clearing and increasing the width of any barrier to faunal movement. The losses of habitat in Tables 18.20, 18.22 and 18.23 have taken account of extra forest loss through sidecast.

Hydrological changes, brought about by sidecast, causeways or roads damming areas or promoting drainage of others can have impacts on some terrestrial habitats; dryland forests die if flooded, swamp forest complexes and swamp woodland and forest complexes may die if the dynamics of flooding and drying are altered, and floodplain forests will die if flooded for too long (see Appendix 1, Biodiversity Impact Assessment). Although flooding at the wrong time can impact terrestrial biota directly through changes in seasonal and breeding cycles, the major potential hydrological impacting mechanism would be habitat loss. Species adapted to swamp woodland and forest complexes, such as New Guinea flightless rail, are most at risk.

Seven of the mitigations in Table 18.21 are relevant to reducing impacts of erosion and sidecast and most important are those related to routing and the development of an erosion and sediment control plan.

Residual Impacts from Erosion, Movement of Spoil and Changes to Hydrology

In most areas, sidecast will regenerate and stabilise so habitat loss and increased barrier effects produced by this phenomenon will ameliorate over the medium term. However, regeneration will be slow, or forest will be replaced by grasses on some sites. These sites can act as foci to carry fire in dry years and are areas of potential instability where forest erosion through fire can occur. Mitigation aimed at stabilising and/or promoting regeneration of these sites through revegetation measures that will be detailed in the reclamation plan (see Table 18.21) is predicted to reduce this potential considerably. Revegetation procedures will also assist in reducing any enhanced barrier effect on fauna.

Overall the magnitude of the impacts after mitigation on habitat, flora and most fauna is estimated to be minimal and the sensitivity (as stated above) is very high. Where barrier effects are enhanced in the special circumstances discussed in ‘Direct Impacts of Edge and Barrier Effects’ above, the magnitude of impact on those fauna is estimated to be medium after mitigation and regeneration of the ROW.

Considering the upstream project area as a very high receptor, the residual impact significance after mitigation of erosion, movement of soil and spoil, and changes to hydrology effects is predicted to be minimal for most areas and species and moderate for arboreal species in high-altitude karst areas and for many species at high wide cuttings. None of these impacts are likely to eliminate any species or population from the upstream project area or any bioregion.

Direct Impacts of Death of Fauna

Fauna can be affected directly by falling in the pipe trench and perishing, being killed by traffic or losing special breeding or display grounds.

Fauna that may fall in the pipe trench include mostly reptiles, frogs, small mammals and flightless birds. The pipe trench may be up to 2 m deep and there will be ramps to assist egress in many places allowing fauna to escape. The trench will also be patrolled to rescue any fauna trapped.

Fauna deaths due to traffic can be mitigated by traffic and speed controls (see Table 18.21).

Birds-of-paradise and bowerbirds use display areas, trees or specially prepared sites on the ground, which are often traditional and form breeding epicentres for local populations of species (Appendix 1, Biodiversity Impact Assessment). Display grounds can cover several hundred hectares with widely dispersed bowers or display sites, sometimes strung along a narrow ridge (as cited in Appendix 1, Biodiversity Impact Assessment). A road or ROW can disturb a portion of such places. Twenty-one mitigations (see Table 18.21) are useful in reducing this impact, including one specifically designed to protect such sites next to the ROWs.

Residual Impacts of Death of Fauna

The magnitude of impacts of fauna falling in the pipe trench and of the loss of breeding and display grounds is estimated to be minimal after mitigation, while the magnitude of impacts on fauna being killed by traffic after mitigation is estimated to be minimal.

Considering the fauna of the upstream project area in general to be a very high receptor, the residual impact significance of direct deaths of fauna is predicted to be minimal.

Other Direct Impacts

Other impacts on flora and fauna include spills from materials handling, disposal of hydrotest water, dust, noise, lights and other disturbances, and physical damage and disturbance to caves.

Biota can be directly impacted by contacting or ingesting spilt fuels, oils, chemicals, radioactive isotopes and/or solid and liquid wastes. Fauna can also become trapped by wire and other abandoned hardware. If contaminants enter streams, they can impact on frogs and during construction there is the potential for contaminating materials to enter sinkhole swamps or off-river waterbodies. The effects are likely to be local and limited except in the Hides Ridge Special Area where these sinkhole swamps support many hylid frogs. Large accidental spills from fuel tankers are a major potential impact during construction and adequate emergency response procedures will be important.

Numerous mitigations have been devised to reduce impacts from these sources (see Table 18.21).

Hydrotest water can contain biocides, oxygen scavengers and other additives so their disposal presents two special issues: impacts of biocides on fauna such as amphibians through residual toxicity at the point of discharge and the translocation of organisms.

Biocides in the hydrotest water at the point of discharge (if to upstream rivers) have the potential to impact on receiving water organisms such as amphibians but, on the other hand, hydrotest water without biocides could allow the transport of living organisms, including pathogens, between stream catchments (i.e., translocation). It is not only exotic species that are of concern; cross-contamination of streams with native species also serves to break down the natural biodiversity patterns in remote, relatively undisturbed areas like the project area.

Two significant mitigations in Table 18.21 are designed to manage hydrotest water issues. In general, the transport of contaminating organism is the more important ecological issue, so hydrotest water will be discharged in the catchments of origin.

Dust may coat the leaves of plants along the forest edge and reduce photosynthesis but the frequent rainstorms in the upstream project area will wash the dust away and make this impact temporary.

Terrestrial fauna adapt readily to noise but lights can affect the behaviour of nocturnal birds. Experience with the existing oil and gas facilities show that fauna have not been impacted by noise and lights. Any disturbance to fauna causing them to retreat from construction sites will be temporary and fauna will return to the site as long as indirect impacts are controlled.

Direct disturbance by humans does impact on fauna, and lack of such disturbance is a major factor in maintaining the high biodiversity values that occur in the upstream project area alongside the existing oil and gas facilities.

The mitigation relevant to noise and lights in Table 18.21 relates to placement and direction of lights.

Cave disturbance or damage, caused by hunting, construction and blasting, can impact on roosting and/or breeding bats. Reducing the impacts on caves may be generally achieved by conducting bat surveys as part of preconstruction surveys in areas likely to be inhabited by bats and in areas where blasting is proposed. Cave management protocols for worker and contractor inductions will be established to prohibit unnecessary disturbance of bat colonies by project workers.

Other Residual Impacts

The magnitude of the impact of materials handling, hydrotest water, dust, lights, noise, and cave fauna are all estimated to be minimal after mitigation.

Considering the fauna and flora of the upstream project area as a very high receptor, the overall significance of the residual impact of these other impacts after mitigation is predicted to be minimal.

18.7.4.2 Indirect Impacts on Habitats, Flora and Fauna During Construction and Operations

Appendix 1, Biodiversity Impact Assessment, concluded that indirect impacts are likely to be of far greater significance than direct impacts. Indirect impacts can come from construction and operations of the project itself and from the increased access that roading could allow.

The major potential indirect impacts are fire, the introduction of exotic weeds, fauna and pathogens, hunting, collection of flora and forest products and improved access to the project area increasing the potential for forest loss and degradation.

Indirect Impacts of Fire

Fire is a potent factor in tropical forests and, during drier periods, even very wet forests can burn. Broad-scale fires are not uncommon in New Guinea, occurring mostly in El Niño years, but can be catastrophic events with long-term, widespread effects that often involve permanent deforestation.

Fire in the forests on karst pavements, swamp forest complexes and swamp woodland and forest complexes could burn away the organic soil layer and root mat leaving bare rock or subsoil, upon which regeneration of the original vegetation would be impossible or very slow. It is not known how the upland *Nothofagus* forests in the Hides Ridge Special Area would respond to fire.

The length of the project footprint means that propagation of wildfires from points along the ROW has the potential to promote widespread ecosystem degradation over large areas of the upstream project area should such fires spread. The mitigations in Table 18.21, particularly the development of a fire management plan, are designed to help prevent such occurrences resulting from project activities during construction and operations.

Residual Impact of Fire

The magnitude of the impact of fire is estimated to be low after mitigation. Considering the upstream project area as a very high receptor, the overall significance of the residual impact of fire is predicted to be moderate.

Indirect Impacts of Pests, Weeds and Diseases

The spread of noxious and undesirable organisms is a global ecological problem and, because of the enormous amount of material to be imported, volumes of project traffic, large workforce, length of the project footprint and long period of construction activities, the project presents a unique opportunity for exotic weeds and fauna and introduced diseases to invade and spread. Because the project traverses such a large area of Papua New Guinea and penetrates into previously undeveloped areas, this may be one of the greater potential impacts in the upstream project area.

Unlike direct habitat loss, which generally acts at a local level, pests, weeds and diseases can spread and have landscape wide effects.

Invasive Species – Exotic Fauna

Accidentally or deliberately introduced invasive animals can be serious environmental and/or agricultural pests and can have far reaching landscape impacts. Species such as small Indian mongoose (*Herpestes javanicus),* rosy wolfsnail (*Euglandina rosea*), slider turtle (*Trachemys scripta elegans*) and cane toad (*Bufo marinus*) have had a major impact in tropical areas. Of particular concern is the spread of the crazy ant (*Anoplolepis gracilipes*) now established in Australia and the crab-eating macaque (*Macaca fascicularis*) established in West Irian.

The mitigations relevant to quarantine and control of pests, weeds and diseases in Table 18.21 include exotic fauna as a mitigation target.

Invasive Species – Weeds

Exotic weeds present serious environmental problems worldwide, some, such as *Piper aduncum*, are capable of altering even forest habitats. Such species are not yet present in the upland forests of the upstream project area but once weeds penetrate native habitats they can bring about permanent changes including major changes to ecology and biodiversity. Intact tropical forests tend to be resistant to invasion and it is a problem usually associated with opening up of forests by roads and clearing (Appendix 1, Biodiversity Impact Assessment) allowing weeds and other exotics to enter and establish.

The potential impact of weeds is being approached in the project by quarantine and hygiene plans, designed to not only mitigate the potential introduction of exotic weeds but also to mitigate the spread of know weeds in Papua New Guinea such as *Piper aduncum.* The plans also include preventing translocation of native species since intermixing of plants from different geographic provenances can impact the integrity of local genetic resources (Appendix 1, Biodiversity Impact Assessment).

Thirteen mitigations in Table 18.21 are relevant to quarantine issues for weeds.

Dieback and Other Forest Diseases

Dieback is a serious disease caused by a range of root-rotting fungi that can kill a variety of plants and has been found in parts of the upstream project area (see Appendix 1, Biodiversity Impact Assessment). The disease manifests under a range of environmental conditions. For example drought may play an important role by stressing trees and predisposing them to infection, and in the lowlands changes to drainage patterns can produce dieback. In the highland *Nothofagus* forest where dieback patches of up to several hectares can occur, causes are less obvious and may reflect natural senescence of a stand as well as infection by fungi.

While dieback is the major focus of plant diseases in the upstream project area, there are a range of exotic diseases found elsewhere, including within Papua New Guinea, that have not yet been recorded in the upstream project area.

Eleven mitigations in Table 18.21 are relevant to impacts of dieback and other forest diseases, prominent in which are quarantine plans for the whole project and pathogen and weed management plans for Hides Ridge and the Juha area. These plans include forest hygiene plans that recognise that not only vehicles but equipment, such as chainsaws, can carry dieback spores and that the interconnected root systems of *Nothofagus* allow rapid spread of the disease beyond the initial infection point.

Residual Impacts of Pests, Weeds and Diseases

With implementation of the rigorous quarantine plans and mitigations, the magnitude of the impact of invasions and spread of weeds, diseases and exotic fauna is considered to be low. As the habitats, flora and fauna of the upstream project area are considered very high receptors, the significance of potential impacts after mitigation is moderate.

Indirect Impacts of Hunting and Collecting

Many birds and the larger mammals and turtles of Papua New Guinea suffer greatly from hunting which can drive some species to local extinction. Many of the conservation-listed species in the upstream project area (see Section 18.7.4.5, Direct and Indirect Impacts on Listed Species During Construction and Operations) are threatened by hunting. Sustained collection of specific plants (e.g., orchids), firewood or construction timber in small areas such as around camps may cause local extinctions of some species, thereby degrading local habitat.

Experience with the management of the present oil and gas facilities has shown that heavily hunted species difficult to see elsewhere in Papua New Guinea remain abundant near the oil facilities. For example Pesquet’s parrots and birds-of-paradise are still common alongside the facilities at Kutubu and southern cassowaries are numerous between the Kaiam and Mubi crossings.

Five mitigations in Table 18.21 are designed to prohibit hunting and collecting by project personnel.

Residual Impacts of Hunting and Collecting

The magnitude of the potential impact of hunting and collecting by project staff and contractors is estimated to be minimal on fauna and flora after mitigation. Considering the habitats, flora and fauna of the upstream project area to be very high receptors, the overall significance of the residual impact after mitigation is predicted to be minimal.

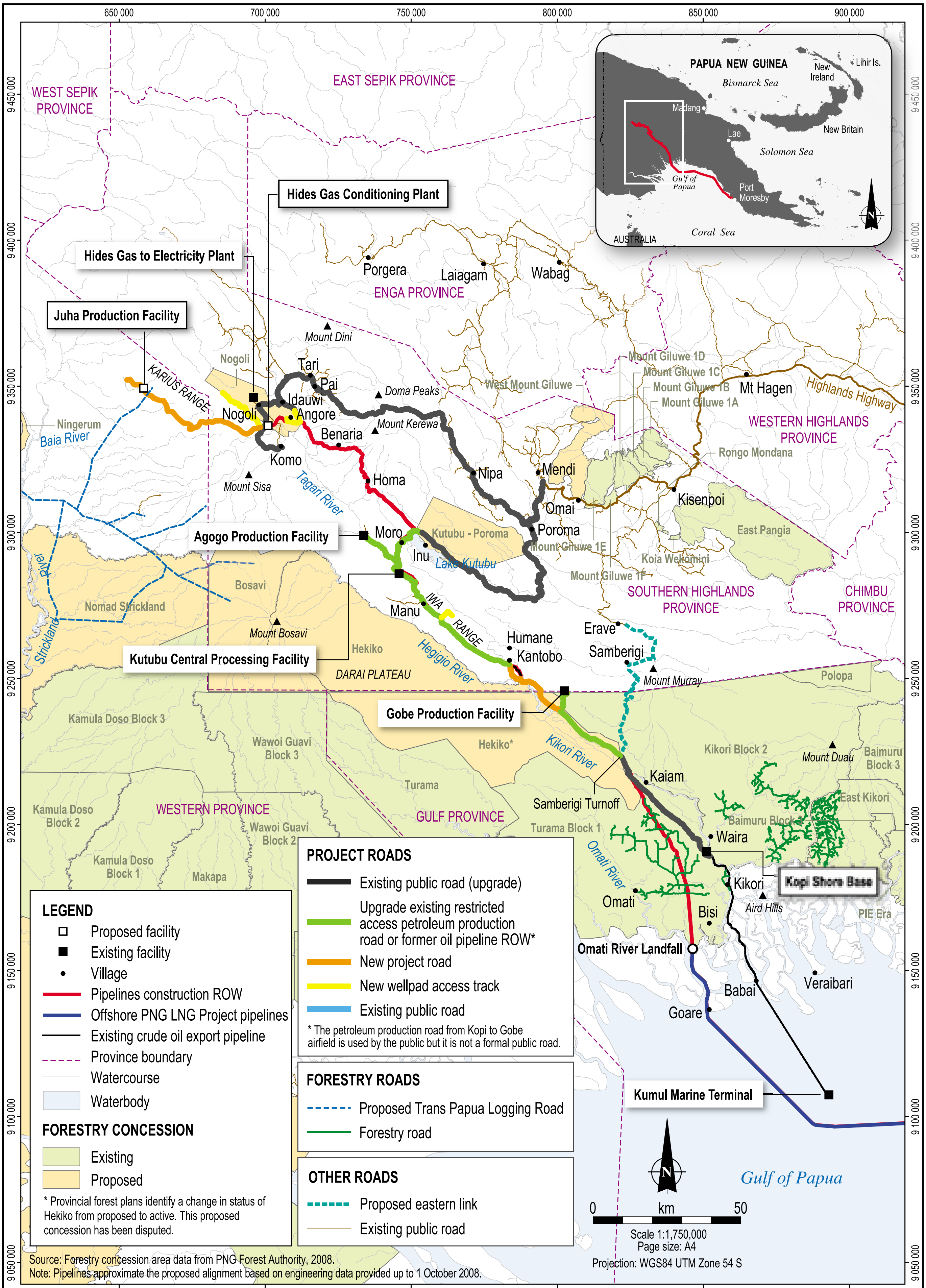
Indirect Impacts of Improved Access

Isolation and difficulty of access have probably been the most important factors maintaining the ecological integrity of the upstream project area and all indirect impacts will be exacerbated by any improved accessibility along the project roads and access tracks. Improved access in its own right facilitates biodiversity losses by encroachment and clearing along roads, facilitation of illegal logging, over-hunting, increasing probability of the accidental or deliberate introductions of weeds, pests and pathogens, increasing the probability of fire, and facilitation of broad-scale agricultural schemes such as biofuels plantations and fish farms, resulting in broad-acre habitat loss.

The global experience with roads in tropical forests indicates that long term uncontrolled access results in loss of fauna and often deforestation leading to landscape fragmentation. There is a potential for this problem to occur at all altitudes.

Mitigations for these potential impacts (see Table 18.21) include maintaining the roads constructed by the project as private roads and controlling access, and maintaining and encouraging the conservation activities of environmental non-government organisations.

Facilitating logging may be one of the most immediate indirect results of improved access. Appendix 7, Forestry Impact Assessment, describes the forestry industry in the project area. There are four existing Forest Management Areas within the upstream project area: Turama Block 1, East Kikori, Kikori Block 2 and Hekiko, and three proposed: Bosavi, Nogoli and Kutubu-Poroma (Figure 18.4). Logs from Turama Block 1, Kikori Block 2 and East Kikori are exported by effective river transport down the Omati and Sirebi rivers respectively and the project infrastructure would not influence this.



PNG LNG	Date: 21.10.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F18.04_GIS_HB	Esso Highlands Limited PNG LNG Project	Foresty concessions and roads	Figure No: 18.4

The Hekiko Block has not been logged yet but the operators of this concession would probably follow existing log export practice and construct a road to a point on the western bank of the Hegigio River, from which barges would travel down river to ships moored off the Kikori River delta. If the river were too shallow, a second possibility would be to move logs across the river to the eastern bank for trucking to a barging point (see Figure 18.4). This could be accomplished using the existing road from Kopi to Gobe, or the newer project road beyond the Gobe turnoff to the Mubi River, the latter section of which is separated from the Forest Management Area by steep grades, swamps and polygonal karst and, on the opposite bank of the Kikori/Hegigio River, from most of the southwestern portion of this Forest Management Area. The most obvious road that may facilitate logging this concession already exists. The PNG LNG Project infrastructure would be a less than suitable road to use and the mitigation to retain as private suggests that the project will not facilitate logging of this block.

Project infrastructure is too distant from the Bosavi Forest Management Area to influence its logging activities.

A minor upgrade of the existing road system in the Nogoli area would allow logs from the proposed Nogoli Forest Management Authority to be transported by road to a mill at Tari (Hekele, pers. com., as cited in Appendix 1, Biodiversity Impact Assessment). However, accessing the timber of the Hides Ridge area would probably be uneconomical since a separate road would have to be built as the PNG LNG Project's access road is private; this would be a difficult and expensive undertaking in this very rugged terrain. Therefore, while the improved public road system associated with the project could, in principle, lead to expanded or accelerated timber harvesting in the southern section of this Forest Management Area, this seems unlikely for the foreseeable future.

This proposed Kutubu–Poroma Forest Management Area is likely to be too far inland to supply export markets in the near future but may be able to support small-scale local operations. Much of the block is in steep karst terrain, where logging is nominally precluded for environmental protection reasons.

The block overlaps the road from Moro to Poroma, which was built in the early 1990s as a condition of approval of, and subsequent to, the Kutubu Petroleum Development Project. This road is not required for normal operations at Kutubu and has been untraffickable for much of the time since it was built. However, it will be repaired and upgraded to service the PNG LNG Project construction phase, and so could become a factor contributing to the feasibility of logging this Forest Management Area (if it were to be declared). However, this seems unlikely for the foreseeable future.

There is minor potential for increased agriculture in the upstream project area (Bleeker, 1975, as cited in Appendix 1, Biodiversity Impact Assessment) and there may be interest in biofuels plantations but the maintenance of project infrastructure as private will not add to the spread of these activities in the upstream project area.

In terms of population movement, the project roads that will be built or upgraded by the PNG LNG Project will not change people's ability to travel between previously disconnected parts of the upstream project area and between adjacent areas and there is unlikely to be any flood of migrants from the highlands to Gulf or Western provinces (see Section 24.3.7, Population Growth and Mobility). Maintaining infrastructure as private will ensure the project does not impact on the status quo.

Residual Impacts of Improved Access

If increased indirect impacts are mitigated through project-constructed roads remaining private and controlled, the overall magnitude of impact is considered to be low. As the upstream project area is a very high receptor, the overall significance of the residual impact is moderate. However, the effectiveness of mitigations to minimise other indirect impacts of fires, pests, weeds and diseases will be reduced by the activities of non-project personnel to whom procedures do not apply. Increased migration to the upstream project area brought about by increased access could compound this situation.

18.7.4.3 Direct and Indirect Impacts on Noteworthy Areas During Construction and Operations

Juha

The direct impacts discussed in Section 18.7.4.1, Direct Impacts on Habitats, Flora and Fauna During Construction and Operations, are unlikely to be any more severe in the isolated Juha area than elsewhere in the project area, except for the fact that the Juha habitats, flora and faunal populations have not been disturbed. With implementation of the mitigation measures, the impact magnitude is considered to be minimal. Considering that this area is a very high receptor, the residual impact is minimal.

However the major potential impact of the project in this area will be through reducing the isolation of the area and the protection it engenders. This will allow indirect impacts to possibly manifest (i.e., wildfire, pests, weeds and diseases, hunting, and increased access), which have the potential to impact the area’s biodiversity and ecological characteristics. With implementation of the plans related to quarantine, access control and control of the projects’ workforce, the magnitude of indirect impacts is low or minimal and the residual impacts moderate or minimal.

Hides Ridge

With the special mitigations focussed on reducing construction footprints, damage to the forest edge, managing materials handling, controlling the workforce, and quarantine, the magnitude of the direct impacts of construction in this area are considered to be low. As the area is considered a very high area, the significance of the residual impact after mitigation is moderate.

Indirect impacts are the most significant to this special area. Invasion by weeds or exotic pest fauna, the spread of dieback, over-hunting and facilitating the spread of logging and deforestation could produce a very high magnitude impact. However, mitigations aimed at controlling access to this special area, including good quarantine plans and developing a fire management plan, are expected to reduce the probability of these events occurring. The resulting magnitude is therefore considered low, and the significance moderate.

The significance rating for Hides Ridge is considered to be greater than for Juha, primarily due to the greater steepness at Hides (which may lead to more damage from sidecast and fragmentation) compared with Juha. There is therefore a higher magnitude of residual direct impacts for Hides Ridge. The Juha area is also more remote from population centres and indirect impacts will be easier to control.

High-altitude Forest Above 1,800 m

Because this forest area is located on deeper soils with better regeneration capacity, it is not as sensitive as Hides Ridge. It is close to Benaria and the walking track from Homa to Benaria passes through it.

With implementation of the mitigation measures, the magnitude of direct impacts is considered minimal. This is a very high receptor, therefore the significance of the residual impacts is minimal.

Indirect impacts are more significant than direct impacts. Fire, invasion by weeds or exotic pest fauna, the spread of dieback, over-hunting and facilitating the spread of logging and deforestation could produce very a high magnitude impact. However, mitigations aimed at controlling access to this special area, including good quarantine plans and developing a fire management plan, are expected to reduce the probability of these events occurring. The resulting magnitude is therefore considered low and the significance moderate.

Caves

Cave bats are very sensitive to disturbance and often need very specific microclimates. They can be impacted by loss of roosts and maternity colonies by caves being damaged during construction or through the bats being disturbed by blasting, by being hunted, and being disturbed by human visitation, especially during the breeding season.

The seven mitigations for caves (see Table 18.21) aim to identify whether significant caves occur near the proposed works and then to implement mitigations dependent upon the proximity of the cave and the inhabiting species. When added to other mitigations to control workers and contractors disturbing caves, to control blasting near caves and to avoid locating quarries near caves, the magnitude of direct and indirect impacts is low.

Considering bat caves are high receptors (see Appendix 1, Biodiversity Impact Assessment), the significance of the residual impacts after mitigation is likely to be minor.

Sinkhole Swamps

Direct potential impacts on swamps in shallow dolines and sinkholes (less than 50 m vertical depth) are predicted to be highest in Hides Ridge where it is likely some 40 shallow sinkholes lie within 100 m of the ROW for the Hides spineline. Not all of these will contain sinkhole swamps and not all will be impacted; however, assuming that all are impacted, they would comprise between 5% and 9% of the sinkholes in the 50-km^2 area surrounding the Hides spineline.

However, as well as impacting sinkhole swamps, construction may help create them by blocking drainage in dry sinkholes.

Considering the fraction of sinkholes that will be impacted, the large areas of sinkholes and dolines on the nearby Karius Range and in the ranges to the northwest, the overall magnitude of impacts after mitigation is low.

Sinkhole swamps are high receptors (see Appendix 1, Biodiversity Impact Assessment) so the significance of the residual impacts is likely to be minor.

Indirect impacts will act on these habitats like any other in the upstream project area and invasive weeds, pests and diseases are likely to be the major elements of these potential impacts. Given the mitigations proposed (see Section 18.7.4.2, Indirect Impacts on Habitats, Flora and Fauna During Construction and Operations), the magnitude is considered low, and the likely significance of the residual impacts minor.

Upland Streams

Direct and indirect impacts on the vegetation at the heads of upland streams could impact their amphibian communities and species such as Salvadori's teal, torrent-lark, torrent robin and hydromyine rodents that inhabit the riparian vegetation.

One of the specific mitigations for habitat loss is designed to protect such sites above altitudes of 1,800 m, so the magnitude of direct impacts after mitigations is predicted to be low.

Upland streams are high receptors (see Appendix 1, Biodiversity Impact Assessment) so the significance of residual direct impacts after mitigation is likely to be minor.

Indirect impacts will act on these habitats like any other in the upstream project area and fire and invasive weeds, pests and diseases are likely to be the major potential impactors. Given the mitigations proposed (see Section 18.7.4.2, Indirect Impacts on Habitats, Flora and Fauna During Construction and Operations) this could be reduced to low and the likely significance of any residual impacts after mitigation to minor.

Swamp Forests

Swamp forest complexes and swamp woodland and forest complexes may be impacted directly by clearing and/or by changes to hydrology brought about, for example, by causeways that may affect the wetland characteristics of these forests, and indirectly by fire, pests, weeds and diseases.

Swamp forests tend to be resilient to physical disturbance of the vegetation but can be destroyed by fire in drought years and eliminated permanently by changes to hydrology. They are converted to freshwater swamps by ponding and to dryer forest formations, scrublands or grasslands by drier conditions.

It is predicted that with implementation of mitigations (see Table 18.21) and rapid regrowth of vegetation, the residual magnitude would be low.

Swamp forests are high receptors (see Appendix 1, Biodiversity Impact Assessment) so the significance of residual direct impacts after mitigations is likely to be minor.

Indirect impacts could be more severe and a wildfire burning the substrates in a dry year and/or the introduction of a vigorous exotic weed species could have very high magnitude impacts. However, mitigations will reduce indirect impacts to low and the likely significance of any residual impacts after mitigation to minor.

Stream Refuges in Unstable Landscapes

The survey at Baia River (see Section 10.3.7.8, Stream Refuges in Unstable Landscapes) suggests that in unstable areas where landslides are common, patches of mature habitat on more stable sites such as in stream heads or small plateaux act as refuges for the regional fauna.

While a specific mitigation for habitat loss is designed to protect such sites, it is likely that these areas co-occur with the more stable areas suitable for construction and it may not be possible to entirely mitigate all possible losses in areas directly affected by construction.

The magnitude of the impact is likely to be medium after mitigation. Stream refuges in unstable landscapes are high receptors (see Appendix 1, Biodiversity Impact Assessment) so the residual direct impact significance after mitigation are likely to be moderate.

Indirect impacts may be more severe. A wildfire burning the refuges in a dry year and/or the introduction of a vigorous exotic weed species, and/or increasing hunting could have very high magnitude impacts in these refuges, but mitigations would likely reduce this to low, and the significance of any residual impact after mitigation would be minor.

Lowland Rivers in Stable Landscapes

While lowland rivers are a special area, none of the specialist reports (annexes to Appendix 1, Biodiversity Impact Assessment) suggested major mitigations are required at the smaller pipeline crossing points, where some loss of riparian vegetation will occur. However, at the crossing points of large rivers where horizontal directional drilling is required, the areas needed for operations will be set back from the rivers so the riverine vegetation will only be disturbed at the access way crossings.

It is predicted that with mitigations (see Table 18.21) and the rapid regrowth of vegetation, the magnitude of the direct impacts is minimal.

Considering these rivers are high receptors (see Appendix 1, Biodiversity Impact Assessment) the overall significance of the residual direct and indirect impacts after mitigation are predicted to be minimal.

Off-river Waterbodies

There are probably numerous off-river waterbodies, (also called off-channel waterbodies) along the major rivers in the lowlands, and the loss of one or two at the main crossing points is likely to produce an impact of low magnitude. At the Baia River where these waterbodies are known to occur, the impact may be of medium magnitude because of the instability of this landscape.

Off-river waterbodies are high receptors (see Appendix 1, Biodiversity Impact Assessment), so the significance of any residual impacts after mitigation are likely to be minor or moderate.

Indirect impacts could be more severe and wildfires, and/or the introduction of a vigorous exotic weed species, and/or ease of access increasing hunting could have very high magnitude impacts, but mitigations could reduce this to low and the significance of any residual impact after mitigation to minor.

18.7.4.4 Direct and Indirect Impacts on Conservation Areas During Construction and Operations

Kikori River Programme

The significance of impacts within the Kikori River Programme area, formerly known as the Kikori Integrated Conservation and Development Project, will be virtually the same as those for the upstream project area, with the exception that the percentage of vegetation lost will be slightly increased because the Kikori River Programme area is smaller. No broad vegetation group within the Kikori River Programme area will lose more than 0.25% of its area and, with the regeneration that will be allowed on the ROWs and construction areas, these losses will be rapidly regained.

Overall it is estimated that direct impacts on the Kikori River Programme area before mitigation would be of moderate magnitude and low to minimal after mitigation. Being a very high receptor, the overall significance of residual direct impacts after mitigation is predicted to be moderate to minimal.

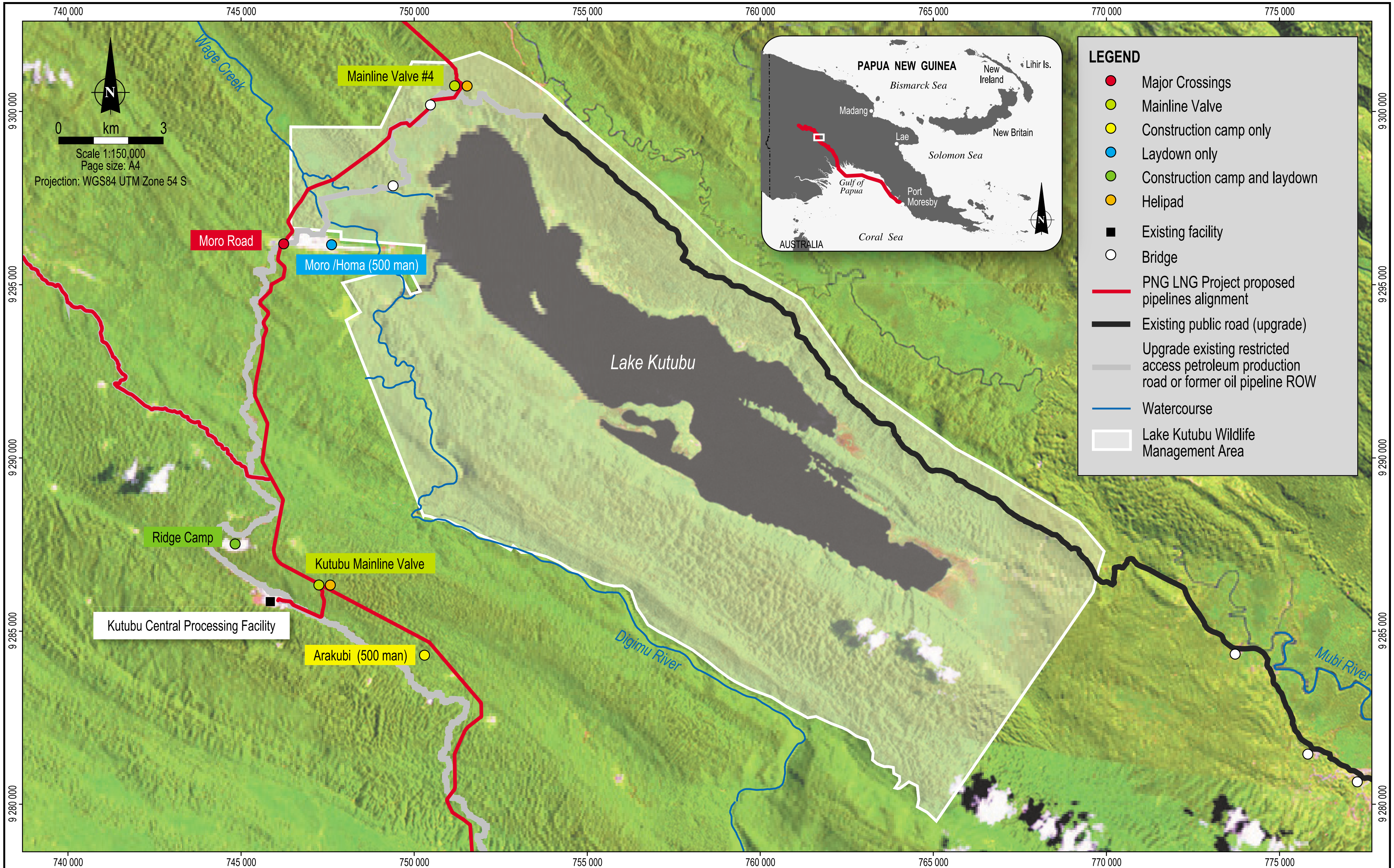
The most important impacts to mitigate are indirect impacts. Introduction of a vigorous weed, disease or pest, a major wildfire or improved access leading to widespread forest degradation or conversion could have system-wide impacts within the Kikori River Programme area. The Kikori River Programme was originally set up to manage potential indirect impacts and continuing active management will be even more necessary with the commencement of the PNG LNG Project.

Unmitigated indirect impacts could have a very high magnitude and in this very high receptor the significance of the impact would be major. With the mitigations (see Table 18.21) designed to reduce the likelihood of indirect impacts, the magnitude could be reduced to low, and the significance of any residual impact after mitigation is likely to be moderate.

Wildlife Management Areas

The Kutubu Wildlife Management Area is the only wildlife management area that the project footprint intersects and in which direct impacts will occur. The other four wildlife management areas (Neiru/Aird Hills, Libano–Arisai, Libano–Hose and Sulamesi) are distant from the project footprint, and no direct impacts are expected.

The pipeline traverses the Kutubu Wildlife Management Area. Two valves stations will be constructed in this pipeline section in the wildlife management area and there will also be a road upgrade and two bridge upgrades (Figure 18.5). No construction camps or any other part of project infrastructure will be built within the wildlife management area.



Note:
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008

PNG LNG

Date: 17.12.2008
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File Name: 1284_09_F18.05_GIS_HB

Esso Highlands Limited

PNG LNG Project

Lake Kutubu Wildlife Management Area

Figure No: 18.5

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Approximately 0.3% of the terrestrial habitats will be lost and up to 2.28% of the lower montane small crowned forest will be lost from the Kutubu Wildlife Management Area. With the ROW allowed to regenerate for half its width, these losses will be regained rapidly and, if there are no wildlife management area-wide indirect impacts, there should be no species losses from the wildlife management area.

Overall, it is estimated that direct impacts before mitigations on the Kutubu Wildlife Management Area would be of medium magnitude, and low to minimal after mitigation. Being a very high receptor, the overall significance of residual direct impacts after mitigation is predicted to be moderate to minimal.

As was the case for the Kikori River Programme, unmitigated indirect impacts have a far greater potential to impact on the Kutubu Wildlife Management Area than direct ones. The possible introduction of weeds, pests and pathogens, aquatic species has to be considered as very significant because the conservation of Lake Kutubu is the central rationale for the wildlife management area's existence. The swamp forests also form a critical part of the lake ecosystems and need to be protected from wildfires.

Indirect impacts within the upstream project area have the potential to impact on the other four wildlife management areas that will be free from any direct impacts. As for the Kikori River Programme area, wildfire management, quarantine and the control of access along the upstream project area infrastructure are the fundamental mitigations that will be used to manage any indirect impacts on the wildlife management areas.

The wildlife management areas are all very high receptors and unmitigated indirect impacts could have a very high magnitude and be of major significance. With the many mitigations designed to reduce the likelihood of indirect impacts the magnitude of impacts could be reduced to low or minimal, the significance of residual indirect impacts after mitigation are likely to be moderate to minimal.

WWF Significant Biological Areas

Five of the WWF significant biological areas (Upper Seribi River and Lubu River, Mount Bosavi, Darai Plateau, Blind Fish habitat, and Mt Sisa) will receive no direct impacts, and the total vegetation losses of six of the remainder is less than 0.5%. Only in the Agogo and Iwa Ranges Significant Biological Area do the losses approach 1%.

In two of the impacted areas, Utiti Creek and Kantobo/Wasi Falls and Gobe karst ridge system, there will be no loss of either undisturbed primary tropical forest (Class A1) or disturbed primary tropical forest (Class A2). However, the bulk of predicted losses in the Agogo and Iwa Ranges Significant Biological Area will be undisturbed and disturbed primary tropical forest.

These vegetation losses are highly unlikely to lead to any extinctions or diminution of fauna or flora populations in any significant biological area but the losses of undisturbed and disturbed primary tropical forest in the Agogo and Iwa Ranges Significant Biological Area needs to be considered in the context that this significant biological area also hosts the oil facilities and infrastructure. The predicted losses from the upstream PNG LNG Project are in addition to those losses that have already occurred from hydrocarbon resource development. However, the project mitigation of allowing the pipeline ROW to grow back to 15 m in the short term means that only

50 ha (0.15%) will remain clear until project decommissioning 30 years later. The cleared area itself will have leaf litter and probably be allowed to develop a shrub layer.

Of the six WWF significant biological areas that the PNG LNG Project intersects, it is estimated that, except for the Agogo and Iwa Ranges Significant Biological Area, direct impacts before mitigations would be of low magnitude and minimal after mitigation. For the Agogo and Iwa Ranges Significant Biological Area, unmitigated direct impacts may be of a higher magnitude approaching medium before mitigation but low after. Being high-sensitivity conservation assets, the overall significance of residual direct impacts after mitigation is predicted to be minor for all but the Agogo and Iwa Ranges Significant Biological Area for which it will be minor, especially as experience with the oil project indicates biodiversity conservation values remain unchanged in the Agogo and Iwa ranges with the development.

Unmitigated, indirect impacts have a much greater potential to impact on the significant biological areas. Possible introduction of weeds, pests and pathogens could immediately impact on the core set of significant areas along the pipeline routes and eventually reach those significant biological areas on the periphery of the Kikori River Programme that escaped any initial direct impact.

As for the wildlife management areas and the Kikori River Programme area, the control of wildfire initiation, quarantine, and the control of access along the PNG LNG Project infrastructure are fundamental mitigations required to manage any indirect impacts on the significant biological areas.

The significant biological areas are all high-sensitivity conservation assets and unmitigated indirect impacts could have a very high magnitude and be of major significance. With the mitigations designed to reduce the likelihood of indirect impacts, the magnitude of the impacts could be reduced to low and the significance of any residual indirect impacts after mitigation would be minor.

18.7.4.5 Direct and Indirect Impacts on Listed Species During Construction and Operations

Appendix 1, Biodiversity Impact Assessment presents individual impact analyses for all 142 listed species.

All but a few of the listed fauna species are either widespread in the upstream project area or occur as other populations with New Guinea. The major threatening process for the bulk of the fauna species is hunting; however, mitigations will ban hunting by project workers and contractors.

The only situation where entire populations of a listed species of plant or animal would be threatened by direct impacts would be if it existed as one very small population that could be eliminated or severely reduced by clearing. Of the listed species, the Fly River leptomys, the two bats (Bulmer's fruit bat and *Pharotis imogene*) and the tree *Helicia acutifolia* are all only known from one to three localities on the island of New Guinea. Of these, only Bulmer's fruit bat might exist as a single colony in the northern part of the upstream project area; and if it exists and is accidentally destroyed, the magnitude of impact would be major. Mitigations aimed at surveying for caves of this species and establishing a management plan (should it be found) are predicted to reduce the significance of any residual direct or indirect impacts to minimal and minor respectively.

The other species either do not occur near the proposed infrastructure or would occur as more widespread, although localised, populations. *Pharotis imogene* is likely extinct and is only known from near Port Moresby. Mitigations on directional felling of trees would safeguard any colonies of this species should they occur in the lowlands of the upstream project area.

The significance of any residual direct impacts after mitigation for all listed species is likely to be minimal. (Table 18.25).

Table 18.25 Residual impacts on listed species

Category of Receptor	IUCN Status *	PNG Status **	Residual Impact		
			Direct	Indirect	
			Minimal	Minor	Minimal
1	CR	-	7	1	6
2	EN	-	5	2	3
	VU	-	26	6	20
	VU	P	4	4	0
	VU	R	2	2	0
3	NT	-	29	1	28
	NT	P	2	0	2
	NT	R	2	0	2
	-	P	24	6	18
4	DD	-	15	3	12
	-	R	26	11	15
Totals			**142**	**36**	**106**

Note: Entries are number of species.

* CR=critically endangered, EN=endangered, VU=vulnerable, NT=lower risk but near threatened, DD=data deficient.

** P=protected, R=restricted.

Indirect impacts are considered to be more significant than direct impacts for all species because the latter are local but the former can be widespread and impact on an entire species' range within the upstream project area.

For species that are prime targets for hunting, indirect impacts brought about by improving access are major issues. It is assumed control of roads and access will be effective, so in most cases the significance of any residual impact after mitigation is considered to be minimal for most species other than the largest and most valuable species. For the latter it is assumed the keenness to acquire the animals will likely render mitigations less than 100% effective, so the significance of any residual impact after mitigation is considered to be minor.

The significance of any residual indirect impacts after mitigation is likely to be minor for 36 species and minimal for 106 species (see Table 18.25).

18.7.4.6 Direct and Indirect Impacts on Migratory Fauna During Construction and Operations

No significant habitats of migratory species will be impacted in any part of the project area and residual impacts on these species after mitigations are predicted to be minimal.

18.7.4.7 Conclusions

In his book *Collapse*, Jared Diamond (cited in Appendix 1, Biodiversity Impact Assessment) devotes most of a chapter to the existing Kutubu Petroleum Development Project. He analyses the reasons why 'In effect, the Kutubu oil field is by far the largest and most rigorously controlled "national park" in Papua New Guinea'. The reasons why the Kikori River Programme area retains wilderness values, yet contains one of the major export earners of Papua New Guinea is a result of the fastidious operational, security, environmental and safety systems of owners and operators and the limited access to the area.

Construction of the upstream portion of the project need not itself change this situation for terrestrial biodiversity. The residual direct impacts of construction will be mostly minimal, and the amounts of forest that will be lost are low in relation to the area of forest in the upstream project area and Kikori River Programme area. A narrow ROW that will be allowed to regenerate back to 15 m wide will limit edge and fragmentation effects, and judicious mitigation can reduce residual direct impacts in the special areas, the Kikori River Programme area, wildlife management areas and WWF significant biological areas to very low levels.

The generally low to minimal residual significance of direct impacts is a product of the fact that clearing and construction is not concentrated in a particular area but spread over several hundred kilometres. However, it is this same vast spread that facilitates the greatest risk to biodiversity, that is, indirect impacts. During construction and over the 30-year operational life of the PNG LNG Project, the potential indirect impacts, such as wildfire, dieback, weed and pest invasion and enhanced access to these remote and pristine parts of Papua New Guinea, present some of the greater challenges to the project.

High quality, efficient and focussed quarantine and hygiene systems together with fire management and assiduous control of use of the project infrastructure by others, will assist in maintaining the conservation assets of the project area.

18.8 Air Quality

This section presents impact assessment criteria (Section 18.8.1), the principal issues (Section 18.8.2), proposed mitigation and management measures (Section 18.8.3) and residual environmental impacts (Section 18.8.4) of the project related to potential air quality impacts during construction and operations. This section summarises the findings of Appendix 9, Air Quality Impact Assessment, which reports the project's upstream air quality impacts.

18.8.1 Impact Assessment Criteria

Papua New Guinea has no formal air quality guidelines, and so the project has followed the approach suggested by the World Bank (World Bank, 1998 and 1999) . The project's assessment air quality criteria incorporate World Bank, World Health Organization (WHO) (WHO, 1987, 2000, 2005b) and the Texas Natural Resources Conservation Commission (TNRCC) guidelines (TNRCC, 2008), as shown in Table 18.26.

A detailed explanation of how criteria were selected for each substance is provided in Appendix 9, Air Quality Impact Assessment.

Table 18.26 Project air quality assessment criteria

Substance	Assessment Criteria (Average)	Project Target ($\mu g/m^3$)
Sulfur dioxide (SO_2)	10-minute 24-hour	500 20
Nitrogen dioxide (NO_2)	1-hour 1-year	200 40
Carbon monoxide (CO)	15-minute 30-minute 1-hour 8-hour	100,000 60,000 30,000 10,000
Hydrogen sulfide (H_2S)		No offensive odour at boundary, less than 5 mg/m^3
Benzene*	1-hour 1-year	170 4.5
Toluene*	1-hour** 1-year	640 1,200
Ethylbenzene*	1-hour 1-year	2,000 200
Xylene*	1-hour 1-year	3,700 370
p-Xylene*	1-hour 1-year	2,080 208
PM_{10}	24-hour 1-year	150 70
$PM_{2.5}$	24-hour 1-year	75 35
Total suspended particulates (TSP)	24-hour 1-year	150 to 230 60 to 90

*TNRCC uses effects screening levels (ESLs) to evaluate effects of exposure to these compounds in the air. They are not ambient air standards and, if exceeded, do not necessarily indicate a problem but rather trigger more detailed review.
**Note that the 1-hour ESL is less that the annual ESL for toluene. This is because the 1-hour average criteria is based on odour and the annual criterion on toxicity. Meeting the 1-hour goal would ensure no odour or health impacts.

The guidelines for air quality are designed to protect human health, flora and fauna and other aspects of the environment.

Background air quality levels are described in Section 10.2.10, Air Quality.

18.8.2 Issues to be Addressed

18.8.2.1 Construction

Construction activities related to the upstream components of the PNG LNG Project are described in Chapter 2, Producing the Gas, Chapter 3, Transporting the Gas and Chapter 5, Project Logistics. Activities that may affect air quality include construction of the onshore pipelines and associated access ways, gas production and processing facilities, wellpads, and wellpad drilling.

Emissions to the atmosphere during the construction period will consist of fugitive dust generated during earthworks (i.e., vegetation and soil removal and wind erosion of exposed surfaces, soil stockpiles and spoil), together with exhaust emissions from construction vehicles and earthmoving equipment, high temperature waste incinerators and minor emissions from welding fumes. These sources will temporarily increase the local concentrations of airborne particulate matter and combustion gases.

Airborne particulate matter in dust can affect human health, particularly as PM_{10}[4]. Total suspended particulates (TSP) and dust deposition have an aesthetic and amenity impact.

18.8.2.2 Operations

The main emissions to air will be combustion gases at the Hides Gas Conditioning Plant (which will generally be operating 24 hours a day), principally from the following items of equipment:

- Three low-NO_x Solar Mars generators.
- One high-pressure flare system.
- One low-pressure flare system.
- Three pipeline compression systems.
- Two fuel gas conditioning skids.
- One MEG vent gas incinerator.
- One industrial incinerator.

(Note: The low and high pressure flare systems do not operate on a 24-hour per day basis.)

Air emissions will be in the form of NO_x (as NO_2), CO, SO_2 and PM_{10}.

Diurnal heating and cooling of the rich-MEG tank and the process of filling the tank will produce minor emissions of benzene, toluene, ethylbenzene and xylene (BTEX) compounds from the tank's vent pipe. Emissions are expected to be minor and disposal under consideration is by thermal destruction or industry good practice. Similarly pig launchers and receivers will release minor quantities of hydrocarbons when they are in use.

There will also be emissions of NO_x (as NO_2), CO, SO_2 and PM_{10} from the high temperature incinerators located at the Hides and Kopi waste management areas.

While the location and layout of the Juha Production Facility is yet to be finalised, it is known that the equipment required on site will be similar to that of the Hides Gas Conditioning Plant but at a lesser scale. Consequently, emissions of NO_x (as NO_2), CO, SO_2 and PM_{10} will also be produced by the Juha production Facility.

TEG units will be installed to dry the gas at the associated oil project fields of Gobe, Kutubu and Agogo. Regeneration of TEG will produce minor BTEX emissions, which will be disposed of by thermal destruction or industry good practice.

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[4] Health indicator for respirable dust capable of being inhaled into the lungs.

18.8.3 Mitigation and Management Measures

18.8.3.1 Construction

Construction phase atmospheric emissions will be managed as follows:

- Diesel-powered equipment will be regularly serviced and low sulfur diesel fuel will be used where practicable [M176].
- Fixed and mobile equipment (i.e., high temperature waste incinerators at Hides and Kopi, generators required for welding) will be located sensitively with respect to local people [M177].
- High temperature incinerator wastes will be controlled through the project environmental management plan [M181].
- Speed limits will be controlled via posted speed limit signs on project unsealed roads and pipeline ROWs (when required). Vehicles will be kept to marked trafficable areas, which will be maintained in a damp and compacted condition when required to enhance safety and minimise dust emissions [M178].

18.8.3.2 Operations

Operations phase atmospheric emissions will be managed as follows:

- Use of low-NO_x burners for the turbine generators and gas compressors at the Hides Gas Conditioning Plant and Juha Production Facility will be the single-most important mitigation measure [M180].
- Diesel-powered equipment will be regularly serviced and low sulfur diesel fuel will be used where practicable [M176].
- Fixed and mobile equipment (for example, generators required for welding) will be located and operated with acknowledgment of the dwellings and activities of the people of the particular location [M177].
- BTEX emissions will be disposed of by thermal destruction or industry good practice [M179].
- The high-temperature incinerator wastes incinerated will be controlled through the waste management plans that will be developed prior to construction [M181].

18.8.4 Residual Impact Assessment

The impact assessment for air quality indicates that the project will meet applicable air quality targets (see Table 18.26) beyond the boundary perimeter fence enclosing the Hides Gas Conditioning Plant (see Figure 2.5). People dwelling within the proposed plant perimeter fence will be relocated and compensated, see Chapter 23, Project-wide Socio-economic and Cultural Impacts and Mitigation Measures.

The Juha Production Facility will also be enclosed by a boundary perimeter fence, beyond which emissions will be in compliance with applicable air quality criteria.

18.8.4.1 Construction

Construction of the pipeline ROWs, project roads and access ways will mostly take place in remote areas with low populations and will involve the transient passage of supply trucks and road construction and pipelay spreads.

Fugitive dust from the earthmoving equipment will be naturally low in the normal conditions of high rainfall and humidity. When this is not the case, water carts will suppress dust in line with standard civil construction practice.

Vehicle exhaust emissions will likewise be localised and temporary.

Fugitive dust from earthworks during construction of the Hides Gas Conditioning Plant and Juha Production Facility will produce emissions of TSP and PM_{10}. Modelling of emissions at the Hides Gas Conditioning Plant indicates that construction TSP and PM_{10} levels at residences located beyond the perimeter fence would be in compliance (see Table 18.26) with the assessment criteria.

In the event of complaints relating to nuisance dust emissions, a grievance mechanism will be in place to manage any issues raised by the community during construction activities (see Section 9.8.2, Grievance Mechanism).

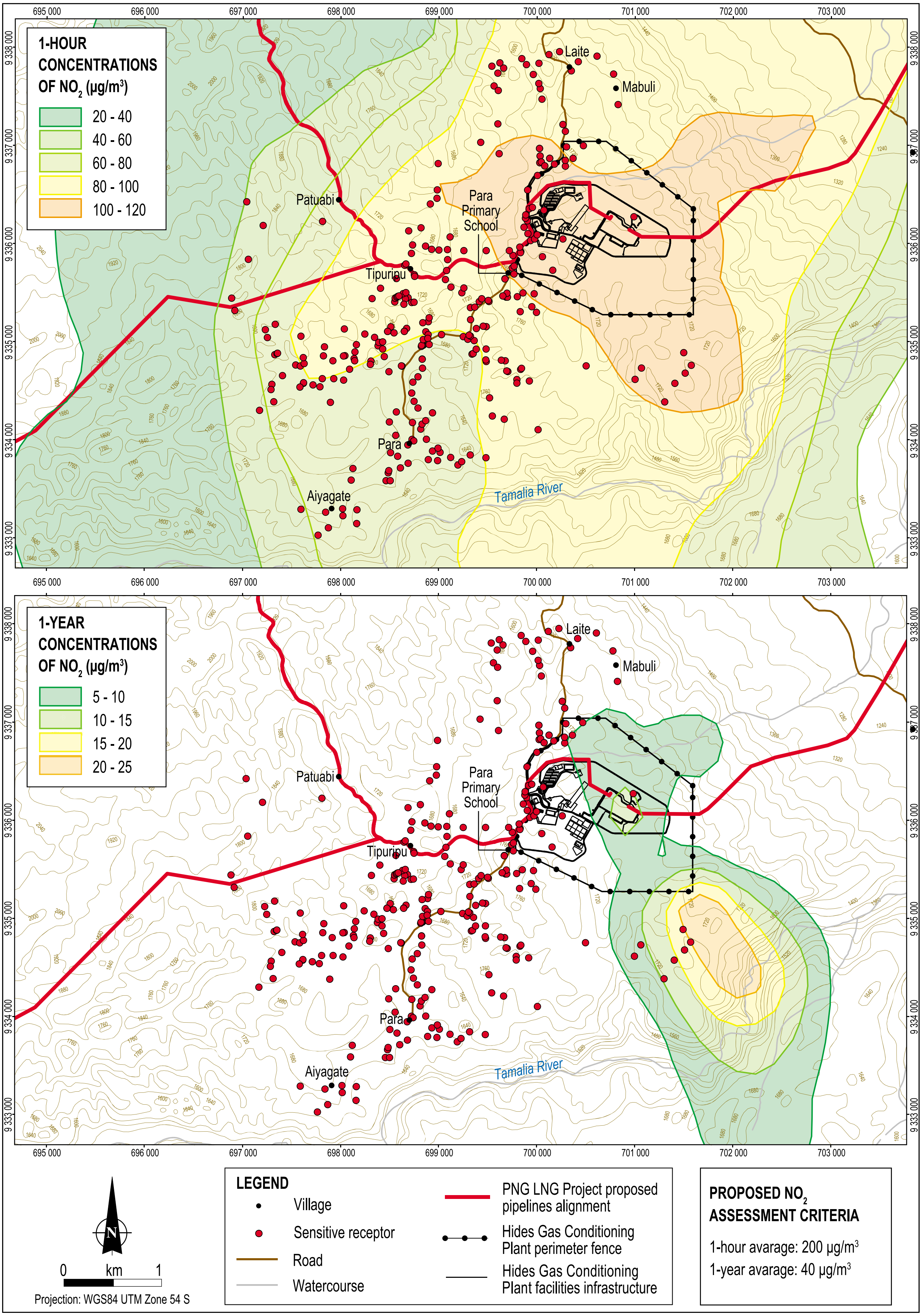
18.8.4.2 Operations

Much of the project infrastructure will have little or no impact on air quality during operations: pipelines essentially operate passively, project access ways and access tracks will be closed to the general public and little used by the project, and emissions from the high-temperature waste incinerator at the Hides waste management area will be minor in comparison to the Hides Gas Conditioning Plant emissions.

The Hides Gas Conditioning Plant and Juha Production Facility will be fuelled by natural gas. Burning natural gas as a fuel will produce very low emissions of particulate matter and CO and ambient concentrations will comply with the guideline values in Table 18.26 by comfortable margins. Therefore, NO_x[5] (as NO_2 primarily from compressor and power generation gas turbines and, to a lesser extent, from time to time from the flare system) is the only air quality indicator requiring dispersion modelling (see Appendix 9, Air Quality Impact Assessment).

At the Hides Gas Conditioning Plant, modelling of ground-level concentrations of NO_x (Figure 18.6) indicated that the predicted 1-hour and annual average NO_2 concentrations at the boundary perimeter fence will be below the assessment criterion (see Table 18.26) even when the cumulative effects of emissions from existing sources (Hides Gas to Electricity Plant) of NO_x in the area are taken into account.

[5] Of the oxides of nitrogen (NO_x) produced during combustion, most is nitric oxide (NO), which is not considered a pollutant, followed by nitrogen dioxide (NO_2), which is harmful to human health. Over time, the NO oxidises to NO_2 and other oxides of nitrogen and it is the rate of conversion to, and the level of dispersion of, the NO_2 that is of importance. Therefore, while criteria are set for NO_2, it is the total NO_x that needs to be modelled.



PNG LNG	Date: 26.09.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F18.06_GIS_HB	Esso Highlands Limited PNG LNG Project	Predicted maximum 1-hour and annual average ground-level concentrations of NO_2 due to emissions from the Hides Gas Conditioning Plant during operations (μg/m³)	Figure No: 18.6

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One-hour and annual average NO_2 ground-level concentrations at the Juha Production Facility are also expected to be well within guideline values.

The BTEX emissions associated with the upgraded processing facilities at Kutubu, Gobe and Agogo will be disposed of by thermal destruction or industry good practice. Should the disposal system fail and BTEX emissions are released untreated, emissions are predicted to still be within relevant assessment criteria.

No other significant increases in air emissions are expected from the associated oil project fields as the gas compression is already in place.

18.9 Noise

This section summarises the findings and assessments presented in Appendix 10, Noise Impact Assessment and presents noise impact assessment criteria (Section 18.9.1), addresses the principal issues (Section 18.9.2), the proposed mitigation and management measures (Section 18.9.3) and residual environmental noise impacts of project construction and operations (Section 18.9.4).

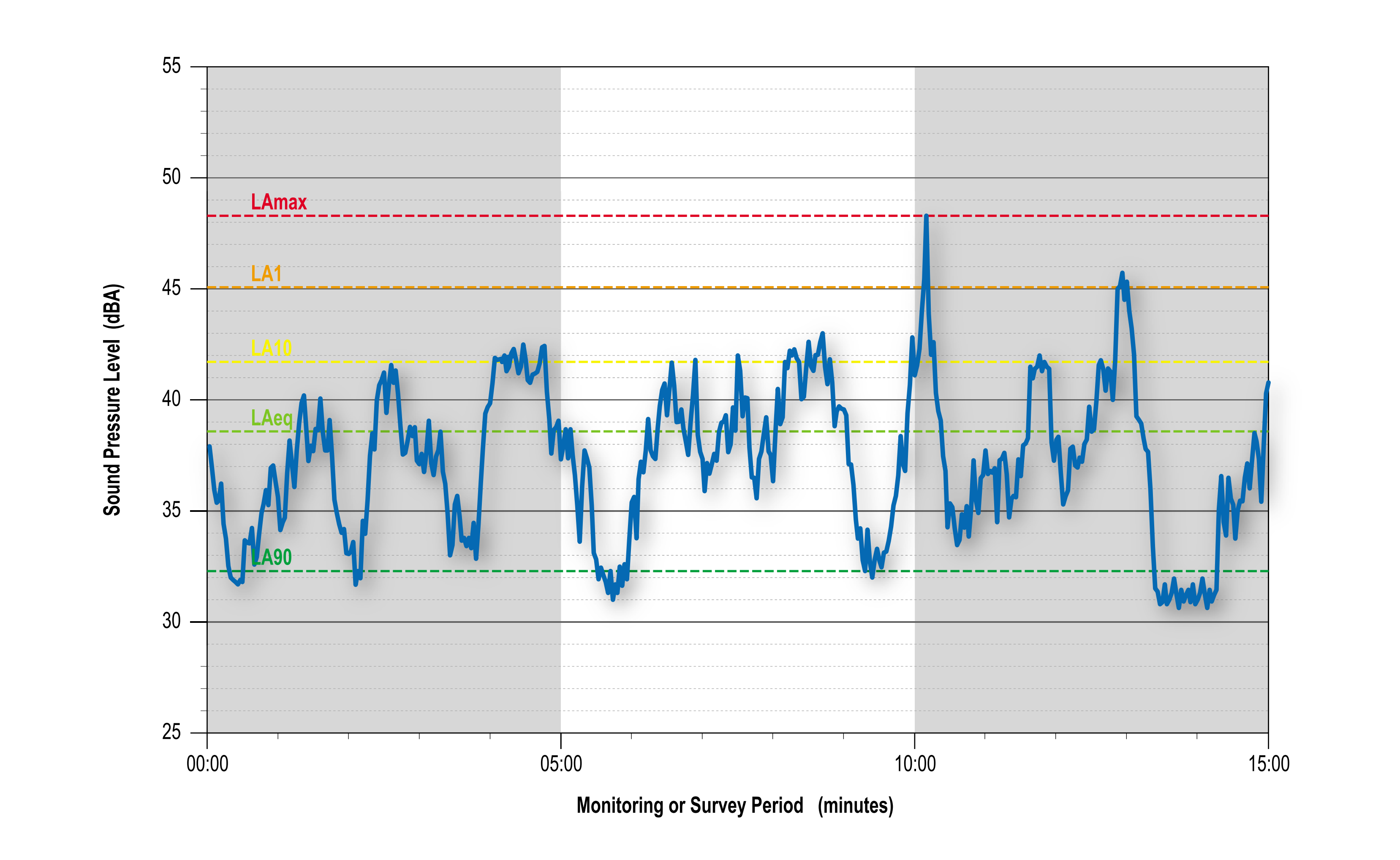
18.9.1 Impact Assessment Criteria

As environmental noise usually varies in levels over a particular period, it is common to present the results of environmental noise testing in the form of statistical descriptors.

An explanation of noise level descriptors typically used for assessing the noise environment are illustrated in Figure 18.7 and described below:

- LA_{max} – The maximum A-weighted[6] noise level associated with a noise measurement interval.
- LA_1 – The noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given interval.
- LA_{10} – The A-weighted sound pressure level exceeded for 10% of a given measurement interval and is normally used to characterise average maximum noise levels.
- LA_{eq} – The A-weighted equivalent continuous sound level. It is defined as the steady sound level that contains the same amount of acoustic energy as a given time-varying sound over the same measurement interval. It can be loosely thought of as the 'average'.
- LA_{90} – The A-weighted sound level exceeded for 90% of a given measurement interval and is representative of the average minimum sound level. It is often used to describe the 'background' level.

[6] A-weighting, though originally intended only for the measurement of low-level noise, is now commonly used for the measurement of environmental and industrial noise.



PNG LNG	Job No: 1284	Esso Highlands Limited	Graphic display of typical noise indices	Figure No: 18.7
	File Name: 1284_09_F18.07_HB	PNG LNG Project		

There are no formal policies or guidelines for environmental noise in Papua New Guinea, and so project noise has been assessed based on the following guidelines and criteria:

- The World Health Organization (WHO). Guidelines for Community Noise. (WHO, 1999).
- The International Finance Corporation (IFC) (World Bank). Noise Level Guidelines. (IFC, 2007j).
- Australian criteria, such as:
  – Environmental Protection Agency (EPA) Victoria. Interim Guidelines for Noise Control from Industry in Country Victoria. (EPA Victoria, 1989).
  – Department of Environment and Climate Change (DECC). NSW Industrial Noise Policy. (EPA NSW, 2000).
  – Standards Association of Australia. AS 2436. Guide to Noise Control on Construction, Maintenance and Demolition Sites 1981 (Australian Standards, 1981).
  – Australian and New Zealand Environment Conservation Council (ANZECC). Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration. (ANZECC, 1990).
  – Standards Association of Australia. AS 2187.2. Explosives: Storage, Transport and Use 1993 (Australian Standards, 1993).

Based on these noise criteria and guidelines, noise levels relevant for assessment of potential impacts for the construction and operation of the project were developed (Appendix 10, Noise Impact Assessment) as follows:

- Noise targets at the boundary of facilities (i.e., the Juha Production Facility and Hides Gas Conditioning Plant) of 55 dBA L_{eq} between 7 a.m. and 10 p.m. and 45 dBA L_{eq} from 10 p.m. to 7 a.m. for both construction and operations. Criteria are the same for both construction and operations due to the lengthy construction period (Figure 1.3).
- Single events (traffic pass-bys on roads etc.) have no day-time criteria suggested but 60 dBA L_{max} would be reasonable design goal. Single events are primarily concerned with sleep disturbance at night and the recommended night (10 p.m. to 7 a.m.) noise criteria is 45 dBA $L_{max.}$
- Blasting should typically be limited to 115 dB with allowances of a small percentage up to 120 dB peak during the day and evening (7 a.m. to 10 p.m.). Blasting should not occur during the night (10 p.m. to 7 a.m.) but if it does then it should not be audible to sensitive receptors.

Existing noise levels in the upstream project area are low (see Section 10.2.9, Noise).

18.9.2 Issues to be Addressed

While sound is a fundamental sense used to perceive the environment, noise is typically described as an unfavourable sound. The assessment of sound is primarily based on human response values such as hearing damage and potential health affects such as stress. The overall level of a sound is usually expressed in terms of decibels (dB(A)), which is measured using the ‘A-weighting’ filter incorporated in sound level meters. These filters have a frequency response corresponding approximately to that of human hearing. Humans are most sensitive to sounds at mid frequencies (typically 500 Hz to 4,000 Hz) and less sensitive at lower and higher frequencies. The level of a sound in dB(A) is considered a good measure of the loudness of that sound.

A change of up to 3 dB(A) in the level of a sound is difficult for most people to detect, whilst a 3 dB(A) to 5 dB(A) change corresponds to a small but noticeable change in loudness. A 10 dB(A) change corresponds to an approximate doubling or halving in loudness.

The nearest potentially affected noise-sensitive receptors (i.e., a village, dwelling or other non-project location where people are continuously present) at the Hides Gas Conditioning Plant are located in the Laite village district. Laite is a linear group of dwellings stretching along the road west of the Hides Gas Conditioning Plant from the village proper in the north to the Para Primary School in the south. The Para Primary School consists of several school buildings around a large open playground and teachers' residences.

Para village district is located immediately to the south of Laite, both further away from the Hides Gas Conditioning Plant site and better shielded on the southern slope of Hides Ridge.

No sensitive receptors are located near the Juha Production Facility.

A number of dwellings exist in proximity to Hides Wellpad A and the Angore wellpads that may be affected by noise during wellpad development and drilling.

Very few sensitive receptors are expected to be located along the pipelines and construction ROWs, but could include existing residences or new ones that have been established to be close to the construction activity.

18.9.2.1 Construction

Construction activities are described in Chapter 2, Producing the Gas, Chapter 3, Transporting the Gas and Chapter 5, Project Logistics.

Pipelines and ROW Construction

The following activities will create noise, primarily from diesel-powered earthmoving and electricity generation equipment:

- Vegetation and soil removal.
- Major earthworks.
- Blasting.
- Rock hammering and blasting.
- Pile driving (during construction of larger bridges).
- Transportation and handling of pipe strings.
- Trench excavation.
- Pipe welding and lowering-in.
- Backfilling and compaction of pipe trench.
- Pipe hydrotesting and dewatering.
- Rehabilitation.
- Electricity generation.

Wellpad Construction and Well Drilling

Drilling equipment and methods are described in Section 2.5, Drilling the Wells and Constructing the Gathering Systems. The main noise sources are the drill rigs themselves and generators, with potential sensitive receptors being settlements near Hides Wellpad A and Angore.

Facilities Construction

The Hides Gas Conditioning Plant, Juha Production Facility, Kopi Shore Base and upgrades to Komo airstrip will be built by conventional machinery and equipment and will generate noise from the following activities:

- Site preparation.
- Excavation and rock breaking.
- Preparation and pouring of concrete foundations.
- Delivery of components to site.
- Installation of structural, mechanical and electrical components.
- Construction of ancillary buildings and facilities.
- Commissioning.

Occasional blasting may be required mainly for project road works and constructing the ROW, particularly in limestone karst terrain.

18.9.2.2 Operations

Pipelines and ROW Operations

Pipelines generally operate passively without noise, except for periodic inspections by vehicle or helicopter and infrequent repair work, which may require digging up the pipe and subsequent reinstatement. These relatively infrequent events would generally be undertaken during the day and be of short duration.

The access way associated with the pipelines will carry infrequent project traffic of light and heavy vehicles.

Wellhead Operations

Generally the only noise from wellheads will be from chokes or, extremely rarely, during cold venting.

Facilities Operations

The Hides Gas Conditioning Plant will be operating 24 hours a day, with the main noise sources being:

- Pipeline gas compressors.
- Booster gas compressors.
- Turbo generator package.
- Elevated flare.

The noisiest items of equipment at the Juha Production Facility will be the:

- Rich gas compressor.

- Turbo generator.
- Elevated flare.

(Note: The flares are not operational 24 hours per day.)

18.9.3 Mitigation and Management Measures

The project will adhere to specific criteria for construction and operations that are aligned to the intent of the IFC (2007j) and WHO (1999) guidelines on environmental noise management. At the Hides Gas Conditioning Plant and Juha Production Facility sites, the boundary noise limit has been set at 55 dBA L_{eq} during the day period and 45 dBA L_{eq} during the night from noise generated from the construction and operation of the facilities to protect the amenity of landowners.

A property perimeter fence line will be constructed around both facilities to coincide with the calculated night-time noise limit of 45 dBA L_{eq}.

18.9.3.1 Construction

Drilling and the construction of the project's pipeline ROWs, roads, access ways, facilities and wellpads will implement the following noise mitigation and management measures, where appropriate:

- Construction work will generally and where practicable, be carried out during the day. Only drilling will generally be carried out 24 hours a day, 7 days a week [M169].
- Where practical, noise mitigation measures (including consultation with local citizens) will be implemented at drilling sites to minimise the noise level as much as possible [M170].
- Construction plant and equipment will reflect industry good practice, with OHS operating and monitoring standards set out in the environmental management plans to be developed prior to construction [M172].
- Noise suppression devices on construction vehicles and equipment will be fitted and maintained [M173].
- If especially noisy construction work is required near a sensitive receptor, the affected parties will be notified of the intended work and its duration [M174].
- Blasting will be carried out under a noise management plan taking ANZECC (1990) guidelines or similar into account and with local communities notified [M175].

18.9.3.2 Operations

The following noise mitigation and management measures will be implemented:

To meet the project's adopted noise control level (see above), sensitive receptors at the Hides Gas Conditioning Plant that are within the perimeter fence will be relocated [M171] (see also Section 18.9.4.2, Operations) in accordance with the project's resettlement action plan (see Chapter 23, Project-wide Socio-economic and Cultural Impacts and Mitigation Measures).

Detailed modelling of noise emissions from the facility will be undertaken to determine the type and location of acoustic insulation (or similar) to be installed at the Hides Gas Conditioning Plant [M171].

No additional insulation is expected to be required at Juha Production Facility for protection of sensitive receivers, as presently none exist adjacent to the proposed site. Should people choose to move closer to the facility the background noise of the area would already be dominated by the facility.

Other measures adopted during construction will also apply during operations.

18.9.4 Residual Impact Assessment

The residual impact assessment process (Section 18.1, General Approach) adopts noise-specific categories and definitions of magnitude of impact, and of sensitivity of resource/receptor (Tables 18.27 and 18.28 respectively). These, in turn provide the two axes of the matrix of significance (see Table 18.1 in Section 18.1.4, Impact Significance Matrix).

Table 18.27 Magnitude of impact – noise

Category	Description
High	Ongoing noise impacts at sensitive receptors above guideline values.
Medium	Short-term noise impacts (less than 12 months) at sensitive receptors above guideline values.
Low	Impact of noise levels within guideline values.

Table 18.28 Sensitivity of resource/receptor – noise

High	Receptors where people or operations are susceptible to noise. This includes residences, schools and hospitals.
Medium	Receptors moderately sensitive to noise. Includes offices and restaurants.
Low	Receptors where distraction or disturbance from noise is minimal. Includes factories, residences not occupied during operational hours.

18.9.4.1 Construction

Pipelines and ROW Construction

For a full complement of equipment working simultaneously in two areas along the ROW and separated by 2.5 km in flat terrain, the model results showed that assessment noise criteria of 60 dBA and 47 dBA respectively would be unlikely to be exceeded at distances greater than 500 m during the day, and 1,600 m during the night.

Construction work is expected to progress along the ROW at a rate of 300 to 750 m per day. The slowest section (between Kutubu and Moro) is estimated to move at an average of 50 m per day.

Sensitive receptors located along the pipelines and construction ROWs will be infrequent but could include residences, either existing or that have moved to be close to the construction activity. Regardless of the circumstances, a dwelling is by definition a high-sensitivity receptor. On the other hand, the construction spreads will be moving at between 50 m and 750 m per day, which means that the time that any given sensitive receptor will find itself within the construction noise envelope will be short. Overall, a noise level of 60 dBA is similar to a single event (traffic pass-by on roads) with sound levels comparable to a general office. As there will be no construction at night-time and on the basis of levels expected and their temporary duration, it would be reasonable to class both the magnitude of impacts and receptor sensitivity as low, leading to a residual impact significance also classed as minor.

Wellpad Construction and Well Drilling

During the drilling of wells, modelling predicts that a wellpad on flat terrain is likely to comply with project noise criteria at distances greater than 250 m during the day and 500 m during the night.

There are existing dwellings within 500 m of Hides Wellpad A and the Angore wellpads that are predicted to experience noise levels above criteria adopted for main facilities sites. Without mitigation, the significance of residual impact would be moderate (magnitude, medium; sensitivity, high).

While this impact may be temporary, the continuous (and night-time) nature of the noise may warrant consideration of implementation of site boundary control measures similar to the Hides and Juha facilities.

The project will undertake consultation with the affected landholders to agree on appropriate mitigation measures.

Facilities Construction

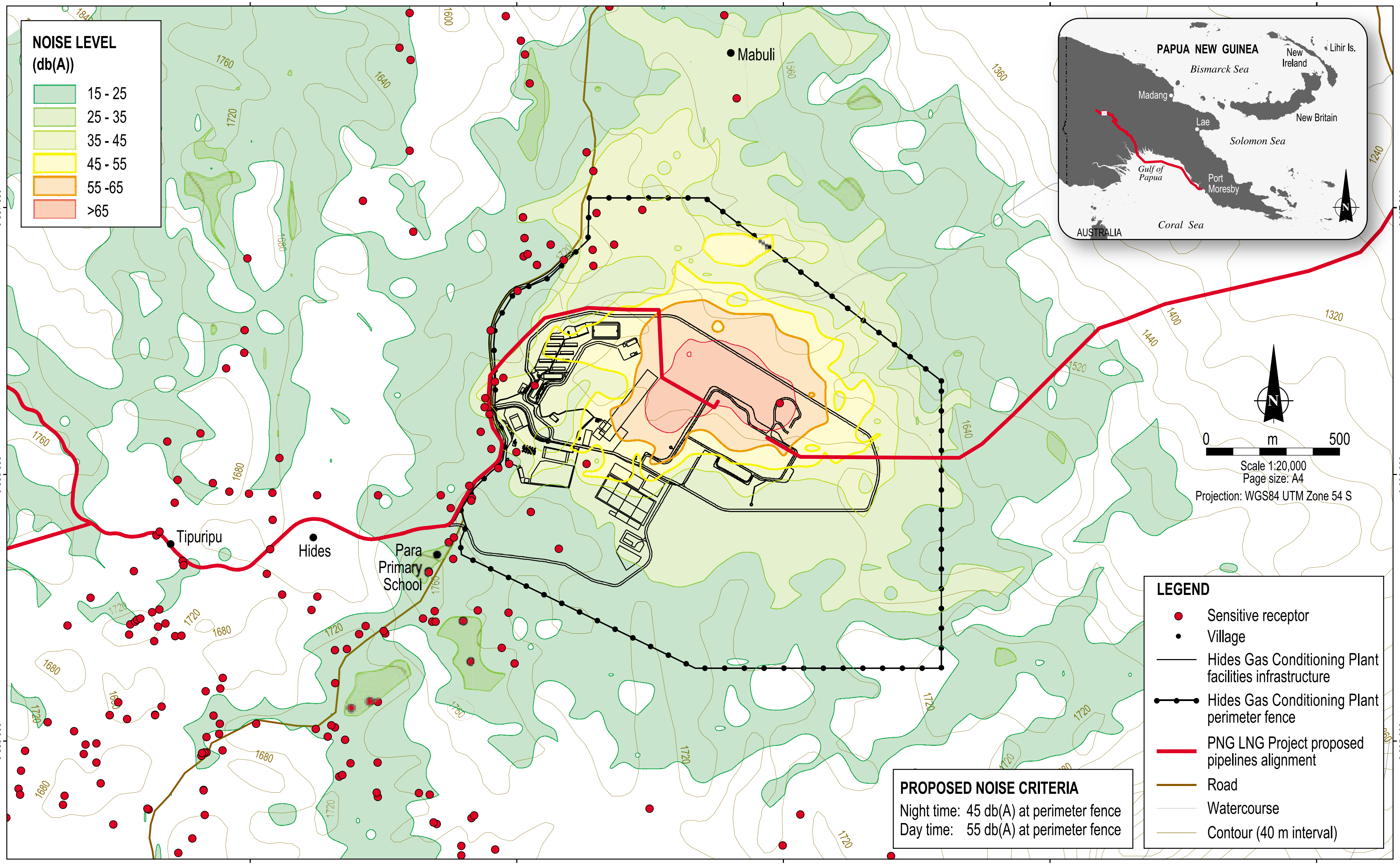
Construction noise at the Juha Production Facility and Hides Gas Conditioning Plant facilities will comply with noise criteria under all conditions during the day (and will probably be inaudible above the existing ambient background noise level at many of the nearby receptors in Laite).

Figure 18.8 shows the predicted noise contours from preliminary modelling during the construction of the Hides Gas Conditioning Plant facilities, utilities and offsites case. The sensitivity of the noise receptors (such as Laite) is high, but the magnitude of impact is low as the noise is expected to fall within guideline levels. Therefore the significance of impact is minor.

18.9.4.2 Operations

Pipelines and ROW Operations

Operational noise along the pipelines will typically only arise during inspections by vehicles or aircraft. These are relatively infrequent and transient events generally undertaken during the day and so the magnitude is considered minimal. Although the proposed pipeline route does pass sensitive receptors, the residual impact significance is considered minimal (magnitude minimal, sensitivity medium).



Source:
Noise contour data from Heggies, 2008.
Note:
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

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Esso Highlands Limited

PNG LNG Project

Predicted noise contours for the construction of the Hides Gas Conditioning Plant facilities

Figure No: 18.8

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Wellhead Operations

Generally the only noise-producing activities from wellheads will be from chokes and these emissions would meet the night-time noise target at a distance of approximately 100 m. Therefore the residual impact significance can be considered minimal (magnitude minimal, sensitivity high).

Facilities Operations

Hides Gas Conditioning Plant

Figure 18.8 shows the proposed Hides Gas Conditioning Plant and surrounding sensitive receptors.

Preliminary modelling of predicted operational noise levels of the Hides Gas Conditioning Plant and utilities shows that noise emissions will comply with daytime noise assessment criteria for all sensitive receptors under normal atmospheric conditions, with one exceedence under adverse atmospheric conditions. The model shows that the night-time noise assessment criteria will be exceeded at two sensitive receptors under normal atmospheric conditions and exceeded at thirteen sensitive receivers under adverse conditions.

As stated in Section 18.9.3, Mitigation and Management Measures, the project has committed to installing acoustic insulation at the plant in such a way that noise criteria are met at the boundary fence. Preliminary modelling conducted to date will be expanded upon during detailed design to guide the selection and installation of appropriate acoustic insulation at the plant to meet the projects proposed noise criteria.

Therefore operational noise impacts have been generally assessed as minimal (magnitude minimal, sensitivity high).

Juha Production Facility

The Juha Production Facility site is in a remote and largely uninhabited area.

Operational noise levels from the Juha Production Facility will be managed and monitored to meet the daytime noise criterion of 55 dBA and the night-time criterion of 45 dBA.

There are no noise sensitive receptors within these distances; therefore the overall significance is minimal.